AI based early stage design support for efficient buildings

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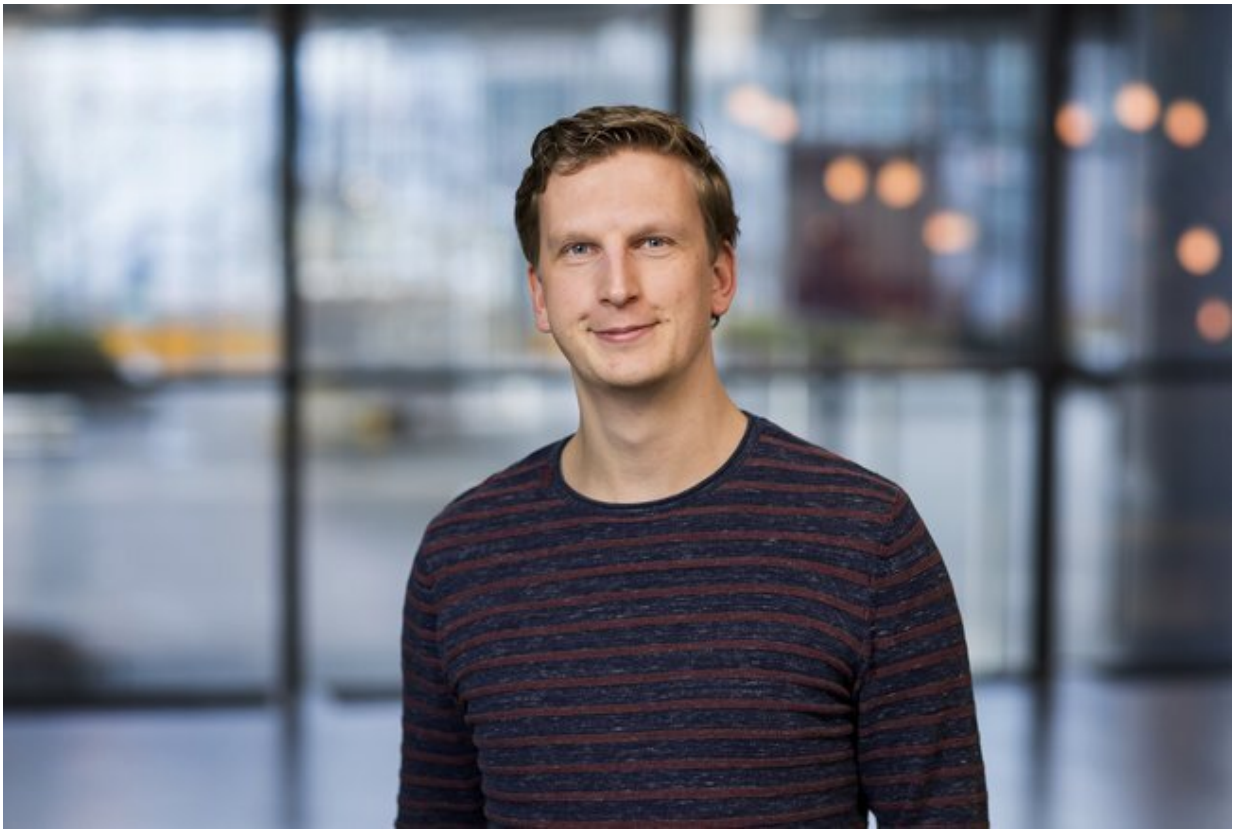

Sjonnie Boonstra developed AI techniques and optimization technology to support building designers in making influential decisions. Credit: Eindhoven University of Technology

The construction, exploitation, and demolition of buildings make up for

about 40% to 60% of the total energy and resource expenditure in Europe. It goes without saying that improving the material and energy efficiency in the built environment will be very beneficial with respect to societal challenges like climate change, environmental pollution, and resource depletion. With the help of AI techniques and optimization technology, the Ph.D.-research of Sjonnie Boonstra can support designers to make influential decisions during the early stages of a building's design, aiming at improving material and energy efficiency.

When starting the design of a building, a designer has some ideas and a design brief in which the goals and constraints of the building are defined. Naturally, at this stage, the designer does not yet know about material costs or the energy demands of the final design. However, the design ideas and decisions at this preliminary stage have the most significant impact on these aspects. Imagine, for instance, what the impact of a building's shape, and orientation to the sun, is on the heating and cooling demands.

AI techniques and optimization can help to explore design possibilities, however, even state-of-the-art optimization methods cannot deal with the sheer amount of design possibilities at the early stage of a design process. This is the challenge that has been addressed by the Ph.D.-research of Sjonnie Boonstra and his collaborator Koen van der Blom at Leiden University.

Methods based on expert systems

To do so, they focused on minimizing the material use and heating and cooling demand of a building design by changing the spatial layout and dimensions of a building. In Eindhoven, Boonstra has developed several methods based on expert systems: conformalisation, automated grammars, spatial modifications, zoning, and structural stabilization. These together can find promising ranges of design possibilities by a

method that simulates the reciprocal influence of different disciplines on a building spatial design; so-called co-evolutionary design processes.

In Leiden, van der Blom developed state-of-the-art optimization methods that are tailored to early stage building spatial design. Boonstra then created a novel hybrid method by combining the simulations and the optimization methods, which uses optimization to explore the promising design possibilities that are found by the simulations. With this hybrid method it is now possible to effectively explore and suggest a much higher number of design possibilities.

Open source toolbox

To realize his research, Boonstra has developed and published an open source toolbox with the aim to support the development of new building spatial designs via design and optimization methods. This toolbox contains various methods to describe a building spatial design, automated techniques for the generation and evaluation of a building spatial design for different disciplines, and tools to visualize designs and analyze data.

Boonstra found that these tools may also have other applications, such as design support. In that light, he developed a new method to efficiently generate and suggest optimized structural designs, which can help designers to find optimal material layouts for the structural design of a building.

The research is a promising step towards improved support for preliminary design. The developed methods have already successfully been applied in a design environment that is used in practice. Moreover, data generated during the research has been processed by data mining techniques to discover new design rules, which can be used both in the simulated co-evolutionary design processes and in practice.

NWO will finance a sequel Ph.D. project, which targets the inclusion of more design aspects like daylighting, the exploration of an even more sophisticated range of design possibilities, and user interaction.

Provided by Eindhoven University of Technology