# SECRET WHISPERS & TRANSMOGRIFICATIONS:

*A case study in online teaching of Augmented Reality technology for collaborative design production.*

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**Abstract.** This paper focusses on teaching the integration of Augmented (AR) and Mixed Reality (MR), combined referred to as Extended-Reality (XR), and photogrammetry technology into handicraft using an online-taught digital fabrication workshop as an educational case study. Set up in response to restrictions from Covid-19, workshop "Secret Whispers & Transmogrifications" had students and instructors around the world participate in a course that challenged our understanding of educating craft and technology without the necessity of physical presence. The integration of AR into craftsmanship enhances architectural design and fabrication processes as it overlays computation-driven information onto the hands of the end user. These computer-numerically-controlled workflows incorporate and rely on manual actions as an integral part of a process that is typified by inevitable, unpredictable, human error. In doing so, the workshop questions common infatuation with precision in digital fabrication and construction by striving for alternative approaches that embrace the inaccuracies and imprecisions innate to technologically-augmented human craftsmanship. Participants took part in a hands-on clay modelling "secret whispers" experiment that was designed to introduce theoretical concepts and applications of XR technology into the production workflows. This paper concludes by highlighting that the accessibility of today's technology enables AR-enhanced craftsmanship to be successfully taught remotely and online.

**Keywords.** Collaborative design; augmented-reality; mixed reality; human-computer interaction; tolerances and error.

## 1. Introduction

Workshop "Secret Whispers & Transmogrifications" had students and instructors around the world participate in a course that challenged our understanding of educating craft and technology without the necessity of physical presence as being set up in response to restrictions from Covid-19. An online taught digital

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fabrication workshop was used as an educational case study on teaching the integration of Augmented (AR) and Mixed Reality (MR), combined referred to as Extended-Reality (XR), and photogrammetry technology into handicraft.

### 1.1. COURSE FOCUS: INCREMENTAL SLIPPAGE

The workshop website describes how ”*[...] Augmented Reality (AR) integration into craftsmanship promises a radical overhaul of architecture and design production as it brings computational power directly to people's fingertips. Yet, with the hand becoming a key component in these computer-numerically-controlled workflows, innate and unpredictable human imprecision, inaccuracy, and error become an inevitable part of the equation.*” (Crolla et al., 2020). By seeking beauty in incremental slippage from technologically augmented human craftsmanship, ”Secret Whispers & Transmogrifications” challenged the ”Digital's” obsession with control and precision. Participants were exposed to both theoretical concepts and practical applications of AR technology integration in design and production workflows by participating in a hands-on ”secret whispers” experiment. Positioning itself in a ”Post-Digital” context, the work employs alternative notational systems in implementation methods that aim at humanising digital technologies through interplay between digital and analogue material systems (Crolla, 2018).

### 1.2. COURSE CONTEXT: AR AND CRAFTSMANSHIP

With the arrival of easily accessible AR/MR technology, opportunities present themselves for an increased and productive dialogue between collaborating designers and craftsmen, providing greater local agency and prospects for more diverse design output (Goepel and Crolla, 2020). Architects and engineers commonly use AR applications to facilitate information extraction from design information models to improve the efficiency and effectiveness of workers‘ tasks (Chi et al., 2013; Chu et al., 2018). These include onsite applications where AR can be seen implemented in Smart Helmets and Tablets, primarily for helping engineers to make more accurate and rapid judgments for construction review tasks (Ren et Al., 2017). In industrial settings, case studies of AR systems' user experiences have demonstrated their potential to reduce errors in assembly and improve the quality of maintenance work (Aromaa et al., 2018).

Showcases for the integration of AR into fabrication and design processes in architecture and the arts include work from peers that used MR for tasks such as bricklaying (Franco, 2019) plywood construction (Jahn, Wit and Pazzi, 2019) steel artwork production (Jahn et al. 2018), bamboo construction (Goepel and Crolla, 2020), and many more, indicating that a paradigm shift in manual production has been set in motion. Instead of surrendering human skill to automation in manufacturing, AR enhances the human capacities to participate in complex processes through simplified instructions (Goepel, 2019).

We foresee human-computer interaction as in AR/MR to become far more effective in a “Post-Digital” context than e.g. robotics or other forms of computer-numerically-controlled (CNC) production, because AR enables augmentation of onsite skill through the direct visual overlay of specific holographic instructions onto manual actions (Goepel and Crolla, 2020).

### 1.3. COURSE TASK: SCULPTING AND 3D REFERENCING

The workflow and methodology applied in this workshop relied on 3D referencing and 3D replication. This study builds up on prior research in which a series of AR-aided clay sculpting methods were developed and tested in a demonstrator case study and adds to this more elaborate AR-aided sculpting method for remote operation.

## 2. Method

### 2.1. SETUP

The workshop set out as an experiment in which a set of fourteen sculptures, of which digital model files were sourced online, was altered through several morphing cycles that oscillated between the analogue and the digital world. Each iteration began by hand-modelling a sculpture based on a given digital file through the aid of holographic instructions, displayed through an AR application on the participants‘ mobile devices. The result was then captured through multiple photographs, taken with these devices’ high-resolution cameras, that were then processed in a photogrammetry software. The resulting digital 3D geometry model files were then passed on to the next person for the following sculpting cycle until four iterations were achieved (see Figure 1, 2 and 3).

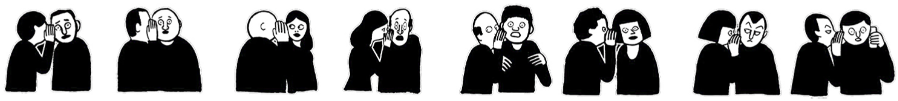

Figure 1. Workshop concept, based on “Chinese Whispers” (image by Jean Julien).

Figure 2. Left: Original sculpture. Middle left: Iteration 1 by Student X. Middle right: Iteration 2 by Student Y. Right: Iteration 3 by Student Z.

To speed up the start of the workshop, the instructors preselected fourteen figures from free access online libraries such as 3D warehouse. These figures were resized and trimmed to similar-scale sculptures using a Grasshopper® script in 3D modelling software Rhinoceros®. Mesh resolutions were automatically optimised to be suitable for seamless AR streaming, keeping sufficient detail for precise modelling. These models were distributed to each student for the first iteration of the secret whisper experiment. Throughout the process, these were gradually transmogrified in three further steps until they reached their final form (see Figure 2 and 3).

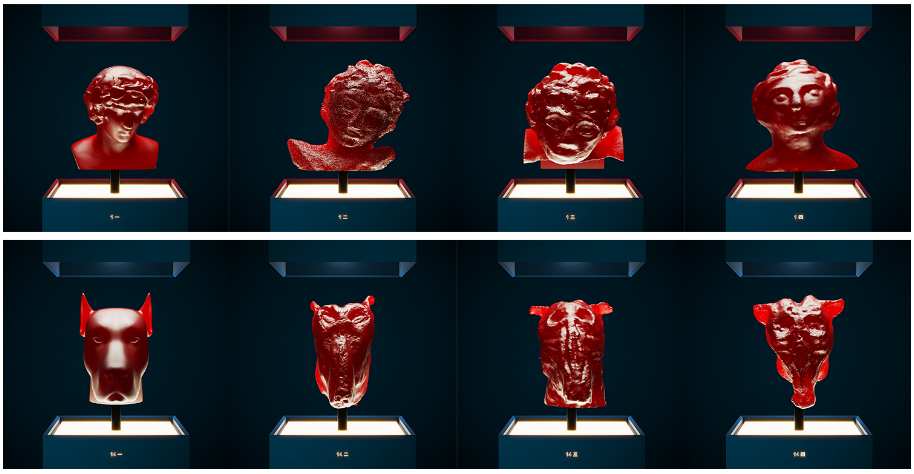

Figure 3. Sculpture transmogrifications.

## 2.2. BESPOKE AR-APP

Fologram®, a Grasshopper® software add-on, was used to stream model data through a custom developed AR application to the mobile handheld devices. The app references itself and the clay block in the real-world environment through an image target placed on the edge of the clay block (see Figure 4).

The custom AR application starts by using a digital bounding box which equals the size of the physical clay block with the to-be-modelled digital sculpture in its centre. The digital sculpture is intersected with several planes to identify and highlight its contouring profiles. An interactive parametric slider determines the spacing between each plane in X, Y, and Z direction. Intersection points are connected with a curve, resulting in several silhouettes in each direction. Using simple control buttons inside the app, users can switch between the X, Y, and Z axis, and through sliders one can decide which silhouette is shown.

Figure 4. View through smartphone of customised AR application, showcasing the overlay of holographic instructions on top of the physical clay model.


Figure 5. Analogue sculpting process informed by holographic instructions.

Augmented reality is then used to holographically overlay this digital information directly on top of the analogue sculpture. App controls give users the real-time ability to switch between the display of the predefined contours and silhouettes, allowing them to decide, as they sculpt, which necessary guides to access to inform their addition or removal of material. This process is repeated until an analogue interpretation of the digital file is accomplished (see Figure 5 and 6).

Figure 6. Top: View through mobile device with holographic instructions and view on clay model where mass is removed or added accordingly. Bottom: Sculpting while viewing through mobile device with holographic instructions. .

## 2.3. PHOTOGRAMMETRY

Photogrammetry software packages Meshroom® and ReCap® were then used to capture the analogue clay sculpture and bring it back into a digital modelling environment. A photo series taken by the participants was used as input to regenerate a digital 3D model approximation of the analogue model (see Figure 7). This digital model was then passed to the next participant for the next modelling iteration.

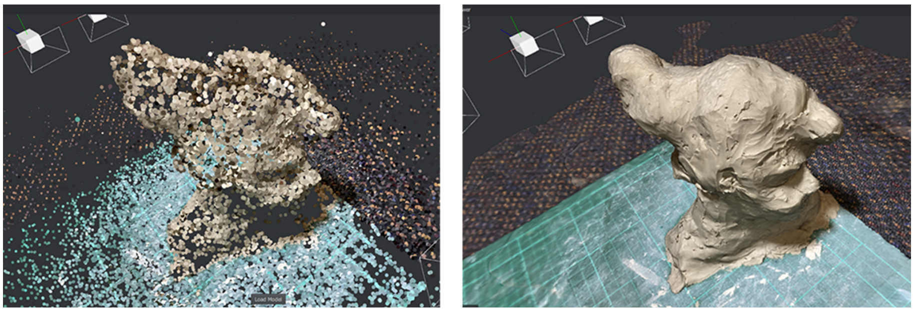

Figure 7. View of scanned clay model in Meshroom photogrammetry software.

Photogrammetry typically requires dozens of pictures of one object, a software setup, processing time to convert the images into a 3D model, and post-processing time for cleaning the mesh outcome in a 3D modelling software. This process can take up to a few hours, depending on the used photogrammetry software.

Good photography skills are crucial to achieve successful photogrammetry result. The object should be captured from all 360-degree angles and from the top, middle and bottom. Image quality and resolution also affects the scan results, with more recent handheld devices with better camera specifications typically producing better results. Artificial lighting can possibly unfavourably affect the scan outcome, whereas daylight conditions typically increase the quality of the final scan. Used computer's processing power also played an important role, as one might only see an unsuccessful result after hours of processing, impacting timelines. Clay properties also effected the scanning result: darker sculpting clays resulted in less detailed scans than light-coloured material, as shadows and highlights of the sculpted clay seemed to be less recognisable for the cameras on dark surfaces.

## 3. Outcome

Unique characteristics and qualities emerged as the transmogrifications by multiple authors accumulated with each step. Three cycles were completed, producing a total of 56 sculptures. Their digital models were rendered for display in an online exhibition presenting the collection in a virtual space visible by means of walkthroughs with 360-degree views (see Figure 8).

This exhibition and website was created with free online virtual tour creator Theasys®, a tool which allows for a series of digital renderings to be interconnected through a navigation system to create and publish a 360° Virtual Tour. The exhibition can be either experienced with virtual reality goggles as an immersive 3D environment or through web browsers where visitors can navigate through the exhibition space by clicking on arrows and using the mouse or finger to direct the view.

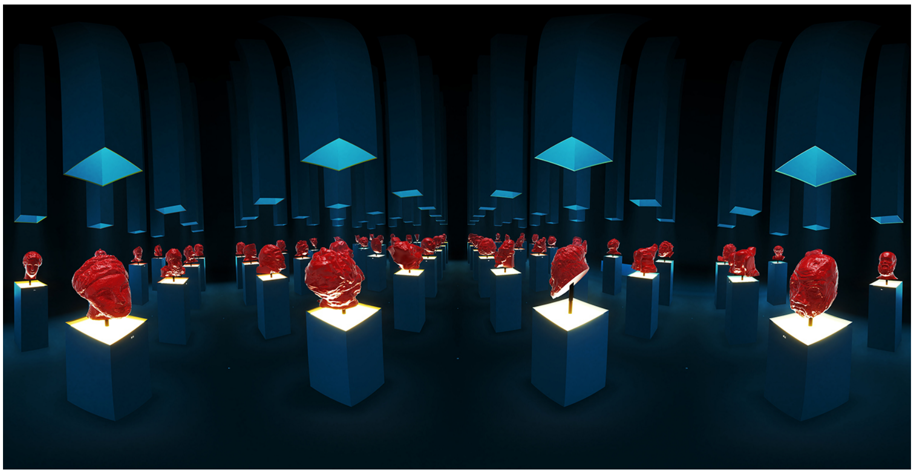

Figure 8. Virtual exhibition.

Exhibition visitors can observe and compare the sculpture transmogrifications which are highly informed by the incremental slippage in the translation of the sculptures. Rather than striving for accuracy in precise replication, the show highlights the emergent characteristics in each iteration, leaving within each sculpture a trace to the multiple co-authors' hands, making the overall a collective art piece.

The photogrammetric scan and the human sculpting hand became the two contradicting authors, placed in a bi-directional dialogue between accuracy and transgression throughout a modelling process centred around the holographic guidelines. A high-resolution scan, for example, will directly affect a following iteration's similarity far more than a low-resolution scan, and a precise replication of the holographic overlay will sway the following scan more favourably than an unprecise copy. The level of participants' prior sculpting skill also substantially differed within the group, which can be observed in the execution of the models. The participants' learning curve for working with holographic guides also affected the resolution of the outcomes. Each participant's first iteration can therefore be seen as a first prototype with the technique, rather than as a well-executed, holographically guided model which can be found the last iterations.

## 4. Discussion and future opportunities

The scanning technology used in this workshop relied on photogrammetry, which today can be accessed with free software and does not require additional hardware. The integration in latest mobile devices of LiDAR hardware, a technology found for example in the fourth generation Ipad Pro and the Iphone 12 Pro, presents an increase in usability and quality of 3D scanning technology. LiDAR stands for light detection and ranging. The LiDAR scanner measures how long it takes light to reflect back from objects, so it can create a depth map of any space you're in (Apple, 2020). LiDAR has been used for several years now, for example in self-driving cars, robotics and drones, but the integration into a mobile device opens up a whole new world of possibilities for 3D scanning and the use of AR. It allows devices to understand their surrounding space by mapping it in 3D, enabling the accurate placement and interaction with virtual AR objects. It also allows for the generation of 3D objects based on a quick scan with apps such as 3D Scanner App. Within a few minutes one can create a meshed-out 3D object. The quality of the 3D mesh scan is not as decent as the method presented in this paper yet, but considering the acceleration of the workflow, we can see a potential use of integration LiDAR mobile 3D scans for future applications.

XR integration today has become rather straightforward: workshop participants were able to quickly grasp the setup and installation of the apps, and an intuitive understanding of the holographic instructions could be observed. The user-friendly interface of the Fologram app permitted participants to just follow the instruction given by the bespoke guides. The Fologram app was streaming information directly from a Grasshopper file, rather than being a standalone app, so a prior knowledge of that platform was helpful, as this allowed users to adapt and customise certain functionalities.

Future studies could benefit from incorporation of other softwares, such as Unity Reflect, that allow sending data from third-party plugins such as Rhinoceros, Revit, or Sketchup to a Unity Reflect cloud server or to a Reflect server on your machine. This data is then pushed to the device of choice, such as IOS or Android phones or the Unity Editor itself where the data can be enhanced. This improves overall workflow, because a live data link can be set up between the base geometry and the applications. This data change can be viewed simultaneously by users across multiple applications.

## 5. Conclusion

Today, AR enhanced craftsmanship has the ability to be taught remotely and online around the world by the aid of XR integration. This study demonstrates that XR and photogrammetry technology have the ability to enhance clay modelling craftsmanship, allowing for a technology-driven democratisation of skill. The incremental slippage between sculpting iterations showcases how, as the hand becomes a key component in these computer-numerically-controlled workflows, inevitable innate and unpredictable human imprecision, inaccuracy, and error can become a constructive, qualitative part of the creative process. In doing so, this study proposes a counter-narrative to common research on robotic or CNC fabrication aiming for high accuracy and precision.

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