AI in the Built Environment

Department of the Built Environment – TU Eindhoven

Introduction

Our **built environment** has a huge impact on all aspects of our lives, not in the least **quality of life** and **climate change**. As an effect, huge potential resides in digitizing this industry and making data available for **intelligent management and optimization of our environment** (acoustic performance checking, sensor-based building management, IoT-enabled construction sites, etc.). Various **Artificial Intelligence** techniques are investigated and adopted in the Faculty of the Built Environment and used for improving the quality of our built environment.

In this document, we give an overview of the **research themes** that are followed in the Faculty of the Built Environment, as well as the **application domains** in which they are used. Whereas research themes focus on AI technology groups, application domains focus on use. Finally, the document also lists a number of **moon shots** that indicate long term vision and goals, as well as a number of **reference projects**.

Research Themes

AI Research in the Built Environment is structured along the following three themes.

- **Digital Twins** of buildings and urban areas are of use for monitoring and improving operational buildings (HVAC, lighting, solar shading, etc), construction sites (feedback loop with construction site equipment), and for urban flow monitoring (people, goods, traffic).

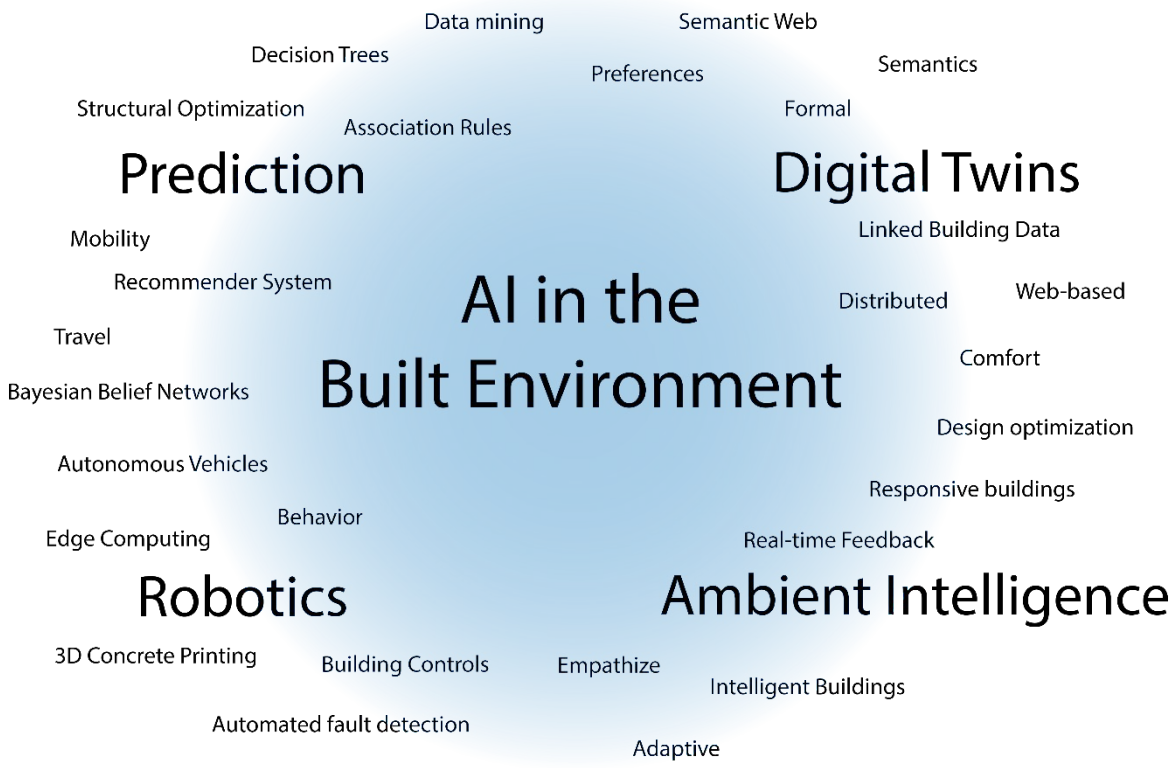
- **Robotics** are of increasing importance to construction sites, manufacturing plants, cities and operational buildings, thus transforming the built environment in a semi-automated environment with high-tech robotics in all its aspects.

- **Prediction** has always been of major importance in the built environment, particularly for facilitating informed decision-making in the design and engineering phases. Machine Learning techniques are increasingly adopted to predict behavior of buildings, urban areas and their use (flow monitoring).

- **Ambient Intelligence** is receiving much attention for realizing smart buildings and smart cities where sensors and algorithms are incorporated in the environment to optimize processes in real-time ranging from in-door climate control to public transport services.

Projects and Focus points

These four research themes can be recognized as the main research lines around which interdisciplinary and overlapping research initiatives are clustered. The following **research focus points** and techniques are hereby of reference:



Application Domains

Additional to the four identified research themes, the Built Environment relies on AI techniques in a number of **application domains**. There are typically quite diverse and broad domains. Most particularly, the following domains rely on AI techniques in the Built Environment:

- **Energy Transition**: A huge shift in energy use is needed for the built environment. Switching from the use of natural gas to renewable heating sources relies heavily on AI algorithms (prediction, learning, monitoring) and devices (ambient intelligence, edge AI).

- **Urban Mobility**: In order to improve urban mobility, an increasing number of personal information systems and decision support systems are built and used, relying on advanced visualization techniques (VR, AR), digital twins of people in the environment, and machine learning algorithms for prediction and providing personalized advice.

- **Healthy Working and Living Environments**: With increasing pressure in our daily work and life, it is difficult to maintain a healthy balance and healthy environment to live in (air quality, acoustics, ambiance, and so forth). Sensing our environment and adjusting it to our individual and common needs requires AI techniques (ambient intelligence, digital twins, prediction).

- **Heritage**: The big data derived from heritage documentations and from technological advances such as indoor and outdoor sensors support the protection of cultural heritage buildings and sites, especially when supported with AI and digital twin applications.

- **Smart Cities and Buildings**: The built environment, both on a building and urban scale, is heavily embedded with devices, sensors, and actuators. As a result, the environment is made artificially intelligent, and it actively responds to its users (interactive ambient intelligence).

- **Industry 4.0 in Construction**: Construction sites and manufacturing for construction is heavily digitized and automated (digital twins, robotics). Autonomous robots are increasingly incorporated in factories and construction tasks, improving the productivity of the construction industry.

- **Autonomous Vehicles**: Urban mobility is shifting heavily, from a more traditional car- and pedestrian centered mobility, into a dense network of various kinds of transportation means. Autonomous vehicles are expected to invade the city fabric and interact with a network of devices (IoT) for a range of daily tasks.

Moon shots

Within its AI-related ambitions, the Faculty of the Built Environment targets at a number of broad societal goals and ambitions:

- **Built environment as a friendly and responsive device:**
  Within a number of years, urban fabric and buildings will transform from a static medium in which we 'are', into an interactive and intelligent medium with which we interact and which pro-actively responds to and takes part in our daily activities. Devices, IoT sensors, actuators, autonomous vehicles, and so on, all build an environment with intelligence on the edge, interacting with its users.

- **A house for everyone:**

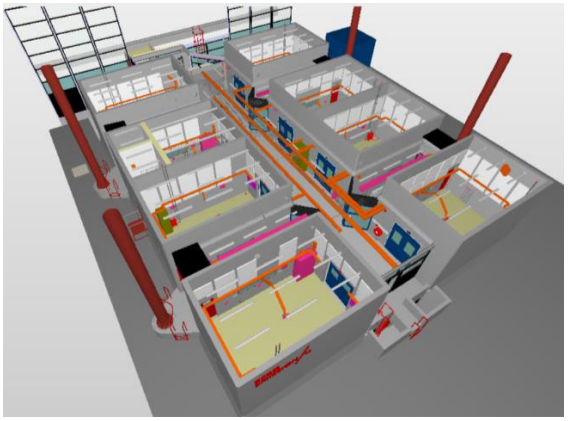
Advanced data-driven design optimization and heavily industrialized robotic manufacturing will transform the construction industry in a digital Construction 4.0 industry. This increase in productivity and profitability (construction site as a factory) will allow affordable and customized housing for everyone.

- **A web-based virtual shadow for every part of the built environment:**
  Both on an urban and building scale, every part of our built environment will have a virtual shadow within a number of years. These digital twins are used for simulation and monitoring purposes, with an active focus on transitioning to a highly sustainable and climate-friendly environment that enables a web-based and distributed circular economy.

- **Space as a service:**
  Instead of selling and buying materials and building elements, we build an economy in which space and environment is traded as a service. We don't buy houses, we trade living space; We don't own offices, we rent workspaces; we don't drive a car, we book mobility.

Reference projects

A number of **reference projects** can be named to indicate example projects that run at the Department of the Building Environment, in line with the above research themes and application domains.



Machine Learning and sensor data
Based on various machine learning algorithms including Bayesian belief networks and decision trees, an integrated data analytics tool is developed to generate the spatial and temporal information related to travel and activities.

Self-adaptive personal information systems
A Bayesian method for incremental learning an individual's preferences based on his or her choice behavior is developed and applied in personal travel information systems.

Digital Twins and Linked Building Data
Web-based information systems are developed, which collect various sorts of data about a building in a decentralized manner, including detailed 3D object models, point clouds, image data, semantic data, sensor data.

AI in manufacturing
Manufacturing of complex geometries (parametric and structurally optimized structures with minimal material use) will be enabled by digital manufacturing techniques, e.g. robotics in construction and additive manufacturing.

House as Robot
By developing extreme scenarios and building mock-up's, we aim to evolve everyday living spaces to adaptive living organisms that understand and empathize with the user.

SWT and Linked Data in Autonomous Mobility
Using ideas behind Linked Data and Semantic Web, allows the AI in charge of handling Autonomous Vehicles to consume valuable information from the surrounding ecosystem in order to achieve more optimal calculation of control parameters of the vehicle while using minimal amount of network resources.

Automated fault detection of photovoltaic (PV) systems
Large-scale monitoring of distributed PV systems in comparison with expected PV output generated by a digital twin network, taking into account dynamic weather conditions, partial shading due to urban surroundings (e.g. from LiDAR data) and the non-linear characteristics of inverters and power systems.

Information
Find more information in the Department of the Built Environment.