

Studying Mobile Context-aware Social Services in the Wild

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ABSTRACT

We have implemented and evaluated IYOUT, a context-aware application for the mobile phone that promotes a digital lifestyle, sharing, and life-logging approach for people on the go. The service incorporates context management technology to abstract data about and around the user into meaningful interpretations of the user's digital trace in the real world. Complementary to the public release of our service, we have conducted a longitudinal field study with 19 users for a period of one month. In this paper, we present findings from this coordinated user trial and provide researchers with advice on the design and implementation of similar systems.

Author Keywords

Mobile Services, Context Awareness, Social Networking.

ACM Classification Keywords

H.5. Information interfaces and presentation (e.g., HCI): Miscellaneous. H.1.2 User/Machine Systems

INTRODUCTION

IYOUT is a mobile application that allows users to automatically collect context information centered on visited places and interactions with other people. It aims at making it easy to collect such data on a standard phone and facilitates instant and light-hearted sharing of personal experiences within communities together with rich contextual tagging for everyday life. In combining and aggregating context sources, IYOUT derives a rich portfolio of personal information to be shared with others on the Web and on the mobile phone.

By hooking up to Web 2.0 services like Flickr, Facebook, and Twitter, IYOUT extends sharing experiences to social online communities commonly regarded as being widely adopted for the exchange of personal information. However, adding a mobile dimension to social communities that

involves sensible context data has not been well exploited yet. In addition to technical aspects in the implementation of context-aware social services like IYOUT, our research focuses on the usability, acceptance and market potential of such systems in practice. In this paper, we report on the results of a longitudinal user trial with 19 users from six countries over one month. We extend and discuss our long-term experiences made by releasing IYOUT to the public since more than one year with the findings from this study.

After some related work, we present a system overview, followed by the setup and methodology of the study. After an in-depth analysis of the conducted user trial we summarize the results and derive guidelines for the design of context-aware mobile applications.

RELATED WORK

IYOUT comprises a broad range of concepts, ideas, and services into one system with various interfaces. To the best of our knowledge, no other system provides a comparable diversity of context-aware social services, also including an extensive mobile client application. A good overview on context-aware mobile computing research until the year 2000 is given by Chen and Kotz [5]. Interestingly, of the 19 projects they analyzed, only two used context information other than location (and the current time). These two added some notion of activity mostly recognized by specifically deployed sensors. In contrast, IYOUT uses available phone sensors to sense and deduce a great variety of context information. Hong et al. [13] further report on general context-aware systems published until 2007. They categorize them according to five layers: concept and research, network, middleware, user interface, and application layer with various sub-categories. The diversity and rich feature set of IYOUT is exemplified by the fact that it covers a total of 8 of the 19 categories of the first four layers and has elements from half of the application areas (information systems, communication systems, and web service). The authors also show that very few research projects provide a fully functional and publically available application.

In the last years, many academic and commercial social platform projects have been created. Many of them are specific to a particular type of information. For example, Picasa, Snapfish, and Panoramio concentrate on sharing images, Google Latitude, Shizzow, and Plazes help people share their current location, and EveryTrail, Dopplr, and

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TripIt are used mainly for sharing travel plans. Obviously, several platforms exist that allow people to share messages, updates, and stories. Examples include Twitter, blogging, and other community platforms (see below) for short messages and status updates.

As IYOUIT incorporates all these features, it can be used by a single person as a notebook and ‘digital life recorder’ for his or her history of location and activity, encounters with others, etc. However, its true potential is unfolded with a community of users. On the same grounds, several social community platforms and applications have emerged. Most of them are specialized to some domain (e.g. LinkedIn for business; StudiVZ for education), restricted to some type of content (e.g. Flixster to movies; Last.fm to music), or are only available or popular within a certain region (e.g. Mixi in Japan; Qzone in China). Similar to IYOUIT, many of those have a web frontend and a mobile client application. However, especially the most popular platforms worldwide such as Facebook, Myspace, Orkut, and QZone do not exploit the rich feature-set of current smartphones and merely provide a simplified interface of their web portals. IYOUIT directly uses phone capabilities (see, e.g. [25] for a similar approach) and the users’ mobility to create profiles and offer multiple services described below.

In order to evaluate our system under real conditions and provide results with respect to its use, we chose a longitudinal field trial. Controlled lab trials or artificial test environments such as the one used for the evaluation of the health-monitoring application by Morla and Davies [15] cannot fully satisfy our needs as we wanted to focus less on the mere usability of the system and more on how it is perceived and used in the real world. There have in fact been very few studies examining the use of such powerful context-aware platforms with web-based and mobile interfaces. Most existing studies e.g. by Tungare et al. [23] concentrate on specific aspects or ways of applying the system or, like O’Grady et al. [17], focus very much on the usability of the specific mobile application and its interface. In contrast, we were more interested in how users accept and use our system. A similar goal has been followed by Jacucci et al. [26]. However, their system is targeted at a quite specific usage scenario (communication at large events) and was trialed in very specific settings over a short period of time.

THE IYOUIT PLATFORM AND SYSTEM

In order to cope with the plurality of context, IYOUIT is built upon a Context Management Framework (CMF) which hosts and combines various services and data sources [3]. As a prototype from our labs, IYOUIT is available free of charge. In addition to a mobile client available for Nokia S60 phones, we have implemented our own IYOUIT Web portal¹ and open APIs to support 3rd party developments

and mash-ups with other services and applications. The framework consists of two main parts. Management components, e.g., ensure secure authentication, implement fine-grained access control, and allow the definition and exploitation of context ontologies. On the other hand, context provider components wrap basic context data sources and can implement aggregations and abstractions. The framework has been designed for an open integration with 3rd party services and is leveraging Semantic Web technology in various places. The platform can be accessed through a web platform and a mobile client application.

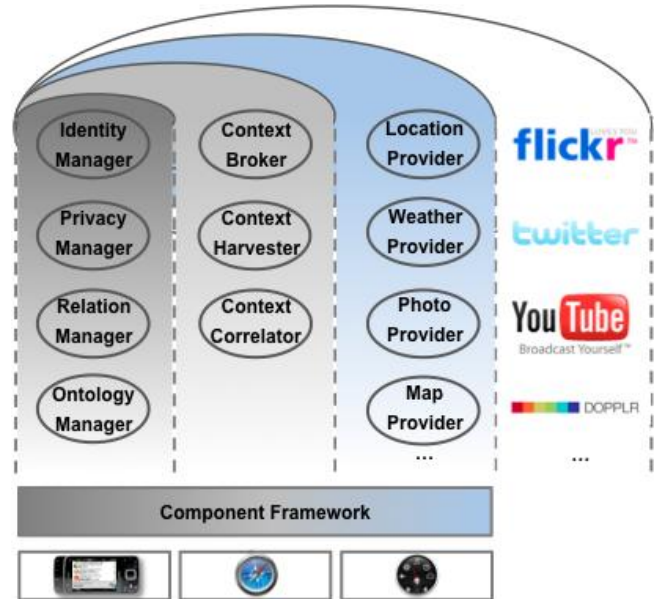


Figure 1: The IYOUIT component framework and connected 3rd party services.

The Mobile Client

IYOUIT has been designed to run 24/7 in the background on modern phones. Our current implementation supports all phones of Nokia’s S60 platform. Figure 2 shows some screenshots of the mobile client’s interface. Each tab either displays a certain type of context information or accumulates various pieces of information in a contextual overview that helps assessing the situation of a user at a given point in time:

Me: the home tab of IYOUIT and the standard entry point. It summarizes recently spotted information in the user’s proximity, highlights the latest presence status, and provides pointers to more detailed information in other tabs.

Buddy: shows the real-time context of all social contacts, including their location, status updates, latest activities, shared photos, and more. It offers different views on context, various sorting orders and context-dependent groups.

Places: summarizes the user’s current whereabouts. The client uses GPS coordinates when available. Otherwise, the location is fixed using cell IDs or exploits existing location

¹ <http://www.iyouit.eu>



Figure 2: Various tabs of IYOUIT's mobile client application.

information stored by the IYOUIT user community (e.g. at WiFi hotspots or fixed Bluetooth devices). Using statistical learning and clustering methods based on [16], places (abstractions from exact location values) are generated. These represent frequently visited places and map to basic semantic concepts such as the user's 'home' or 'office'.

Experience: allows setting IM-compliant presence attributes like activity, mood or availability. Small text notes are automatically complemented with personal context information to be posted, e.g., on Twitter. Using built-in accelerometers measuring movement and gestures, we can automatically set states such as 'sleeping' or 'walking'. Further (semi-)automatic methods are active research [11].

Photo: added pictures are proactively tagged with available context data and can be uploaded to 3rd party services such as Flickr. Beyond widely used tags such as geographic information, IYOUIT adds semantic descriptions like nearby people with the corresponding social relationships, the current place, qualitative weather annotations, etc. As a consequence, managing and sharing photos becomes more intuitive. For instance one can 'find all family pictures taken at the holiday cottage on a sunny day' or 'subscribe to photos captured by friends on the university campus'.

Events: displays a timeline of recently observed significant changes in the user context. Here, entries to places of interest are listed together with social encounters, network information as well as activities observed, e.g., by the accelerometer sensor of the phone. Actions such as switching the phone profile from 'outdoor' to 'meeting', can be attached to places. Similarly, activities such as 'working' may be bound to nearby people.

Scan: collects technical observations in terms of scanned Bluetooth devices and spotted WLAN access points. Observed devices can be associated with buddies while scanned WLAN access points are geo-tagged. Both can be associated with rules to trigger proactive actions such as setting the user's experience or automatically subscribing to WLAN network access in a certain place.

The owner of information (the user whose context is being sensed) has full control about what is accessible by whom.

Initially, the level of accessible information is defined by the manually specified relationship to a contact (e.g. 'wife', 'colleague'). In addition, it can be controlled at various levels (e.g. for all location updates or a single photo).

Further tabs exist for displaying local information on a map, for showing GPS details and statistical overviews of the personal context history. Automatic context tagging is also available for books and products (via bar code scans) as well as sound and video recordings.

The Web Portal

While the primary personal use of IYOUIT is on the mobile phone, the application also materializes on the Web in its own portal. Monthly hits on the IYOUIT Web portal currently average 30.000+ requests.

The Web portal offers similar interfaces as the mobile client but can be more suitable for the display and configuration of complex data. It shows latest public observations and selected bits of collected context together with hints on how the community is evolving. Users can conveniently define social relationships and configure personal privacy policies.

Furthermore, the portal offers a hub to various other online services. Users can thus decide to share their personal context with, for instance, Flickr, Twitter, Dopplr or YouTube. The IYOUIT portal also serves as testbed for selected features from our research lab. In an experimental engine, for instance, users can configure automatic context blogging or profiling.

Given the particular focus on real-time sharing aspects of personal data in the user study, the web portal and its features to display context in an aggregated view over a longer period of time has been of minor interest in this trial.

Public IYOUIT Community

IYOUIT makes it relatively easy to gather and share personal context data. During the design and implementation of the system, our assumption has always been that people will appreciate such sharing features given their privacy is preserved and under their control. We have started to test this assumption by releasing the system for public and free use about two years ago. For this reason, IYOUIT has also been promoted and eventually awarded as part of the

Mobile Experience at MobileHCI'08². Since IYOUIT's public release mid 2008, more than 1.500 users from 50 countries registered with the service. More than 1.5 million location measurements were recorded, 10.000+ pictures were tagged and uploaded, and more than 55.000 local information items, such as weather forecasts, were requested. Albeit already of great value through direct feedback and observation, the global IYOUIT user community provides only limited contribution to a comprehensive and complete understanding of our system. To learn more about how mobile users perceive contextual tracking and sharing as well as other application features implemented in IYOUIT, a profound user study with a clear focus and a relatively controlled setting was indispensable.

EVALUATION

The study on which we report in this paper took place in 2009 and lasted four weeks. One main target of the study was to find details about people's acceptance of general context-aware sharing concepts and various special features within the IYOUIT system.

Study Setup

In the following, we briefly give an overview on the structure, methods, and tools we used.

Initial tutorial: we met with all study participants to introduce the IYOUIT system, distribute compatible handsets if necessary and configure the application if not done already.

Demographics: demographic information about participants was collected in this session with a short questionnaire.

Triggering participation: as stated in Froehlich et al. [9], "participant compliance tends to decrease over time" and triggers can help to counter such trends. We provided weekly challenges and announced small prizes for those who would provide most constructive feedback. In fact, however, the consequences were very limited: only three persons attempted to address some of the tasks, and those only within the first two weeks. Thus, we can practically rule out any effect on the results of the study.

Data Elicitation

During the study, we used three ways of gathering quantitative and qualitative data:

Logging: the mobile IYOUIT client was fitted with additional routines to log and transmit information about actions and context experienced throughout the study in order to reinforce subjective opinions with actual behavior.

Questionnaires: most subjective data has been gathered through questionnaires distributed by email as well as the IYOUIT Web portal. An initial questionnaire gathered demographic data and clarified previous experiences. After two weeks, a questionnaire checked people's participation and tried to spot trends. A final questionnaire collected

feedback about the general concept, user experience and behavior, and application specific features and interfaces.

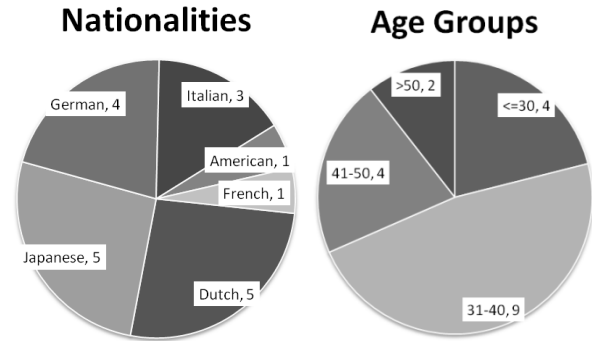


Figure 3: Demographics of the 19 study participants.

Final interviews: we also managed to have individual, face-to-face interviews with 14 participants to clarify some of their answers and to find reasons behind their judgment.

Study Participants

We tried to recruit a variety of different user types from the existing user base and also encouraged additional persons who had not used IYOUIT before. In the end, we covered a range of different nationalities and age groups (26-65 with an average of 37 years, see Figure 3), 15 male, 4 female.

Table 1: Previous experiences and participation of the users.

Participants Characteristics	Rate
Use of Facebook social platform	58 %
Use of Flickr photo sharing	53 %
Use of Twitter micro blogging	32 %
Use of a location sharing platform	21 %

One half of the participants (47%) already knew IYOUIT (but only 21% for longer than 6 months before the study). We also aimed at a mixture of previous experiences with such platforms to study a potential correlation between the actual use of our system during the trial and previous experiences with similar services. Table 1 shows some of the characteristics.

With respect to picture sharing, our sample mostly had experiences with Flickr or similar services. Regarding social community platforms, in total 17 systems have been in use by at least one participant. Among these, Facebook and LinkedIn were most prominent (mentioned >5 times).

ANALYSIS

For this paper, we distilled results about four broad areas of interest and describe the instances from which we elicited the data: general use (usage data and personal feedback), context acquisition and sharing (photo sharing), context aggregation and abstraction (location and a concept called places), as well as social networking and privacy (connections to 3rd party sharing platforms and detailed treatment in the questionnaires).

² <http://mobilehci2008.telin.nl/?sub1=89>

General Acceptance and Use

The application usage throughout the study was very high but varied largely between participants. As Figure 4 shows, the average uptime of the mobile client during the trial period was 38%. Given that these numbers assume a 24/7 usage, the measured average is actually surprisingly high.

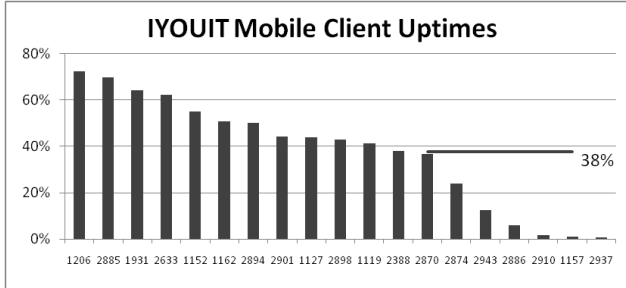


Figure 4: Uptime of the mobile client application (avg. 38%).

Although increased power consumption was mentioned as a major issue of the system by 47% of the participants, Figure 5 indicates hardly any correlation ($r^2 = 0.65$) between problems due to power consumption and the actual runtime. The average number of times that people had the phone powered off because of an empty battery was only 4 times. In the end, battery problems seem to explain only 12% of the cases in which people had IYOUIT not running for some time. This is supported, e.g., by Froehlich et al. [9] who show that people most often recharge their phones considerably before the battery reaches a low level anyway. In addition, IYOUIT also offers several opportunities to conserve energy, e.g. cell triangulation instead of GPS for location estimation and an offline mode.

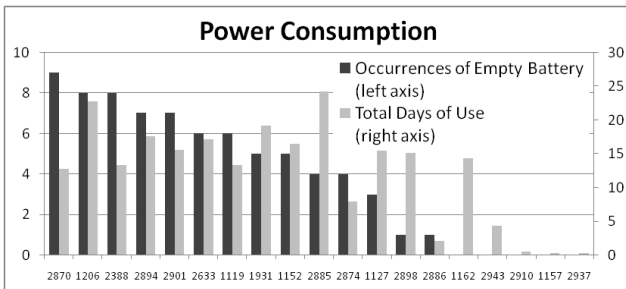


Figure 5: Number of empty battery occurrences per users.

To see which context categories are of most interest to users, we had the participants specify the top three most important types of information (cf. Figure 6). Location and pictures head the list followed by weather information. Curiously, people's activities and mood have not been mentioned very often. One advantage of running this study is that we were able to compare these statements with the actual behavior within the system.

Figure 7 provides more details about the most frequent use of the IYOUIT client. As expected, people were attentively following the context of their buddies. Also the *Photo Tab* for taking, tagging, and sharing pictures was used frequent-

ly. Surprisingly however, and in contrast to what people indicated, the *Experience Tab* initiated more than twice as many interactions as the *Location Tab*. This indicates two aspects: the implementation and presentation of location information has been done in a way that needs little user interaction; and people are in fact interested in collecting and sharing more information than their position.

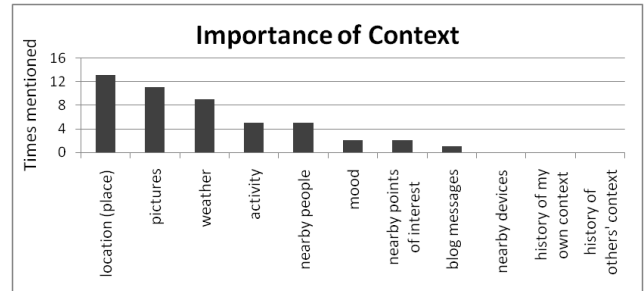


Figure 6: Types of context most important to users.

Still, location-based services are of high importance as the appearance of the *Location*, *GPS*, and *Map* tabs within the chart of Figure 7 proves. Less interesting seem to have been the possibilities to generate statistics (*Statistics* and *Graphs*) about past history of context of oneself or others. This correlates to the fact that no one described context history to be of top interest (Figure 6). However, this could potentially be improved with a better and more interesting user interface or more features such as comparing statistics across users. In fact, in the interviews, 43% pointed out that they would be interested in using IYOUIT as a life-logging application and a dedicated diary service was even requested as additional feature. This indicates a strong need for automatically generating and presenting context to the user in an appropriate way (cf. concept of places explained below).

One interesting result from our final questionnaire was that people stated they learned habits of their buddies (2.9 on a Likert-scale from 0 to 4, $\sigma = 1.0$):

"I just found out that a colleague's hobby is airplane spotting! This buddy-based sharing is definitely a worthwhile feature for the application."

Japanese, male, 34 years.

Context Acquisition and Sharing – Photos

The IYOUIT system provides an excellent framework for photo sharing. Pictures taken with the mobile client are automatically augmented with context information such as location, activity, or mood gathered by the application. Additionally, the user can manually associate tags and descriptions with photos. In conjunction with querying and grouping mechanisms, all this information helps in later retrieving specific pictures (using, e.g., information about the weather conditions or nearby people). As IYOUIT can be directly and seamlessly connected to 3rd party services such as Flickr and Facebook, features from these systems like Flickr's photo sets capability can directly be exploited.

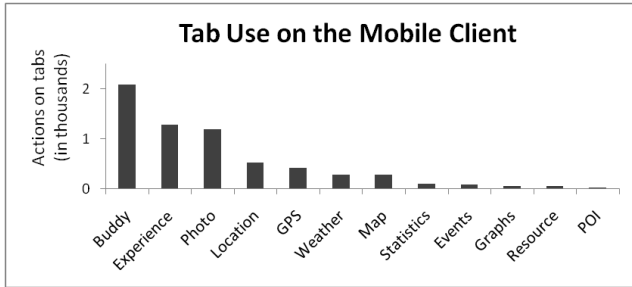


Figure 7: Relative amount of use of the client’s different tabs.

During the trial month, 540 photos were uploaded allowing us to derive interesting insights into the way people share and describe pictures. First, the number of uploads is not related to the uptime of the client. Second, as expected, our current system could not fully challenge dedicated picture viewing applications such as Flickr as it was not designed for this purpose. However, its feature set was rich enough to be attractive and often used. Automated tagging and the transfer to Flickr were very much appreciated. This can be seen in Figure 9 that shows the percentage of photos with manual tags and descriptions. The right bars show only those users that have manually tagged or described at least one picture during the month. The numbers are unexpectedly high as adding descriptions requires some effort: use of the menu and entering text on the phone. This indicates that adding information to pictures is important and IYOUIT can help greatly by automatically adding tags and a title³.

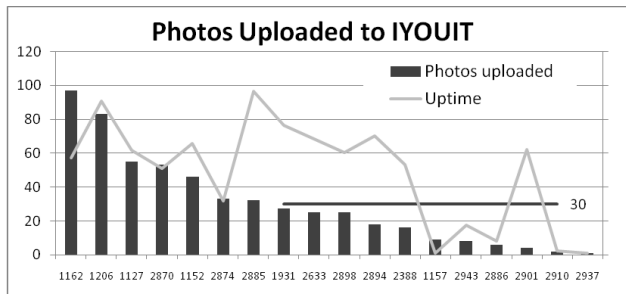


Figure 8: Number of photos shared using IYOUIT (avg. 30).

Out of all tags that have been manually assigned by the users, five categories of tags have been identified. A large number of tags detail the location where the photo has been taken (Figure 10). The mobile application actually could have derived 53% of those (such as city, proximity to a recreational area, or the position close to some landmark). Two other main categories describe some detail depicted on the photo (such as a person or event) or some activity. Descriptions are longer but used for the same purposes, but favor detail over location (e.g. if covered by a tag). These findings strengthen the need for a system providing smart algorithms for automatic tagging that, at the same time, allows for manually adjusting or adding information.

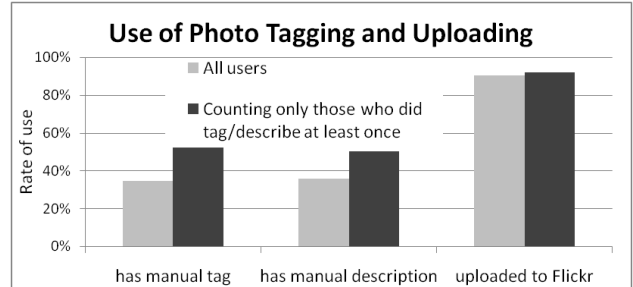


Figure 9: Photos with manual tags and transferred to Flickr.

One main issue that arose within the feedback through the questionnaires and interviews was that many people prefer their digital camera to the mobile phone camera, e.g. because of image quality, flash, and zoom capabilities. Therefore, it has been very well received that IYOUIT also allows for post-processing Flickr images: pictures uploaded from an external camera can be automatically augmented with related context tags at a later point in time.

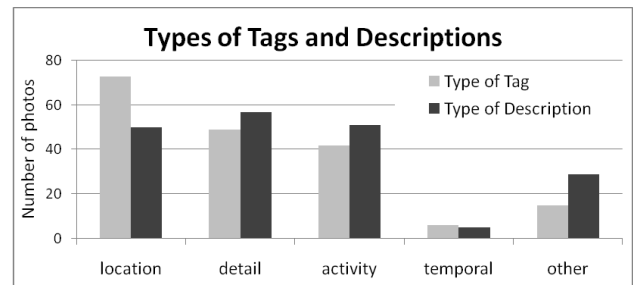


Figure 10: Categories of manual tags and descriptions.

Context Abstraction and Presentation – Places

IYOUIT collects much data while in use. This raw data is often only of limited value to the user and becomes meaningful only after it has been combined and abstracted. IYOUIT uses context ontologies and Semantic Web technologies to implement key abstractions and reasoning features. We refer to Böhm et al. [4] for the details.

We exemplify context abstraction through the concept of places: an IYOUIT *place* is a semantic concept that abstracts from a geographic position and describes it by type and name. Places may expand to cover whole areas. The concept of places is needed for three reasons: first, location measurement on the phone has to rely on imprecise data (Fagerberg et al. [8], note that “place labels are useful no matter the granularity of the positioning system”); second, several real world locations consist of the same place – e.g. within an office building; third, abstractions are necessary to give a more appropriate meaning to locations, e.g. “office” instead of a street (see, e.g. Ashbrook and Stamer [1]). As has been stated before, location is an import type of context and people often rely on and share such knowledge. Grandhi et al. [10], e.g. found that up to 77% of people observed in New York over a 3 weeks period were willing to share their location data (17% even with total strangers).

³ See <http://bit.ly/IYOUITpic> for an example picture

The IYOUIT system holds an ontology of places shared by everyone to coherently share places between users (e.g. ‘home’ vs. ‘office’). Participants used 39 different place types for 235 places indicating that this mechanism is both appreciated and used. Similar to setting experiences manually, we suspected that the manual specification of places would be too much work for most users. Therefore, complementary to manual places, IYOUIT runs specialized data mining algorithms (cf. Nurmi and Koolwaaij [16]) over aggregated location traces and proactively generates place suggestions. Similarly to the reasoning by Ashbrook and Starmer [1] as well as Hightower et al. [12], this is mostly based on the amount of time the user stays within a certain region. We also abstract from concrete positioning methods taking inherent (in)accuracy into account. The user is provided with such place suggestions and can easily decide to name and typify, to ignore, or delete them. This was very well received (about two-thirds of all suggestions adopted) and acknowledged in the questionnaires and interviews.

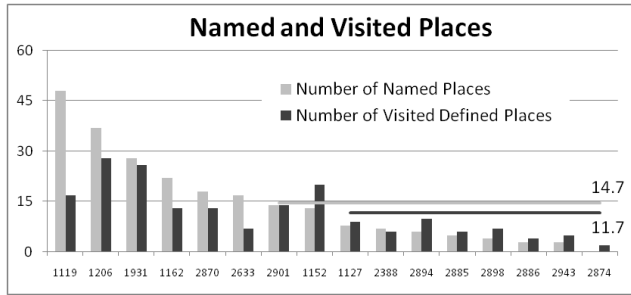


Figure 11: Manually named and subsequently visited places.⁴

Figure 11 shows the distribution of named places of each user with an average of about 15 places per user. The same chart also displays the number of places that have actually been visited during the trial period (this includes unnamed places, see below). Our usage data over a longer period of time shows that, for the majority of people, an average of 12 places seem to cover most regularly visited areas of interest. This is in accordance with previous research, e.g. by Hightower et al. [12] who found that an average of 7 to 8 places are visited regularly within a year and Zhou et al. [24] who discovered on average 15 significant places.

Furthermore, people overall spent over two-thirds (69%) of the time they used IYOUIT in the defined area of a place (Figure 12). In fact, some people have spent about 75% of their time within one specific place (provided one can meaningfully extrapolate beyond the uptime of the client).

This statistic is actually very similar when considering the whole IYOUIT community during the trial period with an average value of 67% to be within a defined place, thus further confirming the validity of the place concept.

⁴ Note that in this and the following chart, only the data of 16 participants are visualized as the short usage times of the 3 users who had IYOUIT running for less than 2% of the time could lead to inappropriate values.

Although places are obviously very personal, we introduced a feature that enables people to inspect and subscribe to places of others (only for places explicitly marked as visible by buddies or the public). Within the trial group, already about 6% of the places have been used in such a way. This is one of the features we think has a high value, especially as soon as the IYOUIT community reaches a certain size and more places are being created.

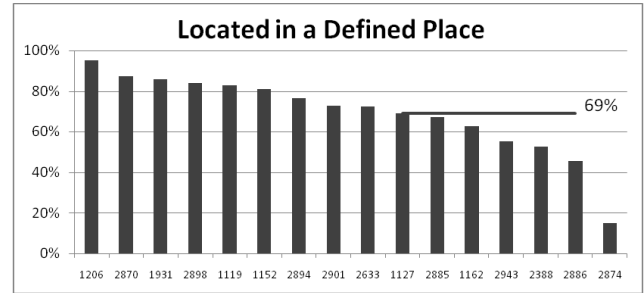


Figure 12: Time users spent within a specific place (avg. 69%).

As a side result, it is interesting to see that many people seem to move between places quite often. The data gives an average of 8.9 times ($\sigma = 7.6$) that a user enters another place per day. Still, this seems to be quite specific to individual users (also indicated by the high standard deviation). Judging from the available data, one could categorize users into the three clusters ‘rather stationary’, ‘average mobile’, and ‘very mobile’ with the distribution within the trial group being 8-5-3. This also suggests that specifying rules based on places, e.g. automatically setting one’s status or activity, can provide a constant stream of sensible data.

Privacy and Social Networking

From the user’s point of view, IYOUIT is primarily a sharing platform for personal information. Here, the social aspects of sharing data and communicating with people, indirectly with context updates and directly by sending messages, blogging, or commenting on other’s context are vital to the application.

Privacy Policies and Directives

A *Privacy Manager* is an integral part of the IYOUIT system (for details see Böhm et al. [3]). In contrast to most platforms such as Facebook that allow full access to personal information for one category of ‘friends’, IYOUIT extends to more defined categories of social contacts and makes sharing fully bound to the personal social network through a fine-grained access control.

Previous studies, e.g. Palen and Dourish [19], suggest giving users full control over privacy directives. In IYOUIT, this has been fully implemented by controlling access to personal information with a general system of rules defined by the user and resource specific access directives as an exception to the general rules. These fine-grained access control mechanisms allow for the definition of rules for groups of people or specific buddies, for distinct

context categories as well as the level of detail that is being disclosed (a requirement also stressed by Consolvo et al. [6]). This means that, for example, access to the user's current location can be prohibited completely or allowed at a country, city or concrete address level. Users may also separately choose to grant access to historic information. Resource specific directives, on the other hand, provide means to explicitly choose the level of disclosure for specific items (such as a picture) case-by-case, independent of the general directive for this context category.

As Sadeh et al. [22] state, giving the user such a flexible and powerful control over privacy and sharing settings can increase the adoption of context-aware services. They also show ways of incorporating more complex rules for granting or denying access to information and provide guidelines in this direction. However, as they and Palen and Dourish [19] correctly point out, this can always be only partly a solution since (location) privacy is a "dynamic process of managing boundaries".

Interestingly, the willingness to choose the level of disclosure for specific items rather than just relying on the previously defined rules or default settings varies greatly for different context categories. Our study participants often wanted to specify the sharing level of photos individually, whereas the sensitivity of location has been seen as rather static. For example, the majority of 62% of pictures were uploaded to be publicly visible, while 30% were for buddies only, and the remainder was only visible for the authors themselves. This indicates that there is a definite need for privacy preserving mechanisms and that they should be adapted according to the type of data.

One finding derived from personal feedback and interviews is that it seems to become easier to define meaningful privacy directives when changing from low-level data to a higher level of abstraction. For example, most users easily understood how to judge the sensitivity level of places, whereas only more 'expert' users were able to express the corresponding rules for spatial data in general.

As a positive result, we regard that 79% were comfortable with sharing context with their buddies through IYOUIT. Furthermore, 63% of all trial participants expressed no need for a more sophisticated privacy management procedure. Others mainly argued for adding control about which picture is transferred to which 3rd party platform with which privacy setting or have not found the opportunities that the current system offers.

We can support the discovery by various works [6, 20, 22] that people's sharing behavior depends on types or groups of people such as co-workers or close friends. To this end, IYOUIT allows to define personal social networks of buddies by defined and typed relationships such as 'friend', 'brother', 'colleague', etc. which are more comprehensive than in most other systems. Relations are pre-configured in

privacy settings that can be adjusted individually but mostly seem to fit the way people interpret these and want to have them: the user interface of the privacy manager was actually only accessed by 9 of the 19 users and only 6 of them modified the default directives. On the other hand, the users' explicit opinions varied: 3 out of 17 people said to be fully comfortable in sharing their context with their buddies. However, in the trial, only one user actually granted full access for his buddies. 4 persons felt uncomfortable with sharing but again only one completely restricted access to others. This is similar to the findings reported by Consolvo et al. [6] who state that the Privacy Segmentation Model [18] into unconcerned, pragmatists, and fundamentalists through interviews does not seem to be a good predictor for actual behavior.

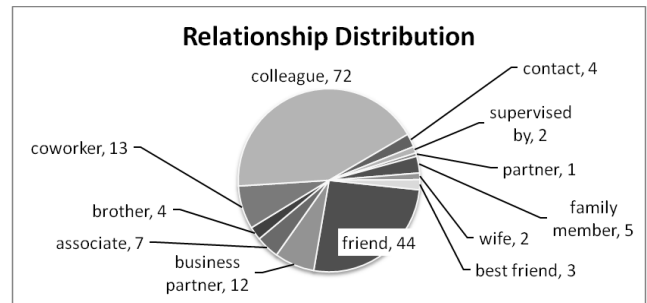


Figure 13: Relationships used to categorize buddies.

Social Networking Platform

In contrast to some systems for which a direct connection between usefulness and number of users is well known as the critical mass (see Rogers [21]), IYOUIT is already valuable without any or with only a small number of buddies. Yet, after the end of our study, everyone had a relatively large network of 2 to 25 buddies with an average of 10 and a total of 184 explicitly defined relationships. shows how study participants categorized their buddy relationships with 63% being tagged as business contacts, 7% as family, and 30% as friends. The high number of business relationships could indicate a potential use in the corporate setting, an application area that has in fact been suggested by several interviewees (Bardram and Hansen [2] show an application for hospitals using context to trigger social awareness between colleagues).

In order to make the most out of the IYOUIT platform and to increase added value, IYOUIT can be configured to connect to existing 3rd party services such as photo sharing platforms (Flickr), blogging platforms (Twitter), and social community platforms (Facebook). The automatic distribution of information across services was valued highly by many users. However, the actual representation or configuration of information within, e.g. Facebook needs to be revised as the following comment made clear:

"My friends really wondered why I suddenly started to comment on me waking up!"

Italian, male, 26 years.

The vast majority of uploaded pictures (90%) were also automatically transferred to Flickr. As Flickr employs a categorized privacy mechanism similar to IYOUIT, the access labels ‘public’, ‘private’, and ‘buddy only’ are directly mapped (the buddy groups differ, though).

For Facebook, e.g., not having this mechanism, only pictures uploaded as public are transferred. In the questionnaire, 55% were very positive towards the automatic addition of status updates in their Facebook accounts and several of them requested an even tighter connection with the IYOUIT application.

Trends throughout the Study

We also tried to spot trends and changes in attitudes during the course of the study. However, besides a slight general decrease in use, there were no significant changes to be observed. We cannot clearly say whether this is due to the duration of the study or the mere absence of changes.

As one example of analysis of the quantitative data we collected, we let people judge whether IYOUIT increased their communication between buddies before and after the study. The plus of 0.4 points on the Likert-scale (to 2.1, $\sigma = 1.3$) was not significant ($F = 0.71, p > .2$).

Some behavior also seems to be an individual preference, independent from the amount of use. For instance, there was no correlation between the number of photo uploads and photo tagging per user ($r^2 = 0.07$).

Some interesting results appeared with regard to thoughts about privacy. Our questionnaires before and after the study revealed that, on average, the use of IYOUIT made people more confident to share data with close family members and friends (see Figure 14). However, people also became aware that the information being disclosed can be rather delicate and detailed and the readiness to share dropped slightly for more distant relationships.

On the other side, two people acknowledged that they learned to restrict the amount of information made available and thus also became more comfortable to provide some data even to lose contacts.

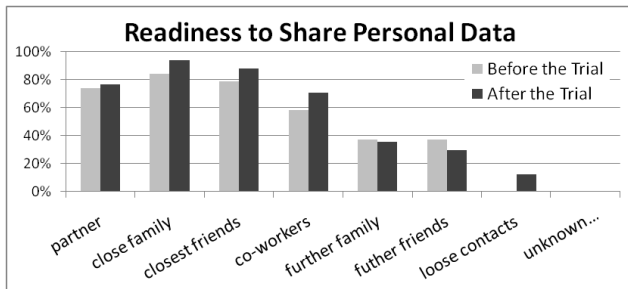


Figure 14: Willingness to share context with specific groups. People generally shared more information with family members or friends and became more careful in sharing with more distant persons.

RESULTS AND OBSERVATIONS

In the following, we distill and abstract from the study findings reported in the last sections to provide a set of outcomes that have been proven successful in the design of IYOUIT and can therefore also be relevant for those active in the area of context-awareness and social networks.

General Usage

Combining data and meta-data from various sources and with various services is an important feature, live and also after data collection (e.g. post-tagging pictures on Flickr).

Most important types of context as expressed by the users are location, pictures, weather and presence information.

Power consumption is an issue although, in our study, this had only minor impact. Still, users see which features impact battery life and should be able to turn those off.

Proactive versus Manual Actions

The concept of places has been widely understood and used. Users highly valued automatic place suggestions. In general, automatic abstraction mechanisms from raw (sensor) data proved to be an effective tool for leveraging personalized information exchange.

Automatic context tagging can relieve users from manual input. However, what the system can derive automatically must be shown, with the possibility to manually adjust it.

Automatic activity recognition needs more research before the process can (if ever) be fully automated. However, recommendations from which a user can choose can be a meaningful shortcut to express assumed presence states.

Privacy and Sharing

Explicit sharing is more subject to privacy concerns than automatic sharing: people tend to be reluctant to share manually entered information (such as mood) in detail. Automatically gathered, yet personal data (e.g. spatial information), however, has been regarded as less sensitive.

3rd party services offer high potential, especially a connection to social platforms and automated information updates provide a strong added value for users. However, the user must remain in control of what is transferred and generated content should be explicitly marked or separated.

A dedicated privacy mechanism that is accessible, understandable, and modifiable by the users is essential. Although people like to be in control and use an item-by-item strategy for some data such as images, privacy settings per type of buddy relation are accepted. Thus, we suggest changing the opinion of Consolvo et al. [6] and Lederer et al. [14] that "who is inquiring about one's location" is a strong factor to "the relation to the one who is inquiring". This implies a greater number of relationship types than available in most current systems is beneficial.

SUMMARY

We have evaluated IYOUIT, a freely available platform and mobile application for social, context-aware computing. A trial has been performed with 19 users over four weeks. Results have been presented in the categories of general acceptance and use, context sharing, context abstraction, as well as privacy and social networking. We collected and presented results in four categories about use, context sharing, context abstraction, and privacy.

We feel that this study has greatly enhanced our own understanding of context-aware social systems. In the future, we plan to further investigate and study the potential and acceptance of enhanced profiling algorithms to derive patterns about users, which promise more targeted personal services. As a starting point from a commercial point of view, 76% of the participants would accept targeted advertisements within the application. Complex derivations of suggestions and profile data will then, however, need further research to enhance their understanding and acceptance on the user side (cf. Dey and Newberger [7]).

REFERENCES

1. Ashbrook, D. and Starner, T. Learning significant locations and predicting user movement with GPS. In *Proc. ISWC'02*. 101-107. 2002
2. Bardram, J. E. and Hansen, T. R. The AWARE architecture: supporting context-mediated social awareness in mobile cooperation. In *Proc. CSCW'04*. 192-201. 2004
3. Böhm, S., Koolwaaij, J., and Luther, M. Share whatever you like. In *Proc. Workshop CAMPUS'08*. 2008
4. Böhm, S., Koolwaaij, J., Luther, M., Souville, B., Wagner, M. and Wibbels, M. Introducing IYOUIT. In *Proc. ISWC'08*, 804-817. 2008
5. Chen, G. and Kotz, D. A survey of context-aware mobile computing research. *Technical Report UMI TR2000-381*. Dartmouth College. 2000
6. Consolvo, S., Smith, I. E., Matthews, T., LaMarca, A., Tabert, J. and Powledge, P. Location disclosure to social relations: why, when, & what people want to share. In *Proc. CHI'05*. 81-90. 2005
7. Dey, A. K. and Newberger, A. Support for context-aware intelligibility and control. In *Proc. CHI'09*. 859-868. 2009
8. Fagerberg, P., Espinoza, F. and Persson, P. What is a place? Allowing users to name and define places. In *CHI'03 Extended Abstracts*. 828-829. 2003
9. Froehlich, J., Chen, M. Y., Consolvo, S., Harrison, B., and Landay, J. A. MyExperience: A system for in situ tracing and capturing of user feedback on mobile phones. In *Proc. MobiSys'07*. 57-70. 2007
10. Grandhi, S. A., Jones, Q. and Karam, S. Sharing the big apple: A survey study of people, place and locatability. In *CHI'05 Extended Abstracts*. 1407-1410. 2005
11. Györfi, N., Fábián, Á. and Hományi, G. An activity recognition system for mobile phones. *Mobile Networks and Applications* 14(1). 82-91. 2009
12. Hightower, J., Consolvo, S., LaMarca, A., Smith, I. and Hughes, J. Learning and recognizing the places we go. In *Proc. UbiComp'05*. 159-176. 2005
13. Hong, J.-Y., Suh, E.-H. and Kim, S.-J. Context-aware systems: A literature review and classification. *Expert Systems with Applications* 36(4). 8509-8522. 2009
14. Lederer, S., Mankoff, J. and Dey, A. K. Who wants to know what when? Privacy preference determinants in ubiquitous computing. In *CHI'03 Extended Abstracts*. 724-725. 2003
15. Morla, R. and Davies, N. Evaluating a location-based application: A hybrid test and simulation environment. *IEEE Pervasive Computing* 3(3). 48-56. 2004
16. Nurmi, P. and Koolwaaij, J. Identifying meaningful locations. In *Proc. IEEE MobiQuitous'06*. 2006
17. O'Grady, M., O'Hare, G. M. P. and Sas, C. Mobile agents for mobile tourists: A user evaluation of Gulliver's Genie. *Interacting with Computers* 17(4). 342-366. 2005
18. P&AB. Consumer privacy attitudes: A major shift since 2000 and why. *Privacy & American Business Newsletter* 10(6). 2003
19. Palen, L. and Dourish, P. Unpacking "privacy" for a networked world. In *Proc. CHI'03*. 129-136. 2003
20. Patil, S. and Lai, J. Who gets to know what when: Configuring privacy permissions in an awareness application. In *Proc. CHI'05*. 101-110. 2005
21. Rogers, E. M. *Communication technology: The new media in society*. 1st edition. The Free Press. 1986
22. Sadeh, N., Hong, J., Cranor, L., Fette, I., Kelley, P., Prabaker, M. and Rao, J. Understanding and capturing people's privacy policies in a mobile social networking application. *Personal and Ubiquitous Computing* 13(6). 401-412. 2009
23. Tungare, M., Burbey, I. and Pérez-Quinones, M. A. Evaluation of a location-linked notes system. In *Proc. ACM-SE 44*. 494-499. 2006
24. Zhou, C., Frankowski, D., Ludford, P., Shekhar, S. and Terveen, L. Discovering personally meaningful places: An interactive clustering approach. *ACM Trans. Inf. Syst.* 25 (3). 12-42. 2007
25. Raento, M., Oulasvirta, A., Petit, R., & Toivonen, H. ContextPhone: A prototyping platform for context-aware mobile applications. *IEEE Pervasive Computing*, 4(2). 2005
26. Jacucci, G., Oulasvirta, A., Ilmonen, T., Evans, J., & Salovaara, A. Comedia: Mobile group media for active spectatorship. In *CHI'07*. 1273-1282. 2007