Zukunft Bau

SHORT REPORT

Title

Longtitle: "Human-Robot-Cooperation in Timber Construction: Potentials for Prefabrication

Motivation

Nowadays timber construction is based on lightweight construction systems with a very high degree of off-site prefabrication. The level of factory floor automation in timber construction however still remains very low compared to other industries. The goal of this project is therefore to analyze and evaluate a possible use of collaborative human-robot fabrication in order to increase the level of automation in timber construction prefabrication while keeping it flexible.

Subject-matter of the research project

The research is based on four-step approach of analysis, systematization, development, and evaluation: based on the analysis of the current state of timber construction and available human-robot collaboration (HRC) technologies and a systematization of the findings, feasible HRC workflows are developed and evaluated through a series of production system research prototypes. This approach is reflected in the four general work packages: process analyzes, identification of potentials, review of areas of application, and evaluation through prototyping.

The investigation was from the beginning specifically focused on finding solutions for small and medium sized enterprises (SME) that creates absolute majority of timber construction companies in Germany. The industrial partners Müllerblaustein Holzbau GmbH and KUKA Roboter GmbH supported the research project to this end.

In the **first work package** a thorough investigation was conducted of modern timber construction prefabrication processes and the analysis of the whole prefabrication chain. The tasks involved in timber construction prefabrication were categorized and decomposed to their atomic processes. In parallel an overview was compiled of available HRC technologies and common scenarios in other industries as well as the relevant normative documents.

The **second work package** of the investigation focused on identifying promising applications of HRC in the timber construction prefabrication chain and possible technological solutions. The processes with a high potential were divided into two broad categories with respect to the character of the work: dirty, dull, and dangerous processes, on the one hand, and processes that require significant adaptation to their implementation from project to project on the other. Four specific subcategories were further selected and evaluated in more detail: Assembly, quality control, repeating tasks and logistics, and heavy und unpleasant tasks.

In the second part of the work package, the HRC was evaluated in a larger perspective and divided into two general branches: cognitive collaboration and behavioral collaboration. From technological point of view, a human-robot communication was determined as a crucial aspect of any successful HRC strategy. As a conclusion of the evaluation, three high level HRC strategies were identified to be investigated in the next steps: "occasional coordination", "transfer of tasks", and "direct cooperation".

In the **third work package**, the three previously mentioned HRC strategies were further developed and concretized. They were evaluated based on their innovation potential and level of automation and an implementation strategy was outlined for each of them.

In parallel, the **fourth work package** focused on development and testing of the HRC strategies described in work packages two and three. In total two larger experiments were conducted. The first experiment focused on "direct cooperation" and aimed to develop a universal collaborative robotic workbench that can be successfully used even by users with a minimum programming knowledge. A specific emphasis was put on the human-robot communication in form of an augmented reality (AR) interface. The experiment was realized in cooperation with KUKA AG and the result was exhibited as one of the finalist projects of the KUKA Innovation Award at the Hannover Fair 2018.

The second experiment was conducted as a part of larger research project of a wide span timber plate shell in cooperation with Müllerblaustein Holzbau GmbH. The experiment focused on improving a fabrication of the timber plates

using the methods of "occasional coordination". A goal of the experiment was to design and develop collaborative spaces for a safe material and semi-finished product handover between the human workers providing the logistics and the fully automated robotic cell. The resulting timber shell was exhibited as a part of the Bundesgartenschau Heilbronn 2019.

Conclusion

The two conducted experiments outlined the potentials of HRC in timber construction and possible implementations. The goals of the research project were therefore successfully met. Available technology renders even standard industrial robots safe and capable of simple cooperation with humans in a close proximity. It was proven that HRC can radically improve the prefabrication workflow in timber construction. Nevertheless, further research is needed to achieve a seamless human-robot collaboration. To reach higher levels of cooperation it is necessary to further improve the understanding of human intentions as well as carefully design the human-robot communication interfaces.

Key data

Kurztitel: Mensch-Roboter-Kooperation (MRK) im Holzbau

Forscher / Projektleitung:

Universität Stuttgart
Institut für Computerbasiertes Entwerfen und Baufertigung (ICD)
Prof. Achim Menges
Oliver David Krieg
Ondrej Kyjanek
Tobias Schwinn

Gesamtkosten: 264.331,11 €

Anteil Bundeszuschuss: 142.200,16 €

Projektlaufzeit: 24 Monate

FIGURES:

Figure 1: ICD_MRK-Abb_1.jpg
Implementation of the Collaborative Robotic Workbench (CRoW) at Hannover Messe 2018

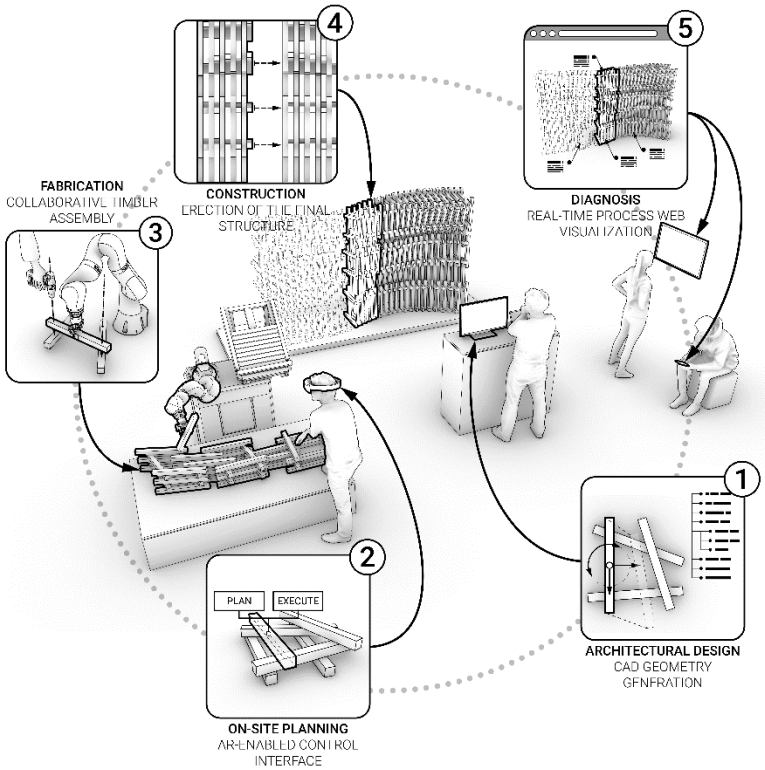

Figure 2: ICD_MRK-Abb_2.png
Process diagram of the Collaborative Robotic Workbench (CRoW)

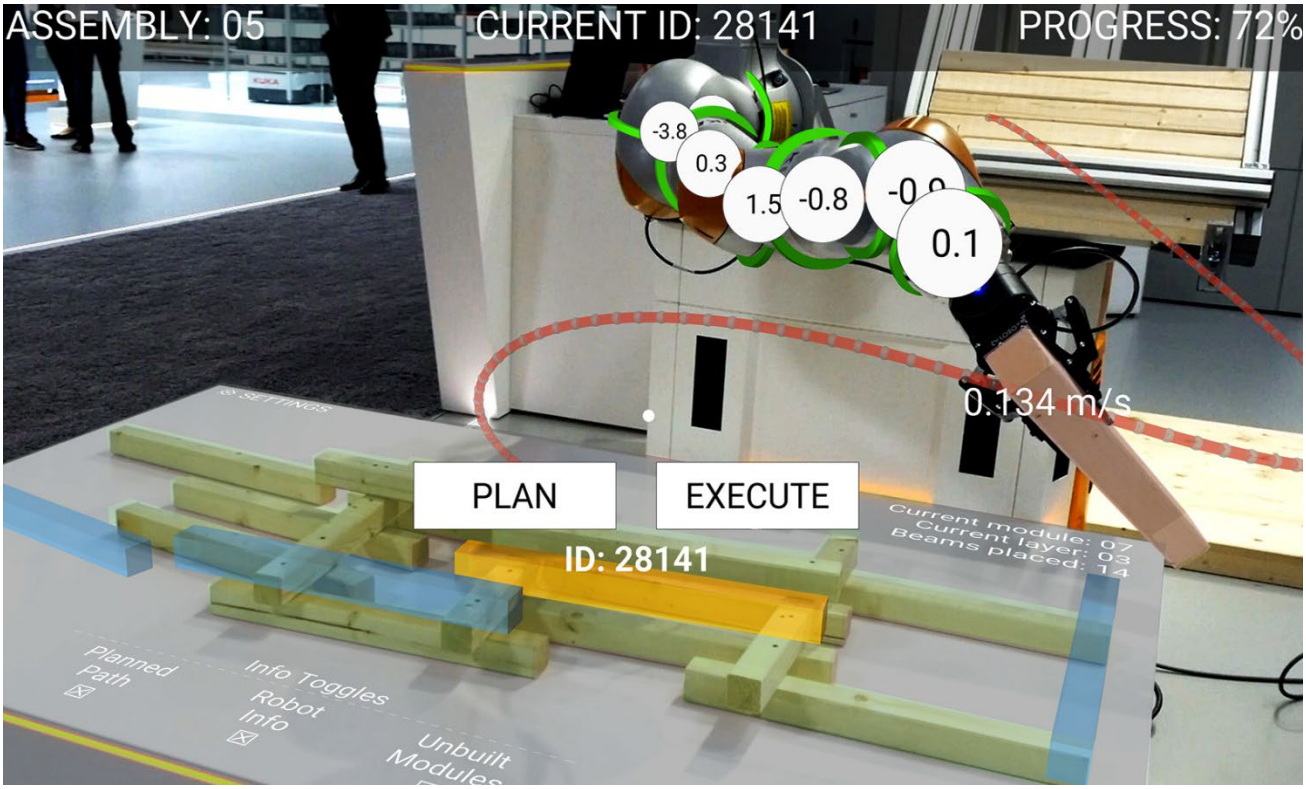

Figure 3: ICD_MRK-Abb_3.jpg
Augmented Reality-Interface

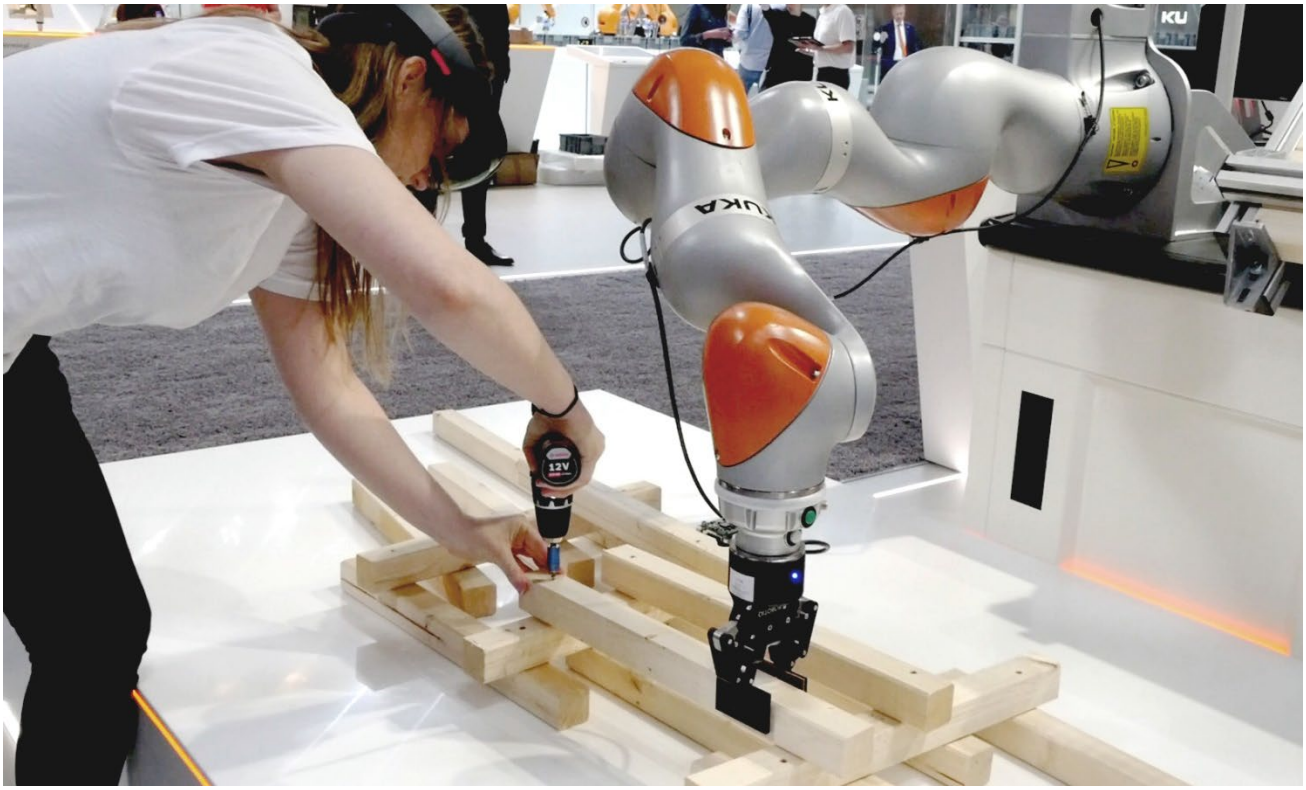
Figure 4: ICD_MRK-Abb_4.jpg
The collaborative assembly process

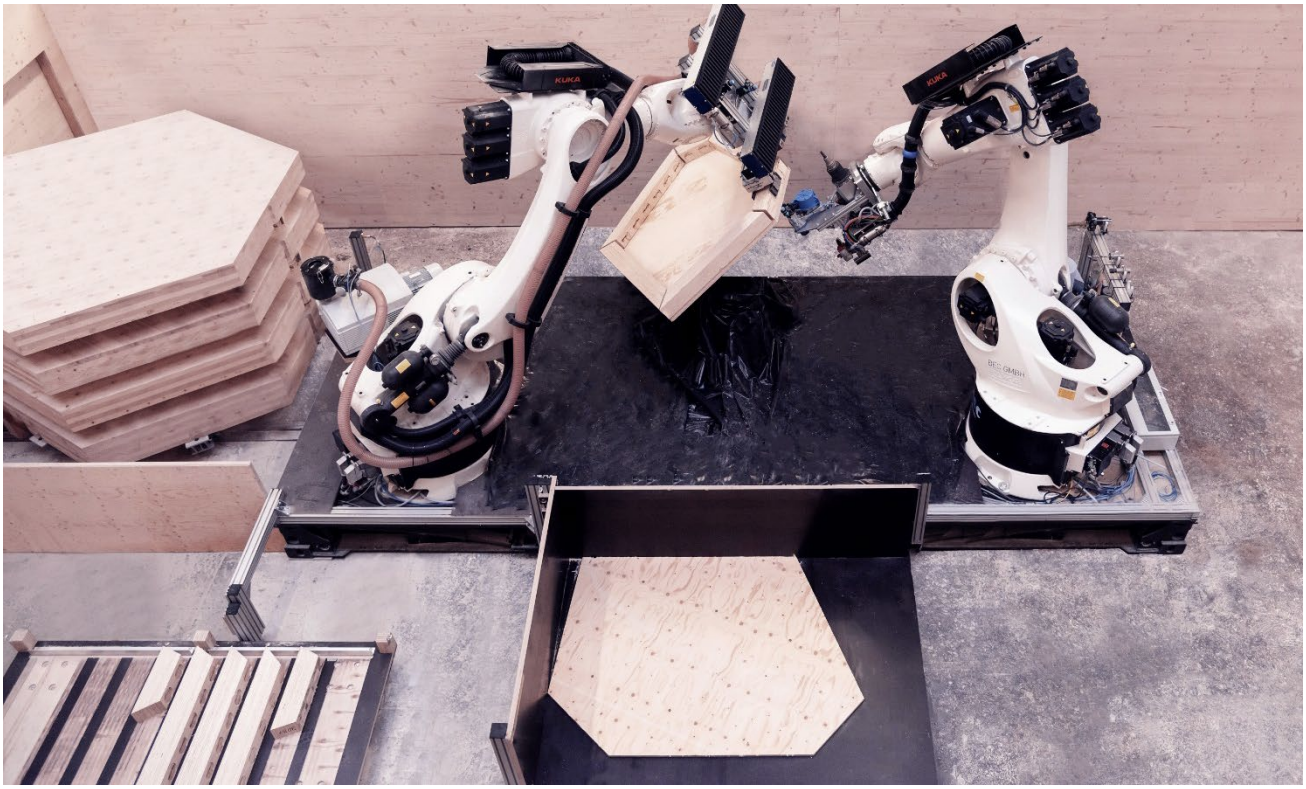

Figure 5: ICD_MRK-Abb_5.jpg
Robotic cell for timber plate fabrication


Figure 6: ICD_MRK-Abb_6.png
Robot inside the safeguarded shared work space.