Traditional Knowledge on Modern Milling Robots

How CNC-joinery machines promote a renaissance to lost techniques in the profession of a carpenter.

Wolfgang Schwarzmann¹
¹ University of Liechtenstein, Institute of Architecture and Planning; https://www.uni.li
¹ wolfgang.schwarzmann@uni.li

The profession of a carpenter is changing significantly. Over the last 20-30 years, CNC-joinery machines became ready to penetrate the market and lead to a significant optimization of daily processes in these firms. In this case study, we take a closer look at the working techniques of a carpenter in the Bregenzerwald. This skilled craftsman found a way, of how to translate his expert knowledge on to a CNC-joinery machine. Instead of only following modern, simplified construction methods, he tried to revive historic methods and developed a way to translate his expertise. By scaling up on a technological basis, he was able to reintroduce the so-called ‘Dovetail joint’ and by that managed to erect the first proof of concept, a single-family house. This research shows, how a new integrated robot enables a way of manufacturing, that otherwise might not be affordable anymore. Benefits of this approach can be seen on a variety of economic and ecologic aspects. As mentioned by the carpenter, these results are encouraging, but for him, the real advantage is the increased empowerment to skill, craft and knowledge typical for his profession.

Keywords: robotic fabrication, carpenter, renaissance, knowledge, tradition, wood construction

INTRODUCTION - CRAFT AT A CHANGE

In central Europe, the profession of a carpenter can rely on a rich and long-lasting history of at least 4000 years (Gerner, 2002). Even though the overall description of these experts on wood almost remained to be the same, the field of activity covered by a carpenter has changed. A continuous stream of technological innovation could be observed. Gradually a change of the former labour-intensive manual work progressed towards a ‘machine supported wood craftsman’.

In this paper, we are going to take a closer look at one specific way of joining wood and by that illustrate a process of translation between men and machine in the environment of a carpenter. The so-called ‘Dovetail-joint’ was a typical and frequent way of joining wood, already used in ancient times. While this seemingly simple connection only consists of a pin and a tail, a high level of precision is crucial when
manufactured. Craftsmen have to gain a significant skill and develop a material-specific knowledge to develop appropriate solutions.

At the beginning of the 19th century, the industrial revolution gave these needs a turn. The industrial rise of nails, steel brackets and other metal fasteners made this labour-intensive way of joining wood expire (Schindler, 2009a). Besides these developments on a material basis, the upcoming science of engineering promoted structural calculations towards a more frequent use of steel parts (Polónyi, 2014). These economic and structural developments fostered a slow but steady vanishing of the ‘Dovetail’.

PROGRESSION OF CNC-JOINERY MACHINES

Since the early 1980s, a turn in wooden manufacturing can be seen. Digital tools promote a faster and more accurate production of wooden constructions. While the very first joinery-machines gave an increase on manufacturing time and precision, a raise in construction complexity could be observed since 1990 (Jeska, Saleh Pascha, & Hascher, 2015).

Even though the industry might already work with robotic manufacturing since the late 1950s (Heßler, 2014), a real starting point of CNC-robots in wooden workshops could be observed from 1989 on. According to the self-claimed world market leader in ‘CNC-joinery machines for wooden workshops’ (Figure 1), it was the first time that CAD-files were directly sent from a computer to a joinery machine (Hans Hundegger AG). As a direct response to a personal request, the Senior Sales Manager, Wolfgang Piatke of Hans Hundegger AG could provide a deeper glimpse. Until 2020, the Hans Hundegger AG shipped approximately 3000 CNC-joinery machines (P8/P10/K1/K2 and ROBOT Drive). Their core business can be seen in the European Union with only a few deliveries to North Amerika. For Piatke the diverse business area of CNC-joinery machines can be explained due to a wide variety of different workshop structures. These structures range from a small family-business (primarily in GER, CH and AUT) to large production plants (North Amerika) (Piatke, 2020). The company is able to cover a broad spectrum of different technological needs, aligned to the individual requirements. However, further research in the ongoing research project shall be invested to collect more data on these application characteristics.

Figure 1
Hundegger K2i working on a Dovetail (Hans Hundegger AG, p. 21); These robots represent affordable and ready-to-use solutions for a carpenter workshop. Even though they optimize issues like precision, speed and complexity of the manufacturing process, they definitely change the workflow and skill of a carpenter.

These technological advantages establish a new basis for the reintegration of wooden connections. While these wood-wood joints were to labour intensive a few decades ago, CNC-joinery machines now operate fast, precise and at a fraction of cost compared to manual work. As described by Jeska et al. (2015) this new application of ‘old’ wooden connections does not only replace steel connections and increase aesthetics in architecture; it furthermore has to be understood as a renaissance of traditional manufacturing techniques with a sense of novelty.

Similar approaches to translating historic knowledge into a modern way of manufacturing were already conducted by Gros (1993), Brugnaro and Hanna (2018) and Klein (2015). By developing a new interpretation of the ‘Ulmer Hocker’ (originally designed by Max Bill, in 1954) Gros (1993) showed, how a design classic can be interpreted in a modern production language (Figure 2). As part of his research, Klein (2015) showed how the craft of Irish crochet could be adopted to a 3d printer which leads towards a new, more contemporary interpretation of textile craft. The final presented ‘Incunabula Dress’ does not aim to imitate historic designs but progresses towards a new aesthetic of crochet. Klein (2015)
translated the intelligence of knitting instead of just repeating shape and form. Recording the human movement when carving a piece of wood and afterwards translating these actions on to a robot were investigated by Brugnaro and Hanna (2018). Their research showed a way of applied 'machine learning' based on human craft, that leads to a variety of craft-inspired design solutions. As finally pointed out by Brugnaro and Hanna, further research needs to be done towards new developments considering the knowledge transfer between ‘human’ and machine.

METHODS
In this ongoing research project, data was collected by conducting an interview with Berchtold (2020). This interview frames the first position in the ongoing research project. As next steps, it will be supported by further expert-interviews, participatory observations and qualitative data sources. Being an experienced carpenter, Berchtold is running a carpentry in the region of Schwarzenberg, Vorarlberg. He and his company (including his employees, machines, etc.) will be treated as being one case. As described by Kumar (2019) a case study can be conducted as ‘in-depth explorations’ that will provide deeper insights into a topic. Information was gathered through observations in the workshop, an analysis of their webpages and by conducting an interview with Berchtold. Due to his unique background, his valuable knowledge and his years of experience as a carpenter, Berchtold can be seen as an expert on the topic of wooden constructions, especially on the manufacturing processes of wooden structures typical for his region.

In this paper, the results will be interpreted in accordance with Actor-network theory (ANT). This theoretical and methodological approach shall help to develop a deeper understanding of the constantly changing relationship between human and technology (Belliger & Krieger, 2006). Arguing in the way of Latour (2006), the presence of technology transforms/translations its surrounding fundamental. Considering these thoughts, it can be said that a carpenter who now owns a CNC-joinery machine, is a different Carpenter than he was before (not only just because of scaling up on a technological basis). The new technological opportunities extend the range of possible solutions, but on the other side cause an unavoidable transformation of the characteristics that were formerly implied by this craftsperson like craft, skill, perception and so on. Following the argumentation of Latour, borders between ‘men’ and ‘machine’ start to blur gradually. A strict separation between ‘human’ and ‘technology’ can/could never be drawn. Equipped with these new, physical and digital extensions, the craftsperson now ought to be described as a ‘CNC-joinery-carpenter’ illustrating a more up-to-date image of this craftsperson. At some point, the machines we operate, the technology we make use of, defines what solutions we are able to offer and implies how we work, inferring what the final product will look like. On the other hand, the machines themselves represent a structure, an accumulation of sensors, actuators and programs that were designed by engineers and designers with the intention to support craftspeople in the very best possible opportunity. The final developed product, in this case, a CNC-joinery machine, will only offer as many solutions, as the construction-team was convinced to imply. Wooden connections that were used infrequently on a manual basis are very unlikely to be translated into the machine program. Therefore, these options will not reappear on the CNC-joinery machine. Possible
solutions a craftsperson might have been able to offer, are then out of reach.

This permanent moment of translation, affects both, object and subject, leading to a continuous process of transformation in the perception/profession of a carpenter and the supporting technologies. This research shall provide another position in the continuous discussion concerning the evolution of human-machine interface, or more precisely state an additional perspective to current research trends (Figure 3).

Figure 3
Men and machine – working together (Schwarzmann, 2019); This image illustrates the current situation of a carpenter and a robot, working together on one piece of wood. The historically rooted profession of a carpenter therefore does undergo a significant change, concerning its way of manual work.

RESULTS
‘Well, the times changed, the demands changed [...] once, there came a time when craftsmen didn’t find the time to make a wooden connection anymore. Everything that was left was a straight cut, a steel bracket and some screws’ (Berchtold, 2020).

Following this quotation of Berchtold, a little frustration concerning the profession of a carpenter in the 21st century can be heard. Similar observations were noticed by Schindler (2009b) who named the steel nail as the end of any manual skill by craftspeople. Induced by his perceptions, Berchtold decided to establish a different approach towards his moral concept of a modern carpenter. For Berchtold, three core values had to be fulfilled to meet his demands of craft:

1. **Cost: The result has to be affordable.** As described by Berchtold, a wooden construction has to be affordable for an average client, with an average project and budget. His new approach shall be an option for all kind of future projects.

2. **Regional resources: Construction material has to be regionally available.** The primarily used building material has to be available in a radius of about 20-40 km. Due to the fact that the workshop of Berchtold is located in a rural area with nearby forests and sawmills, the utilization of industrial engineered wood (CLT, glulam timber etc.) was rejected. To meet the guidelines for insulation, statics etc. large pieces of solid timber (single pieces of solid wood, 30x30cm in cross-section) were chosen. Manipulating these huge logs does require specific skills and knowledge when being dried and processed.

3. **Craft: Construction has to meet his definition as being authentic to the profession of a carpenter.** As defined in the short quote above, the craft inherited by a carpenter did change over the last decades. The concept of Berchtold is characterised by his unique regional surrounding, his cultural network and his own definition of craft. For him, the profession of a carpenter has to be more than just erecting wooden constructions, in the most efficient way. Economical decisions and a constant longing for optimisation transformed the job of a carpenter. Furthermore, in Austria, every company has to educate young craftspeople. Therefore, Berchtold felt responsible to teach these ‘craftspeople of the future’ on a broad variety of construction methods.

Following these three core values, Berchtold found traditional log construction to fit best for his demands. This way of erecting a building can rely on a rich history and therefor provide numerous examples. Especially the corner styles of a log building (dovetail, tooth-edged joint, saddle notch etc.)
seemed to rise a challenge, worthwhile conducting for him.

‘Why can’t we just take a way of constructing a building that did proof for the last 300, 400, 500 years. Something ... where we know what we are talking about ... and just translate it to meet today’s needs!’
(Berchtold, 2020)

Since a few years, the workshop of this carpenter owns a ‘Hundegger’ CNC-Joining Machine. Even though the machine comes with a bunch of pre-programmed dovetail-solutions that might fit for a simple log building, these solutions miss some crucial details concerning structural and functional needs. As described by Berchtold, these pre-programmed dovetails did miss, for example, a so-called ‘wind comb’ (in German, transl. ‘Windkamm’).

At first glance, these details might not look important, but as described by the carpenter, especially these small details did prove to be essential additions when dealing with massive pieces of wood. Figuring out this lack of knowledge in a pre-programmed solution, he got into contact with the machine supplier ‘Hans Hundegger AG’ and started to elaborate on an improved version of their ‘corner-dovetail’. With his carpenter knowledge, Berchtold convinced the ‘Hans Hundegger AG’ towards an optimised solution while the company took charge of all technical issues concerning the CNC-machine. As a result of this joint venture, a traditional dovetail, translated into the language of a modern CNC-joinery machine was developed. Even though the modern solution did look slightly different (due to the milling tools characteristics like round corners on the inside, instead of sharp ones etc.), the ‘intelligence’, the structural behaviour and the material optimization of a traditional connection could be reintegrated (Figure 4). Later on, the exterior corners will be covered with wooden cladding.

Equipped with this new Dovetail-solution, Berchtold could fulfil all three predefined core values. To give the first proof of concept, the carpenter could erect a single-family house (Figure 5). As concluded by him, the success of this project was only possible due to the extensive implementation of his CNC-joinery machine in combination with their expertise.

‘[…] starting a new project right from the absolute beginning, that’s what filled us with pride and confidence. Well … these days [when erecting a building by hand] were exhausting, but they [the craftsmen] could see the whole work from another perspective, in some kind of… as we did it a hundred years ago. […] these challenges, that is where you really can develop your personal skills. (Berchtold, 2020)

Even though a CNC-joinery machine did most of the processing steps, the final project does meet his definition of wooden construction, built by a carpenter. As described by Berchtold, this way of erecting a building is only slightly more expensive than compared to a cross-laminated wood construction (CLT). When comparing the overall building cost to a CLT-construction, the increased cost tend to rise for about 1-2% of the whole budget. In this case, the client was willing to get a building made from regional wood and therefore had to spend an additional 7.000€.
DISCUSSION

Why not imagine a unified design and fabrication process based on a series of conversations between men, designers and workers, and machines, computers and robots? (Picon, 2014)

Following the argumentation of Picon, the ongoing debate on digital transformation in craft has to be seen as a broader discussion between all involved ‘Actants’. When asking the question whether a carpenter/human or a machine/robot built this house, an answer might sound like ‘none of both, but only both of them’. Arguing in the line of Belliger and Krieger (2006), a machine has to be interpreted as a partner, not as simple ‘tool’.

Currently, a lot of research is being done towards new implementations of robots in construction processes. These projects, mainly fostered by architects, designers, engineers etc. could benefit from the experiences possessed of craftspeople and the people who operate these machines on a daily basis. These people own deep and rich knowledge, acquired in uncountable spent hours of working and reflecting on the material/result and therefore might be able to deliver valuable insights.

In this case-study, the carpenter did make use of knowledge, unique for his profession and was able to translate it to a contemporary technological solution. With his insights, he managed to innovate a poor pre-programmed dovetail that is regularly shipped with a CNC-joinery machine. His desire for improving an unsatisfying solution motivated him to translate his expertise and hand it over to a machine supplier who then rearranged the technological circumstances (Figure 6).

The carpenter (together with the machine supplier) managed to translate his knowledge into a language that can be understood by the CNC-joinery machine. On the other hand, the machine enabled new opportunities that the carpenter otherwise could not offer anymore. Only if the carpenter understands, how to translate his knowledge into a form that the machine can handle, an appropriate solution will result. Therefore both involved ‘Actants’ (the carpenter and the CNC-joinery machine) had to find a way to communicate, a mode of translation, to interact with each other. As a result, this mutual approximation does unavoidable influence the ‘craft’ of a carpenter but also the ‘processing’ of the machine and in conclusion, the final revealed product. We, therefore, have to confess that a carpenter with a machine, is a different carpenter than on without.

CONCLUSION

This paper has to be seen as a further contribution to the ongoing discussion of human-machine collaboration. The carpenter in this case made use of modern CNC technology and furthermore found a way to reintegrate his singular expertise when constructing with wood. Knowledge that was crucial for the last few hundred years, but then pushed back over the last decade, now reappeared as contemporary interpretation. In this case, another approach of a human-machine collaboration could be observed. Therefore the ‘machine’ did not only optimize speed and precision of production but furthermore enabled the application of wooden connections that otherwise would not be affordable anymore.

The solution, developed by Berchtold suggests a reintegration of human knowledge into modern production technologies while acting in awareness to his craft specific historic roots.

By developing a solution that follows a line of historic instruments (axe, saw, etc.) but acts with the current state of technology, he could develop an ap-
Figure 6
(Re-)Evolution of the Dovetail in this Casestudy: When illustrating this process of 'reintegration of traditional knowledge', three characteristic stages have to be considered: 1) the 'historic craft', when building material was costly and in comparison, wages were low (until 19th century). 2) The 'industrial solution': when wages rose in comparison to material cost and therefore cheaper solutions than the 'wooden dovetail' were available (20th century). 3) The now available technological solution (CNC-joinery-machine) offers the possibility to fabricate historic solutions at a fraction of cost. The provided case study shall illustrate this process of 'reintegration of traditional knowledge'.

approach to meet his definition of modern craft. This moment of translating knowledge between human expertise and upcoming robotic solutions frames the core of this research and therefore will be further explored in the next steps of this ongoing research project.

REFERENCES
Hundegger AG, H n.a., 'Innovationen für den Holzbau', in Hundegger, H (eds) n.a., Brochure by Fa. Hundegger, Hundegger AG
Berchtold, G 2020, Insights of a Carpenter in the 21st century in the region of the Bregenzerwald, no thesis type given, Interview conducted by Schwarzmann, W
Brugnaro, G and Hanna, S 2018 'Adaptive Robotic Carving: Training Methods for the Integration of Material Performances in Timber Manufacturing'; Robotic Fabrication in Architecture, Art and Design
Jeska, S, Saleh Pascha, K and Hascher, R (eds) 2015, Neue Holzbautechnologien: Materialien, Konstruktionen, Bautechnik, Projekte, Birkhäuser, Basel
Pallasmaa, J 2015, The thinking hand: Existential and embodied wisdom in architecture, Wiley, Chichester
Piatke, W 2020, Direct Email correspondence, no thesis type given, CSO - Hans Hundegger AG
Schindler, C 2009a, ‘Genagelt und geschraubt’, Arch plus,, 193, p. 35
Schindler, C 2009b, Ein architektonisches Periodisierungsmodell anhand fertigungstechnischer Kriterien, dargestellt am Beispiel des Holzbaus, Ph.D. Thesis, ETH Zurich
Schwarzmann, W 2019 ‘How Does the Process of Industry 4.0 Change the Job of a Carpenter?, Börekci, Kocyildirim et al. (Hg.) 2019 - Proceedings of DRS Learn X, pp. 949-952