Participation and communication in urban planning, visualisation, spatial perception, and motivation through gamification are discussed and system requirements derived. An augmented reality multi-client communication prototype is described improving transparency and utilising local expertise in planning processes. The selection, processing and visualisation of planning data takes individual stakeholders' knowledge and skill levels, cultural backgrounds, and interests into account to facilitate understanding through moderation and the ability to change perspective.

Keywords. Augmented Reality; Gameification; Communication; Public Participation; Visualisation.

1. Introduction

Planners traditionally communicate design ideas and concepts, highlight assets of proposals, advise contractors on what to build, and record existing buildings or building processes through plans and visualisations. Communication about “planning” becomes difficult however, when those who make the plans (experts) and those who are supposed to follow them (other experts or novices), do not have the same understanding or background in planning. Planning is therefore, not simply a cognitive process, but also a social one involving many different stakeholders.

This “ill-defined problem”, a term coined by Rittel (2013), presents a number of issues. Planning problems cannot be definitively expressed, nor do they have a definable end, there are infinite solutions, which are neither right nor wrong but rather good or bad, and the solution depends on how a problem is framed and vice versa. As a result, it has become clear that communication is not a quality in planning, but a necessary medium for the success and sustainability of planning solutions; “communication is not everything, but planning without communication is nothing” (Quote translated by Authors; Selle 2005). This changes the question from whether we should communicate with the public in planning, to how we should communicate with them.

In Germany planning proposals must be laid out for the public to view, inquire and comment on prior to the acceptance of a planning application in accordance.
with formal information processes determined by planning legislation (e.g. § 3 BauGB). Whilst formal public participation processes are desirable, the execution often fails due to a locational displacement between the actual site of the planning proposal and the plans which the public can view; the visual representation of the proposals; the physical accessibility to these plans by the public; and the people’s heterogeneous backgrounds (Mühlhaus 2017).

Because of this, some offices are implementing informal processes, which go beyond what is required by law. These can include leaflets, presentations, workshops and discussions. What almost all these processes have in common is that the content is generated especially for the purpose of public participation and are therefore time consuming and costly. In addition, these processes require the public to sacrifice their free time and actively participate without a clear, direct or immediate benefit to themselves. This can lead to rational ignorance (Downs 1957), the refrain from gaining knowledge on a subject when the cost of education outweighs the benefit. Consequently, it is difficult to find a representative number of participants for these more informal processes (Deutsche Stadettag 2013). To succeed, public participation needs to become less time consuming and costly for both planners and the public. Public participation needs to become a by-product of the architectural and urban planning process.

The development of computer aided design systems (CAD) and later building information modelling systems (BIM) made the fast and precise production and straightforward replication and dissemination of building plans a natural part of the planning process. These systems have become established, functional tools founded on both geometric and semantic information to create three dimensional intelligent models that can be used for presentations and simulations.

Based on this idea and a theoretical analysis of both content and technical system requirements (see sections 2 and 3), an augmented reality communication system was conceived and prototypically implemented as a tool for public participation. The presented prototype, based on a parametric city model (Seifert et al. 2016), is able to extract relevant information from this city model for “on-the-fly” visualisations on hand-held or see-through devices. By combining digital models, and their existing semantic knowledge, with augmented reality technologies as defined by Azuma (1997), which are readily available and allow for contextual integration, this communication system provides a significant potential to address planning communication deficits in public participation, by providing planning information and the possibility to influence planning solutions in preliminary and early design phases, where costs (money and time) to adapt design variants are still relatively low. This approach highlights the high potential these early phases have in strengthening active participation over simple information processes.

2. Framing the Context

Public participation, expert-laymen communication, vision, visual perception, and motivation form the theoretical foundation for the augmented reality communication system supporting public participation.
2.1. ABOUT PARTICIPATING

In 1962 Arnstein defined eight levels of empowerment, known as the Ladder of Citizen Participation. She developed a ladder system of eight rungs divided into three categories; “non-participation” which she considers pseudo participation on the bottom two rungs; “degrees of tokenism” for rungs three to five (informing, consulting, placating), which she regards as a vital first step towards citizen empowerment; and finally, “degrees of participation” (partnerships, delegating power, citizen control), allowing public bodies full decision opportunities. The OECD (2001) summarises this theory in its three-stage model of information distribution, consultation and active participation (OECD 2001). An issue faced in public information processes is the psychological effect of loss aversion, the fear of losing what we already have, which makes any change to our existing situation a threat and a potential loss. Because of this people are unable to see the social and personal benefits of planning proposals. Part of the challenge is making this clearer to them by enabling more active participation.

2.2. ABOUT COMMUNICATION

People who have knowledge on a specific subject, such as planning experts, tend to assume that others have that knowledge too. They overestimate how widely spread that knowledge is and they overestimate the depth of knowledge others may have on that topic. In his book, Expert-Laymen-Communication, Rambow (2000) identified several differences between how experts and laymen perceive planning and the planning world. Firstly, he found there to be a visual-semantic communication gap. Planning is highly professionalised with a strong use of convention and code to clearly communicate and avoid misunderstandings when communicating planning intentions to other professionals. Additionally, planners still predominantly use two-dimensional representations of three-dimensional spaces when discussing. Secondly, the technical language of planning does not only include technical terms, as is the case in most professions, but also includes a high number of metaphors to explain and verbally visualise concepts. Thirdly, experts and laymen organise information differently, which means that the different stakeholders will search for, identify, and connect planning information differently. Finally, experts and laymen experience and perceive the architectural and therefor the planning world differently. For an expert, any building is associated with planning, whilst laymen only connect iconic buildings with architecture and planning, buildings which they tend not to interact with in their daily lives. Changing perspective is an approach to bridge the communication between experts and laymen.

2.3. ABOUT SEEING

Physically we perceive information through ocular motor stimuli adjusting our eye muscles and focus. Visually we perceive through monocular cues and binocular cues. Monocular cues are indicators influencing our depth perception that only require one eye. They include the relative size of an object, how close an object is to the horizon, texture, motion parallax, overlap or interposition, shading and
lighting, etc. These indicators are all related to imagery and play a great roll in information visualisation and architectural renderings (Ware 2013), (Tufte 2005; 2007). Monocular cues can also be related to the position of an object in relation to oneself over time, in other words, the objects motion. Binocular cues on the other hand, are visual clues we get from both eyes. This is known as stereopsis; horizontal disparities gained from two slightly shifted images (one image from each eye), which is processed in our visual cortex enabling depth perception. The problem with common visualisation practices is that they only address a single aspect of visual-spatial-perception; imagery (monocular). Physical (and digital) building and city models have a significant advantage in this respect as they provide a rich source of three-dimensional and contextual information. Technologies such as augmented reality support understanding through the integration of both monocular and binocular visual cues and context, for example by situating engagement (Korn 2013).

2.4. ABOUT VISUALISING AND PERCEIVING
Visualising planning information is a key part to tackling these communication problems. It enables large amounts of data to be comprehended, facilitates the perception of patterns and the understanding of information beyond a person’s expertise and helps in the formation of hypotheses (Fiske and Jenkins 2011). Visualising information is making it visible to the eyes using graphs, maps, images or diagrams. “Tufte argues that ‘the principles of analytical design are universal - like mathematics, the laws of Nature, the deep structure of language - and are not tied to any particular language, culture, style, century, gender, or technology of information display’ (Tufte 2007). In contrast Ware clearly differs between arbitrary and sensory principles and aspects. Sensory aspects are described as biological, using the brains perceptual processing power without a need for learning. They allow cognition without prior knowledge, are resistant to instructional bias, and are valid across cultures (Ware 2013). Arbitrary aspects however, are governed by society and culture. Because they are symbols which don’t resemble their object (Saussure et al. 2011) they are hard to learn, can be easily forgotten; are capable of rapid change; and are formal in structure, such as in mathematics (Ware 2013). In traditional planning and architectural visual communication, many of the visualisations fall into this second category” (Jenney and Petzold 2017).

2.5. ABOUT MOTIVATING
Without participants there can be no participation. "The use of game design elements characteristic for games in non-game contexts” (Deterding et al. 2011) or "the process of game-thinking and game mechanics to engage users and solve problems” (Zicherman and Cunningham 2011), "usually intended to create gameful and playful user experiences, motivate desired user behaviors, and generally, increase joy of use” (Deterding et al. 2013) is known as gamification. These elements or mechanics include "a feedback layer of points, badges, leader boards, and incentives” (Fuchs et al. 2014), as well as story, challenge, quests, competition and collaboration, conflict, levels, rules, goals, progress information,
etc. and often include multiple players (Schell 2010), (Fullerton et al. 2014). Gamification shows a high potential for public participation as key aspects of intrinsic motivation, such as experiencing one’s own competency, having autonomy and social relatedness can be addressed. By making personal and social benefits visible to a user and supporting intrinsic motivation, the overall benefit of a planning proposal is increased, favouring participation (countering rational ignorance). A game-full and collaborative approach to solving problems can lead to broader consensus as it enables us to view a problem from different angles, supporting objective reasoning. This improves understanding and ones’ willingness to compromise and is therefore well suited in mediation situations such as planning.

3. System Foundation and Requirements

The augmented reality communication prototype is based on a planning tool, developed to support political decision-making and urban strategy development in early planning phases. This tool was developed by the Urban Strategy Playground Research Group (USP) to analyse and compare different strategies and development measures. The developed USP system makes it possible to consider the variants by automating key computation steps while continuously monitoring limiting parameters, such as building codes. The modular expandable system architecture of the USP system uses a parametric city model as a planning basis and combines it with a visual programming interface for the definition of functionalities. The result is an accessible and highly customisable planning tool for early design phases (Seifert et al. 2014).

The parametric city-model is composed of elements representing the legal and regulatory structures and functions of a city (block, plot, building, etc.) and the related semantics needed to use these structures and functions within the context of German planning regulation. Additionally, the geometry of the model is based on a Petri net (also known as place/transition nets) (Seifert et al. 2016). Within this dependency graph primitives, values and modelling functions define the final geometry. The resulting model has three main advantages which can be tapped by the augmented reality communication prototype explained in this paper:

- It is possible to access and implement necessary functions and key value parameters (e.g. depth, height, etc.), independent of the approach used to model the geometry.
- It is possible to lock individual input primitives and value parameters, to constrain the changes possible within the petri-net for different users or tasks.
- If the geometry is changed, it is possible to identify precisely which other elements or geometries are affected by this change through the execution path.

Exporting plans, datasheets, and models for digital fabrication (CNC-milling, rapid prototyping, etc.) as a basis for discussion, archiving and submission to authorities are also implemented in USP using the expandable visual programming language. These export capabilities however, focus on static and analogue media, as they are currently commonly used in discussion and public participation procedures.
Figure 1. Information loss by exporting static media from digital planning models. As depicted using the USP-Planning-Tool example.

Planning, on the other hand, is a dynamic process. Questions arising from discussions may require information which is not available at that moment in time. Traditional architectural plans or models contain some of this information implicitly in their visual representation but today’s digital design methods, which are based on rich semantic data models, make visualisation-on-demand feasible, enabling a user orientated tailoring of visualisation and information depth for independent audiences and situations (Tory and Möller 2004).

Building on the advantages of the USP model and the literature research into participation processes, visualisation, communication, visual perception, motivation and gamification, the following requirements on the augmented reality communication system were derived:

- **Accessibility**: The necessary technologies to access planning-information in-situ have permeated our living rooms and even our pockets. This means that there are new ways to reach a large number of people. The system should be designed in a way that it is platform independent and easily adaptable to special augmented reality (AR) or mixed reality (MR) hardware.

- **Low Cost**: Early Participation has the most value, for both planners and citizens, as the opportunities for influence are still high and resulting financial costs low. Public participation should be by-product of planning efforts as far as this is possible.

- **Flexibility**: The system should allow for different situations, such as in-situ or using a model or plan, as well as for different communication scenarios, e.g. for moderation, discussion, or self-education etc.

- **Tailoring**: The system should be able to take different knowledge levels, planning backgrounds and interests into account, but also enable exploration of planning information. It should be able to deal with arising queries by adapting information to the user’s needs.

- **Direct Feedback**: The system should motivate participants to interact with it and enable two-way communication, i.e. it should include a direct feedback loop as well as make one’s actions and their results visible.
4. System Concept and Prototype

Figure 2 depicts the system concept. Planners and authorities develop strategies and make plans for city development with the USP-Planning-Tool (1). Different planning strategies are created on basis of a reference model, which defines the initial situation. Strategy variants are always put in relation to this reference model, making different strategies comparable. The projects and models are stored in a central project database (2). When a project is advanced far enough it can be made available to the public. It can then be accessed by the participation server (3). This server manages the communication with the participating clients. Whenever a client (5) connects to the server a new client specific process is created, handling tcp/ip and udp connections and initialising the visualisation-communication pipeline (4). User accounts store user profiles defining the knowledge level, interests and rights determining which templates are accessible to the client. Templates (6) describe which functionalities and information are presented, how they are presented, and which possibilities exist for feedback and modification based on the participation context (in-situ on site, augmenting a physical model, at home) and the user profile. Template suggestions are provided; however, the user is free to explore all templates within their profile rights. The visualisation-communication pipeline (4) adjusts information based on the template in use.

It is possible for the client to participate, give feedback and comment (7) within the category and the spatial context of the problem, for example using pins or annotations on the three-dimensional model. The comments can be either public, i.e. visible for others to join the discussion, or private, only visible to the planner or a defined user group. These comments are saved in a participation database (8) through the visualisation-communication pipeline (4) including their...
links to spatial context, user profile, and comment category. The machine-readable nature of these contributions enables planners to sort, evaluate and filter them for incorporation in the planning process. More extensive analyses, simulations, calculations, or queries are incorporated as services (10). These are available to both the planners, to support the decision-making process, and the clients, to support understanding.

The software environment is designed as an interactive expandable IT system. Based on the USP-model the system is developed in JAVA, whilst the client is developed using the game engine and authoring software Unity. Unity provides a robust and well-established platform that is supported by many third-party developers. Therefore it is possible to produce applications from one project for a wide variety of platforms, including Virtual Reality (HTC-Vive, Oculus Rift, SteamVR, Windows Mixed Reality), Augmented Reality (Vuforia, ARCore, ARkit, HoloLens), Android and iOS applications for tablets and smartphones, and browser with only minor adjustments. While at its core unity is an authoring tool, the scripting possibilities enabled us to realise a highly customisable communication platform using Unity mostly as render engine. The scene, geometry, and graphical user interface is generated “on-the-fly” based on the data received by the participation-server.

Figure 3. Left: USP-planning-tool, Right: Unity augmented reality mockup showing exploration of design variants.

In the current prototype the parametric-semantic petri-net model is transformed into a geometry model that is then streamed to the client. Client interactions with the model are realised using individual pre-constrained control points and values, which are linked to the petri-net, and occur through the client’s user interface. Changes made by the client are communicated to the participation-server, the parametric-semantic petri-net model is then updated on the server side and the changed geometry is sent back to the client. Clients that are connected to the same project and are publicly visible can share their current field-of-view allowing users to visually support their explanations letting others take a look through their eyes. When a client “follows” another, the participation-server acts as a broker and mediates a direct connection between the two clients (9). This provides the
future potential for users to communicate with each other through chats, etc.

5. Conclusion and Outlook

For public participation to be successful the cost of preparing and participating in these processes needs to be reduced for both members of the public and planners. For planners, this means that public participation needs to become a by-product of existing planning processes. We suggest that this is possible by introducing a “middle man” between models used by planners and the information accessible to the public in the form of a visualisation-communication-pipeline with feedback capabilities, where visualisation is generated on-the-fly in response to user and situation requirements and queries. The implemented working prototype proves the technical feasibility of this approach.

To improve physical and cognitive access, the suggested prototype uses augmented reality on hand-held and see-through devices which have the technical capabilities necessary and are already established, readily available, and widespread, such as mobile phones. Using user profiles, situation templates and visual-perceptual parameters, information can be tailored to users' needs and interests as well as the situation in which participation is occurring (discussion, moderation, self-education, etc.). User profile requirements will be analysed in an upcoming research project in collaboration a large housing company. Furthermore, a project with students will be developing prototypes to investigate the requirements of in-situ augmented reality communication processes in terms of both content required and visual interpretation.

It is not enough to only improve physical and cognitive access, processes must become more motivational by visualising actions and their impact. Gamification will be explored within this system, to strengthen public experience, interaction and participation. This could be used to influence the selection of the user profile or adjust the profile over time through levels, leader boards and scoring systems. Planners could set challenges or quests when in need of local information and in this way, utilise local knowledge. In turn, the public can track both the progress of a building project but also visualise their own input or influence, providing the user with multiple levels of feedback and interaction. Finally, the individual components of the system concept need to be brought together.

References


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