Artificial Intelligence in the field of Building Automation

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The term "AI – Artificial Intelligence" is increasingly associated with buildings and building automation. The question is: what is it, where do its tangible benefits lie in this field, and how does the building infrastructure need to be adapted to realise those benefits?

Today's building automation systems in the main operate 'statically' in response to fixed time programs or simple control parameters. Room temperature control is based on a preset temperature that is the same throughout the day. Lighting is operated manually, with switches, or on the basis of simple presence switches. None of this is truly 'intelligent.' The new dimension that AI can add into the building automation environment is to use autonomous analysis of the data as a basis for optimised operation. Thus the heating and cooling dynamic of rooms, weather forecasts, predicted room occupancy during the course of the day can all be factored into the operation of the heating. Similarly, cleaning schedules can be based not only on the current actual values in terms of the intensity of use of kitchens, canteens and toilets and other areas, but can be based on predictions drawn from an analysis of usage patterns in the previous days and weeks. This kind of forward looking building management can be applied in almost every area of building services, leading to increased energy efficiency, reduced operating costs, improved space utilisation and other advantages.

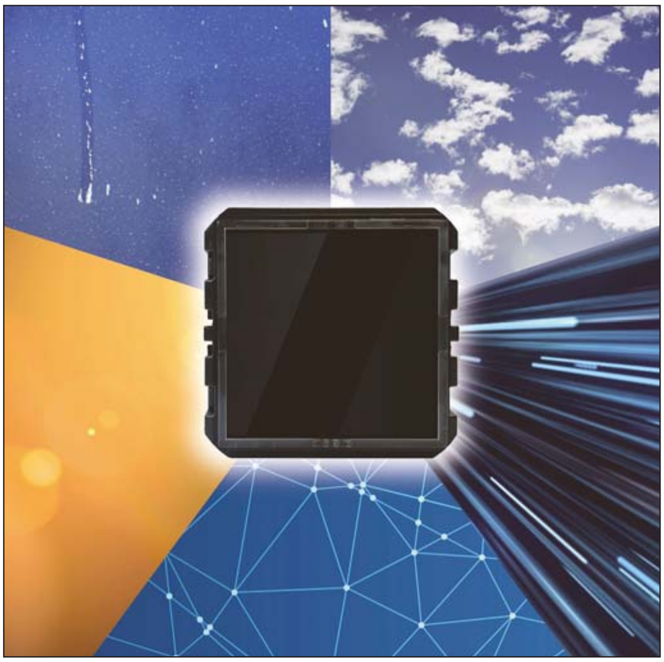
All this - and much more - is possible when data on building system status and conditions is intelligently evaluated. This requires intensive processing of large amounts of data, with many variables to be considered. Artificial Intelligence (AI) offers many new, tailor-made solutions which are eminently suited to efficient building management.

"Building Automation", "Smart Building" and "Cognitive Building"

Initially, „Building Automation" was comparatively „un-intelligent". Systems were programmed to follow a set of simple rules, allowing for quick system start-up and subsequent ease of maintenance.

The „Smart Building" typically builds on this classic building automation with flexible IT-based management systems . These offer unrestricted programming using modern IT languages and tools, easy integration with other IT systems such as workspace/room reservation systems or data banks, and data visualisation for facility managers and for „ordinary" users.

The growing assimilation of sensor-generated data into the IT-based management level opens the way for more advanced data processing solutions to come into play - such as AI tools. This is the pre-condition for the implementation of any prognosis-based form of building management. The sophisticated processing of sensor-generated data makes the Smart Building into a „Cognitive Building".



AI-learning process

The first step in any Artificial Intelligence process is system learning. This can take three forms.

Unsupervised Learning

Supervised Learning

Reinforcement Learning

„Unsupervised Learning" is used when large quantities of data must be processed and categorised. This grouping enables the recognition of deviations from norms and interdependencies. For example, sensor data from identical circulation pumps can be grouped. If data from one pump or group of pumps deviates from the norm, there may be a defect and a human engineer can be sent to investigate.

„Supervised Learning" often makes use of neural networks. They consist of entry and exit nodes as well as further nodes in the intermediate layers. Mathematically weighted relationships exist between the diverse nodes (neurons). In order to optimise these relationships, the neural network is subjected to a training phase with known input and output patterns. In the field of building automation, for example, a neural network can ‚learn' the current consumption profiles of different appliances and which appliances are active when. This information can be used to avoid ‚spikes' in building energy consumption, by shutting down some appliances and extending the operation time of others.

Another form of Artificial Intelligence is represented by processes that autonomously determine which actions are appropriate in a given situation. They emulate human behaviour whereby different solutions are tried in order to determine the best way forwards in a hitherto unknown situation, and conclusions drawn retrospectively. The learning task becomes more challenging when feedback is given much later and hinges upon events in the relatively distant past. This is true in a human context, and equally true in computer environments. The best-known example in this category is „Reinforcement Learning“. Consider the issue of determining the optimal start and stop times of heating to achieve a comfortable temperature when the building opens. At the simplest level, the learning algorithm receives the value from the room temperature sensor and can act on the actuator on the radiator. By a process of trial and error, the algorithm can determine the necessary lead time. However, this simple example ignores the fact that, for instance, the speed of heating also depends on the outside temperature, so the reading from an exterior temperature sensor needs to be considered. Instead of providing a pre-set target temperature, the algorithm may be be given evaluations (good / OK / cold) during the day and must learn in response to this feedback. In addition, the algorithm can be provided with an addditional rating every month based on the overall energy cost: encouraging efficient behaviour and discouraging inefficient responses. A ‚stable‘ response that balances comfort and efficiency can be established, but exploration should continue to accomodate changes in behaviour and the environment.

It can be seen that these three approaches are complementary. The learning method should be chosen depending on the task in hand - each has its merits.

Concrete applications

Many diverse AI-based applications are available in the field of building automation. They can be broadly categorised as follows:

Optimised facility management: needs-based control of heating plants, circulating pumps, lighting etc. (as opposed to control on the basis of simple parameters or by timer).

Optimised utilisation of spaces and infrastructure: capacity analysis and forecasting, e.g. for meeting rooms, canteens, pantries, transit areas, toilets and parking spaces as well as the provision of information in the short term (for building occupants) and in the long term (for facility managers, e.g. in form of advice on building restructuring).

Load management: forward-looking operation of electrical systems in order to avoid (costly) peak loads.

Precautionary maintenance and optimised servicing: analysis of failure probability, timely maintenance and consequential avoidance of technical failures.

Employee-oriented value added services: mobile devices can - for instance - be used to generate space utilisation forecasts, view canteen usage intensity, request parking space availability and preferred workspace location or select individual meals.

Compensation of skilled-staff shortages: making effective use of facility maintenance staff in managing the building's technical systems.

Focus on meaningful sensor data: generate as much data as possible from as few sensors as possible - reducing redundancy, cutting investment and operating costs.

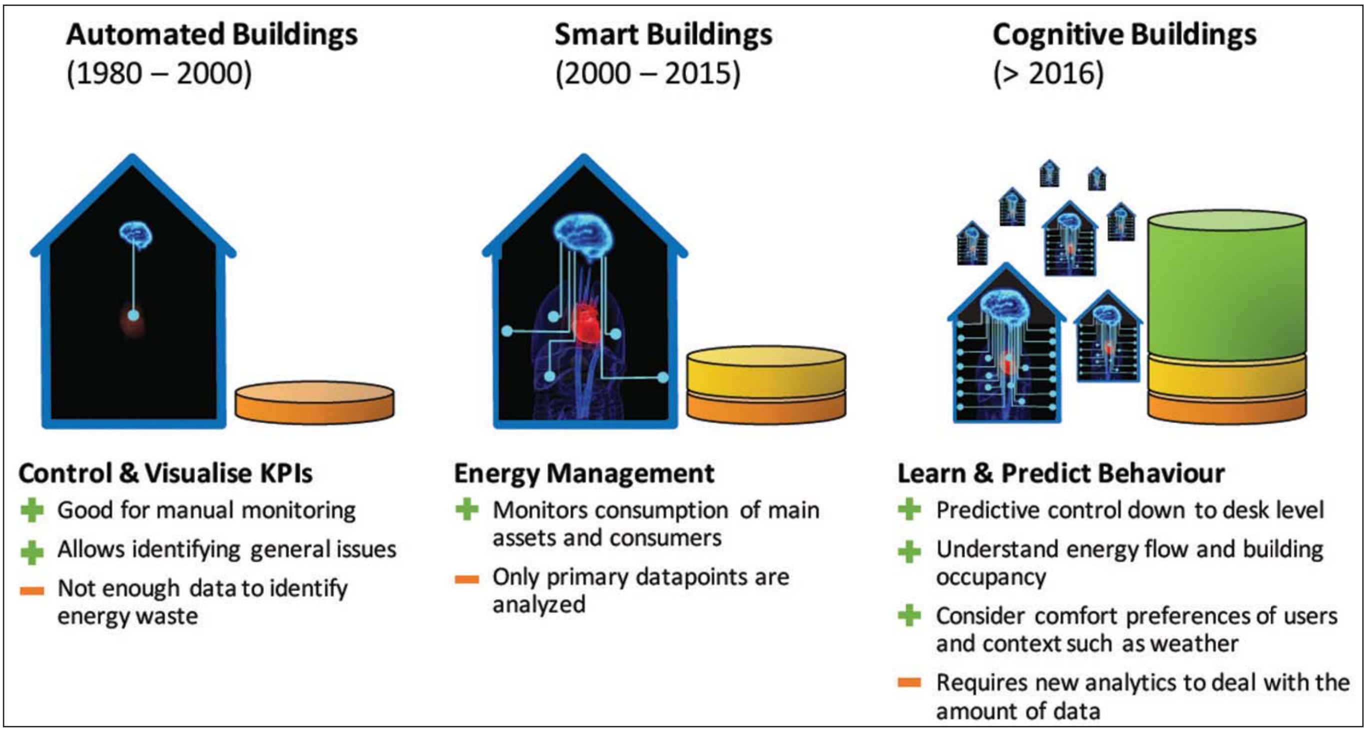
Demands upon system architecture

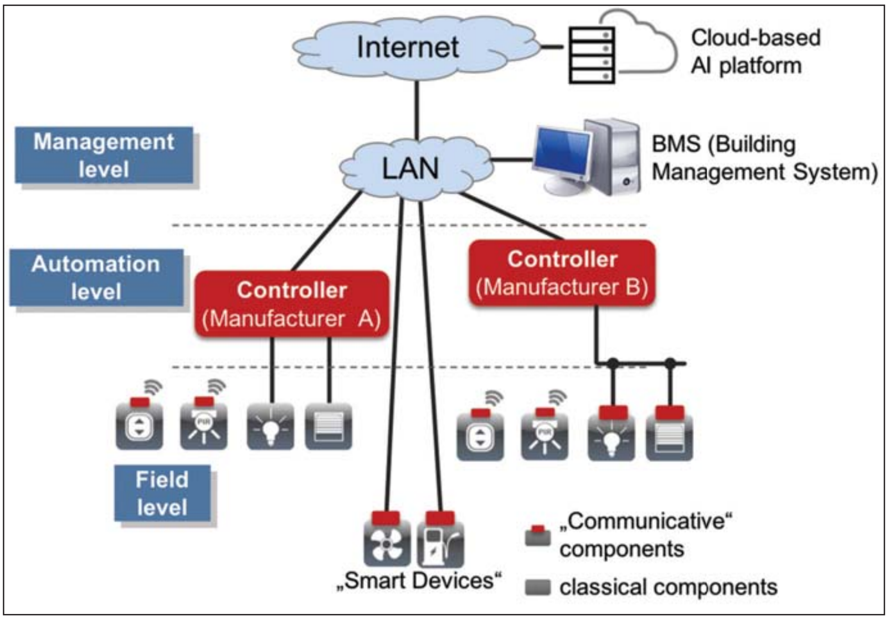
An AI platform is indispensable for the introduction of intelligent learning processes such as those described above. This can be either cloud-based or server-based. Cloud-based server farms offer more processing power, and cloud-based AI frameworks offer a broader range of features, so this currently represents common practice.

The AI platform is built on a Smart Building infrastructure, and all technical systems should ideally be connected to a BMS (Building Management System). The BMS must be able to govern the building facility and room automation systems.

Demands on building infrastructure

The AI platform requires a rich set of data from a variety of sensors around the building to operate effectively. Conventional smart building systems use a sensor network to determine the





status of a building now.' Cognitive" buildings store and analyse historical sensor data to make predictions for the future. For this reason, such buildings are even more critically dependent on the data inputs they receive for their success. Cognitive buildings need to be instrumented throughout with IoT sensor devices that make the algorithms fully aware of every aspect of their operation: environment, occupants, energy requirements, service needs, security, and safety. The richer the data, the more complete and intelligent the response of the AI. Wiring sufficient sensors into an established building is hugely expensive – and even if it were done would create an inflexible architecture that couldn't be adapted as new applications emerge and learning progresses. The only effective solution is battery- and maintenance- free energy harvesting sensors that can be fitted in a moment and moved at will. Energy harvesting wireless devices utilize the tiniest amounts of energy from their environment. Kinetic motion, pressure, light, differences in temperature are converted into energy which, in combination with ultra-low power wireless technology, creates maintenance-free sensor solutions for use in smart buildings and the IoT.

The EnOcean Alliance eco-system offers more than 5,000 multi-vendor interoperable energy-harvesting sensors enabling data collection for multiple applications, such as room or desk/chair occupancy, temperature and air quality, energy usage and restroom usage. In addition to the traditional option of collecting and analysing the data via the BMS (Building Management System), this can now be done by using the existing Wi-Fi network with the building. By securely interfacing those IoT devices with new and existing Aruba Wi-Fi 5 and Wi-Fi 6 Access Points via a plug-in 800/900MHz radio, building control and business applications can become hyperaware of their operating environments. This information can be used to better model building behavior, to optimize human activity monitoring, organizational redesign, augmented reality, human productivity, and occupant health and safety.

Conclusions

AI-based processes enable a broad range of applications in the field of building automation. The concrete benefits anticipated from AI-based solutions should be clearly defined before implementation, since this plays a determining role in the choice of learning process and its modelling, as well as in the choice of AI platform and the type, number and location of the energy harvesting sensors needed to supply the data inputs.

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