Executive Summary

Title: *Multimodal Data Integration in Intelligent Buildings*		**Project ID: 7a.025-TUT**
Today's Date: 14 Feb 2018	**Estimated Start Date:** 1 Aug 2018	**Type:** [x] New [ ] Continuing
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Project Description: Data plays an essential role in future intelligent buildings. Different data are acquired from the building services equipment (e.g. CO2-meters or thermometers), from sensors installed to follow the usage (e.g. cameras or IoT), and from wearable sensors (e.g. mobile phones and activity bands). Analysis of available data can lead to many improvements to the user experience such as adapting air conditioning according to real need or adjusting the lighting to refresh or relax as needed. A key research task is to learn how to combine efficiently data from different sources. Towards this goal, information from different sensors can be integrated using multimodal analysis. Multimodal analysis has been a research focus in the machine learning community. The state-of-the-art work limits themselves in investigating static modalities, including images, texts, and audio clips. However, data generated from different sensors, such as real-time videos, air quality data, and other sensor data from intelligent buildings are largely overlooked. In this project, we aim to find a multimodal integration solution for both static and time-series data, i.e. real-world dynamic scenes from different sensors. Moreover, missing data from one or more modalities will further complicate the task. Accordingly, new techniques will be investigated to tackle these challenges.

Experimental Plan: During the project period, the team will work towards:

- Collect data from the sensors of interest
- Formulate a multimodal model for data analysis
- Develop a novel semi-supervised model which can be applied when sensor data is missing or not complete
- Develop real-time implementations using parallel and distributed processing

Related Work: Multi-view learning has been well studied in our research group and worldwide [1] [2]. Numerous multi-view statistical learning techniques have been studied and a novel discriminant analysis was proposed in [1]. Meanwhile, several multi-view discriminant analysis and semi-supervised learning techniques [2, 3] are developed recently for numerous applications. Our goal is to integrate the information from multiple sensor data, and make superior analysis and decisions in intelligent buildings.

[1] G. Cao, A. Iosifidis, K. Chen, M. Gabbouj, "Generalized multi-view embedding for visual recognition and cross-modal retrieval," IEEE Trans. on Cybernetics, 2017

[2] M. Kan, S. Shan, X. Chen, "Multi-view Discriminant Analysis," IEEE Trans on Pattern Analysis and Machine Intelligence, 2016

[3] F. Nie, J. Li, and X. Li. "Convex Multiview Semi-Supervised Classification," IEEE Transactions on Image Processing, 2017.

How this project is different: Existing methods have studied learning representations for cross-modal retrieval and recognition in images and texts. We want to learn from incomplete and unlabeled multi-view data from sensors and videos. Moreover, we aim to learn from the raw data to achieve an end-to-end solution for multi-view learning.

Milestones:

3 months: Data acquisition

6 months: Multimodal learning for videos

9 months: Semi-supervised learning for numerous sensor data

*12 months:*Combining and testing both models

Deliverables:

1. Dataset from different sensors
2. Trained multimodal model for sensor and video data analysis
3. Trained semi-supervised model for sensor and video analysis
4. Combine both models
5. Software development of the proposed model

Proposed Budget:

Researcher Salary	€34,400
Indirect salary costs	€18,232
Overhead	€50,527
Travel	€8,000
Material and other costs	€3,841
Total	**€115,000**

How this Project may be transformative? The project can improve sensor and video data analysis and data integration, where videos and missing data are present in future intelligent buildings.

Potential Member Company Benefits: Multimodal fusion solution for different sensors technologies can improve many different aspects of intelligent buildings such as indoor navigation, surveillance, people and resource management, accurate alarms, and energy efficiency.

Progress to Date: A rich set of machine learning algorithms has been developed by TUT in the past 5 years. Recently, we have tested existing multi-modal data fusion (both shallow and deep) methodologies and developed novel optimization criteria for extending performance in classification and retrieval applications.

Estimated Knowledge Transfer Date: 12 months