ENERGY
INFORMATICS

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# Multimodal Occupancy Sensing Solutions based on Machine Learning Algorithms and Metadata Inference

## Background

The built environment including buildings, squares, paths and parks are a key fundament for a thriving society. It is a challenge to maintain and develop the built environment given the available resources with the increasing urbanization, demand for economic growth and sustainable choices [3]. A key piece of information when maintaining and developing the built environment is quantified information about human behavior to understand the usage of the built environment. For instance, in buildings to improve decision-making and optimize their operation with energy efficiency and comfort goals in mind. The digitalization of our society based on concepts from pervasive computing including mobile, wearable and Internet of Things devices and low-cost sensors open new possibilities for mapping human behavior and its context via objective sensor data. However, to gain the full potential of using resources on collecting quantifiable data on human behavior requires that data is not only collected for one time use but also shared with other organizations and individuals.

To address the challenges in built in environment while evaluating the estimation and modelling techniques, we should have the crux knowledge of which sensor modality should be deployed for the purpose [2,4]. So, influencing parameters that affect the sensor modalities play a crucial role in selecting the complementary modalities to gain precise and accurate information for human behavior. To be able to exploit the advantages of the multiple sensor modalities it is necessary to fuse the data delivered by these sensors [1]. The fused data should ensure a higher certainty about the existence of objects and free space, which is used for detection. The fusion of these sensor data therefore becomes a mandatory and very crucial aspect of the perception process in almost all automated, assistance and autonomous systems. Multi-modalities together offer advantages in terms of being able to sense various complementary aspects of an object or scene with the different modalities, i.e. increasing information gain. Due to the uncertain nature of sensor measurements, the fusion of the (time series) data is non-trivial. Fusing sensors with different modalities is even more challenging because the sensors perceive different aspects of the environment. One sensor might sense an object while the other sensor might not see it at all because of the material of the object, for instance seeing through glass with a visual camera and getting a return with an ultrasound sensor. Oftentimes the sizes and the distances to the objects are also reported differently.

## Problem Statement

*"What are the multimodal sensing and processing elements of an open data methodology for mapping human behavior in its context to optimize the built environment"*

Quantitative data on occupancy behavior (i.e. presence, counts or actions) enable software applications that quantify how buildings are used and optimize the energy efficiency of building systems for delivering indoor comfort. Quantitative data on occupancy behavior is collected using occupancy sensing which covers estimation, modeling and prediction of occupancy behavior based on measurements from sensor infrastructures. A core scientific challenge for occupancy sensing is the diversity of occupancy behaviors and geometries and materials of indoor spaces. To address this challenge the PhD project will study multi-modal occupancy sensing solutions based on machine learning algorithms and metadata inference. The project will also evaluate the solutions in case settings for accuracy in different environments. The solutions will be implemented in software as extensions to the OccuRE software platform for processing occupancy behavior data. Furthermore, the solutions applicability will be studied covering cases within public and commercial buildings on space use optimization and energy efficient control of building systems. In the Figure below, an autonomous building can have several modalities of sensing technology, but the crucial task would be how to link heterogeneous data about human behavior and infer details regarding human activity from the metadata and algorithms to evaluate performance matrix in heterogenous settings and address privacy and protection of the shared data.

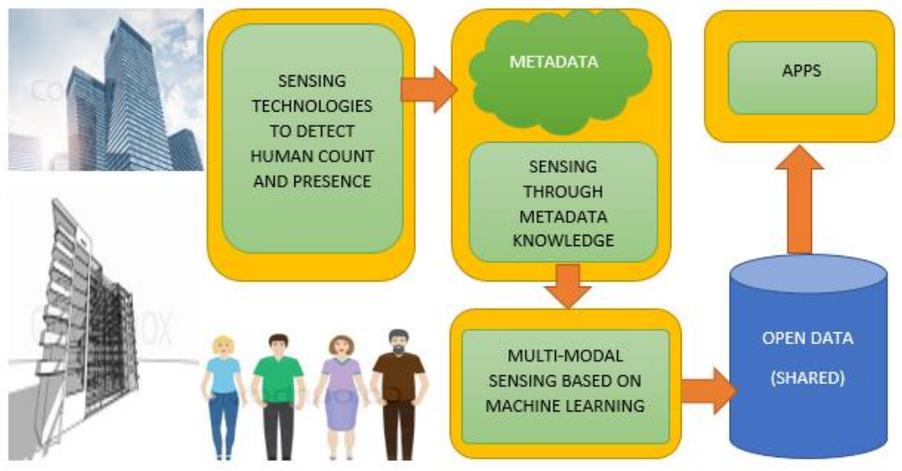


Figure: An overview of the architectural flow of the project

## Overall Project

This Ph.D work cover contributions to two projects – ODEx and IoT Control. Multimodal sensing focuses on the different modalities available for sensing human behavior. The main contribution is to integrate the heterogeneous information and develop algorithms based on machine learning that provides accurate knowledge about the human activity.

## Project Outcomes

The outcome of the project will include pragmatic methodologies for mapping human behavior in context to optimize built-in environment.

## Project Period

23rd October 2017- 22nd Oct 2020

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