AI-Aided Ceramic Sculptures: Bridging Deep Learning with Materiality

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Abstract. With the advent of neural networks as powerful tools for generating various forms of media, so-called 'Deep Learning' (DL) has entered the sphere of art production. The concept of creative artificial intelligence (AI) has become part of popular discourse around 2D digital image-making, but can AI exceed the limitations of 2D media and be applied creatively in more tactile 3D media such as sculpture? In this paper, we describe what happens when AI is applied in a real-life production line, from concept to physical object. The article presents a case study that explore DL's potential for creating a tactile sculpture guided only by text prompt and a 3D model. In the production process, we mix several methods, including neural, digital, and traditional, to achieve the final results. In terms of methodology, this is an artistic study that explores existing DL tools for 3D object generation and later manufacturing in 3D printed ceramics. In the study, we use practice-based research methods to explore what happens when modern technology meets traditional ways of production, such as pottery. Further, we discuss reference art projects that have utilised AI, lessons learned, and the potential use of DL tools in art production. The aim of the paper is to explore new meanings and to open new avenues for investigation that emerge by bringing together creative AI with materiality.

Keywords: Ceramics · AI sculpture · 3D AI · 3D printing · interdisciplinary · physical AI · deep learning · AI art · creative AI · hybrid process · practice-based research · artistic research

1 Introduction

Artificial Intelligence, and especially Deep Learning, has triggered enormous interest and critique within the art world just as it has in other fields. Through their practice, artists are exploring the new meanings and possibilities that this technology offers. Many image-, sound-, and text-based works with AI models,

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Fig. 1. Final result of ceramic sculpture. Different views of *Mermaid in green jelly and pink feather* (Nymph) from the sculpture series *Psychedelic Forms* by Varvara & Mar. (Color figure online)

such as GAN and GPT, have been created. Terms like 'AI art' and 'GAN art' are now on the research agenda for many scholars, including Aaron Hertzmann [9], Lev Manovich [16] and Joanna Zylinska [29], who discuss AI as introducing a new paradigm and potentially transforming the established role of the artist. Well-known examples of GAN art include *Mosaic Virus*[1] (2019) by Anna Ridler and *Memories of Passersby I*[2] (2018) by Mario Klingemann.

At the same time, new tools are being released daily. Today, the discussion has shifted from GAN models to Stable Diffusion, Midjourney, DALLE and similar CLIP-based models, which introduce a paradigm shift into the main workflow and characteristics of AI art. The accelerated pace of the field of AI and DL (Krenn et al., 2022) is a source of excitement for researchers in creative AI, but also presents key challenges.

Although AI is often described as a very powerful tool [14,24,28], but when applied to art production in installation or 3D formats difficulties are soon encountered. As we have described in our previous work, the development of an autonomous interactive robotic art installation has been challenging as neither CLIP models nor robot control software are designed to talk to each other [6]. In this article, we focus on discovering ways to generate 3D objects with neural networks and introduce DL technology into traditional art production methods, such as pottery. More precisely, the art project entitled *Psychedelic Forms*[3] by artist duo Varvara & Mar (also the authors of the article) is a series of ceramic sculptures (see Fig. 1) that serve as a case study in this paper. The project investigates the current potential of DL for creating a physical form guided by text

[1] http://annaridler.com/mosaic-virus.
[2] https://underdestruction.com/2018/12/29/memories-of-passersby-i/.
[3] https://var-mar.info/psychedelic-forms/.

prompt and 3D model. By mixing modern and traditional production methods, we explore the potential and limitations of neural nets in the context of artistic practice. Psychedelic Forms reinterprets and translates ancient sculptures into contemporary forms. The project considers co-creative AI and the shared agency between various production methods-modern, traditional, autonomous, or manual. Thus, it offers a novel approach to bridging DL technology with materiality.

The practice-based research methodology was used to answer research questions: What happens when neural networks meet materiality? And who has the agency in this production process? Our methodology is explained in a section below. Before analysing the available DL models for 3D object generation from a practical point of view, we would like to discuss several reference art projects that aim to extend 2D Generated Adversarial Network (GAN) outputs to the sculpture format.

1.1 Reference Works

The artwork *Dio*[4] (2018) by Ben Snell aims to extend GAN's 2D output to 3D physical space by producing sculptures from the shredded material of the computer used to produce the GAN 2D images of that same exact sculpture. Unfortunately, the author does not elaborate further on the production processes involved. A similar realization strategy-from GAN-generated images to 3D models by way of manual conversion-can be seen in Egor Kraft's *Content Aware Studies*[5] (2018). His work is a relevant reference in terms of re-visiting, or rather restoring, ancient culture through the vista of machine learning. Kraft sees the emerging objects as "[...] synthetic documents of emerging machine-rendered history" [12].

The artwork *Metamultimouse*[6] (2022) by Matthew Plummer-Fernández is a digital and physical figurine that used a GAN to generate the texture applied to the 3D-modelled shape [20]. The artwork, which is sold as a 100-edition NFT, has two materialities, one as a video animation of the figurine and a second as a digital colour-printed sculpture that appears different in each edition as each uses a single different frame of the video. The pieces are printed in Nylon using HP's Multi Jet Fusion (MJF) technology, which supports very complex geometries and full colour [22]. The double materiality of the piece appears to be a common feature of 3D projects that flirt with AI technology.

In contrast to the generative approach with GANs, another art project from the same year as *Psychedelic Forms*, *AI Sculpting*[7] (2022) by the group Onformative, demonstrates 3D object generation by applying reinforcement learning. In their technical paper, *Reinforcement Learning applied to sculpting: A technical story of AI craftsmanship*, the group described how an AI model was trained

[4] http://bensnell.io/dio/.
[5] https://egorkraft.com/.
[6] https://feralfile.com/artworks/metamultimouse-wzq?fromExhibition=doppelganger-jgz.
[7] https://onformative.com/work/ai-sculpting.

to sculpt in a 3D environment [23]. Starting with a cube and 3D object as an input, the model begins to subtract mass from the shape step by step until the final form is reached. Various different digital substractive tool heads determine the final aesthetics of the surface. Although this method for using a model to produce the final object is reminiscent of the traditional way of sculpting from a block of stone, the project remains in the digital realm. This again illustrates the gap between the DL models' output and that of physical manufacturing, which this paper explores.

Currently, there are very few artworks that would generate a 3D object directly from a neural net. In *Psychedelic Forms* the generated output was an '.obj' file that was later crafted into the ceramic sculptures and colouring also had an important place in the process and final aesthetics of the sculptures. Because of this, and the way project brings together modern and traditional ways of production, it introduces a novel method to art creation.

2 Case Study: Psychedelic Forms - Text-to-Ceramics

Fig. 2. Final result of ceramic sculptures. *Snake and Angel on Blue Moon* (Dionysus) from the sculpture series *Psychedelic Forms* by Varvara & Mar. (Color figure online)

The project described in this article is inspired by classical sculptures, an ancient way of producing ceramics, and the limitations of DL models when it comes to tactile object production. Seeing that the GAN models are limited to 2D, we began to experiment with options how to achieve a tactile object from the neural net. By using a 3D object and text prompt, we guided the AI model that stylized the mesh. After numerous iterations of object generation using different input models and text prompts as inputs, based on the criteria the most fitting models were chosen (among the AI art community this process is known as 'curating' AI output). Later, the model was manually altered and prepared for 3D printing in clay. Glazing happened by hand, often inspired by the AI-generated object's vertex colours. The artwork demonstrates the embodied experience and transformation of a DL model through artistic practice.

The project name *Psychedelic Forms* came during the process. Psychedelic refers to unexpected or unexplored imagination that a human mind has not seen before. Although the original input was well-known ancient sculptures, like Venus, the AI model was capable of stylizing the mesh with the inputted text prompt in such a way that the new form was hardly recognizable (see interaction process in Fig. 3). The complex form emerged because of the co-creation between human and AI, and interplay with material and production processes (see Figs. 1, 2, 8, 9). The hybrid processes that combine digital, physical, chemical and ancient craft worlds are embedded into this project and described below.

Our choice to work with clay was connected with the ancient origin of the sculptures that were used as conceptual ready-mades. According to Meredith and Barnett, "a conceptual readymade is a contemporary artist's use of a classical work selected as a key point of reference taken out of time" [17]. Our idea was to re-interpret the classics through neural net algorithms and again return to the antique through matter.

The art project brings together ancient culture, craft, poetry and emerging AI tools. This practice-based research revisits known forms and processes from a novel angle and sets out new possibles.

2.1 Methodology

In this exploratory research project, practice-based research methodology was applied to analyse the available DL models for generating 3D models and to investigate how this technology could become part of an artistic production process in ceramics. The study combines DL with CAM technology and traditional craftsmanship. According to Candy et al., since the emphasis is on the creative process and the artefacts that contribute to new knowledge, the current research can be classified as practice-based (Candy et al. 2006). Although at first glance a practice-based approach may seem subjective, expert knowledge that stems from a long experience in art practice and applied research has significant value that should not be underestimated. The idea of 'art-as-research' is that art creates new theories in the act of making. According to Busch: "Art and theory, in effect, are nothing more than two different forms of practice interrelated through a system of interaction and transferences." (Busch 2011). Hence, the practice can provide valuable insights that can be helpful for understanding how innovative technology can be applied in art making and what kind of shift in the relationships of these processes it introduces. When it comes to the procedure of applied methodology, the project had four stages. Each demonstrates a translation process:

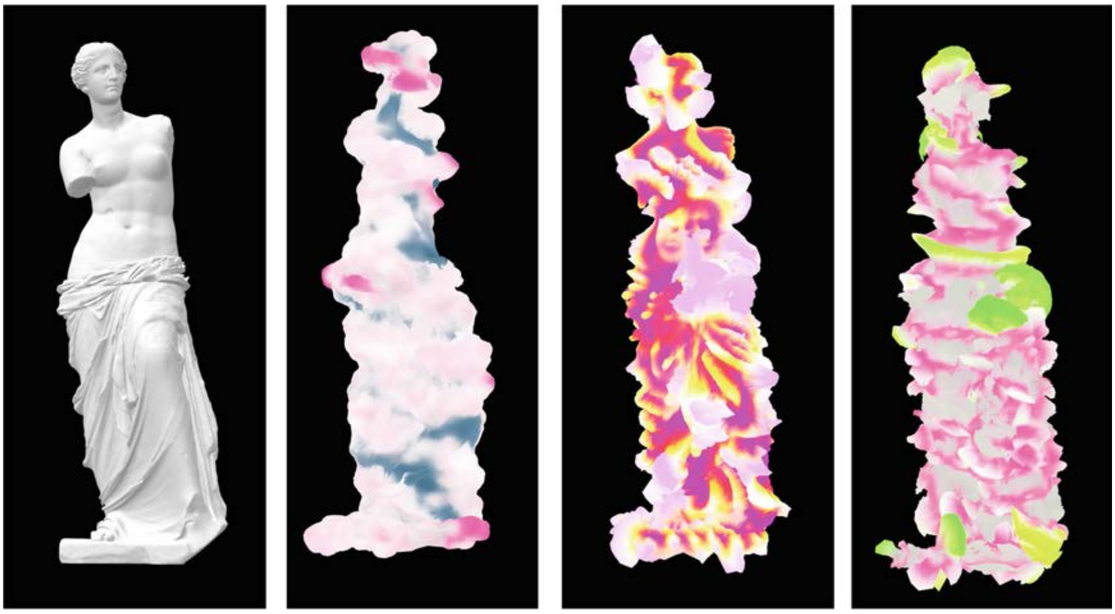

Fig. 3. Iteration process: Text2Mesh outputs using the same input 3D object and different text prompts

1. **From exploration to concept: research.** Field research into existing DL models for 3D shape generation was conducted. When a possible tool was identified, the artistic concept and hypothesis of the project were developed. The hypothesis was that DL can be used for the translation of different processes and semiotic spaces, thereby contributing to creativity and value in the context of art and creative AI.
2. **From neural to digital: curating.** The selection and creation of inputs (3D object and text), iteration and curating of generated results belong to this next phase. The criteria for selection were set by the experts (the artists). There were two main criteria: a model had to be reparable, possible to produce, and it should have an interesting form. The first two criteria are more of a technical decision, while the last is purely artistic. At this point, the artist decides if the generated result is artistically valuable or not. This process is known as 'curating' in the AI art community.
3. **From digital to physical: fabrication.** This is the 3D-printing process in clay. This phase demonstrates the interplay between digital fabrication technology, material, and traditional pottery.
4. **From physical to chemical: coloring and firing.** This is the final phase where drying, multiple firing and glazing processes took place.

2.2 Translation Processes

The artistic project started with a simple question back in 2021: Is it possible to generate a 3D object with the available DL models? Later, when the practice-based research project evolved, we began to explore the relationships between different agencies and the meanings behind them. Although in recent years, there has been lots of research in the field of 3D with deep learning [7,21,26,27], we found it difficult to find any model that could be applied in our project. We conducted our own field research on various different DL models. Such algorithms as 3D GAN, pytorch3D, Texture synthesis to 3D, and Text2Mesh, were tested. Based on the selection criteria, the freshly released Text2Mesh model was identified as the most suitable for the project. The model deforms a 3D object's mesh guided by text input [11,18]. Text2Mesh is an AI model that transforms object mesh based on text input using CLIP, which is very similar to what CLIP can do in image models but in 3D [18]. Simply speaking, we could create, or more precisely alter, the input 3D model with our words. Here it is important to note that the model does not create a new object but modifies the existing one. In the developers' words: "[...] we consider content as the global structure prescribed by a 3D mesh, which defines the overall shape surface and topology. We consider style as the object's particular appearance or affect, as determined by its colour and fine-grained (local) geometric details" [18].

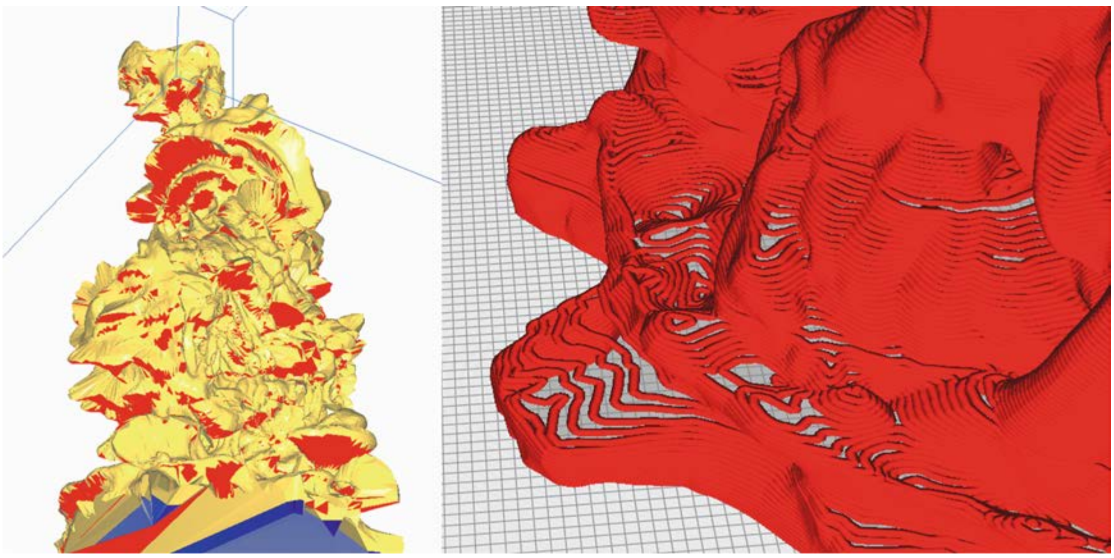

Fig. 4. An overhang problem with a Text2Mesh generated model. The image on the left indicates problematic areas in red. The image on the right shows problem with steep angle. (Color figure online)

The particular DL model used in this project and others that deploy CLIP or GPT algorithms work at the level of the concept and not the meaning. Thus, the generated mesh reflects upon the decoded concepts recalled by the Dadaistic short poems submitted by the artists as text prompts for the algorithm. This illustrates a new way of navigation, detached from meaning in the 'concept-plus-image' neural space and then superimposed onto the surface of the 3D model.

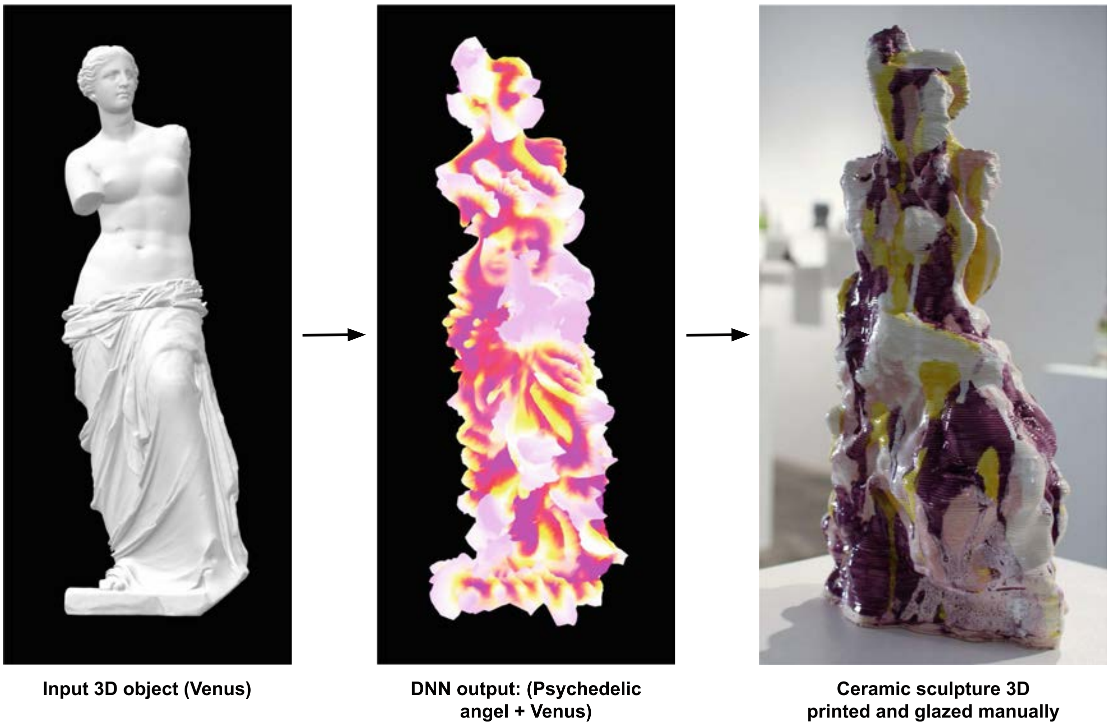

Fig. 5. The visual change during the translation process from an original input to a ceramic sculpture. Case study with Venus as input 3D object and *psychedelic angel* as text prompt.

Following the 'exploration to concept' phase was the 'neural to digital' phase, which involved the selection and creation of inputs, iteration, curation, and reparation processes. After experimenting with many digital objects and text inputs, digital copies of antique sculptures were fed into the algorithm and served as a point of departure for the creative process-Venus, Nymph, Double Herm of Herodotus and Thucydides, Dionysis, and Milford Lane-together with the text prompts created by the artists to style or re-mould the input form. Figure 3 demonstrates the iteration process using the same 3D model but with different text prompts. Although the vertex colour generated by Text2Mesh was later sometimes used as an inspiration for glazing, it did not play a role in the process of selecting an object for the next phase. The selection decision was based on the criteria set out at the beginning.

The last step in this phase was reparation and remodelling. In addition to a broken mesh, there was a big issue with the overhanging parts that was an obstacle for 3D printing in ceramics (see Fig. 4). In order to solve this problem, the generated 3D models were manually altered and overhangs were minimised.

In addition, aesthetic variations of the model were made. Figures 5 and 6 depict the translation process that the original model underwent.

The 'digital-to-physical' phase demonstrated several challenges too. First, printing large formats and complex shapes in clay is problematic because, in contrast to plastic, clay does not dry in minutes but takes days or even weeks if the environment is humid. Several attempts to 3D print failed by sculptures collapsing or falling in the middle of the printing. For that reason, instead of an autonomous process, printing was constantly supervised by human. Figure 7 illustrates the production pipeline of ceramics work: preparing clay and inserting it into the 3D printer's tank, supervising the 3D printing process, the first firing (after drying), and glazing. All sculptures in ceramic have 25–35% of infill. Only one sculpture is hollow inside, which was printed in recycled plastic. The translation process to a physical object revealed its tactile shape, but the material and production method also intervened in the visual aesthetics of the artefacts. Clay added extra risk and tension to the process as it required a lot of care and introduced its own limitations and aesthetics. The gravity and density of the clay influence the form, as do the drying and firing processes.

The last phase, 'physical to chemical', involved glazing and firing in the kiln and so colour was applied. In ceramics, glazing is a chemical process where glazing powder mixed with water is applied by hand to pre-fired pottery (see Fig. 7). Pouring technique was used for colouring the sculptures. This was an artistic decision that resonated with the process of AI, where control is heavily disturbed by chance. This method served as a metaphor for the thermodynamics of meaning spaces in latent spaces.

The selected colour pallet was sometimes inspired by the generated objects, but not always, as Fig. 6 clearly demonstrates. The colour selection was an artistic decision, too, based on the aesthetic taste of the artists as is common in most art practices. Nevertheless, the final outcome could not be entirely controlled because the technique of glazing technique is a little like painting blind as the colours appear only after the chemical reaction at high temperature during the firing process. Before firing, one does not see the colour or the composition and so the final result is always a surprise when it emerges from the kiln (see Figs. 1, 2, 8, 9). The colour aspect of this project is, therefore, quite unique as it has rarely, if ever been explored by artists working with AI tools.

3 Discussion on Agency and Creativity Within AI-Aided Processes

Although DL technology offers many novel formats, they all tend to remain within the digital realm. As the experiences of this study and the demonstrations of the reference projects show, practitioners quickly encounter the limitations of AI models when moving into the physical space. This project shows vividly that the output of the AI model was not ready for being reproduced in physical material form. Many laborious hours were spent fixing and preparing the 3D models for print. In addition to gravity, clay sets its own limits to what shapes

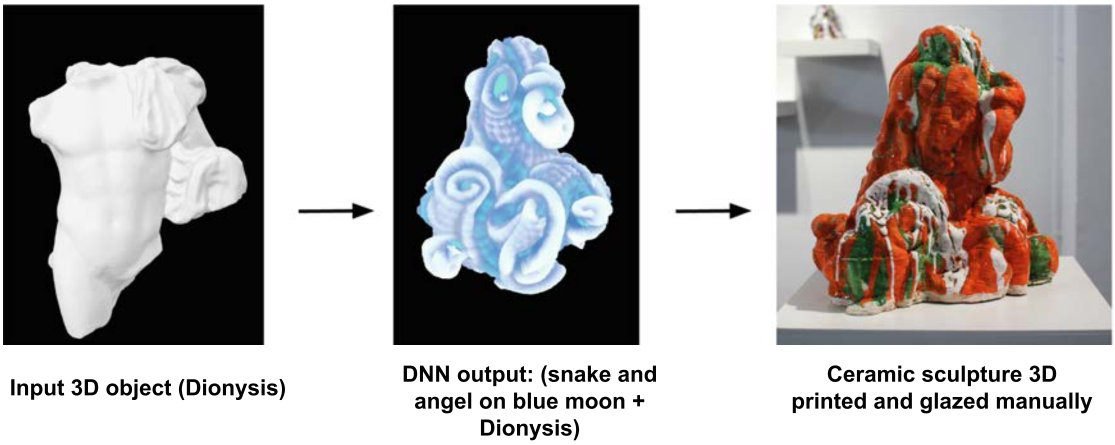

Fig. 6. The visual change during the translation process from an original input to a ceramic sculpture. Case study with Dionysis as input 3D object and *snake and angel on blue moon* as text prompt. (Color figure online)

Fig. 7. Working with ceramics (from left to right): 1. mixing clay with water and filling a 3D printer tank with it. 2. supervising 3D printing process 3. glazing process.

Fig. 8. Final result of ceramic sculpture. *Snake and Angel on Blue Moon* (Dionysus) from the sculpture series *Psychedelic Forms* by Varvara & Mar. (Color figure online)

can be produced finally. Having said that, we should mention that all partners with whom we have worked in ceramics and industrial 3D printing said that our project involved some of the most complex shapes they had ever printed. Thus, the project pushed not only the limits of AI but also of CAM technology. However, as the number of scientific publications and related applications on DL continues to grow quickly and processes develop [13] so these limitations may soon be overcome as new and better options for shape generation appear.

By introducing clay as the material of the process, the destruction and alternation of the form continued to deform and evolve. The interplay of neural networks, digital, physical and chemical processes created new meanings and experiences. We see this as a meaningful and tangible way to navigate latent space. Such transversal and translation processes are related to the ideas of New Materialism, a cultural theory that de-territorializes disciplines by cutting across them rather than acting in opposition, and that sees agency as a two-way relationship instead of an act of possession [3,5,25]. The research project has demonstrated the four phases of creation that AI-aided ceramics sculptures underwent, and how each tool, technique, and material carried its own agency. This interplay of agencies was made explicit through the applied methodology.

More precisely, the research design was based on the four translation phases: exploration to concept, neural to digital, digital to physical, and finally, physical to chemical. It can be summarized as being a text-to-ceramics approach that led to unexpected results from the initial inquiry of our research questions. Charles Peirce, who is the father of formal logic and semiotics, describes the principles of inference as being based on induction that classifies, deduction that reduces choices, and abduction which explains [19]. This creates a combined approach that leads to new ideas as a source of creativity [1]. According to Yuri Lotman, art is the ultimate, most effective process of meaning-making [15]. Thus, this research project creates unexpected connections that provide for the creation of new meanings that emerge from foundational models like CLIP, and the allows the imprecision of translations to provide for a space of potentiality.

Semiotician Yuri Lotman describes the translations of various semiotic spaces as a strategy for augmenting creativity [15], and this can now be explored by utilising deep learning models such as CLIP to act as foundational models. Lotman investigated how new information be generated with translations into different mediums, such as image-to-text or text-to-image. In simple terms, by translating semiospheres, new sources of creativity emerge [8]. The authors of On the Digital Semiosphere describe how different semiotic spaces are incommensurable, and so efforts to translate between them constitute the very essence of creativity [8].

Translation systems can prompt the emergence of mutations that artists can use creatively in combination with generative deep learning models. The translation of media through such models translates the text to image and transfers the outcome to a distinct semiotic space which, according to Yuri Lotman, may be different from the input prompt and that the AI model unaware of. This phenomenon is related to Bender and Gebru's findings of language models [4] and is associated with the complexity of dealing with dimensional spaces of meaning. Accordingly, artists can benefit from the potential of AI navigations with text prompts as a creative inspiration and for generating accidental creative outcomes.

According to Yuk Hui's concept of 'cosmotechniques' there is no singular cosmos but instead there are multiple cosmologies that "[...] imply ways of knowing and being that cannot be simply rejected because they don't comply with modern scientific theories" [10]. In craft, multiple cosmologies can also be found, where knowledge manifests through manual work and materiality. Therefore it is vital that the universal cosmos of high-tech (for example, the foundational models used in DL are an example of a singular cosmos) does not erase or constrain our cultural knowledge, but instead is revisited and constantly reinterpreted. Ultimately, it is vital that there be sufficient opportunities for emerging relationships between the agencies instead of opposition.

This paper presents the potential of DL technology for craftwork when working with material. As Sofian Audrey emphasises, it is critically important that artists engage with AI technology in their practice because that is where ethics meet aesthetics. In his words: "[...] artists reveal both the inadequacies of AI and its untapped potential by imagining, through the materiality of AI itself [...]" [2]

Fig. 9. Exhibition view. Final result of ceramic sculpture. *Clouds in my head* (Double Herm of Herodotus and Thucydides) from the sculpture series *Psychedelic Forms* by Varvara & Mar.

4 Conclusions

The paper introduces the novel production method that is text-to-ceramics, which embeds AI into ceramics. The practice-based research methodology was applied to explore creative dialogue and potential between DL technology and sculpture-making in ceramics. The artistic project discussed here juxtaposes archaic craft method and ancient culture with innovative AI technology. The production of AI-assisted ceramic sculptures had four translation phases: exploration to concept, DL to digital, digital to physical, and physical to chemical. This introduces a new translation pipeline that contributes to the field of art and creative AI.

The project's conceptual and experimental properties helped connect the dots between new technologies and ancient production methods. The project demonstrates the artistic exploration of latent space and its translation to material, colour and shape. As a result, recent DL technology mixed with artisan techniques and processes offered irregular transformations that contribute to creativity and augment imagination. In other words, irregular mutations can lead to new creations that would not happen otherwise.

Finally, the study shows that creative AI can be applied to 3D form generation, and most importantly that DL technology can be used in sculpture making. However, this is currently possible only in combination with other digital and CAM tools, manual labour, and craftsmanship. This means that AI is often merely a departure point in artists' creative practice. Thus, the fear that AI will replace artists remains speculation. Nonetheless, in this project DL technology has enabled the artists to achieve unexpected results that would not have been possible without it. As demonstrated in *Psychedelic Forms*, AI can assist in the creative realisation of fictional ideas, thereby pushing the boundaries of technology and acting as a catalyst for the further development of creative AI.

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