ROBOTOWN

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Abstract. The potential robotization of architecture, its fabrication and assembly impacts design education today. In the near future it will contribute to the emergence of the new forms of urbanization. Our design research is focusing on the small scale urban conditions and build fragments that make up intelligent city. It is undertaken by the multidisciplinary team of architects and mechatronics engineers in academic context. The ROBOtown is understood as an urban structure containing intelligent town fragments. It has to consider the participatory design process involving architecture, mechatronic, robotics and lessons derived from Industry 4.0.

Keywords. Design; Internet of Things; Architectronics; Mechatronics; Robotics.

1. Introduction

Future cities should become more efficient, inclusive, and sustainable. This can be achieved through more efficient resource management, improvement of governance at the local level, effective connectivity and public participation. Robotics play an increasingly important role in responding to the anticipated exponential growth of the XXI c. urban populations (Sassen 2018). The intelligent robo-town calls for design research of small urban modules that make up the neighborhood as an alternative to the prevailing, large scale urban projects. It combines the concepts of information flow in the city (Stock 2011) as well as proposals for the design and reorganization of buildings and infrastructure using robots and mechatronic systems at the scale of dwelling, building, neighborhood, or town. Robotics are deployed not only in fabrication but also in activating new, interactive and responsive urban environments.

1.1. BACKGROUND

Robotics can be seen today as creative tools in the processes of designing, modeling and urbanizing global society of knowledge. The use of automation and robotics affects the city of the future and its architecture is of central importance. In the architecture supported by mechatronics, like in the industry 4.0. all phases are managed with IT and online (Berroneet al. 2018). From the creation

of the concept, through design development, virtual modeling, and simulation, automated and robotic construction, quality control, marketing logistics, service and repairs, to utilization of generated waste - all phases are managed with information technology. In the future towns mechatronisation of the design process, building and using architecture in the context of intelligent, responsive urbanizations will play a significant role (Schmitt 2015). Fabrication, assembly of structures and elements of architecture built with the use of robots become a reality. Kinetic architecture can be also one of the forms of interface, responsive to changing environmental conditions and changing user’s requirements. These dynamic conditions and requirements for the modern city are direct analogies of changing requirements and their implementation in relation to Industry 4.0 products and processes. Social participation can be applied on a large scale thanks to modern technology and information solutions belonging to the new industrial revolution. The postulate of open data and ability to easily obtain data from the Internet of Things (IoT) based on the current needs of users and the safe cooperation between human and robot systems can increase the role of participation and automatization in architectural and urban design.

2. ROBOstudio

ROBOstudio is an experimental project, implemented at the Faculty of Architecture of the Warsaw University of Technology in cooperation with the Faculty of Mechatronics since 2011, based on the concept of Architectronic (Meyboom, Wojtowicz 2010) - synergy cooperation of architecture and mechatronic, is a new approach applicable in the area of prototyping and fabrication as well as designing responsive structures (Wrona, Wojtowicz 2017).

ROBOstudio aim to solve technological problems by going further than simply reusing existing solutions, already adopted in architecture. Students are encouraged to be creative and draw inspiration from various technologies and fields. While still in the conceptual phase, the main goal of the studio is a creative search for future generation of solutions that may now seem utopian, but can serve to improve the quality of life architectronic users, including seniors and the disabled.

2.1. ROBOSENIOR IN URBAN PLANNING CONTEXT

The ROBOsenior - topic of the editions carried out in 2017/2018 and 2018/2019, the project involved solving problems of the elderly and starting research on individual problems they face. The basis of the design is an attempt to solve the real problems of residents - it initiates the possibility of creating and thinking about the new intelligent town.

The projects went from the scale of details - equipment increasing the comfort and safety of seniors, through the design of the entire residential unit, to the vision of creating neighbourhood spaces by a group of capsules, or their integration with the existing urban tissue.

A series of lectures accompanying the project introduced students to the basics of mechatronics, the concept of architectronic and the integration of digital
systems in the field of fabrication and responsive architecture. In addition, course participants attended introductory workshops on robotics, provided by the Faculty of Mechatronics of the Warsaw University of Technology.

In the first phase of the project, students got to know and did research on available and planned technologies both in the field of care for the elderly and technological equipment that would increase the quality of seniors life. At the same time, they got to know the technical aspects responsible for the possibility of implementing the kinetic architecture and residential capsules.

In the second part of the course, students were focusing on the needs of residents, they developed a detailed design of functional solutions of the capsule, a plan of a residential unit and the concept of its functioning in urban, suburban or free space, depending on the individual approach to the topic of the group.

The final task of the course was to focus on one particular kinetic aspect of the proposed solution and build a physical, performing model of it. By that time, students already completed Arduino workshops and were ready to program basic actuators on their own. Work on the physical model was aimed at encouraging students to do in-depth geometric analysis of solutions and checking their feasibility. It also helped them develop algorithmic thinking, required to program their abstract designs into a real, working proof of concept.

In the first edition, they were to concentrate on the best technical solutions which can be implemented in an architecture environment to solve seniors’ problems - physical, psychological and social. During the second edition taken in 2018/2019, students were encouraged to consider the future of the robotic capsule (Dąbrowska-Zółtak, et. al., 2018), and ask what are effects of a wider range of solutions, located mostly to the city center (figure 1.).

![Figure 1. Comparison of areas of implementation and degree of mobility of ROBOstudio projects released in 2017/2018 (circles outlined dotted line) and 2018/2019 (circles outlined solid line).](image-url)
2.2. ROBOSTUDIO 2017-2018

The first edition of this topic, implemented in the 2017/2018 academic year, tutored by prof. Jerzy Wojtowicz and Karolina Dąbrowska-Żółtak, assumed that the result of the project must be a self-sufficient, mobile capsule adapted to provide comfort and safety for the elderly and disabled. As a result of such assumptions, the solutions developed in most cases took the form of extensive modular suburban buildings. Examples of such projects are the projects: Connectivity Net, Housing Ring and Flexible Membranes (Graduation Towers).

2.2.1. Suburban Capsule Net

In the scale of neighborhood units, the residents of Connectivity Net assumed the possibility of implementing neighboring elements such as creating cities based on a network of connections - neighborhood units - walking to the nearest services, including health care. The city as a safe network enables navigation, e.g. using augmented reality, control points in the city and provides security and access for people with dementia.

In the Ring project, a physical network was set up to enable services on an urban scale - quick transfer of physical items between capsules in the ring, like laundry, meals, shopping. The extension of this project is the elements responsible for transmitting physical data within a neighborhood unit or city - automated mail with delivery to a building or house being able to replace people in the services sector.
In the project **Flexible Membranes** external material of the capsules create a favorable microclimate inspired by graduation towers and common caves. The tent structure of the living capsule and telescoping retractable windows would allow the living space to be expanded if, for example, children and grandchildren are hosted.

### 2.2.2. City Centre Capsule

The exception was the **Future Capsules - Multigeneration Hauses** project, in which students assumed that an alternative to living outside the city could be the use of roof surfaces in the city centers, where capsules could be set up with a flexible structure to adapt their shape and dimensions to the current needs of users.

### 2.3. ROBOSTUDIO 2018-2019

The second edition of the ROBOsenior theme implemented in the 2018/2019 tutored by prof. Stefan Wrona, Karolina Dąbrowska-Żółtak and Marcin Strzała, instead of focusing on designing easy-to-transport housing units, allowed students to reinterpret the capsule as an apartment, mechatronic equipment of existing housing, supporting seniors and their safety, or megastructures equipped with mobile housing units dedicated to elders. Prepared projects present an overview of solutions from minor interventions in the existing urban tissue through the introduction to existing apartments of modular mechatronic solutions enabling equipment (POKEhouse, Robotic Arm), through independent capsules they fit into free urban spaces in a smaller room, as well as mobile units (Truncated CUBE, ROBOTaco) and the larger buildings (Doors) where individual capsules are a mobile part of appropriately dedicated building cores, up to mega-structural assumptions containing residential and service parts, both those located in the city centers (Moving Capsules) as well as in green areas (Integrator).
2.3.1. Equipment

The POKEhouse project assumed the creation of a modular system consisting of a range of basic modules performing various functions, including; sensors collecting data and detecting potential threats, speaker that can send warning signals and messages in order to interact with the user, system resembling an airbag, opening at the time of detecting the risk of falling, to minimize a user’s injury.

The modular system adaptable to existing flats, assuming that it can become a residential capsule of the future after equipping them with modern technological systems aimed at improving the safety and comfort of users. Consisting of active repetitive units it gives the opportunity for the future development of the project and supplementing it with new types of modules along resulting from the discovery of further user’s needs and technological development.

The project assumptions are the new industrial revolution, including the possibility of mass customization of orders based mostly on modules produced as part of serial production, and the automation of the process of collecting data
on apartments that would be adapted to the needs of older people by equipping them with the POKehouse system.

The basic premise of the Robotic arm project is to equip the future living space with a multifunctional robot arm suspended from the ceiling. It would act as an assistant helping seniors to perform basic tasks and protecting them from physical fall. The project assumed the use of safe collaborative robots suspended on a ceiling system that would limit the number of robotic arms while ensuring their access to all required space in the capsule or apartment. The project assumed the possibility of installing the Robotic arm system in existing flats as well as in the mobile, modular housing capsules.

2.3.2. Independent capsules

The ROBOtaco project involves the use of space above the parking lots located in city centers. Capsules raised above cars would be a mobile, flexible and inexpensive alternative to apartments in well-connected and served locations of the city. The size of a single capsule would fit within a 2.5 x 5m parking space.

As part of the project, two basic types of modules are envisaged - (1) capsules with a flexible structure of the outer covering enabling free joining and reorganization of several capsules, and (2) transport capsules, designed to run a set of several capsules that make up a given residential unit during road transport.

Figure 8. Truncated CUBE. System of capsules located respectively in the natural environment as well as infilling undeveloped fragments of street frontage.

The Truncated CUBE project assumed the creation of modular capsules that could partially adjust their dimensions. The external dimensions would affect both the size of the interior of the capsule as well as a close fit to existing gaps in the building, in case the capsules were to be filled in the city gaps.

The interior of residential capsules would be equipped with a system of pneumatic walls and furniture that would flexibly adapt to the current needs of the user, thanks to which a quick and relatively inexpensive interior rearrangement would be possible. It could be done by the use of a compressed air system and materials with shape memory.
2.3.3. Buildings & Structures

Doors project focused on meeting the social needs of seniors and creatively exploiting their potential. As a solution, a proposal was presented to combine flats for the elderly with flats for students, where kinetic structural elements and furniture allow privacy control for each part while sharing the kitchen, dining and garden parts. In addition to the mobile equipment, the project proposed the use of a movable partition system enabling the connection or separation of staggered capsules of seniors and students.

Figure 9. Doors. (on the left) Kinetic partitions and movable furniture enabling easy rearranging the interior. (on the right) The alternating order of mobile capsules and wedges with the function of a kitchen or winter garden, located around the communication core.

Capsules for students and seniors are mobile units mounted on vertical communication cores equipped with elevators enabling transport of the entire residential unit. This function would serve the possibility of transporting the senior along from his basic living space to both recreational and medical purposes. It was proposed to use a system of movable partitions enabling connection or separation of staggered capsules of seniors and students.

Figure 10. Mobile capsules (on the left) A set of movable capsules, and presentation of the degrees of freedom provided for the mobile capsule. (on the right) Sample combination of modular capsules.
Mobile capsules project is kinetic megastructure, consisting of the unit, which thanks to the built-in rails and drives would be able to move within the megastructure. This dynamic reorganization of residential modules gives the opportunity to shape social bonds through easier access to common spaces and services within the complex and the ability to move the housing capsule in the vicinity of more friendly people without having to move.

The presented vision of mobile, modular architectural fabric may refer to a broader issue - cities of the future, which may be able to be easily reorganized and adapted to the dynamically changing users needs.

The inteGRAtor project focuses on meeting the psychological and social needs of seniors and harmonious integration between participants of social life and the natural world. The project involves the construction of a set of residential towers, in which the set of living spaces, raised above the ground floor level, would be located. The residential complex should be located in a green space, to ensure privacy and contact with the surrounding nature, well connected to the city center. Capsules will be equipped with a system of sensors and screens with the personal assistant displayed on them to keep company with seniors and support the user in accessing information and managing the house.

3. Conclusions

A study based on the research by design method carried out as part of the second edition of the ROBOsenior theme enabled the extension of search areas and specification of the basic areas of robotic and kinetic solutions implementation. The investigation aimed at improving the quality and safety of residents life, including seniors and the disabled, specifying the possibility of using new technologies in architectural scale in the areas of:

- improving the quality of existing buildings,
- design of modular customized capsules that can become a filling of undeveloped urban spaces, including narrow spaces between existing buildings and parking spaces,
- design of modular customized capsules that can become a filling of undeveloped urban spaces, including narrow spaces between existing buildings and parking spaces creating building cores, which can be equipped with modular rooms and reconfigured depending on the needs.

4. Future research

Future research directions are to be focused on the integration of mechatronics, architecture and urban design. Our research aim is to develop cooperation between Architecture and Urban Design with Mechatronics.

In the research experiment in 2019/2020, building on the past ROBOstudios, is expected to explore the potential of robotics and mechanized common space of ROBOnighborhood, thereby directing the study from the scale of the detail and the apartment to neighborhoods, cities, and agglomerations where common space is a natural bridge to the urban scale.
Acknowledgments


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