論 文 の 内 容 の 要 旨

論文題目　Research on Learning by Doing in the Operation of Building Systems: Comfort Scenarios in Data Supported Human-Window Interaction
(建築システムを「使いながら学ぶ」ことに関する研究：人と窓と間のインタラクションにかかわるデータに支援された快適シナリオについて)

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This investigation is oriented to improve traditional human interaction within the built environment towards better indoor environmental quality and reduction of energy consumptions. It considers that through the implementation of information technologies integrated into openings, it is possible to promote the diversification of energy strategies increasing the use of windows systems, which are indicated as a fulcrum in the management of comfort and low-energy flows between inside and outside.

The thesis revolves around the concept of experiential learning. After a first case study and a general discourse on comfort, it takes the example of windows to discuss the possibility of systems capable of supporting users during window operations. In addition to field tests and the development of simulation software as a method of investigation, a novel window system is devised to implement the theory. Eventually, a second field case study is conducted to demonstrate the capability of the system in triggering an initial LBD process towards comfort. Particularly, it involves a group of people interacting with a prototype and responding to a survey on comfort and learnability. The text is divided into five chapters.

'Chapter I' introduces the context of the research. It is stressed the influence of end-users in balancing energy consumption and comfort during building operations. This aspect often creates wrong expectations between design purposes and the reality of building use. To solve such an issue, designers should aim at 'sufficiency' measures that concentrate on improving behavior towards 'good enough' actions.

Their behavior is supported by bioclimatic environments that increase the connection between low-energies and multiple adaptive opportunities to reach comfort goals. Subsequently, adaptive comfort principles are introduced as the main method to identify and assess design measures in favor of people's reactive behavior towards the environment. Therefore, adaptive comfort is considered a way to describe the comfort preferences of users inside naturally ventilated or mixed-mode buildings.

In the central part, the importance of the manual operation of windows is highlighted. In this sense, windows are demonstrated to address ventilation strategies and to balance comfort requirements with energy losses. Eventually, the manual control of window permeability is considered difficult to replace given user's skills in managing generated conflicts and refined operation, thus informing behavior is the right trade-off to be considered inside design strategies.

At the end of the chapter, previous experiences on informed behavior with windows are discussed. The author argues that given the clear impact of human-window interaction, there are a few studies aimed at expanding adaptive opportunities of people and the design of proper window interfaces focused on learning. Eventually, the research moves forward, stating the central hypothesis. It is argued that "Thanks to provisional information in favor of natural ventilation provided by the window system, we could trigger a learning process that increases adaptive opportunities, indoor comfort, and consequently reduces consumptions."

The general aims of the research are to discuss the traditional interaction with windows and find possible learning opportunities, and subsequently, understanding whether feedback technologies can increase awareness about indoor comfort and support people towards it via a long-term Learning-By-Doing (LBD) process.

In 'Chapter II,' the research focuses on how human biology translates external and internal information in adaptive behavior. Specifically, it is considered that discomfort sensations are the trigger towards behavioral change. However, the human mind/body is more capable of defining some stimuli in place of others. Therefore, a qualitative case study was conducted to clarify what is commonly more difficult to detect. Specifically, it measures the skills of a group of people in detecting the variation of different environmental parameters. The experiment highlights that the group was able to recognize distinct temperature stimuli yet lacked in recognize the 'intensity' of humidity and CO2 variation. Therefore, it suggests the correlation between outdoor average temperatures and people's comfort. Additionally, focusing on information about climate parameters difficult to detect becomes a key point to improve the learning process with windows.

In the second half of the chapter defines the LBD concept and investigate how people seek information inside their usual environments. Especially, a literature review on feedback technologies helps to find different modalities to involve user's attention within the built environment. Those mechanisms are introduced in the LBD 5-step cycle, presenting a general framework that considers the implication of the built environment, different users' levels of understanding, and the comfort as aim.

In the first part of 'Chapter II,' the author identifies what drivers trigger and influence traditional human-window interaction. For this purpose, a literature review is performed. Besides measurable environmental parameters, researchers indicate other non-environmental factors linked, for instance, to users' ability/opportunity, knowledge, control perception. The importance of outside temperature as a trigger is confirmed by literature. Nevertheless, researchers do not agree on which factor affects the interaction. In the meantime, grouping the factors from the perspective of the learning process gives further insights. Notably, three distinct categories are suggested: 1) measurable factors, 2) measurable but difficult to perceive, and 3) difficult to measure. Concluding the literature review, it is argued that in such studies, a few ask about the opportunities given by design or the knowledge of the user. Furthermore, they do not indicate any design suggestions.

In light of the above, 'Chapter III' illustrates the design aspects of the devices that constitute the new window system. Then, the system and components of both devices are introduced, indicating communication protocols between the different modules. Furthermore, a control logic illustrates the main functioning of information flow and user's reactions. Afterward, the text lists the primary data collected by the system and describes the process to obtain secondary and tertiary information. In particular, while the former permits to calculate real data of interest, the latter translates them into intuitive information to be displayed on the User Interface (UI).

In the central part of the chapter, a simulation software based on Excel is implemented to demonstrate the program flow from primary data collection to visualization. Mainly, it shows real-time changes in information appearing on the UI when the user is operating the window. Eventually, this software demonstrates the effectiveness of the conversion formulas in displaying qualitative messages starting from sensed data and constitutes a base for the next programming of the prototype.

At the end of the chapter, it is explained how people could learn from the system. For this purpose, three comfort goals are imagined based on three different user profiles. Those scenarios are discussed one by one considering an activity diagram, where the user's scenario of actions is illustrated along with the window outputs.

‘Chapter IV’ is dedicated to clarifying the process that led to the realization of a prototype of the system. In the first part, practical insights on ventilation measurement methods are collected from the literature. It is concluded that due to design constraints, detecting differential pressure is the ideal method.

The second part presents different field tests dedicated to describing the behavior of sensors and their eventual positioning inside the prototype. Particularly, the first test aimed to indicate the maximum and minimum ventilation point of the opening, and then, the second and third tests visualized the airflow profile passing through the window compartment, suggesting the best configuration for the pressure sensors.

The central part of the fourth chapter illustrates the prototype in detail. Specifically, the text explains the main components and the assembly of the hardware modules. Particular emphasis is dedicated to clarifying the connections and positioning of sensors. Eventually, a further field test demonstrates the capability of the system to monitor primary data in the loop.

In the final part of chapter four, the prototype is utilized to conduct a case study in the field, involving a group of participants. The campaign focused on demonstrating the possibility of the system to support an initial learning process towards comfort. The results discussion is based on the comparison of the user’s vote before and after reading the information displayed by the window. Notably, the variation of the answers permitted to interpret the influence of the system on people’s opinions and their consequent behavior.

Due to the general diffusion of the Covid-19 pandemic, the assembly of people and access to the campus facilities have been restricted. Therefore, it reduced the extent, participation, and duration of the test. However, the results are considered a hint that the hypothesis is confirmed, suggesting that an initial learning process is possible.

The last chapter summarizes the main results of the work and discusses the LBD systems in perspective. The main conclusion is that the window presented in the thesis might suggest that similar LBD systems could favor comfort and energy saving increasing end-users’ knowledge of building systems through daily practice.