STARTS Residency Public Report
Content Aware Studies

***Index Terms*—About five keywords or phrases in alphabetical order, separated by commas**

Meta archeology, epistemic focal biases, aesthetics of computational automation, synthetic generative nature, machine learning, data and normalisation

Content Aware Studies series initiates an inquiry into the possibilities of machine learning technologies as tools for speculative restoration. A pretrained neural network model is directed to replenish lost fragments of the friezes and sculptures and to generate never existed objects of classical antiquity by means of computer vision, machine learning performed on both natural and synthetic datasets consisting of thousands of 3D scans of classical sculptures. The algorithm generates results convertible into 3D models, which are then printed in polyamide and used to fill the voids of the original marble sculptures. It tends to faithfully restore original forms, while also produces bizarre errors and algorithmic interpretations of so familiar Hellenistic and Roman art. The process was developed by an artist in collaboration with data scientists at the University of Southampton engaged in training artificial neural networks.
On one side the outcomes of research provides new perspectives of looking at technologies that are at the center of given research as means for automation and augmentation of historical and cultural analysis, museology and instruments for speculative restoration not only within historical and archeological contexts but also in contemporary applications across machine vision and sensing technics, such as, for example, LiDAR scanning. On the other side given research provides a case study for critical examination through the lens of social sciences (including media studies) of potential misleading trajectories in knowledge production and epistemic focal biases that occur at the level of described above applications and processes. Research is to be continued both in practice, in a form of material productions and theory, as writing and further development of film-essay.

I. ARTWORK

The Content Aware Studies is a series of artistic investigations that spans computational, sculptural, screen-based and textual works that together critically examine what artistic, technical and philosophical capacities machine learning technologies hold, both as means for automatic historical investigation and synthetic knowledge production. The process developed by an artist in collaboration with data scientists at the University of Southampton engaged in training artificial neural networks, directed to replenish lost fragments of sculptures and friezes of classical antiquity and generate never before existing, yet authentic objects of that era. The research examines how a number of advanced AIs: specifically modified General Adversarial Networks particularly known as recent advancements in computer vision, cognition and image rendering operate when trained on datasets consisting of thousands of 3D scans of classical sculptures from renowned international museum collections (i.e., British Museum, Metropolitan, National Roman Museum etc.). The algorithm generates models, which are then 3D printed and CNC routed in marble and various synthetic materials, filling the voids in the eroded and damaged marble sculptures. Some of these algorithmic outputs are turned into new machine-fabricated sculptures uncanny in their algorithmic integrity. They render the work of synthetic agency that lends a faithful authenticity to the forms, while also producing bizarre errors and algorithmic normalizations of forms previously standardized and regulated by the canon of Hellenistic and Roman art.

Recent research in General Adversarial Networks (GANs, a class of machine learning systems) has shown outstanding results in hyper-realistic image rendering. The technology is already in use for both investigation of historical documents, incl. Voynich Manuscript[1] and other reported by Nvidia[2] as well as predictive instrument for modelling futures. However, before celebrating such advancements we might also want to critically examine a role of such form of knowledge production at first place; how do we distinguish between accelerated forms of empirical investigation and algorithmic bias? Will the question survive when such forms-of-knowledge-production become ubiquitous knowledge-governing-agencies? Preoccupied by these warnings and questions on biases, authenticities, immaterialities, automations and historicities *Content Aware Studies* attempts to examine what visual and aesthetic qualities for such guises are conveyed when rendered by synthetic agency and perceived through our anthropocentric lens. What of our historical knowledge and interpretation, encoded into the datasets will survive this digital digestion? It examines new forms of historical knowledge and artistic production and calls into question the ethical implications of such approaches in relation to culture and the notion of endangered anthropocentric world.

The main goals of the residency is to extend the depth of technological approach of the project to deepen its capacities of computer science specific approach to artistic and philosophical investigation. And by doing so examining major notions and concerns that are at the center of artistic and critical narratives posed by the project.
Current outcomes suggest that advanced technical approaches have been successfully applied and delivered more sophisticated results, blueprints of which are ready to meet physical productions. Along with those conceptual framework has been extended and better integrated into existing discourses of new materiality, media archeology, epistemic focal biases and surrounding onthologies. (thanks to prof. Jussi Parikka)

References

1. Parikka, Jussi; A Geology of Media
2. DeLanda, Manuel; The New Materiality
3. Artificial Intelligence for Cultural Heritage Edited by Luciana Bordoni, Francesco Mele and Antonio Sorgente [Cambridge Scholars Publishing]
4. A video clip of 'Arrival of a Train at La Ciota' upscaled to 4K 60fps produced by Denis Shiryaev
5. Bruce, Miranda, The Matter with Matter: New Materialist Theory and the Internet of Things, 2014

II. METHODOLOGY

On Data Collection

The following technical steps were executed for data collection, that was used as the foundation of research. 3d scans of sculptures have been located and collected across various online databases as well as requested from renowned museum collections. The dataset was further extended by 3d-scanning various selected plaster casts from the collections of Hermitage Museum and The Academy of Arts in Saint Petersburg.
Various software based technics were involved for the conversion of data into formats suitable for machine vision and analysis, including rich bit-depth imagery, various color information maps and three-dimensional point clouds datasets.

Technical steps.

1. Collection of data

1.1 Locating appropriate scans in online databases optimizing search inputs;
1.2 Adjusting API access and writing scripts for automation of collecting data;
1.3 Scanning collections of plaster casts from Stieglitz Academy, St. Petersburg and Scientific-research Museum of the Russian Academy of Arts;

[1] Did Artificial Intelligence Really Decode the Voynich Manuscript? Some Leading Scholars Doubt It
[2] New Tech for Old Texts: How Deep Learning Deciphers Historical Documents

Raw scanned data of Telephos Frieze cast from Stieglitz Academy, St. Petersburg

Fragment of a porcessed 3D scan of Pergamon Frieze cast from Stieglitz Academy, St. Petersburg

The amount of collected data estimated more than 4000 of unique 3D models.

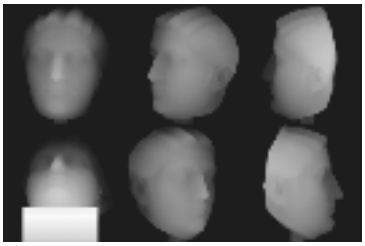
2. Data sorting and classification

2.1 Manually cleaning vast amount of inappropriate automatically downloaded data. ID imagery of the models were used for faster manual sorting of datasets and classification by subject (i.e. friezes, portraits) / era (I.e. Hellenistic, roman, renaissance)
2.2 Compilation of two unique portraits and friezes datasets

3. Conversion of data

3.1 Development of a custom software with basic GUI using TouchDesigner framework for semi-automated depth map conversion and rendering 3D models to produce various synthetic datasets.
We designed a software and UI that allows to rotate models across axises, auto-position, render as raytraced jpeg files and 32 bit depth maps from 10 viewpoints providing 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°, top and bottom views of the model. All datasets included 11753 samples.

Image renders; 1280x1280px jpg files



Depth maps; 32 bit depths, exr files

4. Processing datasets

4.1 We used ImageMagick software to automatically scale, adjust contrast and color space images for pre-training calibration.
4.2 We wrote scripts utilizing Meshlab software for automatic batch conversion of 3D model into .obj format

5. Machine Learning

5.1 We used computational facilities at the University of Southampton as well as especially built portable server with multiple high-end Nvidia GPUs running on Ubuntu Linux;
5.2 We used Tensorflow framework to train various models based on our datasets. We utilized and adopted such neural networks as dcGAN, pGAN, StyleGAN2 and Pix2Pix;
5.3 Networks were modified to allow processing of 24bit png files of depth maps and deliver outputs of the same color depth. Prior to this step a few tests were made to find out that 24bit color depth was necessary to get smooth and generally higher quality geometry when converting depth maps;
5.4 We investigated dramatic differences in outputs produced by various neural networks operating on various versions of dataset;

Outputs from modified dcGAN were achieved comparably faster and produced less realistic and less anthropomorphic results. Outcomes of more advanced neural networks such as pGAN and StyleGAN2 took 3-5 times longer in training time and delivered rather realistic results on both depth maps and image renders;

6. Videos

6.1 Videos as part of the project were produced based on the outcomes of image outputs from training both modified dcGAN and StyleGAN 2 networks on datasets of rendered raytraced images of 3D models;

7. Conversion to solid geometry

7.1 dcGANs network depth maps training outputs were used as shaders for converting to 3D geometry using displacer object class in Cinema 4D software;
7.2 We stitched unique models using several geometries produced from shaders based on depth map projections from multiple viewpoints (incl. 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°, top and bottom views projections)
This step was aimed to test if results delivered by generator are convertible to solid geometry;

Final test 3d solid geometry model was completed in
Materialise Magics software by stitching multiple 3D

geometries produced from shaders based on depth map projections of multiple views

8. Image Completion

8.1 Several models for restoration were selected. Selection criteria was based on two parameters: firstly, finding the most accurate scans in the entire dataset, for further successful and most accurate fabrication, and, secondly, subjective aesthetic decisions;
8.2 The missing areas were marked on various depth map views of selected models;
8.3 We applied deep learning for image completion methods with a trained dcGAN model (paper describing the method: arxiv.org/abs/1607.07539) to generate the content for marked areas on various depth map views of selected models;
8.4 Having received multiple results from various angles we chose the most seemingly accurate and converted them into geometry using them as shaders as described in step 7.1;
8.5 We used Cinema 4D to stitch geometries delivered from various viewpoints projections into solid geometry models of complete portraits;

9. Marble Fabrication

9.1 We used models selected in step 8.1 to prepare stl files for 5-axys marble cnc milling 9.2 Blocks of Italian marble were chosen based on documentations of the original sculptures;
9.2 Programming 5-axys mill and machine operation was outsourced to marble fabrication workshop;

5-axys cnc mill operating on marble blocks

9.3 CNC delivered rough marble drafts of the desired sculptures that underwent manual finishing with the aim to remove stripe shaped footprints left from milling and to add a level of details via the means of classical stonemasonry technics and tools (i.e. mallets, chisels, sanding technics and drilling machines);
9.4 Various nitric acid solution were applied onto final models to achieve an aged marble finish;

10. Scanning and postprocessing

10.1 High precision industrial scanner (Artec Eva) was used for accurate 3D scanning of marble sculptures;

10.2 Scans were cleaned and post-processed with Artec Studio software and Meshlab;
10.3 Scanned results were perfectly aligned with the restored models of original sculptures (from step 8.5) in Materialise Magics software;
10.4 Boolean operations were executed in order to slice the restored and original parts into separate geometries using Materialise Magics software;

11. 3D printing

11.1 Restored fragments (from step 10.4) were prepared for Printing as stl files in Materialise Magics software (this included shelling and mesh simplification);
11.2 Prepared geometries were printed in nylon (Polyamide; also called SLS printing technology);
11.3 Final printed models were mounted onto marble sculptures precisely following their shape and filling the missing voids, while representing accurately materialized data delivered by machine learning outputs;
*Similar technical processes were applied for generating marble friezes with the exception of steps 10 and 11. In case of friezes, generated areas were fabricated in marble along with fragments replicating existing sculptures.

Role of Hardware

The crucial role of the research is dedicated to hardware both on the level of technical specificity and also artistic enquiry. This delves into narratives related to the ideas of non-inert and activated material dynamics that are at the core of the project. In this context hardware configuration enables complex computations, occurring across various levels of software, to eventually shape the material production of sculptures solely based on machine learning outputs. Hence material processes occurring at the level of complex computational apparatus, primarily based on *graphic processing compute units* outputs, define material forms which are converted to marble, CNC routed and 3d printed objects. The hardware here is both agency and authorship, generative means of production and a case study itself.

III. CO-CREATION PROCESS

Describe the functional aspects of the residency and the role of each partner, including resources, communication and production means.

The artist was provided with technical consultations during several review sessions with the Vision, Learning and Control (VLC) research group led by Dr Jonathon Hare and his PhD students; Machine learning computational facilities were provided to the artist by School of Electronics & Computer Science; Data Pitch facilitated communication across departments and various schools within the University of Southampton, including the Winchester School of Art, where an artist held a public talk for BA and MA students. Prof. Jussi Parikka facilitated Egor Kraft's guest seminar on AI and speculative narratives at the Winchester School of Art, Archaeologies of Media and Technology Research group.
The artist was engaged in all the technical steps provided in *Methodology* section above. The artist received and facilitated contribution in a form of data science and programming expertise from his longtime collaborator and programmer Artem Konevskikh. The artist engineered and built a small portable machine learning water cooled server that allowed field work and research take place across various locations. The artist filmed and edited a video-essay on the project including interviews with professor Jussi Parikka, with whom the artist initiated a series of upcoming collaborations to extend theoretical and practical frameworks of the project Content Aware Studies and its methodology.

IV. IMPACT

A. Research Impact

ON RESTORATION AND LiDAR / MUSEOLOGY

EXPLORATION OF TECHNOLOGY

There are many applications of ML aesthetic prediction technology already in use and being rapidly developed, image searching, auto- mated driving, stock prediction, shopping helpers are all being de- veloped using similar algorithms. Code that is able to fill gaps in 3D models by analysing their content with datasets may find its use in LiDAR/terrain scanning. Our ML algorithm architecture and dataset in particular, developed for this project might find its use in restora- tion, preservation and archaeology.

Increasing reliance on such emergent technologies in all areas of life, interaction and in the creation of future knowledge warrant a deeper understanding of (artificial) intelligence and the way in which it will apply meaning and construct future realities.

The work aims to study these potentials, for understanding and gross misunderstanding, for in-depth machine analysis as well as laying bare (literally through the classical figure) the potential for the construction of machine bias and faux-objectivity through, apparently scientific, machine labour.

We would be excited at the chance to further work with international museum collections when building the dataset, particularly the ancient Greek and Roman art collections. This access would give us a wealth of classical figure and form to work with, making highly precise 3D scans of its examples would contribute to the project (and to the museums). These scans would then allow the algorithm to restore and recreate works, producing forms from the apparent and coherent to absurd and disconcerting. As tech project Data Pitch concerns itself with legal frameworks around collection and distribution of data, we would like to develop strategies and approaches for future cooperation with institutions.

B. Artistic Impact

The Role of Materiality

Materiality has reappeared as a highly contested topic in recent art. Modernist criticism tended to privilege form over matter — considering material as the essentialized basis of medium specificity — and technically based approaches in art history reinforced connoisseurship through the science of artistic materials. But in order to engage critically with materiality in the post-digital era, the time of big data and automation, we need a very different set of methodological tools. We may want to address digital infrastructures as entirely physical and to reexamine the notion of "dematerialization", by addressing materialist critiques of artistic production, surveying relationships between matter and bodies, exploring the vitality of substances; and looking closely at the concepts of inter-materiality and trans-materiality emerging in the hybrid zones of digital experimentation.

Content Aware Studies aims to study of the role of materiality as an agent itself forming critical approach in Art today, expanding on the concepts of heritage, time, process and participation of both the viewer and the creator. It ponders upon how materials confront, violate or interfere with the common standards being mediators in processes that are not yet completely understood. It questions methods of preservation and reconstruction along with new challenges in those fields posed by automation and synthetic intelligence. Importantly the project aims to examine and physically embody both interpretations and bizarre misinterpretations of human anatomies and antique subjects through the lense of machine vision, synthetic cognition and sensation. What visual and aesthetic qualities for such guises would they convey when perceived through our humancentric lens? And what of our historical knowledge and mythology / interpretation, encoded into the aesthetics of the datasets will survive this digital digestion?

On New Materiality[3]

The basic idea is: before the clay is sculpted by the artist, it is formless. It only gains meaning, presence, legitimacy and life after it has been given an intelligible form.

[3] Based on and cites Bruce, Miranda, The Matter with Matter: New Materialist Theory and the Internet of Things, 2014

This is an example of hylomorphism: a term from Aristotle to denote the relationship between being and forms—where structure is something that is given to form through being. It has been used as a metaphysical starting point for much philosophy and social theory, whether or not that's been acknowledged. The parallel of hylomorphism I'm suggesting here here is that data is seen as the clay: machines/sensors collect data, to be shaped/sculpted by algorithms and interfaces to be made meaningful.

There have been developments in social theory in recent decades that question this very assumption of matter and capacity. What I'm thinking of in particular is the New Materialist turn.
New Materialism is a theory that's developed recently over the last decade or so, and shares a lot of links with Affect Theory. New Materialism tries not to have a set of maxims, but as a whole it does emphasise a non-anthropocentric approach. Which means it doesn't just pay attention to other organic lifeforms— but also non-organic ontology and agency. It focuses on how all kinds of matter are an organising and agential part of existence.
From the New Materialism point of view: clay as a material is not inert. In fact, it has a very specific molecular makeup, it has specific responses to stimulus, it acts on other bodies in particular ways: for example, it dries out human skin and hardens under high temperature. So instead of passive matter being acted upon by an active life form, the meeting of clay and sculptor is actually an encounter between material bodies, each with their own agency and capacities.

New Materialism might then go on to argue that the capacity to transform that emerges in a specific encounter is immanent within objects, rather than always-already determined from the outside. What this approach does is bring attention to the thingness of things, and gives the assemblages of objects in events a liveliness and complex dynamic. This implies a bigger discussion of methods and practices.

V. ART-SCIENCE INTER-RELATIONSHIPS

Questions in Focus

One of the main questions in relation to technology and culture posed by the projects research is – what are the ethical, philosophical and historical challenges we're facing when using modern automated means of production and investigation. How applications of such technology can allow us to uncover deeper and sharply unsuspected new knowledge but can also mask unacknowledged bias. The Voynich manuscript, a 240-page illustrated manuscript purchased in 1912 by a Polish book dealer, contains botanical drawings, astronomical diagrams, and naked female figures all described in an unknown script and an unknown language that no one has been able to interpret until now. In January 2018 computing scientists at the University of Alberta claimed to have deciphered the inscrutable handwritten 15th-century codex, which has baffled cryptologists, historians, and linguists for decades[4]. Stymied by the seemingly unbreakable code, some have speculated it was written by aliens or that it was a hoax with no hidden meaning. Yet, using a machine learning algorithm over 80 percent of the words have now been found in a Hebrew dictionary, a complete translation still remains elusive. Some scholars have since claimed it was a women's health manual, although this has also been debunked.

Another notorious issue is posed by the story of the infamous Enron Email Dataset, that is well unpacked and artistically expressed in the work *Simulating Enron*[5] of Sam Lavigne and Tega Brain. The publicly accessible email dataset used to develop various algorithms in many common software applications we use today, was in fact generated by a group within the collapsed and disgraced financial institution ran by criminals, a fact which highlights the bias which can creep into apparently objective software tools.

The questions in focus here is to what degree we may and shall be accepting what machine intelligence is able to deliver as a ground for truth when dealing with historical reconstruction of the past. The potential of technological automation for the restoration of collective social memory in *Content Aware Studies* then is connected not only with the concept of meta-archeology, but also with structural psychoanalysis; where AI not only deals with reconstructing fragments and chains of circumstances, but also deals with contents of human consciousness and rewrites the entire large-scale historical streamflow, revealing new causal relationships. Such methodology is essentially synthetic, yet we may claim that many apparatuses designed for research and investigation are, such as the microscope for example. In other words, a more precise way to ask the question will be: to what degree machine learning based approaches help us augment our methods and lenses for analyses as opposed to introducing non-human and machinic logic?

[4] University of Alberta, Using AI to uncover ancient mysteries
[5] *Simulating Enron* by Sam Lavigne and Tega Brain

VI. FUTURE DIRECTION AND ACTIONS

The project is to be continued at the level of physical production, computational development, writing and production of film-essay to serve as documentation of the work and research, a form of unpacking underlying theoretical narrative and ideas and an artistic work itself. Currently the work on the film is planned in collaboration with professor Jussi Parikka as part of a project he is currently engaged in that takes place in Sweden.
A work on the physical production of series of marble portrait and frieze sculptures is planned for the summer 2020. As tech partners project Data Pitch concerns itself with legal frameworks around collection and distribution of data, the artist and tech partner are planning to develop strategies and approaches for future cooperation with institutions, such as for example 3d scanning museum collections. Outcomes of such projects may be beneficial for all parties, i.e. to enrich datasets for artistic research continued by the artist, to help institutions digitize their collections and for Data Pitch to apply their legal framework developments around data distribution. One of the coming goals includes approaching a group of researchers in paleo biology at the University of Bristol and Foundation for Scientific Advancement for potential future collaborations around artificial fossilization.

References

1. Parikka, Jussi; A Geology of Media
2. DeLanda, Manuel; The New Materiality
3. Artificial Intelligence for Cultural Heritage Edited by Luciana Bordoni, Francesco Mele and Antonio Sorgente [Cambridge Scholars Publishing]
4. A video clip of 'Arrival of a Train at La Ciota' upscaled to 4K 60fps produced by Denis Shiryaev
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