COMFORT – DATA-DRIVEN ANALYSIS AND SIMULATIONS OF HUMAN COMFORT IN OFFICE ROOMS

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Introduction

Comfort conditions in rooms and buildings are currently poorly recorded and maintained by the building management due to a lack of appropriate sensors, data management and data analytics. New solutions are required to maintain satisfactory room conditions while achieving optimal energy efficiency. Project COMFORT [1] combines aggregated and enriched data from sensors and simulations to quantify, evaluate and optimise the perceived human comfort in regards of temperature and air quality while taking economic considerations into account. Approaches new to building automation, including machine learning, multi-source data fusion, virtual sensors, simulations, wireless sensor systems and coupling with building information modelling, are used to understand human comfort by analysing multi-modal and heterogeneous data. Thereby, a predictive and concise representation of comfort conditions in rooms and buildings are created. This is researched and investigated in two different test spaces; the first one is a dedicated testing site consisting of two Test Boxes simulating offices; the second one is an office building in Deutschlandsberg.

A central project objective is to augment the collected sensor data so that statements about thermal comfort can be made. Influencing factors on thermal comfort of humans are parameters such as clothing, activity, air temperature (even at different room heights), surface temperatures of the surrounding environment, air humidity and flow velocity. Therefore, building and system simulations on the one hand, and flow simulations on the other hand, are used to gather data which cannot be measured at the test spaces. The greatest challenge is the air flow in the rooms of the test spaces, since it is determined by a large number of influencing variables in addition to the room geometry. Computational Fluid Dynamics (CFD) simulations are used to capture the air flow, including supply and exhaust air flow, surface temperatures, heat input by people, equipment and lighting, and solar radiation.

A metrological recording of all influencing variables is not possible with reasonable effort in the test spaces. Hence, a digital twin is created to determine these variables by means of building and system simulation, carried out in parallel to the sensor data collection done in the real test spaces. Similar to the CFD simulation, the creation of the digital twin also requires a large amount of information about the building. In addition to the building geometry, this includes the structural and technical conditions of the building (component structures, window characteristics, heat input, ventilation systems), the climatic boundary conditions and usage information about the building of the test spaces. All this information is combined in an integrated building and system simulation to achieve the highest possible agreement between metrologically recorded variables and those obtained from the simulation for various target variables, like air temperatures, surface temperatures, CO2 concentration.

The simulation quality—and thus the agreement with the metrologically recorded variables—depends to a large extent on the used input variables. Hence, these are of great importance in the presented task. The more precisely the measurement, the higher the achievable agreement between real world and simulation. Not all input variables are of the same importance. While outside air temperature, solar radiation, presence of persons, activation of sun protection, activation of lighting, activation of device loads, opening of windows and doors are central input variables and need to be recorded with high accuracy, information about of the building services systems (e.g. heating and cooling temperature) can usually be collected well enough via the building services management system and augmented with planning data.

Methods

In the field of energy and building technologies numerical simulations become more and more interesting due to the increasing computing power, the technological advances and increasing accuracy of simulation methods in terms of analysing thermal behaviour and flow characteristics. A very important aspect for simulation is a sound and accurate approximation of boundary conditions having a strong influence on the results. By coupling different

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building simulation models or by integrating sensor data as boundary conditions into the simulation, an improvement in the representation of real conditions can be achieved. Furthermore, the integration of numerical simulations into the control of thermal room conditioning, for instance in form of virtual sensors, can lead to further improvement in the thermal comfort of the room.

Generally, two different simulation methods are used in order to analyse the thermal comfort of single office rooms. At first, numerical simulation models were created and calibrated with two Test Boxes located at the campus in the Inffeldgasse of Graz University of Technology. The thermal behaviour of these Test Boxes is monitored and controlled by mechanical ventilation. Controllable thermal loads are used to simulate office operation. This caters for two things, firstly, a comprehensive comparison between sensor data and simulation results, and secondly, the transferability to real office rooms. By using Building Energy Simulations (BES) predictions can be made about the expected thermal comfort in a zone, like a single room or more rooms considered to be a common zone. CFD simulations provide very detailed observation of the thermal behaviour targeted at the identification of local discomfort, e.g., hot and cold spots or high air velocities. Both simulation approaches are coupled either directly or indirectly by using the same sensor data as input. Furthermore, the CFD modelling approach needs boundary conditions from BES and sensor data.

A major influencing factor is the outdoor climate. While air temperature, humidity, air pressure, wind speed and direction - which are provided by ZAMG [2] - can be measured comparatively easily and are already available in good quality for a large number of locations, the situation is somewhat different for solar radiation. Above all, it is crucial to split up the easy-to-measure global radiation into direct and diffuse radiation. A distinction between direct and diffuse radiation is important to correctly quantify additional interior heat gains via the windows caused by their varying absorption and reflection characteristics of direct and diffuse radiation. A data-driven analysis is carried out in COMFORT to split global radiation data into direct and diffuse radiation by regression models employing additional input data.

The data-driven approximation of direct and diffuse radiation requires a comprehensive set of historical input data for the area of Deutschlandsberg. These historical data sets are provided by Meteonorm [3] consisting of timestamp, temperature, diffuse radiation, global radiation, cloudiness and direct radiation, which are used to train appropriate models to approximate direct and diffuse radiation. Based on these model approaches, an estimation of direct and diffuse radiation by using timestamp, global radiation and temperature – provided by ZAMG – complemented by additional weather data including cloudiness was performed. Besides different regression approaches which use polynomials of 3rd degree as well as 4th degree, several time-related variations like monthly, seasonal or yearly effects have been investigated (e.g. by preparing the data sets accordingly).

References

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