

Immersive Street-level Social Media in the 3D Virtual City: Anticipated User Experience and Conceptual Development

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ABSTRACT

In this paper we explore immersive street-level integration of social media content into collaborative virtual 3D city environments on two levels: *i) public*, where the virtual environment is populated with relevant social media content (e.g. Twitter and Facebook feeds of shops, non-governmental organizations, the City organization); and *ii) personal*, where the virtual user, through his/her avatar, is able to access his/her personal social media feeds while immersed in the virtual city. We conducted a qualitative anticipated user experience study with 14 participants in four focus groups, who were asked to create designs of how they imagined social networking services could be integrated into virtual city environments. Further, participants were asked to comment on two visual concepts created by researchers. Results show that people appreciate the concept of having virtual cities populated with up-to-date content from social media services, but linking their own social media accounts is a more complex issue.

Author Keywords

Anticipated user experience; social media; mirror world; 3D city; collaborative 3D virtual environment.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Virtual worlds represent a frontier in social computing with critical implications for business, education, social sciences, technological sciences, and the society at large [35]. As these worlds become increasingly sophisticated, hundreds or thousands of people can simultaneously “stepping into the Internet” [48] and co-habit realistic virtual cities that are effectively mirror images of real, physical city environments [12,15,23]. Whereas the Internet in its early days was dubbed the “information superhighway”, Messinger *et al.*

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have suggested that the nascent virtual worlds be likened to a “globally shared playground and workspace” [35], where users come together to work, learn, interact, shop and play. Substantial research on collaborative virtual environments [42] (CVE) has been conducted since the 1990’s (e.g. [7]). While CVEs in the 1990’s required specialized hardware and software, today large-scale fictional virtual worlds are commonplace in consumer market (e.g. World of Warcraft and Second Life), thanks to the ubiquitous high speed Internet and powerful personal computers.

As globally shared playgrounds and workspaces, virtual worlds often function as self-contained social networks: Players in massively multiplayer online role-playing games (MMORPGs) such as World of Warcraft form communities, guilds, friendships, or even romantic relationships with other players in the same world [10]. These communities often also spread out to other social networks, and e.g. a player guild can have their own Facebook group where players appear under their real personas instead of as their in-game characters and discuss game-related topics among others. Conversely, this transition does not appear to exist in the other direction, where content from social networking sites would be brought into a virtual world. This is understandable, as the more game-oriented virtual worlds rely on immersion and fantasy which would be broken if more ‘mundane’ content from other social networking sites would be brought in. However, in virtual worlds that are based on non-fiction the separation of ‘virtual world content’ and ‘social networking content’ appears redundant.

We focus our study on so-called *mirror worlds*, defined as “a representation of the real world in digital form [which] attempts to map real-world structures in a geographically accurate way” [43]. A mirror world can be seen as an autonomous manifestation of digitalized reality including virtual elements or other forms in which information is embedded. Hence, “mirror worlds” are connected to real-world and lie nearer to non-fiction, in contrast to the more traditional virtual worlds that typically have no direct connections to the real world and thus are described as fictions. Such digital meta-worlds have been forecast to become an integral part of our reality in the near future [42]. *Virtual city models* (e.g. [27]) are a particular type of mirror worlds that have gained lots of attention since mid 2000’s when their semi-automatic construction at city-scale became feasible [12]. Initially, they were often employed as a passive

digital ‘canvas’ for the 3D visualization of different types of information such as air quality with professional software (e.g. [36]). However, recent developments in 3D web technologies allow deploying virtual city models as open collaborative 3D virtual worlds [46] that general public can access with modern web browsers without any specialized software or hardware.

The mirror world we utilize in this study is a collaborative multi-user 3D virtual representation of the city of Oulu, Finland (later: “3D City”, [2]), consisting of 30 city blocks modelled using WebGL technology and hosted atop the realXtend WebTundra platform [1]. We explore the concept of immersing social media content in a 3D mirror world on two levels: *i) public*, where the environment is populated with relevant social media content (e.g. Twitter/Facebook feeds of shops, non-governmental organizations (NGOs), the City organization); and *ii) personal*, where the virtual user, through his/her avatar, is able to access his/her personal social media feeds while immersed in the virtual city.

We argue that such integration of social media to the 3D City would have several benefits. Firstly, the virtual city will appear more lively as real-time data is continuously displayed in a georeferenced manner (*i.e.* a shop’s feed will appear at the shop’s actual location in the virtual world). Secondly, the user is provided with added value as newsfeeds or offers from locations s/he may not be aware of serendipitously catch his/her attention while exploring the virtual city. Third, the user does not have to pause his/her current task in the virtual world and shift focus to *e.g.* another browser tab or another device whenever a notification from a social media site requires attention. Finally, social interaction between users becomes more natural as real-life links between people are overlaid on the avatars. Figure 1 shows the ‘plain’ 3D City model, and a sketch of the imagined integration of social media services into the model.



Figure 1. Left: 3D City model used in the study; Right: imagined integration of social media into the 3D City model.

This work contributes to the existing body of knowledge by reporting on the first study to understand how the street-level integration of immersive social media content should be designed in a collaborative 3D mirror world. This work is an important first step in studying users’ anticipated experiences and needs for social media integration in such environments, and has the potential to inform the design of future applications and services for virtual cities in general.

RELATED WORK

Visualizing Geotagged Social Media Content

Whereas the common thinking in the 1990’s was to consider ‘cyberspace’ and the material world as separate from each other [16,29], today ‘virtual’ and ‘material’ spaces are recognized as inextricably linked (see *e.g.* [14,17,37]). Graham *et al.* [17] trace the trend of digital augmentation of urban places via three successive moments in the development of Internet practices and technologies, namely: *i) the move towards the mobile Web*; *ii) the growth of authorship*; and *iii) the emergence of a geospatial Web (or ‘geoweb’)*. Closely related to these is the rise of social media platforms like Facebook and Twitter, which currently boast hundreds of millions of active users who produce massive volumes of social content every minute. Further, geotagging content is very common, and this trend makes new, hyperlocal content constantly available in a real-time manner, to be consumed through newsfeeds or as embedded in the environment.

Visualizing and analyzing geotagged content has gained considerable interest also in academic studies. Xia *et al.* [49] presented a prototype titled ‘CityBeat’, a real-time visualization of hyper-local social media content for cities. The system collects a stream of geotagged photos of New York as input to detect hyper-local events, and visualizes this data using an ambient display. Another similar study on detecting hyper-local events from geotagged media was done by Xie *et al.* [50]. Hiruta *et al.* [21] proposed a method to detect and classify real-world events from geo-tagged tweets, and Oku *et al.* [38] presented a method for analyzing and mapping geo-tagged data to create a touristic recommender system. Similarly, Alowibdi *et al.* [3] presented a prototype that can analyze geotagged Twitter data to help people decide on a suitable vacation destination. Janai [51] presented a system for visualizing geotagged photos from Twitter on a map, and also showing them in Google Street View. However, the visualization of images in Street View is rather crude and the images cannot be considered as ‘embedded’ into the view. Finally, Magdy *et al.* [34] presented Taghreed, a complete system for querying, analyzing, and visualizing geo-tagged micro blog websites such as Twitter. Extensive surveys on georeferenced multimedia are available in [33] and [52].

As the literature discussed above suggests, a lot of effort has been expended on creating methods for utilizing geotagged social media content in various 2D scenarios. However, none of the presented work address *street level* immersion of social media content in 3D virtual city models. The first prototype towards such immersive visualization is the recently published Social Street View (SSV) [13], which explores overlaying social media content atop Google Street View panoramas. Here, a single user is able to view and navigate geotagged social media items imposed on 2D scenes, similar to the original Street View service. Our work differs from SSV by immersing social media content inside

a true collaborative 3D virtual environment, the “mirror world” mirroring a real-world city center, and by incorporating personal social media, which in turn enables a two-way interaction between the user and the virtual world.

From Virtual Worlds to Mirror Worlds

Online multi-user virtual worlds are, of course, not new. Already in 1995 a virtual environment called *Alpha World* (later renamed *Active World*) was launched, which allowed users to create their own virtual content including houses, streets, or gardens using pre-fabricated objects. Similarly, a virtual world targeted towards teenage users called *Habbo* offers virtual hotel rooms that can be customized with virtual furniture, and used as a platform for chatting and content sharing among users. *Second Life* is perhaps the most well known (non-gaming) massively multi-user virtual world that has been adopted not only by individual users, but by large corporations as well as an advertisement and promotion tool (see e.g. [25,26]). Similarly, OpenSim is a platform that aims to create a web of *Virtual World Grids* connected through portals allowing avatars to navigate seamlessly between virtual worlds that exist in different administrative domains that are connected to the OpenSim *hypergrid* [6]. For a more thorough overview we refer the reader to a survey of past virtual world research by Messinger *et al.* [35]

These virtual worlds share the common characteristic of being *fictional*. As Roush notes, “*Second Life is a true virtual world, unconstrained by any resemblance to the real planet [...] shaped by the shared imaginations of their users*” [43]. Conversely, *mirror worlds* [15,43] are virtual environments accurately modelled after their physical world counterparts: utilitarian software models of real human environments that describe a much more substantial environment [30]. Roush [43] identifies unique opportunities for both academic researchers, as well as business actors who could e.g. track their wares and explore what-if scenarios such as the impact of a major storm on the supply chain. Leigh and Brown [30] describe mirror worlds as the “*telescope one uses to view and collect data from global resources but goes further, bringing people together [...] to enable collaboration*”. Google Earth and Google Street View [5] are well-known instantiations of the *mirror world* concept. However, these services are 2D instead of 3D, single-user instead of collaborative, and mostly allow the user to simply observe the virtual world instead of having agency as an actor.

For the most part, work on mirror worlds has so far been quite speculative. One notable implementation is *Virtual Berlin* [12], although very little information about the project besides the initial technological report is available. A 3D virtual world titled *Twinity*, originally developed by Metaversum GmbH and later acquired by ExitReality, hosted 3D models of world cities including Singapore, London and New York, but has later removed these real-world locations in favor of a more fantasy-oriented world of their own.

Hence, to the best of our knowledge, the proposed street-level immersion of social media content into a multi-user 3D

mirror world is the first study to begin unpacking this design domain. This is an important first step in understanding these mirror worlds from a collaborative user-centered perspective. With the current raise of VR and the trend towards the 3D Web [4], understanding mirror worlds not simply as utilitarian tools for modelling various real-world phenomena but as platforms for social interaction and play, or *globally shared playgrounds and workspaces* [35], allows researchers to carry out studies ranging from cultural anthropology to human-computer interaction, virtual economies, and so forth.

Anticipated User Experience Evaluation

The purpose of an anticipated user experience (AUX) evaluation is to identify whether a given concept is able to provide the kind of user experience (UX) anticipated by developers for its future users [45]. Studying anticipated experiences with non-professional participants is not easy [47], because non-professionals are not able to imagine a future that is in conflict with their current technology use. Olsson [39] has noted that it is difficult to picture a hypothetical future technology with just textual scenarios and non-functional demonstrations. According to [11], textual explanations with images of concepts can provide more concrete feedback to the design. To be able to study AUXs with visual user interface design concepts, Pakanen [40] suggest using visual design examples (ViDEs). One benefit of ViDEs is that they provide a feeling of empowerment for the participants to change the final design, and also extend the participants’ knowledge on the topic.

USER STUDY

The aim of the study discussed in this paper was to gather information and requirements for the integration of social media content into the 3D City, with the goal of informing the design of a functional prototype. We utilize an existing 3D city model covering nine city blocks of downtown area of the city of Oulu, Finland [2]. The model is built as a photorealistic version of the real city, with buildings that are accurately modeled from laser scanning data and textured with photographs taken from the real buildings. The 3D City model in question is a work in progress, meaning that not all scenes in the model are always up-to-date (for instance, the construction of a large shopping mall at the downtown area is not yet visualized in the model). The model also lacks some street furniture such as benches, plants, and sculptures. The version of the 3D City used in the user study is a development version, *i.e.* there were no other users inside the VE during the study.

In order to study the anticipated user experience, user perceptions, and ideas for integrating social media content into the 3D City, we conducted an exploratory study with 14 participants (7 female) in focus groups of 3-4 people. These focus groups comprised of the following main parts: 1) familiarization with the 3D City, 2) co-design activity, and 3) concept design walkthrough. These parts are described in detail next.

Procedure

At the beginning of the evaluation, participants completed a consent form and a background questionnaire giving their demographic information and prior experience with 3D technologies and social media services. Each focus group consisted of following tasks:

1. Familiarization with the current 3D City model

- Participants were first asked to familiarize themselves with the 3D City model simply by looking at it. They were prompted to give their initial thoughts when first seeing the 3D City model.
- Next, participants were asked to interact with the model by controlling an avatar and walking freely around the City, with no explicit instructions on where to go or what to do. The model in question was not augmented with any social media services (see Figure 1, left). Participants were asked to think out loud when interacting with the 3D City model, and comment on anything that caught their attention.

2. Co-design activity (Figure 2)

- Participants were asked to complete a co-design task on utilizing social media content in the city model using an A3-sized print-out of an existing 3D scene from the model (Figure 3), and various materials such as post-it notes, glue, colored pens, and cut-outs of social media services' logos and avatar figures to construct their idea for presenting social media in the 3D City.
- After participants had created their paper sketches, each one was asked to describe and explain their design to the group.
- Finally, participants were asked to discuss and give feedback for each other and highlight the most liked ideas in each design.



Figure 2. Co-design activity.

3. Concept design walkthrough

- At the end, researchers running the workshop presented the two pre-made ViDEs: Concept A and Concept B to the participants so that the order in which the concepts were presented was counter-balanced between focus groups. Participants were asked to comment on each illustration as the use scenario progressed.
- After each concept, participants were asked to fill in an AttrakDiff [18] inspired 7-point (-3, -2, -1, 0, 1, 2, 3) antonym word pair questionnaire with ten statements

related to the overall concept (Figure 6), accompanied with free-text fields to give rationale for selections.

Data Collection Methods

The main data collection method was a semi-structured interview, which was complemented by a co-design activity. Laddering technique [24] was utilized with semi-structured interview in order to get more elaborate comments and to clarify their meaning. All focus groups were videotaped for further analysis. The total time per focus group varied from 60 minutes to 90 minutes, and participants were rewarded with a cinema ticket worth 10€.

Visual Design Examples

As the 3D City does not yet contain functionalities for integrating social media services and streams, we wanted to provide visual examples on how social media services could potentially be intergrated into the virtual city, and also collect AUX feedback on interaction affordances and design from our participants. For this purpose we created two ViDEs [40] (Concept A and Concept B) with illustrative content from various social networking sites (Facebook, Twitter, Instagram, Tinder, *etc.*, Figure 3). The ViDEs visualized content both on a personal level (user's own social media and notifications), and on a public level (content from *e.g.* local businesses, illustrated in the environment). As an overarching principle, both ViDEs combine various social media icons and feeds within one 3D VE, with the goal of allowing users to stay within one environment and not have to shift their attention to another site/device when *e.g.* a notification requires their attention. A similar concept was used by Hickey *et al.* [19,20] with what they termed "fused services".

Both ViDEs featured the same use case presented with seven illustrations in total (Figure 3). The featured use case illustrates a short walk in the 3D City, where the user's avatar passes by municipal buildings, shops, cafes, and heads towards a public square. While traversing the route, different social media feeds are displayed to the user. In addition, when the user encounters another user's avatar, their public social media profiles are made visible. At the end of the walk, the user receives a G+ notification and opens his feeds to see the message.

The two ViDEs differ both in terms of information visualization and interaction design (Figure 3 & Table 1). We draw on the work of Hickey *et al.* [19,20] in the design of the two ViDEs with the goal of studying differences in perceived user experience between concepts A and B. The main difference in visualization is the presentation of content in the environment: we alter between *location bound, always visible billboards* and *proximity-based 3-step visualization* where the user's location serves as a trigger for transitioning between the 3 stages of content presentation. We also wanted explore whether it is better to combine all social media in one feed, or show the various feeds individually in a tabbed view. On a personal level, the user's private feeds are presented either in a 2D 'line' visualization or as a 3D 'carousel'

positioned on the user's avatar. Similarly, active feeds are displayed either in a tabbed 2D view or as a 3D carousel at the bottom of the screen when the user interacts with them.

Concept A (Figure 3 A, Table 1): social media and other information such as contact details and opening hours of businesses are presented on 2D billboards, which are always visible and oriented towards the user. Different social media feeds are presented as tabs, which can be changed by tapping. User's own social media services are presented on his avatar, arranged in a 2D line. When the user opens his/her own feeds, different services are presented on tabs in the lower 3rd of the screen. Other user's social media feeds are presented as 2D billboards attached to their avatar, and also spread across multiple tabs.

Concept B (Figure 3 B, Table 1): social media content is presented to the user in three visualization steps: *i*) the user sees the brand or logo of various businesses or NGOs in the environment, illustrated inside white circles and attached to the actual location of the business with a white line; *ii*) when the user approaches, icons of all social media services the particular business has linked to the 3D City become visible on the rim of the circle; *iii*) when user is near enough, the circle is replaced with a feed showing a combination of the newest posts from all linked social media sites. The user's personal social media services are presented on his avatar as a 3D carousel. When the user opens his/her own feeds, they are presented also in a 3D carousel alignment, with all linked services visible simultaneously. Other user's public social media feeds are presented similarly as other service providers social media.

Participants

Participants were recruited from social media channels, online user database [22], and from the university campus. We aimed to recruit both active and less active social media users with a 50/50 ratio between male and female. In addition, we aimed at a 50/50 ratio between experienced/not experienced users of 3D games or other 3D environments. Participants' ages varied from 21 to 38 with a mean of 29. Seven participants had experience with 3D games or other 3D virtual environments. Five participants had experience with volumetric 3D devices, such as Oculus Rift. When forming groups, the participants' experience with 3D environments was taken into account. Therefore, in each group, at least one person had 3D game experience.

Data analysis

Data from the focus groups was analysed both statistically and qualitatively. The qualitative data analysis followed general qualitative coding principles [9]. The process was initiated by reviewing the videos from the focus groups, and themes for analysis were set for each task. The video recordings were then transcribed during another viewing, and the transcripts were reviewed using the previously identified themes, and adding new ones where necessary.

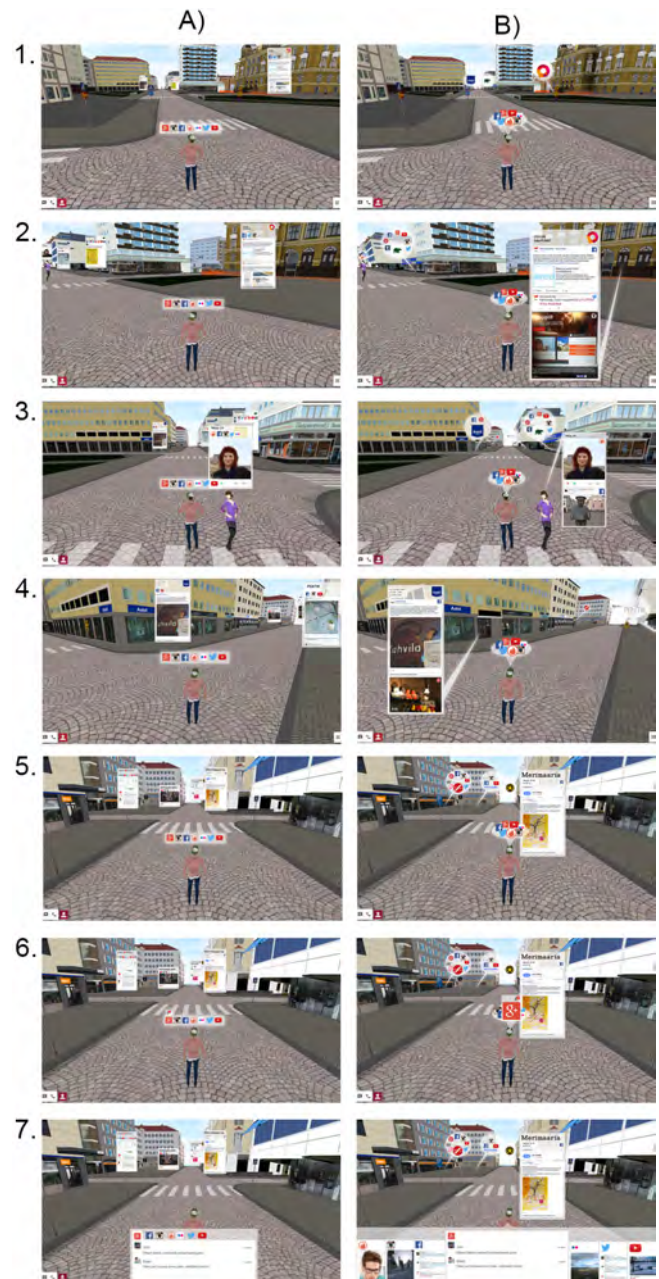


Figure 3. Example visualizations of Concepts A and B.

Next, relevant comments from participants were categorized under these themes. Here, the focus was on gaining understanding of the participants' opinions, needs, and wishes for the integration of social media content into the 3D City. Recurring and one-time comments from participants were considered as equally important. For quantitative data, responses to the Attrakdiff questionnaire were analyzed for statistical significance using the Wilcoxon signed-rank test using the following independent variables: *Concept A*, *Concept B* and *Degree of social media use (heavy/light)*.



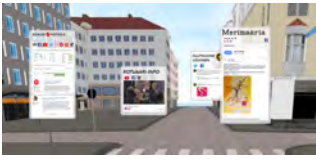



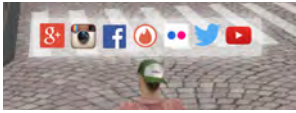



Social media sphere	Variable	Concept A	Concept B
Public	Presentation manner	2D billboard 	3-step visualization 
	Visibility	Always visible 	Proximity based 
	Organization	Tabbed view (different social media feeds in own tabs) 	Feed (different social medias within one feed) 
Private	Presentation manner	2D line alignment 	3D carousel alignment 
	Visibility	Always visible	Always visible
	Organization	Tabbed view (different social media feeds in own tabs) 	Carousel (all social media feeds visible) 

Table 1. Variations in visualization between Concept A and Concept B.

RESULTS

Perceptions of the 3D City Model

At the beginning of each focus group, participants were asked to comment on their first impressions of 3D City. As a general trend, participants first focused on the out-of-date nature of the model. Especially the fact that the new shopping mall complex was missing drew a lot of attention. Participants also commented on shops, cafés, pubs, etc. that had either relocated or gone out of business but were still visible in the model: “[This street] has changed a bit, but you

can still understand where you are located...but it stands out immediately, if something is missing” (P10/M). Participants also commented on the lack of people, traffic, and street furniture: “Looks deserted” (P7/M) and “[a] simplified version without street furniture, people, and plants” (P8/F). The fact that photographic textures in shop windows showed reflections of cars that were not present in the virtual model was also perceived as confusing or irritating (P1/F & P10/M), and the user’s own avatar having no reflection in the windows was considered discerning (P8/F).

Purpose of the 3D City Model

Participants often commented that due to the realistic representation of “City” in 3D format, the model could be utilized as an interactive map for navigation purposes or for familiarizing oneself with the city before travelling there as a tourist: “If this was a place where I have never visited before, then this kind of photorealistic representation would be interesting” (P11/F). Again, the requirement for an up-to-date representation of important points of interest such as shops and bars was brought up: “If it is meant for advertisement purposes, then it would be good to find the shop in real place” (P5/F). Another participant explained: “It would be nice to have real-time information, as for example in Google Street View images are from several years ago, so you cannot trust this information anymore.” (P3/M). Participants were sympathetic to the difficulty of maintaining an always-up-to-date City model: “Of course, it is a challenge to keep [the model] realistic, as the cityscape keeps evolving...” (P11/F). Thus, it was suggested that the model could be updated at least once in a month (P3/M).

The need for such a 3D City model in relation to existing services such as Google Street View was also discussed among the participants: “could this same information be presented in existing service, such as Google Maps?” (P11/F). The added value of 3D City model over online map services was explained by another participant: “...you cannot go inside a building, or climb to the roof in Google Maps” (P13/M).

Graphical Quality of the Model

All participants, regardless of previous experience with 3D environments, thought that the graphical representation was not quite up-to-par with what they consider modern 3D game graphics, but that it was sufficient so that they could easily recognize real-world locations: “Not quite triple-A class... not necessarily good compared to game graphics of the day, but you can recognize the place anyway” (P4/M). Interestingly, participants studying architecture (P8/F & P9/F) thought that the model looked quite precise and illustrated a slightly simplified version of reality that they thought was quite nicely modeled.

These findings suggest that when operating inside a *mirror world* environment, people expect to find familiar urban phenomena such as traffic and other people inside the 3D City. Also the importance of the up-to-dateness and visual quality of the model should not be underestimated, as people tend to mentally link the realistic representation of the 3D City model to online maps and navigation.

Co-designing the Social 3D City

After the participants had familiarized themselves with the 3D City model, they were asked to complete a design task using tools familiar from paper-prototyping. As seen in Figure 4, participants created rich and detailed designs integrating a heterogeneous set of data sources and features, including public and personal social media, links to websites,

general public information, and promotional material from local businesses.

In general, the possibility of integrating social media services and content within the 3D City was considered good as participants thought it would make their lives easier: “I think it is not a bad idea to have social media services jointly here within one service, as there are normally billions of places to check [before locating what I’m searching for]” (P7/M). Participants also appreciated the convenience of finding information about businesses all in one place: “I could check for my favorite shops’ feeds to see if there are there any special offers within one place”(P5/F) and “I would not have to go search for offers from any other place” (P1/F). The importance of thoroughly integrating social media services into the 3D City was brought up, as participants explained that having to redirect from the 3D environment to a 2D webpage to view information would become disturbing and hinder their use experience.



Figure 4. Annotated design from P11/F.

Visualizing Business Information in the 3D Environment

In their designs, participants included basic information about local businesses such as opening hours, contact details, current special offers, and event information. Participants commented that shop windows or building facades would work well for presenting information within the 3D City: “[Visualizing content] on shop windows, where it would not be in the way” (P7/M); “Because it is a shop window, people will know that there is something to be seen there” (P5/F). This is interesting, because when first familiarizing themselves with the 3D City participants were saying that having to manually walk up to windows in the 3D city to see all the content would be very time consuming and laborious due to the slow movement of the avatar. Some designs opted to display a logo in the window, and the user would click it to be able to see the content (P13/M), whereas others were more streamlined: “No need to be like ‘come here and click’, it should show a constant stream of information” (P5/F). Participants acknowledged that while windows would be ok for general information about e.g. shops, they would be less suitable for visualizing other municipal or event information: “But those that are in the middle of the city square, nobody would expect to have anything interactive there, so there

could be some bouncing arrow or YouTube logo” (P5/F). In more open spaces participants opted to visualize social media content by embedding it into the environment through visualization markers such as arrows or logos.

Participants also created two-way interactions between their avatars and local businesses, so that they could contact service providers directly from the 3D City. One participant even included a network of web cameras, so that real-time visual feeds from the physical world could be integrated into the 3D City model: “You could see what it is like in real city from this angle” (P7/M).

Tourism

Participants often included in their designs services aimed for tourists that would help to recognize important locations such as municipal buildings, landmarks and sights in “City”, and to view relevant social media content about them: “Not all people are familiar with the city, so markers are needed to display locations and sights” (P4/M). It was suggested that names of locations (such as “Central Park”) could be shown on the top of the screen to avoid blocking the view (P3/M). Participants also suggested that it would be important to display more in-depth information about locations, such as the type of food a restaurant serves, or reviews of hotels from TripAdvisor, and it should be possible to book restaurant tables and hotel rooms directly from the 3D City. Obviously, such information is now commonplace in 2D web.

Events

As the 3D scene on which the participants did their designs showed a main public square that hosts many events around the year in “City”, several designs included information related to these events: “There is a lot of happening there, but quite often you miss them, obviously the information is somewhere, but as it is spread all over, it is not an easy task to find it... if you have all the information [in the 3D City], you could just go there and check what is going on” (P7/M). Participants imagined both “official” and user generated content being shown in the model, including promotional photos and videos for upcoming events: “...there could be advertising for upcoming event ‘X’ through a video clip or a slideshow of photos pulled from Instagram projected to the facade of a building... and there could be a direct link to Facebook where you could participate or be interested in the event” (P14/F). One participant suggested that a performer could be promoting a future gig as an avatar: “He could be here virtually promoting: ‘Hi am coming here next weekend, why don’t you come too’...it would be really personalized [experience]” (P7/M).

Personal Social Media

Participants wanted to see their friends’ avatars, posts, and recommendations. Also private communication with friends was suggested. Participants also suggested linking GPS data from mobile phones to the 3D City, so that they would be able to see where their friends are moving in the physical world (e.g. a person’s avatar would move in the 3D City as the person moves in reality): “For example if it is difficult to

meet friends due to time constraints for example, then the person could be in two places simultaneously and be able to meet friends” (P7/M). Another participant explained how interactions with friends would be possible: “If he posts something, then a speech bubble would appear here” (P12/M). Also linking personal and business social media was described by participant: “If you notice a nice deal, you could send a message via messenger or Facebook to your friend with coordinates and the question: would you like to come to eat?” (P14/F). However, privacy concerns were also raised by a few participants, who felt that linking their personal social media accounts to such a service could potentially create a data set that can be used for invasive advertisement: “I think it is horrible idea, if it collects everyone’s social media in one place, [as] it is just great from an advertiser’s point of view...” (P5/F).

Concept Evaluation

After participants had completed the co-design activity, they were shown the two pre-made ViDEs (Concept A and Concept B). The order in which participants saw the two concepts was counterbalanced between groups. Next, we discuss themes that participants brought up on the concepts.

Visual Representation of Public Social Media Content

Participants liked Concept B for its calmer and visually less cluttered design. The always-visible 2D billboards in Concept A were perceived to consume too much space: “The problem might occur when there is a street with tens of shops, so how would it look when there are ten billboards on top of each other... especially narrower streets would feel very cluttered” (P7/M). Further, participants appreciated the more minimalistic design of Concept B: “I like this more as these [circles] are clearer” (P8/F).. you have to search in this, but UI is much clearer [than in concept A]” (P10/M). The visibility and readability of text on the 2D billboards in Concept A raised concerns, as participants thought navigating the environment just to be able to read text would become cumbersome: “It is way too time consuming to walk back and forth over there, and you still cannot see [the billboards] properly, they are just blocking the view” (P13/M) and “Pointless to have the text, as you cannot read it” (P8/F).

Concept B was preferred because the scene was less cluttered and feeds opened automatically based on proximity. However, some participants likened this to pop-up advertisement: “people do not like it if items pop-up” (P7/M), “Advertisement pollution” (P5/F), and “[unwanted feeds] slammed to your face” (P14/F). Another issue identified with Concept B was that the proximity of an avatar triggered the associated social media icons to appear around the logo (Step 2), and some participants thought this made the design more unclear: “I thought that the bear [logo of a shop] is some social media icon... is it necessary to have those [social media] icons at all” (P5/F). Participants suggested this issue could be addressed by highlighting shop logos in order to help distinguish them from other social

media icons (P7/M & P6/F). Participants also discussed the thin white line displaying the exact location of the circle in Concept B, and agreed that it is not clear: “*Could it be a pin type?*” (P8/F & P10/M).

Participants preferred the tabbed view in Concept A for presenting different social media feeds. The tabbed view was perceived to allow seeing more content than the all-in-one view in Concept B: “*That tab thing is handy, as it will not show mixed feeds from different services which could result in showing the same post two times*” (P12/M)...”*Yes someone could do a post on Facebook and then again on Twitter*” (P14/F). Participants also noted that it might not be best to show the newest feed first, as it might not be important to them personally, and questioned whether social media feeds are able to provide the best information for users: “*Would a person want to see Facebook feeds, or just basic facts about the city? ...should it be just the webpage?*” (P5/F)...”*or the FB front page, where you can select what you want to see*” (P6/F).

Visual Representation of Personal Social Media Content

Regarding the visualization of personal social media, participants preferred the “2D line” layout of Concept B. This layout was deemed visually clearer than the 3D carousel in Concept B. The positioning of social media icons above the avatar’s head was confusing to some participants, however, and some participants had wrong first assumptions about the functionality of the icons. For example, participant 11/F saw them as content filters: “*If I press Facebook icon then FB content would become visible, like what the city has posted*” (P11/F). Another participant was not sure what she would post through icons: “*Would it take some screen shot of that moment, or is it me, [name], looking at the Facebook feed of the city, or me, [name], using this 3D thing?*” (P5/F).

Participants suggested that their own social media icons should be moved to a less disruptive location on the screen: “*I’m used to typically seeing a person’s name or alias above an avatar... less frequently there are functionalities.. the personal social media icons do not belong there*” (P7/M). It was suggested that personal social media icons could be located in the footer area (P5/F & P8/F, Figure 5) because “*Typically, there is nothing important to see in the footer area*” (P8/F).

Conversely, when personal social media feeds were opened, participants preferred the tabbed view in Concept A. It was perceived as visually clearer and far less cluttered than the carousel view in Concept B (Figure 3, B7): “*This is better*” (P6/F)...”*a lot better, clear, no occluding items like in Concept B*” (P7/M), “*it is bad that all are visible simultaneously [in Concept B]*” (P14/F). The carousel view in Concept B was perceived to be designed for touchscreen devices (P3/M, P4/M, & P10/M) due to the larger buttons and more apparent interaction affordances: “*When you get a message in another place [social media], you can just [shows swipe gesture in the air] to view it*” (P10/M).



Figure 5. P8/F’s illustration of social media in the footer.

Privacy Concerns and Linking Personal Social Media Accounts with 3D City

In general, as expected, participants who stated to be careful about how they represent themselves on social media in their background forms were more hesitant about linking their personal accounts to the 3D City. Conversely, and again as expected, participants who were more open towards social media saw no problem with signing in and linking their accounts. The topic generated a lot of discussion, both for and against, in the focus groups: “*I do not understand why my own social media icons should be visible, it means that I have to sign in, I would prefer it to be open*” (P1/F), to which another replied: “*But you could only observe, if you do not sign in... then you cannot create or put content there either*” (P2/M). For many participants, the 3D City was perceived more for presenting public social media feeds both from municipal organizations and local businesses: “*Not that this is meant to be a kind of Second Life or a dating Service...I think it would be more valuable for me if was for advertising city services, or if you can see nearby shops and cafes and what people are saying about them, than seeing teens walking around with their Tinders on*” (P5/F).

The Use Context of Social 3D City

Perhaps the most unexpected comments were raised when another user’s avatar was shown in the concepts. This generated vivid discussions amongst the participants related to the imagined use case and context of the 3D City. Some participants imagined accessing the 3D City through AR glasses while physically in the City, while others suggested it would be a mobile app that could be accessed on the go: “*It seems to have a lot of functionalities that would be nice if you’re actually in the City, like seeing where your friends are...so this would be used on a mobile device... the model would know where you are moving and when another person with the same app is passing, you can see that person’s profile*” (P3/M). The Tinder feed visible in the concept ViDEs in particular was perceived to mean that the user is accessing the 3D City through a mobile app, because Tinder is based on user’s actual physical location and hence limits the possibility to use the integration if not physically present (P6/F). However, participants felt that the 3D City, due to the large amount of detail, would not work well on a mobile device except for large form-factor tablets: “*...it would be*

squeezed in this little space [mobile screen], so how difficult it would be to use” (P5/F). As a solution participants suggested using the model as an AR application: *“If it would be in smart phone, then I would prefer using it in the way that I can point something with my phone’s camera and the whole city would not need to be 3D modeled in your mobile, it would just show the information overlaid on the [camera’s] image”* (P14/F).

Yet others thought the 3D City would be accessed from a home computer or laptop, while not necessarily being physically present in the City. However, the *displacement of self* (being in two places at the same time) was considered as potentially disconcerting: *“It is a bit disturbing, are you there in reality or not... you are at home drinking beer and pretending to be in that bar”* (P11/F).

Filtering Content

In order to have control over how much information is shown, participants suggested various filters that could be used to turn certain feeds on or off, so that they could only select content that is interesting to them: *“There could be a menu where you could choose certain applications, then it would show, for example, only Instagram content of places”* (P6/F); *“If you want to just look around without a pop-up jungle, for example to see the city more clearly, there could be some [buttons] which allow filtering what is show”* (P7/M). It was also suggested that filtering should be possible also for other users’ avatars: *“I would see my own friends...that I have chosen to see, and people that I know from Facebook or Twitter who are located near me”* (P11/F).

Quantitative Results

The results of the Attrakdiff inspired antonym word pair questionnaire are presented in Figure 6. To establish the general significance of the results, a Wilcoxon signed-rank test was conducted between Concept A and Concept B. No statistical significance was found between any of the word pairs in the two concepts when considering the participant population as a whole. Participants rated both concepts in a similar fashion, with all word pairs leaning towards the positive side of the scale implicating general acceptance of both concepts. This is likely due to the fact that participants liked (and disliked) certain aspects in both designs, and did not see one as better than the other.

We further classified participants into 2 groups based on *degree of social media usage (heavy / light)* (7 participants in both categories), and used these attributes as independent variables in analysis. Classification into *heavy* or *light* social media users was based on an aggregate score of how active each participant indicated s/he is in using social media platforms in the background information sheet.

Analysis using the Wilcoxon signed-rank test showed that heavy social media users ranked Concept A as more *straightforward* than light social media users ($P = 0.05$), and conversely light social media users ranked Concept B as

more *captivating* ($P = 0.05$) than heavy social media users (Figure 6).

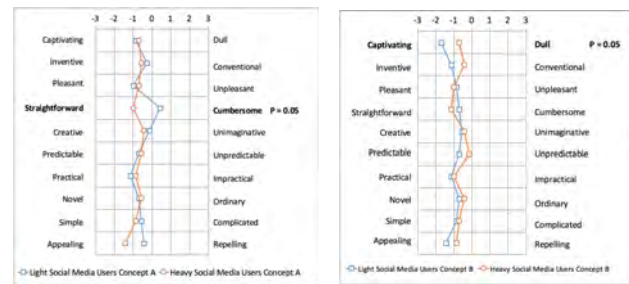


Figure 6. Results from the Wilcoxon Test.

DISCUSSION

Overall, participants appreciated the idea of integrating various social media services and content into the 3D City. The utility value of having all relevant content available through one highly visual service was seen as appealing, and was brought up multiple times during both the co-design task and concept evaluation. However, while participants agreed that having such information of local businesses and municipal organizations embedded into the virtual environment was useful, their opinions were divided on integrating their personal social media accounts into the service. As expected, more active social media users felt more positive about also having their personal content shown in the 3D City than people more reserved about sharing their profile in general. The integration of personal social media also raised many issues regarding the imagined use cases of the 3D City, as participants were somewhat confused about the *displacement of self* and the notion of inhabiting multiple realities simultaneously. Next, we will draw out and discuss findings from our study that help understand this admittedly complex domain. We will also point out important considerations that designers of such systems should take into account.

Street-level Immersion of Social Media

Our participants liked and disliked certain aspects of both Concept A and Concept B. The tabbed view and 2D alignment of personal social media icons of Concept A was appreciated more than the 3D representation of Concept B. However, the proximity-based 3-step visualization of Concept B was considered better than the always-visible 2D billboard visualization of Concept A. The billboards were seen as cluttering the environment, and participants raised issues related to visual occlusion, especially in crowded streets. In 3D environments it has been noted that occlusion can help the viewer make sense of the relative orientation of objects [8]. However, our participants felt that occlusion would hinder their experience, and small text shown in the distance is a poor design choice. Similarly, in accordance with prior findings [41], participants felt that personal social media icons should be presented in areas where no other important information is located, such as the bottom of the screen in order to avoid occlusion and cluttering. An important design guideline for such systems, therefore, is to

ensure that embedded content does not occlude the environment in a way that will become disturbing for the users.

Participants also stressed the importance of being able to filter content, instead of having everything visible all the time, and suggested possible filtering on many levels including spatial, temporal, and contextual. This goes for both public information visualized in the environment, as well as personal feeds or even avatars of friends and strangers. Issues in filtering and visualizing content in 3D environments have also been extensively discussed by *e.g.* Schneiderman [44]. Providing relevant filtering functionalities is another important design guideline derived from our study.

The possibilities of two-way interaction within a collaborative mirror world were also brought up often in the focus groups. Participants expressed their desire to not only passively view information embedded in the environment, but also participate by adding comments and likes, or creating their own content within the virtual world. Further, participants wanted to be able to interact with other users simultaneously inside the mirror world by viewing, commenting, and posting to the user's linked social media channels directly. These functionalities create their own challenges from a visual design perspective, as navigation and object manipulation in 3D environments is different from traditional 2D environments and the interface should intuitively highlight these affordances in a usable and non-intrusive manner. Specifically, it becomes important not to clutter the view with too many actuators, or provide the possibility to hide them when necessary. This design guideline links directly back to the previously discussed issues of occlusion and content filtering.

Context of Use and the Displacement of Self

A classical problem in collaborative virtual environments is that of *presence*, referring to a person having to simultaneously inhabit multiple realities. Lifton and Paradiso refer to the issue as *the vacancy problem* [31], which describes a situation where a user can become non-responsive in one world as s/he carries out tasks in the other. We have termed the confusion arising from the simultaneous occupation of multiple realities as *displacement of self*, referring to comments from participants where they questioned their role and agency as avatars operating in a virtual counterpart of the physical world, while simultaneously occupying a different location in the physical world. This was apparent from, for example, the participant who asked if he would be at home drinking beer while her avatar sat in a virtual pub downtown. While virtual taverns have existed in online role-playing games for decades, the difference here is that the 3D City is a mirror of the physical world and there are no game-like elements such as buying rations or accepting quests from NPCs (non-player characters), like one would find in an MMORPG to justify the avatar's presence in a virtual tavern.

Understandably, participants were confused about where their physical self would be and what interaction affordances their avatar would have in relation to other people while in a given place. While some participants imagined the 3D City as an overlay accessible through an AR headset or their phone, others considered it more akin to a traditional virtual environment and similar to Second Life. Therefore, as a design guideline, it is important to provide some kind of grounding for people, especially if multiple interaction models ranging from AR to desktop interaction and even full-on VR are supported. We have dubbed this multi-reality interaction as *hybrid avatars*, referring to a situation where users from each three realities (AR, desktop, VR) occupy shared virtual/physical spaces [28] and share data from their existing social networks with one another.

Who is the 3D City For?

When discussing their designs, a majority of participants included services for tourists. Previous research has shown that 3D models of real-world places help tourists get a better picture of the place than online maps [41], and as such, integrating up-to-date streams of social networking content has the potential of creating even more interesting showcases of local hotspots or displaying real-time hotel or restaurant recommendations for tourists.

The question of 'who's this for' was brought up by our participants in the initial discussions, as well as when discussing the two ViDEs. While they often saw the 3D City as a kind of interactive map and valuable to tourists and people new to the city, they also noted the potential for long-time residents to better connect with their city and serendipitously discover places they might not be aware of. Further, the convenience of having a comprehensive overview of local events and services in a geographically accurate form was highly appreciated. This goes to show that mirror worlds, augmented with social networking services, have the potential to benefit residents and tourists alike. While it is too early to discuss potential 'killer' applications, the heterogeneous user base imagined by our study participants shows that mirror worlds augmented with social media services have the potential for broad-based adoption.

Challenges from the Changing Real World

The physical city is constantly in a state of flux: new businesses open, existing ones relocate or go out of business, new buildings are built and old ones torn down. All these events create pressure to keep the 3D City up-to-date both on a modelling level as well as on the level of social networking integration.

When first familiarizing themselves with the model, participants commented on the out-of-date details of the 3D City, and were quick to point out shops that did no longer exist, or buildings that had been erected in the physical world but were not yet modelled in the virtual one. They also commented on the absence of cars, pedestrians, and street furniture, noting that the 3D City felt empty, like a ghost town. In line with our initial argument, the participants noted

the benefits of social media integration: having up-to-date content in the 3D City would make it seem more alive, and more like a real place than an empty shell. Hence, it is important for operators of virtual cities to maintain an adequate update cycle. Our participants were realistic, however, stating that a one-month update period would be acceptable. This is something that developers and administrators of 3D Cities should take into consideration.

Another challenge that was not brought up in the workshops but we feel is important to discuss is the mapping of real-world phenomena to the mirror world [31]. For starters, the mapping could include daily and seasonal rhythms such as lighting and climate and real-world weather such as rain or snowfall. Such mappings are increasingly being incorporated in dynamic 3D city models, which make the virtual world feel more alive and more realistic than a static model with no changing seasons. Then, the mapping could be taken further to the level of individual actors and objects as envisioned for example by Lifton and Paradiso [32] and Ricci *et al.* [42].

Limitations

We acknowledge that our ViDEs did not have large conceptual differences as they were more focused on visual and interaction design variances between Concepts A and B. Further, as the design space is very new, we felt it prudent to present designs that were not too “out there” or “over the top”, as our participants were not experts and we wanted to provide them with palatable concepts that would not become confusing. The next logical step in this research is to exploring more ambitious concepts and functionalities.

CONCLUSION

We have presented a qualitative anticipated user experience study for understanding how social networking services and content can be integrated with virtual collaborative 3D city environments that are modelled after real, physical urban spaces. Through an analysis of participant commentary and conceptual designs, we have been able to begin unpacking this complex domain and identify issues and guidelines that designers of such systems should take into consideration. We have learned that integrating social networking services into 3D Cities is perceived to provide added value, as both residents and tourists can gain in-depth and up-to-date information about various events, businesses, and other topics through one highly visual service. The integration of social media is also seen to liven up an otherwise quite empty virtual city. However, our participants were divided in opinion when it comes to also integrating and visualizing personal social media accounts with the 3D City. It is crucial to provide users with enough control so that they can decide what they want to share, and also what they want to see in the environment.

As virtual worlds and virtual reality keep developing further and further, it becomes redundant to maintain existing social networking services as separate from these worlds. This paper has been a first step in understanding how this integration might happen. As a next step, we have begun

work implementing a functional prototype that incorporates findings from this study. This prototype will be evaluated in user trials, and eventually the integration will be made available in the 3D City.

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