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A system design to support outside activities of older adults using smart urban objects

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Abstract. During outside activities, elderly people encounter different challenges than young people. Those difficulties impede their motivation to pursue outside activities. To counter this problem from a human-computer interaction perspective, we propose a support system for seniors to improve their motivation and subjective safety while undertaking outside activities by coordinating smart urban objects. Drawing from an extensive empirical requirements analysis, we identify typical barriers experienced by seniors for which networked smart urban objects may provide assistance. We discuss a conceptual description of an activity support system: the system aggregates user profile data with information about the urban space to suggest possible activities, the elderly user chooses an activity and receives navigational assistance to increase their motivation and feeling of safety while undertaking the chosen activity. Finally, we discuss our approach regarding challenges such as user autonomy, privacy and real-world deployments, which need to be considered in future implementation and evaluation phases of the system.

1 Introduction

When pursuing activities outside their home, older adults have considerations and requirements towards the urban space that young, able-bodied people may not be aware of, such as shorter distances between seating opportunities or the inability to climb steps. When perceived as safety issues, these requirements may severely constrain seniors' outside activities, to the extent that some senior citizens stop leaving their home at all (Generali Deutschland AG, 2017). In the *UrbanLife+* project, we are currently exploring various approaches for encouraging and fostering self-directed activities outside the home in older adults. This entails overcoming many kinds of barriers, both objective and subjective.

To increase the safety of outside activities for seniors, we are developing an activity support system that provides navigational assistance as well as motivational support based on gamified interactions tailored towards the needs of seniors. This paper provides some context based on our requirements analysis, summarizes our system design, provides an example scenario to illustrate the vision behind the idea, and outlines several challenges that we are facing in ensuring that giving our users' needs the highest priority. Eventually, our goal is to extract the lessons learned from designing and deploying our systems into design recommendations for IT systems aimed at seniors that are deployed in the urban space.

2 Related work

A few research approaches have been made into supporting seniors in outside navigation. Teipel et al. (2016) give an overview with a focus on systems geared towards dementia patients. While the target user group's physical needs are closely related, our approach differs in that we focus on senior users who do not suffer from cognitive deficits, at least not to such an extent that it would impair their daily life.

Krieg-Brückner et al. (2015) provide a review of approaches for augmenting personal mobility devices, e.g. wheelchairs, using navigation assistance technology, partly addressing the same problems as the system detailed in this article. The biggest design difference is that *UrbanLife+* aims to install technological assistance into the public urban space itself, rather than focus on personal devices.

An example of a broadly related project that uses statically placed devices to assist seniors experiencing the space is presented by Kempter et al. (2014); however, this and similar systems are only concerned with indoor use.

Another interesting research area related to assistance of daily routines are workflow management systems, which have seen considerable research in the field of Computer Supported Cooperative Work (CSCW). These systems manage and coordinate tasks in business processes by enabling an automated flow of tasks between the participants and supporting the participants during the activity accomplishment (Galler, 1997). The task management and workflow coordination contain similarities to our required support for seniors as they support work activities by providing information to the employee for orientation, e.g. about the process status, task description or other involved employees. However, they focus on different kinds of activities: computer-based activities, indoor activities, business process related activities. In contrast, we are aiming to provide motivation and support during outdoor activities for elderly people, while the activities are not computer-based or business process related.

We believe the outdoor installation of innovative activity support technology for seniors to be a novel research approach.

An essential aspect of technology development is its high acceptance of the target group for which the technology is designed. As seniors are a special target group, there is some research in how to measure and estimate the acceptance by seniors by applying, for example, a *Senior Technology Acceptance & Adoption Model (STAM)* (Renaud and van Biljon, 2008) with the following aspects:

- User context: demographic variables (e.g. personal factors like age and functional ability, social influence)
- Perceived usefulness: "extent to which person believes that using the system will enhance his or her job performance" (Venkatesh et al., 2003)
- Intention of Use: influenced by user context and perceived usefulness
- Experimentation and Exploration: the first usage of the technology and first impressions of the ease of use
- Ease of learning & use: combination of perceived ease of use and final decision about ease of use
- Confirmed usefulness: usefulness of the technology for the user measured with the features the user can learn to use
- Actual use: predicted by the outcome of experimentations and leads to ease of learning & use

Renaud and van Biljon (2008) identify the components *ease of learning & use* and *perceived usefulness* as fundamental factors for the elderly's acceptance or rejection of new technology. As the paper focusses on mobile phone accceptance, it still needs to be verified whether or which of those aspects are relevant when it comes to smart cities and technology in the urban area. However, the STAM may be used for evaluation purposes of our activity support system with a detailed look at those two most relevant acceptance factors of technology for elderly.

As *UrbanLife+* is a multi-year project involving several institutions, a number of early and intermediate infrastructural elements are already available or within planning distance. Chiefly, the project is concerned with the development of smart urban objects (SUOs), devices that can be installed in public or semi-public urban spaces and that provide personalized functionality using networked digital technology (Kötteritzsch et al., 2016; Aleithe et al., 2017; Fietkau et al., 2016; Zimpel and Hubl, 2019). Utilizing stationary devices in the urban space as opposed to personal mobile devices means that interaction surfaces can be larger, the devices cannot be forgotten at home, and retaining battery charge is not an issue.[1]

Among the devices being developed, there are:

- Information radiators: a class of devices that broadcast ambient information visually, ranging from large touch screens to small LED information devices (Koch et al., 2017)
- Adaptive lights: public light installations that can adjust their color and brightness according to user preference or other pertinent criteria (Aleithe et al., 2018)
- Smart park benches: public benches for seating that are outfitted with sensors and actuators to facilitate e.g. advance reservation or subtle nudges to remind users to make room for approaching seniors (Hubl, 2019; Hubl et al., 2018)

Skowron et al. (2019) provide an overview and categorization method for the SUO design space.

The approach of using SUOs to increase seniors' safety was previously mentioned by Kötteritzsch et al. (2016), who describe interactive information radiators as one specific category of SUOs, discuss the topic of a *comfort zone* and how this zone can be extended. The information radiators are either large information displays or micro information radiators with LED lightning or sound signals. Every SUO has a different functionality, but all of them have the aim of increasing the safety of seniors by giving support and information, consequently seniors feel more comfortable in the urban area. For example, a macro information radiator is a large multi-touch-screen containing information about events and activities in the neighborhood or small information radiators can be positioned at, for instance, a traffic light where sound is played to attract the senior's attention and showing a signal with an arrow pointing towards the next barrier-free intersection (Kötteritzsch et al., 2016). The small information radiators are flexible in position and deployment scenarios, while large information screens enable an overview and easy touch interactions for the senior.

We have also published a proposal for how the SUO network could be harnessed to provide seniors with a gamified system to promote outside activities (Fietkau, 2019). We endeavour to keep the repetition of content from that article to a minimum, but will briefly explain our approach as applicable in sections 4 and 5.

These SUOs are connected to a number of backend services for various tasks: SUO enumeration and cataloguing, providing accessibility information about the urban space, storing user profile data etc. This paper proposes an additional *activity support service* to model outside activites undertaken by users and to coordinate pertinent data exchanges between SUOs and other services, whereby seniors can be

[1] These advantages come with the caveat that *UrbanLife+* implements user identification at the SUOs via Bluetooth, for which users (or their caretakers) are expected to install an app on their personal mobile device. Users do not need to actively use their device to interact with SUOs, but merely carry it in their pocket. This approach also allows them to easily switch off the tracking whenever desired.

supported during their whole activity accomplishment. Details on the design can be found in section 4.

3 Requirements

The *UrbanLife+* project has picked the german city of Mönchengladbach (population: about 260,000) as its location for analysis and evaluation. The city was chosen for test deployments within the project and an extensive survey among seniors was carried out in two specific districts (one within the city center – Hardterbroich – and one in a more remote and rural area – Rheindahlen). We defined our target user group as seniors aged 65 and up, who are physically and mentally capable of planning their own everyday activities in- and outside their home and then executing their plans. These criteria exclude some seniors, such as people who are entirely bedridden or who are suffering from advanced cognitive decline to an extent that they can no longer make their own decisions regarding their daily activities. The rationale behind these criteria is that systems to assist outside activities can only benefit users who are capable of deciding on and undertaking such activites.

Through a cooperation with the local governments, all residents aged 65 or older and living in those specific areas were contacted – 6,170 surveys were sent out in total. Of those, 1,302 were complete enough to be evaluated. Subtracting a small number of non-deliverable surveys and unusable return questionnaires, the return rate was 21.5%. The survey covered a number of areas including general demographic data, household and family constellations, health and lifestyle, general IT use, mobility and activites, mobility barriers and perceived obstacles. See Leukel et al. (2017) for a detailed description of the study, and the project website[2] for a summary of the overall results. General implications of the survey results are further discussed in other project publications (Schehl et al., 2019; Schehl, 2020; Schehl and Leukel, 2020). In this article, we will focus on the data items that are directly relevant for our design, which are the responses on mobility aids and perceived barriers for outside activity.

Mobility aids: The most common mobility aid used by the target user group is the walking cane, which is used at least somewhat often by 17% of respondents. Walking frames are almost as common at 13%. Other mobility aids such as wheelchairs are less common. While a very strong majority of respondents does not regularly make use of any mobility aids, the user groups that do use them are far from negligible, especially when viewed as a whole. This means that systems aiming to support seniors' outside activities must incorporate various kinds of mobility aids into their design and cannot assume that their users will be able-bodied, capable of climbing steps or steep inclines, and able to fit through narrow spaces.

[2] https://www.urbanlifeplus.de/2017/09/ergebnisse-der-buergerbefragung-jetzt-online/

Perceived barriers: The survey asked seniors how much several different possible barriers prevented them from going outside. When looking at the percentage of people responding "moderately" or higher, the most common responses in descending order are: 1. lack of public bathrooms (45%) 2. fear of assault/violence (44%) 3. dangerous footpaths (38%) 4. not enough lighting (34%) 5. too few opportunities to rest (32%) 6. distances too long (26%) and 7. too many traffic-related dangers (24%). While our system is unable to fix any of the root causes for these perceptions, they offer valuable guidance for what specific paths or roads need to offer in order to be perceived as safe. Assisting users in finding the benches and public toilets that do exist, and taking care to make use of well-lit public paths wherever possible, are design goals that may help seniors feel more confident about being active outside their home.

4 Activity support

Taking part in activities outside the home necessarily entails navigating to and from the location where the activity takes place. To provide pedestrian navigational assistance to seniors, to account for personal needs on the way (e.g. stops for rest or toilet use) and to foster motivation by as many available means as possible, we aim to utilize a wide variety of networked SUOs which are installed in the urban space, as detailed in section 2. Additionally, data needs to be aggregated from central sources such as the profile service, the SUO management service, and the routing service. As this is a centralized task, it makes sense to implement it as an additional central backend service.

We call this service the *activity support service*. It is connected to the other *UrbanLife+* backend services (for user profiles, SUO data, routing etc.) and it can interface with specific SUOs via the SUO management service. Those connections of the activity service and other components are displayed in the architecture diagram shown in figure 1, containing the *UrbanLife+* backend, SUOs and personal or connecting devices.

Users of the *UrbanLife+* system may view a variety of recommended activities at any large information radiator. As the SUOs can identify an approaching user (provided they have installed the project's mobile app and registered an account or they carry an iBeacon close to them), personalized recommendations can be provided from a pool of available activities in- and outside the neighborhood. To help foster motivation, we also aim to provide a variety of tasks and rewards which are modeled after the "quest" metaphor commonly found in role-playing video games, such that users would be enticed to attempt new activities and offers by small material rewards. See Fietkau (2019) for more details regarding this approach. For the purpose of this article, it is sufficient to know that the activity support system is intended as the central infrastructure to facilitate choosing outside activities, tracking individual progress and managing personal rewards.

When a user has decided to start an activity, the activity support service coordinates smart urban objects and data from other services to provide as much

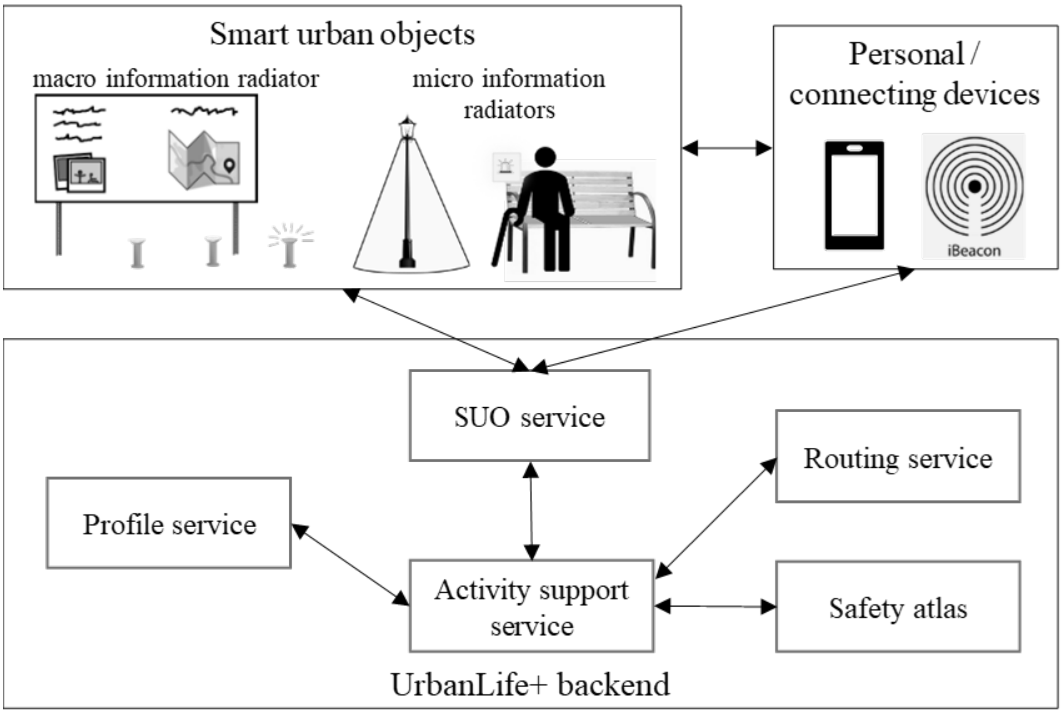

Figure 1. Activity support service architecture diagram with connected components..

support as possible to the user while they navigate to the activity through the urban space, partake in the activity, and then navigate to the next location or back home.

Any action taken by the service is based on a known or suspected *intent* of the user. In our model, "intent" is defined as follows:

- An intent is a mental plan held by a user for a future activity.
- Intents may range from very precise ("be at the dentist at 4:00pm this Thursday") to very loose ("spend some time in the sun this weekend").
- Intents can cover different timescales, e.g. "I want to go buy groceries right now" vs. "I want to check out the new restaurant some time this month".
- An intent may or may not be self-motivated. Some outside activities are entirely voluntary, such as taking a walk, others (e.g. medical appointments) can be externally imposed.
- One user may have several intents at the same time, each one having a different priority and urgency.

This intent model was developed iteratively based on internal correspondence with project members, including experts for elderly care. We started with a minimal model in which one user would have exactly one goal at any time, and then gradually expanded to accommodate ways in which we conjectured that real users would make plans for activities. The intent model has not been specifically validated and, if found lacking, is subject to change.

The activity support service attempts to determine and model user intents. Ideally, the user signals their intent to the *UrbanLife+* system directly, for example by tapping “I want to visit the restaurant right now” at the large information radiator or by sharing their appointments with the *UrbanLife+* system via an as-yet undetermined process. Avenues to infer user intents indirectly may also be explored, although this will be much more difficult to do reliably and in a way that does not confuse or patronize the user.

4.1 Example scenario

Margot Nowak[3] wants to leisurely spend a few hours before dinner. She looks at the large information radiator at the Hardterbroich seniors home for some ideas for what to do. She sees that the Textiltechnikum (a local museum) is currently open and touch-drags the offer into her personal area for immediate use.

The information radiator notifies the activity support service that Margot intends to visit the Textiltechnikum right now. The service queries the routing service to determine the path that Margot is likely to take, and then requests a filtered list of smart urban objects located on or near this path from the central SUO management service. It calculates her expected arrival time based on her expected walking speed (determined heuristically or from previous tracking data, stored by the profile service) and sends an event to all affected SUOs reading something like “Margot Nowak is on her way to the Textiltechnikum and will likely pass by on foot in x minutes”. It may also send an email to Textiltechnikum staff letting them know that a person requiring mobility assistance is on the way.

The SUOs along the way can react to this new event in whichever way they deem appropriate: smart park benches may start a timely seating reservation process, lights may adjust themselves to Margot’s needs and preferences, small information radiators may prepare to show symbols for navigation assistance, etc. Whenever new information about Margot’s location becomes available, updated events may be sent – especially if Margot changes her mind about the activity and turns around to go back home.

Independent of user intents, SUOs may continue to offer their general functionality, such as small information radiators displaying dynamic warnings for hazardous areas like steps that get slippery after it has rained.

5 Discussion

Setting aside the technical and organizational challenges in getting the *UrbanLife+* platform to a functional stage, we view the evaluation from an HCI perspective as the most significant challenge. The goal is to strengthen seniors’ participation in

[3] Margot Nowak is the name of a fictional persona – one of several – which *UrbanLife+* uses for scenarios and usage models. Her demographic data and assistance requirements are an example for a person living in the senior housing residents in the city where the project is being conducted.

the urban space and to make it easier and safer for them to take part in activities outside their home. Possible measures for success could be an increase of such activities, but it would be unrealistic for the scope of *UrbanLife+* to perform a wide-area deployment to allow organic, unsupervised use of the platform. To evaluate our approach, we instead run long-term deployments of individual SUOs in semi-public areas in combination with time-limited, closely supervised installations in public spaces – say, deploying a number of small information radiators along the street during daylight hours for a few days to perform usability tests. Our specific constellation of circumstances prompts us to engage with a number of different challenges.

Firstly, we need to take care to design for user autonomy and self-determination. The activity support system aims to assist users and to open up new possibilites – our intent is to leave all decision making competence in the users' hands. Designing all user interactions to respect this principle will be challenging. For example, users might perceive an arrow that signals them where to go next as a restriction as opposed to an assistance. Our interactions will need to be designed and evaluated to ensure that users are always aware that they are free to change their mind without penalty and to diverge from the provided recommendations whenever they want.

Within our constraints, we can definitely test the usability and user experience of the direct user interactions with the technology. However, determining whether it can have a positive long-term effect is much more difficult. To gauge whether our platform could actually help seniors be more active outside their home, we intend to rely mostly on self-reported results from interviews and questionnaires (e.g. "On a scale from 1 to 10, with 10 meaning "absolutely confident", how confident do you feel about outside activities when using this system?", "On a scale from 1 to 10, with 10 meaning "absolutely confident", how confident do you feel about outside activities when going on your own without technology?"). The reliability of self-reported data in terms of predicting future behavior is limited. We attempt to bridge this gap by evaluating users' observed behavior when interacting with our system – such as their level of engagement and their willingness to continue using it – and drawing an inference from *increased motivation for repeated use of networked SUOs for outside activity support* to *increased motivation for outside activities*.

Furthermore, although more of an engineering than a user research problem, we are faced with the challenge of respecting and protecting our users' personal data. The data that users are asked to provide includes not only personal data commonly considered non-confidential, such as name and age, but also data about users' specific physical abilities and needs for assistance. Even though we are not interested in actual medical data, many users may consider information about their eyesight or walking abilities (it could be considered "health-adjacent data") particularly private. It goes without saying that we follow best practices about minimizing data collection and that all personal data is deleted as soon as it is no longer needed or the study has concluded. But beyond that, we also need to design our systems to minimize the potential for privacy violations. In practical terms, an important design guideline for *UrbanLife+* is that each distributed component of our system only has access to the minimum required personal information about each user, as opposed to a naive “every component can access any data” approach.

At the time of writing, implementation work on our system is ongoing and empirical evaluations are being planned. At the beginning of 2020, we were planning to perform several short-term deployments of SUO networks in the spring and summer, which would be combined with long-term SUO installations that are already in progress. This would give us the opportunity to verify whether the activity support system can help seniors discover and take part in new outside activities. Several of our planned experiments would center around the gamified motivational support described in Fietkau (2019) and will verify the effectiveness of the activity support system as a matter of course, although we expected to gather feedback from other evaluations of networked SUOs conducted in the scope of *UrbanLife+* as well.

Regrettably, as of the writing of this article’s final version, the COVID-19 pandemic has rendered most of our plans infeasible. We are currently unable to ascertain when and how evaluations and observations of our deployments with senior users in public will be able to be conducted safely. We are exploring new avenues for validation studies, but it seems certain that evaluations in the final year of *UrbanLife+* will look entirely different than anticipated.

6 Conclusion

In this paper we have given an overview over the *UrbanLife+* activity support system and described some of the research and design challenges we face. The concept of the presented activity support in this paper contains a central service to determine and model intents of seniors (a mental plan for a future activity) and supports the accomplishment of activities by providing information and guidance through distributed and connected SUOs in the urban area. In our implementation we respond to the identified challenges by ensuring trust in our service in respect to personal data handling and by considering an interface, that signals user autonomy and self-determination to the senior as we do not want our supported guidance to feel like an obligatory rule. In our evaluations so far, the need and interest for higher safety of elderly people was consistently confirmed. Whether our activity support service helps increasing safety feelings of seniors will be evaluated in upcoming and ongoing deployments, to whatever extent circumstances permit.

As the field of HCI involving seniors grows, we are hopeful for continued community discourse around the questions discussed herein. We aim to incorporate current and future best practices into our research.

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