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METHODOLOGY OF ARCHITECTURAL DESIGN AND RULES OF COOPERATION IN THE DIGITAL ENVIROMENT. AUGMENTED SPACE AS A FIELD OF RESEARCH AND ALTERNATIVE ENVIRONMENT FOR ARCHITECTURAL CREATION

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Abstract

The paper is an analysis of the architectural design process as it transforms in the digital age. In the context of the paradigm shift, changes in perception and social transformation, it presents the rules that govern the work of the architect and cooperation among interdisciplinary. The analysis is focused on research aspects of architectural practice. Experimental methodology based on case studies, using simulation models, has been used primarily in the area of improving solutions. Thanks to the digital representations of testing, the number of trials and the efficiency of inference increased. In addition to the tasks optimization, simulation models are used today to support the creation, communication, interdisciplinarity, fabrication and use of buildings. Consistent communication environment, based on a digital medium facilitates the exchange of information. Thanks to it's flexibility, digital model reinforces. From the role of visualization tools it evolved to integration platform. Examples of practical application of the new methods presented in the article, are research and experiments carried out within ASK (Architecture for Society of Knowledge) – the master's studies at the Faculty of Architecture in Warsaw. Among them: augmentation of the communication space, construction of experimental pavilions. The paper discusses the interdisciplinary research project to implement robotic pavilion assisting senior.

Streszczenie

Przedmiotem artykułu jest analiza procesu projektowania architektonicznego w dobie cyfryzacji środowiska. W kontekście zmieniających się uwarunkowań cywilizacyjnych, zmian w sposobie postrzegania i zmian oczekiwań społecznych, przedstawia reguły rządzące pracą architekta i współpracą w gronie interdyscyplinarnym. W centrum zainteresowania stawia badawcze aspekty praktyki architektonicznej. Metodyka eksperymentalna, oparta na studium przypadków wykorzystującym modele symulacyjne, stosowana była przede wszystkim w obszarze doskonalenia rozwiązań. Oprócz zadań optymalizacyjnych modele symulacyjne wykorzystuje się dziś do wspomagania kreacji, komunikacji interdyscyplinarnej, wytwarzania elementów oraz użytkowania budynków. Spójne środowisko komunikacyjne, oparte na cyfrowym medium, ułatwia wymianę informacji, automatyczne tłumaczenie, formułowanie przekazu wariacyjnego. To dzięki niemu model cyfrowy emancypuje się. Od poziomu narzędzia wizualizującego wyrósł do roli platformy integrującej. Przykładami praktycznego zastosowania nowych metod, przedstawionymi w treści artykułu, są prace badawcze i eksperymenty prowadzone w ramach magisterskich studiów ASK na Wydziale Architektury w Warszawie. Wśród nich przeanalizowano uwarunkowania rozszerzenia przestrzeni komunikacyjnej, budowy eksperymentalnych pawilonów do ćwiczeń z interakcją. Omówiono też rozpoczęty projekt aplikacji interdyscyplinarnych badań do realizacji robotycznego pawilonu wspomagającemu życie seniora.

Keywords: **Information; Architecture augmented reality; Simulation; Interaction.**

1. INTRODUCTION

Considering the scale and sustainability of the works, architectural design in its traditional form was never a field of research. Conclusions resulting from construction and use could be recognized as sufficient for the development of crafts. The evolution of the system of proportions, styles and decorative details gave ground to aesthetic discussion. Architecture lacked the ability to create laboratory situations and to test solutions in conditions guaranteeing repetitiveness of outcomes.

Empirical methodology, liberating natural and human sciences opened a way towards research in the field of architecture. The works of Bacon, Locke and Hume provided the tools, such as induction, supporting the study based on incomplete knowledge. Trials concerning real objects, or at least model tests of high capability to represent actual conditions, were required to ensure the effectiveness of experimental methods. For an architectural laboratory we had to wait another three centuries. It emerged thanks to the use of computers in the implementation of engineering tasks. Today, we are able to create plastic simulations, fidelity of which surpasses all previous prediction methods. The pace and character of work is changing. Cooperation of teams and channels for information exchange are transforming. Perhaps we stand on the threshold of a new era in the field of design. Maybe we are looking at the beginning of a new era, an era of intuitive, conscious environment, supported by the ability to predict transformation, taking place in real time thanks to the remote cooperation of global community.

2. INTERDISCIPLINARY SOCIETY OF KNOWLEDGE

Introducing changes in the human environment can be called design only if it takes place by the system route: starting from rational analysis of the circumstances, to the harmonious solution of practical problems [1]. In the context of increasing awareness of global connections, problems lose their individual, strictly localized nature. Any practical situation may remain in connection with the processes that slip away from the limited perception. An engineer that starts producing a solution (a relevant change) should discover these processes and prevent unfavorable consequences.

The roots of modern design methods lie in the action based on experience. In the costly cycle of trial and terror, craftsman knowledge, defining the limits of human interference, was built. This way, the builders of the Cathedral of Beauvais determined acceptable span length, and the Tacoma bridge constructors have experienced the scale of wind impact on a suspension structure. Engineers of the industrial era functioned in the reality of emancipation of natural sciences and the growing importance of design competence. They experimented in search of the best changes of practical situations. They knew that a properly organized experiment must be planned, carried out in a controlled environment, has to deliver observations interpretable with the use of established criteria [2]. The state of consciousness, called in historiosophy the era of disciplinary society, joins roles and trust with personal skills, measured by the ability to carry out specific tasks [3]. Designers fully met these criteria. Through the way of gaining knowledge and personal experience, they acquired a diploma certified ability to solve human needs. When issues complicated to the point where individual skills were insufficient, teams with an expanded palette of skills were created. This way, we evolved from individual to interdisciplinary project, subordinate to a competentive paradigm of the disciplinary era.

Mechanisms of teamwork on a project changed fundamentally only after WWII. As a result of the educational boom, blue collars of the specialized factory workers were superseded in the Western countries by the flexible, multidisciplinary society of white collars. This fact was noticed and originally called meritocracy, then the community of technological revolution, industrial and technological. Even though the terms information age and information society were shaped in the late sixties of the XX century [4], only in 1977 have we gained empirical evidence for the changes in global economy. Mark Porat working on a doctorate at Stanford University drew up a comprehensive report, documenting the growing position of information in the trade flows and its primary role in civilization transformations.

Information society, or more generally – a society of control – benefits from the achievements of natural sciences in a manner similar to the disciplinary society. It differs from the latter in the form of interpersonal interactions and the structure of roles. Certificates achieved through many years of effort, inherited or consequent to being members of groups did not work, meeting the elusive substance of data. The role of diplomas was taken over by the access statutes, codes and passwords, and prestige is measured with knowledge, range of possessed information and the ability to process it.

The interdisciplinary team in the era of knowledge-based society cooperates remotely, using information-translating mechanisms in variable configurations adjusted to the tasks. Popular science visions of Alvin Toffler presented at the end of the last century come true in our environment. Relevant change is not a domain of an authonomic decision of the designer, having an expert decision-making apparatus at his disposal. The modern recipient of an engineering product, prosumer of the goods offered on the market, demands participation in shaping design solutions.

Professor Wojciech Gasparski believes that nowadays in the development of the design methods there occurs a change, following the general civilizational trend. Specialized interdisciplinary teams are superseded by project studies teams i.e. those which posess well-established knowledge about design [1]. It should be assumed that their flexibility and ability to reconfigure will allow to make a significant leap in the effectiveness of solving tasks. What remains is a reflection on the justification and purpose of new, technologically supported methods. Following the footsteps of Gasparski's idea, we have to recognize that the transition to an intelligent design society, compatible with the Toffler concept is still unlikely. It would require common recognition that the planet's resources are limited, that we are striving to overcome threats and that we do it in the most rational way, that is by solving practical problems by designing.

3. DIGITAL MEDIUM

The key technical determinant that affects the functioning of modern engineering is the functionality of the environment in which exchange and processing of information occurs. For the earliest sources of Western civilization communicational specificity we have to search in phonetic language and print with the use of movable font [5]. They gave the definiteness in reception of coded messages using a limited number of characters. Thanks to generalization of computers, mathematical record of reality has become widespread. It is today dominated by propagation of the binary code.

The new medium, or digital medium is characterized by modularity, automation, variability and the transcoding ability [6]. All information recorded in the form of bits are, at the elementary level, of consistent quality. With the use of appropriate translating mechanisms any message can be converted to a level understandable in another language. Information processing undergoes programming treatment with the use of hyperlinks, decision-making loops etc. The peak of digital medium use is automatic creation. Its musical and plastic examples can be found in the days preceding the digital age [7]. Thanks to computers composing algorithms have grown in efficiency. Architects benefit from them too. The works of Hersey and Freedman convince about the effectiveness of a programmable digital medium in the interpretation of the Palladian legacy. H.P. Duarte's projects go a step further. Through setting the rules that define aesthetic coherence and linking them to user requirements, semi-automatic generating of dwelling house projects became possible.

In engineering applications, especially in the field of architecture, urban planning and construction, information has a particular character. It integrates the majority if the available codes that describe reality: text, drawing, flat and three-dimensional projecting, film and model. Even though the last of these methods is the most accurate and efficient tool, in a traditional workshop environment it is also the most difficult to apply fully. The transition of architectural methodology to digital reality took place through the adaptation of techniques in order according to customs determined by years of practice. First the documentation and the means used to create it were computerized: drafting board, T-square and compass. Digital model of a building appeared in the palette of used means relatively late, but it dominated all others immediately. The virtual representation of a building is nowadays the foundation of shaping of ideas and interdisciplinary cooperation. To geometrically determined localizations, which can be associated with components of a structure (walls, ceilings etc.), all other necessary information (text, parameters, images etc.) are added. BIM (Building Information Modeling) methodology allows the engineers to contribute to the project by coordinating real-time actions, taking into account conditions besides building itself, including the consequences concerning the exploitation period [8]. Using again the Gasparski's concept – the digital model of a building becomes in current practice a mean of building the digital science consciousness of an interdisciplinary, dispersed team of co-authors.

4. INTERACTIVITY, SIMULATION, OPTIMALIZATION

Although the well-developed system of informatic

connections affects the working conditions of an architect in many spots, particularly significant phenomena can be indicated. To make a developmental leap, evolutionary improvement of techniques is not enough. There is a need for a stimulus – an invention, tool, a rapid change in practices – that will boost the efficiency, open up a new field for exploration, provide research topics or inspire creativity. In the Renessaince it was the perspective, in the Baroque – Cartesian mathematics, at the dawn of modern engineering – the steam engine, steel and reinforced concrete. The catalyst for the digital era, a phenomenon powered by the computer, located between the sphere of communication and information technologies – is *interactivity* [9].

The society of control is not satisfied with participation in linear processes and relationships. It does not dedicate time to learning procedures. It prefers immediate participation in the events and gradual broadening of consciousness through interaction (with a device, service, group of people) [10]. The classic model of interdisciplinary cooperation assumed determining the competence of the participants and the rules of the information exchange. The design process and the research process were organized in a cyclic or spiral formula. Disciplinary (sectoral) work period were interspersed with periods of cooperation and exchange of ideas. Today's standards are determined by integrated design – in practice and PBL (Project Based Learning) in theory. Both these models are related to the work of experts with diverse competences in the joint venture. The object of research/project must be set out by clearly establishing the purpose and the changes made – clear for all participants.

Utopian assumptions in the light of classical methodology thanks to the use of digital medium and the digital model of BIM become quite real. The interactive designing environment allows modern architects to enter interdisciplinary relationships at the earliest stages of design. In subsequent phases of work the apparatus of evaluation of presented variants comes to the fore. It cannot be arbitrary, it requires a justification clear to the whole team. With help come another inventions, catalysing the design – simulation and optimization. Architecture did not conduct experimental studies, complying with the criteria of empiricism, since construction of the lab and subjecting representative cases to tests was out of question [2]. Fragmentary experiments, on physical models in scale, provided fragmentary results (Gaudi, Otto). Thanks to the digital model mapping of highly complete image of a real building is nowadays possible. This image – a simulation, refers to the physical shape, equipment, dependencies and statistics, plus the processes and changes over time. If the simulated behaviour of a building is parametrically evaluated, optimization of variants in the light of established criteria can be achieved. Thanks to digital simulation, testing of representative architectural prototypes became an effective decision-making tool. What is more, this mechanism, for the first time in history, brought closer the architectural practice to studies complying with the standards of scientific research.

5. ARCHITECTURAL STUDIES – A DIGITAL INTERDISCIPLINARY TRAINING GROUND

Modern architectural practice absorbs digital methods in a manner adequate to the situation. The most modern measures are used in the design of individual buildings of particular meaning. Architectural icons, such as the Beijing National Aquatics Center, Swiss Re Building at 30 St Mary Axe or The Pinnacle in London were created thanks to the dedicated BIM environment, acting as an instrument supporting the creation, solving technical problems and operation management. This process was in fact an architectural experiment, performed in the way of interdisciplinary studies, embedded in a digitally simulated laboratory.

Projects of buildings with typical spatial-functional determinants, which are the dominant part of the output of modern architecture, are also created in digital environment, but powered by standard tools. They rarely use the research features of the new medium, despite the existing possibilities. The interdisciplinary collaboration process runs more smoothly, thanks to the interactiveness of the model and effective visualisation of the relationships. The team organization pattern and decision methods often remain unchanged.

In the context of the new terms of design and social expectations, what gains importance is the evolution of the program of architecture schools. It has to take into account the fact, that today's educational effort should bear fruit in the professional life of the graduates in the next two decades. At the current rate of technological development it is difficult to determine to what extent the design environment will change. In academic centers architectural programs, associated with the use of new technologies, emerged. Their origin is often associated with the application of CAD in design, but nowadays they are evolving towards a methodological quest. An important component of

the digital current is interdisciplinary research serving not only cognitive purposes, but also didactics and actual professional applications. Warsaw Faculty of Architecture offers to graduate students a specialty – ASK (Architecture for Society of Knowledge), which wants to follow this very idea. It integrates traditional areas associated with architectural studies (theory, history, methodology of design) with the fields deepening the awareness of the conditions of the digital medium (programming, robotics, digital production). Thanks to the extension of themes and competencies, it allows to carry out experimental projects, built on the foundations of information architecture – interactivity, simulation and optimization

a. Augmented research area

At the beginning of the road towards independent creativity we examine the principles that rule the logic of existing buildings and entire built context. We discover them by analizing the physiognomy and processes of use. We can also recreate the most essential components of the concept, so in the process of building the model we can learn often hidden determinants of the project.

The modeling course, modified in recent years under the influence of the ASK experiments, is conducted in an expanded environment. It is an introduction to the first independently executed project. Students use digital tools to create representations of the finest realisations of modern and historical detached houses. The models correspond in terms of structure to BIM standards. Content includes both geometrical data concerning the spatial form and other information required to fully understand the idea of the building, and the intentions of the creator. "Drawing like the masters" is done by applying succesive layers of communication. The background for their embedment is constituted by the digital spatial model, prepared in such way, that its reception could proceed in an intuitive way.

The projects presented at the exhibition benefit from technological support to create a direct dialogue with the viewer. The basis must be, in any case, a physical model – the whole or a part of the building. In many cases it is simplified, so that, with the preservation of recognizability, the attention can be directed to the fundamental components of the intention. The predominant part of the message resulting from research is located in virtual space. Parallel digital model is associated with physical presentation thanks to applications for mobile devices (tablets and telephones). Using real-time rendering, the program displays an image against a background of a marker, which is a physical model or a board. It is the viewer who decides at what angle to look and what data to display. Since part of the information key for the reception of architecture has a dynamic character, they slip by in the traditional relay of drawing and mockup. The associated digital model overcomes these limitations. Looking at the augmenting screen, we can dynamically experience the consequences of sensations of passing through a consciously composed spatiotemporal stream. We can admire the dance of the

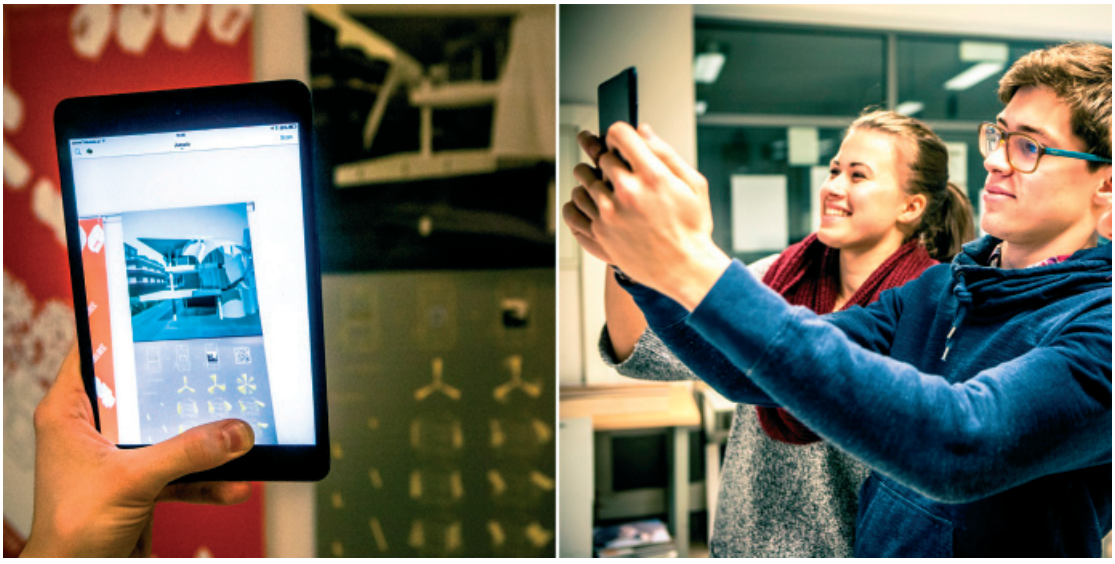

Figure 1.
Interactive communication in augmented reality. 3D modeling course exhibition (Own elaboration)

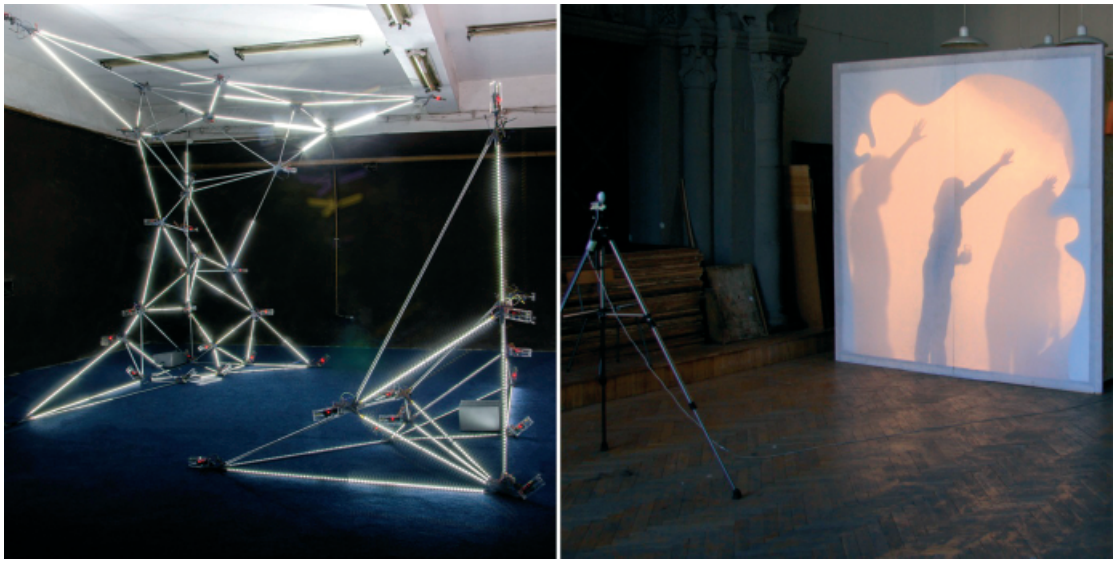

Figure 2.
Interactive pavilions: Modular Light Cloud and ASKtheBOX (Own elaboration)

textile façade in Shigeru Ban's Curtain Wall House, touched by a virtual breeze (Fig. 1).

The use of augmented reality in the study phase of architectural research allows to use the functionality of digital medium and to communicate in a manner appropriate to the sensitivity of the recipient immersed in the reality of information civilization. Analizing theoretical issues, classifying information and creating the communication we take into account that the message has lost its unilateral nature. The final picture of the phenomenon is born in the process of interaction with the multi-layered database, which allows to filter content and to make contact in real time [11].

b. Pavilions of the augmented reality

Workshop preparations, carried out as a part of the modeling classes can be used to make standard projects. In the course of ASK we are trying to go a step further. The digital model allows extending the range of interdisciplinarity. It provides an effective basis needed for the involvement of engineering specialties directly related to information technology. While working on experimental projects, which constitute a compulsory part of the program, we drive the students to undertake spatial, construction, installation, programming tasks. They are carried out with the intention to practically test the solutions of prototype-enhanced space.

Interactve pavilions, enabling direct contact with the user are the most effective tool for architectural research conducted in the course of studies. They give a chance to follow all the stages of project activities, performing installation modifications, essential for the calibration of media expansions and allow the examination of the processes of use.

In the ASKtheBOX pavilion, created in 2012, we concentrated on studying the relationship between the form of the interior, user behavior, and the actions of mounted media installation (Fig. 2). We sought to discover the conditions of interactive environment design. To achieve this objective, it was necessary to create a spatio-informational system, construction and functions of which would not form a cognitive barrier. The physical structure was designed by combining techniques: traditional or parametric modeling, or with the use of haptic manipulators. The media installation based on recording the natural shade of users. The research concentrated on functional scenarios programming. Students interacted in multidisciplinary team, working on multi-layer design project. Fluently assigned roles: sculptors, constructors, composers, programmers and implementers, allowed the participants to understand the determinants of each single discipline and to interact, leading to the transformation of ideas. The basis for effective cooperation was the digital model. The coordination of components and processes was ensured thanks to automation and transcoding – features of the digital medium.

Another version of the pavilion, realized in 2013, expanded the interaction – with the virtue of movement of the structure. In 2014, during a summer ASK

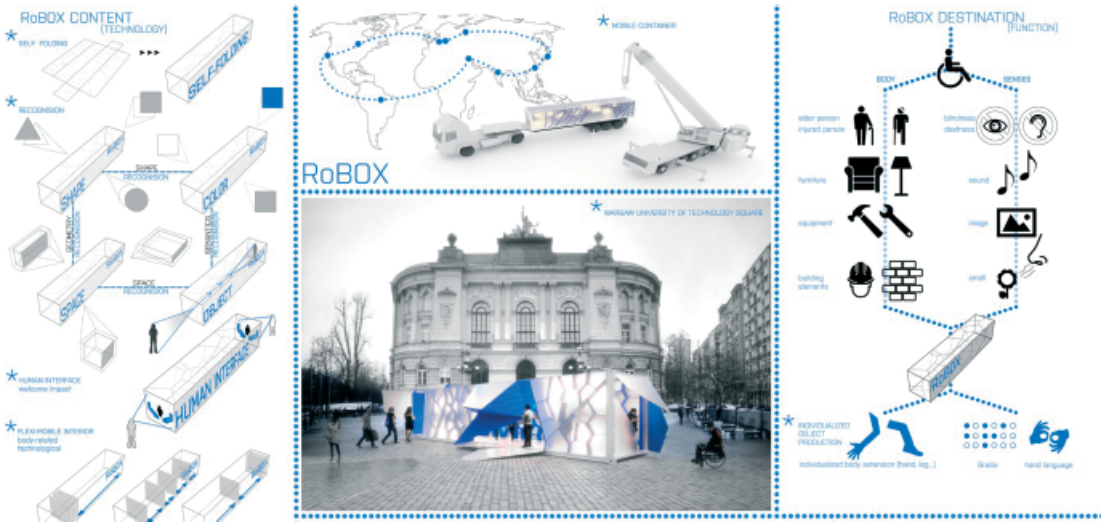

Figure 3.
The scheme of robotic senior's pavilion idea (Research team elaboration)

workshop, led by Jacek Markusiewicz and Marcin Strzała, Modular Light cloud installation was constructed (Fig. 2). It was composed of a spatial network of luminescent elements, equipped with audio sensors activating the action of individual sections. Its use was to support the artistic creation of a dancer.

Interactive pavilions have become an important tool in building interdisciplinary awareness of architecture students. The actual realization and responsibility for publicly presented effect inspire effective cooperation and exchange of ideas between disciplines. Digital environment and methodology focused on the aim/problem facilitate the design process. Simulation, optimization and digital production of components create conditions for the integration of roles and tasks. They support interactive work environment.

c. Robotnic pavilion for testing conditions of the life environment of a senior

ASK research experience formed the basis for the realization of the idea of an object exceeding study character of the semester pavilions. The integration between architecture and information technology may become a measure to ease the hardships of life of the elderly. The increasing average age and changes in public reception of the roles of different age groups promote the effort to treat the situation of limitations (mobility, fitness, mentality) as normal project determinants.

Robotic pavilion investigating the conditions of senior life is a step towards the use of architecture's mobility in compensating the limitations of comfort. The concept is built based on robotic experiments, carried out by students and experts in the field of mechatronics. Taking part in it is a technological partner, FESTO, the world leader in automatics, pneumatic and bionic systems. The main aim is to create a mobile unit capable of positioning itself in a chosen location, collecting data and promoting solutions supporting seniors' comfort. The pavilion will include a spatial structure simulating the conditions of an apartment. Thanks to a system monitoring user movement and pressure onto objects data concerning limitations will be collected. Robotically aided equipment components and architectural elements will be reconfigured. In the final analysis, pavilion will assess the effectiveness of the adjustments, which will be stored in the database (Fig. 3).

Implementation of the concept of the pavilion involves finding resources that are beyond own capabilities of participating institutions. Overcoming this barrier would let undertake interdisciplinary research in the environment of the augmented architectural space, corresponding fully to the opportunities and challenges of modern day. These studies would fit in to the vision of interdisciplinarity outlined in Prof. Gasparski's works – the vision of a society designing in project science teams.

6. CONCLUSIONS

Characteristics of the digital medium, which allows to freely translate, differentiate and program messages, catalyzes the architectural experiments. Computer simulation provides prototype solutions, ones that the practical architecture could not, for ethical reasons, test.

Thanks to the clarification of inference methods, the construction of architectural theory has found a strong ally in the digital environment. Empirical experiments enhance the understanding in the interdisciplinary teams. The exchange of information is carried out efficiently through the use of common models, background of which is made by standardized spatial description.

The prospect of interdisciplinary studies in the digital environment is the function of education. The transformations to which we nowadays submit the educational program will affect the changes in methods of future architectural practice. Striving to reinforce the theory and to create rational foundations of creativity, we need to maintain balance between appreciation of knowledge acquired through experience and experimental methods using modern technological tools.

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