COORDICY NEWS No. 3 - October 2016

VEMCO GROUP NEW AFFILIATED PARTNER IN COORDICY

On August 1st, 2016 Vemco Group A/S joined the COORDICY project as an affiliated partner.

Vemco Group is a Danish company founded in 2005 with HQ and R&D Center based in Denmark. Since 2005 they have developed into an innovative software company within intelligent analytics solutions for retailers. Vemco Group provides a professional solution for people counting, queue management, and wifi-tracking. Their Intelligent Vemcount Analytics platform is developed by retailers for retailers. Vemcount works in a private cloud environment as well as in a hosted cloud solution.

Vemco Group A/S will work in the area of algorithms for estimating and predicting occupancy in buildings. In particular concerning the combination of count line data to estimate the total count of occupants in a zone or whole building and the prediction of future occupancy.

Read more: http://vemcogroup.dk/

COORDICY PRESENTED AT THE NEW YORK ENERGY WEEK 2016

During the 2016 New York Energy Week in June the COORDICY project was presented at two workshops and a panel discussion.

In the first workshop: *Energy performance: Closing the gap and utilizing the potential* representatives from Center for Energy Informatics presented how the research performed within the COORDICY project can help close the energy performance gap of buildings and the technology behind. A persistent problem in buildings is the deviation between the original intent of the building and the actual energy performance.

In the second workshop: *Model & Data Driven Approaches* Assistant Professor Muhyiddine Jradi presented new model driven approaches to energy retrofitting strategies.

Moreover, Head of Center for Energy Informatics, professor Bo Nørregaard Jørgensen was the key note speaker at the event: *The Future of Demand-Side Management: The Intelligent Building* which also had Dr. Rose Grymes from Nasa Ames, also a partner in the COORDICY project, among the panelists. The task of this event was to discuss how to create the intelligent building of tomorrow that is not only cost effective but also part of solving the energy challenges in the city.

The trip to New York also left time for the COORDICY representatives to participate in bilateral meetings presenting the COORDICY research and making way for new collaboration and for visiting interesting buildings and projects in New York.

COORDICY PRESENTED AT DANISH-BRAZILIAN WORKSHOP ON SMART ENERGY SOLUTIONS

In May Innovation Centre Denmark arranged a study trip to Brazil for members of the Innovation Network in Smart Energy. Associate Professor Christian Veje, Center for Energy Informatics participated to present the COORDICY project and research. The visit to Brazil consisted of a workshop entitled *Danish-Brazilian workshop on Smart Energy Solutions* aimed for Commercial and Industrial Building and visits at a number of companies and University of Campinas (UNICAMP). The purpose of the visit was to attract institutions interested in partnering with international players to develop innovation projects in Brazil.

COUNTING USERS

- THROUGH SENSOR TECHNOLOGY AND SOFTWARE THAT COLLECTS DATA ON THE USE OF YOUR BUILDING

New sensor technology makes it easier to keep count of how many people occupy a building over time. These counts can be used to analyze the energy effectiveness of ventilation systems and other energy consuming equipment in a building. As an example the counts can help us notice issues like a massive energy consumption outside peak hours when counts highlight a low level of occupancy.

The counts can also be used for dynamic control of installations in relation to the number of actual users and hereby for instance increase ventilation as soon as a large number of people are gathered in a building instead of waiting for the CO2 level to increase. In the COORDICY project we use 3D stereo cameras. These cameras create a 3D image of the area below them by using two lenses. The amount of people under the camera is counted by detecting human characteristics such as height, movement, and shape. There are also other comparable technologies with the same general characteristic such as infrared cameras, that recognize humans from their temperature and impact on the surroundings, or depth cameras that measure depth via changes in an expected pattern. These type of sensors either provide data on the count of people in a given area or sum up how many people pass a virtual line.

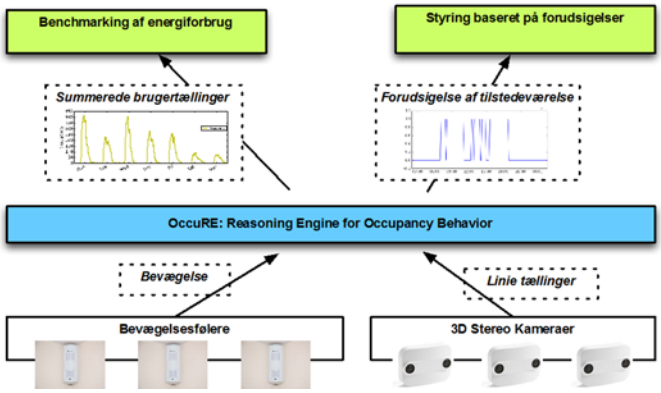


Figure 2 – Illustration of the OccuRE software platform for processing data from various sensor technologies

As part of the work in WP1, Fisayo Caleb Sangogboye and Mikkel Baun Kjærgaard have developed a new occupancy estimation algorithm (PLCount) to accurately correct propagation errors and false occupancy counts associated with stereo-vision cameras. Several sensor modalities for occupancy count estimation e.g. thermal cameras and stereo–vision cameras are quite accurate in a short-term, but usually face depleting detection and estimation accuracy over longer detection periods due to several causes such as occlusion, pixel intensity fluctuations, and poor lighting conditions. Also these false occupancy counts are accumulated over an entire detection period and are mostly detected when the count estimations of a building or zone at any time is negative or when count estimation is greater than zero when a zone or building is expected to be empty. PLCount performs count correction by formulating a count probability and propagation matrix as a forward estimation step and these are culminated by a backpropagation step which performs the final count estimation. PLCount's implementation details are presented in a paper appearing at BuildSys 2016.

Previous and recent approaches for predicting occupancy presence does not leverage or take into account temporal shifts in daily occupancy presence data, the relevance of recent occupancy traits, and inter-dependence between occupants within commercial building. A framework has been developed that improves occupancy presence prediction by leveraging the above stated and obtained prediction results outperforms results from current state-of-art occupancy presence prediction algorithms. This prediction framework has been deployed within the OccuRE platform and is being presented as a poster at BuildSys 2016.

The OccuRE platform provides a flexible and robust framework for deploying several occupancy estimation and prediction applications such as PLCount. Given this framework, a REST API has been developed that enables one-time occupancy queries and subscription to occupancy streams. It is believed that such interface in the long run will enable an online integration of occupancy data for demand-response purpose, correlation analysis between energy performance and building occupancy and investigating and optimizing the energy performance of buildings. In the short-run, the OccuRE platform also provides the custom IDF EnergyPlus configuration inputs to drive occupancy related energy simulations. A demo of the OccuRE platform is also presented at BuildSys 2016.

At University of Southern Denmark, we have established a living lab for research and development activities as a test-bed for the above mentioned sensor technologies. The living lab is comprised by the OU44 building on SDU's Odense campus. The building is 8000 m^2 and consists of rooms for teaching and offices. The building contains 17 3D stereo vision cameras counting users on building and room level.

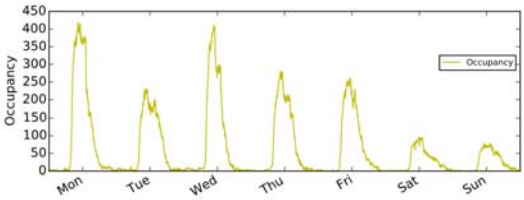


Figure 3 – An example of user counts in OU 44 via 3D stereo cameras.

To illustrate what data can be collected, figure 3 shows data counts collected during a week in OU44. This data is collected via 3D stereo cameras situated at all entrances to the building. The collected data is processed by the OccuRE software platform to reach summed up and cleaned up data. The data show that most activity is during weekdays with some activity during weekends. It aslo shows that some days there are people in the building until late in the evenings.

One way of using the counts is to put them in to a simulation model. Another way to use the data is for optimization of the energy efficiency of buildings. An example of this is to compare actual use with the data counts. In OU44 comparison of the actual use of light and the counts show that a small number of people in the building outside peak hours have a huge consumption of light. Through the counts the extent of the problem can be analyzed and a plan to minimize consumption can be put forward.

More information about this work can be found in publications 4, 5 and 7 of the publication list on page 6.

Associate Professor Mikkel Baun Kjærgaard and PhD student Fisayo Caleb Sangogboye, Center for Energy Informatics, SDU

DATA HARVESTING FROM OU44

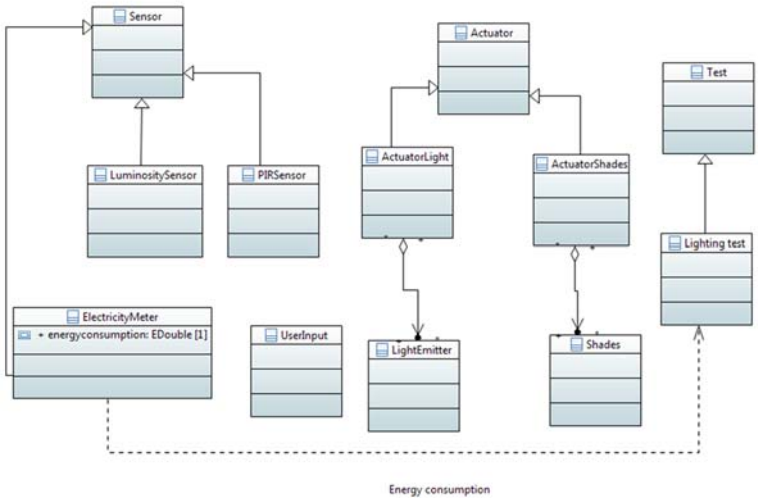
The building OU44 at SDU is a living lab for Energy Informatics. WP3 of the COORDICY project is in charge of making sure that data is collected from all the sensors in the building. PhD student Emil Holmegaard, Post Doc Aslak Johansen and Associate Professor Mikkel Baun Kjærgaard is working on this task. This involves writing drivers that take data from the building instrumentation and deliver them to the center's software defined buildings platform for storage. An important step is to assign proper metadata to all the streams of sensor data. The metadata is essential to provide easy access to the data on the software defined buildings platform. Annotation of the data with metadata makes it simple to request data using queries such as: "give me all points regarding temperature in room Ø22-511-2". This query will return all set points and temperature sensor points for the given room.

To make it easier to annotate points with metadata, PhD student Emil Holmegaard has created a tool called Metafier BI, which can annotate data streams automatically with metadata. The tool does this by mining raw sensor data, and comparing it to reference data sets via machine learning techniques.

More information about this work can be found in publication 2 of the publication list on page 6.

PhD student Emil Holmegaard, Post Doc Aslak Johansen and Associate Professor Mikkel Baun Kjærgaard, Center for Energy Informatics, SDU

MODELING BUILDING COMPONENTS TO FURTHER THE USAGE OF PERFORMANCE TESTING

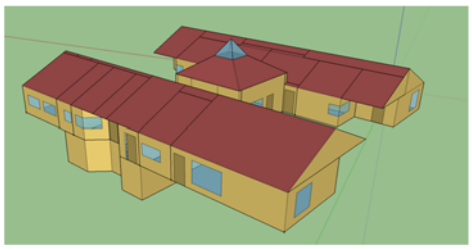


Considering the previously implemented performance tests for hot water, heating, lighting as well as solar cells, a graphical model has been developed with the intention to further the findings behind the results from the performance tests. The model is comprised of a class diagram that takes into account the logical connectivity between the components of the sub-systems in the building, the data required to execute the performance tests, the performance tests related to them as well as whatever constraints the test might imply.

The usage of this modeling takes performance testing a step further by connecting it to all the possible entities related to it. This way, if a performance test fails, a list of potential faulty components would be easy to produce, and therefore it can be taken as an initial step in the fault detection and diagnostics process. If several tests fail at the same time, it is possible to look at the intersecting components that take part in each of the tests, before analyzing them further.

PhD student Elena Markoska, Center for Energy Informatics, SDU

BØGEVANGEN 101 AND RUNEVEJ 107-109



The modeling and simulation work regarding two daycare centers in Aarhus, Bøgevangen 101 and Runevej 107-109, has been completed in collaboration with Aarhus Municipality. 3D models for the two daycare centers were initiated and complete energy models were developed using EnergyPlus software based on plans and data from Aarhus Municipality and field analysis and data collection by two Bachelor students. An overall building energy performance simulation has been conducted and various energy retrofit measures and techniques were analyzed. Based on a technical and economic analysis, supported by data from Aa+ tool at Aarhus Municipality, various retrofit packages have been recommended and reported.

Bachelor students Kristian Emil Oxholm Bloch-Hansen and Casper Fälling Thielsen and Assistant Professor Muhyiddine Jradi, Center for Energy Informatics, SDU

KROGGÅRDSSKOLEN

The work is underway for Kroggårdsskolen as one of the main case studies in COORDICY for energy retrofit. The work which is carried out in collaboration with Odense Municipality and DTI is expected to be completed by October. A BIM model has been developed by research assistant Kenneth Larsen with accurate representation of the building geometry and construction characteristics. The BIM Revit model will form the basis for an overall energy model development of the school as a basis for energy retrofit recommendations.

Onsite inspection has been conducted by Søren Draborg from the Danish Technological Institute and data regarding the ventilation units and heating system was collected. In addition, Sarah Gramstrup from DTI has conducted an anthropologic study on the school including interviews and observations, and a report regarding the occupancy and the school operation was presented. Currently, the energy model for the school is under development taking into account different data input regarding occupancy and school systems. Using the model, energy retrofit and renovation measures will be analyzed and reported to the Municipality of Odense.

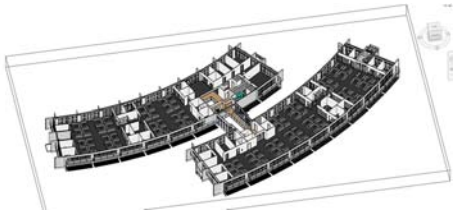
Student Kenneth Larsen and Assistant Professor Muhyiddine Jradi, Center for Energy Informatics, SDU

EJERSLYKKESKOLEN

This work is carried out in collaboration with Odense Municipality. Using building geometry, construction characteristics, and energy supply systems data, 3D model of the different school blocks and an overall energy model is currently being developed by Bachelor students at the Center for Energy Informatics, supervised by Muhyiddine Jradi and Krzysztof Arendt. Using the energy model developed, various energy retrofit recommendations will be provided for the different blocks and final report to Odense Municipality will be conducted.

Post Doc Krzysztof Arendt and Assistant Professor Muhyiddine Jradi, Center for Energy Informatics, SDU

NASA AMES BUILDING



A Revit 3D architectural model has been provided for the Nasa Ames building. Based on the 3D architectural model and additional energy data and characteristics, an overall energy model is going to be developed to simulate the dynamic energy performance of the building and assess various operation scenarios.

Assistant Professor Muhyiddine Jradi, Center for Energy Informatics, SDU

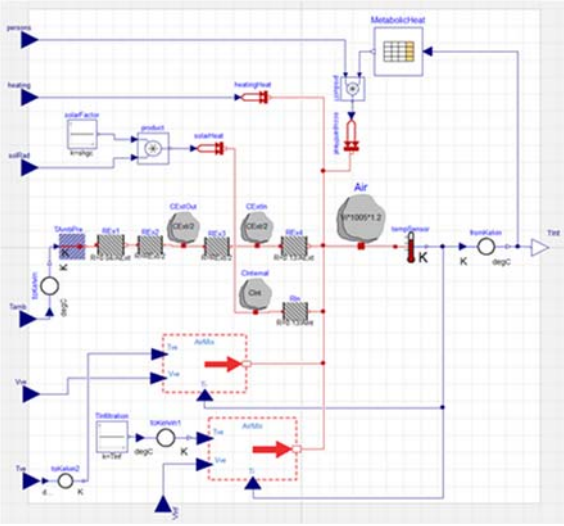
STUDENT PROJECT ON OU44 WITHIN INDEPENDENT STUDY ACTIVITY

Daniel Skarum-Kristoffersen (on the left) and Alexander Boye Petersen (on the right) – the Energy Technology students working on the zone model project within their independent study activity

Last semester, two Energy Technology students, Daniel Skarum-Kristoffersen and Alexander Boye Petersen, chose to work on the zone model of one of the classrooms in OU44 as their Independent Study Activity. Within their project they developed a MATLAB model of a zone. The model was able to calculate indoor temperature and CO2 based on actual indoor occupancy and actuator positions in the ventilation and heating systems. The actual occupancy data was collected by them in a 4h long experiment, during which they were noting the number of occupants and their behavior (e.g. window and door opening). The students won the first prize for the best article within the Independent Study Activity (competition between 4 groups).

Students Daniel Skarum-Kristoffersen and Alexander Boye Petersen and Post Doc Krzysztof Arendt

MASTER THESIS ON ZONE MODELING FOR CONTROLEUM



Current version of the zone model implemented in Dymola/ Modelica, developed by Krzysztof Arendt, planned to be extended by the MSc student

Student Daniel Skarum-Kristoffersen decided to continue his work on zone modeling as his MSc project. His main task is to develop and validate a humidity submodel (currently the zone model calculates only temperature and CO_2 level). The validation will be performed based on the measured data from two test rooms in the OU44 building. As his secondary task, he will try to optimize the zone parameter estimation based on Genetic Algorithm (developed by Krzysztof Arendt). He hopes that the parameter estimation accuracy will increase if the relative humidity (RH) is included in the algorithm (minimization of the error in T, CO_2, and RH). His work is planned to be utilized in the COORDICY project. He will submit the thesis in June 2016.

Master student Daniel Skarum-Kristoffersen
Supervisors: Post Doc Krzysztof Arendt and Associate Professor Christian T. Veje

COORDICY IN THE MEDIA

1. ”OU44 viser vej til fremtidens intelligente bygningsstyring”, Maskinmesteren maj 2016
2. ”SDU-bygning er et stort laboratorium”, Fyens Stiftstidende 26/04-2016
3. ”Systematisk innovation skaber energieffektivt byggeri i verdensklasse”, HVAC Magasinet nr. 2, Februar 2016
4. ”Universitetsbyggeri består med glans”, Byggeri nr. 1, Februar 2016
5. ”Optimeret byggeproces løfter energikrav”, Dagens byggeri, 15. januar 2016

RESEARCH PUBLICATIONS

1. Ana IONESI, Muhyiddine JRADI, Christian Veje. Modeling and Simulation of GTC Energy Performance, University of Southern Denmark, May. 2015.

2. Emil Holmegaard & Mikkel B. Kjærgaard: Mining Building Metadata by Data Stream Comparison, 2016 IEEE Conference on Technologies for Sustainability (SusTech) (SusTech 2016). IEEE Computer Society Press

3. Emil Holmegaard & Mikkel B. Kjærgaard, 2016:NILM in an Industrial Setting: A Load Characterization and Algorithm Evaluation, Proceedings of the 2nd IEEE International Conference on Smart Computing (SMARTCOMP 2016). IEEE Computer Society Press

4. Fisayo Caleb Sangogboye, Mikkel Baun Kjærgaard: PLCount: A Probabilistic Fusion Algorithm for Accurately Estimating Occupancy from 3D Camera Counts. Proceedings of the 3rd ACM International Conference on Systems for Energy-Efficient Built Environments (BuildSys '16) 2016. ACM.

5. Fisayo Caleb Sangogboye, Kenan Imamovic, Mikkel Baun Kjærgaard: Improving occupancy presence prediction via multi-label classification. PerCom Workshops 2016: 1-6. IEEE.

6. Krzysztof Arendt, Ana Ionesi, Muhyiddine Jradi, Ashok Singh, Mikkel B. Kjærgaard, C.T. Veje, B.N. Jørgensen, A Building Model Framework for a Genetic Algorithm Multi-objective Model Predictive Control, 12th REHVA World Congress CLIMA 2016, 22-25 May 2016, Aalborg, Denmark.

7. Mikkel Baun Kjærgaard, Aslak Johansen, Fisayo Caleb Sangogboye, Emil Holmegaard: OccuRE: An Occupancy REasoning Platform for Occupancy-Driven Applications. Proceedings of the 19th International ACM SIGSOFT Symposium on Component-Based Software Engineering 2016: 39-48. ACM.

8. Muhyiddine JRADI, Christian VEJE, Bo N. JØRGENSEN. Towards Energy Efficient Office Buildings in Denmark: The Maersk Building Case Study. Accepted for the 29th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems (ECOS2016), 19-23 June,2016, Portorož, Slovenia.

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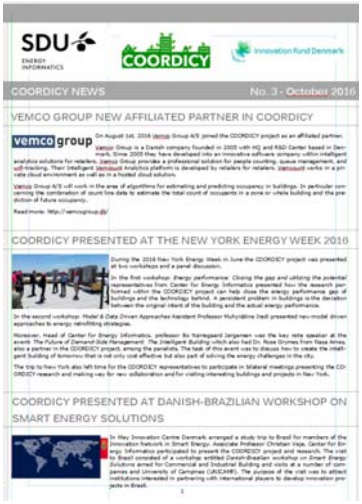
SDU ENERGY INFORMATICS COORDICY Innovation Fund Denmark

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The next newletter will be in April 2017. If you have any input for the next newsletter please contact Heidi Maglekær Jensen phone +45 65 50 35 48 or e-mail: hmje@mmmi.sdu.dk. Any input must be handed in before March 1st, 2017.