Spool CpA #5: Human-Robot Interaction for Carbon-free Architecture

H.Bier, M. Becker, O. Tessmann and J. P. Drude

The Architecture, Engineering and Construction (AEC) industry is facing a threefold challenge involving the (1) digital transformation of all design and planning processes, (2) automation of construction processes, and (3) reconsideration of energy, process, and material use. This challenge involves issues of productivity, scalability, safety, labor skill shift, and environmental impact. There is a particular urgency in transferring effective solutions from research to building practice to meet significant carbon reduction goals by 2040.
The Spool CpA #5 issue makes an inventory of current tendencies in autonomous construction and human-robotic interaction in architecture. It aims at affirming and/or challenging research agendas in the domain of architectural robots. The leading questions are:
(i) What are the fundamental research questions for framing post-carbon autonomous construction?
(ii) What are the interdependencies between machines, humans, and materials?
(iii) How do different implementation timeframes define strategies for transferring research, as for instance, continuous transformation vs. leapfrogging?
Various themes ranging from synthesis of big data to human-robot collaboration, mobile and miniaturized robotic approaches, machine learning for autonomous robots, and robotic spaces, structures and building systems will be addressed covering a ranging from architecture to robotics and computer science.
Authors can submit papers in line with authors' guidelines (https://spool.ac/index.php/spool/about/submissions) via the Spool platform (accessible from https://spool.ac/index.php/spool/about/submissions) or email to J. P. Drude (drude@iat.uni-hannover.de). Paper submissions will be subject to double- or single-blind peer review.
The following timeline is envisioned:
Publication call 1 March 2023; paper submissions 1 March-1 June 2023; Review and revised paper submissions 1 June-1 October 2023; Publication 1 December 2023.

HRI4PCA (compilation from symposium possibly to be published in the 'Dialogs on Architecture' section)

H.Bier and M. Becker

Abstract
The Architecture, Engineering and Construction (AEC) industry is facing a threefold challenge involving the (1) digital transformation of all design and planning processes, (2) automation of construction processes, and (3) reconsideration of energy, process, and material use. This challenge involves issues of productivity, scalability, safety, labor skill shift, and environmental impact. There is a particular urgency in transferring effective solutions from research to building practice to meet significant carbon reduction goals by 2040.

The one-day symposium organized as an online event in 2022[1] was an opportunity to make an inventory of current tendencies in autonomous construction and human-robotic interaction in architecture. It aims at affirming and/or challenging research agendas in the domain of architectural robots. The leading questions for the symposium were:
(i) What are the fundamental research questions for framing post-carbon autonomous construction?
(ii) What are the interdependencies between machines, humans, and materials?
(iii) How do different implementation timeframes define strategies for transferring research, as for instance, continuous transformation vs. leapfrogging?

Description

Various speakers[2] from EU, Australia, Canada, and US presented research developed at TU Delft, LU Hannover, TU Darmstadt, ETHZ, U Stuttgart, UC London, RMIT, McNeel, U Toronto and Boston Dynamics. The themes ranged from synthesis of big data to human-robot collaboration, mobile and miniaturized robotic approaches, and robotic spaces, structures and building systems.

Fig. 1 (...)

Alisa Andrasek reflected on the current synthesis of big data from a multitude of sources enabling context-sensitive and integrated systems within an information-rich simulation and applications as for instance typologies synthesized with local data and computational physics, context-sensitive models for buildings and green energy infrastructure, or Artificial Intelligence (AI) combinatorics for increasing variability of prefabrication.
Daniela Mitterberger presented her work on novel human-augmentation strategies and tools needed for human-machine collaboration to perform non-standard fabrication tasks at full architectural scale answering the question of how cognitive abilities and tacit knowledge of humans can augment the precision, immediacy and speed of machine agents to enable otherwise either impossible or unsustainable tasks.
Henriette Bier presented efforts for advancing robotics in architecture while taking into consideration that more than 50% of tasks can and will be fully automated, while 45% rely on Human-Robot-Interaction (HRI), and only 5% remain in human hands. The 95% are in her research addressed by Design-to-Robotic-Production-Assembly and -Operation (D2RPA&O) methods. These link efficiently computational design with robotic production, assembly, and operation and employ a customizable multi-robot and multi-effector approach relying on Human-Robot-Interaction (HRI) with the goal to facilitate an effective and safe physical interaction between robots and humans implementing complex tasks. Aspects of HRI are implemented in collaboration with Luka Peternel, who considers robots as very good at handling high physical workload and performing precise and fast movements, while humans have superior cognitive capabilities and manual dexterity. He combines these attributes in physical human-robot collaboration for construction and employs methods based on impedance control in order to enable compliant and safe operation. Higher level reasoning and communication between the human and the robot are handled by an AI system based on machine learning (ML) methods and various sensory interfaces.

[1] Link to HRI4PCA announcement: http://www.roboticbuilding.eu/2022/03/09/symposium_hri4pca/
[2] Link to HRI4PCA speakers: http://www.roboticbuilding.eu/hri4pca-speakers/

Fig. 2 (...)

Lukas Lachmayer reevaluates large-scale production, whether additive, subtractive or through forming, which is often realized by upscaled machinery. While this appears the easiest way to achieve required tolerances, such production systems lack flexibility. Enabling mobile robots with infinite workspace to perform building tasks has great potential in construction as confirmed by Brian Ringley, who presented new mobile modalities for more effective site management, as for instance, wheeled/tracked mobile robots. By employing building autonomous navigation systems and agile mobile robots an unprecedented amount of data is captured in dynamic, human-purposed environments. The integration of geospatial hardware, 5G telecommunications, cloud compute, and emerging AI for unstructured reality capture data for feeding digital twins in construction. Twins are the key to establishing reality feedback loops accurately coupling the virtual and the real using heterogeneous robot fleets on construction sites.

Mirco Becker presented the miniaturization of autonomous construction robots and material formats, which involves the design not only of building but building systems. Similarly, Oliver Tessmann explores autonomous assembly of modular systems by means of AI-driven robots equipped with visio-tactile sensors. Dry-jointed and reversible elements allow for their assembly, dis-assembly and reassembly in a circular fashion. In contrast to HRI, the project shifts away from immediate collaboration.

Considering robotic hardware development as part of the overall design process and its output, is in line with Maria Yablonina' approach too. In this context, design moves beyond the design of objects towards the design of technologies and processes that enable new ways of both creating and interacting with architectural spaces.

Somewhat similarly, Serban Bodea develops robotic coreless filament winding as enabler of mass customization of large scale lightweight structures. These are explored by Valentina Soana as well, who develops lightweight structures and shape-changing materials. She designs adaptive material and structural systems that can achieve multiple states of equilibrium. Robotis systems are not anymore tools but become robotic spaces, structures and building systems opening up new interaction scenarios between humans, materials, and machine systems.

(...)

Reflection

(...)

Acknowledgements

(...)

References

(...)