Exploring Creation and Curation as Steps Towards A Gamification of the Arts Through Game Engines

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'... its blank, empty space, suggesting a patch of skin from art history's body, loudly staring back daringly, returning my gaze...' (Garoian, 2013)

'The modern argument of form versus structure is as meaningless as the mediaeval argument of *ars* versus *scientia*, for it likewise disrupts a partnership which can function only in happy union.' (Ackerman, 1949)

'*On peint les gens comme des pots de fleurs.*' (Fantin-Latour, 1836-1904)

'If we take art to mean such activities as building temples and houses, making pictures and sculptures, or weaving patterns, there is no people in all the world without art.' (Gombrich, 1995)

'Intelligence is the faculty of making artificial objects, especially tools to make tools.' (Henri Bergson, 1859–1941)

Dedication

I dedicate this work to my dear family and my lovely family of friends.

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Thank you, my family. Thank you, my friends. You make the path look brighter.

Declaration

This document presents a dissertation entitled 'Exploring creation and curation as steps towards a gamification of the arts through game engines', supporting an application for the Doctor of Philosophy in Computer Science degree at the University of Hull. The text - in its parts and in whole - is being submitted exclusively to the University of Hull.

This dissertation renders independent work performed by me, whereas all contributions from others have been acknowledged. The views expressed within the text are those of the author and not of the institution.

Luís Carlos da Silva Preto Torrão

Abstract

Game engines enable the creation of novel applications that can enhance how art is created and presented and provide new tools to artists. This thesis presents study, research, and development within the frontiers between the arts and computer science, namely about a perceived dual phenomenon of the artification of games and the gamification of the arts. It proposes the hypothesis that through gamification, one can create environments that enable artists to give new possibilities to their art and communicate differently with their audiences, as the digital game engines' artistic multimodality opens possibilities of new kinds of art forms, and artistic creation, experience and curation, and also raises questions about if it could extend the arts' domain and if it could be a resource for the endeavours of the research in computational creativity. This hypothesis is tested with the development of an art studio for multimedia sculptures - TIMAEUS – and an infrastructure that enables people to render such sculptures in virtual spaces, made in collaboration with artists to create examples of their art transformed into digital forms. The work also approaches the gamified possibilities of art curation to create a virtual stoa - or colonnade - for teaching Stoicism and a virtual Odyssey, enabling the presentation of artistic work as a virtual art gallery. The artistic evaluation of the prototypes, in collaboration with creators on different branches of the arts – painting, drawing, poetry – aims to assess the qualities of this approach that has been presented in relevant conferences and evaluated by peers and artists. 'The arts' are here treated as an umbrella term comprehending the whole field of creative expression and are the subject of an experiment of a special kind of gamification, thought as a sort of gamification that is extended to the use and transformation of the digital game software infrastructure itself – the game engine.

Contributions

In Digital Game Engineering

This thesis presents a study about a game engine's expandable architecture and its potential to enable the gamification of the arts, with applications in artistic game development case studies.

Publications

Parts of what is presented in this thesis have been published previously, as follows:

Papadopoulos, Y., Torrao, L., Vakali A. (2019) An Alternative Virtual Odyssey, Conference: *XXII Generative Art Conference* At: Museo Nationale Etrusco di Villa Giulia, Rome

Papadopoulos, Y., Torrao, L. (2019) Meeting Epictetus and Seneca in an Infinite Virtual Stoa: Classical Wisdom as Emotional Education of the Future, In book: *Generative Art – Futuring Past, selected works from the Letterature International Festival in Rome*, Domus Argenia

Torrao, L., Papadopoulos, Y., & Mckie, D. (2018). Infinite Virtual Stoa. In *XXI GENERATIVE ART 2018, proceedings of XXI Generative Art conference* (183-194)

Torrao, L., Papadopoulos, Y., & Mckie, D. (2018). Timaeus: A digital art studio inspired by antiquity. *Generative Art Science and Technology Hard Journal*

Torrao, L., Mckie, D., & Papadopoulos, Y. (2018). TIMAEUS: Three-dimensional Illuminated Media Augmented Sculptures. In *Proceedings of 20th Generative Art Conference*, Soddu C. and Colabella E. (eds), Domus Argenia (459-469)

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Notation

CG	Computer Graphics
AI	Artificial Intelligence
CA	Computer Arts
SA	System Arts
GA	Generative Arts
AA	Autonomous Arts
GE	Game Engine
AT	Art therapy
RT	Reminiscence therapy
CC	Computational creativity
UXUI	User Experience / Interaction

1. Introduction

The application of computer tools in artistic work is today paramount and has had a noticeable impact on the progress of both computer science and the arts. This is visible as a good part of today's creative expression relies on the computer, despite often maintaining the same defining characteristics as many centuries, or even millennia, ago. Art forms such as painting, architecture, sculpture, music, and drawing can now be created by resourcing to sets of software that make expressive tasks more possible, faster, affordable, accessible, and even augmented and autonomous. In computing, this evolution reflects on work such as software development for computer arts and the endeavours for computational creativity and computer graphics, among other fields of computer science.

Because in cinema, in music, design, photography, and other arts, computer tools appeared as an element that can improve artistic work, such devices have gradually become pervasive, up until today, when we naturally expect any form of art to exist – or at least coexist - in the digital realm. However, it seems reasonable to also ask today if the potential of the computer has already been exhausted to the point that there is nothing more of new that we can get from it – or at least nothing more than an improvement of what already exists.

As a singular example of the silicon shift of paradigm in the arts, there is a distinguishable landmark of our current era – or the 'age of digital reproduction' (Davis 1995) (Benjamin, 1935) – which is the digital artefact. This kind of artefact is potentially reproducible countless times; however, this is not like a 100-year-old photography negative, which is repeatable to a considerable but finite extent. Today, the digital art object is simultaneously the negative and the photography itself, released from the weight of material deterioration. This single observation can lead to some

understanding of the impact that the computer has had and can still have on the arts. Something present in daily activities that can quickly be taken for granted, such as writing a poem or capturing a picture and immediately having them publicly available on the internet.

Another example of this evolution can be found in the inception of different natures of art supports and materials. Forms of art that have previously relied exclusively on palpable media have been abstracted into virtual environments. Drawing and painting, besides paper or canvas, can now be instantiated on the pixel. There is an interesting duality about it: more than the small physical electric piece of technology, the pixel also exists as the RGBA (red, green, blue and alpha) data structure abstraction that represents it, that granule, in the whole of the work of art. This new kind of abstraction that the computer has brought to the arts differs from aesthetics, ideas, or feelings but shares the same unpalpable nature. This abstraction can represent the physical and be the support for the immaterial. Parallel reasoning can be drawn about today's sculptures' new marble, wood, or clay: shapes that are made by faces that are made by edges, and in turn made by vertices that can be represented computationally as mathematical vectors with rational x, y, z and w components.

Decades have passed since the inception of the computer in the arts, and it could be argued that CAD software little has changed since it started to be helpful in architecture and design. It could be said that current image composition software is just a better iteration of its twenty years ago self or observed that cinema has used digital special effects for a considerable number of years now, improving with time, but with no apparent essential change in nature. However, computer games seem to contradict that idea.

Digital games offer a platform for multiple kinds of media that can be used to support a variety of digital artefacts. They provide a platform for several types of art forms that can reunite in a unique audio-visual experience. Sometimes considered a medium and

an art form *per se*, inside the computer game, creative access is granted simultaneously to digital abstractions of paper, canvas, clay, marble, film and musical notes and instruments. In games, we can so find artefacts of various art forms: depictions such as delicate paintings, elaborate sculptures, orchestral compositions, and the architecture of imaginary spaces. Coding can also be, in games, a true expressive medium. In speculation, a question that can arise is if there is anything in art that cannot be represented or performed inside a digital game experience. Pushing boundaries to build almost anything, extravagant exercises seem possible, such as making an exact virtual replica of Harold Cohen's 'AARON' - the autonomous painter (Garcia, 2019) – in an instance of a game engine's graphics, physics simulation and coding capabilities – then putting our painter in front of a realistic landscape whilst taking an artistic photograph of him inside that 3d world, that can also have Hellenistic sculptures, Impressionist pictures on the walls, atonal spatial music and Art Nouveau buildings, and record it all as a digital film. It seems plausible to ask whether there is a limit to what can be achieved with games regarding novel art-forms interrelations and art multimodality, suggesting that there may be a landscape of unexplored paths involving digital games and the arts. Another factor that appears to contradict that idea of the dusk of computer applications to the arts is the development of computational creativity, a field of study also making its path in the boundaries of the unknown. The imagination of the art public is captured today by the news of computers creating new Rembrandts (Microsoft, 2017), completing unfinished songs (Sullivan, 2023) and writing stories and poems (Sato, 2016), or interpreting our inputs as new works of art (Ramesh et al., 2022). Regardless of different sensibilities relative to the artistic value of such computational feats, one can hardly ignore the progress they represent and demonstrate in computer science.

This work proposes to investigate the role that the first technology mentioned – computer games and their engines – can have in the arts in a contemporary context of gamification and of the rise of an autonomous nature of the computer arts, exploring

the idea that gamification can help create interesting new forms of art and new forms of curation of art. To pursue the first, it starts by building an art studio named TIMAEUS, and to achieve the second, it continues with the rendering of gamified art experiences in Stoa & Odyssey.

1.1. Field of Research and Context

This work investigates the gamification of the arts in a transdisciplinary study that explores the fields of computer science and enters the arts sphere. It proposes a broader definition of gamification by distinguishing between gamification through game design elements and through game engine digital technologies, which we could call the 'meta-game'. Therefore, it incorporates studies in game-engine architecture and computer graphics, among other topics related to digital game engines.

The tasks of this research have started with the initiatives at the University of Hull to promote interdisciplinary and socially meaningful research projects. These were the first ideas about framing a PhD programme on bringing generative and audio-visual arts to the therapeutic practice context. Art therapy is a resource for dealing with the psychological effects of various medical conditions. Such is the case of dementia, an incurable syndrome that, as people live longer, becomes more and more prevalent and presently causes growing hardship and lower quality of life for many (Cochrane, 2020). Before this work, University of Hull computer scientists had been employing computer graphics technologies 'in collaboration with painters and musicians on projects in the field of generative art' (Appendix I), exhibited at *La Triennale di Milano*. (Appendix I). Additionally, 'informal feedback by clinicians' suggested that such art projects could 'have (a) therapeutic effect (for) people with long-term conditions like autism or dementia' (Appendix I). That was the context for the inception of this PhD project, a 'part of novel interdisciplinary research that intersects computer science, philosophy,

medicine, and art with potentially exciting new applications on conceptual art, art therapy and educational games. (Appendix I)

1.2. Research Motivation and Scope

When proposing the 'imitation game' in 1950, Alan Turing (Turing, 1950) possibly would have imagined that computer games could become an art form by themselves. But it could also have been far too much to predict that they would be used as new tools in artmaking or that the public would today be experiencing art through computer games. In a brief visit to the Sony PlayStation store of virtual reality games, one can easily find and download what can be thought of as experiences of virtual museums or galleries. Such virtual experiences come as a global trend and seem to resonate in the recent times of a pandemic that required people to stay more at home.

AAA games now include elaborate musical pieces, extraordinarily detailed and animated 3D sculptures - or 3D models - the architecture of imaginary worlds, subtle narratives and storytelling, high-resolution depictions, and cinematographic efforts of photography, acting and film. Digital games position themselves in the history of the computer arts as a fast-evolving technology achievement. Capable today of containing and expressing narratives, storytelling, artistic shapes, depictions, music, and other art forms, they offer a kind of hybrid and interactive unity that is sometimes defined as an art form by itself. Arguably, this can be described as a phenomenon of the 'artification' (Shapiro, 2019) of computer games.

However, when observing digital games, not as artistic ends – an art form – but rather as the means - or as tools - for the creation in the arts, and in contrast with the artification of games, one may as well raise questions about the *vice-versa* which is, an inquiry about the gamification of the arts. In studios, *ateliers* and stages, creators assist to the inception of game engines: for virtual production in cinema and broadcasting,

where besides scenography and music, they can also involve human acting; in architecture, complex projects that are hard to visualise otherwise can be previewed in real-time experiences, on-screen or inside virtual reality, as well as for imaginary, virtual spaces; design product ideas can be vividly experienced way sooner than before, in their development process. In sum, creative experiences can now happen virtually and involve the artists' work in digital game-engine-based environments. Today, game engines arise in areas that appear very different from what we could imagine finding on a visit to a public game library, or *ludoteca*. Such is the case of *Eurovision 2019*. The dynamic scenography of the musical pieces - including the live-performed song 'Zero Gravity' - was made with Pixotope (Pixotope, 2023), a piece of software that is an adaptation of the Unreal Engine that explores this game engine's real-time rendering capabilities - along with standard studio hardware - to produce impacting augmented reality live shows that, in this case, also involve singing and dance.

A game engine is a computational tool that generally corresponds to the part of the digital game that can be abstracted and reused to create other computer games, a kind of meta-game. It is simultaneously the digital games' data, programming and design infrastructure that can deal with sound, 2D, and 3D contents, non-linear and dynamic media, artificial intelligence, and physics simulations, among others.

This thesis aims to shed light on the perception of this new kind of gamification, not a gamification that is classically known to consist exclusively of the application of gameplay or rules to non-game situations (Nacke & Deterding, 2017), but rather as a kind of gamification that consists in the general resourcing to technical tools characteristic of digital games for ends related to non-game domains, namely to the arts, including resourcing to game engines themselves. For this, throughout this work, there is an attempt to observe the domain and nature of the arts and observe their characteristics when they occur along with the computer, as well as when they occur along with a principle of autonomy, as when granting autonomy to a creative system.

In sum, 'the arts' are in this work approached as an umbrella term comprehending the field of creative expression, from music to literature or clay artisanship, so that they can be the subject of an experiment of a special 'gamification', thought as a kind of gamification that comprehends the use of the digital game software infrastructure itself for ends broader than mere game creation, as such kind of gamification may raise new questions regarding the relationship between computing and the arts.

1.3. Research Hypothesis

The thesis expands, therefore, within the spaces provided by the digital to the arts. The hypothesis is that gamification can support the creation of interesting new syntheses of art, of the exposition of art, and can improve the creativity of artists by opening possibilities that involve the integration of art forms, multimedia, interaction, and navigation in 3D spaces taking the shape of:

- novel ways of creating art
- new ways of experiencing art
- new forms of art

1.4. Research Goals

To investigate and test the hypothesis, this text will render three steps that encompass systematic research involving design, development, and evaluation and are laid upon the theoretical framework set by a reflection about the topics concerned.

Review of the literature.

Starting with the study of the relevant knowledge, the work tries to comprehend the technical nature of the arts, computer arts, and autonomy in the arts in the context of

gamification. In this theoretical space, it will find gaps with questions that will be subsequently addressed.

Software design to test the hypothesis.

Working with the above-mentioned extended definition of gamification - extended to the use of game engines – will result in different challenges of software engineering, design, and implementation.

Gamification of art creation

The first challenge involves developing a virtual art studio derived from a game engine and purposed for creative activities.

Gamification of experiencing art

To develop new ways of experiencing art, the second step of design and implementation will include gamified explorations of digital curation. Amplified by the resources found in the computational creativity research theoretical framework, the work will enclose attempts to find new forms of gamified and autonomous art.

Application in case studies and evaluation

The documented evaluation consists of performing and reflecting on case studies that occur with the application of the tools created to understand the extent to which the hypothesis is tested.

1.5. Thesis organisation

Organised as a handful of chapters, this thesis describes the theoretical background and how it has derived from the perception of a knowledge gap. It renders new questions, the formulation of a hypothesis and how it is tested by resourcing to modelling,

software engineering and design, implementation, and evaluation. It then concludes by reasoning about what new knowledge is reached within the studies.

Chapters Two to Four: Background

The review work observes the importance of artistic expression in the making of digital games (i.e. the 'game art'). It investigates a contemporary concept of 'artification' (Shapiro & Hainich, 2012), the process by which several forms of creative enterprise have become recognised as new forms of art, whilst framing such concept within the context of digital games, as they too are sometimes identified as a new form of art – or 'games as art'.

The text then delves into the history of games and game engines. It proposes considering a redefinition or generalisation of another contemporary concept – the one of 'gamification' - as a more abstract idea. Not just exclusively in the arts domain, the work looks for an understanding of the nature of games. It sketches a short descriptive chronology and tries to discern if the use of digital game engines for ends other than game creation may be considered an extended form of gamification.

As if taking a photograph in film, the initial distinction between light and shade will come from the exposure to that duality of artification *versus* gamification, drawing an image for the theoretical inquiry. The work will establish the lens through which it will focus on the external domain - the arts – as being perceived from a digital game engineering point of view, that is, the chosen camera. In revealing the picture, three distinctive tints will interact: the technical nature of the arts, of the computer arts, and of autonomy in the arts.

The work will address gaps found when studying game engines and their related topics, such as game engine architecture and computer graphics, whilst aiming to perceive how game engines can enable artistic expression, new ways to exhibit and experience art and possibly the emergence of new forms of art, given their multimodality and openness to

the implementation of computational creativity techniques. The section will shed some light on the characteristics of game engines as abstractions of classical materials and media of the arts, searching for what it means to the arts that such engines function simultaneously with all sorts of static and dynamic, linear, and non-linear media. By contrast with the artification of games, the review work will focus on the gamification of the arts, investigating how such tools characteristic of games are becoming part of the process of artmaking and how gamified experiences are becoming novel ways of appreciating artefacts.

Ultimately, the theoretical framework justifies designing, building, and testing tools of gamified art creation experiences, environments for virtually exhibiting art through games, and combinations with the principles of autonomous arts and computational creativity.

To do this, it starts by assuming a design science methodological approach and assessing the requirements for designing and implementing applications that will test the hypothesis - applications of game engines to artmaking, art experiencing and curation, and possibly new art forms.

Chapter Five: Methods

From a view of software engineering, it will take as the object of study a particular game engine - the Unreal Engine – and will investigate its software architecture to assess how it can fulfil the art gamification research goals – creation, experiencing, curation and new forms of art, which will result in the design and implementation of an extension of a game engine's architecture that will encapsulate the functionalities necessary for the posterior work rendered in the subsequent chapters and also aiming to open a long-term way to where a gamified tool can autonomously promote and assist in the creation of art whilst also aiming to investigate if new forms of art can be achieved or generated

within the multimodal environment of a game engine including when delivering outputs of computational creative methods, mechanisms and devices.

Chapter Six: Timaeus

The sixth chapter comprehends a description of the work of design and implementation of a gamified tool for the creation of art – Timaeus – with a platonic inspiration that enables the making of sculptures that can assume shapes, colours, textures, be illuminated and animated and display film and audio.

A case study is conducted with the application of this tool that aims to help create memory sculptures and represent feelings and ideas through multimedia artefacts. For that, it will approach it from the point of view of software design and user experience and assess its artistic value in collaboration with artists.

Chapter Seven: Odyssey & Stoa

The next chapter focuses on artistic curation through gamification. There will be a study about the gamification of experiencing art where two tools are built for the exhibition of the artefacts created in Timaeus in case study exercises of game design and development.

One, the Odyssey, is an artistic approach to exhibiting and experiencing art through a metaphor – a multimedia *haiku* – that comprises music, poetry declamations and paintings in collaboration with artists.

The other, in the shape of an 'edugame' - the Stoa – explores the creation of a gallery of digital content about stoic philosophy that can be apprehended through a journey inside an infinite procedural space inspired by an ancient geometrical pattern.

Chapters Eight and Nine: Conclusions and Future Work

The concluding sections will document interpretations of how the hypothesis is assessed - through Timaeus, Odyssey, and Stoa - and about the outcomes of these

studies that were presented at art conferences, where the feedback received may offer a form of validation and because the work will result from collaboration with artists, their testimonies will so contribute to the evaluation.

In conclusion, the thesis discusses the research's strengths and weaknesses and tries to estimate the meaning and significance of the resulting knowledge, making sense of the previously presented and reflecting on implications for future work.

2. A story of play

The connections between the domains of Computer Science and The Arts are abundant. However, their idiosyncrasies and discontinuities are also solid and paramount. These initial chapters will render the views taken during an exploratory path through the history and theoretical aspects of digital games and the arts and technology, raising some questions and identifying gaps that will be addressed in the subsequent chapters, all in an attempt to think about the relations between the arts and the computer and to think about the potential in the arts of a particular software technology – the game engine.

This inquiry path starts when observing the reasoning behind a popular trend that argues for the legitimacy of computer games as a new form of art. This is an argument that has also been making its presence in the work of scholars, scientists, developers, designers and in some of the specialised press and is the inspiration for an attempt to understand the 'story' of computer games here briefly.

Seriously ancient

Games have been described throughout history as having influenced the world with their social functions - and as going beyond entertainment – because of their utility as promoters of socialisation, learning and training (Seaborne, Fel, 2015). In antiquity, Plato mentioned play in his work, where he talked about how it was an important element of the child's education but also mentioned it as a more adult device for the educated mind (D'Angour, 2013) (Wilkinson, 2015) (Dörner et al., 2016a).

Fast-forwarding to the twentieth century CE, with computing pioneers such as Alan Turing, the idea of a computer game was born, for instance, in the chess game 'Turochamp' (Bowden, 1957) and, in a publication in Mind in 1953, Turing has also

constructed the idea of a game that could serve the purpose of attesting the occurrence of machine intelligence, that he called the 'Imitation Game' (Turing, 1950). Since his days, games have continuously accompanied the advent of the computer in the form of the digital game and have been persistently present in the steps of the progress of computer science and engineering because computer games have been frequently presented as the means to demonstrate or concretise computational achievements (Melissinos, ORourke, 2013) regardless that they have also agreeably gained themselves the notoriety and status of computational feats. This was the beginning and, in a few decades, something that was only possible on mainframe machines would reach the public, becoming available in personal computers and entertainment devices.

With or without a computer, in contemporaneity, scholars can now dedicate their time and resources to study a derivation of play – gamification - which is, to investigate a process described as the application of games and game design elements – but not technologies - to non-game contexts (Deterding et al., 2011). Arguably, serious games have long existed, and the influence of games is today becoming even more prevalent with their applicability to previously unimagined domains, in that phenomenon known as 'gamification'. Games appear to reiterate their ancient social role and importance, as they take informed shape in serious games for education, training, and health and as their principles are being applied to engage 'players' in activities related to learning, working, consumption and social dynamics, among others.

Modern serious

Serious games can be defined as entertainment games that have at least one additional purpose or 'characterising goal' (Dörner et al., 2016b), be it for education (Slussareff in (Dörner et al., 2016a)), healthcare (Smeddinck in (Dörner et al., 2016a)), for defence, arts and culture, religion, corporate training or advertising (Djaouti et al., 2011). Several authors have already systematised the characteristics of serious games and classified

them into categories based on criteria such as purpose, scope, and market (Söbke, Streicher, 2016).

Despite the fact that the majority of computer games being published today are mainly meant for entertainment, it is also true that as they started to be available to the general public, they appeared side to side with serious games, as was the case of the first video game console Magnavox Odyssey, which delivered entertainment and serious games in tandem (Djaouti et al., 2011).

Contemporary, entertaining

Entertainment games, or the games that aim only to entertain (Dörner et al., 2016b), represent the majority today and embody an exuberant industry whose origins can be traced back to around the 1950s, since the early tic-tac-toe, draughts and bouncing ball demonstrations by Josef Kanets, Ferranti, Alexander Douglas and Oliver Aberth (Wikipedia, 2023), to the 1958 William Higinbotham's 'Tennis For Two', and to 1962's 'Spacewar!'. It was in 1966 that Ralph Baer described the idea of a TV game console, and the first one was launched by 1972. The rise of the arcade videogame industry happened in the early 1970s (Wolf, 2008), and such events started the impulse that is reflected in today's industrial momentum.

Game (as) Art

The growth of the entertainment game industry has been much nurtured by commercial games that today are parallel with Hollywood's productions in terms of audience, project dimension, and budget. But mostly, they have a similarity with cinema at its very core, which is its artistic dimension. Several authors consider that digital games, or at least 'some' (Clarke Mitchell 2013) digital games, have gained the status of works of art. They sustain this statement in the common ground that many game titles are either fully-fledged works of artistic expression, or that digital play is becoming an artful experience, and also because some artists are turning to games as their main

source of inspiration (Gavin, 2014). This occurrence is inclusively resonating in the domain of the philosophy of art, where aesthetic reasoning about video games is emerging.

Aesthetics of play

One branch of the aesthetic discourse that addresses the possible artistic nature of games is that of artification. Arguably, games are consistently being recognised as an art form, as game creators' explore territory traditionally relegated to poetry, painting, literature, or film' (Sharp, 2015).

Games as an art form

Looking back to earlier than the contemporary large-scale production of games, it is possible to find an innate connection between games and art. Wolf mentions a moment in the 1960s when the abstractionism of minimalist art and its simple shapes, lines and colours became a nurturing environment for the artistic welcoming of the then very novel early videogames, with their yet simple and primitive computer graphics and music (Wolf, 2008) and according to Tavinor, it would take just 40 years for them to emerge as a 'sophisticated form of popular art '(Tavinor, 2009).

While Clarke and Mitchel characterise it as a young 'area of digital art' that, despite surging in a panoply of styles, also presents an inner artistic coherence and unity (Clarke Mitchell 2013), Gavin compares the current state of games in the arts with that of the inception of photography, which would have to wait around one century before being accepted and recognised as an art form. (Gavin, 2014). These authors are apparently aligned with Gee's argument that digital play is presently a form that integrates experiences of pleasure, learning and existence 'in ways that we (can only?) expect from art' (Gee, 2006).

However, some controversy in this topic is unneglectable, for instance, the question of whether purely entertainment and commercial games should be dismissed from any

artistic consideration, or be to some extent included (Clarke Mitchell, 2013), or rather if any instincts to tighten the boundaries of what is considered or not entertainment, commercial or artistic (Folkerts, 2011) should be avoided. In any case, such doubts appear to vanish when observing the existence of a different kind of game amongst the ones that are made by indie artists or groups of artists.

The game as a medium

Such games can 'merge the values of contemporary arts and games' (Sharp, 2015) as the artists recognise in the game form a new medium for expression that combines multidimensional depictions, music and real-time interaction (Wolf, 2008), working for the artist - that may or not self-define as an artist (Clarke Mitchell, 2013) - as a new kind of 'oil paint or charcoal' (Sharp, 2015) to compose imaginary worlds, characters and stories that contain artistic meaning, here artistically appropriating the digital game form (Clarke Mitchell, 2013).

Games as subject matter

There is one more kind of artistic expression that derives from the domain of computer games, and that seems to attest to the great impact that games are having on culture. It is the case of artists that choose commercially available computer games as a subject matter (Sharp, 2015), 'appropriating the iconography of games' or even creating new modes of expression such as making cinematographic captures of performances inside games, in a practice known as 'machinima' (Clarke Mitchell, 2013).

Gamification and artification

In sum, there appears to be a historical tendency moving towards the extension of play to other domains, named 'gamification', and on the other hand, digital games seem to be merging with the domain of the arts in the process of 'artification'. The two paths may diverge or not. However, in an exercise of thinking of them as possibly converging into

something new, the next two sections will dive into a more detailed understanding of gamification and then of the artification of games.

Gamification

In his book about postmodernism, Calinescu cites with emphasis a thought of TS Elliot about how people tend to need and use definitions:

> *'we are constantly using terms which we cannot define and defining other things by them. [...] some other way must be found of dealing with them so that we may know at every moment what we mean.' Elliot in (Calinescu, 2006)*

Elliot's words fit a problem around the concept of gamification. It is that definitions of gamification, which is a recent topic, are varied and somehow diffuse. Some authors have tried to address this issue. However, such efforts tend to result in making the neologism 'gamification' strictly attached to a specific meaning, inside a specific domain, and not generalised, hence losing any possibility of working as a concept in other fields such as computer science where - this section will argue - it can represent interesting new concepts.

The definition of gamification

Seaborne and Fels succinctly describe the 'whys' of such confusion in the definition, as on the one hand, the topic is in its 'conceptual infancy' and, on the other hand, there is still 'dissonance among scholars' (Seaborne, Fels, 2015). The term 'gamification' can be traced back to marketing, with the use of 'points cards and rewards memberships' and to education and work productivity (Seaborne, Fels, 2015). In this sense, gamification is stated as an 'inconsistently defined strategy' to motivate and engage (Seaborne, Fels, 2015). Arguably, this view of gamification could be seen here from two lenses: psychology and game design.

In psychology, game mechanics

Psychologically, gamification aims to 'harness the motivational potential of video games' (Deterding et al., 2011) by applying game mechanics to 'change behaviours in non-game situations' such as goals, rules and rewards, dynamics, and emotions, to 'achieve the repetition' of desired behaviours (Robson et al., 2015). So, gamification could be understood as taking 'advantage of human psychology in the same way that games do' (Seaborne, Fels, 2015). Yet arguably, this starts as a very limiting perspective about the concept as it does not put the necessary focus on the game design side of gamification.

In game design, the elements

Perhaps for that reason, there is a more commonly accepted and more generalised definition as 'the use of game design elements in non-game contexts' (Deterding et al., 2011) which does not exclude the psychological nature but also emphasises the design aspects of gamification, being that the 'elements' are these things 'that are characteristic of games' (Deterding et al., 2011), but applied to non-game situations, and without resulting in a complete game. Again, this more general definition, which includes the psychological and game design elements, seems incomplete because it dismisses the cases in which full games are created with a non-exclusively entertaining purpose.

In serious games

Seaborne and Fels report different ways to approach the definition despite Kapp's definition of serious games as a subset of gamification, one that can include 'the transformation of an existing system into a game'. Most important is the consideration that gamification may not be 'the exclusive property of any one discipline or industry' (Seaborne, Fels, 2015). In this thesis, that line of thought results in the rise of an original question.

What is, or what can be, gamification in other domains?

Is gamification extendable to domains other than marketing or psychology and game design, and is anyone allowed to expand or generalise the concept? What is gamification for the mathematician, the economist, and the computer scientist? Von Newman and Morgenstern showed that games could be seen as models with which to understand complex phenomena, and Nash famously found in such models an equilibrium when each participant in the game would no longer benefit or lose from performing any more individual actions. (Nash,1951). This case for game-like thinking precedes many decades of the birth of the word 'gamification', and it is, however, a way of integrated thinking about games that may find parallel in many diverse disciplines, where 'gamification' could have its own disciplinary meanings.

In computer science, what is and what can be gamification?

In digital game development

Can gamification be a concept, too, in computer science? It is given that, being a recent topic of study, there is, for instance, still some confusion revolving around the concepts of serious games and gamification. On the one hand, some authors use gamification and serious games as synonyms (Deterding et al., 2011), and on the other hand, some authors clearly state that equivalent use is a mistake. In the spirit of not 'using undefined concepts to define other concepts' (T.S.Elliot, 1929)(Calinescu, 2006), it seems reasonable to clarify that in this work, the definition of gamification is generally proposed as something 'becoming a game'. As such, serious games are considered a form of gamification – among others – here one where games are designed and developed for non-exclusively entertaining purposes. Arguably, thinking of gamification as the process of 'becoming a game' is more permeable to include different disciplines and topics, and it can hopefully open new possibilities, for instance, in the use of technology.

In game technologies

Despite this confusion, the silver lining is seen, and the emphasis of this thesis is that several authors restrict gamification to the use of game design elements in non-game situations, as opposed to the use of game technologies. The strengths of this position rely on the anecdotical contrast between using a device such as a digital game hand controller (Deterding et al., 2011) for non-game scenarios - which would naturally not be considered gamification – as opposed to achieving psychological effects through game design elements such as game mechanics. However, if taken radically, could interesting ideas about technological gamification be undesirably discarded from the very beginning?

Becoming a game

With the 'becoming a game' premise, in this work, what is suggested is that it is possible to avoid orphaning the word 'gamification' of its multidisciplinary meanings, such as in computer science, and specifically in the use of game technologies – namely game engines - for non-game scenarios. Such a generalised understanding of 'gamification' would not unnecessarily reduce the scope of gamification and would not exclude most of computer science's potential for contributions. In sum, this thesis starts from this definition, this kind of premise that, as artification is the process of becoming art, gamification can generally be the process of becoming a game, be it via game-characteristic design and psychological devices or game-characteristics technologies and engineering – or other. Because this research will approach the duality of artification and gamification in the domains of digital games and art, dismissing the controversy from the start is an important exercise that nurtures the theoretical enquiry and hopefully makes sense, namely because there is today a growing tendency for game engines to be utilised in non-game related domains.

Game engines are presently becoming powerful resources in architecture and design, in the automobile and aircraft industries, real-time scenography, virtual production of live television shows and filmmaking. This is an area with potent developments by Epic Games, the company that is bringing its engine, the Unreal Engine, to the live presentations of the Weather Channel, Sky Sports and the NFL Network, among many other broadcasters (UE, 2023a). Novel experiences are being instanced that range from reliving Apollo 11 on Hololens 2 (UE, 2020b) to Childish Gambino concerts' real-time computer graphics scenography (Blondin, 2019). We can now watch three-dimensional real-time cartoon animations (Gomez, 2019), walk in replicas of cities such as Helsinki (UE, 2020e), and even decentralise filmmaking crews, making it possible for filmmaking teams to work collaboratively from home (Gomez, 2020) and delivering state of the art special effects, from 'Westworld' to 'The Mandalorian' (UE, 2023g). 'Digital twins' (UE, 2023h), a novel concept that is also being introduced is, generally, the possibility of building a game-engine-based virtual replica of an existing reality in order to keep a kind of test and control simulation scenario such as in autonomous vehicles, tracking and the control of a building construction, or a city and its structural and functional maintenance or even a twin planet Earth meant for modelling climate change (Nvidia, 2023). This is the reason why this research opts to extend the neologism 'gamification' to resourcing to game engineering elements in non-gaming contexts rather than just 'using game design elements in non-gaming contexts' (Deterding et al., 2011). This appears to make sense because, indeed, game technologies are being applied to non-game scenarios, and if we want to describe this phenomenon, it is etymologically natural to address it as another nature or kind of gamification. This is an exciting moment for **technological gamification**, as this technology - the game engine - is becoming a pervasive new tool of the trade in so many areas.

In sum, as in this work, 'gamification' is interpreted here as 'becoming a game', and in this point of view, when psychologists apply game mechanics to an educational

environment, the environment is viewed as 'being gamified' and the same applies when resorting to game design elements. Additionally, when a game is created to teach, some parts of education become gamified. When the study of game dynamics produces new strategic insights, there is some part of mathematical thinking that is reasoning as a game. When game technologies such as game engines are used in domains other than play, there might be another variation of gamification. The goal here is a generalisation of meaning and reclaiming a word, 'gamification', that can be used in the following chapters within the specific domains of this thesis: computer science and the arts.

Artification of games

Before addressing issues around the concept of gamification, this text has started by reflecting on another 'ation' concept, the 'artification' of games, or if games are becoming an emergent art form. As said before, several authors coincide in that digital games - or at least some digital games - have gained the status of works of art. Therefore, it seems opportune to try to refine the knowledge about the nature of games as possible forms of art, about their ontology, the artists and artistic practice, training, education, and research. Additionally, it may be fruitful to investigate how disciplinarity (multi/inter/trans-disciplinarity) is important for games, the philosophical discussions surrounding play, how people experience games and if digital games can be thought of therapeutically in the same way as the arts are.

Ontology

The ontology of games is somewhat diffuse; however, most attempts for a definition coincide in some characterising elements, such as being a ruled-based artificial situation in which players engage voluntarily and try to find the patterns of behaviour that produce the desired outcomes (Seaborne, Fel, 2015) (Gregory, 2019). On the other hand, the definition of digital games in computer science can be as concrete as Gregory's succinct concept of games as 'soft real-time interactive agent-based computer

simulations (Gregory, 2019). Arguably, a definitive technical characteristic is the game loop, which makes time play 'an incredibly important role in any electronic game '(Gregory, 2019).

The ontology of games and digital games does not immediately transpire artistic nature. Indeed, it is possibly what most distances it from the arts and artistic expression, perhaps because it is what defines it as a self-contained, unique concept. However, it is also the case that this 'game' idea or entity is frequently used as a creative tool by persons who can also be artists, that artistic education and research are presently embracing multidisciplinary game development and that games are being experienced in many ways as a work of art would, including in therapeutic contexts.

The Artist

The entity of 'the artist' in games is paramount. Arguably, even the engineers who work in commercial digital games owe something to the arts, considering that their craft is in many ways so close to the craft of many artists in history, such as the Renaissance artists who invented ingenious devices to help them in their artmaking.

Game art

Gregory lists the artistic roles in commercial game development: from concept artists to 3D modellers and animators, texture and lighting artists, motion capture and voice actors, sound designers, score composers, and writers (Gregory, 2019). Two other roles seem predominant in triple-A games: game designer and game engineer.

The game designer

Salen, Zimmerman and Gregory place the game designer as 'a particular kind of designer, much like a graphic designer, industrial designer, or architect' (Salen Zimmerman, 2004) that focuses on building gameplay, or 'the interactive portion of the

player's experience' at different levels of detail, that range from the game's goals and story to individual levels. (Gregory, 2019)

The game engineer

Game engineers implement and maintain the infrastructure of the game as they resource or even specialise in their knowledge of mathematics, physics and collisions, rendering, audio, or AI, etc., within their writing and design of code (Gregory, 2019). The reason for including engineers in this section dedicated to the entity of 'the artist' in games is that the boundaries between game engineering and game artistry are not that far apart, as the work in games is substantially multidisciplinary. In fact, Gregory mentions that 'some game designers are ex-engineers who decided they wanted to play a more active role in determining how the game will play' (Gregory, 2019).

The indie game artist

Gavin compares the contemporary digital games' 'struggle to be recognised as an art form' to that of photography in its early days, even though indie artists are finding in games a new medium with which 'to convey a message' (Gavin, 2014), with artistic aims (Clarke Mitchell, 2013) and concerns with 'aesthetic, theoretical, and conceptual intentions traditionally aligned with artmaking.' (Sharp, 2015)

Practice and education

According to Wolf's recount of their history, studies in digital games have started with niche publications for 'hobbyists in electronics and gameplayers', have grown since then through online communities and have later become 'fashionable' and academic in the dawn of the 21st Century CE (Wolf, 2008). To the point that the study of video games involving topics such as software engineering and game design is presently taught at the pre-college and university level (Cooper, Scacchi, 2015).

Research

Today, there is a growing number of conferences and conference tracks dedicated to game development and research, such as GDC, SIGGRAPH, FROG and Videogames Sciences and Arts, conferences focused on serious games such as SGDA and SEGAH, on gamification such as ICGBL and Gamification Conference, and all more that are organised by the Digital Games Research Association and the International Game Developers' Association, among many other organisations.

Disciplinarity

Within the arts

Building commercial games generally implies building imaginary worlds, an activity that connects with the fields of architecture, landscape architecture and design. On the other hand, Martin compares the relationship of games with cinema with how photography, in its early days, tried to emulate famous paintings (Brett Martin in (Clarke Mitchell, 2013)) and Picard describes how, in recent history, there has been actual interaction between Hollywood and game studios that reflected in the surge of game-based movies and of movie-based games. The same has also happened in television broadcasting as well as in comics and animation (Martin Picard in (Wolf, 2008)). Photography, painting, and drawing are artistic disciplines on which game development much depends, as with sculpting (or three-dimensional modelling) and animation. The developments of game story arches enter the field of literature, namely narrative and storytelling, for which it is natural to find writers within game development teams. As in cinema, musical composers can project such imaginary worlds into the audible realm.

Within the sciences and engineering

There is a clear influence of engineering-related disciplines such as mathematics and physics. The resources of computer science are present in the computer graphics infrastructure work, as well as in artificial intelligence and software architecture, to name a few disciplines. Additionally, there is the influence of sound engineering and electronic engineering, and as we have seen before, psychology and marketing also play their part in the multidisciplinary work of commercial game development, so in sum, the work of developing games gravitates around many scientific fields.

Experience

It seems difficult to argue against the artistic nature of play experience whilst the arts are a fundamental part of the multidisciplinary making of games. That might just be because the experience that digital play enables is itself mostly artistic.

Therapy

One of the interesting questions that could be raised here is if the artistic experience of games can also be therapeutic, in parallel with art and art therapy. Arguably, game therapy already exists and is a vibrant field of research, as it is being applied to mental and physical rehabilitation (Martins et al., 2014), although the artistic possibilities of such interventions are not generally the focus point. The creation of art therapy based on games appears as a mostly unexplored field for research and development.

Philosophy

The aesthetic discourse about digital games, besides the already mentioned questions around the phenomenon of artification (Shapiro, 2019), can also result from the sum of the aesthetical reasoning about the elements that compose a game, being its narrative and storytelling (Iurgel et al., 2009) or the creation of characters and other game

elements that involve sculpture and animation (Torrao et al., 2013) and multiple other, such as the architecture of imaginary places. As in cinema, aesthetic thought can also appear when studying the composition of game audio (Mello, 2018) and cinematic photography. The sum of thinking about the artistic parts of a game - 'game art' - along with thinking about the game itself - 'game as art' - can result in a unified aesthetics of games.

3. From Leonardo's tools to the Leonardo paradox, to the game engine

'...such as the Renaissance artists who invented ingenious devices to help them in their artmaking.'(page 24)

Supposing it is true that current aesthetic thought already includes video games as an emerging art form, a question that may arise is how to contextualise this new art form within the domain of the arts. Also, understanding what roles game engines can play in this context. With that in mind, this chapter will approach the arts, guided by a historical perspective that considers as identifiable defining moments the invention and application of tools to the arts, then later the moment when such tools were re-instanced and developed along with the computer, and another landmark that corresponds to the application of the principle of autonomy in such tools for art making. As the title of this section suggests, we are interested in understanding why the tools, devices, and resources that artists such as Leonardo da Vinci invented and used in their artmaking seem to have evolved with the computer and how a historical 'great awakening' of such tools may be unfolding, towards autonomously creating art, by augmenting and sometimes 'superseding the artist' (Mueller,1990). The goal here is to frame the potential of game engines in this double context of computing and the arts as ultimate tools that bring to the 'ars' a synthesis of centuries – or even millennia – of progress made in 'téchnē'.

But before initiating a survey of the technical nature of the arts, computer arts, and autonomy in the arts, it might be insightful to start by trying to understand the present moment concerning the rise of autonomy in the arts. Arguably, there is a concept that is a hallmark of our times: the concept of the 'generative'.

In a Chomskian zeitgeist

Back to the spirit of T.S. Elliot's reasoning about definitions, a possible barrier to understanding the influence of the idea of the 'generative' in our times is the multiplicity of domains and sometimes meanings with which it is used. If one tries to assess the meaning of this word with a mindset of metrics and statistics and resources to Google's 'NGram' tool (Figure 1), one might surprisingly find out that this adjective has been around for a considerable time since Gutenberg's invention. Even more surprisingly, there seem to have been two major peaks of its usage in print books, one today and the other in the sixteen hundreds.

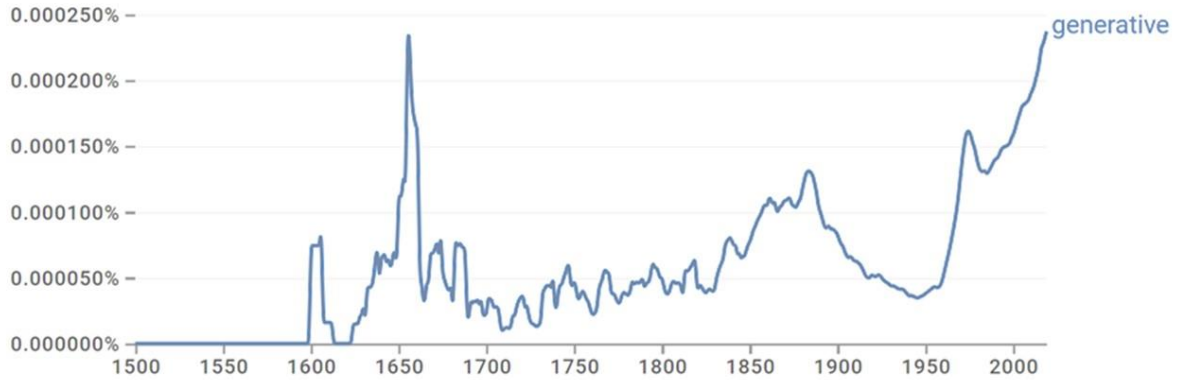

Figure 1 - 'Generative', Google NGram

The present-day peak appears to have surged in the second half of the twentieth century CE, and despite such metrics being raw and contextless, one could dare to speculate that

one factor involved might be the influence that the work of Noam Chomsky in linguistics has had in contemporary culture.

Chomsky proposed in his generative grammar that we should aim to study 'language as a natural object, a cognitive capacity that is part of the biological endowment of our species' (Chomsky, 2002). It is this same sense of 'naturality' (Soddu, 2002) that we may also find in eighteenth-century books of biology referring to the study of the generative structures within the seed of the tree. Chomsky had also found such structures or 'morphemes' (Chomsky, 2006) in the human language. However, this contemporary reapproach to this idea is not exclusive to linguistics, as Lerdahl and Jackendoff have also searched for the mind's natural grammar in music (Lerdahl, Jackendoff, 2017). Computationally, in the 1960s, Bense started reasoning about 'programming the beautiful' (Nees, Bense, 1965) and wrote the manifesto of 'projekte generativer ästhetik, 'analogous to generative grammar, in so far as it helps to formulate the principles of grammatical schema-realisations of an aesthetic structure' (Higgins, Kahn, 2012). His student Nees explored the idea of 'generative computer graphics' (Nees, 1968). It wouldn't be long after that the idea of 'generative art' would appear as a movement involving several authors such as Celestino Soddu, who defined a kind of computational living ontology of entities that are the seed of an artistic idea (Soddu in (Corne, Bentley, 2002)).

To the layman, possibly used to thinking of the arts as picking a pencil or a chisel, this present moment of 'generative' things may feel so futuristic, almost 'sci-fi', to a point that may be disconnected with a more widespread, less technological, idea of art. However, in this thesis, it is argued that that connection with 'téchnē' is ancient and everlasting, and the text draws an invitation to investigate the history of the arts from a particular perspective: the progress of artmaking tools, from their beginnings up to their reinvention with the computer and to the dawn of their autonomy, within the contemporary endeavours of research in computational creativity. Additionally, it is an

invitation to perceive the game engine as a present-day technology that integrates that technical heritage, that technical palimpsest that humanity has built through the centuries, in unity with great potential for the arts.

The Leonardo paradox

Most recently, we have been consistently informed in the news, were surprised and wondered about it, and have also been warned about the possible negative outcomes of generative AI. This is a development that has been in the forge for a considerable time, given the previous decades' endeavours of research in AI but has grown considerably with more recent developments in deep learning and parallel computing, and the exponential growth of interest propitiated by the internet culture. But this is also something that we can find in more ancient literature. For instance, Descartes reasoning about the possible humanity of a thinking artificial machine (Mueller,1990), to Muellers' predictions in the early 1990s about some possible paradoxes that such intelligence could represent - which he group defined as 'the Leonardo paradox' (Mueller,1990) – that already mentioned concerns that are today still state of the art, such as considerations about the possibility of not understanding the inner workings of an intelligent device, today so famously referred as the black box problem.

History

To understand the relatively recent idea of 'computational creativity', an intellectual called Boden can be a good guide. Boden's work shows that computational creativity is important today in the fine arts, architecture, and music and not less in science, as it has turned the computer into the canvas, the brush, the instrument, and the creative agent (Badia, 2013). Boden points out how computational creativity research started, and here again, a connection with games is found. Around the 1950s, some of the first efforts in artificial intelligence, arguably the mother of computational creativity, were to build a

machine that could create winning strategies in games such as checkers, backgammon or chess (Perez, 2015), much before AI was considered 'respectable as a science' (Boden in (Besold, Schorlemmer, Smaill, 2015)) and such efforts have also reached the domain of the arts. All over the world, authors report long-lasting attempts within many of the art forms, from Turing having fun with computer-generated love letters to Weizenbaum's conversational Eliza and the autonomous story creators of Scou Turner's MINSTREL [1993] and Perez y Perez's MEXICA [1990]; from Hiller and Isaacson Illiac suite [1950] to Brian Eno's Generative Music 1; from the computer-generated drawings of Joan Shogren, Georg Nees, Michael Noll, and Frieder Nake [the 1960s] to Cohen's painting fool; (Boden in (Badia, 2013) (Wcizenbaum, 1966) (Besold, Schorlemmer, Smaill, 2015)) and (Monfort in (Perez, 2015)). We have seen that in our days, where art can be generative, creative behaviours may also now be instanced computationally, which deserves a brief reflection about what have been the changes in the technical nature of the arts throughout the times, what has been the influence of computing in them and how they have led to creative autonomy.

Natural arts

Regarding computational creativity, Boden warns about how easy it is for our minds to attribute meaning or artistry to the possibly meaningless or not creative, and this current problem connects with an interesting episode in the history of art. Badia mentions the recent rise and fall in popularity of a series of abstract paintings that had been exhibited at galleries in Vienna. The initial acceptance of the work of an artist called Nonja fell to the ground when the public became aware that Nonja was an orangutan living at the city's zoo (Badia, 2013). A superficial reading of this episode could find it an entertaining, detrimental, or anecdotic demonstration and repetition of the eternal criticism of the 'disgraced status of art in our current era', but careful consideration of it might render some deeper thoughts about the very nature of the arts. Apart from some possible humorous reactions, this episode brings to life the deeply

humane imaginary of Quinn's protagonist, starting to read Ishmael's newspaper advertisement (Quinn, 2017).

Reinventing the wheel

Is it possible to conceive the existence of music without songbirds? To what extent has the human being appropriated music? Can we envision a computer that creates art without posing such kinds of questions? Pachet reports the work of Draganoiu, which has found phrase structures in domestic male canary songs and an instinctive aesthetical preference of the females for the songs that had an increased syllable rate (Pachet in (McCormack, D'Inverno, 2014)). Seeing the nature of the arts, thinking about the engineered perfection of Baya weaver's (Ploceus philippinus) nests, the design of the spiderweb (Starr, 2021) and the perfect geometrical tessellation of the beehive may make us a bit less anthropocentric, less possessive about the arts, but also let us comprehend them with a psychologically deeper, more instinctive, almost mystical sensibility.

The human nature of art, 'it's a kind of magic'

We do not possess enough resources to understand how the human arts have begun. There are some sources that predate history, such as drawings and paintings, that were left permanently in stone and remains of pre-historical flutes made from bird bones, but nothing more perishable could have survived the millennia. Gombrich argues that magical thinking was inherent to the initial making of art, and we, fortunately, have some evidence of this he suggests (Gombrich, 2023). For instance, we can find depictions of music being played in the paintings representing hunting of game in prehistoric caverns (Burkholder, Grout, Palisca, 2019) and wonder why music and dancing rituals were a part of this vital activity. The large scale and the placement of the paintings in some caverns may also remind us of the solemnity we find when entering an ancient cathedral (Gombrich, 2023). We get a sense that such art was more than a mere pictorial

representation, something we can consistently find throughout the progression of history. For instance, much later, the meaning of the word 'sculptor', who was the one who took care of eternalising the dead in ancient Egypt, was literally ‘he-who-keeps-alive’ (Gombrich, 2023).

A first form of writing

With the resources we currently have, we can trace back to prehistory dance, music, drawing (engravings) and painting. Painting may have been our first form of writing (Gombrich, 2023) and on the technical side, the use of pigments and their techniques. Pottery for making flutes, rattles and drums, up to the bronze age with 'bells, jingles, cymbals, rattles, and horns' and the first string instruments (Burkholder, Grout, Palisca, 2019), may make us wonder about today's orchestras and how much of our culture is about maintaining and improving what has been given to us by our ancestors.

Meanwhile, in computing

In the domain of computing, this sense of a formal and temporal ubiquity of the arts and their technologies can also be perceived, such as regarding computations preceding, for instance, the discovery of electronics (Nisan, Schocken, 2021). In fact, in the last half-century, researchers have built many hardware implementations of Boolean functions, including magnetic, optical, biological, hydraulic, and pneumatic mechanisms (Nisan, Schocken, 2021). So, it may be fruitful to have this historical sense of permanence and reinvention around the emergence of numbers, writing systems, and computing, as well as the arts, among other human achievements.

The invention of writing

The invention of writing marks the end of prehistory and provides historians with - sometimes broken - written records of what the arts were at each moment in time that add to the other sources, such as physical remains and paintings. From between the rivers Tigris and the Euphrates, historians were left with depictions, written records,

and instruments - including harps and lyres - that were used in 'wedding songs, funeral laments, military music, work songs, nursery songs, dance music, tavern music, music for entertaining at feasts, songs to address the gods, music to accompany ceremonies and processions, and epics sung with instrumental accompaniment' as well as the oldest known musical notation (Burkholder, Grout, Palisca, 2019). In this period, the diatonic scale is believed to have been invented by the Babylonians, which was not a small feat because it is still used today and because of what the writing of music meant to the history of music (Burkholder, Grout, Palisca, 2019). From the Indus Valley civilisation, we have remains of human statuettes such as the bronze 'dancing girl of Mohenjo-daro', depicted wearing a soapstone seal, which is another commonly found artefact (Government of India, 2023). From the valley of the Huang River, the fragments of history guide us to the calligraphy, paintings, lacquer, bronze work and jade ornaments of the Zhou and Shang dynasties (Smithsonian,2020). From the Nile, there have been attempts to decipher musical notation in hieroglyphs and in the Old Testament, but no consensus has yet been reached (Burkholder, Grout, Palisca, 2019). However, the idea of artistic style was already well established for the Egyptian artists, so much so that their 'correct' way of painting and sculpting has lasted for millennia (Gombrich, 2023), and that notion of style would become, for the arts, the hallmark of each era.

A common division of Western history is well established since the Renaissance: antiquity, the Middle Ages and modernity; and relies on a perspective of the existence of moments of change. Revolution is a word that describes the time necessary for a planet to complete its orbit and, curiously, the history of art is always about the new gravitating the old: classic or modern, classic or gothic, classic or romantic, classic or baroque, classic or mannerist; and that many of the names given to the 'new' were depreciative adjectives that the 'old' have found to criticise it. (Gombrich, 2023) (Burkholder, Grout, Palisca, 2019)

Later, around Crete, the rigid Egyptian traditions in sculpture would be broken for the sake of accurately and vividly representing the human figure, and in architecture, the Doric order would emerge for a new canon that would later be considered 'classical' and would also include the developments coming from Ionia and Corinth (Gombrich, 2023). In festivals, the sound of the aulos accompanied the singing (ωδή) of the tragedies of Aeschylus, Sophocles, and Eurípides, and poetry was sung to the lire; aesthetically, the perfect melos (μελοσ) consisted in the virtuous combination of poetry, dance and music; Pythagoras studied music as a mathematical topic; and some early musical theory and notation remained, including a two-thousand years old song: the Seikilos epitaph; The Romans would later rule the western world, developing the ancient Greek knowledge into a Hellenistic style of sumptuous architecture and sculpture that can still today be found all over the old continent. A fragment of what Roman life used to be can be found in Pompei, where one can also appreciate the vivid frescoes depictions of nature and people. Around that time, Cicero and Quintilian considered music to be key in the education of the cultivated mind. After the Christianisation of the empire, architecture would turn to build the first churches, sculptural and visual arts to their decoration and music to the religious rites, whilst Byzantium would preserve ancient knowledge in the arts that would later be rediscovered and revived. (Burkholder, Grout, Palisca, 2019) (Gombrich, 2023). It is said that great rivers make good wines. In antiquity, we can so find the cultural ancestors that nurtured civilisation with 'agriculture, writing, cities, and systems of trade', 'mathematics, calendar, astronomy, and medicine', philosophy, religion, and the arts.

From magical to medicine

The perception of a healing power of the arts, or at least of music, can be traced back to these times. In the Old Testament, the humble David would send away the evil spirit that tormented King Saul by playing the harp (The Bible, I Samuel 9:16-18). In Greece, it was believed that the Pythagorean musical order of the mathematical universe could

penetrate the soul and restore its harmonia, and Plato argued that the ethos of certain music could stimulate that same ethos in the listener. (Wigram et al., 2013) (Burkholder, Grout, Palisca, 2019). The Roman senator Boethius would later compile the ancient knowledge and describe in his 'De institutione musica' three kinds of music: the 'musica mundana' that consisted in the mathematical rules governing the universe; the 'musica instrumentalis' that was produced by instruments or voices; and the 'musica humana' that united the body and the soul (Burkholder, Grout, Palisca, 2019).

The mechanised nature of art

During the Western Middle Ages, very much had changed, and historians find the primacy of the Church over the empires and over the kings. The arts, that first form of writing, had become the messenger that could bring the religious teachings to the illiterate through the depictions found in the walls of cathedrals, illuminate books and that would nurture the devotion through sacred chants; The temples would become the centre of social life and be built with evermore care for the divine; During this large period until the Renaissance, the accurate measurement of time would become possible with the invention of the mechanical clock (Burkholder, Grout, Palisca, 2019), the work of sculpture would be eased with the creation of mechanical drills (Burkholder, Grout, Palisca, 2019) and there were important achievements in architecture, with the control of the techniques of building interconnected stone arches that would sustain the ceilings (Burkholder, Grout, Palisca, 2019) and both in architecture and in music the travelling of masters through the old empire would initiate and enable the interchange of artistic knowledge that we can still see today in the instances of the International Style or the Gregorian, Byzantine, Ambrosian, Old Roman, Gallican, Celtic, Mozarabic and Beneventan chants; Music would also evolve from monophony to polyphony, with the development of four fundamental concepts: counterpoint; harmony; the centrality of notation; and the separation between composition and performance (Burkholder,

Grout, Palisca, 2019). Musical instruments would be improved and present a greater variety, namely the portative and the church organs. Guido of Arezzo would develop the old neumes into the musical notation we still use today and use the first six phrases of the hymn 'Ut queant laxis' as a mnemonic (ut, re. mi, fa. sol, la), with the invention of solmisation. Along with it, the notion of rhythm would develop (Wiggins in (Perez, 2015)) (Burkholder, Grout, Palisca, 2019) (Boden in (Besold, Schorlemmer, Smaill, 2015)) (Gombrich, 2023). This was happening on the brink of a major technological breakthrough that would decisively pop out knowledge from the rare and expensive manuscripts.

Printing, the invention of a mechanised form of writing

Gutenberg's invention of the machine for the printing of books was preceded 'by several decades' by the printing of pictures by woodcut and engraving (Gombrich, 2023), and sometime later also, music notation would be in print (Burkholder, Grout, Palisca, 2019); because of it, culture would now become accessible to the public as prints were a major promoting factor of literacy; musicians, visual artists, sculptors and architects would now be able to learn from each other and study the reproductions of the work of the great masters; scientific, philosophical and religious thought were about to flourish and become popular and also political; the new tonal musical compositions could now be faithfully interpreted everywhere; it would become possible to admire great masters of painting from a distance; this at the same time that faster travels throughout the globe were becoming a reality (Gombrich, 2023) (Burkholder, Grout, Palisca, 2019) (Laitz, 2016).

The early invention of mixed reality

At this point in this thesis, or even some pages before this, the reader might legitimately wonder why a text on computer science must go into such details about the progress of the arts throughout history. Now that we have reached Gutenberg's technical

breakthrough, arguably a prominent point on the theoretical background for this research has been made that the history of technological achievements is intertwined with the domain of the arts, a domain we want to approach through the resources of another technological achievement: computing. But not without emphasising a sense of permanence in the story of art and art technologies.

For instance, during the Renaissance, the discovery of the rules of perspective by the architect Brunelleschi would inspire painters to invent something that we now call 'mixed reality'. Today, we are resourcing to augmented reality goggles that put a layer of computer graphics on top of our natural vision and stumble upon what is being achieved. It is, however, an idea as old as the desire of Florentine painters to 'break a hole in the wall' and make the devout visitors of churches and cathedrals feel as if they were inside the religious scenes there depicted as perhaps Leonardo da Vinci wanted the commensals before the wall where he painted his last supper to feel they were sharing that same holy bread. Such mesmerising effects could not be achieved without the persistent invention, reinvention and resourcing of tools, devices, or machines meant for artmaking. Arguably, this occurred through the developments of what could be defined as an 'arts engineering' ever since antiquity: mechanisms for drawing circles and ellipses, or miniaturisations via pantographs, or primitive cameras that would allow the discovery of the rules of drawing in perspective, during the Renaissance. At that time, in the north, Jan van Eyck was inventing the oil painting technique to achieve perfection of colour and shading that we today avidly try to reproduce within the graphical rendering pipeline with the game engine. Arguably, the hardware and the software that we depend on today so much may be no more than a newer, refined iteration of tools, instruments, and techniques that have been invented along with the long history of the arts. Another interesting way of looking at this could be integrating this perception with Bill Hamack's observation in history that there seems to have been an 'engineering method' that predated the scientific one and that allowed a mostly

illiterate humanity to build towers that reached the skies and work along with physical properties of matter way before they were - or are - scientifically understood (Hammack, 2023).

More, more machines

Modernity continued through several well-known periods such as the Baroque, Mannerism or Romanticism, as the Western arts were becoming ever more eclectic and absorbing influences from all around the world and the organisation of twelve pitches in octaves in chromatic scales and the wide use of the two clefs would work perfectly with refined instruments such as the piano (Laitz, 2016).

The last stop in this travelling around in art history will be in the Industrial Revolution and its subsequent periods, which brought us Babbage's analytical engine, which Ada Lovelace predicted could 'compose elaborate and scientific pieces of music of any degree of complexity or extent' (Boden in (Besold, Schorlemmer, Smaill, 2015)). Times when 'there was no need for painting to perform a task which a mechanical device could perform better and more cheaply' (Gombrich, 2023), as photography had been invented and when Japanese printing reached the West, triggering Impressionism. Painters like Van Gogh, Gauguin and Cezanne felt that 'something had gone out of art' and hence decided to explore new ways that would lead to Expressionism, Primitivism and Cubism (Gombrich, 2023). The impact of the invention of the photographic camera was not only eminent in painting but also in developing visual perception itself. This was patent when painters started analysing the movement of horses through photographic studies and realised that they could not paint horses as if they were flying, with the resistance of the public, who thought they were now painting them incorrectly (Gombrich, 2023).

By then, autonomous machines had already seduced. That is the case of the mechanised reproduction of music that could, for instance, be found in church carillons and were finely explored by artisans of clockwork mechanical devices known as automata, that would entertain the elites by writing texts in paper with the most delicate calligraphy,

play musical instruments or even present theatrical plays (MAHN, 2018). Much earlier, back in the year 807, Charlemagne had already been gifted a water clock that was animated with 'automated characters and animals' by the ambassadors of Caliph Harun al-Rashid (Foulkes, 2017). Other machines would later reproduce not only creative behaviours but the human senses themselves when it became possible to hear music that had been previously recorded, see images that had been previously photographed, and watch cinematic depictions on a screen.

'Something has gone out of art'

Here may be an answer – or perhaps a counter-question - to the so many doubts raised in today's newspapers about the scares of GPT and other generative AI models. Has 'something gone out of art' again, just like Cezanne, Gaugin, and Van Gogh felt when they saw the birth of photography? Then perhaps the question might be, what has 'gone out of art' now? What can't today's 'photography' show? What can't generative machine learning models create for us; will this change the future of the Arts like photography did before?

Electricity

Back to the 20th century, the breakthrough of electricity would again add to what had already been achieved. Radio and television transmissions would make new 'Gutenberg moments': in the footsteps of how prints had previously originated the fast spread of culture and the arts, now that culture could become a real-time social communication phenomenon, as if in a metaphor where people were constantly travelling and interchanging ideas, but with their minds, their senses, and the telephony. The long-lasting marriage of the arts with technology would meet its jubilee in the avant-garde of the twentieth century when futurism and technologism would bring to the arts the aesthetics of the raw metals and the noises of the machines and skyscrapers (Calinescu, 2006). In 1923, the Bauhaus followed the principle' Kunst und Technik – eine neue

Einheit (Art and technology – the new unity)' (Higgins, Kahn, 2012). In music, composers would find themselves 'competing with the past' and obsess with turning tradition into 'something new' (Burkholder, Grout, Palisca, 2019). Diversity would become paramount, with a spectrum that would go from the iron reinvention of the classical architectural canon - in Art Nouveau - to the rejection of all the standardised, by the Arts and Crafts movement. The metallic musical instruments that evolved from antiquity could now be mass-produced in the same way that, unfortunately, weapons would. In a century shredded by massive global conflicts, art assumed multiple shapes, from bellicose propaganda to the desperate calls for humanity such as Picasso's Guernica and as in the 'consciously shattered' atonal music of Schoenberg, detergent boxes would be put in exposition in renowned art galleries, and Velasquez' popes would be infernally reinterpreted by Francis Bacon. (Wiggins in (Perez, 2015)). Perhaps by then, humanity was becoming too tired of herself but, surprisingly, that same 'bolts and nuts' material realm of the machine granted a thoughtful distraction from ourselves, maybe almost with a certain irony, this would be the century when mainframes that lived mainly in military environments would start outputting the first computer music and graphical art.

The computational nature of art

The computer arts surged in a period of much experimentation, but within a more compartmentalised, divided world and more opaque societies, different from today's more open, communicating wide world, so the whole registry of such experimentation may not have reached our times intact. For this, it is difficult in computer arts to establish a single pioneer, but hopefully wiser to observe the existence of a scattered and open set of computer art pioneers. And the same also seems to apply to the pioneers of computer games and to the history of the arts in general. Just before the computer, even raw electricity would surprisingly make its way as an artistic medium with the

invention of electrical musical devices (Burkholder, Grout, Palisca, 2019) that would bring to Chicago Muddy Waters' electric blues; or kinetic sculptures, but most importantly, electricity would become the medium for the transmission and processing of information. Also, cybernetics, the study of self-governance (Makarieva, 2008) or self-regulatory control systems, had been developing since the early 20th century and would nurture the appearance of a new discipline of artificial intelligence.

It was in music that mainframe machines first gave us a glimpse of what would become the computer arts. Since the early 20th century that composers such as Varese, Cowell, and others, had been looking for new sounds, new instruments. The tape recorder would soon 'make electronic music possible' by allowing 'to record, amplify, and transform sounds, then superimpose, juxtapose, fragment, and arrange them as desired to produce pieces of music', adding to the ability to produce sounds electronically by means of oscillators or full-blown new electronic instruments such as Lev Termen's *theremin* and Maurice Martenot's *ondes martenot* (Burkholder, Grout, Palisca, 2019). But mainframe machines, which were the product of WWII's 'demand for increasing computing power' (Bozhinov, 2015) and their successors, minicomputers, and again later the microcomputers, would pave 'the road for today's ubiquitous digital'. (Higgins, Kahn, 2012)

From mainframe computers...

The 1950s were the cradle for the computer arts, as scientists became attracted to reinterpretations of the concept of art that resourced to the new mainframe machines. In Stuggart, Max Bense, which investigated the 'relation between algorithms (mathematics) and aesthetics (the arts)' (Higgins, Kahn, 2012), would initiate the dynamics of what would be known as the 'Stuggart school', famous for a novel approach to the arts that wanted to 'break with the speculative and subjective approach to making and evaluating art' (Higgins, Kahn, 2012) by resourcing to computers, which can be naively understood as an attempt to make a science out of the arts and was coined as

'information aesthetics'. Approximately at the same time, the vacuum-tube computer lying at the University of Illinois was being used by chemists Leonard Isaacson and Lejaren Hiller to make the first computer musical composition, the *Illiac Suite for String Quartet*, with the goal of regenerating 'existent musical aesthetics' (Higgins, Kahn, 2012). By the end of the decade, at Johns Hopkins University, A. P. Rich would program the computer to 'generate various geometric and random patterns' (Higgins, Kahn, 2012), and a Boeing researcher would describe computer-generated images as 'computer graphics' (Higgins, Kahn, 2012). At Bell Labs, the study of sound was patronised by the 'telephone and telecommunications industry', and James Tenney would 'compose digitally synthesised sound' (Higgins, Kahn, 2012). The term' computer art' first appeared in the 'Computer Art Contest' of the publication' Computers and Automation' in 1963. Such contest would award the 'Splatter Diagram', an output by the Ballistic Research Laboratories Electronic Scientific Computer (BRLESC I) 'printed in an early printer called a dataplotter' (Higgins, Kahn, 2012). In the next year, a student of Max Bense at Stuggart, Georg Nees, would write his first 'aesthetical program', and some of his 'computer-generated graphic works' would be exhibited at a seminar room 'marking the first exhibition of computer art in history'. In April 1965, another public exhibition, this time of Béla Julesz's and A. Michael Noll's works, happened at the Wise Gallery, with computer-generated pictures and 'with computer-generated music as an ambient backdrop' and in November, Georg Nees and Frieder Nake would also exhibit at the Galerie Wendelin Niedlich (Higgins, Kahn, 2012) (Bozhinov, 2015). In music, 'simpler and more compact synthesisers', developed by Robert Moog and Donald Buchla and later commercially available, would appear in works such as *Silver Apples of the Moon* in 1967 by Morton Subotnick and make their way into pop music (Burkholder, Grout, Palisca, 2019), while James Tenney was holding programming workshops with fellow experimental musicians and artists in New York (Higgins, Kahn, 2012). Two popular happenings were about to take place simultaneously and bridge a divided world:

Cybernetic Serendipity in London and *Computers and Visual Research* in Zagreb. The first would announce 'computer art to the Western public', and the second, promoted by the New Tendencies movement, would nurture a 'third culture' of scientists and artists that looked into 'art as research and programming as method' (Bozhinov, 2015) (Higgins, Kahn, 2012).

...to mini-computers and micro-computers...

From military laboratories, minicomputers would end up appearing in 'universities and technical colleges' during the 1960s' and a decade later, 'consumer-level computers (such) as the Altair 8800 and the KIM-1' would lead to the democratisation of computing and so, of experimentation in the computer arts (Higgins, Kahn, 2012). In music, digital processes relying on 1's and 0's would replace the ones that were 'analogue of the soundwaves, such as the undulations in the groove of a record' (Burkholder, Grout, Palisca, 2019), as well as digital synthesisers, delivering 'musical sounds (which) could be reproduced and controlled precisely' (Burkholder, Grout, Palisca, 2019) with the combination of keyboards and computers, where composers' could control all the parameters of pitch, timbre, dynamics, and rhythm' and that 'could be translated directly into music through MIDI (Musical lnstrument Digital Interface'. (Burkholder, Grout, Palisca, 2019).

...to the internet.

The technique of sampling would also be developed, and because it relies on the patching of fragments of previously existing sounds and music, sampling would be one of the techniques that would much benefit from the later appearance of the World Wide Web, but most importantly for this thesis, the decades of the inception of the computer arts were the times where something deeper had arisen, regarding the very nature of the arts: they would become computationally autonomous.

The mother of all demos

Again, in a brief pause to reflect on novelty and tradition in regard to the art technologies and also of human technology as a whole: To our contemporaneity or even futuristic mindset with which today we navigate on the internet and build source-controlled pieces of software, using screens, pointing devices, printers and visual operating systems might be of some surprise that all such inventions have been around for far much longer than one or two decades. Before we could even dare to imagine concepts such as 'digital natives' or the ‘internet of things’, we can find all such inventions being shown at the ACM/IEEE that would be known as 'the mother of all demos, in the 1960’s. (Hintz , 2018).

The nature of the autonomous arts

As with Gutenberg's prints, and as with the prehistoric flutes and drums, or with the classical *camera obscura*, humanity reached a new technological landmark with the computer that would again reinvent a long inheritance but would also bring new dimensions to art, namely with creative autonomy. Autonomous reproduction was already present in automata and carillons, for instance, but not as the creative agency itself. Autonomy in artistic creation can also be found much before the computer, as in the case of Mozart's musical dice (Higgins, Kahn, 2012) or, for instance, in the simple poetry writing and figure drawing algorithm of the Surrealists' *cadavre exquis*, or in the automated method of writing proposed by Claude Shannon in 1949, that consisted in opening a book at random and select a letter at random, reopen the book at random and read until the letter is found, and so on repeat. (Higgins, Kahn, 2012)

Computer-generated poetry, pictorial and musical art would, since the 1950s, bring us this new reality where the artist can interact with the machine, including live and in real-time, with 'varying degrees of autonomy' (Galanter, 2003). But arguably, the

computer would allow for making autonomy in art a much more powerful concept. This was patent in Nake's consideration in 1968 that:

> 'Each painter is a restricted picture generator. So is each picture generating computer program. [...] If we had a proper definition of art, we might enable the computer – a mathematical machine – to produce art. Such definition would have to precede the question of whether a computer would be able to produce art' *(Higgins, Kahn, 2012)*

and possibly even more in LeWitt's later prediction of an 'idea (that) becomes a machine that makes art' ((LeWittt, Paragraphs on Conceptual Art, 80) in (Higgins, Kahn, 2012)). A question that may arise is if this means that the arts are moving towards a platonic supplantation over materiality, almost as if everything was becoming an idea: what if LeWitt's machine could also become an idea itself?

Ideas and identity

In Celestino Soddu´s work the concepts of idea and identity are central to a philosophy of Generative Art, which is a creative logic or process that happens with the artist´s realisation of two elemental parts of creation:

- First, the idealisation
- And then the evolution/variations/increasing complexity of that idealisation, that may happen with given degrees of autonomy.

To better understand this, Celestino notes that whilst we can perceive different figures and shapes in the clouds in the sky, all such clouds have in common the idea itself of being a cloud, that identity, and so in parallel with this, he could project partially autonomous variations of medieval towns, or sculptures that embody the style of Picasso's portraits, for instance (Soddu, 2009).

In his more recent communications at the Generative Art Conferences, Soddu reminds us that we should be thinking Generative Art beyond the autonomous, beyond the technology or the techniques, to avoid the risk of over-simplification of the complex,

subjective, interpretative and so deeply human characteristics of the creative act, not to underestimate the importance of novel techniques, but rather to address the sphere of art and human identity.

Celestino tells us that Generative Art is an 'Author´s AI' 'because works like Artificial Intelligence but the results belong to a subjective vision and to a unique and recognizable poetics' (Soddu, 2023). This may be great news because in a time when some artists question if they have been defeated by technology, Celestino tells us that at most, we rather may have been feeling 'defeated' by oversimplification. He proposes Generative Art as a way for the artist to supersede, not the machine, but himself. This is because 'when an artist performs an idea, normally he tries to represent it with some artworks, but each result is not a full representation of his idea. It's only one of the possible partial performing artwork' and Generative Art is a way to overcome this limitation (Soddu, 2013). So, 'the idea is considered [...] visionary, because it is capable of unpredictable evolutions towards complexity. Therefore, an idea is not just a simplified synthesis of a vision or a concept, but a hypothesis of a possible path towards complexity.' (Soddu, 2023)

It is also useful to read the clarification Soddu gives about what each concept should mean:

> *'**Generative Art** is the human ability to design generative systems.*
>
> ***Generative Systems** are tools, software, hardware, robots and machines that manage the designed artificial DNA and produce events, all different but belonging to an identifiable designed artificial DNA and produce events, all different but belonging to an identifiable artificial species.*
>
> *The **Generated Events**, all different and unique as natural individuals, represent the human vision that was at the basis of each generative project.'*
>
> (Soddu, 2018)

4. Contextualising game engines and the arts

An essentially abstract realm of the arts - even platonic (Balaguer, 2023) or idealist (Guyer, Horstmann, 2023) - seems possible within a technology that may have greater potential than its direct artistic applications. The game engine, with which digital games are created, due to its multimodal nature that can deal with a variety of forms of art, due to the panoply of technical achievements it contains and due to its computational nature, may become that ideal space of exploration of new forms of creativity. This thesis will develop the idea of the game engine as an ideal space for research in art creation, experience, and form. This can start by drawing a multidimensional parallel between the arts 'then and now', their history, their ontology, the artist himself/herself and their artistic practice, education, and research.

Additionally, questions can be made about how this relates to games and game engines and with this thesis hypothesis, which in turn can raise software development questions as well as questions that can be put forward to artists and other stakeholders.

Ontology

Defining creativity

One of the tasks of computational creativity research is to model human and non-human creativity. The evidence of how difficult it might be to model creativity computationally is demonstrated with a modest question: How can one define creativity?

Corne and Bentley list attempts to do so by many authors, and they generally output sentences where they adjectivise verbs with words such as 'new', 'innovative', 'valuable', 'novel', 'alternative', 'unseen'; where the verbal forms are such as the action of 'going beyond' or 'generating'; and are relative to the subject of 'collection of natural and/or technological processes' (Wiggins in (Perez, 2015)) within a 'search space', a 'knowledge', the 'bounds of representation', 'requirements' or 'previous solutions'. But others may put it as simply 'expressing your soul' (Corne, Bentley, 2002) and (Kowaliw et al., 2009) and Boden argues that there are two creativities, a personal (or psychological) and a historical one, that creativity can be exploratory or creational (Wiggins in (Perez, 2015)) but also that the question of if a computer can truly be creative is of philosophical nature, and not scientific, and indeed there have been made efforts in that sense, for instance, in the work of philosopher John Searle (Cole, 2023).

Boden also makes a fair point, heuristic, that arguably a computer output can be considered creative if that same output, being rendered by a human being, would be considered creative as well (Boden, 2009) and (Boden in (Besold, Schorlemmer, Smaill, 2015)).

Nevertheless, we have seen that the arts may not be exclusive to human beings and that the pre-historical records of human arts suggest a connection with human nature that is closer to a magical state of mind. Art was, so, more valuable then, as a sometimes magical representation of something or someone than as an effort of creative expression of the artist (Ernest W. Adams in (Clarke Mitchell, 2013)). In antiquity, we have seen a depuration of artistic technique and style, but Western art reached the medieval age being 'closely connected with religious themes and was (by then) 'almost inconceivable' otherwise' (Gombrich, 2023). Arguably, that appreciation of creative expression is a modern concept that has discreetly matured over the ages, from the Renaissance to Pollock's work and is also related to the changes that occurred in the societal role and importance of the artistic profession.

Contextualising game engines and an ontology of the arts

Gombrich graciously states that there is 'no such thing as art, but artists' (Gombrich, 2023). This open way of defining art is coincidental with the openness found in the computer arts, that when granted autonomy, already raise questions regarding who the artist is - the human or the machine? - despite such controversy is commonly dismissed as a possible goal of computer arts endeavours is to augment, and not to 'kill' the artist (Figure 2). Also, as seen before, in digital games, the figure of the artist is omnipresent. Moreover, the game engine seems to enable such kinds of new artists, so possibly also new kinds of art?

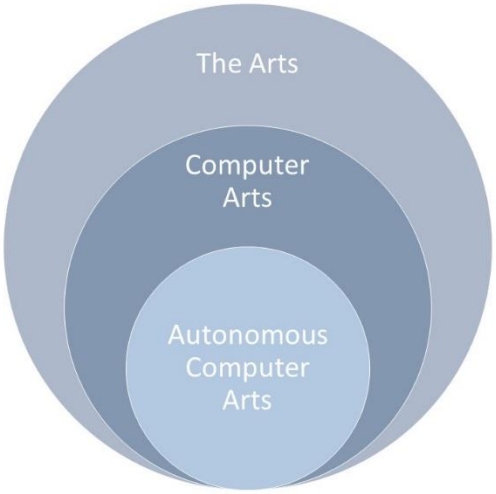

Figure 2 - Domains of the Arts, Computer Arts, and Autonomous Arts

Predictions and questions raised

In light of the hypothesis, some predictions can be made such that with technological gamification, we can develop gamified prototypes that will render outputs that may be perceived as new kinds of art, such as, for instance, artistic curation.

This could lead us to new views of software development and game development, where questions can be raised about how can we create new kinds of transdisciplinary art and if this could alter the ontology of the arts.
The input of artists and other stakeholders could answer some questions, such as if they would see new kinds of art forms in such outputs.

The artist

From that mage of pre-history, who communicated with deities, to AARON, the autonomous painter, the concept of 'the artist' has meant different things throughout the ages and geographies. In the Athenian Agora, poets were highly appreciated, but sculptors or painters were considered inferiors because they worked with their hands and with dirt (Gombrich, 2023). That societal prejudice would nevertheless be broken by artists such as Pheidias, whose sculptures would be highly admired (Gombrich, 2023). While 'vigorous and very realistic pictures were made by humble greek craftsmen at a low price' (Gombrich, 2023), on the other side of the globe, the ancient Chinese artist was a poet of images, not a reproducer of reality. The paintings were the result of imaginary compositions and meditations (Gombrich, 2023).

The traveller

Later on, the travelling of artists would result in the first global movements, such as the International style (Gombrich, 2023). During the middle ages, music professionals such as bards, joungleurs, minstrels and troubadours would entertain the public, and some even start organising into guilds, whilst 'courts, city governments, and churches continued to sponsor music-making as they had for centuries'. (Burkholder, Grout, Palisca, 2019).

The author

According to Gombrich, Giotto would start a new era in the history of art, as it would from him onward become the' history of great artists' (Gombrich, 2023), now with the work of painters and architects being coveted by popes and kings. Because in the north, the Reformation would prohibit painters from their traditional themes, they would turn to portraits and naval scenes and would start depending on the opinion of the public to which they could sell (Gombrich, 2023), as did musicians. During the Enlightenment, a growing interest in the arts by the public led writers and artists to address popular topics (Burkholder, Grout, Palisca, 2019), such as William Hogarth's moralistic engravings, which had more prestige with the public than with art critics (Gombrich, 2023).

The inventor

If, with the French Revolution, artists would paint the 'religious, Greek mythologies and Roman episodes and allegories' in the twentieth century ', artists had to become inventors [...] to strive for originality rather than for that mastery we admire in the great artists of the past' (Gombrich, 2023). Later on, popular artists and the popular arts would develop along with industries of records, broadcasting and distribution, and would not be impermeable to the inception of the computer in the arts. But despite most of today's music 'uses technology developed by the pioneers of electronic music', such endeavours never conquered more than small audiences, like Xenakis' music based on mathematical concepts (Burkholder, Grout, Palisca, 2019). Both in musical and visual computer arts, the artists-pioneers lived in a balance between science and the arts, facing suspicion from both worlds (Higgins, Kahn, 2012) and initiating a 'third culture' (Bozhinov, 2015), but they were also sometimes untrusted, due to the military origins of the first computer machines. They have also faced authorship issues since the very beginning, such as in 1962, when Noll saw his request for authorship registration of his'

Gaussian Quadratic' at the Library of Congress go back and forward along the bureaucratic meanders because 'a machine had generated the work' (Higgins, Kahn, 2012). Who was now the artist? 'Is it or is it not art?' (Nake in (McCormack, D'Inverno, 2014)) Arguably, the developments in the autonomous computer arts go in tandem with a newly distributed, possibly fragmented, or an open set of concepts of artistry, an unrestricted new idealisation of the artist.

An artist that can be an algorithm…

According to Galanter's perspective on generative art, 'a system with a given set of rules' can be purely generative if it 'involves no subsequent intervention after it has been set in motion' ((Galanter, 2003) in (Jones et al. in (McCormack, D'Inverno, 2014))). That seems to be the case of AARON, the autonomous painter. Cohen, its creator, graciously mentioned that he might be 'the first artist in history to have a posthumous exhibition of new work' as his creation can potentially continue generating numerous works of art *ad aeternum*. This joke he had made at a cocktail party was - to his surprise - frequently quoted, possibly being that its greatest merit is in how it plainly exposes the paradox of who is the artist in a generative system (Cohen, 2002). Indeed, in the more recent 'The Painting Fool' by Colton, there is a clear goal to perpetually 'build an autonomously creative system' in a general enterprise to build 'software which is independently creative' that can be an 'artist, musician, writer, designer, engineer or scientist' (Colton in (McCormack, D'Inverno, 2014)). Bentley also mentions how his creative evolutionary systems always surprise him by superseding him in the ability to create works of art, to design and to compose music (Bentley in (Corne, Bentley, 2002)). However, Cohen still considers AARON to be just an 'extension of his artistic process, rather than an independent, autonomous creative entity'; Cohen is still the creator, after all.

….or an algorist…

Nake notes that 'when they started in the 1960s, they were often called computer artists, a term most of them hated'. He adds that such postmodern artists, the algorists, 'live between aesthetics and algorithmics' as they are the ones who do the artistic thinking and then delegate the execution to the devices they establish (Nake in (McCormack, D'Inverno, 2014)).

… can be someone from the history of art…

But can that established device be himself a representation of a human artist? That seems to be what happens in generative works that dive into the history of arts to relive artists such as Picasso (Soddu in (Corne, Bentley, 2002)), Escher (Eiben et al. in (Corne, Bentley, 2002)), Rembrandt (Microsoft, 2017), the Beatles (Sullivan,2023) or Frank Sinatra (Robitzski, 2020) and produce new, but recognisable artistic outputs.

… that can be a virtuoso…

Or can that autonomous artist condense the ideal capacities of artists, such as virtuosity in music performance? Pachet's 'Virtuoso' is based on Levine's approach to jazz music as something consisting 'of 1% magic and 99% explainable' things, and trying to condense in the machine those things, 'and making the remaining 1% explicit' (Pachet in (McCormack, D'Inverno, 2014)).

… and that can also be a partner

The possibility of creative autonomy working as a partner in art-making is mentioned in the work of many generative artists. For instance, Colton mentions his goals to develop software that can - besides its own independence - also be a collaborator in the arts (Colton in (McCormack, D'Inverno, 2014)). Blackwell talks about a 'Live Algorithm' that can improvise along with musicians (Blackwell et al. in (McCormack, D'Inverno,

2014)), and Jones aims for a 'computer (that) can be used as a partner to augment the practice of musical composition' (Jones al. in (McCormack, D'Inverno, 2014)).

Contextualising game engines and the artist

As autonomous computer art seems to potentiate new kinds of artists (Figure 3), it is noticeable that such artists are also instantiable within the game engine. If it is true that there is no art but artists, what could be the implications to the arts of the instantiation of artist entities within the creative space enabled by the game engine? There seems to be potential as, on the one hand, the game engine is multimodal in art forms. On the other, due to its computational nature, it is open to the endeavours of computational creativity.

A question that can be made is about what such a novel game-engine-artist system could be. How would it practice the arts, and could it learn and how? Could it be an autonomous gamified researcher in the arts? It might prove worthy to reflect first on such dimensions in the arts.

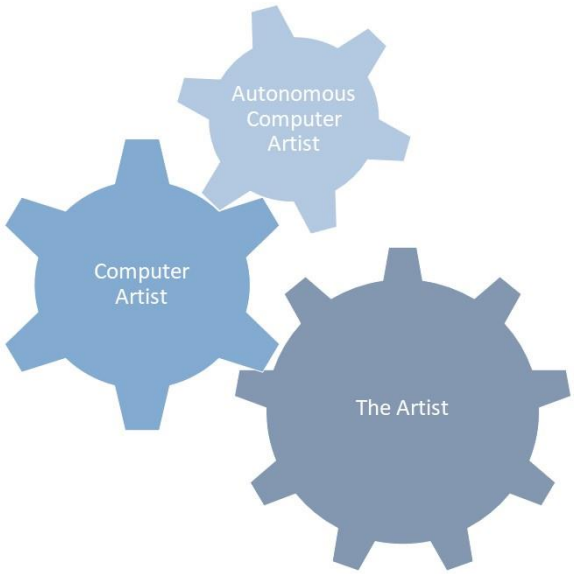

Figure 3 - The Artist, computation and autonomy

Predictions and questions raised

Considering the hypothesis, some predictions can be made, such as that we can develop gamified prototypes that are perceived as artistic whilst exploring multimodality - the interplay between different representational modes such as between images and written/spoken words (Korhonen, 2010) - and that such tools may creatively empower the artist.

In the view of software development and game development, questions can be raised about how to drive the game engine's multimodality in order to empower and/or augment the artist and about what are the relationships between the entities at play: the artist, the computer artist and the autonomous artist.

The input of artists and other stakeholders could answer some questions, such as if they perceive artistry or artistic merits in the outputs.

Practice and education

Back to the natural arts, questions can be made that, surprisingly, seem to apply to the most advanced computational arts. For instance, do birds learn new melodies, and how? Back to the first humans, the same question: were the Altamira caves paintings a result of any sort of transmission of knowledge on artistic techniques between the primitive generations? In antiquity, we do have records that consistently show that artistic education was very well established. Indeed, Gombrich tells us that:

> *'the Egyptian style comprised a set of very strict laws, which every artist had to learn from his earliest youth. Seated statues had to have their hands on their knees; men had to be painted with darker skin than women; the appearance of every Egyptian god was strictly laid down: Horus, the sky-god, had to be shown as a falcon or with a falcon's head; Anubis, the god of funeral rites, as a jackal or with a jackal's head. Every artist had to learn the art of beautiful script.'*
> *(Gombrich, 2023)*

The same author also mentions that the 'great awakening' of ancient Greek sculpture drank from the teachings of such Egyptian traditions (Gombrich, 2023). In Athens, learning to play the lyre was central to the education of young men and women, played for recreation, and for accompanying 'dancing, singing or recitation of epic poetry like Homer's Odyssey' (Burkholder, Grout, Palisca, 2019). With the Romans, we find the same opinions about the importance of arts education. For instance, for Boethius, music was important in the education of the youth' both in its own right and as an introduction to more advanced philosophical studies' and was included in his *quadrivium* of the four mathematical disciplines: geometry, arithmetic, astronomy, and harmonics (Burkholder, Grout, Palisca, 2019). On the other side of the globe, Chinese artists learned by studying the techniques in the work of the great masters and then travelling 'to contemplate the beauty of nature' (Gombrich, 2023). During the Middle Ages, wandering students would play songs known as *goliard*, about 'love, satire and earthly pleasures' (Burkholder, Grout, Palisca, 2019) and by the Renaissance, sculptors and painters would study the nude and draped human body and poses, animals and plants, reliving the classical knowledge of ancient Greece and Rome, as well as the 'optics of perspective and the use of colours' (Gombrich, 2023) (Gombrich, 2023) and the Renaissance masters would then be studied all over Europe by means of prints of woodcut and engravings (Gombrich, 2023).

By the eighteenth century, the academisation of artistic knowledge would start taking the place of the old methods of 'master to apprentice' education, visible in the appearance of institutions such as the Royal Academy of Art (Gombrich, 2023) (Gombrich, 2023). Art schools would, from then on, become the norm, and some would famously feel dissatisfied with what they had learned there, inventing new ways of painting, like Cezanne, Van Gogh and Gaugin' (Gombrich, 2023) and were the precursors of the liberation of the rigidity of tradition that would happen in the twentieth-century art education (Gombrich, 2023). In music, education would now

consist in exercises of 'singing, writing (composition), analysing, listening, and playing' (Laitz, 2016). When computing reached the arts, the computer was even more inaccessible than cinema (Higgins, Kahn, 2012); however, it would gradually become more affordable and become central in the 'digital revolution' of contemporary education (Perez, 2015). Today, education may train to use but also to build software (McCormack & D'Inverno in (McCormack, D'Inverno, 2014)), and there is a growing interest in the language of 'new media' (Filimowicz, Tzankova, 2017) and 'how to create expressive interactive experiences such as digital games, interfaces, art installations, [...] mobile applications' (Filimowicz, Tzankova, 2017) and creative coding (Guglielmetti and McCormack in (Filimowicz, Tzankova, 2017)). Computational creativity and generative art are also starting to appear in university education despite being historically mostly research topics. On the other hand, such endeavours bring a new dimension to art learning and practice, namely when they approach it from the point of view of the autonomous machine.

Contextualising games engines and the practice and education of the arts

Today, artistic education with game engines can be seen in secondary and higher education, as well as professional and self-paced further education in areas related to Design and New Media, Computing and Communication, among others. Game engines seem to appear at the three layers in creative education: in the arts in general, in the more specific computer arts, and in the autonomous arts. Artistic education, besides its traditional components that represent the collection of techniques, tools and devices developed throughout their long history, have also today a strong component of computational creativity education, be it on the level of resourcing to software to practice and reinvent the tradition, be it in delegating to the machine some part of the creative process.

Here, we can see that game engines appear with interesting strength because they absorb the potential of the tradition, the computational and the autonomous whilst adding to it the game's characteristic multimodality and interplay of different forms of art, placing them virtually as a nice tool of the trade in the arts, artistic education, and research.

Predictions and questions raised

In light of the hypothesis, some predictions can be made, such as that technological gamification can enable the emergence of new ways of making art as well as render new ways of learning and teaching.

In the view of software development and game development, questions can be raised about how to drive the game engine's multimodality in order to enable new ways of making art and to enable new ways of learning and teaching.

The input of artists and other stakeholders could answer some questions, such as if they see in the results new ways of making art and new ways of learning and/or teaching.

Research

Arguably, artistic research has consistently been on par with the artistic practice, at least since in ancient Greece, the rigid style and rejection of novelty of Egyptian art started being questioned, that time when 'philosophy first awoke among men, when the theatre first developed out of the ceremonies in honour to Dionysius.' (Gombrich, 2023). As Gombrich puts it, 'the Egyptians had largely drawn what they knew to exist, the Greeks what they saw; in the Middle Ages, the artist also learned to express in his picture what he felt' (Gombrich, 2023), and the Renaissance period is well known for the reliving that spirit of discovery, with 'the mathematical rules of perspective [...] the secrets of scientific anatomy, the study of Roman monuments' (Gombrich, 2023) and so is Leonardo da Vinci, who 'did not rely on authorities but tried and experimented, anatomy of the human body, 'the laws of waves and currents' 'the flight of insects and

birds' 'the forms of rocks and clouds' 'the effect of the atmosphere on the colour of distant objects' 'the growth of trees and plants' 'the harmony of sounds', which were 'the foundation of his art' (Gombrich, 2023). The history of technical discoveries may unravel the story of the art, from Goya and the technique of Aquatint, the novel painting of light by Manet, or the impact of Japanese prints in the work of Van Gogh, Ferdinand Hodler, Toulouse Lautrec and Aubrey Beardsley (Gombrich, 2023). Or George Seurat and the science of vision: if we pass a magnifying lens on a contemporary LED screen, the RGB dots might reminisce of Seurat's pointillism, who, by studying the 'scientific theory of colour vision', discovered that if he painted small patches of polychromatic inks, 'that would lead to the colours blending on the eye (or rather on the mind) without their losing in intensity and luminosity. ' (Gombrich, 2023). New doctrines and schools would succeed in reinventing through experimentation, resulting in novelty such as the Expressionist' dream of pure visual music' (Gombrich, 2023) or the posterior Bauhaus discovery of 'forms and colour schemes' (Gombrich, 2023) that are still today important elements in graphic design. In music composition, Milton Babbitt' argued that composers, like scientists, engage in research that advances knowledge and should be supported for that work, even if it lies beyond most peoples' comprehension' (Burkholder, Grout, Palisca, 2019), and electronic music has progressed inside of research studios that have appeared, since the 1950s, at universities radio stations throughout the world (Burkholder, Grout, Palisca, 2019). In 1964, the first article published on the subject of computer art was entitled 'The Electronic Computer as an Artist, in Canadian Art, by A. Rockman and L. Mezei' (Higgins, Kahn, 2012). Mitra argues that computational creativity is presently in the third of three generations of research. Starting with the first AI systems that demonstrated that 'some intelligent activities are quite algorithmic', 'the second generation (when) tools were developed to prove that computers can be actually creative' and 'third generation systems (that) are

far more matured and are targeted toward broad ranges of practical problems rather than to prove any small set of hypotheses' (Mitra, 2008).

Contextualising game engines and research in the arts

Presently, the focus of computational creativity research is scattered on a myriad of topics, including relatively ancient practices such as randomness, proceduralism, generative grammars and, more recently, machine learning and generative models, and novel algorithmic approaches such as putting both a generator and a discriminator neural network in contest, known as generative adversarial networks. It is noticeable that today, many frameworks are available, and the possibility of making them accessible inside game engines results in a possible gap and open field of research.

Predictions and questions raised

Considering the hypothesis, some predictions can be made, such as developing gamified prototypes that open new spaces for artistic research.

In the view of software development and game development, questions can be raised about how to create new artistic research landscapes through game engineering.

The input of artists and other stakeholders could answer some questions, such as if they see new spaces for artistic research in this multimedia software practice.

Disciplinarity

Whether in research, in education or in practice, the artistic approach has historically been interdisciplinary, something that is well documented with the Renaissance artists, who 'turned to nature, to science and to the remains of antiquity' to produce their art (Gombrich, 2023), resourcing to 'the mathematical rules of perspective [...], the secrets of scientific anatomy, the study of Roman monuments', something that was characteristic of this 'modern era' (Gombrich, 2023). Later on, the architects the Baroque would no longer plan just buildings but 'fantastic' worlds, with interventions

in vast lands (Gombrich, 2023) and 'painting became an exquisite detail of architecture, as it only aimed to spectacularly break the frame of the walls and ceilings' (Gombrich, 2023). Gombrich says, relative to a picture of a sea storm by Turner, that it gives him the same 'awe' parallel to the one he finds in reading a romantic poem or listening to romantic music (Gombrich, 2023) and mentions how the term 'picturesque' or 'like a picture' was used to describe landscapes or gardens reminiscent of the works of Claude Lorrain (Gombrich, 2023) as well as noting the concept of 'visual music' by the Expressionists (Gombrich, 2023).

Cerda argues that computational creativity is inherently and originally interdisciplinary (Cerda in (Perez, 2015)) or, as Tzankova and Filimowicz put it, transdisciplinary, for its ability to 'synthesise knowledge' in 'hybrid practices' that 'forge new disciplines' (Tzankova and Filimowicz in (Filimowicz, Tzankova, 2017)). Computational creativity shares boundaries with many scientific disciplines, such as cognitive science, when trying to 'understand the mind' on the 'psychological processes underlying creativity' (Boden in (Besold, Schorlemmer, Smaill, 2015)); computational psychology, when 'studying perception, language, memory and problem-solving' (Castro in (Perez, 2015)); or mathematical reasoning such as in the case of BACON, 'a program (that was) capable of rediscovering important scientific laws using the "generate and test" mechanism' and also as in the case of the Automated Mathematician (Badia, 2013). The variety of disciplines to which it is connected is reflected in the panoply of methods, mechanisms, and devices that appear in computational creativity research.

Mechanisms for computational creativity

Being so difficult to define creativity, modelling creativity computationally can be arduous. However, it is also inspirational enough for many to adhere to the challenge. Early work, in that sense, can, however, be found much before the inception of the computer. For instance, from the 1000s, when Guido of Arezzo created a rule system for

composing hymns (Boden in (Besold, Schorlemmer, Smaill, 2015)) to the early twentieth-century search for true randomness that inspired Vera Molnar's graphic work (Nake in (McCormack, D'Inverno, 2014)). It is informative to review some other methods, models, mechanisms, or devices which have been idealised for making the computer create. Computational creativity has a wide variety of applications and methodologies and is not limited to modelling human creativity. It builds on computational approaches to creativity that use or combine a panoply of mechanisms such as templates, human-expert-defined rules, search, grammars (Lucci, Kopec, 2022) and cellular automata (Lucci, Kopec, 2022) and also that can be inspired in mathematics, biology, physiology, and cognition and social sciences, namely mechanisms such as randomness, Markov chains, probabilities, fitness functions, evolution, optimisation and genes, swarms, synaptic and neuronal (Lucci, Kopec, 2022) and psychological mechanisms such as 'conceptual integration/blending', metaphors or revision/reflection (Perez, 2015).

INVOLVING KNOWLEDGE

Heuristic search

Heuristic search is a well-known way for computational creativity. It is through this mechanism that Deeper Blue beat Kasparov, and this method has been very relevant in' problem-solving in computer science, especially in artificial intelligence (Taylor, 2014). Also, in art, despite creativity does not have a 'one and only' correct output. This is a kind of search for a solution that is 'constructed gradually with rules of thumb that choose each successive part' such as choosing one from the possible next chess moves after reasoning about which would result in the best chances for the autonomous player (Corne, Bentley, 2002). Heuristic search has been a 'key feature of computer art's exploratory process' as it 'offered the opportunity to [...] Molnar and others [...] to navigate the sea of possible forms generated by the computer' (Taylor, 2014).

Knowledge-based systems

Close to grammars, knowledge-based systems operate on sets of rules, too, but in this case, instead of a language, we have a domain, and the rules are given by the experts in that domain. (Corne, Bentley, 2002)

INVOLVING NATURAL PHENOMENA

Evolution

Other kinds of computational creativity models recur to a Darwinian inspiration and treat the solution domain as the result of the selection of the best fit within a varied range and mutations for solving a problem. Different mechanisms can be used as the criteria for such selection, and one of the simplest is optimisation, which means finding the best among the possible candidates (McCormack, D'Inverno, 2014) (Corne, Bentley, 2002). Boden mentions that 'programs using evolutionary algorithms can evolve unexpected structures, and that 'these structures may lie in the visual, graphic, or musical arts, or in chemistry, engineering, or robotics.' Boden in (Corne, Bentley, 2002) (Boden in (Besold, Schorlemmer, Smaill, 2015))

Neural

Another famous approach is that of trying to reproduce our own neural activity through interconnection - or convolution - processes. For instance, studying the 'special reaction of pleasure that is related to the generation of new ideas' (Martins et al. in (Perez, 2015))

Swarms

If we divert computing to biology and go directly to the study of the collectives of animals such as ants, bees, fish and birds, we will find research on swarm painting, ant colony paintings and other multi-agent systems.' (al-Rifaie and Bishop in (Besold, Schorlemmer, Smaill, 2015))

Other natures

The observation of natural phenomena appears as a never-ending source of new approaches for making the machines create, such as when translating spiderwebs into music (Starr, 2021).

INVOLVING MATHEMATICAL PHENOMENA

Cellular automata

Even in such a brief review of devices for computational creativity, again digital games can give an air of their grace. Conway's Game of Life is a computationally universal or Turing-complete game that was based on previous work by Ulam and Neumann on cellular automata. When playing it, one can visually enjoy the generation of living patterns and get a glimpse of why such automata have become an inspiration for the endeavours for computational creativity (Corne, Bentley, 2002).

Markov chains

The probabilistic state transitions of mathematical systems, such as the Markov chains, can also be used as mechanisms for the generation of artistic outputs such as in the case of Pachet's Continuator, where the system learns the player's style sequences and continues playing them. (Pachet in (McCormack, D'Inverno, 2014))

Fitness functions

Another abstract mechanism or tool of mathematical nature widely used in evolutionary computational creativity is to score the candidates according to how close they are to satisfying the given problem. Evaluation functions or fitness functions become the selection pressure on the populations and determine the outcome of the evolutionary process. (Corne, Bentley, 2002)

INVOLVING THE HUMAN MIND AND COGNITION

Grammars

In the study of languages, grammars structure knowledge by setting functional and organic rules. A speaker can decide whether to strictly follow or break some rules and if the listeners allow it, that 'lenience facilitates (the speaker's) creativity'. A parallel with such reasoning in architecture led, for instance, to Stiny and Mitchell's 'grammar for designing villas in the style of Palladio' (Corne, Bentley, 2002). Additionally, 'Knight (1980) constructed a grammar for Hepplewhite chair backs; Koning and Eizenberg (1981), [...] a grammar for generating house designs in the style of Frank Lloyd Wright prairie houses; and Flemming (1987) [...] a grammar for designing houses in the Queen Anne style. ' (Corne, Bentley, 2002)

Metaphor

The modelling of creativity with metaphors and their computational interpretation appeared because they are considered a fundamental cognitive agency. (Martins et al. in (Perez, 2015)) (Veale et al. in (Perez, 2015))

Goal and context-oriented

Other mechanisms are based on goals that determine the processes of 'selection, projection and elaboration' over a context of the application, in contrast with the Darwinian way in which all possibilities are ‘generated and tested individually’ (Martins et al. in (Perez, 2015)).

Collaboration

Collaboration and real-time interaction have also been the inspiration for creative techniques, such as the interaction between 'some (agents that) may only listen to the sounds ("audience")' and 'others (that) may be fully engaged in the generative process ("musicians")' resulting in the emergence of creative outputs (Miranda in (Corne,

Bentley, 2002)); or when improvising along with a real-time jazz music algorithm in Biles' GenJam (Biles in ' (Corne, Bentley, 2002)).

Conceptual blending

Recent work has been done around the ideas of conceptual blending, an idea in line with what Koestler defined as bisociation in the creative process. One can think of it as two reasonings for different subjects such as poetry and physics that are integrated into novel mathematical thinking (Martins et al. in (Perez, 2015)) as if 'human cognitive capabilities come together and trying to explain them separately conduces to error'. (Turner in (Perez, 2015)) Turner links apparently distant fields such as 'language, art, music, mathematical intuition, scientific discovery, religion, [...] and dance' (Turner in (Perez, 2015)).

Algebraic semiotics

In the formalisation of conceptual integration models, which is to try to find connections of concepts that belong to different domains, Martins et al. Mention Goguen's work on algebraic semiotics for treating inputs as systems of symbols and outputs as semiotic morphisms, which are mathematical mappings from one object to another in Category Theory. (Martins et al. in (Perez, 2015))

Great diversity

In sum, there is a great diversity of approaches to computational creativity that interact with disciplines that may seem very apart at the surface, and it seems logical to expect other transdisciplinary ways for creativity to continue surging and recombining as, for instance, the creativity methods based on style, that have recently been extended from grammars to neural style transfers, where a trained neural network applies a given style.

Contextualising game engines and the arts disciplinarity

Game engines, on the other hand, are also strongly multidisciplinary constructs. They involve the science of vision and the science of sound, computer science and computer graphics, among other fields of knowledge. Game engines offer an interrelation of disciplines among the arts, being able to represent virtually any existing form of art. The transdisciplinarity of computational creativity research appears to live in the same unlimited realm for experimentation that the game engine enables.

Predictions and questions raised

In light of the hypothesis, some predictions can be made, such as that by exploring the game engines' multimodality, we can achieve new multidisciplinary art forms.
In the view of software development and game development, questions can be raised about what smart ways of exploring the game engines' multimodality/multidisciplinarity could be to achieve new kinds of transdisciplinarity in the artistic outputs.
The input of artists and other stakeholders could answer some questions, such as if they will recognise more than one modality/art form in the results and if they also work as an artistic unity.

Therapy

Audible sound stimulation has been found to interfere with the expression of genes within the cell (Kyoto University, 2023). Perhaps music and other arts might not be disentangled from the essential natural phenomena. Music has been associated with the ethos of the human soul since ancient Greece. Writers such as Aristotle thought that the Pythagorian *harmonia* of music 'could penetrate the soul and restore its inner harmony '(Burkholder, Grout, Palisca, 2019). References to the arts as therapy are as ancient as the study of music (Jacobsen et al.,2019), and presently, the study of art therapy can be

part of the curriculum of artistic studies. A question that may arise is how we can describe this relationship of the arts with therapy and how computers and autonomy have influenced this field.

Contextualising game engines in the art therapies

As in the arts, games can be therapeutic. There is a growing record of research on the creation and application of digital games for health improvement and management, be it in physical and neurological rehabilitation, therapies for mental conditions, or as a form of remediation. However, the artistic nature of such gamified therapies and interventions is not usually the focus. Although such games tend to contain artistic work - as any game does - neither the artistic process of developing such games nor the possible therapeutical effects of game art and of games as art are fully appreciated. Let alone the possibility of creating games for art therapy. There seems to be a vast field for exploration here, given the potential for art-making that game engines seem to offer. Besides being able to contain all sorts of artistic expression, game engines deal with real-time interaction and are open to computational creative techniques that could, for instance, enable the augmentation of creative expression in an art therapy context.

Predictions and questions raised

Considering the hypothesis, some predictions can be made, such as that technological gamification may enable the creation of digital art therapy applications.
In the view of software development and game development, questions can be raised about how to design such gamified tools for the practice of art therapy.
The input of artists and other stakeholders could answer some questions, such as what the perceived advantages and shortcomings of using such tools for art therapy are.

Experience

The efforts to create a vivid experience of art seem to project ancient concepts to the postmodern contemporaneity and promise exciting outputs – this just by taking into account two concepts that today are presented as the most advanced technological feats: style transfer and mixed reality. That Egyptian rigidity of style that was the cradle for many generations of new styles, that idea of style, is today one of the prominent factors in computational creativity research works. The other concept that strongly connects current advances in technology with the long history of the experiences enabled by the arts is that of 'mixed reality'.

Gombrich's description of the history of art consistently shows, throughout the pages, that for long have artists aimed to show 'vigour and realism', 'creating the illusion of depth', 'lifelike figures', 'create the illusion that the sacred story was happening before our eyes', 'to spectacularly "break the frame" of the walls and ceilings, 'to break a hole into the wall', 'adding more and more details from observation and trying to copy the surfaces of things down to the minuest shade', 'modelled in light and shade', 'perspective and composition' (Gombrich, 2023).

Contextualising game engines in the art experience

With this ambition that undoubtedly has been inherited by today's game engine developments, computer graphics and physics aim to mimic the laws of light, shade and sound, colour and shape, and that same desire to 'break a hole' in reality is exceptionally realised in game-related technologies such as the *Hololens*, the *Magic Leap* and others. It seems reasonable to admit that we are always moved by that same force, that permanent impulse.

Predictions and questions raised

In light of the hypothesis, some predictions can be made, such as that technological gamification can enable new ways of presenting and experiencing the arts and that they may also be transformative.

In the view of software development and game development, questions can be raised about how to provide and maximise the novel possibilities of experiencing the arts through gamification via game engineering and if the final outputs will be totally transformed or recognisable.

The input of artists and other stakeholders could answer some questions, such as if they will recognise their works/modalities in the multimedia software outputs and, if so if they are presented in interesting new ways or if the outputs are rather more of a transformative nature.

Philosophy

From its utilitarian origins to the age of computing, the arts have always been a source of philosophical thinking and debate, especially around the topic of beauty. If initially, artefacts 'were made for a definite occasion and a definite purpose' (Gombrich, 2023), from being 'closely connected with religious themes '(Gombrich, 2023) in the medieval ages, they would end up being 'diversified to themes that were not forbidden' (Gombrich, 2023) by the Reformation and later Rembrandt would shockingly not 'worry with beauty' (Gombrich, 2023) and a difference between artistic crafts and High Art would appear around the era of the French Revolution (Gombrich, 2023).

Aesthetic concepts such as style would outlive antiquity and reach the contemporary, metamorphosed. Starting with the rigid style of ancient Egypt that would famously flourish into a new and free way of thinking about the arts in ancient Greece (Gombrich, 2023), to the English eighteenth-century revival of historical styles, (Gombrich, 2023),

thinking about style is still central in the age of computational creativity (Besold, Schorlemmer, Smaill, 2015).

From utility to the expression of feeling and abstractionism in Expressionism (Gombrich, 2023), or the early abstractionism in the music of centuries fifteenth to sixteenth (Burkholder, Grout, Palisca, 2019), to the functionalism of the architecture of Frank Lloyd Wright (Gombrich, 2023) and the technicism of the Bauhaus (Gombrich, 2023), some ancient philosophical questions remain, and some new seem to appear, along with the inception of the computer arts. On the one hand, the debate seems to face opposing sensibilities of technophilia versus technophobia, something that was latent in the 'cool', sometimes 'aggressive' reception to the pioneers of computer art, with reactions criticising it as 'mechanical sterility', 'scientific kitsch' and bleak' or 'cold and soulless' (Higgins, Kahn, 2012), something that was not that new, given that already in the eighteenth century, Jacques Vaucason's automata also caused delight and at the same time 'extreme indignation over the Promethean powers it seemed to engender' (Higgins, Kahn, 2012). On the other hand, with the rise of computation, the aesthetical debate seems to dilate and become permeable to reasoning in other disciplines, for instance, the question of the artificial vs the natural, approached in the mathematical study of language by Marcus Kracht, that argues against that Chomskian dichotomy by making an analogy with 'chemistry (that) applies to naturally occurring substances as well as artificially produced ones' (Kracht, 2003). Other questions appear, such as assessing the difference between automatic and autonomous systems (Blackwell et al. in (McCormack, D'Inverno, 2014)) and the philosophical implications of that idea of 'computational creativity'. Nake points out that we live in an age obsessed with 'creativity', which is now a fashionable virtue, as before where *arete* and *agon* in Greece, *fides* and *pietas* in Rome, and later *humanitas*, enlightenment and progress (Nake in (McCormack, D'Inverno, 2014), possibly suggesting that we might be living some cultural bias towards an ideal of creativity, something that is difficult to measure,

despite there are already attempts to bring the power of computation to the aesthetical evaluation itself (Cohen et al. in (McCormack, D'Inverno, 2014)).

Boden warns us about a possible pitfall, which is the natural human capacity to attribute meaning. Boden finds it, for instance, in the reactions to some works at the 1968 Cybernetic Serendipity exhibition, and it is that the human being is possibly not a good evaluator of creativity in computational systems because we tend to project our own minds and sensibility into the computational outputs we experience (Boden in (Besold, Schorlemmer, Smaill, 2015).) Boden, so, reminds us that this field is still emerging and not without some scientific controversy. It is possible that this is one of the prominent concerns in the minds of the detractors of computational creativity, who argue that a computer could never truly be creative and that it would always result from a shallow attempt to simulate the human mind (Boden, 2009)(Gervas in (Besold, Schorlemmer, Smaill, 2015)) or by artificial intelligence that is 'neither artificial nor intelligent'. Badia addresses this question interestingly by reminding us that because we do not have a full understanding of a process, that does not necessarily mean we cannot make it happen on the computer, providing the example of how we have today reached a point in which both the human mind and the computer are highly successful in performing pattern recognition tasks (Badia, 2013). But in this era when we frequently ask overwhelming questions such as about 'the computer as substitute consciousness or as the extinction of consciousness' (Calinescu, 2006), it might be wise to recall Gombrich's thoughts that 'the greatness of art does not lie' solely 'in new discoveries' (Gombrich, 2023) and that 'the whole story of art is not a story of progress in technical proficiency, but a story of changing ideas and requirements' (Gombrich, 2023) and that 'art not only wants to keep step with science and technology, it also wants to provide an escape from these monsters' (Gombrich, 2023).

Contextualising game engines in art philosophy

Generative Games

Creative autonomy has been a part of the development of game engines since their inception. Modestly, it appeared in the generation of landscapes and procedural contents and behaviours. Today, because resourcing to machine learning models has accelerated and multiplied the ways in which content can be created autonomously, game engines' proceduralism seems to be at the very edge of exploding into a myriad of novel and unexpected developments.

The transience of computer art media and discovery

More than the application of recent computational creative ideas to game development, game engines connect with apparently more profound dimensions of this new era of art. For instance, in their versatility, they seem to fit well some conclusions of the study of Carvalhais on artificial aesthetics. Carvalhais finds that the *new media* or *post-computational media* are very recent and, besides presenting great potential in their implementations, are also always in an apparent transitory, ephemeral state, open for further exploration (Carvalhais, 2016) an idea which we can possibly better understand if we contrast *new media* with an ancient linen canvas, so perennial, so immutable. Carvalhais says that *new media*, at each moment in time, are reinvented and that we need them to be 'versatile enough to accompany the ongoing transformation' [...] 'which (in turn) is not a transitory phenomenon' (Carvalhais, 2016).

Predictions and questions raised

Considering the hypothesis, some predictions can be made, such as that the novel solutions may extend the domain of the arts.

In the view of software development and game development, questions can be raised about whether we are extending the arts domain, what are the Aesthetics of gamified

art outputs and what are the philosophical implications of exploring multimodality as a path for new forms of art, creation, and experience.
The input of artists and other stakeholders could answer some questions, such as what the perceived philosophical implications are of aiming for new forms of art, art making, and experiencing by exploring multimodality.

The game engine and the arts

The next section will approach game engines, this versatile computational construct that is simultaneously a pinnacle of 'téchnē' and a multimodal representation of the *ars* that can altogether be open to computational creativity applications as well as represent the most unassuming and traditional forms of art.

4.1. Game engines or art engines?

According to Gregory, the concept of a game engine first appeared around the last two decades of the XXth century, along with the development of a commercial game, Doom, that already contemplated an architectural separation between software and data assets, which Maggiorini et al. mention, would lead the way to the later release of Quake Engine as would happen with Unreal Tournament's Unreal Engine (Maggiorini et al., 2016). Game engines work as the commonality between games, being the part of the code that is reusable for creating other games, sharing core elements such as the rendering, the audio, and the physics systems, and reusable components (Anderson et al., 2008). According to Gregory, 'a data-driven architecture is what differentiates a game engine from a piece of software that is a game but not an engine' (Gregory, 2019). Since then, the list of available commercial and open-source game engines has only grown, including some other well-established brands, such as the CryEngine, Sony's PhyreEngine, Microsoft XNA Game Studio (MonoGame) and Unity3D (Gregory, 2019).

It is interesting to observe this technology as if instead of game engines, they were taken as art engines. On the one hand, because of how technological advances that are known from the history of the arts – on perspective, colour, shading, lighting, sound and acoustics, to name a few – seem to condense and be further developed inside these software constructs. On the other hand, game engines do seem to act as art engines in the sense that they manage data that are a representation of various instances of art forms – painting, photography, cinema, music, sculpture – to, in turn, assemble and take the shape of another art form, the game, and to do so, they include multiple modalities of representation, from text to audio, from pictures to movies and 3D models.

Game engines and 'téchnē', science, mathematics, and the arts

Game engines and mathematics

As Gregory puts it, 'mathematics pervades everything we do in the game industry [...] from trigonometry to algebra to statistics to calculus. (Gregory, 2019). This is why game engines usually include a math library that 'provides facilities for vector and matrix math, quaternion rotations, trigonometry, geometric operations with lines, rays, spheres, frusta, etc., spline manipulation, numerical integration, solving systems of equations' (Gregory 2019).

Game engines and physics

The physical properties inside the game, such as the movement, acceleration, and collision of game objects during play, is credible to the player because the laws of physics are embedded into the game engine as it includes and performs the calculations of rigid body dynamics, collision detection, deformable bodies, cloth, hair, and fluid dynamics, among other (Gregory 2019).

Game engines, computer graphics, and the science of vision

Games are predominantly visual experiences, so game engine resources include knowledge about how vision works and about how to create two-dimensional or three-dimensional visual outputs in runtime. This involves a substructure that can be called a Rendering Engine by itself, working with geometries, textures, rendering pipelines, buffers, lighting, and visual effects (Gregory 2019).

Game engines, sound engineering, and the science of sound

The game engine generally contains a substructure dedicated to audio rendering, which can be called an Audio Engine by itself. This is how the player can enjoy soundtracks and sound effects during play, with a correct simulation of acoustics, and movement becomes more credible when the game performs physically based audio synthesis or the runtime creation of spatial sounds that correspond to the objects' physical behaviours (Gregory 2019).

Game engines and software engineering for performance

Game engine design is generally oriented by the principles of abstractness, modularity, simplicity, and reusability. Building and maintaining a game engine implies dealing with hardware, memory architectures, file systems, datatypes, concurrency, parallelism, debugging and error handling, or linking and compilation, in good knowledge of programming principles and best practices (Gregory 2019). Game engines are also built with performance in mind, and the current most common approaches combine data-driven design and the entity-component-system (ECS) pattern.

According to Gilbert, data-driven design is a design method in which the structure of the software is arranged to reflect the structure of data in how it is processed by the system'. Because cache memory is faster to read and write than main memory, a sequential data layout means fewer iterations to retrieve data, and to achieve this, in the data-driven approach, functionality is separated from data and is general in purpose,

and data is arranged sequentially, which allows for parallelisation, efficient cache usage and modularity of the codebase. (Marc Gilbert, 2021). The entity-component-system pattern, included, for instance, in the most recent versions of the Unity3D engine, as Ben Humphreys puts it, 'can empower designers and artists to create and iterate on games. Rather than programmers writing custom logic for every part of the game, with hardcoded values, classes and behaviours, programmers instead create a suite of behaviours and tools that designers and artists can experiment with to create the best possible game' (Ui, 2022). Additionally, the separation of dataless entities, data components and specific systems allows for important performance gains due to parallelisation.

Game engines and software architecture patterns

As Nystrom puts it, change is the main driver for resourcing to software architecture patterns (Nystrom,2014). It is the idea that it is because software needs to adapt that certain structures become necessary, in opposition to a static piece of software that no one will ever alter. The decision to go with ECS is well-known in the Unity3D game engine development. However, the case of the Unreal Engine is not so clear. The Unreal Engine, according to Dimitroff, goes halfway between Object Oriented Programming and Component Oriented Programming (Dimitroff, 2023), proposing its own kind of entities - the Actors – which are class objects that live (or act) within the game world. Actors can then have collections of components. Components, on their hand, can be ticked within the game loop and can be Actor Components, which abstract behaviours and non-physical concepts; Scene Components, which have a position and/or rotation; and Primitive Components, which have renderable and/or physical geometry (Dimitroff, 2023).

Game engines and the taxonomy of the arts

Ernests Adams, studying the artistic nature of games, briefly maps the domain of the arts by listing and organising many different types of art:

> 'The entry for "Art" in the Encyclopaedia Britannica divides art into a number of types. Among them are the literary arts: writing and drama, which are characterized by the presence of narrative. Film and television also belong to the literary arts. Then there are the fine arts: sculpture and painting, music and dance. There are also the decorative arts: wallpaper, fabrics and furnishings. Architecture is regarded by some as a form of art, and industrial design, but at this point the types move more and more away from "pure" art and into areas with more utilitarian considerations. Industrial design, for example, is not really art so much as it is an aesthetic applied to utilitarian objects. The boundaries between art and non-art are not hard and fast; there is a grey area.' *(Ernest W. Adams in (Clarke Mitchell 2013))*

Parallel classifications

Brett Martin makes analogies of games with several other forms of art that have appeared recently in history, such as photography, cinema, and video, because 'new mediums are often commercially based ventures, and are not easily accepted as art'. Brett mentions the case of photography, where the pioneers' chose subject matter to mimic traditional art and exhibit the capabilities of the new invention.' (Brett Martin in (Clarke Mitchell 2013)). The same is said about cinema, which 'also relied on past mediums to gain momentum in its early years', such as theatre and literature, and the author reflects on how special, lighting and lens effects set cinema apart from theatre, a necessary separation that was still to happen, he argued in 2013, between cinema and games (Brett Martin in (Clarke Mitchell 2013)). It would be interesting to know if in the current day Martin still thinks we should stop trying to make 'interactive movies' and rather strengthen the digital game as a form of art in its own right.

Taxonomies of art

There were not many authors who dared to systematically taxonomise the domain of The Arts. There was, though, the work of Thomas Munro in the 1950s (Munro, 1957) that was acclaimed at his time and by then considered a work of such quality that hardly would have to be updated in the foreseeable time. It listed 400 kinds of art. Now, it is no longer up to date, as the computer arts, for instance, could not be mentioned in the work; however, Munro's taxonomy (Table 1) can arguably be reinterpreted in the light of current technology and still serve as a base for understanding the taxonomy of the arts, the computer arts, the autonomous arts, and how this has correspondence inside the virtual space provided by the game engine.

How does a game engine represent?...

MUNRO'S TAXONOMY	PERCEPTION	IN GAMES	REPRESENTABLE IN GAME ENGINES
I. VISUAL ARTS	*Visual*	*Yes*	*2d textures, 3d models, text, fonts, light sources*
II. MUSIC; AUDITORY ARTS	*Auditory*	*Yes*	*Audio files, midi, synthesiser*
III. LITERATURE; ARTS OF VERBAL COMPOSITION	*Visual + Auditory*	*Yes*	*Text, synthesised speech*
IV. ARTS OF PUBLIC PERFORMANCE; THEATER ARTS; CEREMONIES AND ENTERTAINMENTS	*Visual + Auditory*	*Yes*	*Audio files, midi, synthesisers, 3d models, 2d textures*
V. LOWER-SENSE ARTS AND FACTORS IN ART	*Pallate + Olfact + Tactile*	*No*	
VI. ARTS OF PERSONAL APPEARANCE AND ATTRACTIVENESS	*Visual + Auditory*	*Yes*	*3d models, 2d textures, audio files, midi, synthesisers*

Table 1 - Munro's taxonomy, games, and game engines (full table in Appendix II)

Taxonomies of computer art and autonomous arts

If Munro's taxonomy could be reviewed in light of the advances in computing in the arts, then possibly such a review would, in most cases, correspond to a digital version of the arts that Munro listed. With an exception for tactile, olfactive and palatal senses – the kind of hardware necessary for this is still in its beginnings - the remaining taxa are

already perfectly implementable today as their digital versions and are also interesting as a subject of possible exercises of autonomy. Or, in the words of Boden:

> 'Today, computational creativity is thriving. It has given rise to various genres of computer art, besides fostering countless individual styles. *''Boden in (Besold, Schorlemmer, Smaill, 2015)*

Updating Munro's taxonomy could start early with mainframe computer arts - music, art and intermedia, poetry, film and animation (Higgins, Kahn, 2012) - and follow the history of computing towards the mini and microcomputers, towards the age of internet, and to the first and later generative or autonomous examples such as when we have seen 'the computer as a nanny, a coach and a colleague 'Lubart (2005) (Jones et al. in (McCormack, D'Inverno, 2014)), or software outputting autonomous architecture (Corne, Bentley, 2002) (Frazer, H. Koning, Celestino Soddu, G Styny & W.G. Mitchell, G. Hersey; and producing visual/graphic/plastic arts (Johan Shogren, Georg Nees, Michael Noll, Frieder Nake, Harold Cohen (AARON), Simon Colton (Painting Fool)) (Heath et al., Perez Y Perez et al.) (Nake in (McCormack, D'Inverno, 2014)), or music (David Cope) (Boden in (Besold, Schorlemmer, Smaill, 2015)) (Eigenfeldt and Pasquier, Rhodes et al., Toivanen et al., Hoover etal.); and autonomous literature and poetry (Perez y Peres in (Perez, 2015)) Boden in (Besold, Schorlemmer, Smaill, 2015), (Oliveira and Cardoso in (Besold, Schorlemmer, Smaill, 2015)) (Veale, Toivanen et al.) (Margaret Masterman); narrative (Monfort et al., Cavallo et al., Negrete-Yankelevich & Morales-Zaragoza) 'in (Maher, 2013) - Proceedings Computational Creativity Conference (Sydney); or the computational narrator (Perez y Peres in (Perez, 2015)); and also sculpture (Gordon Pask, Edward Ihnatowicz).

Multimodality of game engines

In her BCS Lecture in October 2019, Mirella Lapata approached the topic of multimodality, and that talk inspired this thesis work. This is because that sense of multimodality and the possibility of translation between modalities seemed to fit the

multimodal nature of games and game engines (Table 2). Arguably, the game by itself can be considered a medium, as well as its individual text, picture, video, 3D models and audio files, to name a few that live inside that same game.

The case of Unreal

MODALITIES	TEXT	TEXTURE	3D MODEL	AUDIO	FONT	GAME LEVEL OR SCENE
ART FORM	I, III	I, IV, VI	I., IV., VI.	II, III, IV, VI	I	Virtually, all modalities.
EXAMPLE FILE FORMATS	CSV, JSON	JPG, PNG, JPEG, BMP, DDS, EXR, HDR, PCX, PSD, TGA, TIF, TIFF	FBX, OBJ, gITF, GLB	AIF, FLAC, OGG, WAV	TTF, OTF	UMAP; extended USD COLLADA or OpenGEX

Table 2 - Filetypes, media and art forms (UE, 2023)

However, there is currently no existing universal file format for games. In comparison with 2D textures, for instance, where there is a myriad of files that are accepted by most 2D editing software, games (or game levels) in the Unreal Engine are saved as *.umap binary files, which are not humanly readable nor compatible with any other game engine. There seems to be a case for the implementation of a universal game file that could possibly be attained by extending Pixar's USD, COLLADA or OpenGEX or, in a different logic of approach, possibly by building an XML-based file that could translate to Unreal's *.umap and also other engines level or game files, possibly built with, for instance, the Open Data Description Language (OpenDDL), with an abstraction that could avoid external coupling by not dealing with imposed external formats.

Game engines as art engines

Besides the arguments before presented, which are indicators in that direction, a question that may be raised is what are any further reasons why this thesis looks towards an approach where game engines can be understood and explored as art engines.

Multimodal translation

Thinking about the functionality, one possible novel implementation - by extending the game engine architecture – would be to produce developments that would allow multimodal translation. More specifically, one could implement a universal asset, a runtime multimodal asset, that could translate from and to any modality existent in games (such as text, sound, depictions, sculptures, or digital games themselves).

Multimodal Generation

Yet another functionality that could be built on top of that universal asset is that of multimodal generation. For instance, if the runtime content asset contained only information relative to the musical form, the other contained art forms could be generated to fill that void by resourcing to multimodal translation via machine learning.

As a 'total' artist

There could be, therefore, space for a game-engine-based multimodal artist - an artist of total or synthetic art - that could produce autonomous outputs and possibly also amplify or assist the artist/player, given to choose from a spectrum of greater or lesser autonomous intervention by the system, for instance.

As new forms of art

Then, the classic question of 'Is it art?' would naturally be present in the evaluation of the outputs. Additionally, a less common question could also arise: 'Is it a new art form?' As we have seen before, in a perspective of artification, there is a natural permeability of the boundaries of the domain of the arts, so it is not unplausible that an autonomous system resourcing to the mechanisms of computational creativity and capable of interlacing such panoply of art forms could deliver outputs that combine the different modalities in unexpected, possibly novel ways, generating new modalities or art forms.

5. Methods

5.1. The vision: a game-engine-based synthetic art studio

Layered software architectures and the vision of a universal runtime art engine

If we take a moment to think and view the world via the prism of the Object Oriented Paradigm, where everything can be an object, with the potential of creating software classes to represent every object and the way they function, aligned with another view of the prism of Layered Software Architecture and Open Source, there seems to be an unlimited potential for software creators to build a realm of interconnected and compatible pieces of software with which we can represent the world, not only physical but also the world of ideas. Like ants or bees, developers can individually or collectively make their own contributions to the landscape of a digital realm (or hive). This makes the ideas and practicality of Computer Vision, Computer Intelligence and Cognitive Augmentation not so farfetched or unattainable. This, too, seems to be the case for Computer Arts, where the construct of the game engine seems to fit a specific layer in that realm. A layer where multimodality of Arts can connect with lower layers of software and hardware and be the base for an upper layer for the Computer Arts.

Téchnē

In the previous sections, it has been noted the coexistence, throughout history, of technology and the arts, in that same way that Groysman reminds us of the original

meaning of 'téchnē' (τέχνη), the Greek word for art, which was used to refer to both art and technology at the time (Groysman, 2011). It is well established that for ancient Greeks, the expression, imagination, creation, aesthetics, beauty, thought, and emotions which are integral to 'téchnē' 'were not confined to fine arts'. It is also possible to address the question of how this connection between technology and art is relevant in today's digital age and how it relates to a particular technology, the game engine.

The previous sections observed the history of the arts with a particular set of lenses that made a distinction between three technological domains of the arts. The first - the arts in general – as a more global domain where technologies can exist as tools to facilitate the creative enterprise, and another domain - that of the computer arts (CA) - posterior to the invention of computer technologies that have inherited and extended the functional utility of the previously mentioned tools of the arts. This goes in line with Jones, who notes that computers were a liberator technology for artists (Jones, 2006). The third domain starts when autonomy is provided, and we can reach new strands of digital art, such as the one that has become known as generative art. Monro (Monro, 2007) cites Philip Galanter's widely circulated definition of generative art as 'any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is then set into motion with some degree of autonomy contributing to or resulting in a completed work of art'. The author does, however, note that computers, or even machines, do not have to be imperatively present in the creation of generative art. Within our lenses, the third domain is filtered by this same defining criterion of autonomy, but in this work, instead of generative, it is more generally referred to as the domain of the autonomous arts (AA) inside the domain of the computer arts (CA).

The efforts to model creativity

Models have a historical and preponderant role in computer science, from Von Neumann's computational models to the efforts to computationally model all kinds of

phenomena, including the aim to model creativity. But Perez y Perez explains how difficult it is to computationally model creativity – something far too complex to be easily represented – and how it involves interdisciplinary work by merging methodologies, points of view and mechanisms of evaluation (Perez, 2015).

Game engines in the service to the Arts: from multimodality to synthetic art and new forms of art

However, if the focus of modelling creativity is shifted from creativity itself into a more concrete concept of 'tools for art making', the gamification of the arts through game engines allows us for a multimodal approach that may include mediums of the autonomous arts, such as code as a medium, and of all branches of the computational arts. Within the game engine, we can give use to the scripting system that lets us run live code, for instance. The event system and the game loop allow us to run real-time computational art creative tasks that may have colours, text, and involve two-dimensional and three-dimensional depictions (pictures, movies, sculptures) or audio and music. It is a melting pot of artistic forms, and it is up to us to find if we can structure this melting of the arts in ways that could deliver interesting outputs by resourcing to the mechanisms already discovered by the researchers in the autonomous arts and computational creativity. And this work can become complete by opening the question of whether new forms of art, besides creative assistance, can be implemented or result from the gamification of the arts. So, the natural question that can be raised is about how this can be achieved. A proposed answer to achieve it is by resourcing the architecture of the game engine. There, it is possible to create a simple extension to the general game engine architecture based on a proposed idea of a runtime editable multimodal content at the level of the engine's assets/content management.

	Predictions in the light of the hypothesis	Questions in software and game development
Experience		
	Technological gamification can enable new ways of presenting and experiencing the arts, that may also be transformative.	How to provide and maximise the novel possibilities of experiencing the arts thorugh technologial gamification and game development? In the end, will the source works be recognised by the original authors or totally transformed?
The artist		
	We can develop gamified prototypes that render outputs that are perceived as artistic whilst exploring multimodality. Such tools may enpower the artist creatively.	How to drive the game engine's multimodality in order to empower/augment the artist. What are the relations between the entitites: the artist, the computer artist, the autonomous artist.
Practice and education		
	Technological gamification can enable the emergence of new ways of making art; and also render news ways of learning and teaching.	How to drive the game engine's multimodality in order to: enable new ways of making art; new ways of learning and teaching
Research		
	We can develop gamified prototypes that open new spaces of artistic research.	How to create new artistic research spaces through game engineering?
Disciplinarity		
	Exploring the game engines multimodality can result in new multidisciplinary art forms.	What would be smart ways of exploring the game engine's multimodality/multidisciplinarity? What new kinds of transdisciplinarity in the outputs?
Therapy		
	Technological gamification may enable the creation of digital art therapy applications.	How to design a gamified tool for the practice of art therapy?
Philosophy		
	The novel solutions may extend the domain of the arts.	Are we extending the domain of the arts? What are the Aesthetics of gamified art outputs? What are the philosophical implications of exploring multimodality as a path for new forms of art, creation and experience?
Ontology of art		
	We can develop gamified prototypes that render outputs which are perceived as new kinds of art (i.e. Artistic curation)	Can we create new kinds of transdisciplinary art? How does this alter the arts ontology?

Table 3 - Questions in software/game development

How? Proposed Software Architecture

The first design approach to the problem domain is born from the study of the generic game engine architecture in the same spirit that Mayra states that 'design research also involves the processes of 'meta-design', or researching the game design methods and their underlying logic (Mayra, 2012). Söbke and Streicher report reviews that, however, show that 'software architecture and software reuse are among the less focused topics'

within the invigorated research field of game software engineering (Söbke, Streicher, 2016).

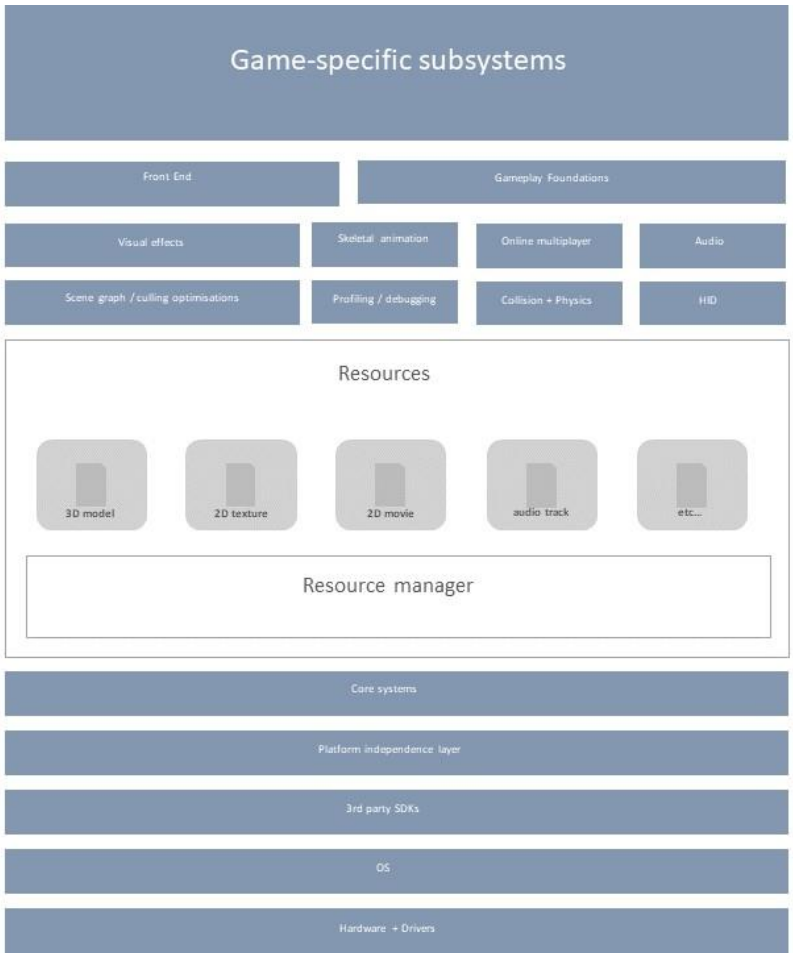

Figure 4 - Game engine generic architecture, based on (Gregory, 2019)

Game engines' architecture

Gregory proposes a layered view of the generic game engine (Figure 4), in which we can identify the hardware, operating system and platform independence layers at the base. They are responsible for any game developed with the engine to run on the supported devices' hardware and operating systems. Third-party libraries allow game engines to include well-established sets of functionality, such as in the domain of physics and

mathematics, that add up to the engine's own core functionality that includes the main loop and the timer, network operations and the management of resources, input devices, audio, graphics and rendering, among other. Many engines also provide support for scripting, which allows the game creator to add functionality at runtime' (Freiknecht et al., 2016).

Total art and game engines as multimodal systems

Bernsen approaches the topic of multimodality by building taxonomies. The author considers the existence of 'pure generic modalities' in a list which includes spoken, written and touch language; sounds; 2D and 3D graphics and forms (Bernsen, 1994) that can also have the qualities of being analogue, arbitrary, diagrammatic, static or dynamic. Within this taxonomy are included spoken, written and touch letters, words; numerals; other language-related sounds, text, lists, tables; musical notation; single sounds, sound sequences, music; diagrams, pure maps; photographs, naturalistic drawings; points, lines, boxes, circles, volumes; animations; films, videos and graph space containing 1D, 2D or 3D geometrical forms.' (Bernsen, 1994)
Arguably, these are all forms that can be represented within a computational environment, namely on a game-engine-based application. This also finds reflection in the field of the arts, for instance, in total or synthetic art, where multimodality is paramount.

The game engine works in tandem with external tools

Due to that same multimodal nature, game engines must performantly manage a panoply of media such as 'texture bitmaps, 3D mesh data, animations, audio clips, collision and physics data, game world layouts' (Gregory, 2019).
However, game engines also delegate the creation and editing of such content to tools external to its runtime architecture (Figure 5), which is more of a beneficial feature than an architectural defect if one considers the complexity that would be added if the

functionality for creating games was monolithically tied to the functionality for creating game content - also known as 'game art'.

So, generally, in the workflow of game development, game art is created by artists capable of working with tools such as *Photoshop* for creating textures and generally working with 2D depictions, *Autodesk's Maya*, *3ds Max* and *ZBrush* for sculpting and animating 3D models and *SoundForge*, *Cubase* or other tools, for creating audio content' (Gregory, 2019)

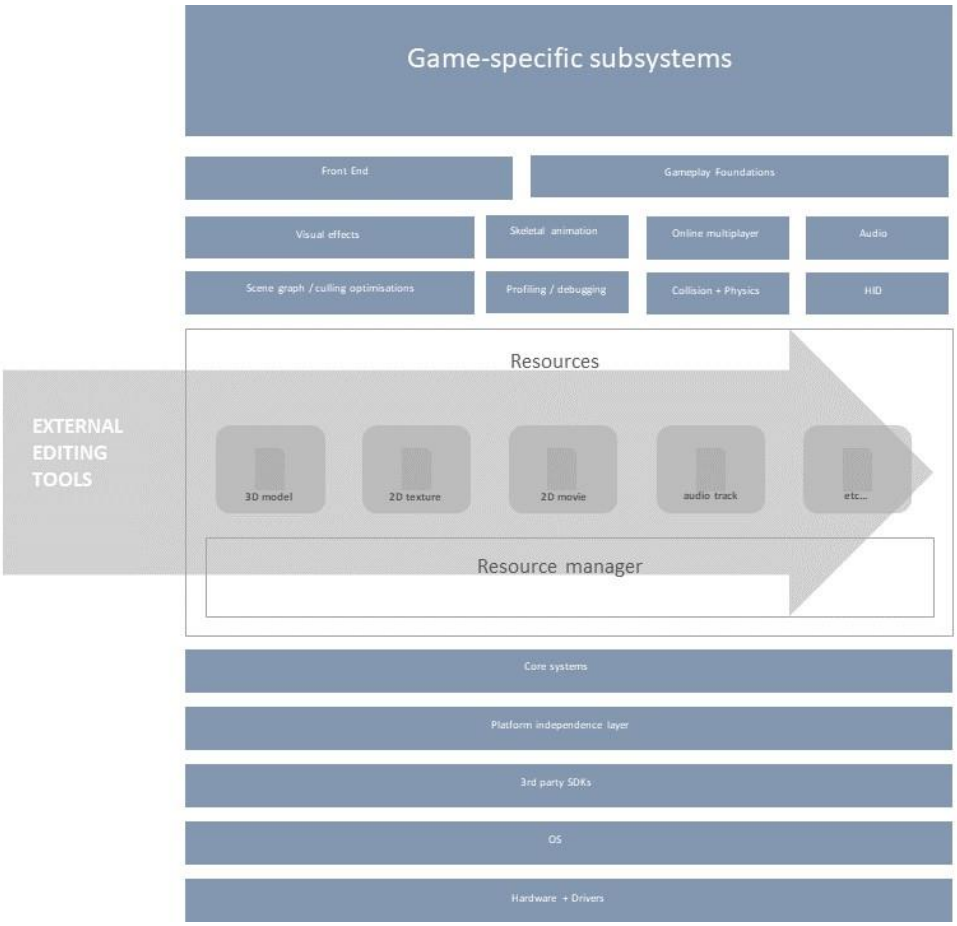

Figure 5 - Dependency on external tools

Regardless of how important this architectural openness to external edition tools is for the workflow of game development, arguably, there could be some advantages, namely

in what concerns the hypothesis we are addressing, in considering alternative approaches to content management, such as the possibility of including in the game engine architecture a new kind of resource, a new kind of content that can be created or generated in runtime and that can have a multimodal nature.

Modelling simple solutions

Again, the architectural approach will embody the spirit that 'design research also involves the processes of 'meta-design', or researching the game design methods and their underlying logic (Mayra, 2012). Referring to research in computational creativity, Monfort argues for an attitude of aiming to build models that are concise, as their simplicity is arguably very useful by modelling specific techniques in the domain of creativity, and so, questions could be raised, such as how many classes of entities are necessary for the theory, how many axioms are proposed as a hypothesis, and how simply can they translate to code (Monfort in (Perez, 2015)). Seeing our problem domain through a filter of software architecture might enable that same solution elegance that Monfort proposes.

Problem domain

We have seen that because game engines are strongly data-driven, as they manage multimodal content that can range from simple colours to 2D textures, 3D models and music, this forces the engine architecture to be open to other kinds of software, such as modelling, CAD, image manipulation and music production, etc.

Because we are looking for a way to integrate game engines as tools in the artistic workflow, our other goal of such a tool to be capable of producing total/synthetic art outputs suggests that this very openness to external editing tools can be central to our solution.

The problem of multimodality

Working with text, image, video, or sound is inherent to the game development workflow, and if we propose to use game engines as artistic tools, we will be better off by understanding which advantages and difficulties such multimodality may present. If working with multimodality suggests an ability to produce works of art described contemporarily as 'synthetic art' or 'total art', then this mandatorily depends on external tools (several other software), or in the alternative, building a universal, simple and unified solution for gamification of the arts through game engines.

Solution domain

Nevertheless, if we consider the possibility of adding just one special class to our generalised engine, we could both work on and generate all kinds of artistic forms. That would be a runtime editable multimodal content (Figure 6).

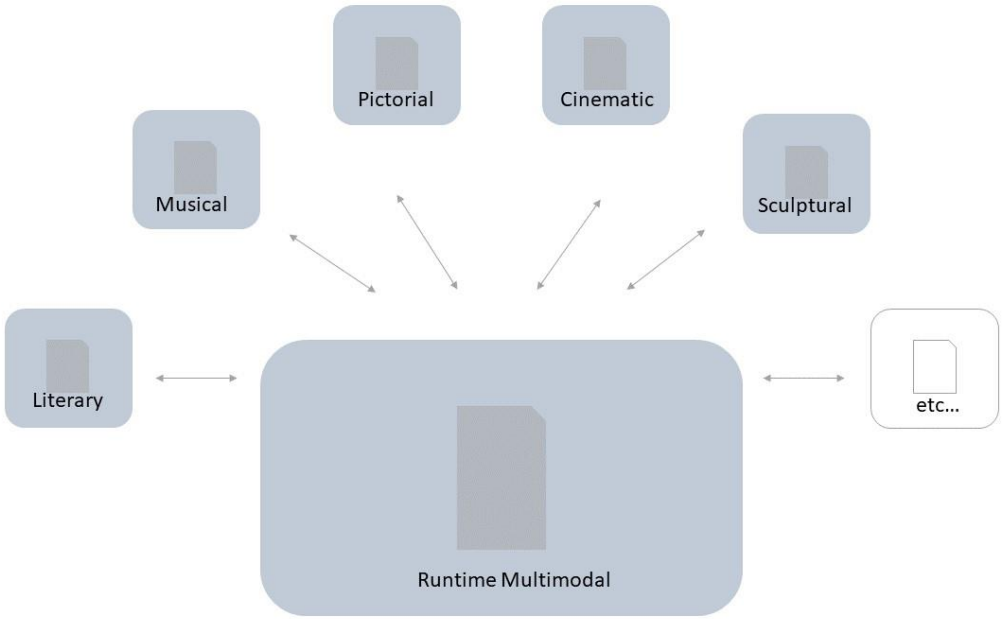

Figure 6 - Runtime multimodal content, pipe and filter view

Such multimodal content could:

1) be editable or generated in real-time
2) be translatable, bidirectionally, to the other modalities

On reinventing the wheel

Fortunately, such a simple design would not necessarily mean that a full-fledged game engine would have to be built from scratch, as many high-quality commercial engines are also open to the development of plugins through which we can cleverly add functionality that extends their architecture (Figure 7).

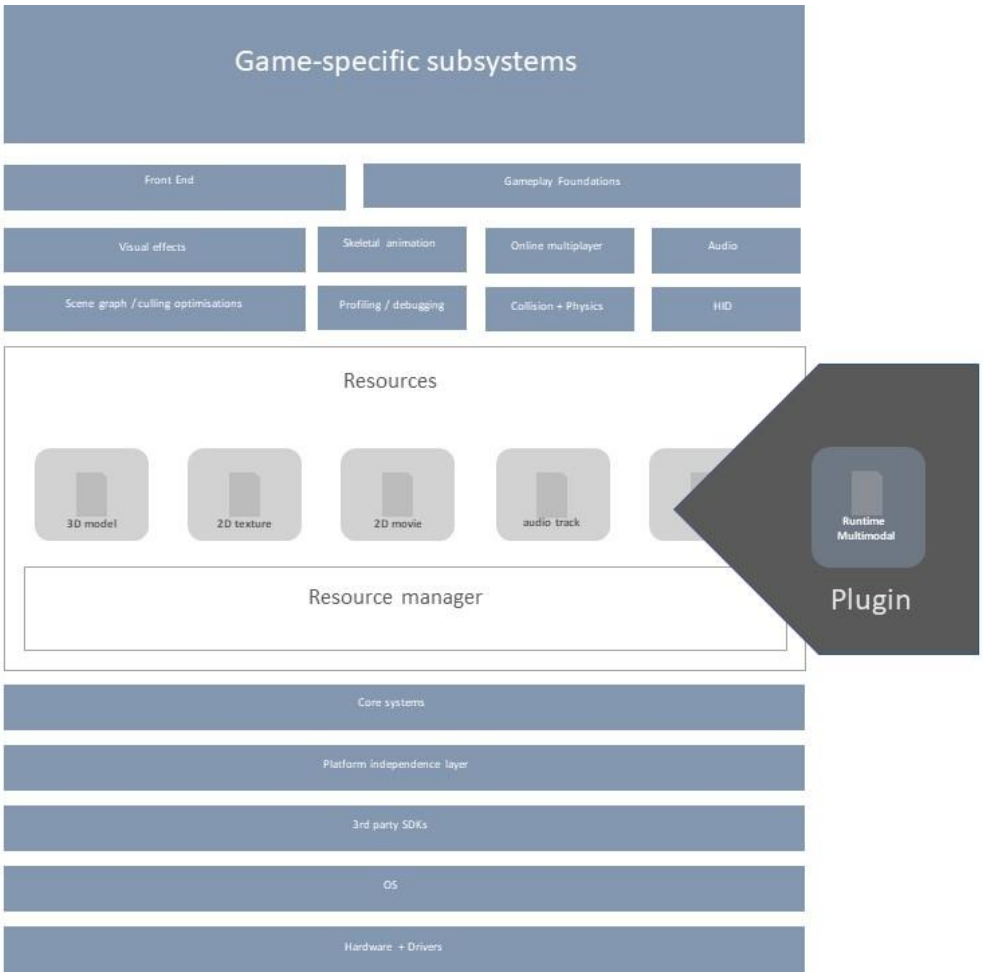

Figure 7 - Plugin solution

Unreal Engine plugins

The *Unreal Engine* is one such commercial high-quality engine that exposes its code and is open to plugin extensibility. Historically, patches and plugins have been one of the resources in the artification of games, patent for instance, in the '1999 exhibition "Cracking the Maze: Game Plugins and Patches as Hacker Art", one of the first to exhibit game modifications as art' (Clarke Mitchell 2013).

Runtime functionality

Another advantage of Unreal Engine is that its plugins can work in runtime. That is the case of Conways's 'Runtime Mesh Component', and many other available open-source plugins designed to include runtime functionality such as Fast Fourier transforms or mesh morphing, among others (Conway, 2023).

Dimensionality vs multimodality

In this plugin for a universal asset of runtime (and real-time) editable and generable content, we can simplify the complexity of multimodality by reducing it to its dimensionality. We can, for instance, taxonomise the existing modalities according to the lowest common denominator of dimensions necessary for that particular form, so there can be 1D, 2D, 3D, 4D (etc.) runtime content that can be translated from one to the other, with new content to be generated of 1D, 2D, and higher.

A simple yet extensible architectural model

Without the ambition to be a computational model in a strict sense or even a computational creativity model, this architectural model, due to its simplicity, is virtually applicable to any game engine and allows explorations such as the ones presented in the following chapters.

The gap, artification of games and gamification of the arts

Gamification of the arts

The previous chapter's review of the history of games and their significance led us to the topic of gamification. We have thought about the definition of this concept and aimed to discern why and how it is used. Historically, Mesárošová and Hernández observe that the concept of gamification was introduced in 2002 by Nick Pelling, a game designer (Mesárošová, Hernández, 2015). It is a way of thinking that involves the application of concepts of computer games in social contexts, taking the dynamics of games and implementing them in real life, converting tedious tasks into playful activities and, in general, applying game mechanics to any situation, idea or project (Mesárošová, Hernández, 2015). However, in this work, the view of gamification is being generalised to the inclusive idea of 'becoming a game', including serious games such as current research that involves games and health.

The vision of a game engine as a space for art creation, augmentation, curation and experiencing

Because of engagement

The relevance of gamification could be reduced to the ideas of engagement and usefulness. For instance, software vendors have adopted it to increase customer adherence (Durga et al., 2014), and research in gamified training, illustrated by examples such as medical serious games, has been applied to surgery and infection prevention and to increase dexterity (Kooji et al., 2014). Additionally, in Odontology and Nursing, in areas such as diagnostics, decision-making, treatment protocols and risk and pain management (Ricciardi, De Paolis, 2014). Moreover, and importantly for this research, gamification is being applied in medicinal and psychological therapies because it may have the potential to address difficulties associated with sustained

engagement in behaviour change strategies', and psychologists may use well-established tasks to train specific cognitive abilities, benefiting from the transformation of routine tasks into playful activities (Kooji et al., 2014). As another example, Ricciardi and De Paolis report the use of several physical rehabilitation serious games that were perceived by the patients as a credible training approach (Ricciardi, De Paolis, 2014).

And because of game engines

However, in our view of 'becoming a game', we also address the topic of gamification by extending it to the domain of software engineering with the use of game technologies. We have argued that a commonality among digital games, the game engine, can provide fruitful results in software development for non-game-related domains, so we chose to focus on the field of gamification of the arts.

Game engines in the service to the Arts: art creation

The first of four exercises of software design will focus on the act of art creation itself. The coming chapter will render a study of how the creative practice - and its possible therapeutical outcomes - can be conducted through the resources provided by digital games and the instantiation of the TIMAEUS art studio.

Game engines in the service to the Arts: art curation and experiencing art

Within the proposed extended perception of the concept of gamification, there seems to be an interesting potential for computer games to become a compelling medium to create engagement in healthier lifestyles and in learning and teaching (Durga et al., 2014). In mental health, Agmon et al. provide some evidence that suggests positive impacts on depressive symptoms, cognitive performance, and mental health-related quality of life (Agmon et al., 2011). We will also investigate how we can intervene in how art is experienced in ODYSSEY by resourcing to digital game development and also in the domain of education for philosophy with STOA.

Game engines in the service to the Arts: augmentation and total artists and art forms

Autonomous music, cinema, or painting provide good examples of possibilities that are realised when jumping from one simpler medium to a more complex medium that incorporates a degree of autonomy. This observation opens space to consider that the gamification of the arts could be greater than just using non-linear media and more than an interactive multimedia synthesis. The possibility for an autonomous art synthetic game emanates from the diversity of its organics. Modern digital games, from the point of view of a game engine, provide real-time functionalities in varied domains: real-time graphics and sound that can be enriched with autonomous algorithms; autonomous contents can be generated and can take the shape of game narratives, poetry, music, text, voice, cinematics, 2D and 3D imagery and shapes. It seems plausible that the digital game has the potential to be a synthesis of a vast panoply of autonomous art forms. A question is raised of if such autonomous art forms could be integrated and unified and if the clients, in their own art-making, could reap the benefits of that unity using it through a spectrum of autonomy. In this synthesis, there is a possibility that new autonomous forms may also emerge that are not necessarily a mere sum of the previous.

Methodology to follow: preliminary case studies by implementation - creation and curation

We start by assuming a design science methodological approach and assessing the requirements for the design and implementation of applications that will test the hypothesis - applications of game engines to art-making, art experiencing and curation, and possible new forms of art, being that the subject of the study will be the arts as seen from a therapeutic point of view.

The object of study

From a view of software engineering, it will take as the object of study a particular game engine - the Unreal Engine – and will investigate its software architecture to assess how it can fulfil the art gamification research goals – creation, experiencing, curation and new forms of art, which will result in the design and implementation of an engine plugin that will encapsulate the functionalities necessary for the posterior work rendered in the subsequent chapters.

Methodology

Working with method is intrinsic to scientific knowledge generation. It is a well-thought-out algorithm for knowledge discovery that is applied from the beginning, during, and at the conclusion of a research process. Despite the idea of process also exists in the arts, the nature of that process in science is established according to principles that help to attain goals of objectivity, validity, reliability, and reproducibility, among others.

Methodology is the task of thinking about methods, their application and suitability for every case. A paradigm division exists between what are called quantitative and qualitative methods. As the name suggests, the first look for mathematical - namely statistical – conclusions, whilst the qualitative approach dives deeper into the realm of words and their subjectivity. This divide is not tight proof. Indeed, far from being black and white, scientific discovery happens many times in the middle, with what are called mixed methods. This permeability between categories of methods is also a defining characteristic, and many times, the researcher learns how to draw knowledge from the spectra of methodology.

The nature of games

The methodology followed for the work presented in this, and in the two following chapters, has been a compromise, a balance between competing factors. This is because

game development shares a nature of software product development as well as of creative industry (Mayra, 2012). Here, there are also implications regarding positive computing and the clients of such products, as the studies assume a goal of 'researching with people, not on people'.

Art research

In this research, there is a need to address and be sensitive about the intersections between computer science and the arts and their idiosyncrasies. If research on digital applications for the arts is naturally different from artistic research, it is also not that evident where the boundaries are sharper or more diffuse. In this work, we can assume beforehand that there will be a dimension of artistic research within the main flow of computer science research.

Computer science research

The work that will be described can be summarised as a cascaded development flow, starting with the definition of requirements and a stage of solutions design involving software architecture and game design. Following this, the designs will be implemented, and the work concludes with their evaluation.

Design science

The methods of design science or design research in computer science include a process of iterating between two research activities (Wieringa, 2014).

1) solving a real-life problem: the design cycle consists of delivering an artefact - software - that improves something for the stakeholders (Wieringa, 2014).
2) solving knowledge questions: the empirical cycle of design science consists in approaching the theoretical problems that may derive from the primary design cycle and provide satisfactory solutions that may help to make the cycle successful (Wieringa, 2014).

Requirements

The collection of requirements can result directly from the knowledge questions raised by the hypothesis but also from the study of a metaphor of a universal active client with real-life needs in the domain of art creation and experience inspired by the principles of positive computing.

Design, architectural + game design

The collection of the requirements will expose the need to approach the design stage in a two-fold manner. On the one hand, there will be explorations in software (game-engine) architecture for the arts, and on the other, there will be several different instances of software (game) design in applications to the arts.

Software (game-engine) architecture research

The architectural design challenge consists of the integration of game engines within the creative workflow of the arts, addressing the questions raised about how the gamification of the arts, in the sense of 'becoming game' through resourcing to game technologies, can produce useful outputs.

Software (game) design research

This research aims to design technologies to foster wellbeing. Mayra states that 'game research can make a contribution in the development of games by opening up alternative directions for game design or by providing important feedback from users to the developers during the game production' (Mayra, 2012). ShapiI et al. observe that, for instance, in cognitive rehabilitation, there is a great heterogeneity of impairments to address, and cost-effective ways for game creation are desirable (Shapi'I et al., 2015). The theoretical context of the first iteration of development - with TIMAEUS - lies in the potential within the digital and the art therapies, which also leads to knowledge questions about the nature of the computer arts. This art creation focus of the project

looks forward to being aligned with the principles of positive computing that Calvo and Peters define as the opportunity found in the psychological impact of pervasive technologies for designing and developing 'new technologies to foster psychological wellbeing and human potential', equipped with a theoretical and practical approach of 'validated methods and instruments for evaluation of impact' (Calvo & Peters, 2016). It also draws inspiration from the vision for a 'positive psychology movement' as proposed by Wiederhold and Riva. An endeavour for technology that can promote a 'digital experience that is deeply human-centred' (Wiederhold & Riva, 2012). Naturally, research for human-centred software involves jumping out of the strictly theoretical landscape and getting to interact and experiment with people. Art therapy is used in health contexts of varied nature. In the study, we will build a design metaphor of art therapy clients and practitioners that will guide the process.

User Application Testing

Artists

Despite opting to rely upon a metaphorical relation between art therapy clients and practitioners, and although the possibility of the implementations to be tested by clients is left open, the focus of the evaluation will be on how artists value the outputs of the tools. In collaboration with artists, we will ask for their input on TIMAEUS, STOA, and ODYSSEY.

Conferences

Another dimension of artistic evaluation will be potentiated by presenting the works at specialised conferences and assessing their acceptance.

6. TIMAEUS

6.1. Applications to Creating Art

Gamification of creating art

This chapter focuses on the potential of digital games and gamification for art creation by implementing an art studio that enables artistic expression within the creation of personalised, customisable, and autonomous sculptures. It renders the background, inspiration, and development of TIMAEUS. This digital art studio environment enables the creation of personalised three-dimensional sculptures built with expanding and interconnected volumes of atomic blocks. TIMAEUS sculptures can be customised with media, e.g., pictures, videos, and music, which are overlaid or seeded in the sculpture. Media can represent memories or, more generally, facts, including live internet feeds that can be used to create artistic narratives in space. Such facts are embedded in the sculpture and can be experienced in different ways, with the capability to zoom in and out, rotate, view from different angles, and apply sounds and soundtracks. Sculptures can be hollow and translucent. They can be illuminated, and the space that they enclose can be viewed internally. TIMAEUS incorporates autonomous art components. For instance, features of images, videos or music can be algorithmically extracted and used to modify the shape or movement of a perpetually mutating or dancing sculpture where these media have been applied.

TIMAEUS surges from a design metaphor of a study in art therapy of dementia patients where artistic memory sculptures can both aid reminiscence and create a much-needed sense of well-being. Reviewing one's life in an artistic manner may help to place fragments in perspective as well as work out gaps and conflicts. This could nurture

feelings of relaxation through artistic creation and of a stronger, more coherent self. Timaeus was inspired by the homonymous Platonic dialogue and its geometric, atomic cosmogony and cosmology (Plato, 360 BCE).

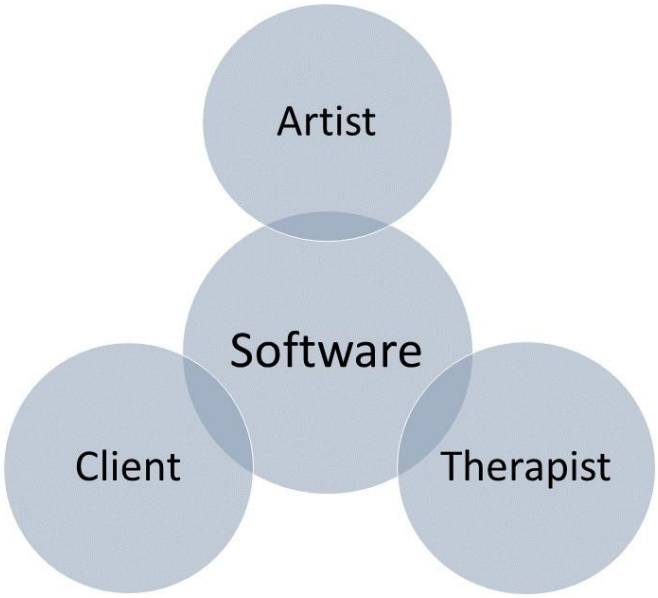

Figure 8 - Client/Artist/Therapist requirements

6.2. Requirements

Moving On from Art Therapy to the Arts

As mentioned in the beginning, the work of this PhD programme started with ideas of framing digital audio-visual and generative art into art therapy. At this point in the thesis, this seems to make even more sense as a technological gamified approach to art therapy. However, as this section will expose, such a scenario may only be considered once a solution for collaborative art creation is achieved. This becomes evident when trying to understand how to create user requirements for TIMAEUS. If considering an art therapy session, one would naturally identify the art therapy client and the therapist

as stakeholders (Figure 8). However, the goal of an art therapy session is to produce art and use it as a vehicle for therapeutic goals. So, it can be said that the art therapy client works in the setting as an artist. The same can be said also about the art therapist. This agrees with the fact that art therapy is one of the possible specialisations in higher education in artistic studies. Undoubtedly, the art therapist is also an artist.

So, possibly, a good way to elaborate requirements for an art therapy studio run by art therapists for clients is to see it simply as an art studio for collaborating artists (Figure 9).

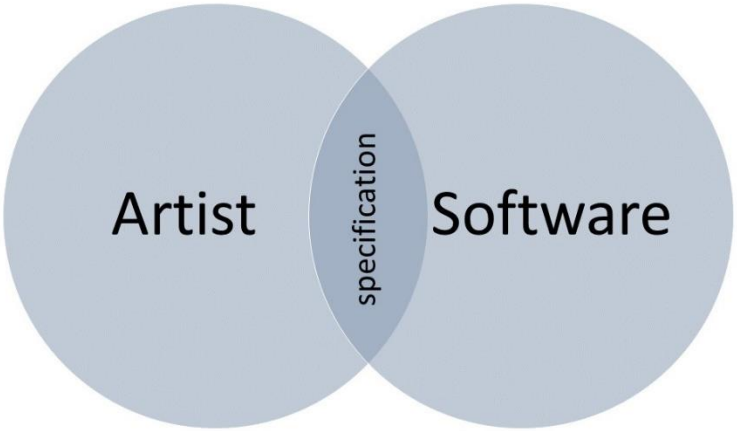

Figure 9 - Artist/software requirements

6.3. System specification

Target platforms

TIMAEUS is currently designed for personal computers (Windows, OSx, Linux), touch-enabled smartphones and tablets (Windows, iOS, Android), the PlayStation 5 and PlayStation VR2. This is possible because the games developed with Epic's Unreal Engine are deployable to almost every major platform, with the exception of HTML5, a platform to which official Epic support has been discontinued recently. This is the main

limitation of this choice of tools in this regard, as HTML5 would be an almost universal platform by itself.

Figure 10 - TIMAEUS, interactor (menu)

Functionality

The studio enables the creative processes of building multimodal sculptures through a set of functionalities:

The menu and the palette

The goal when designing the TIMAEUS user experience and the interface was to achieve a user feeling of 'computerless computing'; this is, allows the user to interact with the studio as if all functionality resulted naturally, and one could forget it was interacting with software and focus on the artmaking. At an initial state, this is reflected in the simplification of interaction through a minimalistic interface based on a few icons (Figure 10). The user can interact with TIMAEUS via either the menu, a 3D palette, or

both. However, the menu is more suited for PC and mobile targets, and the 3D palette is better suited for virtual reality (Figure 11).

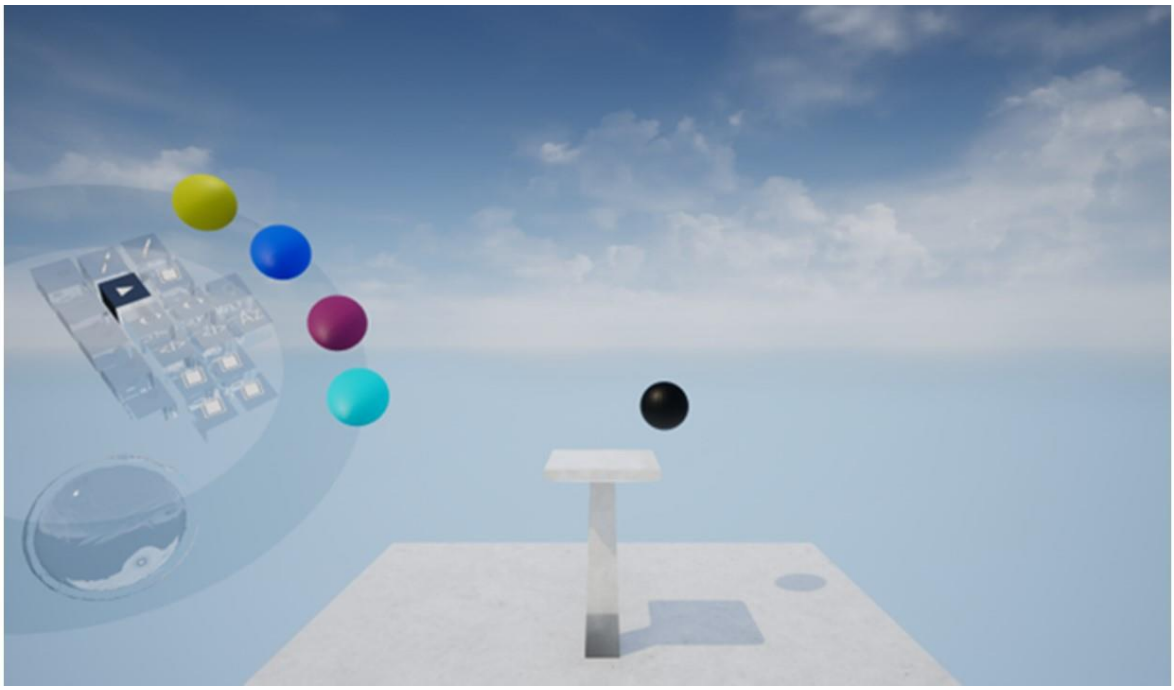

Figure 11 - TIMAEUS, interactor (3d palette)

Sculpt to add or remove volume

The user can add or remove three-dimensional material to the sculpture as if working with a kind of virtual clay. To make this possible, the system developed includes data structures that can represent the sculpture, a loop cycle that alters and renders the current sculpture state, and a set of interactors that allow the user to change the state of the sculpture.

Choose sculpting mesh and size

Sculpting happens through a three-dimensional brush, which can be loaded in any desired shape and added with controllable scale and rotation. The possible shapes are the tetrahedron, the hexahedron (cube) and the sphere. Additionally, the user can

interact with an online web service via a prompt where the user can search for shapes available in the Internet Archive. For instance, the user can write a prompt for 'Plato', and the brush will assume the shape of a sculpture of Plato.

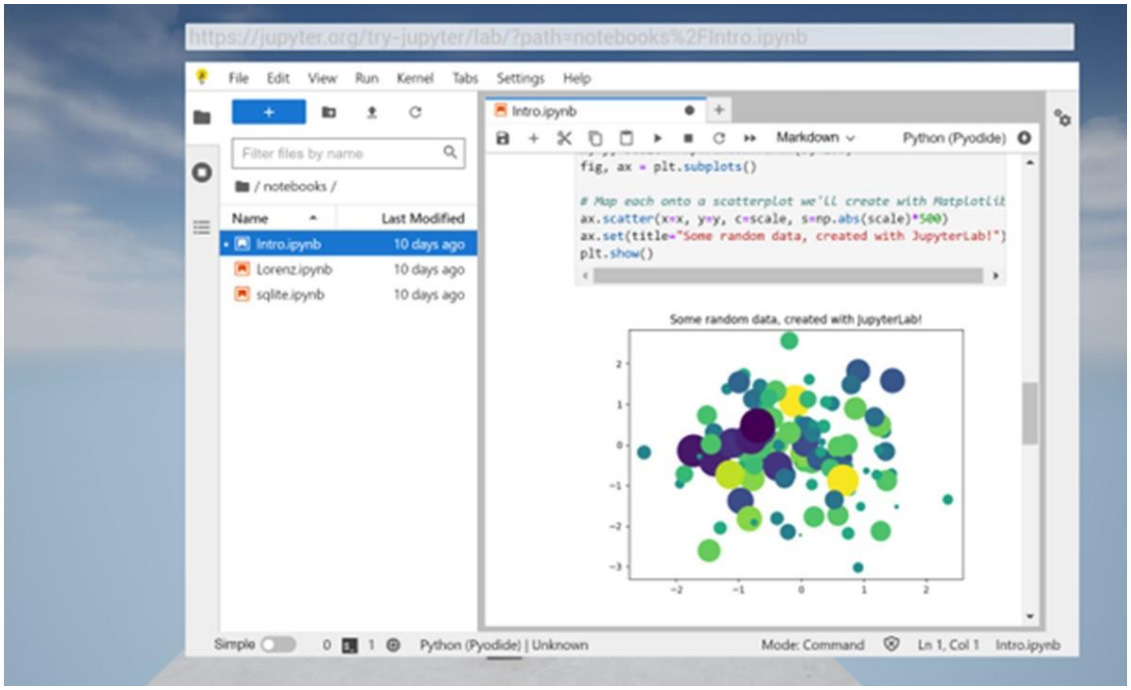

Figure 12 - Running a Jupyter notebook

Paint materials

The artists can use several different dynamic materials that conserve a state for a particular colour, lighting, texture, shaders, and movies. With this, the sculptures can be interactively illuminated, added with shades, and enriched with media in a multimodal assembly.

Paint textures, choose paintbrush size and colour

The paintbrush colour can be chosen, and the paintbrush is scalable. In the same manner that the artists can add and remove volume to the sculpture, the sculpture's texture is editable, as the brush functions as a 2D paintbrush here.

Load pictures

Any picture can be loaded from the internet into a material. The texture of a particular material can be edited to produce images that wrap the sculptures and can be moved, scaled, and rotated. This allows the addition of personalised images to the sculptures that can be directly imported by the user or also result from a search in the prompt that interacts with the web service.

Load music

Spatialised sound can be loaded from the internet, per material, or directly imported. This means that the sculptures, besides their visuals, can also produce sounds that are echoed by their surroundings.

Load videos

Videos with spatialised sound can also be imported and loaded from the internet per material. So, the sculptures can be wrapped with videos and played on demand.

Orientation

The client can rotate, scale, and displace the 2D media along the surface of the sculptures. This means that the artist can adapt how the textures and media wrap the sculptures to achieve the desired effects.

Illumination

The artist can control the sculpture's illumination by material. With this, the sculptures can act as multimedia and animated sources of light.

Change material mode

The user can opt to present the materials' colours, textures, and movies by themselves or in simultaneous combinations.

Add text

The user can add subtitles to the sculptures. They are interactive and change according to the player's position relative to the sculptures.

Undo

The client can correct erroneous sculpting inputs as the studio goes through timestamped files.

Save/Load files

The sculpture's state can be saved to a file and loaded.

Autonomous behaviours

There is one branch of functionality reserved for the implementation of autonomous behaviours. For instance, the sculpture's mesh can be transformed in real-time according to the music being played.

Python for playing with machine learning

The user can open a Jupyter Notebook to work with machine learning and interact with the game environment via universal runtime content. This means that the runtime content is both patent in the visual environment, editable via the interactors provided and also the data structure that can be subject to changes implemented with Python and its libraries via the Jupyter Notebook in real-time (Figure 12).

6.4. Non-functional requirements

Quality attributes and trade-offs

Correctness and efficiency

The question of whether TIMAEUS enables the creation of art can be validated by end-users and other stakeholders. It is the predominant question that will be asked of the artists and assessed via the reception of the public in specialised conferences.

Performance

The ability of the software to work with real-time interaction is inherent to a good user experience. The sculptures, the media, the textures, and further modalities should play with the user interaction without glitches. This is particularly challenging when dealing with 3D real-time sculpting and has been a major spot for optimisations during development.

Reusability, Flexibility, Maintainability

The code should be easily expandable and maintainable. This is achieved in a twofold manner. On the one hand, the choice of tools, and on the other hand, the way code was organised. The choice of the Unreal Engine meant that all the code could be added as an extension or plugin, and the code was organised in accordance with the practices characteristic of the Unreal Engine development, on the extension side, and of reusable/modular game development on the game development side.

Security

The system is data agnostic and relies on well-established third-party authentication and data frameworks such as GitHub.

6.5. Software Architecture and Design

Software architecture and design patterns are the commonality of software design approaches consistently used in the industry to solve the same problems. The process of building TIMAEUS shared that same commonality in regards to patterns in game development and others, such as singleton, command, state, double buffer, semaphore, event queue, dirty flag and client-server.

Patterns

Game Loop, Component and Update

The triad of the Game Loop, Component and Update patterns is ubiquitous in the development of TIMAEUS because it is a game-engine-based, digital-game-like application with a continuous real-time cycle of updating and rendering of objects.

Command

The command pattern is necessary in TIMAEUS because, in this way, the user interaction can be processed and undone if necessary, as every request turns into a stand-alone object that contains all information.

Singleton

There are unique instances in TIMAEUS, and this is achieved by resourcing to the singleton design pattern, as in the case of each sculpture's runtime multimodal data.

State

TIMAEUS can be in different editing and viewing states, for instance, editing can happen at the level of the 3D volume (sculpting), and at the level of the sculpture's texture (2D painting) or in the application of sculpting materials (3D painting), and the visualisation the sculpture can also happen in different viewing modes.

Double Buffer

Like a double buffer is necessary for real-time computer graphics, the sculpting of objects is achieved by separating the sculpting sculpture from the rendered sculpture in the same way.

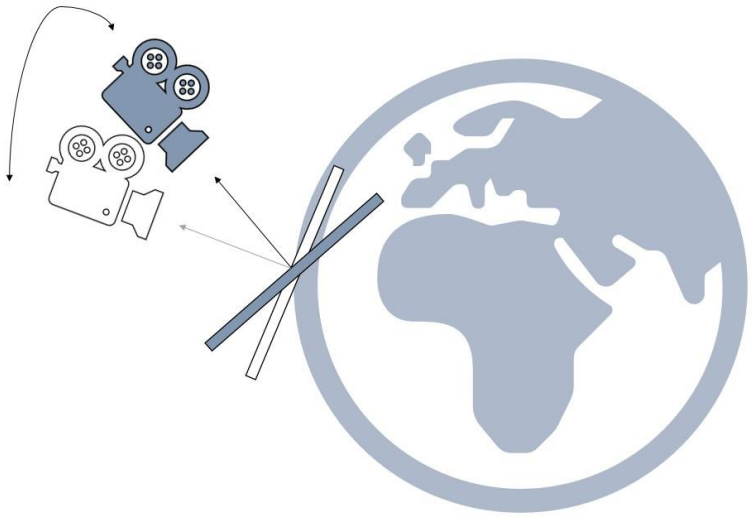

Figure 13 The billboard technique (or camera-facing sprite)

Semaphore

The semaphore pattern is necessary for sculpting with parallelism, as it is how no additional sculpting changes are made to any portions of the volume that are already busy.

Event Queue

An event queue handles behind all instant sculpting commands that are then sequentially run in game loop time.

Dirty Flag

The dirty flag pattern is used to distinguish between an edited sculpture that has been already rendered or not.

Client-Server

The web service that serves TIMAEUS with real-time search of sculptures, movies, pictures, and audio follows the client-server design pattern.

MVC

It could be argued that TIMAEUS uses a design similar to the MVC pattern, but in that case, the Interactor class would replace the Controller.

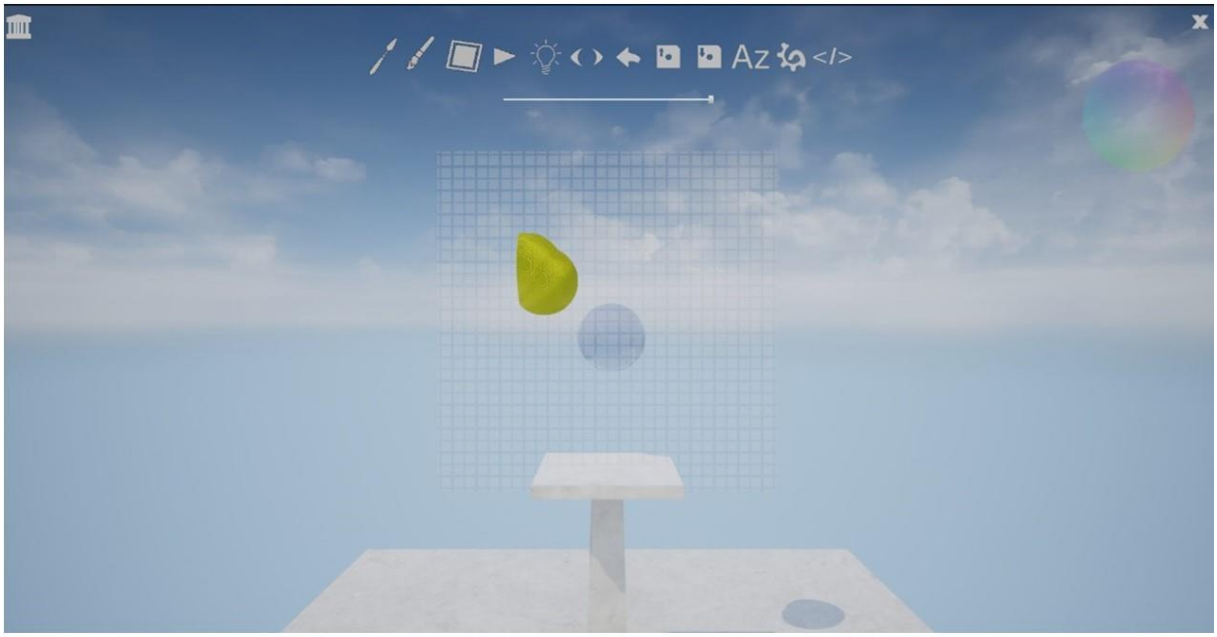

Figure 14 - 'Millimetric' billboard for sculpting

A billboard for 3D sculpting

Billboards are a useful technique in game development. They consist of simple planes that always show their faces to the player. When such planes hold a picture of, let's say,

a tree, this becomes a way to avoid using a 3D model of a tree and still make a landscape of trees sufficiently realistic. It can also be used to create an illusion of vegetation, such as grass. The basic principle is that the plane holding the picture is much lighter computationally than having a 3D model, and this can work well when the tree is far away from the user enough so that the illusion or trick will not be perceptible.

This practice was the basis for a technique developed for TIMAEUS but with a very different purpose. Instead of illuding the viewer, the idea here was to use a front-facing plane or billboard as a way of capturing the sculpting inputs in the 3D space.

This is because 3D sculpting involves locating the mouse cursor (a 2D location with X and Y coordinates) inside a 3d space. The way found to achieve this was by resourcing to an invisible billboard - called 'millimetric' (Figure 13) - that always faces the camera, and a pointer mesh that lives in that rotating 2D plane. This way, we can establish X, Y, and Z coordinates for a given mouse position (Figure 14).

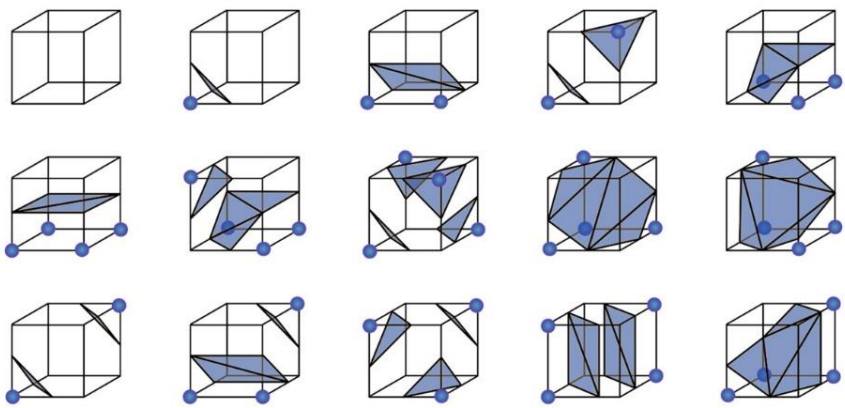

Figure 15 - The cases of the Marching Cubes (source: Wikipedia)

Experimenting a 3d volume transformation into a surface with marching 'octotetra'

In computer graphics, there is a known problem (with several solutions) for the task of generating a 3D surface (the mesh) from spatial data. For instance, we can have data about a volume made of voxels but then want to extract the isosurface that that data represents. A widely used algorithm that achieves this is known as the 'Marching Cubes' algorithm (Figure 15). Its logic is elegant and simple: From the moment we have the positional data in a regularly divided volume, such as with hexahedra or cubes/voxels, we can then match it with one of the possible cases for surface generation. When we attach all the small surfaces it generates, we get the complete 3D mesh of the object represented.

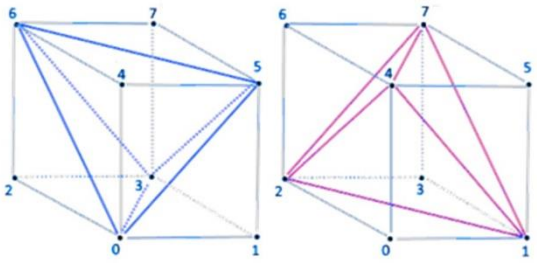

Figure 16 - The lattice for the Marching Tetrahedra (source: Wikipedia)

The Marching Cubes algorithm is widely used, and there are also variations, such as the 'Marching Octahedra', which explores that the octahedra is the dual polyhedron of the cube, and the 'Marching Tetrahedra' (Wenger, 2013) that tries to explore other geometries in the division of space (Figure 16). To achieve this, the authors still divide the space with cubes, but then inside each, there is a further subdivision in irregular tetrahedra.

The Platonic inspiration for this work, and as exposed by the character Timaeus in the homonymous dialogue, led to a search for other kinds of regularity in the division of space besides the before mentioned regular cubes, their dual, and the irregular tetrahedra. The purpose here was not just to find a better or more optimal way of performing the isosurface extraction but rather to explore the different paths that could be followed in the regularity of the division of space and in finding ways in which such regularity could result in novel ways of generating surfaces from positional 3d data, in a sense that such techniques may have artistic value by themselves, in the line of being new tools as the ones developed throughout history by artists in their artmaking.

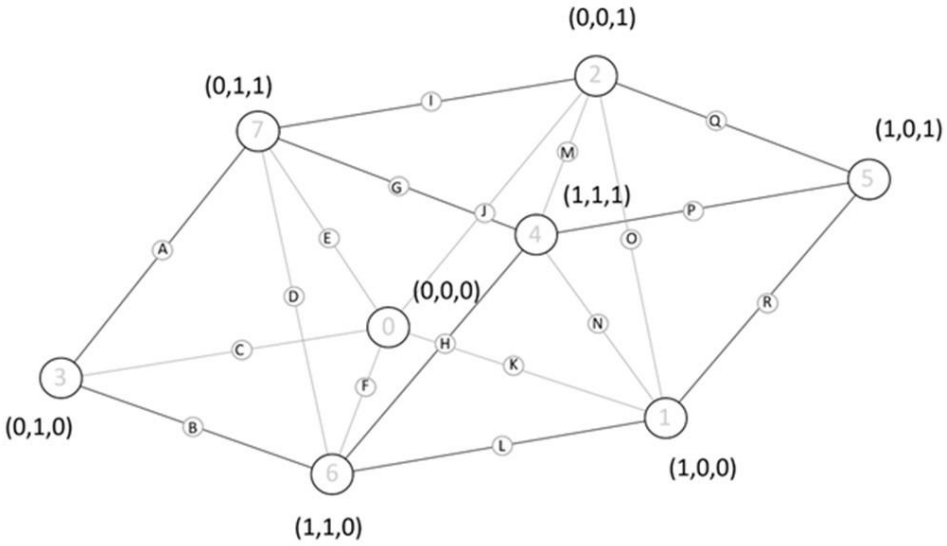

Figure 17 - Sheared, central octahedra and two lateral tetrahedra

Shearing the cube

An inspiring observation was made regarding regular lattices. It is that, if we shear a regular honeycomb of cubes at a certain angle, we can obtain another fully regular honeycomb of regular octahedra and tetrahedra, here called 'octotetra' (Figure 17) but

which mathematical name is more precisely ' tetrahedral-octahedral honeycomb'. This shearing operation lets us so consider another variation of the Marching Cubes algorithm, this time resourcing to units of one octahedron surrounded by two tetrahedra contained inside a sheared hexahedron (or cube).

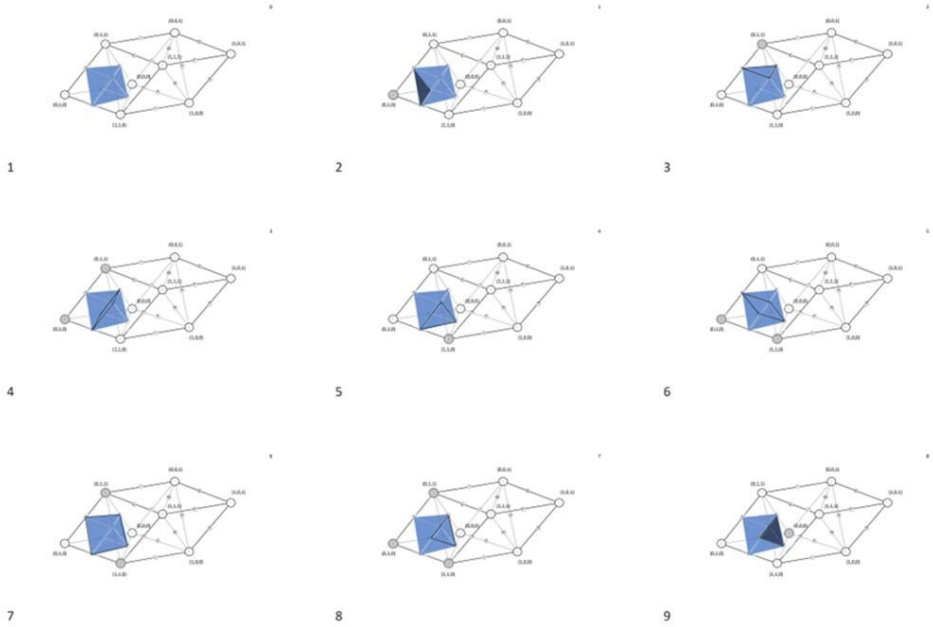

Figure 18 - First 9 cases (of 16) of tetrahedron 1

The cases of the Marching Octotetra

A serendipitous result of shearing the voxel was the realisation that the logic of considering possible cases for surface generation still applies to the octotetra, as it did to the Marching Cubes and Marching Tetrahedra. So, the 'Marching Octotetra' have surface generation cases regarding its two composing tetrahedra and one octahedron. The two tetrahedra contribute 16 cases each, of which some are shown in the picture, and the octahedron contributes 64 (Figure 18).

Because the shearing of the voxels can be done in a single matrix multiplication, it is possible to easily switch between the cubic lattice and the octotetra, and so in TIMAEUS,

the rendering of the sculptures can happen both via Marching Cubes and with this new Marching Octotetra algorithm (Figure 19). This also opens possibilities for further experimentation with isosurface generation, being that one characteristic of TIMAEUS is that it has an inspiration on the regular division of 3d space with platonic solids and its potential for the exploration of new ways of doing computer graphics.

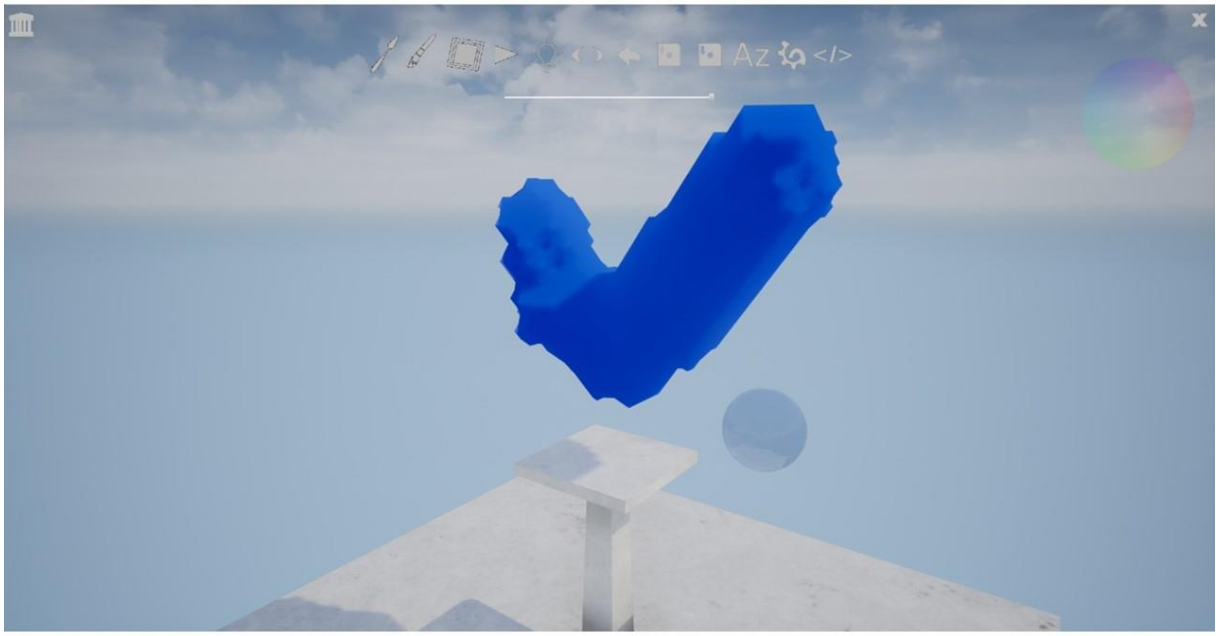

Figure 19 - Sculpted surface with Marching Octotetra (scaled up)

The rendering process relies on the Unreal Engine's 'Procedural Mesh Component'. This component can be added to an Actor class and fed with the data for a 3D mesh, with arrays of vertices positions, triangle indices, normals, UV coordinates, colours, and tangents after they are calculated. The Procedural Mesh Component accepts creation data but also updating data, which means that it can be changed every tick cycle according to the changes made by the user to the sculpture's 3D data. One good alternative to the PMC could be the Runtime Mesh Component (Conway, 2023), which is specifically designed to handle fast-changing 3d meshes, so it is ideal for this

sculpting purpose, although less stable than Epic's solution because the latter is already integrated into the engine's source.

Figure 20 - Sculpting with a tetrahedral brush

Sculpting 3d shapes

Another feature of TIMAEUS sculpting lies not in the sculpture itself but in the brush that is used to create sculptures. This brush can also assume platonic shapes such as the tetrahedron, the hexahedra and also the sphere and meshes obtained via a prompt.

Sculpting tetrahedra

In order to sculpt with a tetrahedral brush (Figure 20), the code behind relies on an algorithm that mathematically tests if a given point in 3D space is inside the brush volume. This is highly optimised, as the volume of a tetrahedron is one-sixth of the scalar triple product = $(a \times b) \cdot c$ of the vectors representing any three co-terminal edges of the tetrahedron. If a given point's possible tetrahedron volume relative to every three

edges of the test tetrahedron is less than the test tetrahedron volume, then the point is inside the test tetrahedron. This makes it possible to rapidly sculpt with a tetrahedral brush.

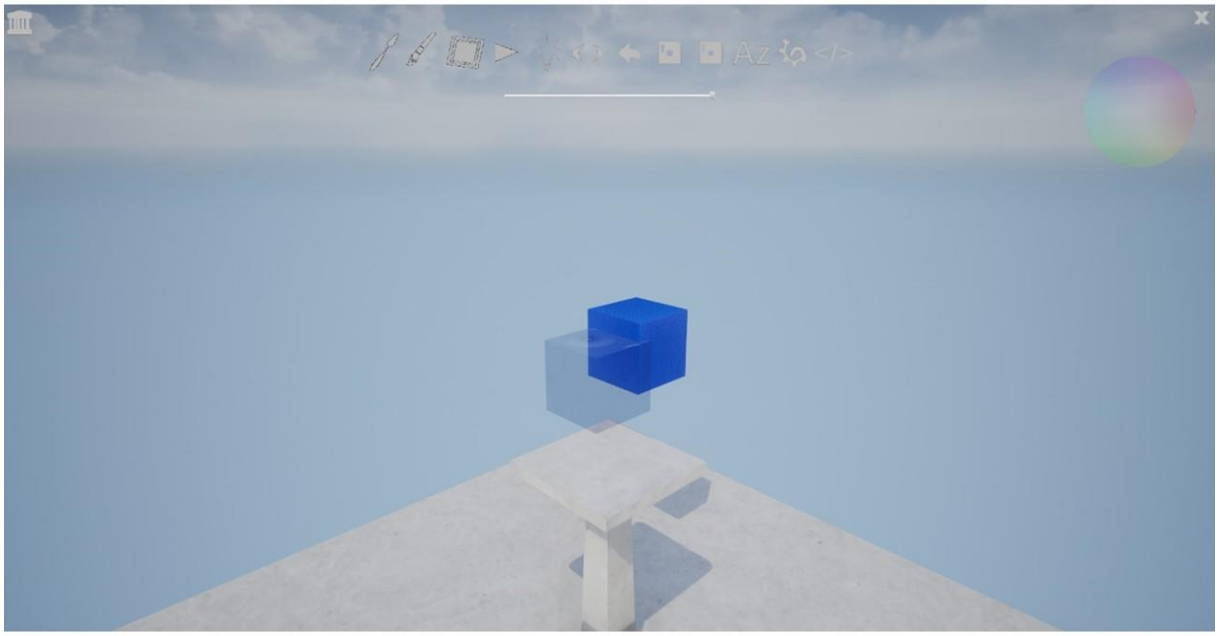

Figure 21 - Sculpting with a cubic brush

Sculpting hexahedra

Even simpler is the cubic brush shape (Figure 21), which only tests if a given point is within a certain range of X, Y and Z coordinates. The methods that produce geometrical brush sculpting are also optimised with parallelisation. This means that, instead of iteratively testing if a point is inside the brush, one at a time, the sculpting methods rather resource to the power of Unreal Engine's iterator 'ParallelFor' from the 'TaskGraph library', and tests all inside positions as soon as possible in accordance with the parallelisation capacities of the deployment machine TIMAEUS runs on.

Sculpting spheres

The sculpting sphere (Figure 22) is also obtained by simply testing if the points are within a certain radius and the brush position is in the 3D space. Here again, parallelisation works in tandem with the shape's simplicity to achieve one of the best performant brushes within all present in TIMAEUS.

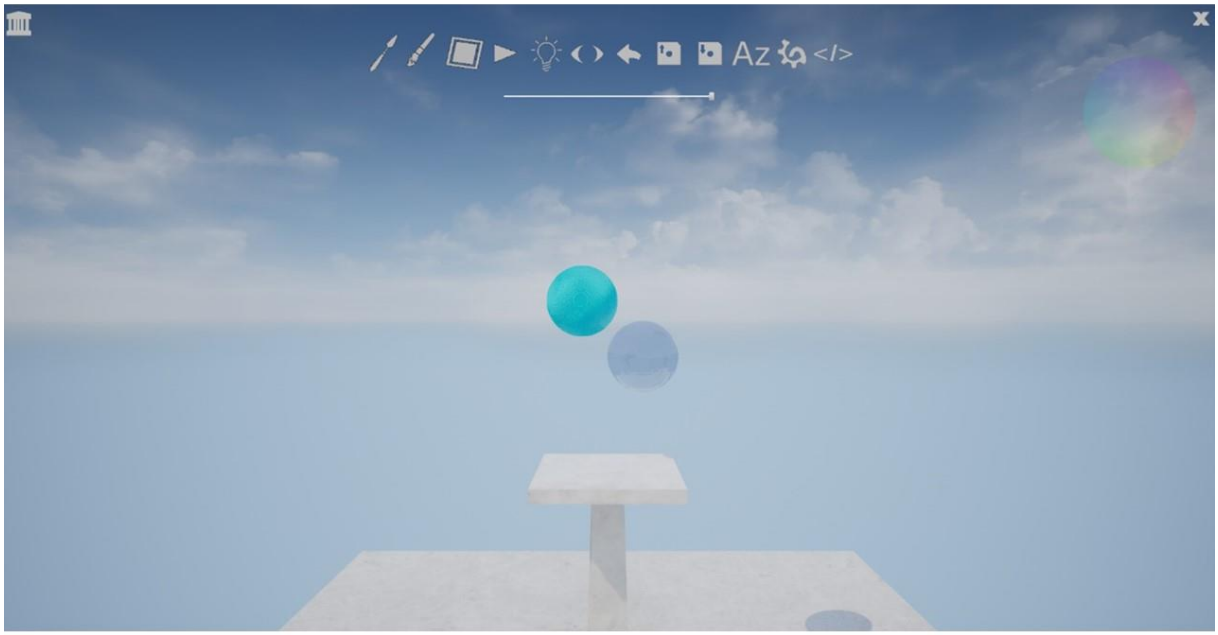

Figure 22 - Sculpting with a sphere brush

Sculpting meshes

However, besides platonic solids or spheres, the user may also choose as brush arbitrary 3D meshes that can be directly imported or downloaded at runtime by querying the Internet Archive through a rest API inside TIMAEUS (Figure 23).

Sculpting with mesh brushes is a more complex task performed by TIMAEUS, less optimal due to the greater complexity of 3D meshes versus the previously mentioned simple shapes that are directly translatable to fast mathematical functions.

In the case of the mesh brush, testing if a given point is inside the mesh brush and, hence, should be sculpted is done by testing its position regarding the triangles that compose the mesh brush. Eventually, the most precise information necessary for sculpting is to know if a given sculpting point is inside the enclosure made by the mesh's triangles or outside of it.

Figure 23 . Sculpting with brush by querying 'man' in the Internet Archive prompt

The best algorithm found to do this was simply to get the mesh's nearest triangle to the sculpting point and then test if the normal vector of that triangle points towards or outwards that point via its dot product. This method is not as performant as the sphere or the cube because finding the nearest triangle becomes as fast as simpler – or with fewer triangles – the brush mesh is.

A hyper-sphere, a lookup table and a colourmap of UV coordinates

Having a sculpture that can change and morph, to which we can add and remove the material as if clay, is another problem to solve when thinking about the surface of that sculpture or mesh. Because the goal is to wrap the sculpture with pictures and other media, there lies the issue of deformation of the surface and making the pictures or videos dress the volume without losing consistency. Otherwise, when the sculpture grew or shrunk, the media wrapping the surface would deform to a point where it would lose its characteristics. Making this possible whilst sculpting in real-time is also a challenge. The solution to this was threefold: hyper-sphere coordinates, a UV lookup table, and a colour map.

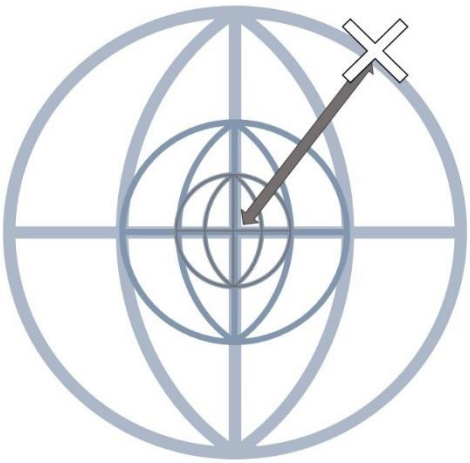

Figure 24 - Hyper-sphere UV coordinates

The hyper-sphere approach (Figure 24) is well-performant as it consists of calculating a mathematical function on the run. In this function, the existence of an origin or central point is assumed, and the UV coordinate of any other 3d point can be calculated by supposing a sphere placed at the origin, a sphere whose surface intercepts that point. So, if our point of interest displaces an amount, let's say, in the X axis, the sphere we

would be considering would be again centred at the origin and its surface, intersecting the new point.

Figure 25 - UVs, a colour checkerboard wrapping the sculpture

So, essentially, the whole 3D volume is mapped by this function into successively growing spheres starting at the origin – hence 'hypersphere' – and we get the UV coordinate by getting it from the relevant sphere. The performance of this can be improved if, instead of calculating the function on the fly, we first build a lookup table - actually a three-dimensional array – containing the precalculated UVs for each cell/voxel of the 3D volume and then interpolate these values to get the UV coordinate of a particular 3d point. This works well if the sculpture is not very far from the origin point, allowing it to grow and be reduced without losing its surface wrapping consistency or suffering too much deformation (Figure 25). Finally, a different approach using a colour map has also been implemented. In this way, the sculpture is wrapped with a texture that contains all possible combinations of RGB colours, each colour

corresponding to a particular UV coordinate. Then, when sculpting, finding the UV coordinate is a matter of getting the exact colour under the cursor. This requires a hidden buffer, which is, every cycle, the sculpture is rendered two times. One is a normal render to show on the screen, and the other is a hidden render where the texture wrapping the sculpture is our colour map. It is from this hidden rendering that we get the colour corresponding to the UV coordinate.

Figure 26 - Sculpture wrapped with an editable 2D canvas

An editable texture2D/canvas

Having the UV coordinate behind the editing cursor, it is possible to edit the wrapping texture using a brush – in this case, a 2D brush – that can also be directly imported or queried and downloaded via the prompt. The bi-dimensional data structure holds the data for the image, and changes are made to it via the brush in the same manner as when sculpting, but in 2D.

A downloader for online mesh data, textures, and other media.

In order for the user to be able to query the Internet Archive to get public domain media such as sculptures, pictures, videos and audio, a simple web service has been developed and deployed to a server that sleeps and wakes up on the activity. This web service is the intermediary between TIMAEUS and the Internet Archive rest API.
When the user makes a query in TIMAEUS' prompt, a GET HTTP request is sent to the web service, which wakes up and, in turn, queries the Internet Archive and finally sends back to TIMAEUS the data of the 3d model, the video, the audio, the picture or the text.

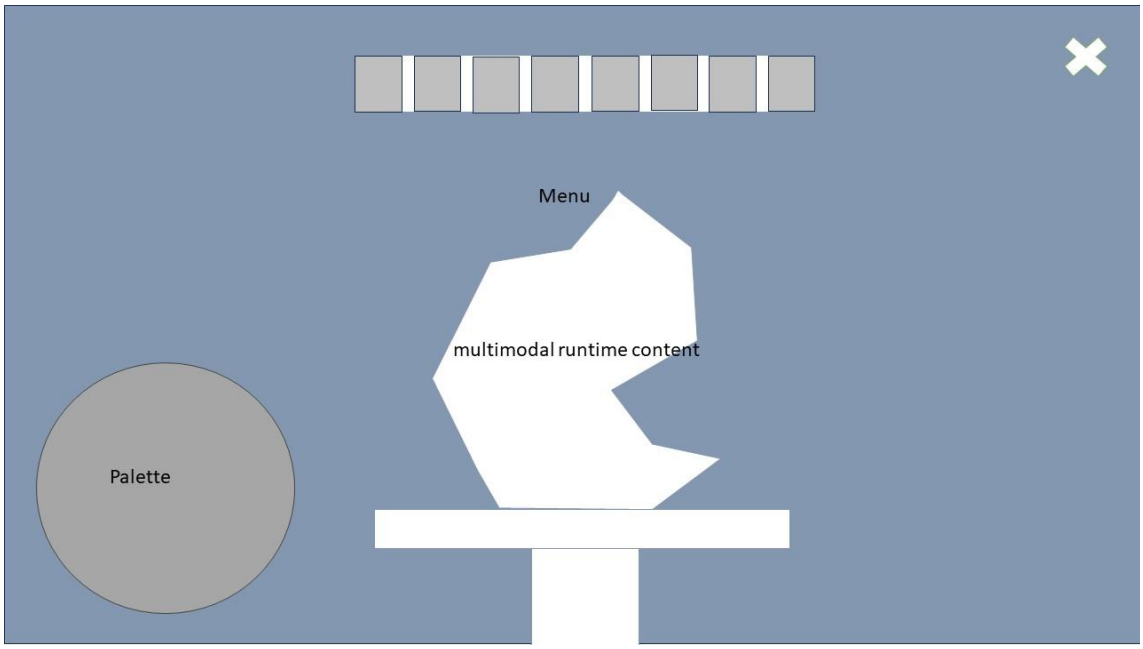

Figure 27 - Conceptual mock-up

Safe queues, Hub Control

In order to correctly add and process user inputs and render the outputs, the inputs are added via a custom class for thread-safe queues. They are accepted by a control class

that then unloads the queue of inputs on every game cycle, separating the reception of inputs from changing the data and then reading and rendering it.

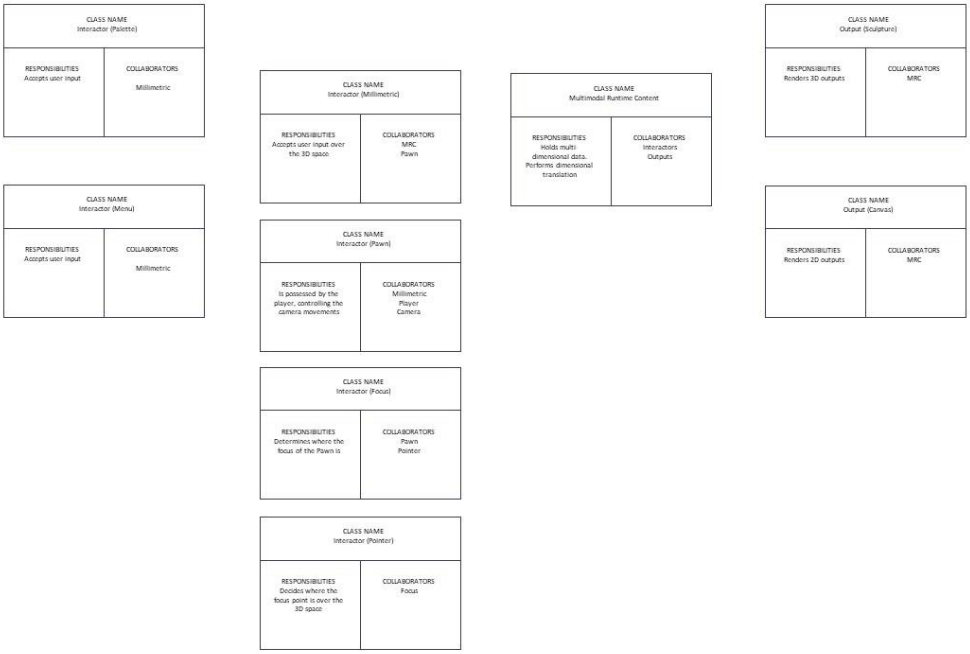

Figure 28 - CRC cards

Conceptual Design

Conceptual Mock-up

The first drafts of TIMAEUS (Figure 27) as conceptual mock-ups reveal a simple interaction environment with an Interactor (menu or palette) and editable multimodal runtime content placed in a 3D space.

Class Responsibility Collaborator (CRC) Cards

CRC cards (Figure 28) allow to envision the general scheme of playing parts and their interactions

Technical Design

Object oriented class design/architecture

The general operation goes around four main classes (Figure 29), that appear as:

- **Hub class**

This hub class holds references of all other classes in the game (association) and manage their ticking along with the game loop.

Multimodal Runtime Content

This class also holds references to all data used in TIMAEUS as, for instance, the 2D array that holds data of the canvas and 3D array that holds the data of the sculptures.

- **Interactor classes**

The interactor classes interface the inputs and the outputs.

1) Interactor Focus
2) Interactor Millimetric
3) Interactor Pointer
4) Interactor Pawn

- **Output classes**

The output classes deal with all that is presented to the player, outputs such as the 2D canvas and 3D sculpture.

1) Output Sculpture
2) Output Canvas
3) Output Audio
4) Output Text

Technical Diagrams

Class Diagrams

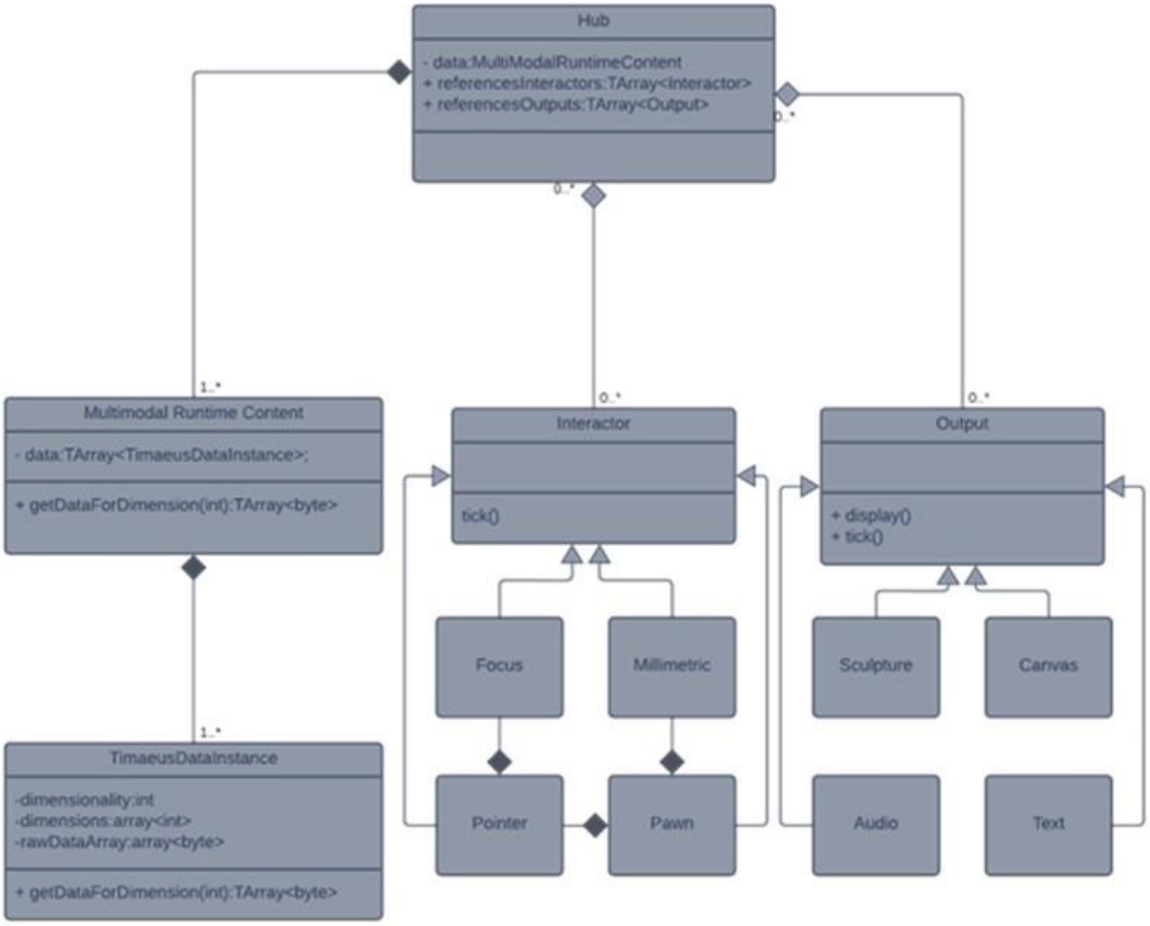

Figure 29 - Class diagram

Sequence Diagram

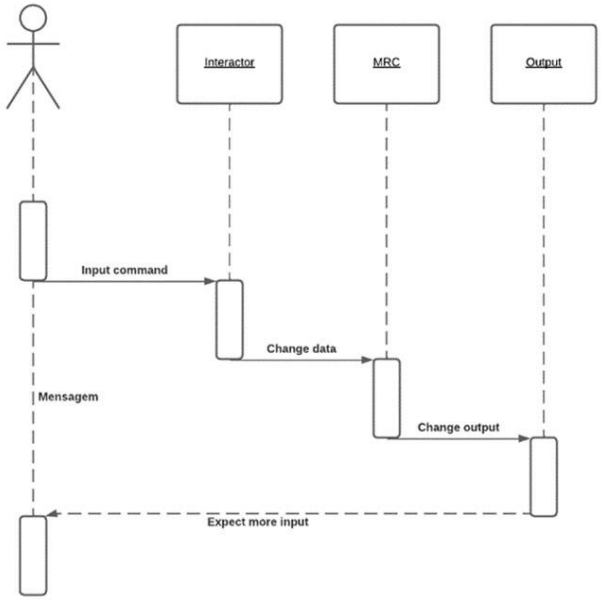

Figure 30 - Sequence diagram for input

6.6. Deployment

TIMAEUS is being deployed to SONY PlayStation 5 with PSVR2. Later, the deployment will expand to personal computing, with Windows, OSx and Linux, and to embedded systems such as Android and iOS tablets and phones (Figure 31).

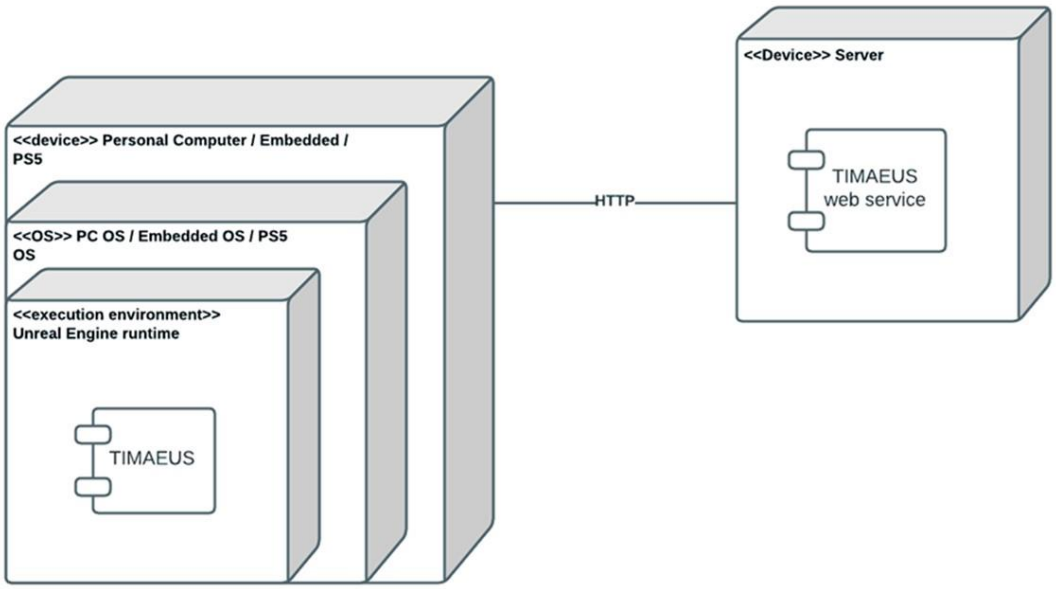

Figure 31 - General deployment diagram

Unreal Engine makes it very simple to deploy to such a large scope of devices, as it provides runtimes for every one of them. On the server side, there is the TIMAEUS web service that allows for searching and adding images, audio and 3d models in real-time.

6.7. Memory Sculptures

Inspiration from Plato

The Platonic dialogue of Timaeus has inspired the conception of the homonymous art studio. The dialogue develops a geometric cosmogony in which the world, much like the mosaics of Ravenna, is composed of atoms, which in the dialogue are shaped as the five perfect solids discovered by Plato. Apart from its literary value and an example of dialectic argumentation, the dialogue provides extraordinary insight into later scientific discoveries in the field of chemistry and biology, which have discovered

harmonious, often geometrically perfect, structures in the fabric of matter. TIMAEUS effectively aims to construct memory worlds from atomic units and entities.

Timaeus also contains the original reference to the myth of Atlantis, the lost city or lost continent, depending on which narrative one reads out of the many stories created in centuries of literary speculation that followed Plato. The myth makes a relevant connection to the loss of memory and, therefore, the topics of reminiscence and dementia that this research aims to address. Moving beyond this obvious connection, modern psychological and neuroscientific theories suggest that memories are continually reconstructed on the fly as opposed to being recalled. This is precisely what happened in the case of the myths surrounding Atlantis, but it is also how memories are recreated in an artistic fashion within the TIMAEUS art studio (Figure 32).

Figure 32 - TIMAEUS, memory sculpture

Dancing Sculptures

As an exercise on the many possibilities for autonomy, we can pick music as an example of input that can be processed to then create a generative effect on a sculpture under design. Via Fast Fourier Transformations (FFT), we get a value for each audible frequency in any given moment of the track and that results in a dynamic sculpture that has a constant, editable shape, while floating in the air, that is calculated as sine and cosine function variations of the surface shape that are fed with the results of the song's mapped frequencies. By enabling this function, the player creates a sculpture that can be constant but that at the same time reconfigures itself to the variations of the frequencies of the music. While sculpting, the shape comes back, and then it floats again, so there is a perceived sensation of dancing with the sculpture (Figure 33).

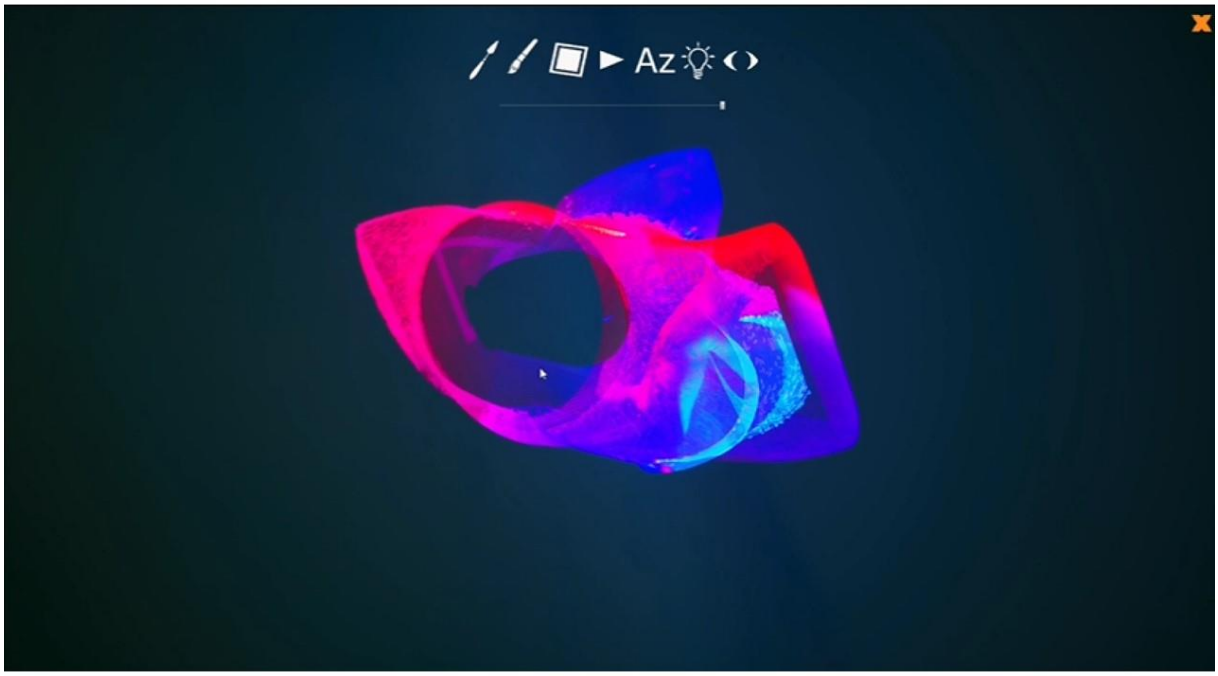

Figure 33 - TIMAEUS, media sculpture

Thinking in terms of complexity, and in a parallel with Soddu's 'New Naturality', the sculpture is fed with an 'always differing flow of information' (Soddu, 2002), in this case, derived from the soundtrack, that then is dependent on the player's interaction. Still, in that parallel, possibly more interesting sculptures could be achieved if, instead of simple surface sine and cosines, more complex design decisions were made regarding the shape. The dynamic feeling of 'dancing with the sculpture' emerges from this exercise.

6.8. Combining artworks

Figure 34 - TIMAEUS, colourful mountains

The above picture (Figure 34) displays an example of a memory sculpture created in Timaeus. A colourful painting by abstract artist Roberto Bono (Bono, 2023) covers the surface of the sculpture; hanging within and on the boundary of the curved space, there are personal images forming an internally illuminated 3D collage that can be navigated both internally and externally.

7. ODYSSEY & STOA

7.1. Applications to Experiencing Art

Perez y Perez, in his book about computational creativity, emphasises the rise of new opportunities for research in what he calls 'alternative digital spaces', or the possibility to computationally model and/or build worlds. (Perez, 2015). There are some documented experiments - since at least the 1990s - of using the technology of games to recreate museum experiences, such as Bernstrup and Palle Torsson's Museum Meltdown series and Fuchs and Eckermann 'The Expositur' (Clarke, Mitchell, 2013). Virtual museum's audio-visual experiences are more common today, as a visit to the PlayStation VR experiences store can demonstrate. However, there is a virtually endless realm of possibilities for the shape that such experiences can assume because building such worlds is also a creative enterprise. Arguably, one could say that there is room for the artification of virtual museum, gallery, and library experiences.

7.2. As an artistic journey

For over 25 years, Athenian painter Stefanos Zannis has been painting Homer's Odyssey but with a twist: delving into verses of the original poem that many would find obscure. This ancient poem has always been a quintessential symbol of the journey of life that we all go through, complete with the monsters we face and the longing for a spiritual home, or end-goal, symbolised by Odysseus' island home, Ithaka.

We take inspiration from Stefanos's work on this epic poem to create an 'alternative virtual Odyssey' in multimedia form, an artistic reinterpretation of the poem that

throws light on unheroic but important and emotionally loaded aspects of this journey. This virtual Odyssey takes place in a navigable virtual gallery of Stefanos's works, which are projected on multimedia sculptures created with the Timaeus art studio (Torrao, Papadopoulos, McKie, 2017). Sculptures are customised with media, including images, videos, music, and narration, and can be hollow and translucent, illuminated, and navigated either externally or internally. These become curved spaces or 'worlds' where projected episodes of the Odyssey can be experienced in three dimensions. TIMAEUS is thus a medium for creating spaces appropriate for experiencing the elements of this alternative Odyssey. Apart from Stefanos's paintings, we can integrate relevant poetry by Greek poets Konstantinos Cavafy and Alexandros Vanargiotis.

Figure 35 - Odyssey

Odyssey

Composed around 800 BC, Homer's Odyssey is a cornerstone of Western literature. It takes the form of an epic poem telling the story of Odysseus in his quest to return home

to the island of Ithaca after the Trojan War. The poem describes a ten-year-long trip in which Odysseus encounters the fury of Gods while he battles with mythical creatures and monsters. It also narrates events back home in Ithaca, where a group of suitors are competing for the affections of Penelope, Odysseus's wife, and the throne of Ithaca. The Odyssey is an epic, a long narrative poem written in an elevated style dealing with the feats and struggles of a great hero. The poem was most likely written to be recited with musical accompaniment (OC, 2019), and it has wonderful musicality in its expression. Odysseus is brave and strong but, most importantly, rational and intelligent. The epic celebrates these virtues in the context of heroic action but also throws plenty of light on human weaknesses and failings, addressing a range of universal themes related to human nature that are still relevant.

Figure 36 - Odyssey

There is a groundbreaking narrative structure beginning in medias res, i.e. in the middle. The poem does not start in Troy but ten years after the beginning of Odysseus's

trip, focusing first on Telemachus's attempts to stave off the suitors who plot to assassinate him. Odysseus first appears in the fifth rhapsody (book) in the middle of his trip to the island of Calypso, a beautiful nymph who wants to make Odysseus immortal and keep him with her (Nagy, 2019). Odysseus has spent seven years with Calypso, but at this point, the Gods have decided to free him. Reluctantly, Calypso sends Odysseus on his way on a small raft, which the god Poseidon shipwrecks on Phaeacia, a place of hospitable people who welcome Odysseus and encourage him to tell his adventures. His narrative contains the most intriguing part of the epic. Among other fascinating episodes, Odysseus talks about his encounter with people who lack memory as a result of eating lotus fruits; the Cyclops, a race of uncivilised, brutal, one-eyed giants; the cannibalistic Laestrygonians, the beautiful and cruel sorceress Circe, the Sirens, and an attack by a six-headed monster named Scylla. Odysseus leaves Phaeacia and ultimately lands in Ithaca, where he proves his identity to his compatriots, then slaughters the suitors and is finally reunited with his family and throne.

Interpretations and Inspiration

The influence of this poem in art and literature has been immense: over time, people have created their own interpretations or stories that have references to the epic. A prominent example is James Joyce's Ulysses (Erll, 2019) (Latin for Odysseus), a novel about an anti-hero in Dublin written in stream of consciousness and widely accepted as a masterpiece of modern literature.

Ithaca by Konstantinos Cavafy

In the early 20th century, Greek poet Konstantinos Cavafy wrote a great poem called 'Ithaca'. The poem is inspired by Odysseus's literary trip but is a metaphor for the journey of life. A fine translation by Edmund Keeley and Philip Sherrard (Cavafy, 2019) follows.

As you set out for Ithaca

hope the voyage is a long one,

full of adventure, full of discovery.

Laestrygonians and Cyclops,

angry Poseidon — don't be afraid of them:

you'll never find things like that on your way

as long as you keep your thoughts

raised high, as long as a rare excitement

stirs your spirit and your body.

Laestrygonians and Cyclops,

wild Poseidon — you won't encounter them

unless you bring them along inside your soul,

unless your soul sets them up in front of you.

Hope the voyage is a long one.

May there be many a summer morning when,

with what pleasure, what joy,

you come into harbours seen for the first time;

may you stop at Phoenician trading stations

to buy fine things,

mother of pearl and coral, amber and ebony,

sensual perfume of every kind —

as many sensual perfumes as you can;

and may you visit many Egyptian cities

to gather stores of knowledge from their scholars.

Keep Ithaka always in your mind.

Arriving there is what you are destined for.

But do not hurry the journey at all.

Better if it lasts for years,

so you are old by the time you

reach the island,

wealthy with all you have gained on the way,

not expecting Ithaka to make you rich.

Ithaka gave you the marvellous journey.

Without her you would not have set out.

She has nothing left to give you now.

And if you find her poor, Ithaca

won't have fooled you.

Wise as you will have become, so

full of experience,

you will have understood by then

what these Ithacas mean.

In wonderful language and with seductive metaphors, the poem talks about life as a personal journey through a world of discovery. This journey is not only physical through space; it takes place in our home and hometown, where our relationships with people and our roles in the family and society are formed and evolve with time. The poem suggests that this metaphorical journey is more important than the destination. Indeed, there will be little to know about the self without exploring the world. How else do we enrich our memories and experiences and improve our judgement if not by escaping the prison of what we have been taught in order to understand other lives, cultures and history? Cavafy writes that the wild dangers that Odysseus encountered, the 'Laestrygonians and Cyclops, the wild Poseidon — you won't encounter them unless you bring them along inside your soul unless your soul sets them up in front of you'. In a similar spirit about the journey of life, Montaigne (De Montaigne, 2019) wrote that 'Travelling through the world produces a marvellous clarity in our judgment. This great world is a mirror where we must see ourselves in order to know ourselves'. This journey does not happen only when we take a plane; it also happens in books, in the vast resources of the internet, in our minds and in our ordinary lives. Cavafy takes inspiration from the ancient epic to give us a great personal, but also political, poem in an age when ideas of nationalism, isolationism, and religious fundamentalism are on the rise.

Circe by Stefanos Zannis

In Greek mythology, Circe is a bad and dangerous woman, a goddess of magic, an enchantress and a sorceress (GM, 2019). When Odysseus visits her island of Aeaea, she transforms his crew into pigs and forces Odysseus to live with her. In Western literary tradition, Circe is mostly depicted as the archetype of the predatory female who is a big threat to men and masculinity. Stefanos Zannis, who has been painting a much quieter alternative, gives us a different and less neurotic view of Circe. In the painting, Stefanos

shows a charming view of the sorceress weaving a fine red fabric in her loom. There is something endearing and attractive in observing a person work with calm, devotion and fine skill on something that they love doing. The painting shows another side of Circe, which might better explain why Odysseus stayed and fathered two of her children. Perhaps the hero was not coerced by the sorceress; perhaps he was rather charmed by her character, her talent, her elegance, and her devotion to her artful work. Perhaps human relations are much more subtle than a desire for control. Stefanos takes an unheroic view of the Odyssey, one which brings it much closer to the journey of life that we all experience. His paintings are charming and emotional, mastering colour and shape with a fine impressionist touch. In his painting of Circe, he employs a wonderful palette of complementary colours, and his atmosphere is stunning and reminiscent of the Lace Maker by Caspar Netscher (Netscher, 2019).

Circe by Alexandros Vanargiotis

Alexandros Vanargiotis is a contemporary Greek poet who produces verses of unique sensitivity and beauty. His poetry is often inspired by themes of classical Greece and is reminiscent of Cavafy: poems unfold softly with simplicity and harmony in expression but move towards a meaning/concept that has motivated them and which they sharply embody and convey. Alexandros is a gentle poet of the everyday and ordinary; above is an example of how he writes about the inevitable disappointments and disillusionments of life (Figure 36).

Such poetic thoughts could belong to a modern Odysseus. The poem suggests that, in our youth, the world seems full of prospects and hope and susceptible to positive change in which our potential agency is overestimated. As we grow up, disappointments pile up, hopes are dashed, and it dawns on us that humanity is fundamentally flawed. Some people like Alexandros learn to sublimate this feeling of disappointment into an

appreciation of the joy of small things: pebbles, flowers, trees, and dim stars in the skies. Instead of blaming others for their failures, they look into themselves, into these unexamined internal spaces, for an insight into the human psyche and the condition of humanity as a whole.

As a young man I tackled
the big issues trying to
interpret the world.

Now, naked and empty,

in order to understand the
sea

I look at water paddles.

For the rocks,

I stroke pebbles.

For meadows,

I converse with flowers.

For the forest,

I listen through the night

to the sound of the lonely
trees in a

fertile field

Before dawn,

I hear the forgotten stars on
the

horizon speaking of heaven.

And for people ...

Ah, for people,

it is a long time now that I
wander,

In my own wilderness.

Like Stefanos with his paintings, Alexandros has written poems with an alternative take on themes from the Odyssey. A translation of 'I met Circe once' follows. There is no sorceress in Alexandros's poem but a tormented soul that, if someone could see, they would love:

Like others, I met her too.

She had the reputation of a witch.

If you approached her,

you would lose your mind.

She was naked and beautiful,

her eyes were enormous,

two shiny mirrors.

When you woke up next to her,

they would reflect your face.

Don't ask me; I won't say

whether I saw a pig in them or a

rabbit.

I'm still shaking, though.

I heard she married

someone who, they say,

drunk the potion of Love

before meeting her.

And instead of being reflected in

her eyes,

he saw behind them

a soul, tormented.

The Corpus of Stefanos Zannis on the Odyssey

Stefanos Zannis started working on the Odyssey in 1992 as a student of the School of Fine Arts at the University of Athens. In 2007, he conceived of a grand visualisation of the 24 rhapsodies of the Odyssey in an equal number of large bound books, where each book would include paintings, drawings and original text in calligraphy. Since then, this project has become a constantly evolving work in progress. Stefanos has been focusing on subtle 'unheroic' episodes and verses of the original poem that many would find secondary or obscure. One such episode depicts Goddess Athena appearing in a dream of the Phaeacian princess Nausica (1998) (Maicar, 2019). People familiar with the Dutch Grandmaster Johannes Vermeer may find this painting reminiscent of the Letter

Reader (1663) (Vermeer, 2019). There are conceptual similarities in the scene, the treatment of light and the overall dignified and serene ambience. Stefanos's painting is less representational and more impressionistic in style. However, it is also charming and emotional, providing a unique and original interpretation of the relevant Homeric verses in the spirit of Vermeer. The latter was not only a master of light and atmosphere but also made a radical departure from religious, military, and mythological themes and started painting ordinary life, showing beauty and elegance in it (Chapman, 2000).

His famous paintings depict a maid pouring a glass of milk, a young woman thoughtfully reading a letter under the light of a window and a mysterious and anonymous girl with a pearl earring. Like Vermeer, who gave value, prestige, and dignity to ordinary life, Stefanos shows the beauty of ordinary and often bypassed moments within the great epic. In another episode of his journey, Odysseus travelled through the Ocean River to the land of the Cimmerians, where, according to Homer, people are covered by clouds and fog, the sun never casts her rays on them, never travels towards the starry skies and never returns to earth; this is a land where the unfortunate mortals live perpetually under gloomy grey skies. Stefanos imagined a strange and wonderful Cimmerian land in a painting entitled 'There is Always a Passageway through the Land of Fog'. The Cimmerian land is shown in a stunning composition of a dreamy, fantasy landscape emerging from the surfaces of a room, perhaps the bedroom of an imaginative child. This work is reminiscent of landscapes by Turner in its atmosphere, with vague forms of people, trees and buildings gently emerging out of a hazy background. The painting includes masterfully crafted elements of surrealism in the wonderful use of colour in texturing and creating the complex elevation of the landscape, the fine perspective of this strange room and land, the weird and elegant figures and details, the window with its light grey clouds, the beautiful diffusion of light, the slice of watermelon that looks like a boat, and the toy plane hovering above the landscape. This is a wonderful composition and would deserve a place next to one of the

Turners in the British National Gallery or between a Manet and a Dali in a museum of modern art.

Another painting of Stefanos depicts a key dramatic moment in the Odyssey just before a major disaster unfolds. At a certain point in the trip, the god of winds, Aeolos, gives Odysseus a bag that safely contains storm winds, leaving only a gentle west wind to take him home to Ithaca. Odysseus doesn't tell his crew and steers the ship by himself for days. In the crucial moment, though, he falls asleep, and his men who see Ithaca on the horizon decide to open the sack. They expect to find a hidden treasure, but as they open the bag, the storm winds rage out and blow the ship away, undoing all their efforts. Stefanos paints this in a gentle but dramatic manner the moment before the bag is opened. Dark and ominous clouds gather from the four points of the horizon and cover the Mediterranean sky, leaving only a small patch of turquoise blue from which rays of the sun enter the picture. They illuminate the clouds from above and create gentle light effects on the land and seascape below. A few of the clouds are similar in colour and texture to the rocky island below, looking like 'rocks of the sky' and cast their dark shadows on Ithaca. The marble temples and civic buildings of Odysseus's hometown appear graciously on a hill by the port, vague but glimmering with silver light from above. The sea is just about to become stormy, and one can almost feel the energy gathering in the waters. In Greek, 'opening the sack of Aeolus' means 'opening a can of worms', and the episode speaks volumes about humanity. Like Odysseus's crew, humanity sets big collective goals, which we manage to undermine because of greed or lack of trust in each other. We also suffer from inadequate communication. Odysseus did not communicate well, so his crew were unaware of the risks. We could imagine how many troubles could be avoided if people just communicated their knowledge, feelings, and thoughts better instead of waiting to be mind-read. It would be impossible to discuss all of Stefanos's work on the Odyssey here as it includes over 100 paintings and drawings, and it goes beyond this medium.

Telemachus now knew
about Helen,

for the sake of whom his
dad,

Odysseus, went to war.

They had harsh words for
her

in his town.

But Telemachus had
finished

high school now;

he had grown up.

He spent time on the beach

sculpting Helen in the sand;

creating and destroying her

feminine form,

creating and destroying her
again.

She was an elusive form this

Helen, so hard-to-reach.

What a beautiful and original thought on a story that has been told thousands of times! The sculpture was done one summer, and the waves took it like time takes everything else. It is not often that someone so talented, passionate and persistent reinterprets so beautifully and originally one of the classics of Greek literature. Stefanos's work became the main inspiration for this alternative virtual Odyssey.

7.3. Software Design: ODYSSEY

The goal of the project was to realise a virtual environment where the creative presentation and synthesis of various alternative artistic and literary projects, in this case, those inspired by the Odyssey, could be achieved. To facilitate this, we have created a virtual art gallery that currently hosts works that combine the paintings of Zannis and the poems of Cavafy and Vanargiotis. This gallery is an interesting space that offers

artistic possibilities and sensibilities for the presentation and exploration of these works. It is configured as an open and potentially infinite seascape that is dotted with 'islands' of three-dimensional sculptures inspired by these artworks. This virtual gallery is an audio-visual implementation of a symbolic haiku (Minami, McCabe, 1991) in Greek.

Έτσι είναι, Οδυσσέα,	*(So it is, Odysseus,*
ήταν πάντα εσύ και η	*it was always you and*
Πηνελόπη,	*Penelope,*
μόνο.	*solely)*

The haiku is dedicated to Odysseus and Penelope and others like them with disconnected lives: people who have memories together and apart, experiences of arguments and play, hesitations and decisions, virtues and failings, hopes and disillusionments. Such lives, even when they are lived in parallel and in isolation, can be deeply connected and subconsciously projected onto each other. The virtual navigation of the gallery resembles a poetic, spiritual trip where the visitor can experience the feelings left by the sea in the soul of someone who discovers that, through a journey, they can achieve a richer understanding of life.

The audio-visual sculptures were designed with the resources provided by TIMAEUS, the virtual art studio that has been inspired by Plato's homonymous work, especially the Platonic geometrical cosmogony. The sculptures contain audio, films, pictures, and texts that can be continuously displayed and played. They can be hollow and translucent, illuminated, or navigated either externally or internally by visitors. In ODYSSEY (Figure 37), the sculptures are populated with displays of paintings by Stefanos and readings of poems by the two Greek poets.

Figure 37 - Odyssey

The software that implements Timaeus and renders the gallery draws heavily from tools provided by the Unreal game engine, over which a layer of software has been added to enable custom use by artists who wish to make creative digital compositions of their works. In this case, we also incorporate a path-finding algorithm that can forge a path through the virtual seascape of Odyssey. The algorithm exploits weights assigned to sculptures, which form a graph upon which the symbolic distance between Odysseus and Penelope can be continually established and minimised.

In ODYSSEY, we can experience music, declamations of poems and ancient sculptures 'dressed' with paintings in a metaphorical journey between Odysseus and Penelope that can be described as a gamified artistic collage. They result from collaboration with artists, rendering the artistic paintings of Stefanos Zannis along with declamations by Angelina Vakali and poems by Alexandros Vanargiotis.

7.4. As an educational gallery

Gamification of experiencing art

Stoicism has lasted millennia and still carries valuable lessons for humanity. There are contemporary communities of practising stoics. Hence, there is no reason to believe that stoicism will cease to exist and develop in the future. To facilitate this, this chapter proposes an infinite virtual Stoa that will enable hosting an expandable online repository of resources about stoicism. The internet is already potentially infinite, but we can aim to create a more interesting virtual space that offers artistic possibilities and sensibilities for the presentation and exploration of stoic ideas. Thus, we will configure our gallery as a virtual collonaded Stoa that is reminiscent of the original Stoa Poikile. A Stoa that has no boundaries being allowed to grow *ad aeternum*.

The STOA gamification experiment takes the shape of an educational experience and, at the same time, enables a virtual space for the exhibition of contents created in TIMAEUS. The theme for the experience is stoicism and patterns (Figure 38).

Patterns and the mind

There are two noticeable connections between the realm of patterns and the human mind. The first is that the mind has the tendency to be attuned and attracted to regularity, as in symmetric patterns, in which it finds beauty (Summerfeldt et al., 2015) (Cardenas, Harris, 2006). The second is that patterns have an influence on processes and flows within the human mind. For instance, temporal patterns have the power to induce an 'inner clock' that influences the perception of music (Povel et al., 1985).

Figure 38 - Stoa

One recognises and remembers different birds by the melodies they sing. Studies in psychology have also investigated intrinsic and extrinsic structures of stimuli and their relationship with discrimination, classification, judgement of similarity (Garner, 2014) and, particularly in music, in long-term memorisation of melodies (Dowling, 1981). Additionally, the repetition of static images and sculptures is also interpreted as 'visual rhythm, or an impression of coherence and movement' (Levitin et al., 2018). The 'same measure' of patterns is also mentioned in some mental pathologies, as is the case of the obsession with symmetry in obsessive-compulsive disorders (Summerfeldt et al., 2015).

Stoic patterns

Stoicism is an ancient philosophy that encompasses logic, physics, and ethics in a comprehensive philosophical system from which much can still be learned about tranquillity, resilience, mental balance, tolerance, and openness in society. Stoic philosophers used the analogy of a 'garden' to describe their system (Morford, 1987). In

this analogy, philosophy is seen as a garden that is fenced by logic, protecting it from erroneous reasoning often motivated by imperfections in human nature. Within the garden, physics is the soil where we cultivate our understanding of the world, including that of our human nature. The fertile soil of physics, in turn, yields the fruits of philosophy, which for stoicism is the 'ethics', or living a 'good life' characterised by serenity and justice that can be experienced individually and collectively.

Stoics have made contributions in many areas of intellectual enquiry. Chrysippus, for example, is known to have founded propositional logic, an early form of the formal reasoning system employed in contemporary analytical philosophy and computer science (Bobzien, 2020). However, one of their most significant and lasting contributions is in psychology. Stoicism is indeed the first systematic attempt to understand patterns of fallacious reasoning that cause disturbances in human psychology and behaviour, and Stoics proposed remedies that still inspire modern cognitive therapy (Robertson, 2010). To populate our STOA experience with philosophical content, we can focus on three areas of human behaviour where Stoics identified dysfunctionalities caused by fallacious thinking and where they proposed interesting remedies: anxiety, agitation, and tribalism.

Anxiety

Many of us tend to live in constant anxious anticipation of stressful events, e.g. fearing loss of status, wealth, health, or reputation. According to the Stoics, such anxieties are largely caused by mental confusion and the inability to consider a basic dichotomy between those things that we can control and those that we cannot. Status, wealth, and health are largely defined by external events which can be random and outside one's control. Realising this can lead to a fundamental shift in how one then responds to unfortunate events. It is not the event itself that matters - argue the stoics - but our responses to it, and these can be adjusted. Once one understands, for example, that job promotion is not entirely in one's control but depends on the circumstances and

personalities of others, then failure to obtain the promotion becomes less personal and hurtful, and therefore, one can be less anxious about the outcome and rather focus on the effort. Stoics instead propose that life should prioritise the pursuit of four cardinal virtues: wisdom, courage, justice, and temperance, and all these are entirely in our control. A good life is defined as acting with wisdom, being courageous and doing the right thing, treating others justly and responding to events with moderation. Status, wealth, health, and reputation, on the other hand, are simply defined as 'preferred indifferents', i.e. things that may be nice to have but one should easily part with (Durand et al., 2023).

Stoics developed some excellent advice around this theme. Epictetus, one of the eminent stoics, for example, advised us to think of our loved ones not as possessions but as borrowed from the universe (Matyszak, 2012). When the time comes to return them, we should not be devastated but be grateful for the time we had with them as we would be grateful when we have returned a good book lent by a friend.

Agitation and anger

Stoicism attributes agitation and anger to overt optimism and unrealistic expectations. In his Enchiridion, Epictetus gives a lucid illustration of this using the example of a citizen visiting the Roman baths for cleansing, relaxation, and recuperation.

If you are going to bathe, picture to yourself the things which usually happen in the bath: some people splash the water, some push, some use abusive language, and others steal. Thus, you will more safely go about this action if you say to yourself, 'I will now go bathe and keep my own mind in a state conformable to nature. For thus, if any hindrance arises in bathing, you will have it ready to say, 'It was not only to bathe that I desired, but to keep my mind in a state conformable to nature, and I will not keep it if I am bothered at things that happen' (Epictetus, 2018). For the stoics, 'nature' in the above effectively means 'reason' (logos) because nature is both logical in its regularities and has gifted humanity with the capacity to reason. Epictetus makes a very apt point: overt

optimism disappoints and agitates. Indeed, many of us regularly get upset about traffic jams and aggressive drivers as if we lived in a world where these things were extinct. We use computers for online banking but hope never to suffer malware, and when we do, we get angry. However, the Stoics had a very clear view of anger as a temporary suspension of mental faculties. In his famous essay, Seneca described anger as temporary madness (Harvey, 2013). The stoic message is that unrealistic expectations lead to disappointment, agitation, and anger. Thus, it is preferable to be realistic, and when we encounter potential triggers of anger, we create mental space between external events and our responses to allow reasoning and calm reflection to take place.

Tribalism

Tribalism assumes that a strong cultural or ethnic identity, often based on proximity or kindship, separates one member of a group from the members of another group. Various forms of tribalism, including nationalism, have historically exploited false and simplistic conceptions of history which glorify the tribe or the nation and exclude other groups. The stoics developed an antithesis to tribalism based on a cosmopolitan view of human nature and society. According to the cosmopolitan view, we are social animals who participate not in one but many groups, which are increasingly larger. In each of those groups, we may assume different roles which, if performed well, lead to collective benefit. The word cosmopolitan derives from the Greek κοσμοπολίτης, meaning being 'citizen of the world'. Hierocles, an eminent Stoic, developed a brilliant illustration of the concept by placing the individual in the centre of a series of expanding circles of concern: the smallest circle is the individual itself, next comes the close family, the extended family, the city, the neighbouring cities, the country, and finally the larger circle is humanity. Our task - stated Hierocles - is to compress those circles so as to bring humanity closer to the core of our concerns (Goldin. 2011). Cosmopolitanism thus becomes the idea that all humans belong to one community based on our shared nature and capacity for logic and morality.

7.5. Software Design: STOA

Stoicism is a philosophy that considers the object of life to be ataraxia (αταραξία), a state of psychological stability which is undisturbed by exposure to phenomena and circumstances that lie outside one's control. Such circumstances may include ill-health, poverty, natural disasters, corrupt social orders, and unrequited love, and may cause loss of composure and mental balance through feelings of pain, humiliation, insufficiency, envy or greed. Stoicism is a coherent system of powerful ideas about how to pursue a life of equanimity in the face of adversity, which has nurtured philosophy and psychology to this day. The founders of Cognitive Behavioural Therapy have cited stoicism as their main inspiration (Robertson, 2010). Stoicism flourished in ancient Athens and Rome at a time when ancient democracy was dying, and people experienced a loss of control over their lives under authoritarian and imperial regimes. In an age of serious global economic, environmental, and psychological uncertainty and crisis, stoicism still has pressing and valuable lessons to teach us about calm, composure, resilience and emotional stability.

Stoicism owes its name to Stoa Poikile ('painted porch' in Greek), a collonaded building in the Athenian agora where Zeno of Citium founded his school in the 4th century BCE. In this project, we develop an 'Infinite Virtual Stoa' to host an expandable online repository of resources about stoicism. The repository exists in the space defined by the Stoa, which is a collonaded building that takes the form of the ancient and sacred to many cultures, a geometrical motif known as 'the flower of life'. The building is composed of multiple and evenly spaced, overlapping circles arranged in a flower-like pattern with six-fold symmetry that is potentially expandable to infinity. The Stoa is immersed in water, with pools regularly forming in the space between the collonaded walks that delineate the space and becomes an art gallery-library for the exhibition of online stoic resources: quotes, stories, books, paintings and videos. Stoicism explored

patterns of psychological fallacy on the one hand and patterns of thought and behaviour for the pursuit of ataraxia on the other. The Stoa is built on a geometrical pattern that is expandable to infinity. Thus, the concept of pattern is central to this work. We can approach patterns as they occur in mathematics, science, the arts and the mind. Additionally, we can discuss patterns within stoicism and include them in the design of the infinite Stoa.

Téchnē and 'Arthematics'

We can start by reiterating the vision where mathematics, geometry, and computer science may be embraced in the sense of the unified arts and technology suggested by the ancient meaning of the Greek word téchnē (τέχνη). Stefanie Mandelbaum interestingly coins' Arthematics' as a crossing field between the arts and mathematics (Mandelbaum, Guttman, 2018). This also goes in line with another neologism we have observed, that of 'artification' (Heinich, Shapiro, 2015), which gives name and meaning to the fusion of the artistic and the - apparently - non-artistic, that then sublimates to a new form of art. As we've seen before, in this context, we are specifically interested in the dynamics between artification of games and gamification of arts.

Mathematics, patterns and the arts

The appearance of perspective in Renaissance painting is intimately related to the influence of 'the science of sight' (Field, 1997) and the mathematical notion of infinity. It is an example of mathematical thinking that proved to be instrumental in the making of artistic masterpieces. This advance in the arts was driven by the Renaissance artists' brave geometrical thinking, including the contemplation of insightful but counterintuitive ideas, such as equating the existence of parallel lines that do end up meeting (Sibley, 2015). Deeper in history, humanity has left us with an ancient panoply of beautiful patterns still exposed in old walls, windows, floors and ceilings, or visible in other kinds of artefacts - such as ceramics - of antique cultures like the Assyrian,

Greek, Roman, Byzantine, Iranian and Arabic (Willson, 2012). This heritage has inspired artists through time. Technically, the motifs and regularities can be classified by periods and styles or even in more systematic ways, and they, too, have an intimate connection with mathematical knowledge. These ancient arrangements are still present in contemporary works of the decorative arts of ornament and in prints. Yet their influence is not limited to those fields of creativity. Escher, for instance, has used them - and has also developed his own ideas over them - in his engravings and drawings, introducing the visual senses to new heights of thinking geometrically.

Perhaps the harmonies of symmetry, isometry and geometry are desirable and explain that the order present in the universe is also present in cultural artefacts such as Art, Music, and Architecture (Swoboda, Vighi, 2016). Such thoughts led Ackerman to state that 'the modern argument of form versus structure is as meaningless as the medieval argument of ars versus scientia, for it likewise disrupts a partnership which can function only in happy union' (Ackerman, 1949).

In music, as in the visual arts, geometry and 'téchnē' also coexist. In musical composition, geometric transformations and symmetry are known to have played a role in the works of Bach and Bela Bartok (Fauvel, Flood, Wilson, 2006). There are also known composition symmetries, such as the 'Friezes patterns' (Fauvel, Flood, Wilson, 2006) and tonal and rhythmic patterns, such as dissonance, two-voice vs coloration, and ostinato patterns (Berry, 1987). These are resourceful tools for the composer because patterns in music can also be derived from one into another by variation (Volk et al., 2012).

Historic technologies in the service to the Arts

The history of the synthesis of mathematics and the arts is also exemplified by several engineering artefacts, such as the tools that have helped artists achieve extraordinary paintings and sculptures. From the chisel to calligraphy pens, the compasses and the

proportional dividers to more complex tools for achieving a correct perspective in painting, such as the perspective machine depicted in Leonardo's 'Draftsman Drawing an Armillary Sphere' (PB, 2018) or the pantograph, a linkage device invented in 1630 by Christoph Scheiner that makes it possible to draw a scaled copy of a smaller depiction (Weisstein, 2018). The automation that presently is the focus of interest of the autonomous arts is also rooted in history, from the legendary Antikythera mechanism to the pervasive echoes of the music of the automatic carillons of Mafra (Carvalho, 2018) and the writing, drawing and musical automata of Jaquet-Droz (MAHN, 2018).

Patterns and Computer Science

Patterns are also prevalent in computer science, and that indeed is the case in the fields of pattern recognition and machine learning (Bishop, 2006). Pattern recognition searches for regularities in data and deals with their automatic classification (Bishop, 2006). In computer science, a pattern is an abstraction of an object that can be understood as a class described by certain attributes, and that can be searched for in the data (Murty et al., 2011). Patterns can usually be recognized statistically or syntactically (Murty et al., 2011). It is, for instance, possible to run pattern matching algorithms in a musical piece to study its 'motifs and their variants' (Volk et al., 2012). Efforts are also directed towards understanding pattern formation and to 'describe universal classes of pattern' in a 'precise formalism which serves as the conceptual basis for synthesizing and analysing patterns' (Grenander, 1976).

The geometry of the circle

Computationally, an infinite virtual Stoa can be built procedurally. This requires some form of structural arrangement that can be repeated in Stoa's architecture. We can create a linear Stoa, but we can also choose a more interesting motif of seven overlapping circles known as the flower of life (Figure 39).

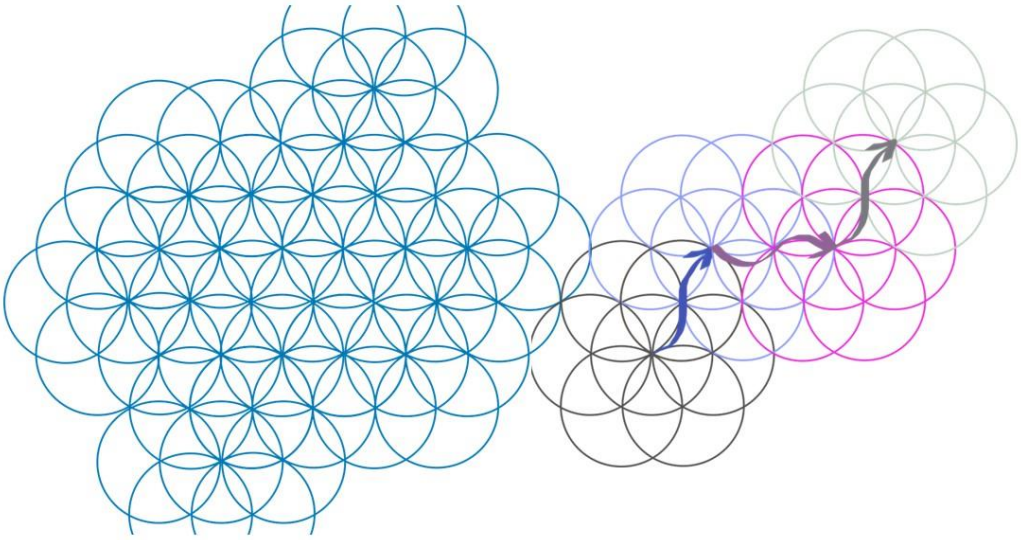

Figure 39 - Pattern of circles

This arrangement has the particularity that by the connection of all points, another pattern can be found, one that combines the projections of all platonic solids, known as the 'Metatron Cube', which is a figure that shows 'perfect proportions and relations between its geometric components' (Esquivel, Navas, 2005). This hidden pattern has also been known since antiquity, and archaeologists have found it in the architecture of a defensive structure of the Copper Age in the Iberian Peninsula (Esquivel, Navas, 2005).

Pantographs and Splines

The prominent technical device necessary for building the pattern is the spline, a computational resource with roots in the ancient art of making tools (Garcia, 2008), namely the pantographs that were conceived and used for drawing elliptical arches in the 17th century (NMAH, 2018).

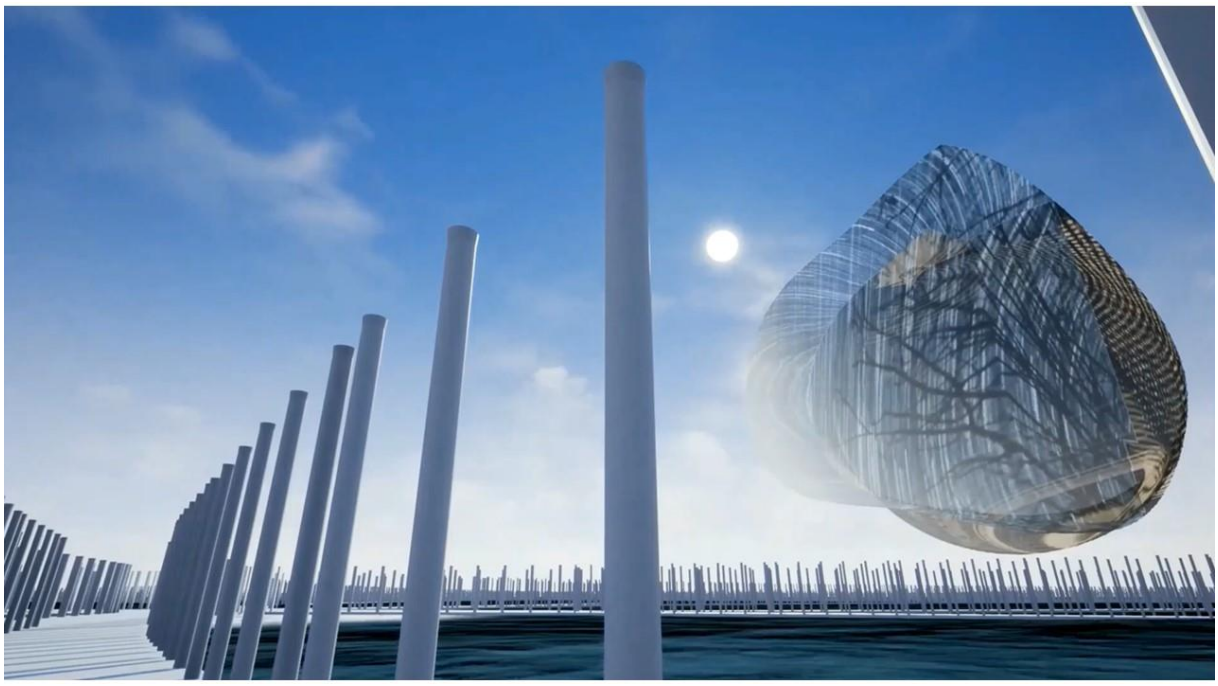

Figure 40 - Stoa

In the 1950s, automotive design required novel ways to represent volumes and shapes, which led to the invention of computational splines (Farin, 2014). The invention of splines moved from the elliptic pantograph to defining curves algorithmically, an innovation that also moved on from defining the arch inside a sectioned 2D rectangle to a 3D parallelepiped (Farin, 2014).

Presently, splines are present in all kinds of drawing and modelling software and digital game engines, along with multitudinous other technical advances in the service to the arts, which mostly have their roots in historical engineering. Among contemporary applications, splines can, for instance, be used to extract the geometrical features of digitally reconstructed parametric model representations of objects (Li et al., 2008). The Stoa's modelled section is reproduced along a spline. By resourcing to splines, it is possible to section them equally and populate their parts with three-dimensional models.

Figure 41 - Stoa, aerial view

In the Stoa, the spline sections are associated with a reduced 3D model of a small motif of a segment of a Stoa that can be repeated, and then sections are harmoniously collated (Figure 41).

Every spline instantiates a circle of the flowered pattern, and infinity is achieved by making the rendering of the Stoa dependent on the player's navigational directions. The circles also have anchor points that can work as the origins for further splines/circles. So, by being generated on the fly, in conformity with the navigation of the viewer, the Stoa becomes virtually infinite in any browsing direction.

The result is that moving towards the horizon creates new space. This is a characteristic of what is known in game development as 'procedural world generation'. By navigating, the world is created instantly, and it is also possible to recreate previous paths towards where the audio-visual sculptures have been situated.

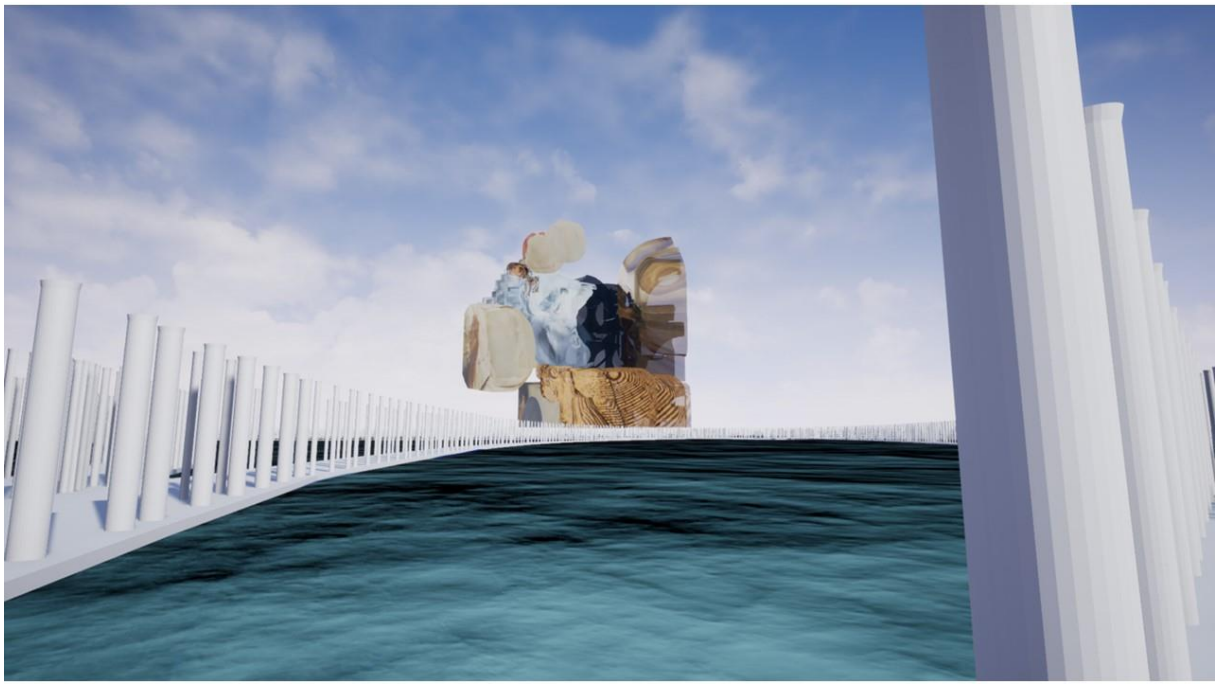

Figure 42 - Stoa

Proceduralism, and digital games

Proceduralism in the realm of digital games allows the automatic creation of infinite and randomised worlds. These can be populated with procedural models and game objects, geometries, textures, levels, and AI behaviours, and with impact on the dynamics of narratives, story, and in music generation where, for instance, musical piece sections are repeated according to dynamic patterns (Watkins, 2016). Dynamic music can be parametrised by variations of tonality, rhythm, harmony, 'andamento', pitch, and themes and can have an impact both in immersion and inclusively play with the narrative and player interaction, as in the use of the 'leitmotiv' in dynamic game music (Mello, 2018).

A procedural art gallery for viewing artworks

Navigating the Stoa resembles walking on an infinite, unbounded labyrinth. Along the continuous paths, the player can find audio-visual sculptures (Figure 42) that can be

designed with the resources provided by TIMAEUS, sculptures that contain audio, films, pictures and texts that are continuously being displayed and that can be visited from inside by the wanderer.

8. Conclusions

This corpus of research was started by the initiatives at the University of Hull to investigate how computer art – namely generative art – could play a role in therapy for patients with long-term conditions.

This main thread of thought has remained an inspiration, and the work of this research was established in finding the connecting lines between digital games - with their extraordinary technical capacities – and the arts.

The hypothesis proposed that new ways of expression, exposition of art, and art forms could originate from working with digital game engines in the process of technological gamification of the arts and tandem with the contemporary phenomenon of the artification of games.

This resulted in software development questions that led to the development of an artmaking studio – TIMAEUS – and experiences of digital curation with Odyssey and Stoa. This work was done in collaboration with established artists, such as Roberto Bono and Stefanos Zannis, who contributed with their artistic inputs that were transformed through the proposed digital experiences.

This, in turn, led to pursuing an evaluation of the qualitative and ethnographic results, as the artists did not think a questionnaire was the appropriate form and preferred an open-form letter.

8.1. On assessing the hypothesis

The work on a multimodal runtime content plugin required viewing the problem domain from a software architecture point of view. This has resulted in a structured

solution/model for a general game-engine architecture extension that enabled the posterior work.

TIMAEUS

The work of TIMAEUS approached the software development question of how game engines could enable new forms of art creation. This work involved digital game engineering disciplines, such as computer graphics and interaction design, to create a studio based on the Unreal Engine that enabled the creation of multidimensional and multimodal works of art that would later be used in artistic curation experiences of Odyssey and Stoa.

STOA

The world is full of recurring patterns that repeat themselves in entirely different areas. The branching of the trees is similar to that of veins, the delta of rivers, the wrinkles of a palm and cracks in dry soil. In this work, we discussed the concept of the pattern as it occurs in Mathematics, Science, the Arts, the mind, and the philosophy of Stoicism. *Stoicism* is a philosophy that explores patterns of psychological fallacy on the one hand and patterns of thought and behaviour for the pursuit of ataraxia on the other.

Building on the themes of patterns and Stoicism, we designed an infinite virtual Stoa using a classical geometrical pattern that is expandable to infinity. The Stoa could be used to host and present artistically an infinite number of past and future resources about Stoicism. It can host areas of study devoted to great philosophers, like Epictetus, Seneca and Marcus Aurelius, or thematic areas where stoic ideas are explained with quotes, text, animations and videos. Specific ideas or themes can be presented creatively to the viewer as multimedia illuminated sculptures using TIMAEUS. The gallery is designed to be accessible online. Stoa can be seen as a serious game for education and learning or a development towards gamification of experiencing the arts.

ODYSSEY

In that same path of gamifying the experience of art, ODYSSEY drew inspiration in artistic collaboration with Zannis's monumental work on the Odyssey and poems by Cavafy and Vanargiotis, which have led to the creation of a virtual gallery where poetic journeys through compositions of these artworks can be experienced. The computing infrastructure we have developed to achieve this virtual Odyssey is reusable and allows a more general design of spaces. In the future, it could be used for creative exhibition of other works of literature and art in synthetic, multimedia, and immersive new forms.

Art and validation

These were the three pillars of this research, which were tested, exposed, evaluated, and well received by the artists - it comes from engagement with the artists to understand their needs and responses - and the specialised artistic community, namely in the Generative Art Conference. Our strategy to assess user acceptance testing has been based on the principle of the artist entity representing both the client and the therapist of a metaphoric art therapy session. Hence, we have looked for artistic acceptance in a twofold fashion: by presenting the work at specialised artistic conferences and by receiving feedback from artists within the collaborations.

8.2. Discussion

For the goal of making artful contributions, we needed to discuss, iterate and develop versions of the art that would surprise and delight the artists, giving them the feeling of new horizons opening.

Experience

We predicted that technological gamification can enable new ways of presenting and experiencing the arts, and that may also be transformative. For this, we looked into how

to provide and maximise the novel possibilities of experiencing the arts through technological gamification and game development.

Curiosity made us question if the source works would be recognised by the original authors or totally transformed, and the artists recognised their artistic work in the multimedia software results and nevertheless saw it presented in interesting novel ways (Appendix IV).

The Artist

We predicted that we could develop gamified prototypes that would render outputs that would be perceived as artistic whilst exploring multimodality and that such tools may empower the artist creatively. To the question of how to drive the game engine's multimodality in order to empower and augment the artist, we have created an art studio and curation experiences that explored the relations between three entities: the artist, the computer artist, and the autonomous artist. The collaborating artists confirmed that they perceived artistry and artistic merits in this approach to presenting their work (Appendix IV).

Practice and Education

We aimed at a technological gamification that could enable the emergence of new ways of making art and also render new ways of learning and teaching, which led us to drive the game engine's multimodality in order to enable new forms of creation. The collaborating artists saw in the software results new ways of making art and new ways to learn and to teach (Appendix IV).

Research

We aimed to develop gamified prototypes that open new spaces of artistic research and asked how to achieve this through game engineering. Some evidence that this multimedia software practice creates new spaces for artistic research is in its acceptance

in the work of the REF of 2021, where the work that underpins this thesis was included in VETA together with other applications for Radiotherapy and Emergency Services and achieved a score of 3.5 out of 4 across the two impact case studies' (Appendix IV).

Disciplinarity

Exploring the game engines' multimodality has resulted in new multidisciplinary art forms as the artists recognised more than one modality or art form in the results and that they worked well as a unity (Appendix IV).

Therapy, Philosophy and Ontology of Art

This research has been a step towards a technological gamification that may enable the creation of digital art therapy applications, starting to envision how to design a gamified tool for the practice of art therapy.
Some questions that may be addressed are what would be advantages and shortcomings of using this approach for art therapy, and also more general aesthetical and philosophical questions such as if the novel solutions may extend the domain of the arts, what are the Aesthetics of gamified art outputs and what are the philosophical implications of exploring multimodality as a path for new forms of art, creation and experience.

8.3. In conclusion

We have started this thesis work by studying the connections between the arts and technologies, rendering a historical viewpoint where artistic tools appeared as devices for enabling art creation, passing through their reinvention as computational tools, and reaching today a degree of autonomy that makes one question the role of the artist in the artmaking.

We have argued that game engines are a technology whose inclusion in this historical route may prove beneficial to the endeavours of research in computational creativity. They place themselves as devices that can be used for novel ways of creating and experiencing the arts and possibly extend the domains of the arts by generating novel forms or modalities.

We have centred the work on a metaphorical design challenge of art therapy for long-term conditions, which gave us the requirements for clients and practitioners of art therapy, which can be represented as a single entity of 'the artist'. In collaboration with artists, we have explored the domains of poetry, painting, sculpting and music.

Expanding the boundaries of expression surprising and aesthetically pleasing, conceptually interesting, and exploring multimodality, this research succeeded in a useful aesthetic effect, enhancing creativity in the creation and curation of art.

9. Future Work

9.1. Potential for Art Therapy

Timaeus is already at the stage where interesting further case studies could be put in place. We are considering including interaction possibilities such as natural input and language so that we can consider the possible therapeutic applicability of Timaeus. Importantly. Timaeus opens the possibility to provide augmentation in creation in a way that inabilities to draw, paint, and sculpt, or limitations such as the loss of dexterity, may be surpassed in an overall beneficial and expressive experience. This involves concepts such as cognitive amplification, augmentation or prosthesis. Augmenting in disability is a challenge transversal to assistive technologies for the elderly, considering that 'computers may have the potential to augment human cognitive processes in ways that could be beneficial' (Alm et al., 2004). Peterson reported that 'a computer's ability to capture and amplify even the smallest movement made art therapy treatment available to those with limited mobility' (Peterson, 2006) and Astell notes that an important goal when developing technologies for people with dementia should be in building on, maximising and extending retained abilities and mitigating the natural cognitive limitations (Astell, 2009).

In conclusion, the work in TIMAEUS demonstrated the gamification of creating art and paved the way for subsequent developments and very relevant for this study, Sauer mentions how important opportunities for creative expression are for those with dementia, who might have seen the erosion of other abilities of self-expression and mastery (Sauer, 2014).

Multimedia in art therapy

Conventional and digital media and multimedia are generally present in art and reminiscence therapy systems, and they appear as an essential element of this approach. As an example, Tony et al. report Hellen Bonny's Guided Imagery and Music method in the 1970s, aimed for self-development work where music may be selected, and images may be used for building a metaphorical dialogue with the therapist (Tony et al.,2002); or the inherent presence of media in the Antunes definition of reminiscence therapy for dementia, in 'the use of life events, photos, music and other supports' to remember the past and promote dialogue (Antunes, 2015). Several authors report on the benefits of the use of multimedia, e.g., helping to engage patients and improve communication. Elements such as texts, photos, videos, music and songs, possible to use in the work of day-care settings, can provide entertainment and recreational experiences; they can be used as a vehicle for reminiscence conversations (Alm et al., 2004). Alm et al. report that staff enjoy more pleasant caregiving experiences (Alm et al., 2004), and Peterson describes patients creating digital images and movies with the advantage of unnecessarily getting 'messy during their art therapy treatment' (Peterson, 2006). In addition, Carswell et al. report enhancements in well-being and brain stimulation (Carswell et al., 2009), and Blandford et al. explain that high satisfaction with the use of multimedia in reminiscence results in a 'strong tendency towards repeated use' (Mulvenna et al., 2010). Noticeably, it is also reported that there is a strong preference for personal, in contrast with generally themed materials (Mulvenna et al., 2010). Lazar et al. assert that 'access to rich and engaging multimedia reminiscence materials' helps the clients to 'participate in social interactions and take ownership of conversations, and that there is also a resulting reduction of barriers due to motor deficits' (Lazar et al., 2014). Antunes makes a comprehensive listing of several existing applications of multimedia in the context of dementia: like multimedia biographies, where the caregivers collect materials that are then continuously

displayed in a device at the client's home; or Portrait, purposed for nursing homes and day care centres; and computer-assisted reminiscence therapy, with personal photographs, and photographs taken from public places known to the patient and playlists of songs they can relate to, where the carers noticed that the clients had increased focused time, in comparison with non-digital media; or the use of YouTube in group therapy sessions, where caregivers can set playlists that will work as reminiscing triggers, and where the patient's enjoyment was visible; and Friendcrafting Memories, a web application with an interface resembling a bookshelf where the patients can choose to open themed books about people, places, and interests; or Friendsourcing and Remember-Me, that use the functionalities of social networks to collect reminiscence materials; and even the use of virtual reality, providing immersive experiences that transport the client to familiar places (Antunes, 2015).

Considering the differences between dynamic and static media, Blandford et al. state that ‘dynamic media, like video, can provide more context than static media, such as photos’ (Mulvenna et al., 2010). Media can also be linear or non-linear. Linear media, like a song or a movie, has a beginning and a point of completion. Non-linear media incorporates continuity within the possibly endless complexity and can also be beneficial in art therapy.

The specification of TIMAEUS art studio brings back the metaphor of the art therapy session. Clients' and therapists' domains interact differently with the software domain. However, there is the commonality that both represent the artist's domain.

Play and art therapy

Whilst discussing contemporary art, Sweeney emphasised the pivotal meaning of play in deriving pleasure from art, making a mention to Plato, who considered that pleasure 'does no good or ill' itself but it is important and conditioned to do good by other factors such as virtue and practical wisdom (Sweeney, 1959). This sense of play is also present

in Hayes's look into the role of the creative arts in dementia care. Hayes reminds us that 'when we play, we do not question the validity of what we do or make', hence resulting in a joyful experience for patients and the staff (Hayes, 2011). This, in turn, can have a therapeutic effect, especially if contextualised properly. Play is important in this kind of therapy that is person-centred in quality experiences (Hayes, 2011). Killic focuses on the delicate nuances that might exist between play and game by noting that the obtrusiveness of rules of the latter might invalidate the first (Killic, 2013), which seems a wise and important consideration in the design of serious games.

Creation of artefacts, moments, memory sculptures

Timaeus as an art studio is envisioned to be a digital gamification platform for art therapy, providing an interactive audio-visual experience for generatively augmented expression and creativity that can be used for reminiscence and life review with dementia patients, care staff, and artists. The Platonic inspiration provides an opportunity for bringing a philosophical dimension to the project with links to geometry. TIMAEUS should provide, with simple interactions designed to address problematics such as loss of sight and dexterity, an imaginative environment for the generatively augmented expression of ideas, memories, and thoughts through the creation of sculptures collated with sounds, images, videos and other media, and illuminated. Despite its unique technological advances in the links drawn with art and therapy, the underlying action of creating reminiscing artefacts is an established therapeutic methodology, including in digital form, in reminiscence therapy for dementia, and is well documented in Thiry's doctoral thesis (Thiry, 2013). This is a work that was focused on a specific type of reminiscing, described as ‘a process that may involve many 'turns' and that produces a personal legacy artefact’. Thiry observes that artefacts may be scrapbooks, memoirs, oral histories, photographs, newspapers, and letters (Thiry, 2013). In a functional view, artefacts may be created to remember or to

share and be remembered or just 'because it is pleasurable in and of itself' (Thiry, 2013). To remember travelling, for instance, in that moment or in the future, or to share with a grandson a personal journey, stories and knowledge the patient feels should be preserved for younger generations (Thiry, 2013). In terms of therapy practice, Thiry reports that 'artefacts have emerged as an important aspect of reminiscences with older adults' and that despite 'HCI researchers have explored a variety of different approaches to the creation and use of personal legacy artefacts', 'very little attention has been directed to how personal legacy artefacts might be created and authored' (Thiry, 2013). In terms of patients' requirements regarding technological approaches to the creation of personal legacy artefacts, Thiry mentions the desires expressed by the users of the greatest simplicity possible in the software and also a preoccupation with the possibility that the technologies might later become obsolete and their legacy lost (Thiry, 2013). This information is very valuable for this research because it strengthens a justification for possibly including 3D printing of the memory sculptures in the workflow.

Besides looking into Thiry's work concerning digital reminiscence and artefact creation, Timaeus's research task also investigates the artfulness of such artefacts and the creative experience and joy that are more related to art therapy. Here, another strong inspiration and reference is the work of ArtCare in bringing workshops of non-computerised reminiscence 'using poetry, art, music and handling objects' into the interior of hospitals to 'inspire staff, patients and visitors' (ArtCare, 2010). This research considers precisely doing this but in a technological and possibly ubiquitous way. In the same line with 'cognitive dynamics' work of combining reminiscence activities and art therapy 'to validate Alzheimer's patients in their current state, helping to honour their life stories, restore and preserve their sense of self', improving the patients' communication and expression, concentration, attention and ease of care (Potts, 2014). The above is the current stage of experiments with the creation of software that enables innovative ways of producing art, namely handmade therapeutic generative art,

through a system in the form of a touch-based game that facilitates the augmented expression through the creation of transparent 3D sculptures, drawing, texturisation, illumination and semantics and may help to reflect the patient's thoughts and facilitate reminiscence and life review exercises. In TIMAEUS, the client can create moment/memory sculptures, can paint, create a multimedia collage (picture, audio, video, illumination) and control variables for autonomous art exploration.

Art therapy: Seeing the hypothesis through a metaphor of stakeholders

To find a common denominator of the needs of the art therapy client, this study could merge the general requirements that would be expected if the client was a dementia patient and also if the client was a child, idealising so the two ends of a spectrum of requirements in which all other possible clients could be included. With this spectrum in mind, the design of any application will have to be open to limitations in dexterity and computer literacy, for instance, and deliver smart approaches to engagement.

The artist/art therapist

Another challenge is to think about the artist's needs when operating a piece of software for a satisfying creative expression.

Non-functional Requirements

Accessibility

One of the primordial requirements for the universal client is accessibility, as any barriers to the use of the applications may result from inadequate UXUI design or functionality that makes it hard to operate.

Performance

Since the developments will be strongly based on providing real-time audio-visual experiences, the issues of performance must be addressed.

Reliability

Another possible barrier to engagement could be that of the implementations behaving unexpectedly and undesirably.

Scalability

The implementation's operability should be independent of the size of the client domain. It should function consistently from one to many.

Functional Requirements

Create art

The client/therapist/artist should be able to express herself through the applications.

Total/synthetic art

Such expression should be possible by resourcing to the multimodality provided by the game engine, resulting in a panoply of art forms to work with, separately or combined.

Experience art

It should be possible to experience the created artefacts and possibly combine several artefacts that may or may not be of one's own creation.

Experience autonomous artmaking

The tools could deliver autonomous and multimodal artistic outputs.

Assistance when creating art

The client could be supported in her artmaking flow by choosing from a spectrum of autonomy.

Part of a long-time project

The work in this thesis is meant to be part of a longer-time project aimed at bringing digital art therapy to the public. In that sense, there are three main moments estimated:

STAGE I – Prototyping

Design-Science-based Implementation Case Studies (this PhD)

STAGE 2 – Beta Action Research, Community-driven

STAGE 3 – Full Product, Qualitative and Quantitative measurements

9.2. Art in the very fabric of game engines

Repetition, tilings, and tessellations in computer graphics

Going back to the works of Leonardo da Vinci and the Renaissance, it is remarkable to see that his description of dealing with perspective essentially matches the contemporary approach for rendering a 3D scene to a computer screen. Long before the Renaissance, the Romans had also used small tiles – tesserae - to build mosaics that could fill the plane with depictions. This regular tiling of the plane or even space is hence called 'tessellation'. Still today, the 'tessellation stage' is one of the steps of current graphics 3D rendering pipelines. Other kinds of regularities are also thought to be fundamental in computer graphics. The symmetrical divisions of the plane and of higher dimensions are crucial for rendering pictures, movies and geometries as they can be reduced to structural repetitions of bidimensional pixels and three-dimensional voxels. They are an integral part of the game engine's graphics pipeline, which includes the stages of tesselation, vertex processing, texture sampling, fragment processing, and fragment rendering, among others.

A tetrahedral motif

Nake reports a historical revolution in the autonomous arts that had started with polygons as they 'became the signature of earliest algorithmic art', being 'Nees', Noll's, and Nake's common first interest'. Nake in (McCormack, D'Inverno, 2014).

Arguably, we can place this revolution in a wider background, that of the inspiring world of geometrical thinking that can be traced back to the remaining writings and translations of the works of Plato, Aristotle and Pythagoras.

Interestingly, there is an episode in geometrical thinking and philosophy that involves Aristotle and his teacher Plato, which is the tessellation of space by platonic solids, namely the regular tetrahedron. As ancient as that, there was a confusion that for long left the unanswered question of whether regular tetrahedra tesselate space.

That question has been an artistic motif in the structural design of TIMAEUS, in the likes of the polygonal inspiration of that early algorithmic art of Nees, Noll and Nake.

It is well established that the regular hexahedron is the only platonic solid currently considered to tesselate 3D space, whilst the packing of regular tetrahedra is a recurrent scientific problem with applications in various disciplines. Possibly derived from a misinterpretation of Aristotle's De Caelo philosophical rebut of Plato's vision of his elementary solids, in Timaeus, this question also appears in the 1900 Hildberg's 24 problems and is still a contemporary topic of study.

Despite the misunderstanding – described by Addabbo - being resolved by Maurolico in the 15th century, a question it originated has survived if one can put together tetrahedra with such density as close to tesselate space. Maurolico is considered to have proved full packing was not possible, and there are contemporary estimates for the possible densest packings. However, in the search for the motif for the structural design of TIMAEUS, by reframing the question from density towards geometrical regularity, there is a scenario in which one can consider the tetrahedron to also fully tesselate three-dimensional space.

This is because a honeycomb of triakis truncated tetrahedra (quarter cubic honeycomb) reveals a common structure that can be interpreted as a full tessellation of space by regular tetrahedral voids if we view the problem of platonic solids tessellations from a different geometrical perspective - where 3D points, lines and planes can be corporeal and have a volume – to find new solutions that fit the initial problems, such as the one raised by Aristotle.

A hollow honeycomb of regular tetrahedra

The geometrical motif is an extension of Plato's Timaeus inspiration in the TIMAEUS art studio and is the root for how the sculptures are built at an atomic level, thinking in the possibility of working with only tetrahedra or the other platonic solids.

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APPENDIX I

Initial Project Description

Generative audio-visual art for art therapy for long-term conditions

To celebrate the University's research successes, the University of Hull is offering 20 full-time UK/EU PhD Scholarship or International Fees Bursaries for candidates applying for the research areas within the six interdisciplinary research areas, including the following project in the theme of Health and Wellbeing to candidates with or expecting a 1st, 2(i), or equivalent degree.

This project is part of novel interdisciplinary research that intersects computer science, philosophy, medicine and art with potentially exciting new applications on conceptual art, art therapy and educational games.

The Computer Science department has strong track record in technologies that support this type of research: software engineering, graphics, games and artificial intelligence. Specifically, Hull computer scientists have been employing these technologies in collaboration with painters and musicians on projects in the field of generative art. An example of this work is a conceptual artwork (generativeart.net.dcs.hull.ac.uk) that is being presented at the XVI International Generative Art Conference and exhibited at La Triennale di Milano - the main contemporary design museum in Italy.

Informal feedback by clinicians who have experienced this artwork suggests that it can have therapeutic effect, e.g. on people with long term conditions like autism or dementia. The aim of this PhD is to expand the portfolio of this art and test this hypothesis. We have planned a series of musical painting sculptures that include a musical art sphere and a painted Möbius strip that will be virtualised and

enhanced with technologies to create interesting art works which, beyond their artistic merit, can also provide case studies for art therapy. Much of this work can also evolve in a form of an educational game.

We seek candidates with a first or upper second-class degree in computer science and interest in visual art, music, philosophy, art therapy or social sciences.

APPENDIX II

Munro's taxonomy of the Arts, extended to games, and game engines

I. VISUAL ARTS				VISUAL	YES	2D TEXTURES, 3D MODELS, TEXT, FONTS, LIGHT SOURCES
B. PICTORIAL ARTS AND TYPES OF ART:				VISUAL	YES	2D TEXTURES
2. TYPES OF PICTORIAL ART AS TO MEDIUM AND PROCESS: MATERIALS, INSTRU MENTS, TECHNIQUES.				VISUAL	YES	2D TEXTURES
a. Painting. Painting as an art is the arrangement of pigments on a surface				VISUAL	YES	2D TEXTURES
	I'. Oil painting.			VISUAL	YES	2D TEXTURES
	II'. Tempera painting.			VISUAL	YES	2D TEXTURES
	III'. Watercolor and gouache.			VISUAL	YES	2D TEXTURES
	IV'. Fresco.			VISUAL	YES	2D TEXTURES
	V'. Encaustic.			VISUAL	YES	2D TEXTURES
	VI'. Sand painting.			VISUAL	YES	2D TEXTURES
b. Drawing. Drawing as an art is the representation of objects or the mak-				VISUAL	YES	2D TEXTURES
	I'. Pencil drawing.			VISUAL	YES	2D TEXTURES
	II'. Pen and ink drawing.			VISUAL	YES	2D TEXTURES
	III'. Brush drawing; wash drawing.			VISUAL	YES	2D TEXTURES
	IV'. Crayon and pastel drawing.			VISUAL	YES	2D TEXTURES
c. Print-making; producing pictures or representative, decorative, or sym-				VISUAL	YES	2D TEXTURES
	I'. Engraving, hand; on wood, metal, etc.			VISUAL	YES	2D TEXTURES + 3D MODELS
	II'. Etching, drypoint, aquatint.			VISUAL	YES	2D TEXTURES
	III'. Mezzotint.			VISUAL	YES	2D TEXTURES
	IV'. Lithography.			VISUAL	YES	2D TEXTURES
	V'. Photo-engraving; half-tone.			VISUAL	YES	2D TEXTURES
	VI'. Collotype; gelatine processes.			VISUAL	YES	2D TEXTURES
	VII'. Silkscreen; serigraphy.			VISUAL	YES	2D TEXTURES
d. Photography (still). In black and white; in color. Microphotography; telephotography; X-ray photography.				VISUAL	YES	2D TEXTURES
e. Mosaic, pictorial.				VISUAL	YES	2D TEXTURES + 3D MODELS
f. Wood inlay; intarsia, pictorial.				VISUAL	YES	2D TEXTURES + 3D MODELS
g. Tapestry; pictorial weaving.				VISUAL	YES	2D TEXTURES + 3D MODELS
h. Embroidery and other needlework, lace, etc., pictorial.				VISUAL	YES	2D TEXTURES + 3D MODELS
i. Collage and montage, pictorial; cut paper pictures; silhouettes.				VISUAL	YES	2D TEXTURES
j. Colored lights, static and pictorial.				VISUAL	YES	LIGHT SOURCES
3. TYPES OF PICTORIAL ART AS TO NATURE OF PRODUCT.				VISUAL	YES	2D TEXTURES + 3D MODELS
a. As to form, size, location:				VISUAL	YES	2D TEXTURES + 3D MODELS
	I'. Mural pictures; on walls and ceilings.			VISUAL	YES	2D TEXTURES + 3D MODELS
	II'. Floor pictures, esp. in tiles and mosaics.			VISUAL	YES	2D TEXTURES + 3D MODELS
	III'. Easel pictures.			VISUAL	YES	2D TEXTURES + 3D MODELS
	IV'. Scroll pictures.			VISUAL	YES	2D TEXTURES + 3D MODELS
	V'. Miniature pictures; separately or as manuscript and book			VISUAL	YES	2D TEXTURES + 3D MODELS
	illumination.			VISUAL	YES	2D TEXTURES + 3D MODELS
	VI'. Vase painting.			VISUAL	YES	2D TEXTURES + 3D MODELS
	VII'. Screen painting.			VISUAL	YES	2D TEXTURES + 3D MODELS
	VIII'. Various shapes in the above: rectangular, round, triangular,			VISUAL	YES	2D TEXTURES + 3D MODELS
	pendentive, irregular.			VISUAL	YES	2D TEXTURES + 3D MODELS
b. As to subject, function, and mode of treatment.				VISUAL	YES	2D TEXTURES
	I'. Figure pictures: of humans or supernatural and imaginary			VISUAL	YES	2D TEXTURES
	II'. Animal pictures.			VISUAL	YES	2D TEXTURES
	III'. Landscapes and seascapes.			VISUAL	YES	2D TEXTURES
	IV'. Still-life pictures.			VISUAL	YES	2D TEXTURES
	V'. Decorative, semi-abstract, abstract, and non-objective pictures;			VISUAL	YES	2D TEXTURES
	non-representative designs.			VISUAL	YES	2D TEXTURES
	VI'. Symbolic pictures; emblems, insignia.			VISUAL	YES	2D TEXTURES
		A'. Religious symbols, such as the Cross, Crescent, and Star of		VISUAL	YES	2D TEXTURES
		B'. Political symbols: national, city, etc. Flags, seals, coats of arms		VISUAL	YES	2D TEXTURES
		C'. Heraldic symbols, of a family or hereditary rank or title.		VISUAL	YES	2D TEXTURES
		Coats of arms, crests.		VISUAL	YES	2D TEXTURES
		D'. Commercial symbols; trade marks.		VISUAL	YES	2D TEXTURES
		E'. Club and association symbols.		VISUAL	YES	2D TEXTURES
	VII'. Illustration (for books, magazines, posters, etc.).			VISUAL	YES	2D TEXTURES
	VIII'. Fashion-illustration.			VISUAL	YES	2D TEXTURES
	IX'. Cartooning; caricaturing.			VISUAL	YES	2D TEXTURES

F. USEFUL AND DECORATIVE ARTS AND TYPES OF ART; UTILITARIAN DESIGN; INDUSTRIAL DESIGN.		VISUAL	YES	3D MODELS, 2D TEXTURES
2. TYPES OF USEFUL AND DECORATIVE ART AS TO MEDIUM OR MATERIAL: those using		VISUAL	YES	3D MODELS, 2D TEXTURES
a. Hard, inanimate materials, and soft materials which harden. To be carved, molded, hammered, etc.		VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Masonry; stonework (decorative).	VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Ceramics (non-sculptural); earthenware, pottery, porcelain.	VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Tilework and brickwork, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
	IV'. Plasterwork, stucco, cementwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
	V'. Glassware.	VISUAL	YES	3D MODELS, 2D TEXTURES
	VI'. Enameling.	VISUAL	YES	3D MODELS, 2D TEXTURES
	VII'. Lacquerwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
	VIII'. Ivory and bone-carving (non-sculptural).	VISUAL	YES	3D MODELS, 2D TEXTURES
	IX'. Gem-cutting; lapidary art (non-sculptural).	VISUAL	YES	3D MODELS, 2D TEXTURES
	X'. Goldsmithing and silversmithing.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XI'. Jewelry, as including gems and metal settings, costume jewelry	VISUAL	YES	3D MODELS, 2D TEXTURES
	of non-precious materials, etc.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XII'. Ironwork and steelwork, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XIII'. Coppersmithing.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XIV'. Bronze casting, non-sculptural.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XV'. Other metal crafts.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XVI'. Woodcarving (non-sculptural).	VISUAL	YES	3D MODELS, 2D TEXTURES
	XVII'. Cabinet-making; fine and decorative carpentry.	VISUAL	YES	3D MODELS, 2D TEXTURES
b. Those using soft and pliable, inanimate materials. To be twisted, woven, tied, knitted, felted, sewed, pasted, etc.		VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Basketry.	VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Cordwork and stringwork, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Weaving; textiles; rug and tapestry weaving.	VISUAL	YES	3D MODELS, 2D TEXTURES
	IV'. Lace-making.	VISUAL	YES	3D MODELS, 2D TEXTURES
	V'. Knitting and crocheting.	VISUAL	YES	3D MODELS, 2D TEXTURES
	VI'. Needlework, embroidery, appliqué, etc. (esp. non-pictorial).	VISUAL	YES	3D MODELS, 2D TEXTURES
	VII'. Feltwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
	VIII'. Tapa or barkcloth-making.	VISUAL	YES	3D MODELS, 2D TEXTURES
	IX'. Paper-making, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
	X'. Paperwork, decorative; products of cut, folded, pasted papers,	VISUAL	YES	3D MODELS, 2D TEXTURES
	plain and colored.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XI'. Plastic cloth-making, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XII'. Leatherwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XIII'. Featherwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XIV'. Beadwork and quillwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
	XV'. Fur-making; designing and executing garments, rugs, etc., of	VISUAL	YES	3D MODELS, 2D TEXTURES
	fur along with other materials.	VISUAL	YES	3D MODELS, 2D TEXTURES
c. Those using plants, and related natural objects (earth, water, stones, etc.). To be cultivated, trained, and arranged into groups and		VISUAL	YES	3D MODELS, 2D TEXTURES
d. Those using animals; animal breeding and husbandry, for aesthetic as well as other qualities; e.g., for shape, coloring, graceful m		VISUAL	YES	3D MODELS, 2D TEXTURES
3. TYPES OF USEFUL ART AS TO PROCESS OR TECHNIQUE.		VISUAL	YES	3D MODELS, 2D TEXTURES
a. Handcrafts.		VISUAL	YES	3D MODELS, 2D TEXTURES
b. Machine crafts; mechanized industries.		VISUAL	YES	3D MODELS, 2D TEXTURES
c. Partly mechanized; combinations of hand and machine technique.		VISUAL	YES	3D MODELS, 2D TEXTURES
d. Large-scale, mass production methods (e.g., specialized work and assembly line, whether by hand or machinery).		VISUAL	YES	3D MODELS, 2D TEXTURES
4. AS TO NATURE OF PRODUCT; FORM AND FUNCTION.		VISUAL	YES	3D MODELS, 2D TEXTURES
a. Clothing arts; design and manufacture of garments and accessories for personal wear; also for dolls, marionettes, etc.		VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Tailoring and dressmaking.	VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Hat-making; millinery; head-dresses.	VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Shoemaking, bootmaking.	VISUAL	YES	3D MODELS, 2D TEXTURES
	IV'. Glove-making.	VISUAL	YES	3D MODELS, 2D TEXTURES
	V'. Lingerie, underwear, corsetry, etc.	VISUAL	YES	3D MODELS, 2D TEXTURES
	VI'. Costume accessories.	VISUAL	YES	3D MODELS, 2D TEXTURES
	VII'. Masks, adapted for wear.	VISUAL	YES	3D MODELS, 2D TEXTURES
b. Products for war and hunting.		VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Weapons.	VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Armor, helmets, etc., for man and horse.	VISUAL	YES	3D MODELS, 2D TEXTURES

C. WRITING AND PRINTING; NON-PICTORIAL GRAPHIC ARTS.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
2. Calligraphy and hand lettering;in cursive or detached characters; manuscript writing.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
3. Typography.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
a. Type designing.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
b. Printing.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
c. Layout (non-pictorial); page-arrangement.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
4. Other kinds of lettering and visual wording, as by carving in stone, by electric lights, etc.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
D. COMBINED PICTORIAL-VERBAL ARTS AND TYPES OF ART.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
1. Picture-writing, primitive and modern; pictographs; hieroglyphics, pictorial symbols. (In primitive culture, preceded the separation of wr	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
2. Manuscript and page illumination and illustration; hand painting combined with calligraphy.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
3. Printed layouts, pictorial-verbal; page, poster, and cover design, book and magazine illustrations with text. Advertising and other comm	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
4. Packaging, as involving printed pictorial-verbal arrangements.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
5. Postage stamps, banknotes, and other common types of form, combining pictorial and decorative elements with words, numbers, etc.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
6. Maps, charts, pictorial diagrams and displays for explanatory and utilitarian purposes; often combining realistic details with arbitrary syr	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
7. Luminous displays combining pictorial and graphic elements.	VISUAL	YES	TEXT, FONTS, 2D TEXTURES
E. SCULPTURAL ARTS AND TYPES OF ART.	VISUAL	YES	3D MODELS, 2D TEXTURES
2. TYPES OF SCULPTURE AS TO MEDIUM AND PROCESS.	VISUAL	YES	3D MODELS, 2D TEXTURES
a. Stone sculpture.	VISUAL	YES	3D MODELS, 2D TEXTURES
b. Ceramic sculpture; clay, earthenware, porcelain, terra cotta, plaster, etc.	VISUAL	YES	3D MODELS, 2D TEXTURES
c. Metal sculpture, in bronze, iron, copper, gold, silver, lead, etc.; casting and other processes.	VISUAL	YES	3D MODELS, 2D TEXTURES
d. Glass sculpture.	VISUAL	YES	3D MODELS, 2D TEXTURES
e. Ivory and bone sculpture.	VISUAL	YES	3D MODELS, 2D TEXTURES
f. Wood sculpture (including totem poles, fetish figures, etc.).	VISUAL	YES	3D MODELS, 2D TEXTURES
g. Wax sculpture; soap sculpture.	VISUAL	YES	3D MODELS, 2D TEXTURES
h. Gem carving, cameo and intaglio, with effect of sculptural relief.	VISUAL	YES	3D MODELS, 2D TEXTURES
i. Paper and papier-mach6 sculpture.	VISUAL	YES	3D MODELS, 2D TEXTURES
j. Sculpture in plastic and synthetic materials, string, cloth, etc.	VISUAL	YES	3D MODELS, 2D TEXTURES
k. Taxidermy; habitat groups; animal figures reconstructed and arranged.	VISUAL	YES	3D MODELS, 2D TEXTURES
l. Embalming and mummifying (of human and animal bodies; esp. in ancient Egypt). Use of skulls and dried heads as statues.	VISUAL	YES	3D MODELS, 2D TEXTURES
3. TYPES OF SCULPTURE AS TO FORM OF PRODUCT.	VISUAL	YES	3D MODELS, 2D TEXTURES
a. As to form, size, and function:	VISUAL	YES	3D MODELS, 2D TEXTURES
I'. In the round.	VISUAL	YES	3D MODELS, 2D TEXTURES
II'. In relief; low, high; steles, tablets, on walls and monuments.	VISUAL	YES	3D MODELS, 2D TEXTURES
III'. Free-standing.	VISUAL	YES	3D MODELS, 2D TEXTURES
IV'. Engaged, attached to a building (e.g., as caryatid) or to a piece of furniture or utensil. As architectural ornaments.	VISUAL	YES	3D MODELS, 2D TEXTURES
V'. For magical use, as in amulets, fetishes.	VISUAL	YES	3D MODELS, 2D TEXTURES
VI'. Mobiles, stabiles; combined types. Wind-moved; hand-moved; mechanical. String figures.	VISUAL	YES	3D MODELS, 2D TEXTURES
VII'. For religious use, as in idols and ikons.	VISUAL	YES	3D MODELS, 2D TEXTURES
VIII'. For commemorative monuments, often with architectural bases.	VISUAL	YES	3D MODELS, 2D TEXTURES
IX'. As interior ornaments; esp. small reliefs and statuettes.	VISUAL	YES	3D MODELS, 2D TEXTURES
X'. For wear, esp. ceremonial and theatrical, such as masks.	VISUAL	YES	3D MODELS, 2D TEXTURES
XI'. For theatrical use, as in marionettes and puppets.	VISUAL	YES	3D MODELS, 2D TEXTURES
XII'. As emblems, insignia, for indentification, as in carving heraldic crests.	VISUAL	YES	3D MODELS, 2D TEXTURES
XIII'. As advertising devices, displays (three-dimensional).	VISUAL	YES	3D MODELS, 2D TEXTURES
XIV'. Dolls and similar toys involving three-dimensional representation.	VISUAL	YES	3D MODELS, 2D TEXTURES
XV'. As to size: colossal, heroic; lifesize; small (statuettes, figurines, bibelots, netsukes, toys, etc.). Small reliefs, as in coins	VISUAL	YES	3D MODELS, 2D TEXTURES
b. As to subjects represented:	VISUAL	YES	3D MODELS, 2D TEXTURES
I'. Figures: human, animal, supernatural, diabolical, fantastic. Equestrian groups; totem poles.	VISUAL	YES	3D MODELS, 2D TEXTURES
II'. Portraits; busts; full-length portrait statues. Masks, realistic and fantastic.	VISUAL	YES	3D MODELS, 2D TEXTURES
III'. Sculptured plants, flowers, fruit, and other natural objects.	VISUAL	YES	3D MODELS, 2D TEXTURES
IV'. Reliefs with scenic, quasi-pictorial backgrounds.	VISUAL	YES	3D MODELS, 2D TEXTURES
V'. Semi-abstract and non-representative sculpture; constructivist designs.	VISUAL	YES	3D MODELS, 2D TEXTURES
F. USEFUL AND DECORATIVE ARTS AND TYPES OF ART; UTILITARIAN DESIGN; INDUSTRIAL DESIGN.	VISUAL	YES	3D MODELS, 2D TEXTURES
2. TYPES OF USEFUL AND DECORATIVE ART AS TO MEDIUM OR MATERIAL: those using	VISUAL	YES	3D MODELS, 2D TEXTURES
a. Hard, inanimate materials, and soft materials which harden. To be carved, molded, hammered, etc.	VISUAL	YES	3D MODELS, 2D TEXTURES
I'. Masonry; stonework (decorative).	VISUAL	YES	3D MODELS, 2D TEXTURES
II'. Ceramics (non-sculptural); earthenware, pottery, porcelain.	VISUAL	YES	3D MODELS, 2D TEXTURES
III'. Tilework and brickwork, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
IV'. Plasterwork, stucco, cementwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
V'. Glassware.	VISUAL	YES	3D MODELS, 2D TEXTURES
VI'. Enameling.	VISUAL	YES	3D MODELS, 2D TEXTURES
VII'. Lacquerwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
VIII'. Ivory and bone-carving (non-sculptural).	VISUAL	YES	3D MODELS, 2D TEXTURES
IX'. Gem-cutting; lapidary art (non-sculptural).	VISUAL	YES	3D MODELS, 2D TEXTURES
X'. Goldsmithing and silversmithing.	VISUAL	YES	3D MODELS, 2D TEXTURES
XI'. Jewelry, as including gems and metal settings, costume jewelry	VISUAL	YES	3D MODELS, 2D TEXTURES
of non-precious materials, etc.	VISUAL	YES	3D MODELS, 2D TEXTURES
XII'. Ironwork and steelwork, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
XIII'. Coppersmithing.	VISUAL	YES	3D MODELS, 2D TEXTURES
XIV'. Bronze casting, non-sculptural.	VISUAL	YES	3D MODELS, 2D TEXTURES
XV'. Other metal crafts.	VISUAL	YES	3D MODELS, 2D TEXTURES
XVI'. Woodcarving (non-sculptural).	VISUAL	YES	3D MODELS, 2D TEXTURES
XVII'. Cabinet-making; fine and decorative carpentry.	VISUAL	YES	3D MODELS, 2D TEXTURES
b. Those using soft and pliable, inanimate materials. To be twisted, woven, tied, knitted, felted, sewed, pasted, etc.	VISUAL	YES	3D MODELS, 2D TEXTURES
I'. Basketry.	VISUAL	YES	3D MODELS, 2D TEXTURES
II'. Cordwork and stringwork, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
III'. Weaving; textiles; rug and tapestry weaving.	VISUAL	YES	3D MODELS, 2D TEXTURES
IV'. Lace-making.	VISUAL	YES	3D MODELS, 2D TEXTURES
V'. Knitting and crocheting.	VISUAL	YES	3D MODELS, 2D TEXTURES
VI'. Needlework, embroidery, appliqu6, etc. (esp. non-pictorial).	VISUAL	YES	3D MODELS, 2D TEXTURES
VII'. Feltwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
VIII'. Tapa or barkcloth-making.	VISUAL	YES	3D MODELS, 2D TEXTURES
IX'. Paper-making, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
X'. Paperwork, decorative; products of cut, folded, pasted papers,	VISUAL	YES	3D MODELS, 2D TEXTURES
plain and colored.	VISUAL	YES	3D MODELS, 2D TEXTURES
XI'. Plastic cloth-making, decorative.	VISUAL	YES	3D MODELS, 2D TEXTURES
XII'. Leatherwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
XIII'. Featherwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
XIV'. Beadwork and quillwork.	VISUAL	YES	3D MODELS, 2D TEXTURES
XV'. Fur-making; designing and executing garments, rugs, etc., of	VISUAL	YES	3D MODELS, 2D TEXTURES
fur along with other materials.	VISUAL	YES	3D MODELS, 2D TEXTURES
c. Those using plants, and related natural objects (earth, water, stones, etc.). To be cultivated, trained, and arranged into groups and sequ	VISUAL	YES	3D MODELS, 2D TEXTURES
d. Those using animals; animal breeding and husbandry, for aesthetic as well as other qualities; e.g., for shape, coloring, graceful motion,	VISUAL	YES	3D MODELS, 2D TEXTURES

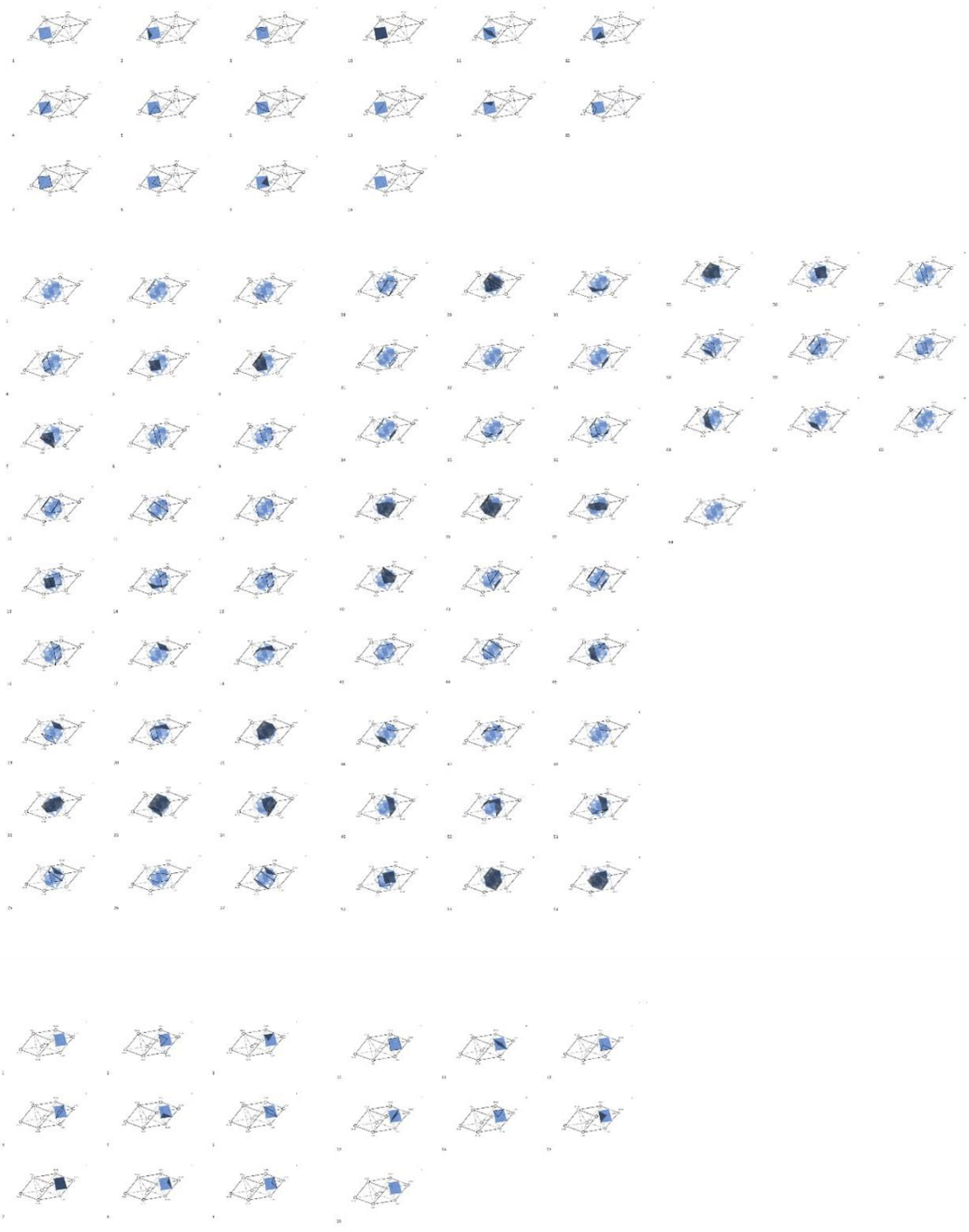
3. TYPES OF USEFUL ART AS TO PROCESS OR TECHNIQUE.				VISUAL	YES	3D MODELS, 2D TEXTURES
a. Handcrafts.				VISUAL	YES	3D MODELS, 2D TEXTURES
b. Machine crafts; mechanized industries.				VISUAL	YES	3D MODELS, 2D TEXTURES
c. Partly mechanized; combinations of hand and machine technique.				VISUAL	YES	3D MODELS, 2D TEXTURES
d. Large-scale, mass production methods (e.g., specialized work and assembly line, whether by hand or machinery).				VISUAL	YES	3D MODELS, 2D TEXTURES
4. AS TO NATURE OF PRODUCT; FORM AND FUNCTION.				VISUAL	YES	3D MODELS, 2D TEXTURES
a. Clothing arts; design and manufacture of garments and accessories for personal wear; also for dolls, marionettes, etc.				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Tailoring and dressmaking.			VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Hat-making; millinery; head-dresses.			VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Shoemaking, bootmaking.			VISUAL	YES	3D MODELS, 2D TEXTURES
	IV'. Glove-making.			VISUAL	YES	3D MODELS, 2D TEXTURES
	V'. Lingerie, underwear, corsetry, etc.			VISUAL	YES	3D MODELS, 2D TEXTURES
	VI'. Costume accessories.			VISUAL	YES	3D MODELS, 2D TEXTURES
	VII'. Masks, adapted for wear.			VISUAL	YES	3D MODELS, 2D TEXTURES
b. Products for war and hunting.				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Weapons.			VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Armor, helmets, etc., for man and horse.			VISUAL	YES	3D MODELS, 2D TEXTURES
c. Tools, utensils, furniture; equipment for home, work, school, church, recreation.				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Tools and machines for occupational use.			VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Utensils, instruments, smaller home and personal accessories such as dishes, cutlery, tableware, desk equipment, wat			VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Furniture and fixtures; larger appliances, movable and immovable.			VISUAL	YES	3D MODELS, 2D TEXTURES
	IV'. Rugs, carpets, linoleum, and other floor coverings.			VISUAL	YES	3D MODELS, 2D TEXTURES
	V'. Draperies, upholsteries, and other decorative fabrics adapted for use in rooms, trains, vehicles, etc.			VISUAL	YES	3D MODELS, 2D TEXTURES
	VI'. Wallpapers and other wall-coverings.			VISUAL	YES	3D MODELS, 2D TEXTURES
	VII'. Book-manufacture, including folding and sewing pages, binding,			VISUAL	YES	3D MODELS, 2D TEXTURES
	VIII'. Toymaking, including dolls and children's games, utensils for play, small copies of products used by adults, etc.			VISUAL	YES	3D MODELS, 2D TEXTURES
	IX'. Food-preparation, visual aspects of; shape, color, texture of foods, esp. ornamental cakes, candies, desserts.			VISUAL	YES	3D MODELS, 2D TEXTURES
	X'. Consumable and disposable products, made with attention to visual and other aesthetic qualities: soaps, paper handke			VISUAL	YES	3D MODELS, 2D TEXTURES
d. Interior design and decoration. Room composition. The art of planning				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Selection and arrangement of furniture, fixtures, appliances,			VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Table setting and decoration; selection and arrangement of			VISUAL	YES	3D MODELS, 2D TEXTURES
e. Displays (of solid objects in three-dimensional space). Decorative and				VISUAL	YES	3D MODELS, 2D TEXTURES
f. Stage and scene design; large representations of rooms, outdoor scenes, etc.; built, painted, lighted, and equipped for dramatic present				VISUAL	YES	3D MODELS, 2D TEXTURES
g. Dioramas, peep-shows, small-scale model rooms and house interiors, built in three dimensions. Solid objects and figures arranged in d				VISUAL	YES	3D MODELS, 2D TEXTURES
h. Building arts; architecture, civil engineering.				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Civil and military architecture (the latter including castles, forts, and fortifications).			VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Religious architecture: designing and building temples, churches,			VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Secular architecture: designing and building dwelling-houses,			VISUAL	YES	3D MODELS, 2D TEXTURES
	IV'. Other types of building, often involving architecture and engineering: bridges, dams, highways, piers, harbors, aquedu			VISUAL	YES	3D MODELS, 2D TEXTURES
i. Landscape and garden arts. Arts involving the cultivation and arrange-				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Landscape architecture: the art of arranging plants and other			VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Water-designing: fountains, cascades, pools; usually in relation to architecture and gardens.			VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Gardening: as an art, the arrangement, planting, and care of			VISUAL	YES	3D MODELS, 2D TEXTURES
	IV'. Horticulture: the science and art of growing plants, including			VISUAL	YES	3D MODELS, 2D TEXTURES
	V'. Topiary art; ornamental clipping and training of plants.			VISUAL	YES	3D MODELS, 2D TEXTURES
	VI'. Flower arrangements; set pieces, bouquets, wreaths, garlands.			VISUAL	YES	3D MODELS, 2D TEXTURES
	VII'. Arrangements of driftwood, shells, and other natural objects.			VISUAL	YES	3D MODELS, 2D TEXTURES
	VIII'. Tray landscapes (esp. Japanese).			VISUAL	YES	3D MODELS, 2D TEXTURES
j. Community designing; town, city, and regional planning. The art of planning and arranging the form of an inhabited area so as to provid				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Civil and town planning; urbanism. Community planning and			VISUAL	YES	3D MODELS, 2D TEXTURES
	designing in the case of large or small cities, towns and villages.			VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Regional planning and designing; geo-architecture. Community			VISUAL	YES	3D MODELS, 2D TEXTURES
	planning in the case of large areas, which may include many			VISUAL	YES	3D MODELS, 2D TEXTURES
	towns and villages with intervening farms or vacant land, parks,			VISUAL	YES	3D MODELS, 2D TEXTURES
	highways, bridges, waterways and waterfronts, dams, irriga-			VISUAL	YES	3D MODELS, 2D TEXTURES
	tion, etc.			VISUAL	YES	3D MODELS, 2D TEXTURES
k. Transportation; vehicle design, for appearance, outside and inside, as well				VISUAL	YES	3D MODELS, 2D TEXTURES
	I'. Land transportation:			VISUAL	YES	3D MODELS, 2D TEXTURES
		A'. Saddles, harness, etc., for riding on animals.		VISUAL	YES	3D MODELS, 2D TEXTURES
		B'. Litters; sedan chairs, human power.		VISUAL	YES	3D MODELS, 2D TEXTURES
		C'. Sleds and sledges; without wheels; human or animal power.		VISUAL	YES	3D MODELS, 2D TEXTURES
		D'. Chariots; animal power.		VISUAL	YES	3D MODELS, 2D TEXTURES
		F'. Carriages, carts, wagons; human and animal power.		VISUAL	YES	3D MODELS, 2D TEXTURES
		F'. Bicycles, tricycles, motorcycles.		VISUAL	YES	3D MODELS, 2D TEXTURES
		G'. Railroad trains; steam, petroleum, electricity; cars for sleeping, dining, etc., comparable to hotel rooms		VISUAL	YES	3D MODELS, 2D TEXTURES
		H'. Automobiles: steam, petroleum, electricity.		VISUAL	YES	3D MODELS, 2D TEXTURES
		I'. Trailers, built and equipped as dwellings, offices, etc.		VISUAL	YES	3D MODELS, 2D TEXTURES
	II'. Water transportation; surface and submarine:			VISUAL	YES	3D MODELS, 2D TEXTURES
		A'. Canoes, rowboats, gondolas, galleys (human power).		VISUAL	YES	3D MODELS, 2D TEXTURES
		B'. Sailboats and sailships (windpower).		VISUAL	YES	3D MODELS, 2D TEXTURES
		C'. Automotive ships, boats, and submarines. (Steam, petroleum,		VISUAL	YES	3D MODELS, 2D TEXTURES
		D'. Combined types.		VISUAL	YES	3D MODELS, 2D TEXTURES
	III'. Air and space transportation:			VISUAL	YES	3D MODELS, 2D TEXTURES
		A'. Balloons; lighter than air; some automotive, dirigible.		VISUAL	YES	3D MODELS, 2D TEXTURES
		B'. Airplanes; heavier than air. Gliders. Automotive planes. propeller type; jet and rocket types.		VISUAL	YES	3D MODELS, 2D TEXTURES

II. MUSIC; AUDITORY ARTS			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
B. MUSICAL ARTS AND TYPES OF ART, AS TO MEDIUM AND PROCESS OR TECHNIQUE.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
1. Composition and performance.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
a. Musical composition.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
b. Musical performance, including playing instruments, singing, and conducting.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
2. Kinds of music as to medium or instrument used. (Each kind includes both			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
composing and performing.)			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
a. Vocal music; singing, with or without instrumental accompaniment. (N.B.: Humming, whistling, and other types of vocal sound are sor			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	I'. Solo; soprano, alto, tenor, bass. (Usually with instrumental accompaniment.)		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	II'. Choral: men's, women's, mixed; vocal group. (Often without instrumental accompaniment.)		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
b. Instrumental music.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	I'. Solo: alone or with subordinate accompaniment; piano, violin, pipe organ, clarinet, drum, etc.		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	II'. Small and medium-sized groups; ensemble; chamber music, dance orchestras.		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	III'. Orchestra; large groups of different sizes.		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
c. Combined vocal and instrumental music, as in chorus or solo singer with orchestra; anthems, oratorios, operas, cantatas.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
3. Techniques and processes in musical composition; often regarded as distinct			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
arts.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
a. Melody-writing.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
b. Counterpoint; polyphony.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
c. Harmony-writing.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
d. Orchestration.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
4. Skills and activities related to music and sometimes classed within it.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
a. Sound effects in drama, film, radio, television.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
b. Breeding and training birds for song and speech.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
C. MUSICAL ARTS AND TYPES OF ART AS TO NATURE OF PRODUCT; FORMS AND FUNCTIONS.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
1. Music for active use. (The same piece of music may be put to different uses.)			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
a. For worship and ritual; religious music.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
b. For work, war, marching, etc.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
c. For dancing, games, festivals, etc.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
d. For psychotherapy.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
2. Concert music: mostly for quiet listening; for aesthetic perception.			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
a. With words: songs, chants, hymns, oratorios, cantatas. (Non-theatrical; without acting.)			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
b. Instrumental music with little or no use of words. (Voices can be used as instruments, without words.)			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	I'. Fugues, toccatas, madrigals, and other polyphonic pieces.		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	II'. Suites, sonatas, and other types of music for one or more instruments.		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	III'. Symphonies; symphonic poems and other forms for full orchestra.		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	IV'. Quartets, quintets, sextets, etc. for chamber group. (Often in sonata form.)		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
	V'. Concerti for orchestra and solo instrument or instruments.		AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
3. Music as a component in a combined, diversified art. (Such music can often be performed separately, for concert use.)			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
a. Operatic, ballet, film, and ceremonial music. Where music is an important part of a more complex work of art, including acting, costum			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
b. Incidental music; music as a subordinate accompaniment to dance and theatrical programs, radio, TV, films, etc			AUDITORY	YES	AUDIO FILES, MIDI, SYNTHESIZER
III. LITERATURE; ARTS OF VERBAL COMPOSITION			**VIS + AUD**	**YES**	**TEXT, SYNTHESISED SPEECH**
B. TYPES OF LITERATURE, AS TO LINGUISTIC MEDIUM.			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
1. Ancient languages: Greek, Latin, etc.			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
2. Modern languages: English, French, etc.			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
C. LITERARY ARTS AND TYPES OF ART AS TO FORM AND FUNCTION OF PRODUCTS.			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
1. As to development of word-sounds (with related characteristics of emotional intensity, diction, etc.).			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
a. Prose literature. Prose is composed in a form like ordinary conversation in that it lacks rhyme, regular meter, division into verses of eve			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
b. Poetry writing; verse and versification; prosody. "Verse" is literature composed in lines or verses with some regularity in the sounds of v			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	I'. Metrical verse.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	II'. Free or non-metrical verse.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	III'. Rhymed verse.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	IV'. Unrhymed verse; blank verse.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	V'. Alliterative verse.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
c. Prose poetry; poetic or lyrical prose. Intermediate between prose and poetry; not in verse form but with considerable regularity of word			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
2. Literary arts and types of art as to development of ideas: as to function and general mode of composition. (All the following types overla			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
a. Narrative literature; narration. Tells a story or connected sequence of			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	I'. Epic and verse romance: long verse narratives.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	II'. Ballads and other short or medium-length tales in verse.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	III'. Novels and prose romances; long fictional narratives; sagas.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	IV'. Short story, novelette, prose tale, fable, anecdote; short or medium-		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	length fiction in prose.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	V'. Journalism; short factual narrative; news reporting, in newspaper,		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	magazine, or book form.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	VI'. Symbolic stories and moral tales; allegories, parables, fables.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
b. Dramatic literature; play writing; composition of verbal texts, scripts, or			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	I'. Tragedy, high and low; dramas of pathos, failure, and suffering.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	II'. Comedy; high and low; comedy of manners; farce, burlesque,		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	satire. Dramas of success, happiness, and amusement.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	III'. Tragi-comedy; mixed and intermediate types of play, esp. serious		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	plays with happy or partly happy endings.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	IV'. Morality, miracle, mystery, and passion plays.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	V'. Masques.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
c. Lyric writing. Lyrics are written to be read independently, and also to be set to music as songs. A lyric may include some narration, dran			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	I'. Songs; lyrics suited for singing.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	II'. Sonnets.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	III'. Odes.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	IV'. Pastoral poetry; idyls, bucolics, eclogues.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	V'. Poems for special occasions: elegies, epithalamia, etc.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	VI'. Dramatic poems; dramatic lyrics and monologues; lyrical dramas.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
d. Expository and hortatory literature; explanation and rhetoric. Writing to explain, instruct, discuss, or persuade.			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	I'. Essays (short).		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	II'. Treatises (long).		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	III'. Speeches, orations, sermons, hortatory letters, etc. (Considered here as literature only.)		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
e. Mixed and variable types of literature:			VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	I'. History; supposedly factual narration and explanation of events,		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	II'. Biography and autobiography; also supposedly factual, but often with much imagination or bias.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	III'. Conversations, as reported in writing, more or less factually;		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	IV'. Philosophic dialogues; mostly expository but in dramatic form;		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	V'. Prayers and rituals; of various religions. As literature, the verbal		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	VI'. Letters (factual or fictional).		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	VII'. Diaries; journals; meditations. Daily or occasional notes, usually unsystematic. Events, thoughts, comments.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	VIII'. Epigrams; proverbs. Very short poems or prose sentences with		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH
	IX'. Epitaphs. For tomb inscriptions, or as if so intended.		VIS + AUD	YES	TEXT, SYNTHESISED SPEECH

IV. ARTS OF PUBLIC PERFORMANCE; THEATER ARTS; CEREMONIES AND ENTERTAINMENTS	**VIS + AUD**	**YES**	**AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES**
B. DANCE; BALLET; BALLROOM DANCING:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
C. PANTOMINE; EXPRESSIVE GESTURE AND POSTURE:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
D. SPEECH ARTS:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
1. Oratory; eloquence; speech-making; lecturing.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
2. Dramatic speaking; dramatic diction as a part of stage, film, or television performance by two or more actors.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
3. Spoken literature; recitation; elocution; dramatic reading.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
a. Monologue, where one speaker presents the whole composition, including	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
all parts if it is a dramatic work.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
b. Story-telling as a special type of oral, literary presentation. Usually	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
prose narration by a single speaker, with freedom to vary the wording	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
of the story. An ancient art, now especially popular with children.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
c. Choral and other group speaking. Several speakers deliver different parts	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
of the piece and perhaps combine in choruses. Not limited to dramatic	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
compositions. Story-telling in which several speakers take part.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
4. Conversation (as an art of speech).	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
E. DRAMATIC REPRESENTATION; STAGE PERFORMANCE (AUDIO-VISUAL):	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
F. OPERA; MUSIC DRAMA:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
1. Grand opera; serious opera.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
2. Light opera; comic opera, operettas, revues, musical shows, musical comedies.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
G. VAUDEVILLE:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
H. PUPPETRY, MARIONETTES, SHADOW PLAYS:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
I. MOTION PICTURES; FILM ARTS; CINEMA:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
1. Types of film art:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
a. Film dramas or photoplays, including comedies, tragedies, crime and detective plays, farces, etc., photographed from life.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
b. Documentaries, newsreels, educational films. Informative as well as entertaining; usually without definite plot, though a story element	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
c. Animated cartoons; mobile drawings and paintings. Usually acting out a story or drama.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
d. Mixed cartoon and "real life" films.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
e. Abstract and semi-abstract films; sequences of non-representational or slightly representational images and designs.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
2. Some component arts and processes in film-making:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
(a) Production; (b) Direc-	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
tion; (c) Scenario and script writing; (d) Costuming and make-up; (e)	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
Scene designing; (f) Lighting; (g) Acting; (h) Motion-picture photography;	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
cinematography; (i) Editing and continuity; (j) Montage and special effects;	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
(k) Animation; drawing and painting for films; (1) Three-dimensional ef-	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
fects.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
J. RADIO AND TELEVISION:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
Not yet independent arts, but means of communicating other auditory and audio-visual forms. Now developing original forms and change	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
K. FIREWORKS; PYROTECHNICS:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
Rockets, set pieces, etc. Usually for spectacular visual effect; sometimes to represent objects, characters, scenes, events.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
L. LUMIA; THE CLAVILUX; MOBILE COLOR:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
Directly projected on screen or walls, without films. Non-representational "color music" with sequences of changing forms; with or withou	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
M. CIRCUSES, PAGEANTS, AND OTHER SPECTACLES:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
N. RELIGIOUS RITUALS, CEREMONIES, FESTIVALS:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
O. FEASTS AND FESTIVALS; SECULAR RITUALS AND FORMALIZED AMUSEMENTS:	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
1. Seasonal festivals;	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
2. Ceremonies and festivities for special occasions.	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
3. Children's games of a ritual type	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
4. Feasts, entertainments, formalized parties	VIS + AUD	YES	AUDIO FILES, MIDI, SYNTHESIZERS, 3D MODELS, 2D TEXTURES
V. LOWER-SENSE ARTS AND FACTORS IN ART	**PAL + OLF + TA**	**NO**	
B. COOKING; CUISINE AND BEVERAGE-MAKING; ARTS OF TASTE OR GUSTATORY ARTS.	PALATE	NO	
1. Cooking	PALATE	NO	
2. Beverage-making;	PALATE	NO	
3. Meal-planning;	PALATE	NO	
C. PERFUME AND INCENSE; OLFACTORY ARTS OF ODOR, SCENT, SMELL.	OLFACTORY	NO	
1. Incense;	OLFACTORY	NO	
2. Tobacco-making;	OLFACTORY	NO	
3. Perfume:	OLFACTORY	NO	
D. TACTILE QUALITIES IN ART.	TACTILE	NO	
1. As presented factors in the total aesthetic effect of clothing, furniture, food, etc.	TACTILE	NO	
2. Tactile presentation of sculpture, literature, and other arts, esp. for the blind.	TACTILE	NO	
4. Tactile imagery suggested in literature, painting, etc.	TACTILE	NO	
VI. ARTS OF PERSONAL APPEARANCE AND ATTRACTIVENESS	**VIS + AUD**	**YES**	**3D MODELS, 2D TEXTURES, AUDIO FILES, MIDI, SYNTHESIZERS**
B. BODILY APPEARANCE AND FRAGRANCE; PERSONAL BEAUTIFICATION.	VISUAL	YES	3D MODELS, 2D TEXTURES
1. Cosmetics;	VISUAL	YES	3D MODELS, 2D TEXTURES
2. Hairdressing, coiffure;	VISUAL	YES	3D MODELS, 2D TEXTURES
3. Medical aids to beautification;	VISUAL	YES	3D MODELS, 2D TEXTURES
4. Tattooing.	VISUAL	YES	3D MODELS, 2D TEXTURES
C. DRESS; COSTUME:	VISUAL	YES	3D MODELS, 2D TEXTURES
D. VOICE AND SPEECH:	AUDITORY	YES	AUDIO FILES, VOICE SYNTHESIZER
E. POSTURE AND CARRIAGE.	VISUAL	YES	3D MODELS, 2D TEXTURES
F. SOCIAL BEHAVIOR:	VIS. + AUD.	YES	3D MODELS, 2D TEXTURES, AUDIO FILES, MIDI, SYNTHESIZERS

APPENDIX III

The cases of the 'Marching Octotetra'



APPENDIX IV

Statement by Professor Yiannis Papadopoulos

'Significant evidence of evaluation and the value of TIMAEUS and the other work described in the thesis is given by its contribution to the Research Excellence Framework (REF) submission of the University of Hull in Unit of Assessment 11 (Computer Science).

The REF is a nationwide evaluation of Academic research in the UK that takes place every 7 years and leads to university rankings in terms of excellence of research. As part of this exercise, universities are required to document the impact of their research in respective impact case studies.

In the REF of 2021 (REF2021), the department of Computer Science submitted two impact case studies, one of which was on "Virtual Environments for Training Applications (VETA)". The work that underpins this thesis was included in VETA together with other applications for Radiotherapy and Emergency Services, and achieved a score of 3.5 out of 4 across the two impact case studies. This score translates to a qualitative description of "50% internationally recognised and 50% internationally excellent impact". In turn, this put the university of Hull in 26th position among 125 institutions in REF2021 for the impact of its research in Computer Science. The relevant text included in the VETA impact case that references this thesis follows:

"Still in the area of virtual environments, the DEIS and VARS research groups are collaborating on research on digital art and intersections with philosophy and science. Applications of this work are increasingly becoming impactful. A result of this work is TIMAEUS a digital art studio environment that enables creation of personalised 3-dimensional virtual sculptures. These sculptures can be customised with pictures, videos and

music, which are embedded and can be experienced in different ways with the capability of zooming in and out, rotating, and viewing from different angles. TIMAEUS is used in applications from art therapy to education on philosophy and literature; examples are the creation of a Virtual Digital Stoa and an Alternative Virtual Odyssey. Papadopoulos gave an invited talk on "Meeting Epictetus and Seneca in a Virtual Stoa: Classical Wisdom as Emotional Education of the Future" in the annual Literature Festival of Rome (2019). These efforts give encouraging signs that the UoH's work into VR, training and digital learning will continue to generate exciting and impactful results."

https://results2021.ref.ac.uk/impact/8f740f82-5ab5-4629-ac71-465161798acc?page=1 '

Statement by artist Roberto Bono

STATEMENT OF EVALUATION

By Roberto Bono

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91100 Trapani, Sicily
Italy
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Bono Art Gallery

15/10/2023

I am Roberto Bono, a painter of abstract art residing in Trapani, Sicily, where I curate the Bono Art Gallery, a space dedicated to exhibition of my art and that of other local artists. My creations often engage with contemporary political discourse. Notably, my series titled "Sea Guernica" stands as an exploration of the plight faced by Mediterranean migrants amidst other thematic explorations in contemporary politics.

Through the guidance of Yiannis, Luis's supervisor in his doctoral journey, I've engaged with Luis's innovative approach which harnesses digital games and their engines in the domain of art.

Luis, in his experiments with multi-modal art, has seamlessly incorporated fragments of my work, combined them with video and music and gave them a different life and virtual existence. He actively sought my insights into the transformative elements inherent in his exploration of multimodality in art.

His inquiry revolves around whether these transformations retain recognition of the original artist's essence or pave the way for complete metamorphosis. Moreover, Luis is intrigued by the novelty of presenting conventional visual art in this manner and seeks to understand whether new exciting forms of artistry emerge within these results. His quest extends to evaluating the value added by digitalization and augmentation in art, as well as the utility of his tools for artistic research, teaching, and therapeutic purposes, and the philosophical implications of his work.

In his experiments, Luis digitally reimagined some of my paintings, birthing new multi-modal art forms where my creations intermingle with music and video. The outcomes are aesthetically enchanting, presenting my work in unexplored dimensions. Notably, my Sea Guernica paintings were amalgamated with evolving 3D shapes in digital sculpting software, accompanied by impactful rescue operation footage and poignant melodies. The resulting video outputs from the Timaeus software tool exhibit accomplished aesthetics, have have pleasantly surprised me with the dynamic beauty of this new synthesis and rendering of my work. Luis's digital environment fosters novel approaches to creating, presenting, and engaging with art, unveiling fresh avenues for learning, teaching, and artistic research within

this multimedia software. Other experiments saw my art, with its patterns and colors, morph into landscapes and skies, vividly colouring Mount Olympus and its surroundings.

These collaborative efforts culminated in presentation at the Generative Art Conference, garnering appraisal and subsequent publication in the Generative Art Science and Technology Hard Journal.

Reflecting on Luis's thesis inquiry, I can see in his work multiple art forms converging harmoniously, forming a new breed of multimodal art facilitated by his software. This innovation holds promise in the fields of art education and art therapy, presenting intriguing philosophical prospects in exploring multimodality and forging new art forms and experiences.

As an artist, I am exhilarated by the myriad possibilities unfurled by this innovative approach. The augmentation, synthesis, and evolution of diverse modes of artistic expression into dynamic digital forms have invigorated my artistic spirit. I am keen to continue these experiments, especially those focusing on practical education and art therapy, exploring the uncharted territories of artistic expression.

Roberto Bono, Trapani, 15/10/2023

Statement by artist Stefanos Zannis

STATEMENT OF EVALUATION

By Stefanos Zannis

Stefanos Zannis Art Studio
21 Xenias Str
11527, Athens
stefanoszannis1963@gmail.com
Link to Odyssey

29/11/2023

I am Stefanos Zannis, a painter from Athens, known for my two-decade-long dedication to capturing the essence of the Odyssey through my art. Over the years, I've delved into depicting episodes from this epic tale together with novel original commentary on its themes. My artwork has been exhibited in multiple occasions and venues and has been published in illustrated books.

My acquaintance with Luis stems from our shared interest in exploring the intersection of digital gaming, game engines, and the synthesis of multiple art forms in innovative ways. Our connection was forged through Yiannis Papadopoulos, Luis's esteemed PhD supervisor. In pursuit of his thesis work, Luis has sought my insights on specific aspect of artistic art creation and presentation.

He aimed to comprehend the nuanced line between maintaining the essence of original artworks and undergoing complete transformative processes in his explorations. Additionally, he's curious about my perspective and judgements perspective on his novel approach to presenting my art work and whether it stands as a pioneering form of artistic expression.

Furthermore, Luis was eager to ascertain if the results of these endeavours possess standalone artistic merit and if they signify a potential emergence of a new artistic medium or technique.

His inquiries have extended beyond the artistic realm, venturing into the realm of educational, therapeutic, and philosophical implications within the arts and aesthetics.

In support of Luis's evaluation of his research, I have engaged in a project entitled "VIRTUAL ODYSSEY" where Luis has ingeniously translated my paintings into a virtual world. These visual renderings are accompanied by the eloquent poetry of Alexandros Vanargiotis, passionately recited by Angelina Vakali, and accompanied by a gentle musical backdrop. The culmination of these elements have resulted in a visual and auditory journey that is not only aesthetically pleasing but also conceptually invigorating, providing a fresh impetus to my original work, which I would call "a modern "Odyssey through the corpus of my work"

Experiencing my art through this multimedia software has been a revelation, offering perspectives and dimensions that were previously unforeseen when limited to paintings, sculptures, or poetry declamations. Witnessing my artistic expressions in this novel form, curated in a navigable gallery of sea and waves, has shed new light on my work, revealing artistic nuances that were previously concealed. Undoubtedly, I recognize the inherent artistic merits in this approach, as evidenced by the captivating and surprising results showcased in the video demonstration.

This pioneering approach not only enriches the artistic palette but also offers a creative platform for visual artists to narrate and present their work in diverse and compelling ways. Our collaborative effort was recently showcased at the Generative Art Conference, receiving commendation from an audience specialized in the field.

Reflecting on Luis's thesis questions, I am enthralled by how he has seamlessly integrated various art forms – poetry, music, sculpture, and my paintings – into a harmonious ensemble, creating a wonderful masterpiece that went far beyond my creative imagination. We are currently building on this work, using Luis's tools and preparing exciting installations of chapters of a virtual Odyssey in forthcoming exhibitions of my work.

Stefanos Zannis, Athens, 29/11/2023