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THE EXTENSION OF THE CRAFTSMAN'S HAND BY ROBOTICS

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ABSTRACT

This paper reflects ongoing research about how new technologies create new possibilities within crafting and how new technologies can build on traditional techniques within the field of ceramics. This research explores how the use of robotics extends the craftsman's hand to utilise both the quality of the craftsman's touch and the robot through wire cutting a lump of clay. The research shows how the craftsman can upscale the power and range of the craftsman's hand and, at the same time, deal with small details and repetition beyond the work of the craftsman's hand.

INTRODUCTION

This paper reflects ongoing research about how novel digital means create new interfaces and processes between human, space and material.

The experiment in question in this paper focuses on the possibilities that robotics brings to ceramic craft practice. Focusing on these ceramic practices, the question is how and where traditional craft-based knowledge, rooted in the skills and experience of making three-dimensional objects, can inform novel ceramic processes that utilise robotics, and how such a new technological development opens spaces for new expressions and allows a rethinking of traditions within craft practice.

Craft practice is based on the idea that the interaction with a responding material guides the ceramicist (Leach, 1940; Dormer, 1994; Sennett, 2008), and crafting and execution work together in a way that is intuitive and humanistic (Leach, 1940; Dormer, 1994; Groth et al., 2013). Craft practice can here be understood through its immediate interface to matter and the result of this reflective conversation with the material is for this purpose named *the craftsman's touch*.

The experiment in this research focuses on using an UR robot, also referred to as a collaborative robot or a 'cobot'. The UR robot is characterised by being easy to programme, e.g. by manually recording the movement of the robot's arm.

Instead of thinking of craft and technology as diametric positions, technology is seen as an enabling force following McCullough's (1998) idea about the close connection between digital work and craft practice.

Thus, the project focuses on robotics as an extension of the hand. It is not based on automation or imitation, but rather on the synergy between *the craftsman's touch* and the robot's ability to scale up the power and the range of the craftsman's hand and its ability to accurately handle small details and repetition at the same time

The use of a cutting wire is a classic technique in ceramics that is often used in conjunction with other techniques such as throwing, extrusion or modelling. The cutting wire technique forms the basis for the initial experiments with the UR robot. A cutting wire is mounted on the robot arm and examined through the making of tile and brick-like shapes. The focus is on the curves and traces produced by the wire.

DIGITAL CRAFTING THROUGH THE USE OF ROBOTICS

The typical robot consists of a 6-axis robot arm with a customised tool attached. A robot is not a tool itself but becomes a tool when targeted by the user through programming and the use and design of the attached tool. These tools may vary from commercially developed tools to customised tools developed by the user ranging from simple homemade tools to advanced automated tools.

The Robotic Fabrication Laboratory (RFL) developed by Gramazio Kohler Research at Eidgenössische Technische Hochschule (ETH) in Zürich specialises in robotics and customisation of tools for their research projects. These projects include the use of clay as well. One such example is RobotSculptor: Artist-Directed

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Robotic Sculpting of Clay, which includes a customised loop tool that can be attached to the robot. Professional sculptors use a loop tool for cutting clay when modelling. Their use of the RobotSculptor enables them to define the style of the result and automates the sculpting process executed by the robot's arms (Zhao Ma et al., 2020)

Another example is the Institute of Advanced Architecture Catalonia (IAAC) research on additive manufacturing technology, such as 3D printing in clay. Their research shows examples that enable the customisation of the form of a building on multiple scales, from the global form to the resolution of the section of the wall, including cable robotics for large on-site, scale 3D adobe printing (Dubor et al., 2018).

Finally, another example is the project *Diversity*, a collaboration between the Danish companies Strøjer Tegl https://www.strojertegl.dk and Odico https://odico.dk (Bundgaard, 2021). In the project, they combine clay extruding through a pre-programmed robotic wire cutter. The clay is cut with a metal-wire while the clay is extruded, and by the movement of the wire, the curve and texture are designed as bricks. In this way, the project takes advantage of the soft material of clay in a traditional production technique in conjunction with the advancement of new technology.

These examples represent the different possibilities in the use of robot technology within the field of research. Nevertheless, *the craftsman's touch* is neither reflected in the making nor in the design in these examples. In this research, *the craftsman's touch* is precisely the pivotal for using robotics, and how the idea of *the extension of the craftsman's hand by robotics* should be understood.

METHOD

The method in this research is explorative and based on practical design experiments. Experimental design practice is used as a method of inquiry and reflective practice, in which the designer engages in a reflection through and on the action (Schön, 1993). 'Design is a way of inquiring, a way of producing knowing and knowledge' (Downton, 2003) and are also used as a material practice for knowledge production (Koskinen et al., 2008). The design experiments are concerned with moving away from the known by creating examples of what could be done and how and by general suggestions about a change to design practice (Binder and Redström, 2006, p.3).

AN INITIAL WORKSHOP

The experiment in question is based on a study with a group of first-year bachelor design students at The Royal Danish Academy that was focussing on how robotics extends the craftsman's hand through wire cutting a lump of clay. The experiment was part of an overall exploratory workshop about the possible synergy between traditional techniques and new technologies.

Initially, the students participated in a workshop with only traditional, analogue techniques. It means that no digital tools have been involved in that part. The initial workshop was based on exploring possible surfaces and textures that could be achieved when cutting with a wire through a lump of clay.

The approach was experimental, and associated with the craftmanship of risk and not certainty (Pye, 1968). The outcome had to be revealed and explored through practical experimentation and was unpredictable.

Some examples of the results from the initial workshop are shown in Figures 1 and 2.

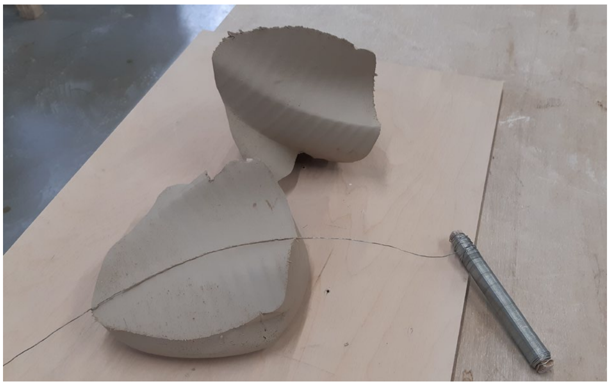

Figure 1. A basic example of wire cutting through a lump of clay

Figure 2. Example of wire cutting through a lump of clay

The students became experienced regarding the idea of *the craftsman's touch* and also familiar with the techniques and materials for the actual experiment with the robot.

The initial workshop results showed various possible curves and surfaces based on the experiential knowledge obtained through the experimentation. The following question for the experiment was how this experience could be transformed and utilised by robotics. The focus was to investigate how this experiential knowledge could be utilised and merged with the ability of the robot to scale up the power and the range of the craftsman's hand and its ability to accurately handle small details and repetition at the same time.

THE ROBOT EXPERIMENT

At first, the students were introduced to the overall setup, consisting of the UR 10 robot with an attached wire tool and a graphical user interface (GUI) for controlling the robot. The graphic interface was based on the graphic programming interface, Grasshopper, developed by David Rutten (http://www.grasshopper3d.com/), which works as a plugin for the 3D-modelling software Rhino (Robert McNeel & Associates http://www.rhino3d.com/).

The overall process within the experiment consisted of the following steps:
1. Recording a movement by moving the tool attached to the robot.
2. Applying a curve to the recorded movement, here named a filter.
3: Executing the cut by the robot arm through a lump of clay.

RECORDING

By manually moving the attached tool on the robot, it is possible to record the robot's movement (see Figure 3). Since the students now were experienced, they were able to utilise and practice the learnings from the initial workshop. The recorded movement maps the intention of crafting with a wire through a lump of clay, based on the idea of *the craftsman's touch*. Crafting and execution are intuitive and humanistic. Subsequently, the robot is able to execute the movement by itself.

Figure 3. The movement of the robot is recorded by manually moving the attached tool.

The recorded movement is reflected as a curve at the GUI, and it is possible to scale the curve up or down, which will change the range for the execution of the movement by the robot. Furthermore, the recorded movement reflected as the curve consists of a number of recorded points over time. Thus, if the movement is fast, then the distance between the points is longer along the recorded curve. The distance between the points is important since it affects the further process.

THE FILTER

In this experiment, the filter represents a curve that is possible to add to the recorded curve before the final execution of the cut by the robot arm. The added curve is referred to as 'the filter' since it adds refined details to the recorded curve without transforming it as such.

The GUI for controlling the filter is shown in Figure 4. A curve represents the filter based on the pre-sets of mathematical graph types and functions that can be manipulated. Furthermore, it is possible to draw and add a curve as the graph manually.

The filter is added and merged in relation to the number of points at the recorded curve and will either be stretched or compressed depending on the number of points. Few points will stretch, and many points will compress. Thus, using the filter makes it possible to add sophisticated and refined details that can be integrated with *the craftsman's touch*.

Figure 5 shows the recorded curve with the filter.

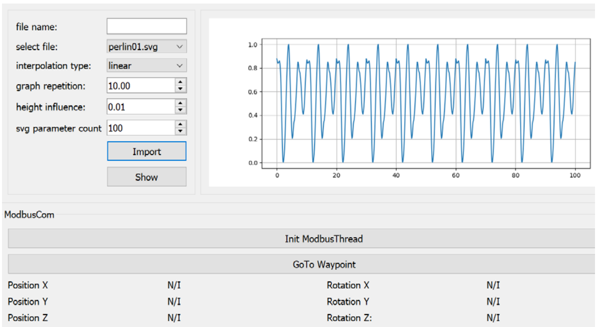

Figure 4. The GUI for controlling the filter.

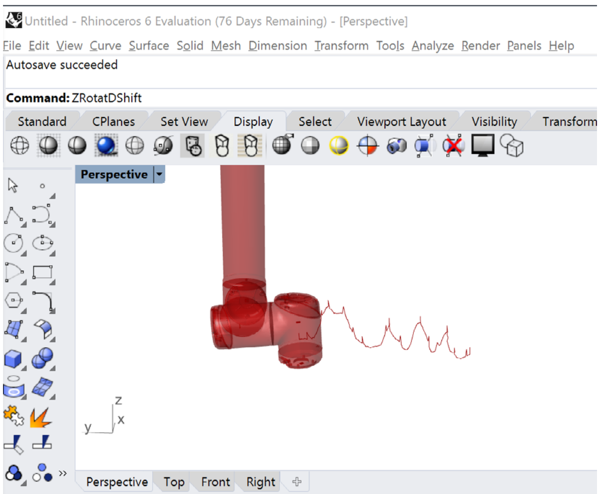

Figure 5. The recorded curve with the filter.

EXECUTION

After scaling the recorded curve and adding the filter, the cut by the robot arm with the attached wire tool is executed through a proper lump of clay (see Figure 6).

Figure 6. The execution of the cut by the robot arm through a lump of clay.

RESULT

The presented process of the experiment was executed several times. Examples of the results are shown in Figure 7–9. What is of interest is how the relationship between the recorded curve and the filter appear. Overall, the curve that steam from the recorded movement is recognisable as the overall curve of the objects. The filter is reflected as lines across the objects indicated with red dots in Figure 7–9. The direction and distance between the lines across the objects are of interest since they reflect the speed and movement of the hands. Thus, the position of the lines reflects how the filter is merged in relation to the recorded curve that is *the craftsman's touch.* Overall, this relationship demonstrates how it is possible to utilise the quality of *the craftsman's touch* and the robot at the same time when wire cutting through a lump of clay.

Figure 7 shows a soft concave object with an overall linear rhythm of crossing lines. Nevertheless, the distance between the lines is not the same on closer inspection. If we view the object from left to right, it is clear that the crossing lines of the object are closer than to the right. Thus, the movement from left to right started slow and then sped up. The crossing lines based on the filter are low but reflect the preciseness and accurateness of the machine. Nevertheless, the crossing lines are dynamic and alive since the distance is not linear, reflecting the personal movement of the hands, i.e. *the craftsman's touch*.

Figure 8 shows an overall dramatic curve, with sharp crossing lines. The sharp crossing lines are striking but appear only a few times and with more or less the same distance. The movement by the hands was dramatic but steadily and quickly executed.

Finally, Figure 9 shows a soft convex object with dynamically clear and defined crossing lines. When viewing the object from left to right, the crossing lines reveal that the recorded movement started fast then slowed down, with some differences in speed in between. At the same time, the crossing lines differ in the distance from side to side. At certain places, the same lines are joined on one side and spread on the other side of the object. Though the lines are precise and similar, they fate across the object. It all shows how the position of the hands dynamically varied in both speed and position.

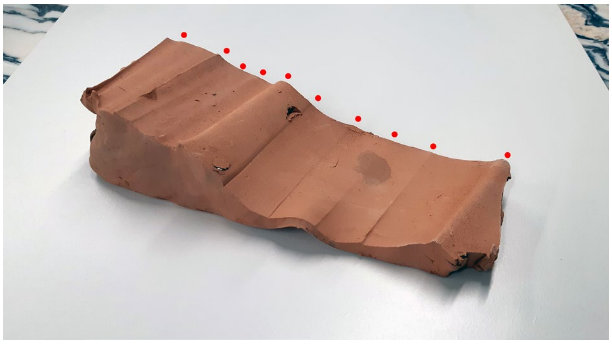

Figure 7. Object with an overall linear rhythm by crossing lines. Length: approximately 50 cm.

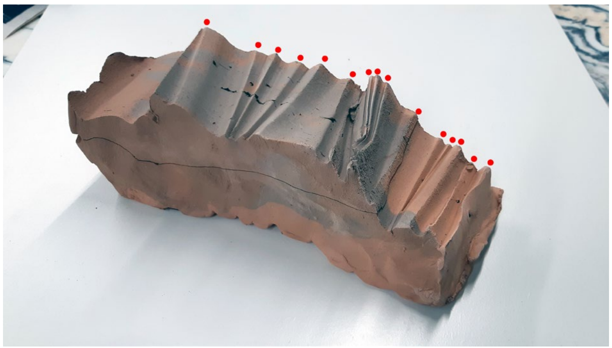

Figure 8. Object based on an overall dramatic curve, with sharp crossing lines. Length: approximately 50 cm.

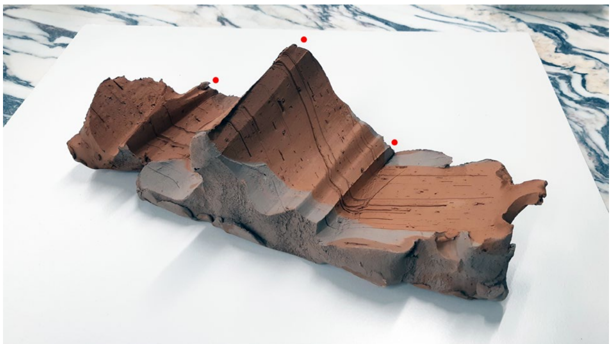

Figure 9. Object with dynamically clear and defined crossing lines. Length: approximately 50 cm.

Overall, the three examples show the possible variation of the setup. The combination of the personal movement and the refined details coming from the filter makes them unique. Thus, the examples represent what the possibilities of the dynamic relationship between *the craftsman's touch* and the robot when wire cutting through a lump of clay.

DISCUSSION AND CONCLUSION

Overall, the experiment has shown how the use of robotics can create new interfaces and possibilities within crafting.

The use of robotics is notable because of its immediate interface to matter, which differs from the experience of using 3D software on a typical computer screen.

Furthermore, the experiment has shown how the use of robotics can extend the hand of the craftsman. By upscaling a recorded curve of the user's hand movement and subsequently applying a detailed curve to the recorded movement as a filter, the results of the experiment have shown how it is possible to extend the craftsman's hand in a way that includes both large and small scale at the same time.

The experiment was based on an initial workshop with only traditional, analogue techniques following the idea of *the craftsman's touch*. No digital tools were involved.

Nevertheless, though the approaches are similar, there are important differences to consider between the initial workshop and the robot experiment in question. The wire cutting in the initial workshop was based on the handhold wire tool as a one-step process. The wire cutting by the robot experiment was a process with several steps: recording the movement of the hands, applying the filter, and executing the wire cut by the robot. In addition, when recording the movement, there is neither a visual feedback nor resistance from the material. To the idea of *the craftsman's touch* interesting aspects are still to be developed.

Nevertheless, the experiment has identified useful, interesting results to build upon. The recording of the curve links to the idea that crafting and execution work together. The application of the filter and the ability to scale up the range and power of the recording opens spaces for new expressions and allows a rethinking of traditions within craft practice.

A further step is to control the robot in real-time by a device such as a Wii-mote. Controlling the robot in real-time by a device makes it possible to have the filter and the change in scale as an integral part when crafting by the use of the robot. Working in real-time will provide a one-step process and visual instant feedback, which will allow a further extension of the craftsman's hand based on the idea of *the craftsman's touch*.

Thus, the robot experiment has demonstrated how it is possible to build on traditional craft-based knowledge by the use of new technologies. This is not limited to the field of ceramics but is representative and relevant for similar craft fields such as textile, fashion, and furniture design where the immediate interface to matter is of special relevance.

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