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Chapter 1
Implications of Robotics and AI in Architecture

Henriette Bier

Robotic systems are increasingly incorporated into building processes and buildings. The question for the future is thus not if but how robotic systems will be integrated into architecture and the built environment. Such systems have a major impact due to the convergence of multiple technologies such as artificial intelligence (AI), large-scale machine-to-machine and human-to-machine communication (M2M and H2M), and the Internet of Things (IoT). Implications are explored and presented in this section in relationship to historical and theoretical interpretations and current manifestations by presenting ongoing research implemented at institutions such as McGill and Cornell Universities from North America, Technical University Delft from Europe, and the Chinese University of Hong Kong from Asia.

Theodora Vardouli is drawing from early research on 'responsive environments' that is looking at topological ideas as both metaphors and operative artifacts for architectural adaptability. The chapter gives an overview of topology's status in post-war mathematical and architectural cultures, including the Architecture Machine Group's efforts to produce computationally enhanced 'soft architectures' that co-evolve with their occupants using graph theory. Her argument is that both, metaphors and operative artifacts, help to historicize an imagination of design as fluid, soft, and malleable, while also foregrounding frictions with the discrete, symbolic logics of digital electronic computers—frictions that have practical and theoretical implications on contemporary perspectives on adaptive environments.

Practical implications on contemporary perspectives are presented by Yixiao Wang and Keith Green by reporting on user preferences for various interaction modes from pushbuttons to AI when interacting with robot surfaces—malleable, adaptive,

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physical surfaces that spatially reconfigure interior spaces within the built environment. They argue that with global mass-urbanization, the utility of robot surfaces in reconfiguring compact space into 'many spaces' is supporting and augmenting human activity. The question of the interaction between human and such space is explored with users in a lab study at Cornell. It identifies preferences as split between AI- and user-controlled interactions because of the contexts of different scenarios and the complexity, accuracy, discretness, and feedback speed of different interaction modes.

AI- and user-controlled interactions are explored by Henriette Bier et al. via Design to Robotic Production and Operation (D2RPO) processes that link computational design to the materialization and operation of responsive building components. These processes are presented in a case study involving the development of urban interventions that activate residual spaces by introducing diversification of flora and fauna and by engaging neighbors and passers-by in 'caring' for the new species that are colonizing those spaces.

Urban spaces and their use are the focus of investigation for Jeroen van Ameijde as well. He explores how computational tools for site analysis and monitoring enable data-driven urban place studies that connect to generative strategies for public spaces and environments at various scales. He argues that today's 'smart city' initiatives seem to be contemporary interpretations of Negroponte's vision of computational processes that are open to participation and presents a series of theoretical and procedural experiments conducted through academic research and education, involving user-driven generative design processes in the spirit of 'The Architecture Machine' (Negroponte 1970).

While all chapters in terms of content acknowledge that the advent of ubiquitous computing, and the embedding of sensing and actuating technologies in buildings and building processes, open up new scenarios for design, production, and operation in architecture and the built environment, approaches differ ranging from theoretical to more applied. All are involved at some level in robotics, AI- and/or user-controlled interactions. It is generally acknowledged that the design of physical environments incorporating sensor-actuators are concerning (1) physical environment, (2) information flows and processes as well as (3) H/M2M communication. The challenges to integrating the design of interactions with the design of physical environments are addressed by establishing feedback loops and by relying on the understanding that the physical environment is consisting of building components that are cyber-physical in nature, and their design and production are informed by material, structural, functional, environmental, and operational considerations (Fig. 1.1).

While robotic systems can significantly contribute to improving material-, energy-, and process efficiency, as well as the structural, environmental, functional, and operational performance of buildings and building processes (Inter al; Bier 2018; Sawhney et al. 2020), it is to be expected that data-driven automation involving AI will cover 50% of all tasks, whereas 45% will rely on human–robot interaction (HRI) and 5% will require human intervention (Inter al). Hence, humans and robots will operate building processes and buildings side by side.

Fig. 1.1 Human-assisted robotic assembly of non-uniform linear elements implemented with PhD and MSc students © RB lab, TUD and UASA

Considering the 50% of tasks that cannot be completely automated, robots will not replace humans but rather support them by taking over repetitive and/or heavy tasks. The human role will be mainly focused on envisioning new forms of physical environments and advancing novel means for their construction and operation as well as supervising and intervening when the non-human agents require assistance. This implies that cyber-physical systems integrated into buildings and building processes will increasingly share agency in the use of means of production and space.

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