4th STSM Report – COST Action TU1403 – Adaptive Façade Network

Date:	01/08/2016
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Host (institution):	Prof. Valentina Serra (Polytechnic of Turin, Italy)

1. Summary

The present document reports about the research activity carried out by Emanuela Giancola, Researcher at the research center Ciemat, Madrid, during her Short Term Scientific Mission (STSM) at the Polytechnic of Turin, hosted by Prof. Valentina Serra.

One objective of the STSM was to bring together and analyze the existing information in the field of Parametric and generative tools for building performance, studying the full potential of parametric design integrating the simulations over different interrelated physical domains using different coupled tools, evaluating emerging technologies for which models may not be directly available in the specific BPS tool used.-This objective is in line with the partial fulfilment of the Task 2.2 and 2.4 of WG2, as well as with Deliverables 2.1, 2.2 and 2.4.

A secondary objective of the STSM was to explore the possibility of joint research projects between the Polytechnic of Turin, the CIEMAT and others (involving national and international funding).

The experience was evaluated as positive both in terms of the progress made in research content, and also in terms of exchange, considering networking and the possibility to discuss and get relevant feedback from peers and experts.

2. Purpose of the STSM

The work carried on the performance prediction of Adaptive Façades has mostly focused on the use of Building Performance Simulation (BPS) as a tool for analysis. Recently, however, there is a growing interest in the use of Parametric and generative tools for performance-based generative design and architectural form. These applications, mostly driven by dedicated plug-ins that interface BPS programs with Parametric tools such as Rhinoceros, Grasshopper, can also have potential when applied to design of adaptive facades.

Current Building Performance Simulation (BPS) tools have limited capability at evaluating the performance of adaptive building envelope technologies due to the following issues:

a) it is not possible to change thermo-optical properties of the materials during simulation runtime, even though they include built-in models for relatively established adaptive glazing technologies (i.e. thermo-chromic or electro-chromic glazing);

b) co-simulation is required in order to evaluate the performance of an adaptive envelope technology in different physical domains (thermal, lighting, etc…), as a single BPS tool is unable to model the behaviour of an adaptive façade in these multiple domains.

In order to overcome these limitations different modelling approximations can be typically adopted:

1) the properties and the performance (i.e. energy consumption) of the building adopting an adaptive building envelope are calculated as the sum of independent static solutions, simulated separately;

2) if an active component is simulated, the control of the thermo-optical properties providing a certain performance is found by a combination between the independent simulations.

These assumptions can results in gross errors in the simulation results. Therefore there is a need to develop new simulation tools, overcoming the above mentioned limitations.

During the STSM, visual comfort and energy efficiency were analysed through an integrated approach. HoneyBee and LadyBug, two add-ons for Rhinoceros parametric plug-in Grasshopper were used to perform this study for their capability to effectively calculate daylight (through the Radiance/Daysim engine) and energy consumption (through the EnergyPlus engine). The schedule control for the visual and thermal proprieties of the TC glazing was carried out parametrically by the integration of EMS system of Energy Plus in HoneyBee (through Grasshopper).

As far as the secondary objective is concerned, due to the common research interests of the UiE3 research group, at Ciemat, and of the TEBE research group at the Polytecnic of Turin, this period was useful to explore the possibilities of cooperation between the two institutions (research projects, PhDs), financed by means of national and international funding.

3. Description of the work carried out during the STSM

The description of the work carried out in order to achieve the primary objective of the STSM can be divided in three phases, more or less corresponding to the 3 weeks duration of the STSM. These three phases consists in:

1) Knowledge exchange;

2) Thermal and Light model;

3) Integration of the two models into a unique integrated simulation strategy;

3.1. Phase 1 – Knowledge exchange

The choice of the hosting institution was motivated by: a) the common interests of the research groups on performance evaluation of adaptive building envelope technologies; b) but most of all by the complementary knowledge of the involved institutions on this topic. In particular PhD work of Luigi Giovannini, who has already a good experience in evaluating the daylight performance of adaptive transparent technologies with HoneyBee/Grasshoper/Daysim software, which have been be very helpful to develop the innovative performance evaluation simulation strategy. Moreover TEBE research group is involved in different projects involving the technological development of innovative adaptive transparent technologies, which would strongly benefit from the innovative simulation strategy to be developed. Emanuela Giancola, on the other hand, has already developed a scientific background, mainly related to the energy simulation strategy at Ciemat adopting the BPS tool EnergyPlus.

The first phase of the STSM was therefore spent in order to get familiar with the different tools to be integrated (EnergyPlus, EMS system of EnergyPlus and HoneyBee/Grasshoper), and the simulation strategy adopted to model the optimal control of an adaptive façade. Most of the time was involved in studying the theory behind.

3.2. Phase 2 – Thermal and control model

The aim of the second phase was to build a thermal model to fit the purpose of a case study with EnergyPlus and EMS, whose control of the adaptive façade could be simulated according to the results of both the daylight and thermal simulations. This was completed by means of the following stages:

a) analysing a thermal model in EnergyPlus reflecting a case study under consideration (a building with a thermocromic window). This model, as the daylight one, is completely parametric, as far as the following variables are concerned: 1) climate; 2) orientation; 3) thermo-optical properties of the transparent façade (any thermo-optical property of the façade can be controlled on an hourly basis);

b) integrating the thermal model with a Parametric (HoneyBee/Grasshoper) tool by means of the Python language, in order to optimise the control of the adaptive façade (thermochromic in this case) according to one or more objective functions;

3.3. Phase 3 – Integration of daylight and thermal model

The aim of the third phase was to integrate the two parametric models (daylight model in HoneyBee/Grasshoper and thermal model in EnergyPlus) into a unique simulation tool. This was achieved by completing the following task: enable the communication between the results of the daylight model and the thermal one during simulation runtime, by means of developing i) a script in Python/Grasshopper that generates inputs for the thermal model in EnergyPlus (Illuminance results for different façade configurations), and ii) different scripts in the EnergyPlus thermal model by means of the EMS submodule, in order to calculate daylight metrics and lighting system energy use according to a scheduled control strategy. This was the most delicate and time consuming part of this phase, given the high number of variables and simulation step involved.

The architecture of the integrated simulation tool developed consists of: the coordination layer (the interface) is designed in Python/Grasshopper, the evaluation layer is constituted by EnergyPlus (Thermal model) and Daysim (Daylight model). The coordination layer is used to enable the communication between the different evaluation models.

The workflow of this simulation work consists of the following steps: (a) The Thermochromic properties of the glazing are modelled in Grasshopper by entering its spectral data. (b) The initial daylight calculation, based on the first set of individuals, is run by means of HoneyBee (through the Daysim engine) in order to evaluate visual comfort and create artificial lighting use schedules for the material states defined. The Termochromic model is then built in EMS system. Consequently by developing i) a script in Grasshopper that generates inputs for the thermal model in EnergyPlus (Illuminance results), and ii) different scripts in the EnergyPlus model by means of the EMS submodule, daylight metrics and lighting system energy use final schedules are calculated, by selecting and merging the data from the schedules generated in the initial daylight calculation step. (c) HoneyBee Energy Plus component collects the final artificial lighting schedule and performs a yearly thermal dynamic simulation. As a result, final energy consumptions for heating, cooling and artificial lighting are provided

4. Description of the main results obtained

The post-process and interpretation of the results from a case study, and the case study in itself, are still in progress and will result in a manuscript and will be also the object for future STSMs.

The main results of the STSM are two-fold:

1) a parametric simulation strategy/tool was developed in order to evaluate the performance of building integrated adaptive façade technologies. This tool integrates daylight, thermal analysis, and enables the optimisation of the control of an active adaptive façade according to multiple objectives. In particular this tool can be really useful in filling the gap between technology driven and performance driven product development in the context of adaptive facades. In fact it enables to evaluate the highest performance of an adaptive façade achievable, according to different objectives, if optimally controlled. This is important to guide and steer the product development based on the performance objectives;

However, given that the length of the STSM is not enough to carry out a case study, the STSM would serve to define the boundaries and set the evaluation method. This purpose was partially accomplished, because even though real progress was made in terms of gathering information for this definition, there is need for more information to set the final set of criterion. As tangible results from the STSM, there is a preliminary evaluation method that needs to be tested and validated.

2) new relationships and research interests were created between different research institutions by means of this STSM. This can potentially result in different joint publications in the first instance; in fact different papers were planned between the two research groups, one including also an other research groups, but also in the writing of common research projects.

5. Future collaboration with the host institution

Different topic of collaboration were found, all of them adopting the simulation tool/strategy developed during the STSM:

- evaluation of the possibility of controlling different adaptive transparent façade by means of simpler control metrics (to reduce calculation time and control implementation), such as control of glare based on illuminance levels;

- evaluation of the performance of different smart glazing technologies that are under development at other institutions;

6. Foreseen publications/articles resulting from the STSM

The work developed during this STSM is in the process of writing in order to be submitted and will be shared in the form of a Congress article (either Building Simulation Conference, IBPSA 2017; Mid-term Conference of Cost TU1403) or a journal paper for an international journal (either Energy and Buildings or Solar Energy, published by Elsevier)."

7. Confirmation by the host institution of the successful execution of the STSM

Please refer to the letter attached.

8. Other comments