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Lighthouse

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Beacons – indoor navigation and mobile interactions

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1 Introduction

This paper is a report of an exploratory research project conducted during the course "INF5261 - Development of mobile information systems and services" at the University of Oslo (UiO) in autumn 2015. The project, named "Lighthouse", explores the use of Beacons in location aware applications by first examining theoretical questions as well as technical issues and later during a practical design process of a daily planner app for students.

Beacons are a relatively new addition to the world of "internet of things". This technology was first introduced commercially under the name iBeacon by Apple in 2013, and has later been made available to other mobile platforms as well (Pocket-lint.com, 2013). Beacons are small, battery-powered devices that continuously send out a data packet with a unique message via the Bluetooth LE protocol. This signal is available for mobile phones to read and applications can act according to the data received from a particular Beacon, enabling for example tailored messages to be sent to a phone when a user approaches a Beacon.

Being a relatively new technology, the Beacon stack holds an exciting opportunity to explore new ways of interaction with the mobile phone. At the same time there exists research in related areas such as context-aware computing, social navigation or ubiquitous computing. This led us to believe that this new technology has a potential to touch several important subjects in research of mobile systems and strengthened our feeling that we had chosen an interesting and important research field.

1.1 Research questions

Initially, this is a very large research area and thus our research questions were rather broad and vague. We started out by discussing what possibilities for interaction exists between the user of a mobile phone and a public building they find themself in, using a new technology - that is Bluetooth Beacons. In what use contexts could we apply this technology, solving specific user problems? This also implies some ethical challenges, for instance when monitoring and recording the user's location, and questions arose on how to solve these issues.

We needed to narrow down our research focus and we decided to investigate usage of Beacons in light of the concept of autonomous decision making of applications. To test our theoretical concepts we decided to apply them to a real-world scenario - a daily planner app for students at the Department of Informatics (IFI) at UiO to help the students navigate and plan their daily activities. Our research questions are therefore as follows:

1. What are students needs when navigating the university and perform their daily routines? Can we use Beacons to help them accomplish their tasks?
2. Can Beacons be of use in achieving the right degree of manual vs. autonomous context acquisition and communication when performing such tasks?
3. What ethical issues arise when monitoring and recording a user's location and how can we solve such issues?

2 Theory/ Literature Review

In this chapter we shall discuss relevant research on the topic of context aware communication to give us a better basis for developing our mobile application.

2.1 Defining context

When we are developing context aware applications, it is important to define and analyze the components of context. If we analyze the relationship of these components Agre (2001) argues, we can understand what it means for a device to be aware of its context. To him, context is built up of architecture, institutions and practices.

2.1.1 "Space" and "Place"

Architecture is defined as any built environment, and includes relevant objects within it. Almost any architecture is built with one or several purposes, structuring and supporting different social roles and rules governed by human institutions. Institutions therefore create the framework for practices. "Practices" consists of "the ensemble of embodied routines that a community has evolved for doing particular things in a particular place" (Agre, 2001, p. 5). This way of defragmenting human life can also be seen in the light of Harrison and Dourish (1996) discussion about space versus place. They argue that architecture is just a space of potential, but that potential is being fulfilled as we embody it with our practice. It becomes a place as we fill it with meaning and events. They have a good example of this: “A house might keep out the wind, but a home is where we live” (Harrison & Dourish, 1996, p. 69). We might say then, that the Ole Johan Dahls Hus is where we students are enrolled, but the Institute of Informatics is where we learn. The rooms in OJH are just potential *space*, waiting to become a *place* for knowledge acquisition and social bonding. As such, each classroom, group room, the library, and so forth, is a place mapped with its own activities and customs. But the emergence of ubiquitous devices loosens the bond between place and practice, because of the users taking part in multiple contexts. Context is therefore both physical and mental.

2.1.2 The mind-body divide

To understand context of an application is therefore also to understand its users; where they are and what they are doing. Traditionally, computing has meant being physically stationary, either following local practices, or entering a digital world with its own set of practices, like the classical “forums” or massive multiplayer online games (Harrison & Dourish, 1996). But they have always been acted upon more or less separately. The mobile and other ubiquitous devices bring about the “mind-body divide” (Agre, 2001, p. 2); the body can be in one place, but the attentive mind can take place in both exogenous and endogenous practices, thus transcending the constraints of architecture and institutions. As such, participants are no longer even bound to be physically present to constitute an institutional role. They can hold multiple roles, due to the “always on” (Fleurent, 2013) setting of modern technology and applications (and in a wider sense, our modern minds). This can disrupt and change the local negotiation of practices formed by architecture and institution.

2.1.3 Flexible context

There is also a flexible balance between the relationship of architecture and institution. Some applications follow the tight coupling on both of them, and on the other end of the scale there are applications that leans heavily on just one of them. An example of this is medical devices that monitor institutional aspects of context, like a heart rate monitor. Between there is “a barely unmapped space of possible institutionally organized activities that are loosely couples to places” (Agre, 2001, p. 9). Beacon requires physical presence in one context. But when the system is connected to a whole network of Beacons, this can pose a challenge when defining context, since the local context can expand accordingly to the connectivity to other contexts. But, as Ager states further, "most aspects of context, however, are defined to some extent by the institutions that structure both the ongoing activity and the social relations within which the activity is embedded" (Agre, 2001, p. 10). It is therefore paramount to look at the current practices, as well as the changes, and accommodate these when developing a context aware system.

2.1.4 Mobile context

Tamminen, Oulasvirta, Toiskallio, and Kankainen (2004) identifies some characteristics of mobile contexts (here we only mention the ones being most relevant to our project), the first being "Situational acts within planned ones"– meaning that when navigating in urban environments you might run into someone you know, or you might make a short de-tour when you see an interesting store you would like to walk in to. These short de-tours do not however, according to Tamminen et al., make you forget where you are going. To link this to our project – our application should not be affected by minor de-tours. We do not wish to make an application that hinders social interactions you might run into on the way to your destination. We should, however, investigate how we can separate these de-tours from actual change of plans. This results in us having to *monitor and adapt to sidestepping*, which are two of the design implications introduced by Tamminen et al. (2004).

Another characteristic is the "Social solutions to problems in navigation" – having problems navigating, according to Tamminen et al's (2004) data, often resulted in the person navigating using his or her mobile phone to help navigate or to inform people that the schedule had changed. This characteristic might lead us to add a social feature to the navigation – to let people know you are late so they can adjust accordingly, or simply to get help to get past an obstacle not expected neither by the application or the person navigating.

2.2 Context-awareness and communication

In our project we are constantly on the verge of important design decisions regarding how to use the information about a user's location. Depending on the environment, schedule, situation, position, preferences and goals, we want to give the user context-sensible information to aid them where they are. With the emphasis on context, we are faced with a lot of dilemmas on how to use the context the best possible, autonomous way.

Schilit, Hilbert and Trevor´s article titled "Context-Aware Communication" (2002) presents five application categories for a number of context-aware communication applications, and even though the technology the applications are based on may be outdated compared to the wireless technology we have available today, we are solely interested in the concepts of these. The authors present a broad definition of communication, and define context-aware communication as "the class of applications that apply knowledge of people's context to reduce communication barriers" (Schilit et al., 2002, p. 2). Further, they describe two dimensions to distinct an application´s autonomy between "context acquisition" and "communication action". This is to organize the applications functionally, conceptually as well at the degree of autonomy, ranging from manual interaction depending on humans doing the work of communicating and understanding context, to a completely autonomous system that does not require, or requires minimal human interaction.

The five types of applications presented in the article are routing, addressing, messaging, providing caller awareness and screening. All five are conceptually important, but not equally important for our research question. As our focus is more on context acquisition than communication we relate more to the types of applications under routing, providing awareness and screening, but not excluding addressing and messaging.

The article concludes by giving design objectives for designers of context-aware systems facing the dilemmas of manual versus autonomous systems. The authors urge us to improve relevance, minimize disruptions, improving awareness, reducing overload and selecting channels (Schilit et al., 2002). They also address the user's sense of privacy when using a context-aware service, which we will discuss later in our project.

2.3 Ethical issues

Rhodes, Minar, and Weaver (1999) helps raise awareness towards where the user profile / user data is actually stored / computed. The authors claim that wearables offer more privacy than ubiquitous computing because the users themselves can keep the data on them wherever they choose to go. This is something we should take into consideration when designing our service - could we do all processing of user information on their mobile phone? This would give some constraints to the features one way or another - for example if we want to add functionality where you see your friends on a map of the building to find out where they are. As Rhodes et al. Mentions - we can't blame the system for giving out information about the users, it is what the system are meant to do – but if we choose to design an application that requires information from the user to be processed externally, or to be sent to others, we should "design a system whereby personal data is distributed on a need-to-know basis" (Rhodes et al., 1999).

Palen and Dourish (2003) discusses, based on Altman, the boundaries that are central to the characterization of privacy management. Starting with the *disclosure boundary*. "At this boundary, determinations are made about what information might be disclosed under what circumstances" (Palen & Dourish, 2003, p. 3) - in other words, what do we choose to share and what do we keep to ourselves?

The next boundary is the *identity boundary* which "is defined by the role taken on by the user" (Holone, Herstad, & Ed, 2010, p. 218). To expand on this and link it to our project – is the role taken by the user to be “just another IFI-student”, or is the role the student as an individual? Perhaps we could give the option to choose different roles visible to different people by adding to a friend-list?

The third and last boundary is the temporality boundary, and it describes "the boundaries associated with time, where past, present and future interpretations of and actions upon disclosed information are in tension" (Palen & Dourish, 2003, p. 3). This means we have to be careful in regard to what data is stored and who has access to it.

3 Reasoning by proximity - a Beacon overview

This chapter will shortly introduce the technology behind Beacons and discuss several constraints that this technology imposes on the user/ developer. This paper is not a study of technical aspects of Beacons but rather of possible interaction scenarios with these devices. Nevertheless it is important to be aware of specific possibilities and constraints when studying it`s possible use cases.

As mentioned introductory, Beacons are small, battery-powered devices that continuously send out a data packet with a unique message according to the Bluetooth LE protocol. This signal is radiated in all directions and available for any device that can “see” it - like a lighthouse that guides ships - hence the name “Beacons”. The signal can for example be received by mobile phones and applications can act according to the data received from a particular Beacon, enabling for example tailored messages to be sent to a phone when a user approaches a beacon.

3.1 Constraints

Beacons are relatively cheap devices - approximately 10-30 USD per piece for small quantities (Estimote, 2015). The low price is partly due to several technical characteristics: A simpler, lower bandwidth message protocol and low power broadcasting make for simple and cheap devices. On the other hand this imposes several constraints on possible use cases.

3.1.1 Signal bandwidth

For the first, one can only send very short messages from a Beacon device. A Beacon broadcast according to Apples iBeacon standard consist of a unique ID for the owner/manufacturer (UUID) that together with a major and minor number form a unique identifier for each iBeacon. In addition to this an iBeacon also sends it`s TX power, a reference number to calculate distance. This means, that in order to make something useful out of this information an app has to do a lookup in a database to know what function to execute and what to present to the user for each individual Beacon.

3.1.2 Accuracy

Further, there are limits to how accurate phones or other mobile devices can measure distance to a Beacon. Basic measurement is done by comparing the strength of the received signal to the TX power number sent by the Beacon which is a reference number representing measured signal strength on an iPhone at a distance of 1 meter. The problem in practical applications is that different phone brands may have placed the Bluetooth antennas at different places, and physical obstacles like buildings and the human body alter the received signal strength of the Beacon. There is research being done trying to work around these problems (Cho, Ji, Chen, Park, & Lee, 2015) but for our case we will follow Apple's (2014) guidelines and divide distance measurements in three zones - immediate, near and far, rather than accurate distance in meters.

3.1.4 Responsiveness

A third constraint is the fact that both Beacon and mobile device have certain intervals for sending messages and scanning. One could increase the these intervals as needed but that would eventually cause the devices batteries to drain quicker. A compromise between battery life and app responsiveness must be found, but there is a chance that a person moves too fast past a Beacon such that the phone never registers the message. This is especially a concern when monitoring Beacons in the background in order to preserve battery life (Young, 2013).

3.2 Similar technologies

There exist several other technologies that support location aware services for mobile devices. We shall give a short overview of these technologies (concentrating on radio based devices, in order to keep this part reasonably short) and compare them with Beacons, thus identifying advantages and disadvantages of the different technologies. Perhaps the most well known and used technology is the Global Positioning System (GPS), a satellite based positioning technology that uses satellite signal triangulation to pinpoint a device location with an accuracy of a few meters. The main disadvantage of GPS is that it does not function well indoors, due to building materials that shield for the signal. Wi-Fi is another technology that might be used retrieve location information in a similar fashion to GPS but works indoor as well. A disadvantage with Wi-Fi is a comparatively high cost of system installation and maintenance.

Other location aware technologies include NFC or RFID. These work only in close proximity between mobile device and tag/ radio transmitter. Somewhere in between Wi-Fi/ GPS based services and close proximity sensors like RFID we might place Bluetooth Beacons.

They have lower range compared with GPS and Wi-Fi and to use them for indoor positioning on a larger scale would require a huge amount of Beacons. On the other hand they allow proximity based interactions similar to NFC/ RFID but with a larger range of up to several meters. One researcher therefore proposes to think in terms of "here I am" rather than "where I am" when designing services with Beacon devices (Ng, 2015). Contemplating on different degrees of autonomous context acquisition according to Schilit et al. (2002) we might argue that Beacons can be placed somewhere in between fully autonomous systems like GPS that track a users position continuously and fully manual systems like NFC where the user has to actively choose to interact with the device.

4 Case and Methods

This chapter gives an overview of how we acquired our empirical data for our research and why we chose to use these methods to address our research question. We will describe the design process and methods used from the start and how they developed over the time of our project.

4.1 Getting started

Initially, we did not have a clear problem for our research, i.e. what kind of task our ideas could solve for potential users. So to get started we did an exploratory research by doing literary reviews and examining the technical possibilities of Beacons, as presented in chapter 2 and 3, to narrow down the research area. This led us to the problem of autonomous versus manual interaction, and when we wanted to apply this to a real world problem.

4.2 Concept and first prototype

In order to investigate interaction with Beacons in a public building we decided to develop a prototype of a Daily Planner app for students at UiO/ IFI. Since our main interest was context awareness and interaction with Beacons and not the app itself we decided to develop a few vertical prototypes, representing interesting scenarios that show examples of interaction with Beacons and different levels of autonomous actions.

The scenarios are based on the basic idea that is a planner/ collaboration app that meshes existing planning services at the UiO website (“Mine studier”) with other calendar tools (Google Calendar, iCal), communication and collaboration tools and adds context awareness to the lot. The app should enable students to manage their daily tasks, both University controlled tasks such as lectures and seminars as well as student driven activities like project group work. Students at UiO are our main target users, but of course there are other potential stakeholders, like professors or university administration.

4.3 Opportunistic evaluation: Live testing and survey

To put our initial assumptions and research questions to the test, we conducted an opportunistic evaluation (Rogers, Sharp, & Preece, 2011) through a simple test of the prototype, followed by a survey. The participants, students and teachers during our midterm presentation of the project, were in the right target group. During the test we also discussed challenges and questions with the participants to get a deeper feedback. The prototype illustrated an automatic interaction with a Beacon, and the students gave feedback through our survey, which is presented in the next chapter. Our survey was made up of closed questions, asking about type of communication applications, automatic functionality, difficulties concerning in-house navigation at IFI, and privacy thoughts regarding location disclosure.

4.4 Expert usability test and prototype #2

A second prototype was then developed and we conducted a cognitive walkthrough as a part of an expert usability test as described by (Lazar, Feng, & Hochheiser, 2010, p. 256). When doing this, we took the feedback and data from the survey into consideration and focused on how the “real world” users would interact with our application, and what specific problems we wanted to solve.

5 Findings

The following chapter will present the findings from our research based on scenarios, feedback, testing and evaluation. The findings are presented chronologically as we iterate through the design process.

5.1 Scenarios and prototypes

In the context of our app we developed two central scenarios that we found interesting in regard to our research questions and that we wanted to build our prototypes around:

- A student is late for a lecture and is uncertain about the location of the classroom. The Planner app gives navigational aid in form of a map. Upon entering the classroom a Beacon detects the students phone and automatically “checks in” for class, thus enabling him to access special content for the lecture. The app might also change certain settings of the phone, adapting to the new context, for example muting sound.

- A student project group needs to meet in order to discuss a project report. One group member suggests a date/time in the planner app. As everybody confirms the date some vacant locations (group rooms) are proposed by the app. As one student “checks in” to a vacant room by approaching a Beacon the other group members are notified about the location.

5.2 First prototype

The first scenario was quite simple to simulate in a high-fidelity prototype and it gives the potential user a good idea about the essence of our concept. The prototype was implemented with the help of the software Beacondo (see http://www.beacondo.com for more information), a simple content management system for Beacon aware apps. It was tested with other students and teachers during a project presentation as described in chapter 4.3. The prototype implemented the basic flow of the aforementioned scenario. A typical calendar view shows today’s tasks and the upcoming lecture (Appendix 1a). Clicking on the lecture button opens a map view, showing the user’s location and the target classroom (Appendix 1b). The prototype does not show the real user location but rather simulates it. Achieving real time tracking in a real app would pose both technical and ethical challenges. It could be realistic though to achieve some coarse user tracking via triangulation of Wifi access points and Beacons. Upon entering the classroom a new screen was triggered by a Beacon placed close to the door, showing the user having “checked in” to class (Appendix 1c). Here we invited the students to take a survey to evaluate the concept and prototype they had been shown. Going back to the calendar view the lecture button now has changed to a “checked” state (Appendix 1d).

5.3 Findings from the early evaluation

Both friends and group members	53 %
Friends or group members	33 %
None	13 %

Table 1.
Positive attitude towards sharing location to specific groups of people

In general, the participants exhibited a positive attitude towards the concept and location sharing. Everyone had either trouble finding a vacant group room or locate a lecture or seminar room, verifying our initial assumptions of this as a common problem at IFI.
In terms of disclosing location as a means of communication, we categorized the answers into three groups. The results displayed in table 1 tell us that there is a positive tendency towards identifiable location sharing, but the app needs have a privacy setting that lets the user control this. On the question about automatic disclosure, the majority wants the opportunity to override it manually at selectable times and context, as it is not always desirable to share location. In addition, one person from each of the three groups does not want automatic location disclosure. We also found that one person from each of the three groups mentioned above does not want automatic location disclosure at all.

Mute sound	87 %
Automessage	53 %
Block incomming call	33 %
Block Apps	20 %
Block Internet	13 %
None	7 %

Table 2.
Percentage who want specific location based functionality limitations.

When it comes to mobile functionality restrictions, 86% of the responded positive to context dependent sound muting. This was by far the most popular restrictions, as can be seen in table 2. Only one of the 15 respondents was not interested in sharing location or block functionality at all.

The usability test also showed some of the technical challenges described earlier. Different phones had inconsistent accuracy in regards of the distance to the Beacon. This might be explained in the simplicity of our prototype and the software used to build it.

5.4 Second prototype

A second prototype was then developed, enacting the second scenario, collaborative scheduling and finding meeting points.

The scenario starts with a fellow group member proposing a group meeting at a certain time. The meeting is displayed as an unconfirmed event in the user's task list (Appendix 2a). Clicking on the event button opens an accordion menu showing the status of all group members regarding the proposed event. The current user can accept or deny the proposal (Appendix 2a1). When all group members have accepted the event changes state to confirmed (Appendix 2b). Clicking on the event button now brings up a map view (Appendix 2c), showing different proposals for possible meeting locations as well as location of other group members if available. The first group member to find a vacant room can "check in" with the help of a Beacon, thus notifying the other members. On the app the event changes to a "location confirmed" state (Appendix 2d). Clicking on the event button now opens a map view helping the user to navigate to the meeting room (Appendix 2e).

5.5 Usability inspection

Given the more complex nature of this scenario, involving several users and technical challenges encountered during testing with the first prototype we had to work with a simpler prototype and evaluation techniques. We built the prototype with wireframes, design mockups and conducted a cognitive walkthrough (Rogers et al., 2011, p. 514) of the tasks with experts (i.e. other interaction design students), playing through different variations of autonomous vs manual decision-making.

Besides pointing out some general usability issues the inspection of the prototype developed into a discussion on the pros and cons of autonomous decision making by the app. First discussed was the possibility for the app to automatically decline proposed meetings when they would collide with other tasks. It was agreed that such a degree of autonomy was not a good idea. It might be the interest of the user to skip an existing task for an new one. It was further mentioned that a possible alternative could be to notify other group members about colliding events, leaving it to the users to make an informed decision whether to change the schedule. Deciding on a location for a confirmed meeting is another detail where the app could show a degree of autonomous decision-making. The app could suggest possible meeting rooms, notify group members when a user finds an appropriate room or even automatically book a proper location. The latter would not fit the practice at

UiO right now where the rule is first come first served. It was therefore agreed that the best possible solution would be for a user to “check in” to a vacant room with the help of a Beacon and let the app automatically notify the other group members that a location was found.

In both scenarios the use of Beacons is essential in allowing a degree of manual control of context acquisition and communication. By using a close range of a few centimeters when “checking in” to a location a lot of possible errors can be avoided. An alternative would be a larger scanning range, registering the whole room or even usage of aforementioned triangulation technique with Beacons and/ or Wifi. Several possible errors were pointed out: The system, if not accurate to the centimeter could register a person inside a room, even if he stands right outside. A person could enter a room as a detour, saying hello to some friends, yet the system would register a “check in”, similar to the case of the stalking PARK Ether phone call described by Schilit (2002). It is therefore essential to let the user have some manual control for “check in”, for example by using Beacons as tags that have to be approached closely. On the other hand there is the function of “checking out” of a room. We can assume that users would be forgetting to do such a task manually, not having any obvious benefits in doing so. On the other hand it is important for the system to know where there are people to be able to give suggestions for available rooms. Here we could let the Beacons automatically register proximity of users at room level and mark the room as vacant when users have been absent for some time.

6 Discussion

In this chapter we will discuss our research questions on the background of the theory reviewed and findings during the design process of our prototype.

6.1 Exploring students needs for daily task planning

Our first, basic question was: What are students needs when navigating the university and perform their daily routines? Can we use Beacons to help them accomplish their tasks?
We initially identified user needs during an internal workshop, since we are members of the target group as well. The survey that was conducted later shows that other users agree with the needs identified. The scenarios that were developed out of these needs are closely

related to the concept of space vs. place (Harrison and Dourish, 1996). In our project the Beacons and the app act as devices that help us define places according to our context. We have also tried to be careful to let our app, assisted with Beacons, take advantage of the established practices (Agre, 2001) of the university, like lectures and group work, and try to assist students to support these practices – making it easier to organize and get to lectures on time. General feedback of the users during evaluation shows that we seem to have identified proper needs and have found a way to address these needs with our app and Beacons in a way that satisfies our users.

6.2 Exploring the concepts of autonomous versus manual actions

The second, central research question of our project was as follows: Can Beacons be of use in achieving the right degree of manual vs. autonomous context acquisition and communication when performing such tasks?

Two basic issues arise when designing an autonomous system according to Schilit et al. (2002). First of all, autonomous context acquisition may erode the user's sense of privacy. The different scenarios in our prototypes show that beacons can be used to give the user some manual control on context acquisition by actively having to approach the device and scan it, rather than being tracked by a ubiquitous navigation system. This ethical issue shall be discussed further later in this chapter. The process of autonomous context acquisition can also be related to the concept of sidestepping as discussed by Tamminen (2004). The need to be able to adapt to detours and unexpected social interaction precludes a high degree of autonomous context acquisition. We mentioned an example earlier when an autonomously acting system falsely could check in a user into a room when he just wanted to say hi to some friends.

Secondly, removing humans from communication might remove "common sense" from the functionality of the software (Schilit et al. 2002). This has been shown in the evaluation of our prototype where we pointed out how autonomous communication by the app, like declining meeting proposals based on existing tasks could lead to decisions that do not reflect the wishes of the user.

Schilit et al. (2002) mention several principles when designing context aware systems, namely improve relevance, minimize disruptions, improving awareness, reducing overload and selecting channels. In some contexts, it is easy to abide to these principles. For example it is obvious that our app could minimize disruptions when a user is in the context of a lecture by muting the sound of the phone. But what about blocking other forms of communication or automatically sending messages on the user's behalf ("..at a lecture - call you later..")? Although functions like these could further minimize disruptions and at the same time improve awareness and reduce overload the respondents of our survey do not agree. Only a few respondents would allow blocking other communication channels and only half would allow an app to send messages on their behalf. Maybe our users would have been more positive if our app would "refuse to ring your phone at the opera unless it's the babysitter calling to say your kids just set the house on fire" as Schilit et al. (2002) put it. But that would require more complicated techniques like machine learning, classifying tasks by importance based on different criteria and experience/ learning - topics that are out of scope for our research.

Our prototype and research around it clearly shows some of the issues of autonomous actions and communication. Initially we had an idea of using Beacons intensively for autonomous functions by sensing location automatically. In the end we found use for such automatic context acquisition merely for general GPS-like navigational tasks and sensing absence of users. Our research shows instead how the benefits of Beacons might rather be the possibility to enhance manual control of context acquisition for users in context aware systems.

6.3 Ethical issues

Lastly our target was to investigate ethical issues that can arise when monitoring and recording a user's location and how we could solve such issues?

We have mentioned the general sense of lack of privacy in context aware applications. In our app we ask the users to potentially cross all the different privacy boundaries, mentioned earlier as defined by Palen & Dourish (2003), the disclosure boundary, by issuing their whereabouts to other users, the identity boundary by telling the system who they are and also the temporal boundary by saving information of past and upcoming tasks (as it is common in calendar applications). We should be very carefully when deciding how to process and share this information, using the principle of "need-to-know" according to Rhodes et al. (1999). The importance of these theoretical concepts are shown in our users responses in the survey: They are extremely cautious to whom they would disclose information on their location and they ask for a high degree of control over sharing this information. Our app should therefore have a user-friendly "privacy settings" page that allows for a clear setting of aforementioned boundaries.

The use of Beacons and focus on manual context acquisition could give the users some sense of control over privacy - enabling them to skip the "check in" functions, thus remaining anonymous. Yet, this poses a dilemma: By letting users skip registration in the app a lot of potentially interesting functionality would not work: Using the app as an interactive device during a lecture (for example running quizzes and votes) would be less interesting with only a few participants. Also the function that suggests possible vacant rooms would not work very well if only a few students would allow the app to register their location in group rooms, resulting in erroneous result - showing rooms as vacant while they are not. Nevertheless, there is another opportunity to use Beacons in a smart way, giving the users a more fine-grained control of their privacy: They could choose not to check in to the room, thus not sharing their location to anyone, yet the Beacon could scan the room on a larger distance and register the proximity of "some anonymous user", marking the room as occupied.

6.4 Universal design

Our main focus has not been directed towards universal design when working on this project. We have, however, identified some steps to take towards making our app accessible for everyone. Please note that this is not intended as a complete recipe for universal design, it is just a few things we have reflected upon.

If we look at the web content accessibility guidelines (WCAG) we can see that we need to take the screen size into consideration (W3C, 2015). This means that even though the resolution on modern mobile phones allow for a lot of content we should keep it simple so we don't clutter the screen making elements small and hard to see. We have tried to keep things simple in our prototype, and not showing more than we have to. Unfortunately, we have not been able to test this, as we did not have time to get in touch with the right users for this project. Another point to make in regards to "screen cluttering" is that the touch elements should have sufficient spacing between them (W3C, 2015). If we have them too close, users with operating problems could have trouble clicking the right button or link in the application. It is also important that we allow for magnification – up to 200% (W3C, 2015) and ensure that the view does not get "messed up" when zooming in.

When it comes to contrast the WCAG 2.0 requires at least 4.5:1 – this can easily be tested using a tool like WebAIM´s color contrast checker, but since our prototype is low-fidelity we have chosen not to experiment with colors and contrasts – the aim has been to explore the concept.

Further, we must ensure that navigating in the app and the grouping of items must be consistent (W3C, 2015). One of the biggest challenges we have identified is to make the map and navigation functionality suitable for blind users. This would require a lot more than explore how we could solve this issue – but we have thought about making an alternative text- or speech-based navigation to work better with screen readers. If we were to take this concept further into development this would be one of the top priorities to explore – hopefully with the assistance of an expert user in this domain. Another challenge regarding the map would of course be the accessibility of the routes proposed with users with mobility issues in mind, as we cannot assume that the fastest route also is accessible by a wheelchair. This would require collaboration with external stakeholders.

As for the technical part – the code – it is important to be consistent and label buttons so screen readers are able to tell the user what a button actually does, and also make everything reachable by a keyboard by avoiding keyboard traps (W3C, 2008) as some users might use assistive technology simulating or actually being a keyboard.

We do believe that this way of navigation has potential to be a good way for blind people to move around offices and large buildings.

Further work regarding universal design would be to explore and try to fix the challenges introduced in this section, and of course spending more time doing research on universal design to identify more issues. We also think it would be both necessary and helpful to get the app tested by users with various needs – for example users with sensory loss.

7 Conclusion

In this paper, we have introduced the technology behind Beacons and discussed several constraints that this technology imposes on the user and developer. We have also taken a closer look at the notion of social relations, privacy, in regards of context and what it implies.

Our aim was to explore how Beacons can help students when navigating the university. As GPS is not suited for indoor navigation, we would explore if Beacons could be of use in achieving the right degree of manual vs. autonomous context acquisition. We inferred that ethical issues would arise when monitoring and recording a user's location, thus we sought how to solve emerging issues.

We found that students have difficulties finding a vacant group room in institution, and some had trouble locating their lectures. Our target group has generally a positive attitude towards automatic, identifiable location sharing to help them communicate with co-students. Initially it is very tempting to automate a user's life in an effort to ease everyday tasks and situations. However, through our research we see that the users need the ability to manually turn location disclosure off in certain contexts, at specific times, or off at the users will. As such, we conclude that the benefits of Beacons could enhance manual control of context acquisition for users in context aware systems. The ethical issues that might arise are many, and users are in general cautious to whom they share their location.

We cannot guarantee that our findings in the early evaluation are reliable, and accordingly generalizable, as the number of survey respondents was limited to 15. Only a larger dataset could possibly prove this. However, our discussions with some of the participants, as well as observations made throughout the usability test, gave us a certain confidence to develop the concept further, based on what we learned.

Beacon technology, and everything it encompasses, is a new field, and there is yet much to explore and develop. Our prototype is just an easy start, and a good starting point for more thorough testing and evaluation with users to highlight more challenges regarding privacy, functionality, and design path. Conversely, as it was not a focus for this study, a significant task for future development is to further explore, identify, and solve issues concerning universal design.

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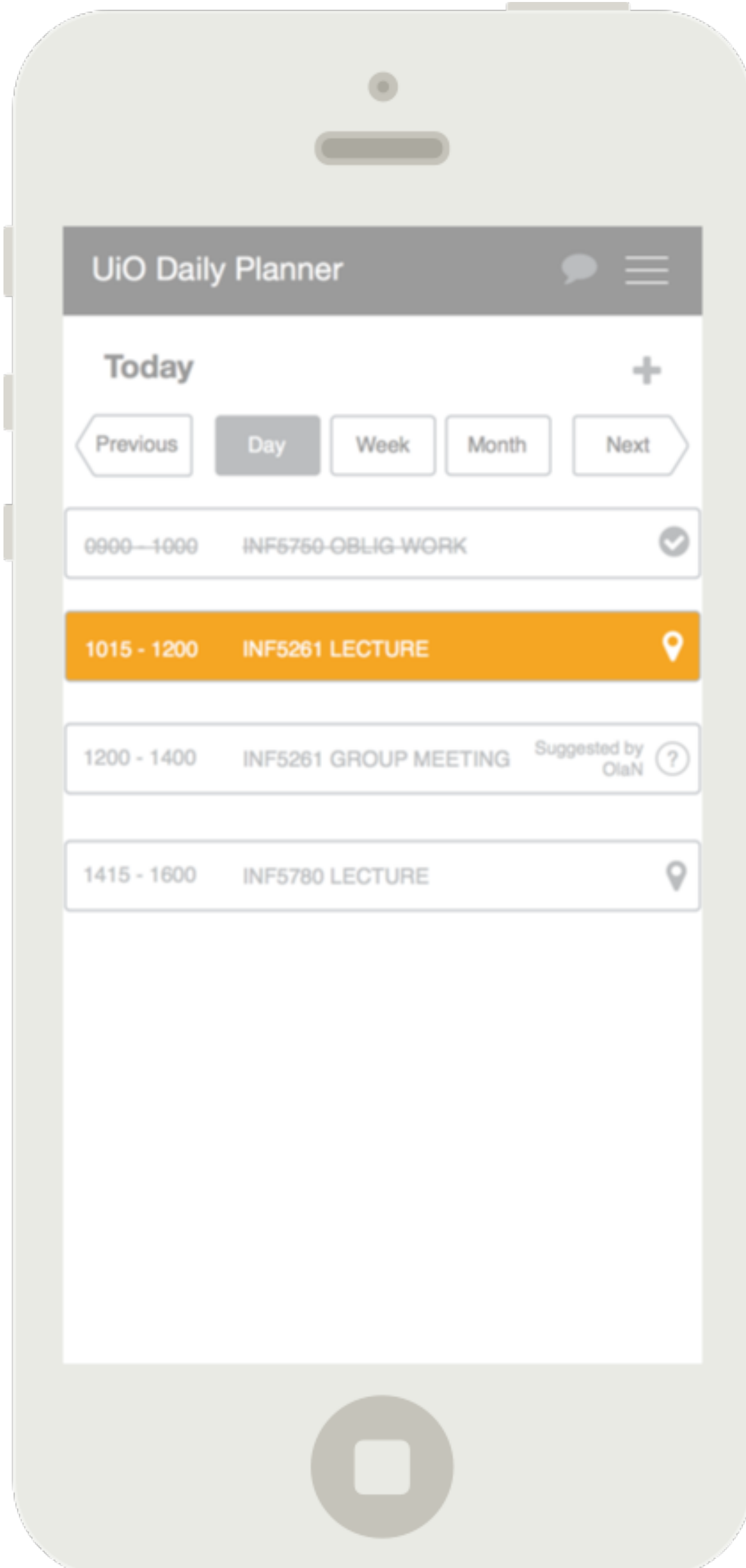
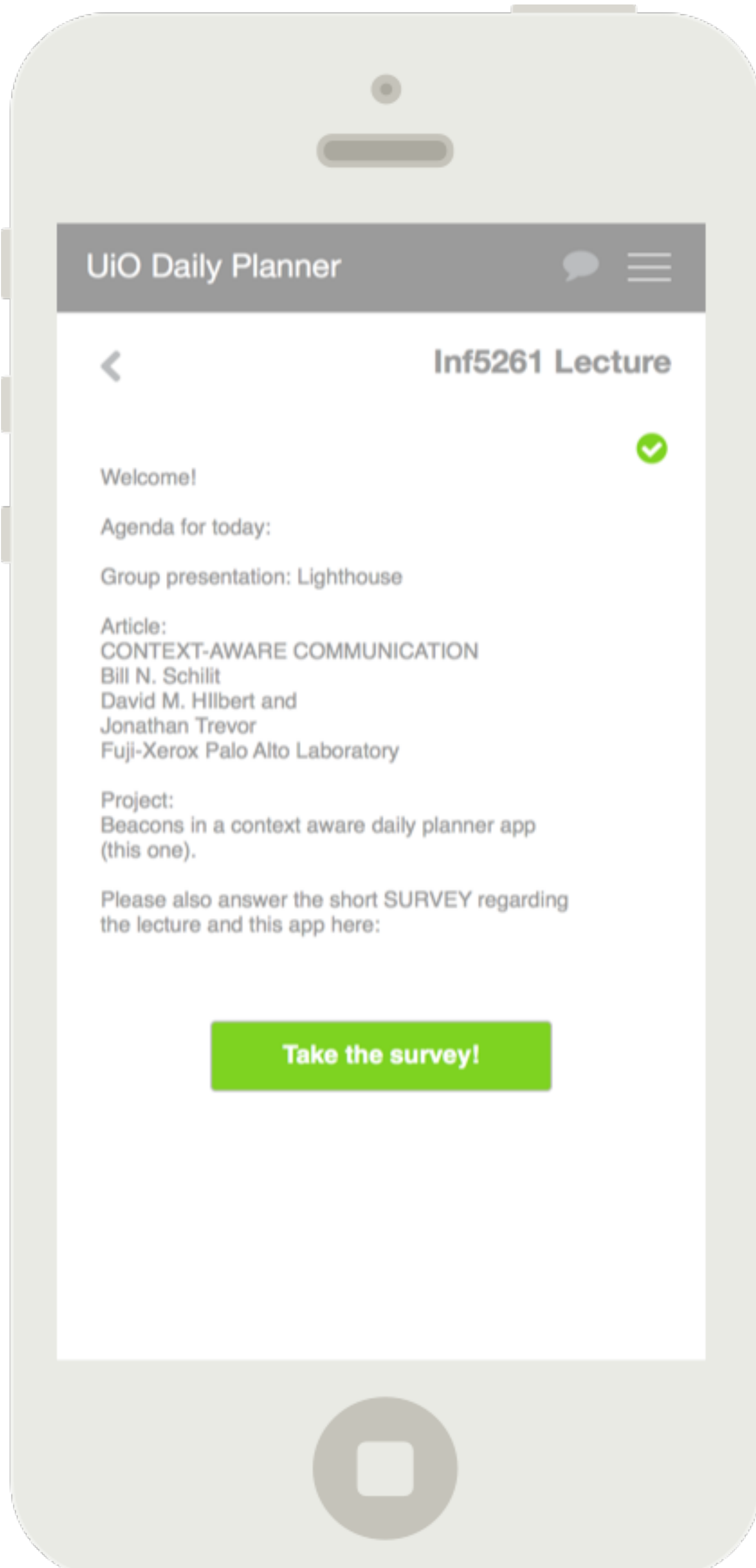
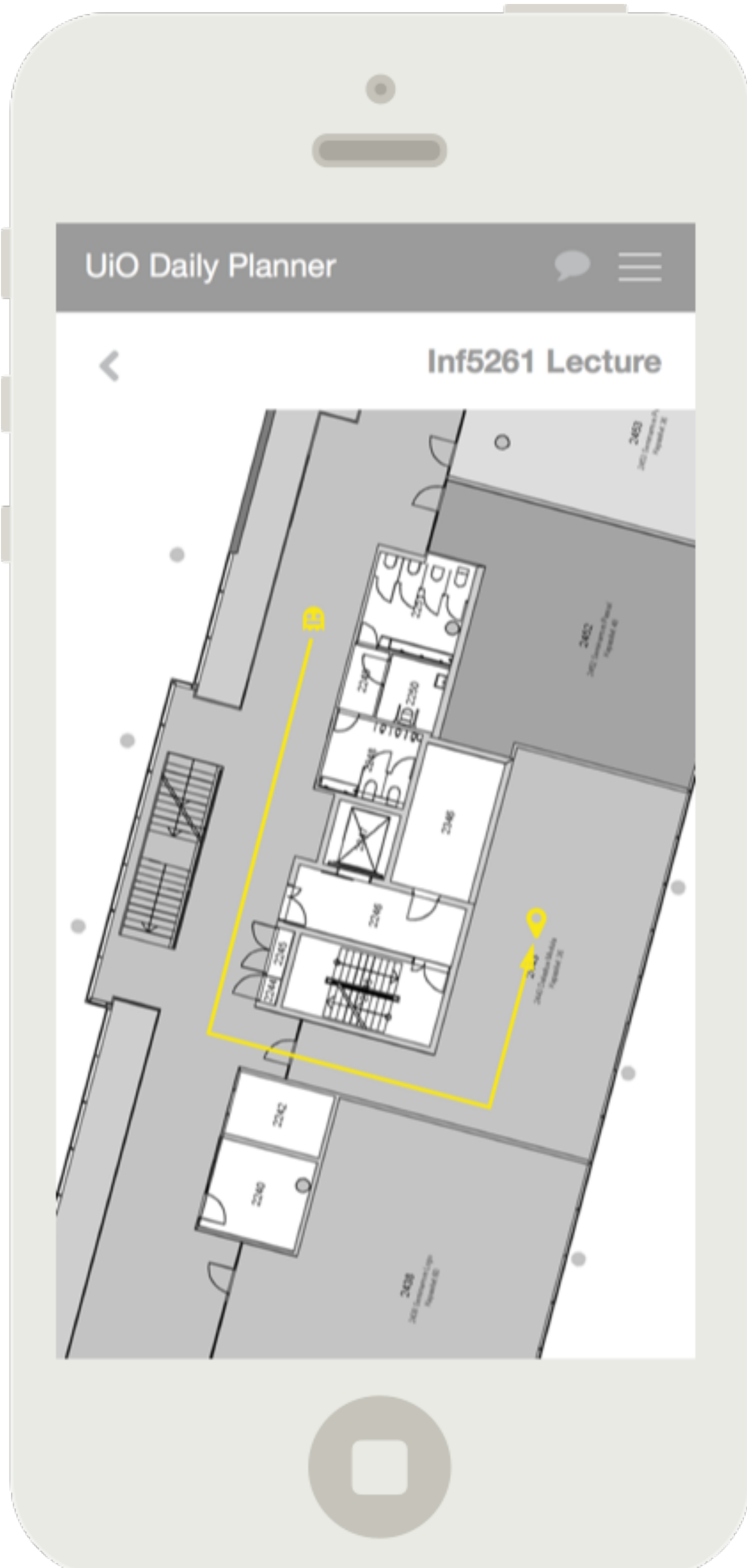


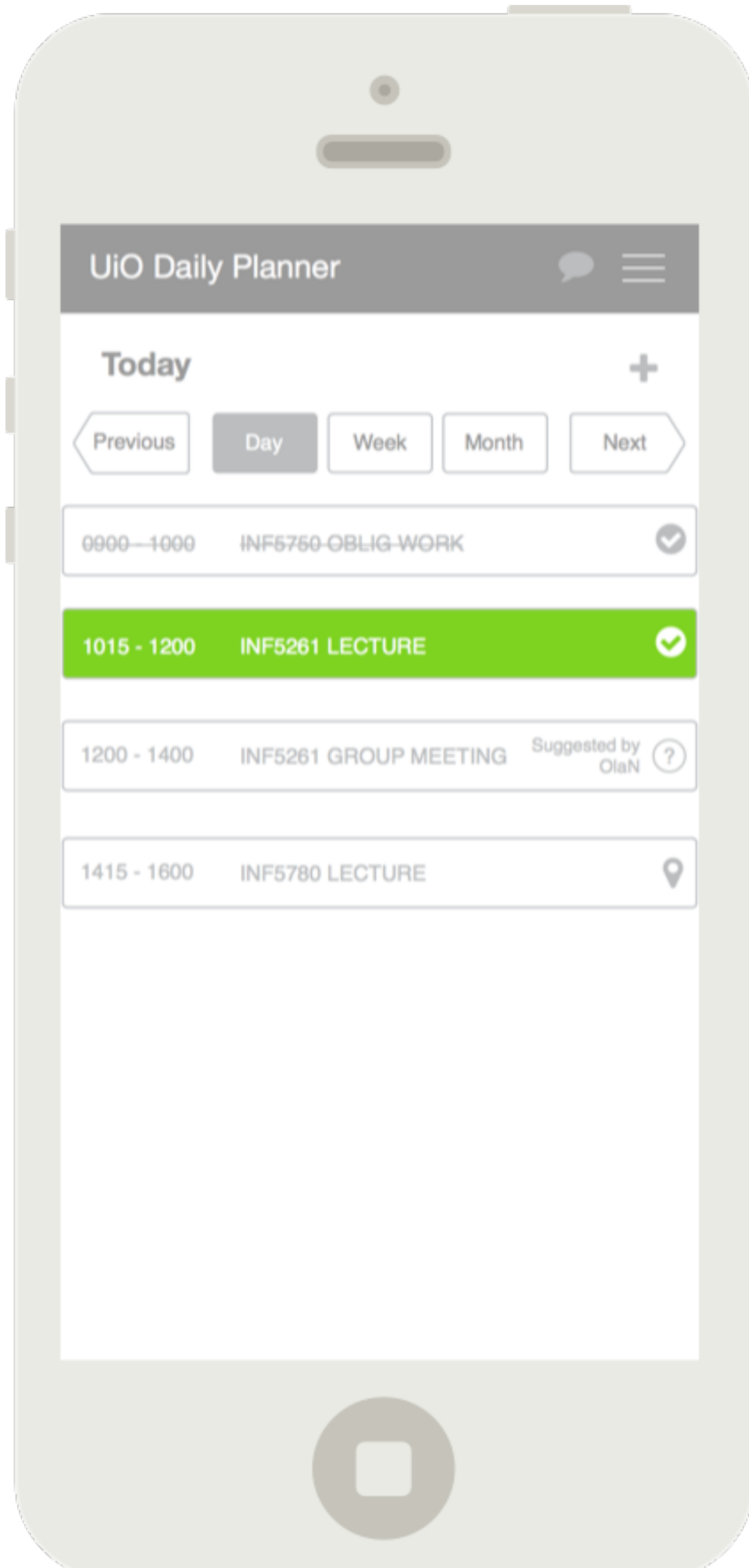
APPENDIX 1a: Today screen showing todays tasks and pending lecture at 1015.



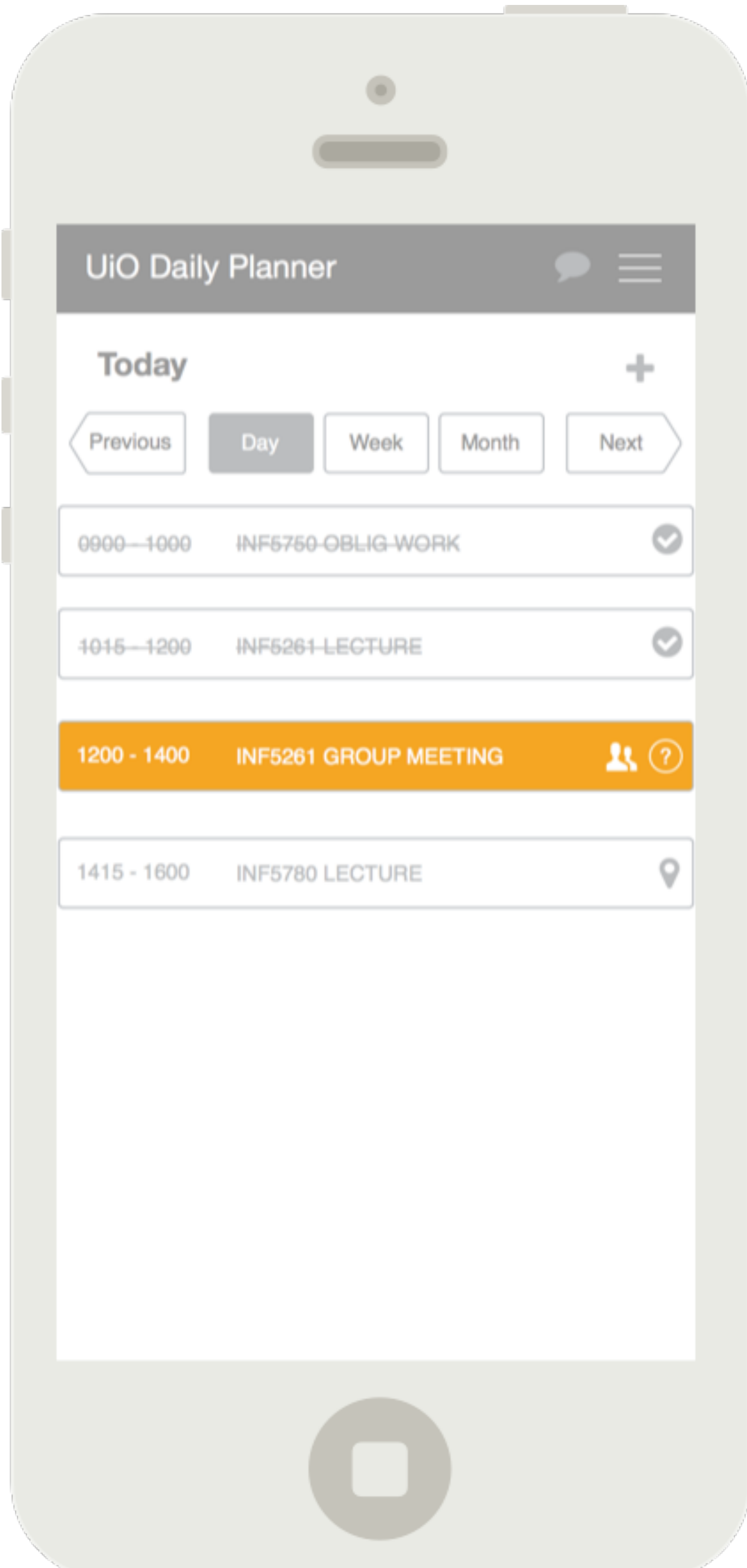
APPENDIX 1b: Map view showing visual guide to lecture room.



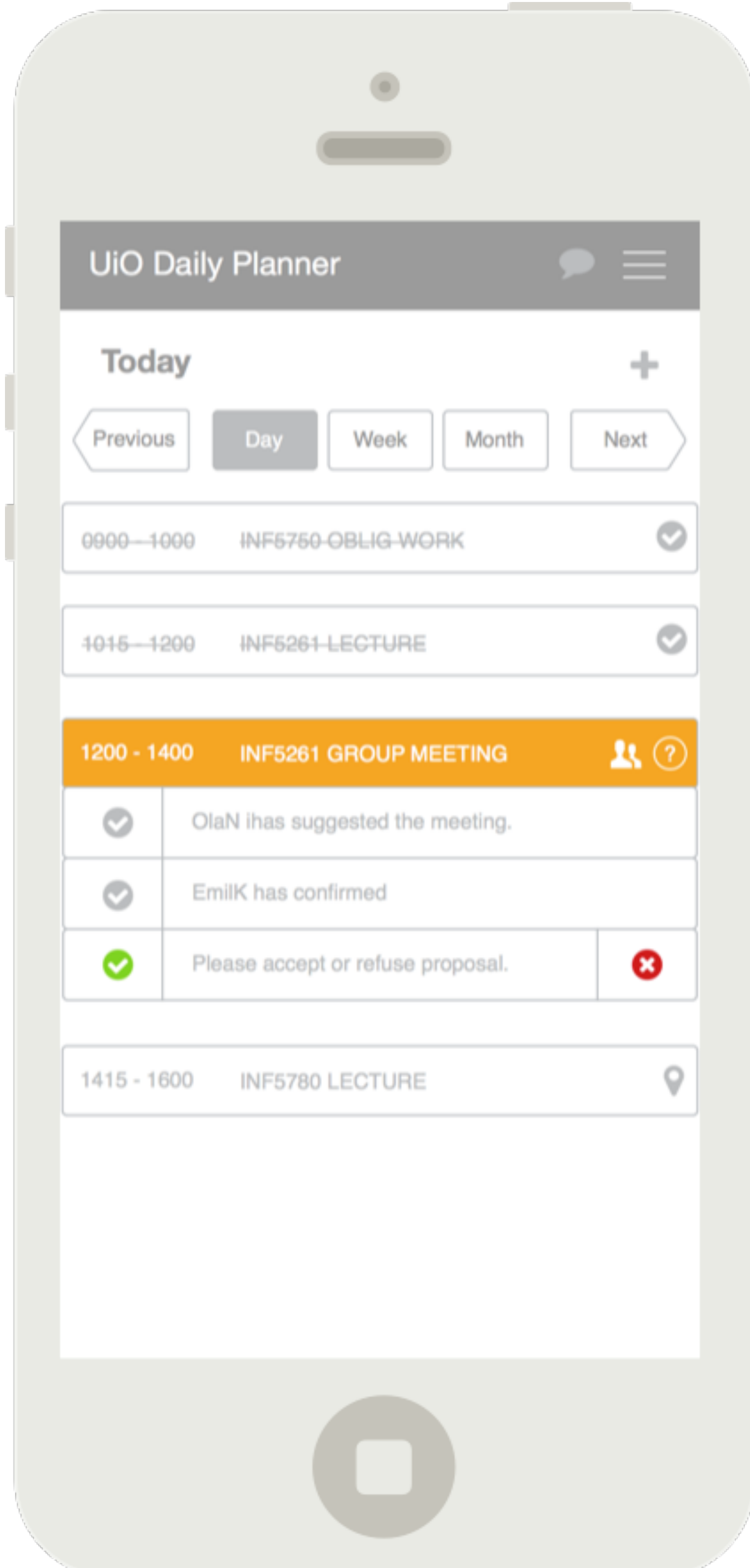
APPENDIX 1c: Detail view of lecture, providing information and special content for this item.



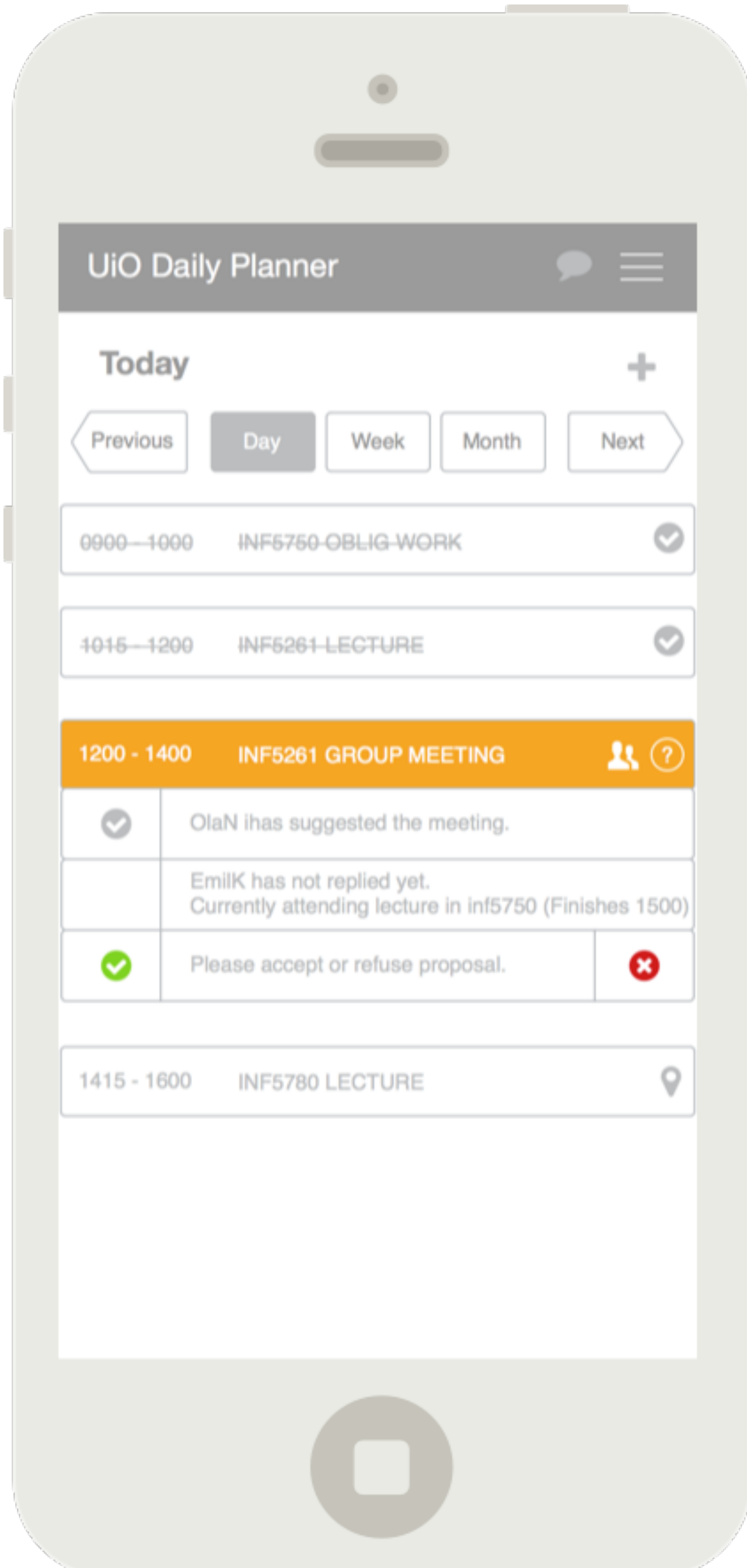
APPENDIX 1d: Successful check in to lecture.



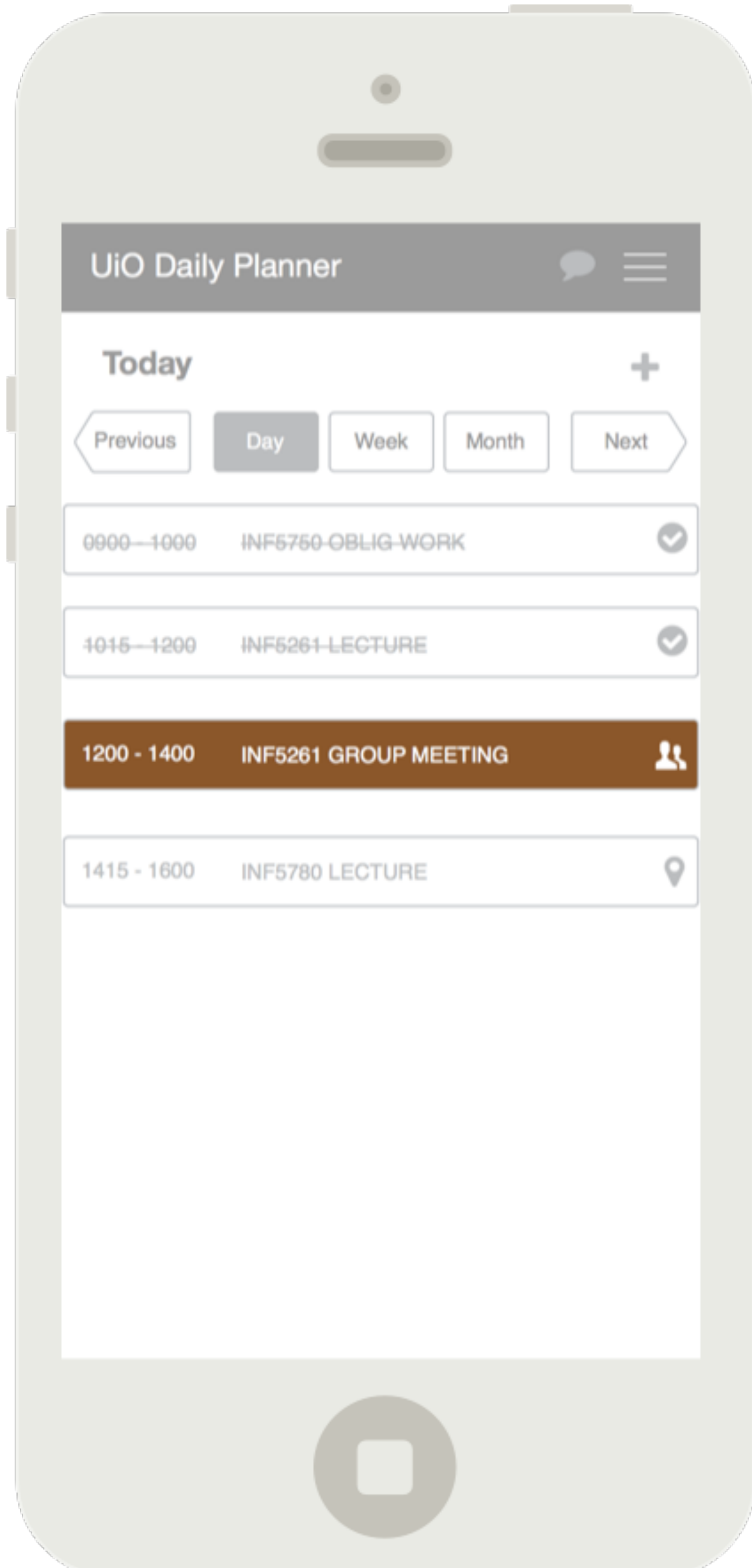
APPENDIX 2a: Today screen with upcoming but uncomfirmed group meeting



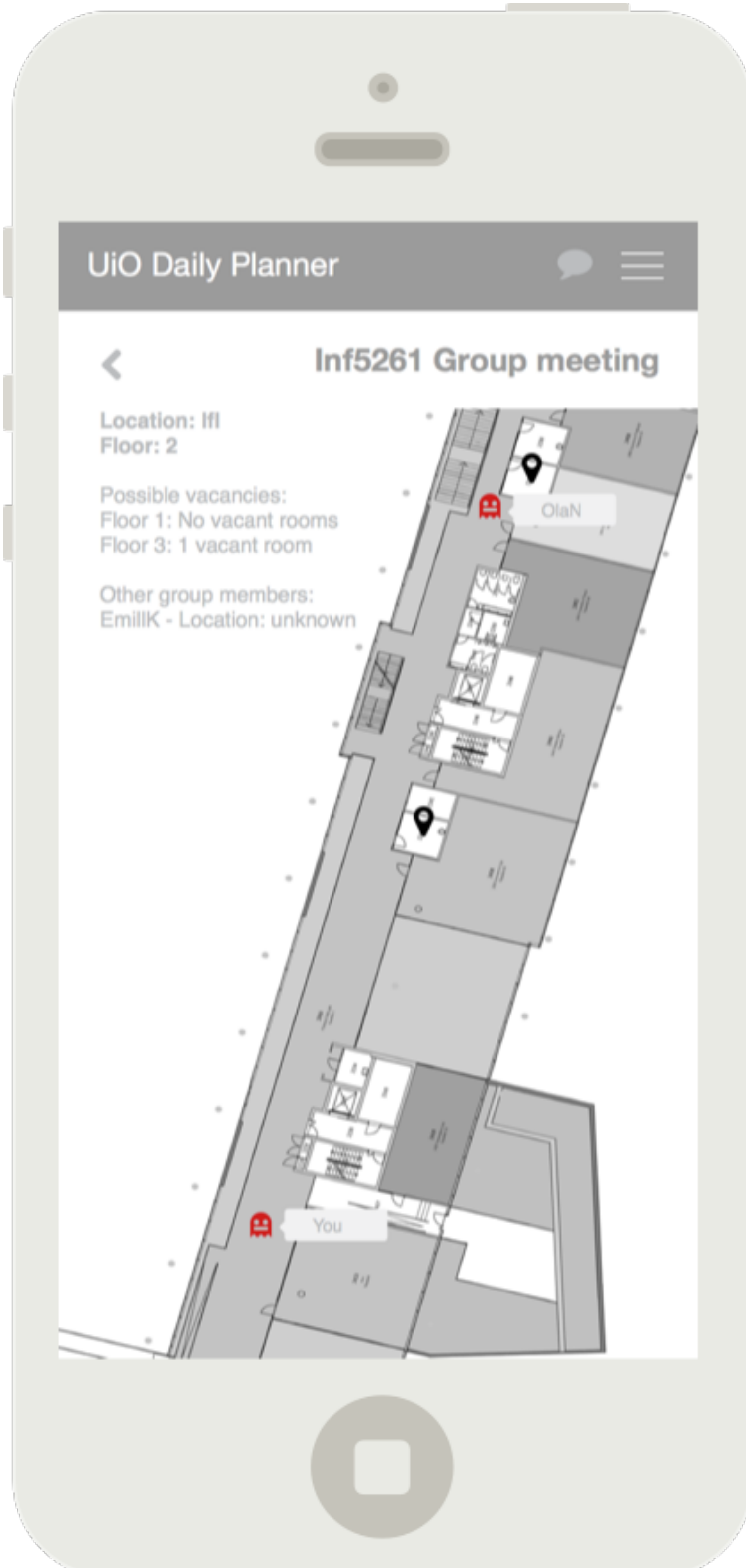
APPENDIX 2a1: Accordion menu showing status of the task. Asks user to confirm or refuse the proposed meeting.



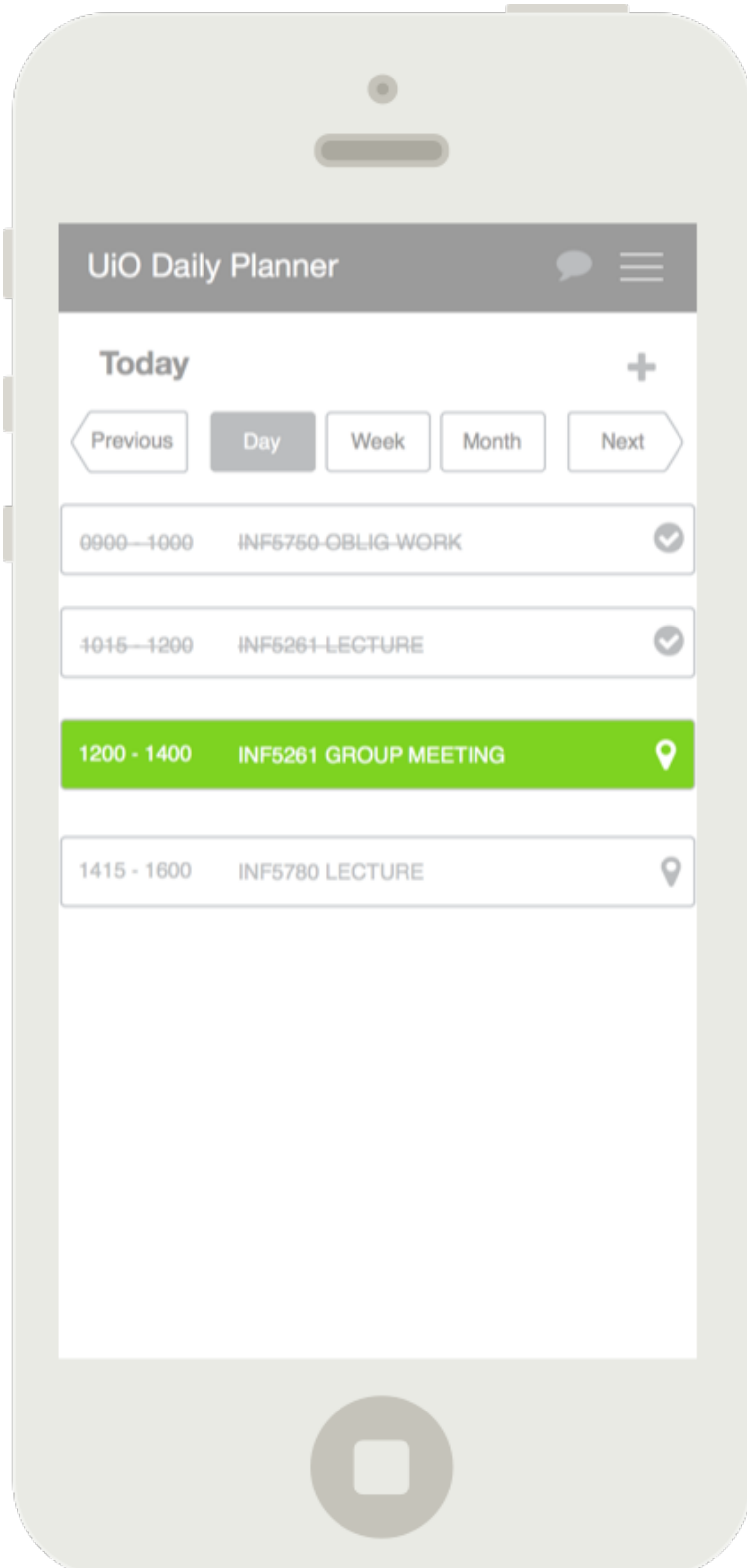
APPENDIX 2a2: Alternative version of the status accordion menu with context aware information on other users.



APPENDIX 2b: Today screen, all users have confirmed meeting.

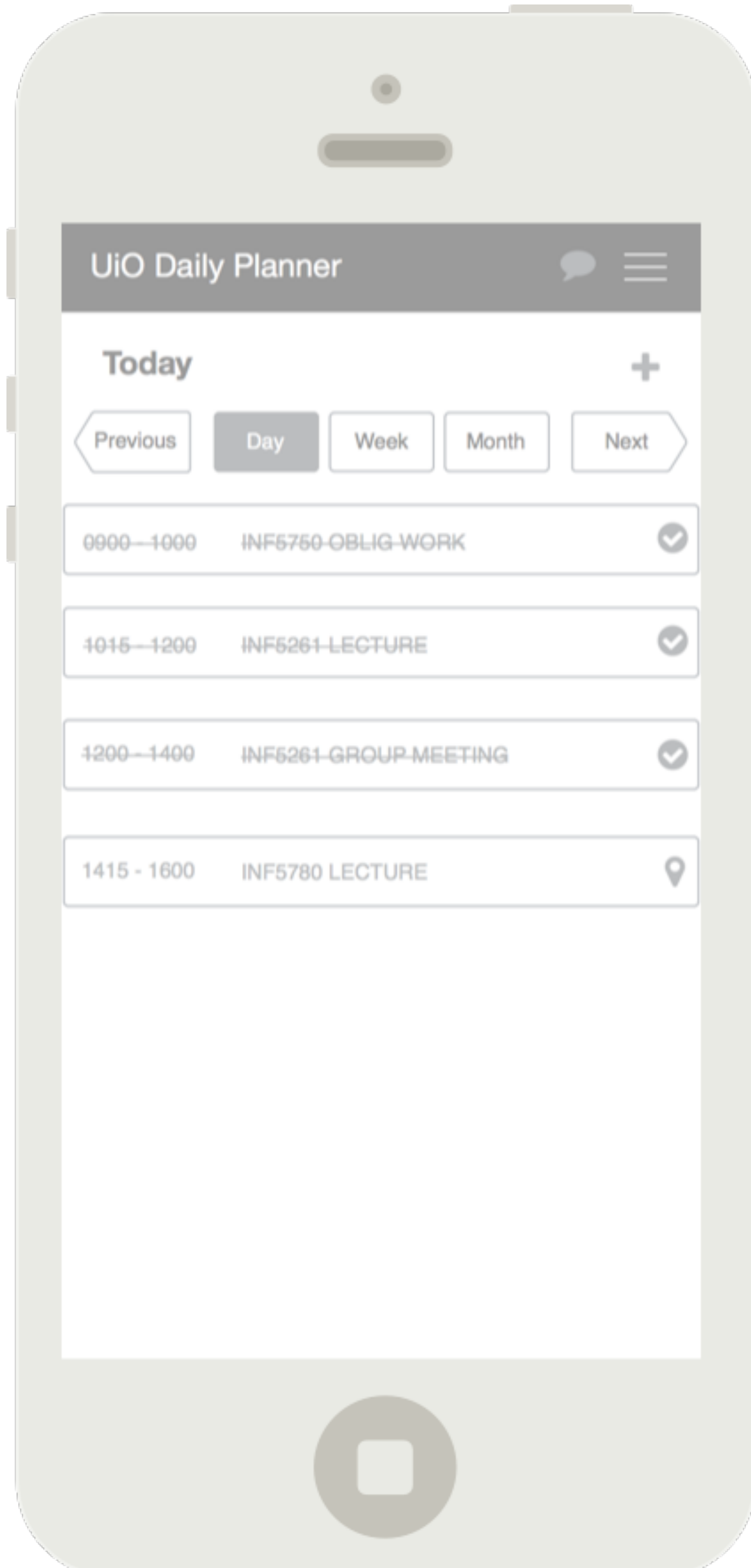


APPENDIX 2c: Map view showing users locations as well as suggestions for vacant rooms.



APPENDIX 2d: Today view. Group meeting has a confirmed location.

APPENDIX 2e: User OlaN has found a room. Map shows confirmed location for meeting.



APPENDIX 2f: After leaving the meeting user is checked out, marking the task as solved.