COMPUTATIONAL MECHANISMS IN ARCHITECTURAL ADAPTATION AND INTERACTION PROCESS THROUGH HUMAN BEHAVIOR PHYSICAL INPUTS

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Abstract
This paper demonstrates and discusses an ongoing teaching and research investigation concentrated on the development of computational mechanisms in the early conceptual design stage as part of architectural adaptation and interaction process. In order to achieve this, computational design strategies are developed involving human behavior physical conditions, which result real time design possibilities to emerge. Analytically, physical data derived from external human behavior influences are encoded and used as the input parameters in our suggested adaptation process. Together with digital or physical adaptive architectural outcomes, control mechanisms are suggested that represent the intelligence of each computational design system. The suggested process is considered as a feedback loop mechanism that cyclically iterates between design generation to perception and evaluation of design solutions according to architect-user personal decision and choice. In this paper, selected teaching and research outcomes are demonstrated and discussed, specifically in terms of their ability to produce desirable results based on the interactivity between digital mechanisms and processes as well as human behavior as physical inputs.

Keywords: computational mechanisms; adaptation; interaction; human behavior; physical inputs

1 INTRODUCTION

The rapid development of computational mechanism in architectural design opens up new possibilities in digital design process. This expands digital tools' ability to be used in architectural design beyond simple representation of forms in the final stage of design, focusing their attention on the early conceptual design development.

The tendency towards computational design investigation introduced in the second-half of twentieth century has been related with the notions of adaptation and interaction. Based on the ideas derived from biological and scientific principles, architects, researchers and theorists introduced and discussed innovative architectural design solutions generated and investigated using mathematical and computational means. Pioneer work by Alexander (1964) discussed in theoretical level the concept of gradual adaptation that produces 'well fitting' results, developing models that investigate functional requirements and their interactivity (Alexander, 1964). Similarly, Negroponte (1973; 1976) discussed adaptable machines in design (Negroponte, 1976) and intelligent buildings that response to environmental influences (Negroponte, 1973). Influenced by similar concepts, Frazer (1995) investigated evolutionary and adaptive architecture by integrating computational methods based on natural principles (Frazer, 1995) involving ideas found in cybernetics through feedback loop, an influential component in adaption process (Frazer, 1993; 1995).

The current tendency towards the investigation of digital design possibilities in the early conceptual design stage is gaining significant ground. Several directions of investigation can be found including works concentrated on the development of software and computational techniques, aiming on the digital optimization and physical transformation of buildings, spaces, etc. In all cases, adaptation and interaction is considered notable aspect of digital or physical architectural solutions. In order to achieve this, new tools focus on the incorporation of different parameters and data inputs with the parallel use of control mechanisms as medium for the production of adaptive and interactive outcomes.

In one direction, parametric-associative design logic is used as the control mechanism towards design generation, modeling and simulation. In another direction, physical systems transform their behavior through kinetic principles and embedded technology. The use of kinetic mechanisms and materials on the one hand, and sensors, microcontrollers and actuators on the other hand shows the multidisciplinary direction of current design investigation in order to achieve physical real time behavior of prototypes (Fox and Kempt, 2009; Achten, 2011).

In all cases, architectural adaptation and interaction might be seem as the output results of the process where environmental, human related or other internal and external conditions are functioning as the input part of the control mechanism. The incorporation of human behavior as physical input into the control mechanism of digital design is gaining considerable attention. This can be achieved using sensors and other devices like Kinect camera, allowing the transformation of physical information into the mechanism for digital design development (Lücker et al, 2013).

This paper attempts to investigate adaptation and interaction in the early conceptual design stage based on a proposed feedback loop procedure where cyclical iterations between design creation and verification of results and the parallel use of human behavior physical inputs are used to find solutions that satisfy architect-users personal criteria. Hence, discussion in regard to the process of adaptation as computational mechanism involved in design and its correlation with decision-making process is under consideration.

2. COMPUTATIONAL MECHANISM AND FEEDBACK LOOP PROCESS

Based on previous work done by the author (Kontovourkis, 2013), this paper demonstrates an updated version of our suggested feedback loop design framework that explains adaption and interaction as part of digital design process. In parallel, the way computational mechanisms are applied towards the development of physical/digital results is explained.

In the diagram of [Fig. 1.] three main areas are distinguished: input, output and control mechanism. The human behavior physical conditions are included in the input area represented as the internal input together with the external environmental related input data. The adaptive physical/digital output results are included in the output area, and finally the adaptive or interactive behavior of the system is included in the control mechanism area.

Analytically, sensors, Kinect camera or other devices are used for the acquisition of human behavior physical input data, which are encoded according to the simulation tasks, different in each case. Output results continuously influence and update the input data leading to the production of adaptive or interactive design results. In parallel, other input data, in this case external, are used in the feedback loop process feeding the systems independently. These can be incorporated into the system influencing also the output results. Through actuator mechanisms that control the

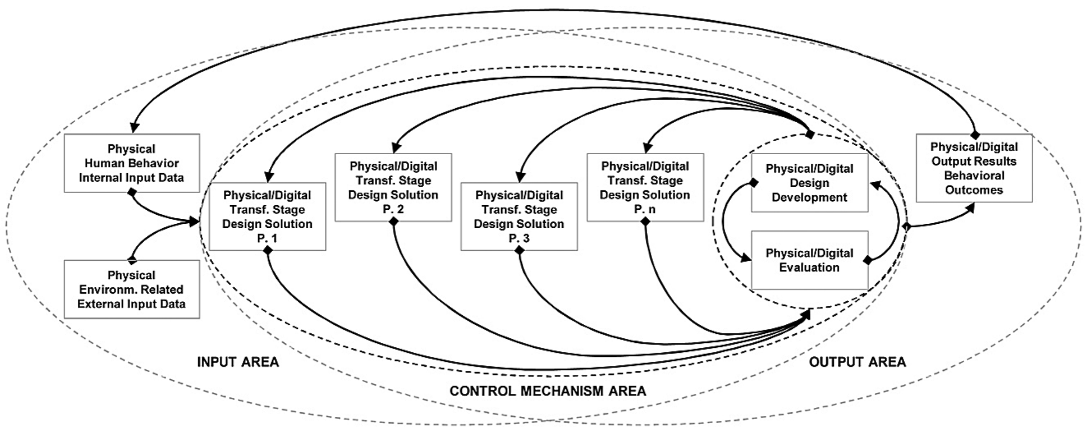

Fig. 1: Feedback loop process for architectural adaptation and interaction: drawing: by author

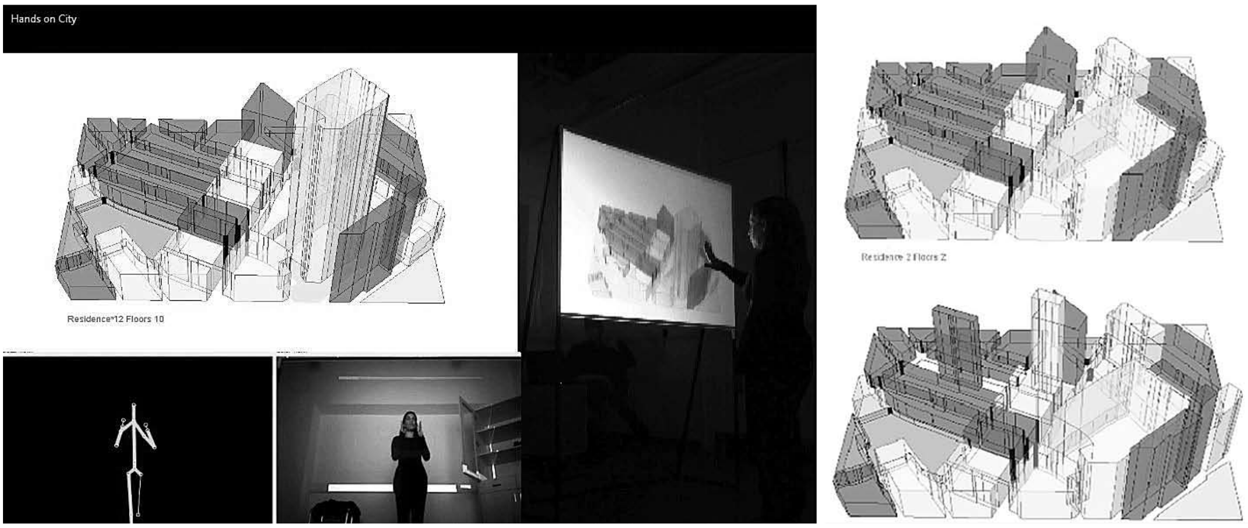

Fig. 2. Adaptation of urban fabric through hands motion behavior.
Authors: Anagiotou Despo, Kyriazis George, Papapetrou Kleopatra, Hatzicharalabous Stella, ARH-522, Fall 2012 (Kontovourkis, 2013)

behavior of kinetic systems or through projection of adaptive or interactive design outcomes in the physical environment, the perception of results by the architect-users can be achieved.

In the control mechanism area that is functioning as the intelligence of the system allowing the adaptation or interaction between human behavior inputs and output results, two main parts are suggested. The part dealing with the design development related to the 'creativity' and the part dealing with the evaluation of proposals expressed as the 'accuracy' part. 'Design development' and 'evaluation' parts are continuously iterated leading towards digital adaption and interaction or physical transformation of the proposed architectural system.

A number of outcomes are produced (1, 2, 3, n) assisting design decisions taken in the early conceptual stage. Numerous repetitions in the open loop procedure allow verification of output solutions through control mechanisms and human behaviour physical input. The decisions taken within this process are not only controlled through algorithmic rules introduced in the 'evaluation' part but also through intuitive process. The human behaviour physical conditions and the way these are encoded influence adaptation and interaction.

Following examples show different computational mechanisms that involve the application of sensors, microcontrollers and actuators. Arduino technology is used to connect the physical with the digital world and vice versa, and is associated with parametric design software Grasshopper (plug-in for Rhino) through Firefly (plug-in for Grasshopper).

3. ADAPTATION AND INTERACTION THROUGH HUMAN BEHAVIOUR PHYSICAL INPUTS

The following experiments are dealing with adaptation and interaction in the early conceptual design stage. These have been developed in the Department of Architecture at the University of Cyprus as part of the course advance topics in computer-aided design. In this course, students are asked to create from scratch their own computational mechanisms based on the suggested feedback loop framework (see previous chapter) involved in the early stage of design decision making process. In parallel, their knowledge and skills in the area of parametric design and physical computing are developed giving attention into the human behaviour physical data acquisition.

Human behaviour data are used as the real time input parameters feeding the control mechanism and in parallel achieving adaptation and interaction behaviour through algorithmic and behavioural control. Output results are developed and visualized by projecting or physical prototyping. Physical/digital transformation possibilities are produced and evaluated based on the criteria specified by the architect-user and according to human input as well as to generated outcomes.

In the project shown in [Fig. 2.], suggested computational mechanism is used to develop an adaptive and interactive relation of architect-users with the selected urban fabric. Human behaviour, in this case hands motion tracked by Kinect camera, is used as the physical data accelerating adaption and interaction with the virtual environment. The role of architect-user as the sole person responsible to take design decisions in regard to the morphological transformation of urban fabric in conceptual level is considered significant.

This project [Fig. 3.] suggests a computational mechanism involved in the human behaviour data acquisition, in this case motion behaviour using motion detectors sensors, which in turn is projected on the interior courtyard of the department. The real time interactive information related to the number and area occupation of users is triggered by their continual movement and perception in the interior of space allowing feedback relations to be developed.

In another case [Fig. 4.] interactivity in a proposed elastic structure based on human bodily movement is examined. Pressure sensors are applied on the floor of the structure accelerating actuator mechanisms (motor sensors) that are responsible for its structural transformation behaviour. Through fluctuations of physical input parameters, as a result of human behaviour, a series of morphological outcomes are generated and controlled by the architect-user.

In all cases, computational mechanisms are developed using visual programming, in this case parametric-associative design logic. Human behaviour physical input conditions are derived from the built environment, encoded and used as the parameters influencing the control mechanisms. In the process of adaptation and interaction, the feedback loop between output results and input human behaviour as well as between design and evaluation plays fundamental role in any architectural system development in the early conceptual design stage. The criteria of evaluation are specified by the architect-user who takes decisions in regard to the algorithmic rules of control as well as in regard to the architectural scenarios under investigation.

Through this investigation, skills related to the use of advanced computational principles, i.e. parametric design, physical computing, etc., are offered to the students, expanding their knowledge, understanding and awareness in regard to the use of computer technology as part of design process. Obviously, results obtained show that such methodology can be used to investigate predefined scenarios, i.e. early conceptual, since the design process presupposes a large number of parameters, criteria and decisions taken in different levels, which cannot be controlled entirely by the computer.

CONCLUSIONS

In this paper, a teaching and research investigation into the development of computational mechanisms in architectural adaptation and interaction is presented, giving emphasis on human behaviour conditions as the physical inputs that feed our proposed conceptual design framework. Based on the idea of a continuous feedback loop mechanism, design results are evaluated in real time under the influence of those physical conditions allowing large number of design possibilities to emerge. However, such tools offered limitations and potentials especially in regard to the general design process. Digital processes can only be part of design decision making process and cannot replace entirely

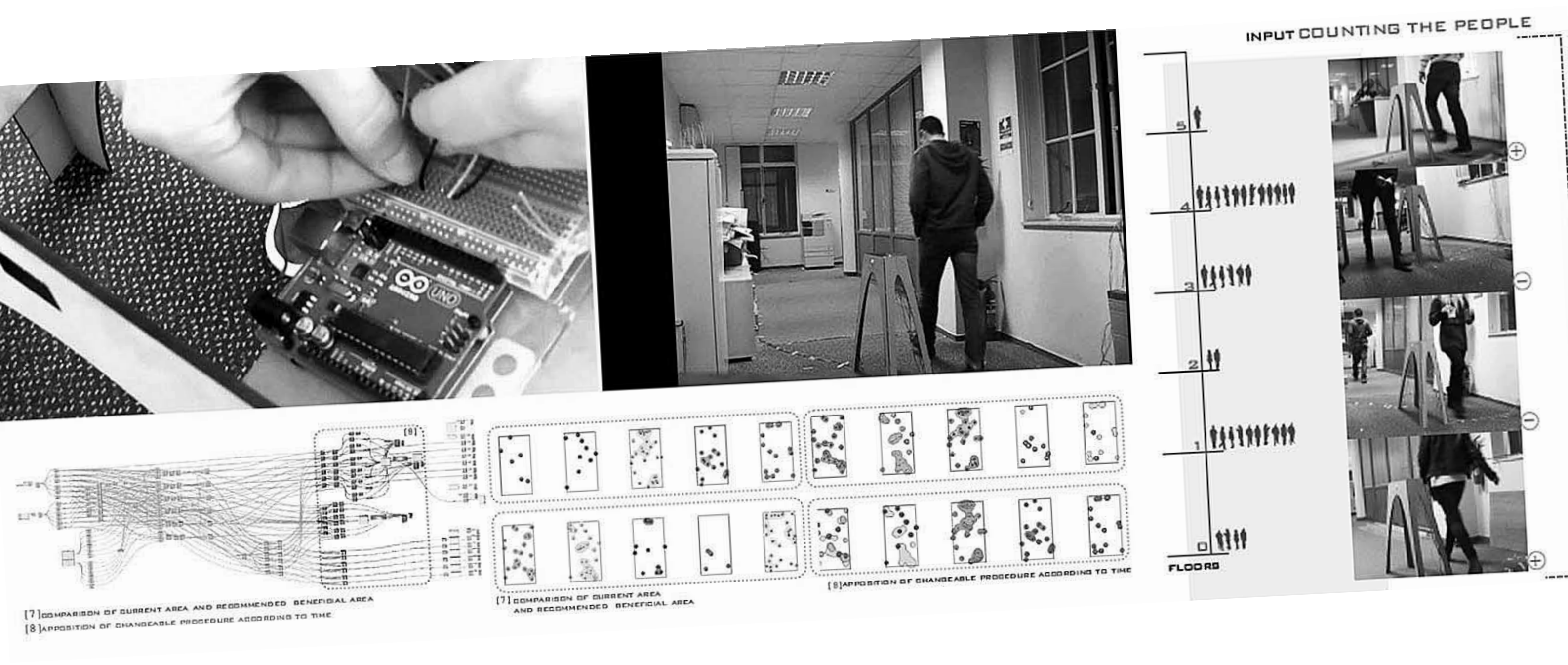

Fig. 3. Human motion behavior and interactivity in the interior space.
Author: Antoniou Melina, Konatzi Panayiota, Neofytou Ifigenia, ARH-522, Fall 2012 (Kontovourkis, 2013)

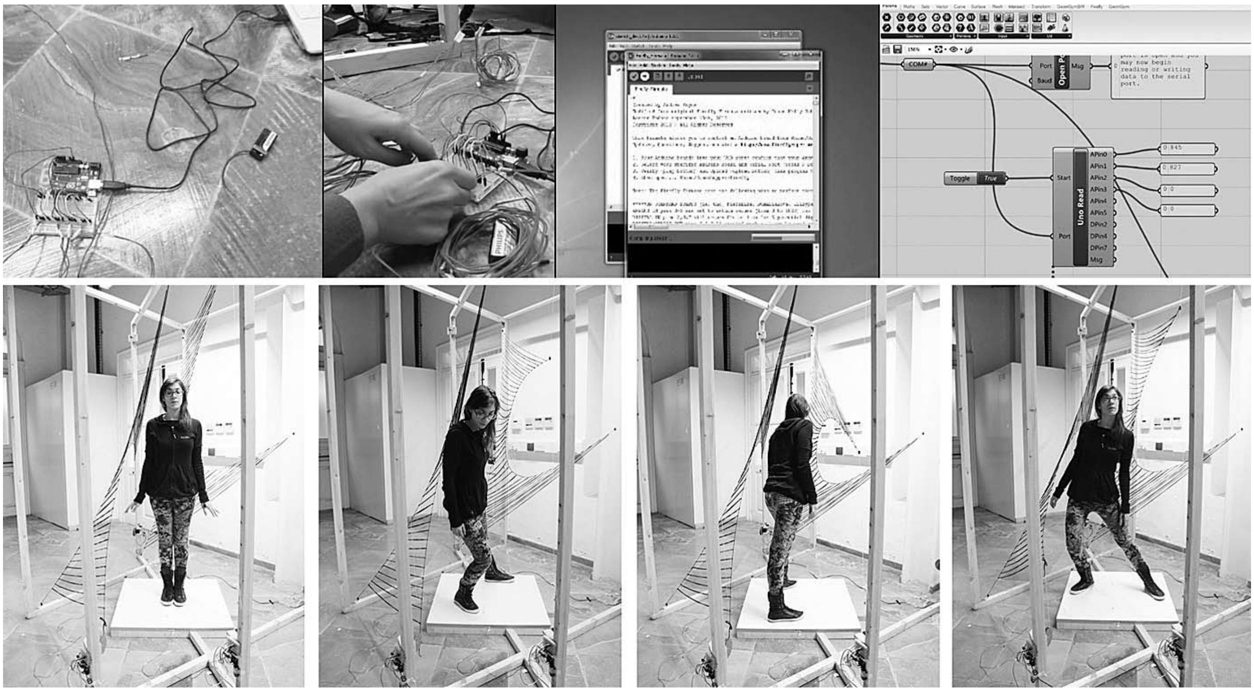

Fig. 4. Human bodily movement and adaptability of a responsive elastic structure.
Author: Georgiou Niki, Pavlou Rafaela, Pirikki Nicky, Polychronidou Pantelina, ARH-522, Fall 2013

the role of architect who is responsible to control design in different stages, an important aspect in this investigation process, which is conceived by the students raising their personal awareness in digital issues.

In conclusions, current teaching and research investigation might offer to the students as well as to the architects new knowledge and skills towards the application of digital tools in design decisions making process, especially in regard to the way new technological issues are applied in adaptive and interactive design process. In this way, developments towards an interdisciplinary research direction that use technology as the medium to connect the physical with the digital world, aiming to find close relations and links with the dynamic influences of the build environment can be achieved.

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