Participation-based Parametric Design in Early Stages

A participative design process for spatial planning in office building

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The term participation has been used to define different activities, such as civil debate, communication, consultation, delegation, self-help construction, political decisions. However, participation in design started from the idea that individuals whom being affected by a design project must contribute to the design process. Recently, designers have been moving closer to the future users and developing new ways to empower them to get involved in the design process. In this paper we rethink the way the early design process is developed in a participatory approach thanks to parametric methods. A use case is proposed showing the potential of parametric design methods to empower the participation of users in the design of their facilities. The use case is dealing in particular with the spatial planning of an office building where the users together with the spatial planning team are able to design the layout spatial configuration by 1) fixing the objectives, 2) manipulating the model, 3)modifying some parameters, 4) visualizing the iterations and evaluating in a real-time each solution in an interactive 3D environment and together with facility managers 5) choosing the configuration of the spatial layout.

Keywords: *Computational design, Participatory design, Optimization , Parametric design*

PARTICIPATORY DESIGN

The term participation has been used to define different activities, such as civil debate, communication, consultation, delegation, self-help construction, political decisions (Davidson et al., 2006). However, participation in design started from the idea that individuals whom being affected by a design project must have a position in the design process. Recently, designers have been moving closer to the future users of what they design and developing new ways to empower them to get involved in the design process (Sanders and P.J. Stappers 2008). The participatory approach (i.e. 'user as partner') has been led by Northern Europeans in the early 1970s. Several projects in Scandinavia set out to find the most effective ways for computer-system designers to collaborate with worker organizations to develop systems that most effectively promoted the quality of work

life (Sanoff, 2000). The participation is not a matter of fact, but a distributed, heterogeneous and relational process (Andersen et al., 2015). This consists into making a move from user-centered design to a participatory design with important impacts on the traditional roles of players and stakeholders in the design process (Sanders and P.J. Stappers 2008). In the classical way of the design process, the user is passive, the designer brings the knowledge from theories, observation and interviews. Different levels of participation have been identified in the past, ranging from manipulation to citizen control (Arnstein, 1969).

In the participatory design, the roles and tasks will be different since the user (eventually with a passive role in the traditional way of design process) is given the position to express his experience and plays an important role in transmitting the knowledge into ideas and concept development (Sanders and P.J. Stappers, 2008). Even with this capability added in the participative design, this remains a responsive system, where the designers are looking for comments about their design and the public is not truly empowered to design (Cimerman, 2000). The concepts around the participatory design and in particular about who should be involved in the collective acts of creativity, design or creation, when, and in which role vary between different studies in social science. In order to support participatory design, a wide variety of methods and techniques have been developed to enhance the involvement of both users and stakeholders in the same design processes (Abras, et al., 2004). More cost-efficient and effective practices are needed for gathering users' needs and requirements in real contexts in order to reflect these needs into the final design. The highest level of empowerment of the users through direct participation is characterized by the direct engagement of the user in the design process. In this case, the user is considered as the decision-maker. This type of participation gets more complex when it is concerned with the community participation. In a variety design instances, the community or individuals' participation is needed in different situation (building participatory residential...).

User participation in architectural and urban design

Community design is an umbrella term that embraces community planning, community architecture, social architecture, community development and community participation, this approach has emerged from the fact that the mismanagement of the physical environment is a major factor contributing to the social ills (Sanoff, 2000). On the other hand, computer application experiences and the development of the technologies, demonstrate that the use of computers with specific methodologies can help the participation and facilitate the integration of the user into the decision-making process. BIM can be perceived as a process that facilitates the participation of users in the design process. Today, the complexity of designing and constructing buildings is more and more increasing. Engaging the user in the design-related process issues will ensure the realisation of the users' requirements in the design since housing and building design emerges as a close cooperation between architect (designer) and the client (user) (Kwieciński and Słyk, 2014). Various researches and practices explored the methods and techniques in order to engage the participation of the users in the design of their living environments. The user participation in the design has emerged as a key to a gap between the requirements and the solutions proposed by the designers (Sanoff, 2000). The traditional participatory models have been heavily criticized because they require meetings that are often ineffective and inefficient, held at a fixed time and place; severely limiting the number of actors taking part (Healey, 1998; Kingston, 2007). In such meetings, it is almost impossible to establish communication that is equal. It is also hard to engage a high number of citizens and to take their experiences into account in early stages of the planning process (Nuojua and Kutti, 2008). Too often the involvement of users is superficial and simply used to bring credi-

bility to the planning and decision-making process without really transforming it (Sennett, 2012). Consequently, the removal of the public from the decision making process leads to a sense of alienation of the users from their environment (Jones et al., 2009). The benefits of community participation in urban planning are: enhancing the capacity of the population to cultivate a "stronger sense of commitment", increasing user satisfaction and creating realistic expectations of outcomes (Al-kodmany, 1999).

INFORMATION TECHNOLOGIES FOR THE BENEFIT OF THE PARTICIPATION IN ARCHITECTURAL AND URBAN DESIGN

Recent developments in ICTs, such as 3D modelling software, communication platforms and computer serious games as tools for urban planning, are offering new potentials of citizen participation in urban planning design (Hanzl, 2007). In general, these software systems enable displaying data in forms that can be easily understood by the participants. The informatics applications allow the simulation of future urban plans by implementing the parameters essential to the planning development. A key feature of most participative design activities is the use of physical artefacts such as sketches, games, or layouts on which participants can place objects to represent houses, gardens, roads... Researchers developed various technological tools to enable participation. Among those, the tangible table can be foreseen as a participatory technology that helps to increase the engagement of users and community in urban design by manipulating physical objects (Maquil et al., 2007). In a later research, Wagner showed how to use a set of participatory technologies in combination with methods to enable a participation to create a vision of an urban project (Wagner et al., 2009). Digital serious games are another approach to enable participatory urban planning design. These aim to support learning in a playful and engaging way. They represent an emerging research area, enabling learning about the environment and an exchange of contrasting views on proposed urban, regional, or landscape plans. By using serious games, the participants are given the possibility to interact with the design submitted, to vote for the preferred option or even chat with other participants (Poplin, 2014). Recent trends in video games industry focus on improving graphic quality and easy to use attractive interface, this fact led to using video games in urban studies, teaching and research (Rufat et al., 2009). One of the most common game to be used is the SimCity, which is developed by William Wrigh. SimCity is used also in universities laboratories for urban simulation research as a tool for participatory design in urban context (Hanzl, 2007).

EARLY DESIGN

Architectural design process in its general terms, is a procedure intended to the improvement of the project through socially situated reflection-in-action (Schon, 1983). In the early phases of the architectural design process the level of detail is typically low: requirements, constraints, larger scale problems and priorities are exposed and restructured before getting into details and smaller issues.This understanding of the design process as a progression of ideas and inputs can be confronted with different factors (Cross, 2011). In the early design phase, evaluating the performance of the concepts on larger scale issues can be achieved on different basis including: energy analysis, daylight modelling, cost and schedule impacts, or even structural analysis. Indeed, one of the important task in architectural early design stages (or even in the reconsideration of an interior layout) is that architects should find solutions to the organization of the interior space planning layout to have an appropriate relations between the different spaces and functions (Calixto et Celani, 2015). For architectural space planning problem, architects explore solutions based on varied parameters. Various parameters such as input features can be taken into account for the space planning layout, these parameters can be related to the adjacency, distance, functional arrangement, occupancy, workspace area standards, financial allocation, sustainable

factors such as energy conservation, daylight, view... (Hassanain, 2010). Besides these, the inclusion of users and their preferences in the reflection-in-action processes in the early design phase can help the restructuring of the design requirements and make the final design more responsive to the people's needs (Commission for Architecture and the Built Environment, 2008).

EXTENDING COMPUTATIONAL DESIGN

Computational tools are fundamentally shifting architectural design practice to another paradigm. In particular, parametric design tools developed in the last three decades allow the designers to make decisions earlier in the design process based on a multi-objective optimization workflows (Brown et al., 2016). In parametric design methods, some constraints can be implemented in the early design phase which can be maintained during the design process. These constraints can be related to requirements, contextual and physical aspect. However, the participation of users in these processes is not supported sufficiently. The participation of the users in the early design phase can empower the design process by the inclusion of non-physical factors related to human preferences aspects. The current practice of parametric design methods needs to be extended to include non-physical aspects in the early design phase. A significant challenge in this venture is that these aspects cannot be easily parameterized and optimized. Rather they can be reflected upon, discussed and negotiated during the course of design. Therefore new ways of enabling in parametric design methods need to be developed to trigger and support meaningful social changes, focusing on emerging forms of collaboration (Manzini, 2015).

Several tools have been developed in order to support the parametric design methods: Grasshopper a plugin for Rhino, Dynamo a plugin for Revit, Generative component, Houdini... These tools are based on visual programming languages accessible by a limited audience. With the digital and parametric era, design workflow continues to be a close collaboration between different stakeholders, (architects, engineers, contractors, and fabricators). This collaboration tends to be practical and ensures a better coordination of the project for supporting what Manzini (2015) calls "expert design". This contrasts with "diffuse design" where the designers aim to trigger and support meaningful social changes between the experts as well with the users, develop and test emerging forms of collaboration. Even for the professionals, the adoption of computational technologies (in particular parametric design tools) seems to have varying degrees of practical experiential knowledge. Thus these tools are generating inaccessible and isolated areas of specialists. Nevertheless, the lack of participatory approaches in these methods, especially in the early design phase is a major challenge in the daily work basis in particular with the paradigm shift of architecture towards a more participatory and social direction. As introduced above, a significant problem of the parametric design process is the exclusion of non-physical factors related to human aspects and the intense focus on performative and optimization based design answering technical issues (solar, energy, cost...).

The application of computational methods for space planning has been increasing recently with both research and real-application fields. Many academic researches was developed trying to investigate in the space planning generated with computational tools. Various applications of evolutionary computing and parametric approaches were deployed for architectural space planning generation (Dutta and Sarthak 2011). These applications vary in terms of objectives and desired output. Some researches considered the space layout and functional parameters, whereas other researches have been focusing in also in the energy and light factors. Autodesk researchers (Nagy et al., 2016) also have worked in developing a flexible workflow for generative design applied to architectural space planning. First, a computational design model was able create a variety of office layouts including locating all necessary programs and people using a small set of input

parameters. Bahrehmand et al (2017) proposed an approach for space planning addressing subjective aspects of the design; the research has developed also a genetic algorithm with a multi-parental recombination method that improves the chance of generating higher quality offspring. This method was able to generate satisfactory feasible floor plans based on spatial quality metrics and designer's taste.

OBJECTIVES OF THE RESEARCH

The scope of this study covers the early design stage in general, although the case study developed deals with the spatial planning, the general approach can cover different situations in early design such as urban planning. Studies have been recently made by the author for the configuration of the early urban space planning for refugees camp (Daher, 2016). As shown in this research, for each space planning on building or urban level, fixed parameters or constraints should be taken into account, such as building physical constraints, orientation and others...

In this research we will rethink the way the early design process is developed in order to allow the participation of users in the early design phase. The need is to include not only the physical factors to the early parametric design process, but also the non-physical factors, and investigate in the participation process of the end users as being one of the solution for empowering the design process by the non-physical parameters. Information development and new technologies, such as 3D modelling software, communication platforms and computer serious games are offering new potentials of participation in the design of facilities. Emergent information and communication technologies and tools can support as foundation for a reconsideration of the culture of design. The need is to develop processes and tools to support different scale of users' feedback to inform the different scale of decision making process in the early design phase.

In this context, the central research questions to be addressed in this study are:

1. How can we enable different levels of participation the early phases of parametric design?
2. How can we include non-physical factors related to human aspects in the early parametric design process?
3. What are the key challenges of and critical factors for this task?

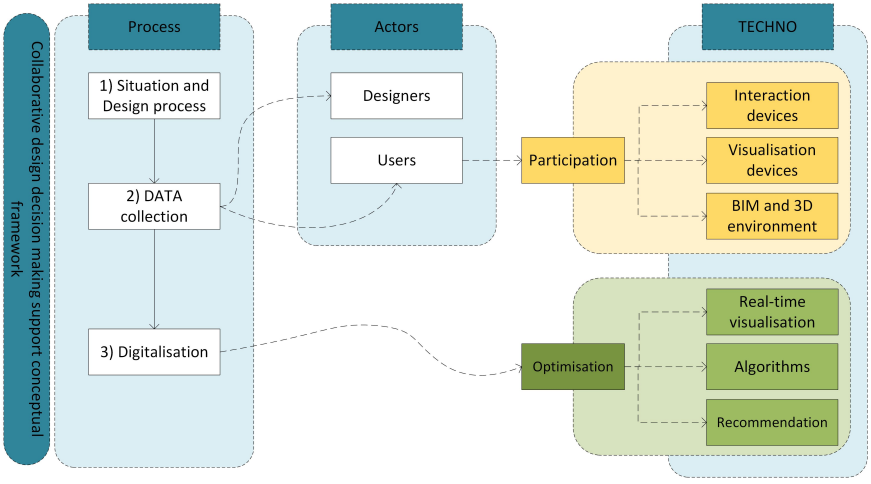


Figure 1
Conceptual framework for the the participative design

CONCEPTUAL FRAMEWORK

To address the issues raised in the state of art we consider a framework conceptually (Figure 1) representing (1): processes and actors involved in the participative design, the associated data (2) and digital technologies (3) enabling to provide a computer-based participative parametric modeling environment.

METHODOLOGY OF WORK

To answer these questions, a case study will be introduced for the design of an office building located in Luxembourg. The focus is to enable the participation of a group of users in the design of their interior layout office building in the early design phase. Once defined, the participation process is implemented through several computer-based systems. To enable the participation process a set of of architectural analytic and parametric design tools will be combined with other participative methods such as a tangible tabletop and graphical interfaces. Design decisions will be constantly evaluated with the use of parametric design tools allowing the users to evaluate each decision and modification in real-time analytic effects; visual indicators on the graphical interface provide constantly information about the modifications. To achieve the objectives of this research, the following activities were carried out:

1. Literature review of the published academic and practical researches considering the space planning and management and parametric approach.
2. Literature review about the technologies used for the participation of the users in the design of their facilities.
3. Identifying the parameters that should be taken into consideration during the space planning design, and identifying which from these parameters should considered into our case study.
4. Conducting different meetings with responsible of the space planning group in our case study organisation to have some insights about how this task is usually performed.
5. Developing a prototype answering the research objectives.

DEVELOPMENT

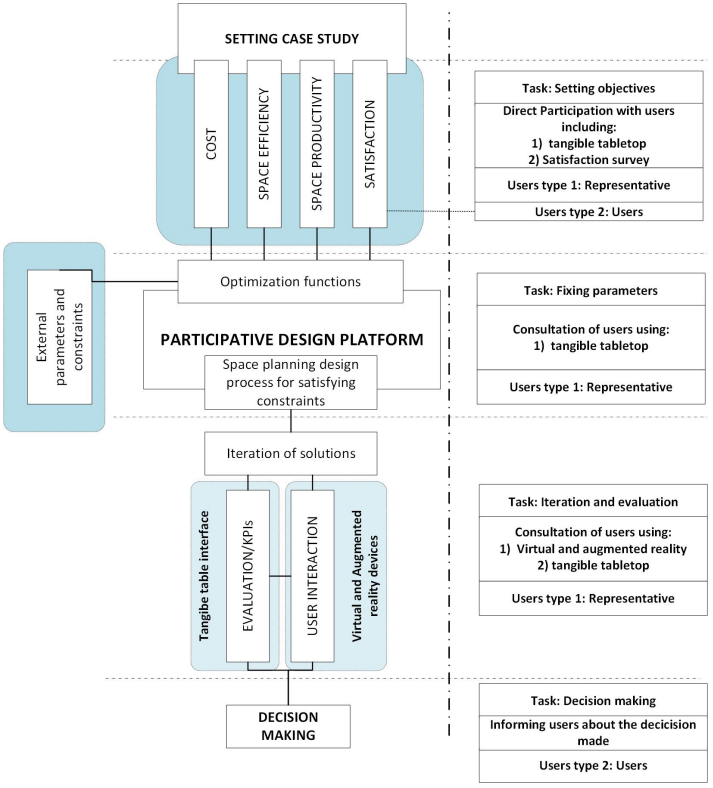
Design process

The participative design process relies on a platform described below (Figure 2). This is a combination of different tools and devices to enable 1) the participation of users in the design, 2) the of design problems based on library predefined in the parametric software and 3) the visualization of the results and the data manipulated, it is expected to use devices such as the tangible tabletop, touch screens and the augmented reality creating a better understanding and visualization.

Identification of parameters. This design process is developed to answer the requirements and needs related to the management of an office building located in Luxembourg. The organizations occupies multiple buildings in different locations, while the use case considers the relocation of worskpaces into one of these buildings. The need is expressed by the "space management unit" to develop tools that help in the space planning strategies for new building in early design stage. The parameters identified to influence the configuration of spaces are related to the:

1. Regroupment and relation between the different departments and the organisation.
2. Adjacency and distance (horizontal and vertical distance) between the divisions and/or units.
3. The circulation between the workspace areas and the informal areas (such as small informal meetings rooms, coffee areas,...).
4. Health, safety and well-being factors are not the main focus in this use case. However, factors like the views (meeting rooms to be in dark areas or areas with no view), and the fire exit (rooms to respect the standard distance to fire exit doors) are considered.

Figure 2
Schematic description of the participative design process platform



In this prototype we use the concept of non-physical parameters as important parameters to take into account in the design process willing to create informal interaction between collaborators which contributes to knowledge sharing and team building. The non-physical parameters are collected by satisfaction surveys conducted with employees located in different buildings of this organization. The surveys are dealing with: open spaces vs. closed offices, view to the exterior, noise and privacy which has an impact on the adjacencies.

Set different objectives. For each optimization process, objectives should be set in order to define the expected solution to answer the requirements. These objectives can be related to cost, environment, energy, space allocation, and routing distance...For this project we set with the space management unit different objectives related to the following aspects:

1. Cost of the configurations proposed
2. Space allocation efficiency (increasing the rentable area and the density of workstations).
3. Space productivity (proximity and distance between different spaces).
4. Satisfaction of collaborators (interaction with informal areas, privacy and visual access of desks).

Users' involvement in the design process. The participation of the users and in particular the space management unit is enabled by giving them the control of the design parameters. Colored and graphical charts will be illustrated to provide some insight to the decisions and iterations made. Users will be able to add, remove walls, generating future layouts by predicting the number of employees and the allocation of each head division. Users will also be able to fix the proximity between the different departments spaces and when needed they were able to modify this proximity. Users will be able to set objectives related to the cost of different space planning iteration and to choose between the different options.

Prototype

A prototype is being developed at the time writing this article, the main features of this prototype are:

Visualisation. Visualization devices were used to help the space planning department to understand the spaces being designed. Augmented reality is the potential mean for representatives to conduct tests and visualize the proposed layouts of the working space. By creating a 3D model of the working space, users were able to interact with the model via the Hololens headset. This helped a projection in the real context of the real space and better understand the solutions proposed. The team is given the ability to easily interact with the model and make some changes in the configuration and update the model. Simultaneously, visualization of the plan will be projected on a digital tabletop. Users are capable to interact with the plans of the working spaces over a tangible interface tabletop that will be mainly used for:

1. Modifying the collected data on spreadsheets and defining the relation between the different spaces,
2. Adding some physical constraints (related to the building geometry, external constraints such as view, energy, daylight and noise),
3. Defining the density of the workstations during different time in the year and predicting the needed spaces for the upcoming collaborators,
4. Fixing objectives and setting the importance level of each objective.

Optimization. Several optimization plug-ins are integrated into parametric modelling software allowing numerical simulation and iteration of different solutions. This helps the users to evaluate the design iteration in terms of KPIs (Key Performance Indicators) for the fixed objectives.

Envisaged participation level in the prototype. The level of user participation (Table 1) in the design process varies from an informing participation where users ares being informed of necessary information, to a direct participation where users are able to have a direct involvement in the design process by setting the objectives and the level of importance of each one. Each department representative is able to set and change by slider each objective according to the needs. Other intermediate type of participation are also envisaged in the prototype such as consultation where the users will be answering surveys for the post-occupancy evaluation.

DISCUSSION AND CONCLUSION

Conclusion

This prototype is a first try to enhance the participation of the users in the design of their building spaces and in particular the space planning layout through a parametric approach. The idea is to incorporate the simulations and iteration of different solutions for the space planning in different participative devices and technologies (Augmented reality, digital tabletop) where users are able to interact with the space planning layout in the early stages of parametric design. The user is able to explore possible scenarios and design alternatives, by manipulating the parameters values and evaluating in real time the results of the modification. The main idea in co-designing is that everyone brings something important to the discussion and that everyone is capable of developing ideas, expressing them, being creative and being part in the decision making. Users are seen as ex-

Table 1
Envisaged participation level in the prototype

Tasks	Users	Type of participation
Setting objectives	Representative of departments	Direct control
Fixing parameters	Representative of departments	Placation
Decisions made	Employees	Informing
Setting satisfaction objectives	Employees	Consultation
Itertion and evaluation of design	Representative of departments	Consultation

perts on the situation and there is shift from a passive role to a co-creator or representative role in the design process. However, this prototype raises several questions related to the participation of users and the number of users that can participate in the design. Another question raised in this prototype is the incorporation of the artificial intelligence and agent-based modelling for the design of workplace.

Discussion

In the co-design process, the users are collaborating with the spatial planning experts and architect in the design of a new spatial environment. This creates new roles for both users and the planning experts or the architects. The role of the spatial experts or architects is to help users to understand the configuration qualities and to point on some issues that need to be solved. The designers are creating a set of meta-design where parameters, constraints and objectives are fixed. This meta-design is creating a limited space of solutions and iterations that satisfy the needs and requirements of the users. As for the users, they help to find the main focus and the most important aspects to be taken into account by the designers and they are being active in the design process. These actions are being taken into account at different stage of the design process and at different levels of participation. Users are also able to justify and explore different solutions and participate in the decision making process.

Challenges

The main challenge is to incorporate a number of users and representatives in the design process developed for this case study. This is resolved by delegating the role of the participation for representative to be involved in the design. Another challenge is dealing with non-professional in the computational environment and the software used, therefore, it is important to work on a *light* easy to use platform and explain to users how this process works. Another important challenge is to transform all useful requirements into a digital model with the appropriate control on parameters.

Another challenge raised is the discussion conducted about equality between the users. The designer as a facilitator has a new task towards achieving this desired equality between the participants. The prototype provides tools that develop understanding of the configuration made with a transparency in implementing of the different guidelines, however, the discussion about equality is raised in particular for assignment of the spaces to each departments.

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