Model based design of intelligent ventilation concepts

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From a product point of view, today's state-of-the-art ventilation boxes for residential buildings are generally reliable, efficient and silent according to formal European and national product standards. Ongoing development projects are focussing on making the products even better, but because of the maturity level of today's solutions, breakthrough revolutions should not be expected.

However, when looking into the real application of ventilation units, there is a significant difference between those formal, rather static product level standards on component level and the dynamic challenges total ventilation systems are confronted with during their full product lifecycle. In our ambition to come to better ventilation solutions in residential buildings, it is key to apply a much more holistic approach, in which several real-world challenges need to be tackled simultaneously. Some typical examples:

- Environmental conditions and even more - human behaviour - cannot be considered in a quasi-static way. In contrast to the static approach of the current type of product performance indicators, it is essential to include dynamic phenomena when analysing controllers and performance of smart ventilation units.
- Intelligent ventilation concepts are typically composed of different components as sensors, actuators or ventilation boxes that are linked for the first time in a specific building with specific characteristics. When developing robust ventilation concepts, one should take into account the variability of building dimensions, ventilation networks, including typical defects or suboptimal topologies.
- The behaviour and health of ventilations systems, including ducts and filters, change over time, affecting the static and dynamic characteristics of the total system. When developing ventilation systems that are capable to guarantee are quality over longer periods, it is essential to validate their capabilities of handling slowly changing system characteristics.
- When analysing the robustness of intelligent systems towards disturbances, this is typically done in a deterministic way (eg fixed climate reference). However, when analysing robustness of systems, it is key to use different realizations of stochastic processes to guarantee overall stability before product release.

When validating new intelligent concepts against above requirements, there is a strong need for extensive testing with different scenario's, building topologies and even product variants. Unfortunately, practical experiments will never be extensive and detailed enough to guarantee sufficient test coverage and at the end, to ensure an efficient and reliable ventilation system in everybody's home. The only way to come to a sufficient test coverage, is to perform concept and algorithm tests in a virtual way, making it possible to increase speed, test coverage and at the end, detailed analysis of some specific phenomena.

Off course, above design challenges are not new and have been tackled before in many other industries. Model-based development processes have been widely used to design and validate smart technologies in high-tech, automated applications as automotive, machine construction or robotics, since those products have the strong requirement to adapt themselves to the local, unknown context in order to guarantee performance, efficiency without loosening safety regulations during their full lifetime.

In this study, an overview is given on the state of the art technology in modelbased product development of ventilation concepts. More specifically, an overview is given on the impact of this design methodology on different aspects of product validation, starting from the relation with suppliers, design of intelligent algorithms, validation of embedded software solutions, supporting service of smart technologies and even the evaluation of intelligent ventilation concepts in close cooperation with research institutes. This study can be considered as an invitation towards different stakeholders to think on how industry and research institutes can create a new, innovative cooperation model to evaluate and to valorise smart ventilation concepts.