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Published in:
Proceedings of OzCHI 2007

DOI (link to publication from Publisher):
10.1145/1324892.1324951

Publication date:
2007

Document Version
Early version, also known as pre-print

GeoHealth: A Location-based Service for Nomadic Home Healthcare Workers

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ABSTRACT
In this paper, we describe GeoHealth - a geographical information system prototype for home healthcare workers who during a normal workday have to attend clients and patients that are physically distributed over a large geographical area. Informed by field studies of work activities and interviews with the healthcare workers, we have designed an interactive location-based service for supporting distributed mobile collaboration. The prototype explores a representational approach to context-awareness and represents live contextual information about clients/patients, co-workers, current and scheduled work activities, and alarms adapted to the users' location. The prototype application is web-based and uses Google Maps, GPS positioning, and Web 2.0 technology to provide a lightweight dynamic and interactive representation of the work domain supporting distributed collaboration, communication, and peripheral awareness among nomadic workers.

Categories and Subject Descriptors
H5.2. [**Information interfaces and presentation (e.g., HCI)**]: User Interfaces - *User-centred design, Graphical user interfaces.*

General Terms
Design, Human Factors.

Keywords
Location-Based Services, Google Maps, home healthcare

1. INTRODUCTION
Recent developments in web-based technologies and services, availability of GPS positioning on mobile and portable devices, and widespread access to broadband mobile Internet has enabled the creation of a whole new class of applications for out-of-the-office use. Combining positioning capabilities with the powers of "Web 2.0" technologies for user-generated content, open API's for geographical interfaces such as Google Maps, and mobile or portable devices with full-blooded web browsers and mature graphical interfaces, now makes it easier than ever to implement location-based services and applications for users on the move that take into consideration their location and the surrounding environment. Rather than relying on proprietary technologies owned by network and service providers, and developing closed stand-alone applications that require cumbersome installation and setup of dedicated software on peoples' devices, a web-based application approach to location-based services opens up potentials for user-driven innovation and for creating so-called "mashups" and "meshups" merging, for example, content from multiple independent data sources into novel services with user experiences that exceed that of the sum of their individual parts. These services and applications will have the capability to unleash some of the still hugely under-exploited potentials of the mobile Internet, for work as well as for leisure.

Motivated by these new technological possibilities, we have been exploring the development and use of location-based services that "augment the city" with electronic perspectives on, for example, people, places and physical surroundings delivered through mobile or portable device web browsers. These "e-Spectives" consist of meshups of sensed and user-generated information about peoples' physical surroundings that would otherwise be invisible, and explore an emerging line of thought within context-awareness where context sensing is used for generating and representing new information as an alternative to making systems automatically react to specific settings.

As a specific case for this research, we have studied work activities in regional healthcare where a group of physically distributed nurses and healthcare assistants have to make house calls to clients and patients living within a large geographical area. Supporting the nomadic collaborative work activities of these home healthcare workers, we have developed a web-based prototype location-based service, which represents live contextual information about clients/patients, co-workers, current and scheduled work activities, and alarms in a map-based interface running in a conventional web-browser on a laptop or tablet PC.

The paper is structured as follows. Firstly, we review related work within context-awareness and location-based services and position our research in relation to state-of-the art. Secondly, we introduce our case of home healthcare workers, and describe a field study of the collaborative work activities of this nomadic user group. Thirdly, we present our prototype system, GeoHealth, and how it was implemented. Fourthly, we describe a user-based evaluation of the prototype and present and discuss highlight finding from this study. Finally, we conclude on our research and point out a number of avenues for future work and work in progress.

OzCHI 2007 Proceedings, ISBN 978-1-59593-872-5

2. RELATED WORK

In this section we outline related work within the complementary areas of context-awareness and location-based services.

2.1 Representational context awareness

There has been a lot of research on context-awareness in recent years. Much of this has enabled computers to collect and formalize information about contextual factors describing, for example, the geographical, environmental, biometrical, and social setting and stage of a user. In parallel, this has inspired the use of machine intelligence to make mobile systems transform themselves accordingly and minimize need for explicit user interaction. Experiences with developing and using such systems are many, and context-awareness has proven possible within specialized domains such as healthcare, industrial process control, and tourism (e.g. Skov and Høegh 2006; Bardram 2004; Cheverst et al. 2000). However, research has also identified many fundamental problems with this approach to human-computer interaction. Even simple adaptations to context, such as the mobile phone that knows when not to ring, are extremely complex to implement, and any context-aware technology is most likely to make mistakes and take control away from the user (Brown and Randell 2004; Barkhuus and Dey 2003). In contrast, it has been stressed that while computational systems are good at gathering and aggregating data, humans are good at noticing, integrating and interpreting obvious as well as subtle cues and determining appropriate actions (e.g. Kjeldskov and Paay 2006). In response, some researchers have advocated that another way to deal with complex and ambiguous context information is to actively involve the user (Dey and Mankoff 2005) and make humans, not machines, the consumers of context information by representing it in the interface rather than automatically adapting to it (Edwards 2005; Aaltonen and Lehikoinen 2005). As a fictive example, a representational context-aware service for socializing in the city would display collected context-information about activities, people and places but leave interpretation and decision-making on the basis of this information to the user rather than to the computer. Real examples of systems adopting this representational approach are still very few but also very promising. As examples, Paulos and Goodman's jabberwocky prototype (2004) use detected patterns of nearby Bluetooth devices over time for visualizing "familiar strangers" in the users' vicinity, and Erickson et al.'s Babble prototype (2002) visualize "social proxies" based on the presence and activities of nearby people. In a more recent study, Lemmelä and Korhonen (2007) use geographical context information, gathered from salient keywords within public "geo-postings", to visualise physical clusters of similar places on a digital map, such as areas with a high occurrence of the key word "restaurant", shopping", "art" or museum". Common for these systems is that they are context-aware but use their awareness to generate new information rather than trying to reduce it. It is also common that they have a particular element of *location* awareness.

2.2 Location-based services

One of the most promising aspects of user context for a mobile or portable computer system to respond to is *location* (e.g. Jones et al. 2004; Kaasinen 2003). As a specific subset of context-aware systems, location-based services represent an emerging class of computer systems providing mobile device users with information and functionality that is particular relevant at a specific geographical location or within a specific distance. Within recent years, this class of mobile or portable computer systems have received increasing attention from researchers within areas such as computer science, human-computer interaction, and interaction design, as well as from software industry. However, examples of commercially available location-based services are still very few. Most are restricted to SMS-based services broadcast to subscribing mobile phone users in particular areas, but recently some services that integrate wide-area broadband wireless Internet access, web resources and geographical information have begun to emerge for PDAs and "smart phones" with GPS and other positioning capabilities.

Yet developing successful location-based services is not trivial. It inherits challenges of context-awareness described in the literature, such as issues of user control, privacy, and determining people's location in physical space, as well as introducing new ones. Given the novelty of location-based services, and of representational context-aware systems, little is known about people's use of such of services, how to design them well, and what is (and isn't) useful. It is unknown how users perceive and use information provided through a location-based service, what content is considered relevant (and what is not), and how people will adopt and appropriate information services that react to their location and combine, for example, web content, satellite imaging, and cartography. Hence, more research is needed into the development and use of location-based services for different purposes within various domains. Through the case study presented below, we aim to make a contribution to this area.

3. FIELD STUDY: HOME HEALTHCARE

Home healthcare is a subset within the healthcare domain where patients and clients are treated or attended to in their own homes rather than at a hospital or a clinic. Home healthcare nursing and assistance is mostly used for aiding elderly people, or people with disabilities, who with this nursing or assistance are then capable of taking care of themselves in their everyday lives. It is also often used as a means of follow-up treatment subsequent to periods of hospitalisation. Making house calls to clients and patients obviously requires nurses and healthcare assistants to be mobile within a specific geographical area "nomadically" moving their location of work from place to place throughout the day. It also requires them to be physically distributed from their co-workers, while still collaborating on shared tasks coordinated through division of labour, shared plans, and ongoing communication.

With the purpose of exploring the design of a location-based service for nomadic healthcare workers, we conducted an empirical field study of work activities in the municipality of Aars in Denmark. The study was done using a rapid ethnography approach (Millen 2000) involving a combination of observations of current practice, contextual interviews, and semi-structured interviews. The study involved 10 healthcare assistants and 11 nurses with different levels of experience with the work domain, and resulted in 17.5 hours of audio data accompanied with field notes and digital photographs. Findings from the study were verified through subsequent meetings with the staff.

The focus of the study was to enquire into the characteristics of the distributed work activities and the collaboration between the healthcare workers. For example, we were interested in knowing who needs what information when and where, how division of labour is negotiated, assigned, represented, and managed, how an individual workday is structured (and restructured), what happens in case of events out of the ordinary, what information is kept as a permanent record for later use, what communication goes on between the distributed workers throughout the day, etc. Furthermore, we wanted to identify potentials for supporting work activities, collaboration, and communication by means of a location-based service representing key contextual data in a geographical interface.

Data from the field study was analysed through a process of grounded coding and affinity diagramming of higher-level themes. On the basis of the field data, we also created four different personas describing key characteristics of prospective users, their work activities, goals and habits with the purpose of serving as hypothetical archetype users for the design team. Finally, we created a number of physical models (Beyer and Holtzblatt 1998) of the workspaces of nurses and healthcare assistants illustrating how they operate during a typical workday around the municipality.

3.1 Findings from field study

In the observed municipality, home healthcare involves two types of healthcare workers: nurses and healthcare assistants. The nurses have overall responsibility for the treatment of patients, and are also the ones who administer medicine to patients at their homes. The healthcare assistants are responsible for the daily treatment of clients and patients, and also serve as "daily observers" reporting back to the nurses in case of, for example, side effects to ongoing medication Currently, the nurses and healthcare assistants use a series of information artefacts (paper-based) and communication technologies (mobile and landline phones) for carrying out their work and for coordinating and communicating with each other.

The healthcare assistants have a rather pre-planned workday. They each have a specific schedule for visiting assigned clients and patients at particular times and in a particular order. The division of work assignments happens in central meetings, but is sometimes also altered temporarily by the healthcare assistants during a day if something out of the ordinary comes up. Supplementing the day schedule, they carry specific task lists for the care taking of each client or patient including, for example, shopping lists for groceries. In addition to this, they carry a paper notebook used to jot down needs for changes to the services or schedule, which are then entered in to the permanent record at the central office by a manager after the shift. Finally, the healthcare assistants carry sheets of paper for documenting mileage, which is used for compensating the use of private cars for work purposes.

The nurses' workdays are more ad-hoc than the healthcare assistants'. Rather than a pre-planned schedule of visits, each nurse carries reference sheets for all his or her assigned patients in the district. These sheets contain personal information, phone numbers for the general doctor or practitioner, overview of health conditions, remarks on treatment and things to be aware of, diagnosis, phone numbers for relatives, lists of nursing tasks, and practical information such as the location of the key the patients' homes. They also indicate what times the patients are usually visited by nurses or healthcare assistants during the week. Every morning the nurses look through their reference sheets, pick out the patients they are supposed to visit that day, and transfer this information to the corresponding page in their calendar. However, rather than making a precise timed schedule for the day, the day-view functions more as a loosely scheduled to-do list with a few notes. In addition to their reference sheets and calendars, the nurses carry paper notebooks in which they register changes to the treatment and/or medication of patients, which they then enter in to the permanent record later at the central office. Finally, the nurses also register private car mileage for compensation.

In order to facilitate collaboration between individual healthcare workers, the healthcare assistants and nurses share a series of paper-based records located either at the individual clients or patiens or at the central office. These records function partly as repositories of information on treatment for documentation purposes, and partly as media for asynchronous communication between workers and between shifts. Firstly, each client or patient have an individual paper-based "book" located at his or her home containing observations on, treatment, notes on medication, etc. used for general "all-to-all" information and communication between healthcare workers, the client or patient, and their relatives. In addition to these client-/patient-books, medicated patients have a paper-based medical prescription located with their medicine for the week, which is used by the nurses to administer correct medication, and to communicate changes to a patient's dosages. Secondly, the healthcare assistant and nurses collaborate and communicate through paper-based records in the so-called "district folder" located at their central office. These records complement the individual client-/patient-books with more detailed information that is not suitable for public view but relevant for care taking and treatment. Obviously, client-/patient-books and the district folder contain redundant information, and the healthcare workers cannot be sure which one is most up to date. Thirdly, the nurses collaborate with each other, and with nurses and doctors outside the home healthcare organization (e.g. at nearby hospitals or clinics) through their clients' and patients' official medical records. These are currently located physically at the central office, but are increasingly in electronic form and accessible from all over the country.

In addition to coordinating their collaborative efforts through shared written notes and records, the nurses and healthcare assistants also make extensive use of direct synchronous communication. When distributed throughout the municipality, this is primarily done through mobile and landline phones. All nurses are equipped with mobile phones, making them immediately reachable in case of an emergency situation. The healthcare assistants do not have mobile phones but communicate by means of their clients' and patients' landline phones, and thus have to estimate the whereabouts of each other before making calls. The nurses and healthcare assistants make three kinds of synchronous communication. Firstly, they inform co-workers (healthcare assistants, nurses, physiotherapists, janitors, staff at the central kitchen, etc.) about progress (or delays) in their work schedule, which may influence the work of others. This could be, for example, when a healthcare assistant has finished bathing a client, who is then ready for the nurse. It could also be in the event that a patient is suddenly hospitalised and thus does not need food delivery or assistance at home. Secondly, the healthcare assistants sometimes call each other to negotiate ad-hoc temporary reassignments of work tasks in the case of something happening out of the ordinary. Thirdly, and perhaps most importantly, the healthcare workers communicate orally in emergency situations, which are usually triggered by patient alarms. When a client or patient triggers their alarm button (situated centrally in their home), the alarm is directed to a dedicated “emergency phone”, which is carried one of the healthcare assistants. This person then has responsibility for responding to the alarm, and for delegating dispatch to the closest healthcare worker. This is done by making a series of phone calls from the closest landline; first to the place of the alarm in order to assess the situation, and then to the colleagues who is believed to be closest o the client/patient in need. Eventually, a worker is dispatched to the alarm. In special situations, particular patients may have their alarm buttons set up to go directly to the mobile phone of their assigned nurse.

From our field studies, it is clear that the way collaboration and communication is currently carried out in the municipality have a series of enablers as well as challenges for doing their work. On the positive side, the lose mechanisms for ad-hoc exchange of work tasks among healthcare assistants makes it easy for the workers to respond to events out of the ordinary. Access to shared repositories of information at the clients’ and patients’ homes, as well as at the central office, makes it possible to coordinate treatment among co-workers, and communicate relatively easily between shifts. Finally, allowing the nurses to structure their own workday allows for ad-hoc responses to the immediate needs of the patients, and for assisting each other if needed. On the negative side, firstly, the use of paper-based notes and records requires double registration of information (first in the paper notebook and then in the official records). It also means that there is a significant delay between the time information is registered and the time of availability to co-workers. Having several parallel paper-based records with overlapping content also introduces an uncertainty about what information is the newest. Secondly, basing communication among the distributed and nomadically mobile healthcare assistants on phone calls between physically anchored landlines, introduces a huge level of uncertainty and inefficiency. Important messages may not reach their recipients in time, and may never be communicated in the first place because of doubt about where to call. In terms of alarms, valuable time may easily be lost in the process of locating and dispatching the closest healthcare assistant or nurse.

4. THE “GEOHEALTH” PROTOTYPE

Informed by our field observations, we designed and implemented a functional prototype, GeoHealth, which supports distributed and mobile collaboration through representation of live contextual information about clients, co-workers, current and scheduled work

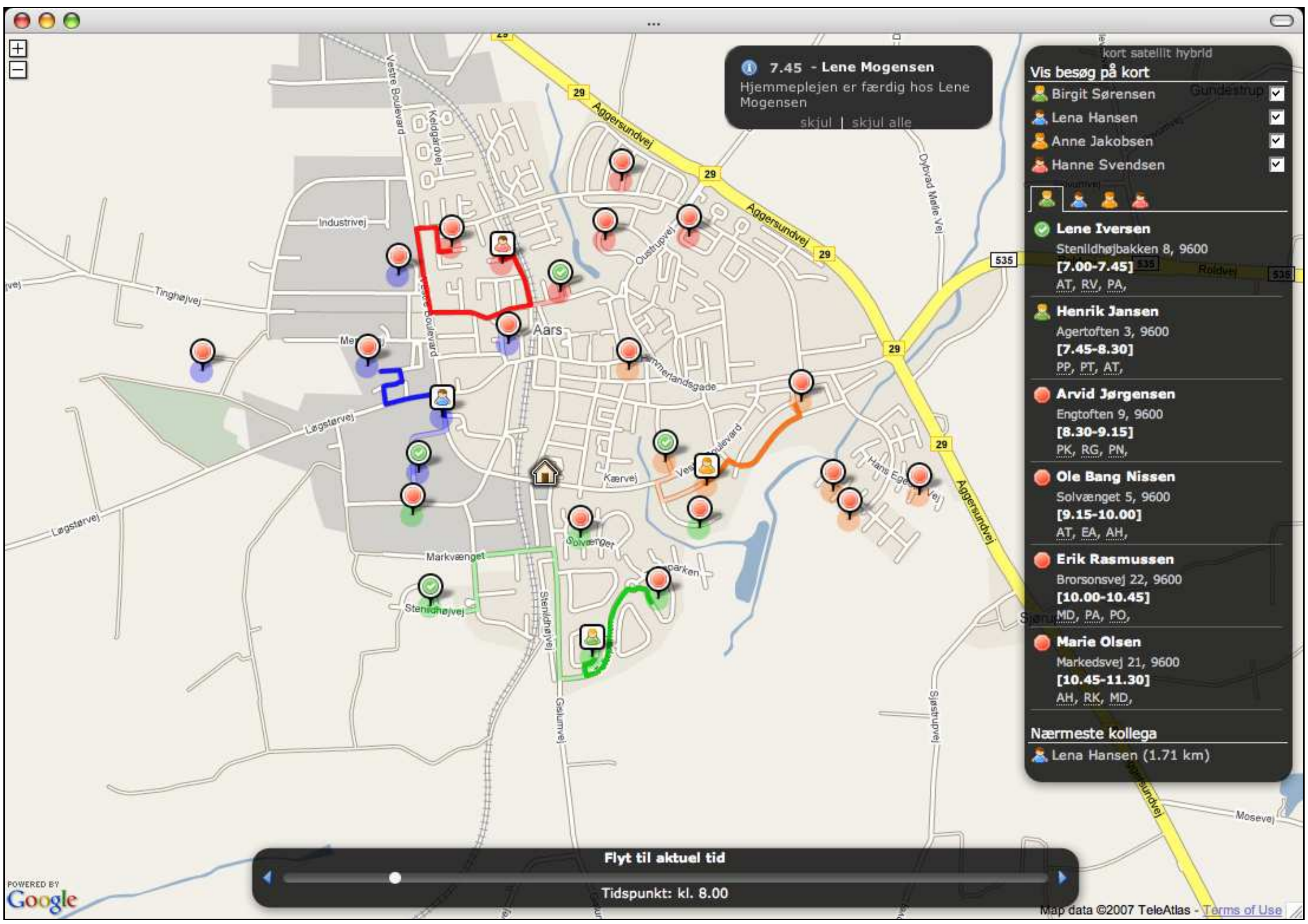

Figure 1. The main screen of the GeoHealth prototype system with the layers of four healthcare workers’ clients, routes and current location enabled. In the palette on the right, the user can see her own scheduled work tasks and keep an eye on which colleague is closest to her. Using the timeline below the map, the user can “fast forward” into the future and see how the schedules for the day will unfold according to plan, or “rewind into the past” to see where people have already been today.

activities, and alarms adapted to the users' location. The prototype explores new technical opportunities for the creation of highly dynamic multi-user location-based web-applications through a combination of Web 2.0 technology, GPS positioning, interactive map/satellite image overlays and mobile Internet access. The GeoHealth prototype was developed through a semi-structured process for moving from ethnographic data towards user interface design, involving activities of design sketching, paper prototyping and technology exploration (Paay 2007).

The basic idea behind the GeoHealth system was to provide the home healthcare workers with an interactive graphical representation of their shared and individual work domains embedded into a digital map. Within this representation, the workers should have direct access to key information about their patients, scheduled tasks, and the location and activities of their colleagues. At the same time, the system should be able to function as a medium for text-based as well as spoken communication, facilitate easy ad-hoc exchange of work tasks, and it should function as a graphical interface to the existing patient alarm system replacing needs for making phone calls. We also wanted to facilitate spoken communication through VoIP, and automate mileage registration for private car use.

It was our intention to make the system context-aware in the sense that it would know the whereabouts and activities of its users, the patients, and scheduled work assignments. However, rather than using this information to make the system "intelligently" suggest to the users what to do, we wanted to represent the context information in the interface and leave the capability of intelligence to the users. Hence, the GeoHealth system deploys *active* context-awareness in the sense that it pushes information to the user when, for example, he or she enters the vicinity of an assigned patient, or if a patient alarm is triggered nearby. However, leaving the user in control, the system also deploys *passive* context-awareness in the sense that pushed context information appears discretely within the interface, and goes away again automatically if the user does not act on it.

The functionality of GeoHealth can be divided into four themes, which are described in detail below: 1) spatial view of the work domain, 2) information tailored to location, 3) ad-hoc exchange of work tasks, and 4) alarms directed to the closest person.

4.1 Spatial view of the work domain

The primary functionality of GeoHealth is to provide the distributed healthcare workers with a spatial view of their work domain. This is done by plotting the locations of clients and patients, the location of healthcare workers (tracked via GPS), and their planned routes for the day, on a full-screen map of the municipality (figure 1). The map can be navigated by means of dragging it left/right and up/down. Zooming and toggling between map view, satellite view, and hybrid view (satellite images with superimposed map information) is done through on-screen controls. By clicking on a client or patient on the map, a call-out box appears with access to all the information available about this particular person (which used to be distributed on different paper-based records) and with functionality for taking notes (figure 2). Through this box it is also possible for the nurses to make changes to medical records, treatment etc. Changes and new information are immediately available to co-workers. Clicking on a telephone number listed in the patient records initiates a SkypeOut call. By clicking on a co-worker on the map, it is possible to initiate a Skype call to this person's laptop.

Layered on top of the map are two semi-transparent control panels. The one on the right contains a list of co-workers, with colour-coded people-icons matching the colour of their assigned clients/patients and routes on the map, as well as a tabbed list of assigned work tasks. Using the check box across from each worker, the user can turn on and off the view of this persons' information layer on the map. In the tabbed list of work assignment, the user can see his or her tasks for the day, with names, addresses, and letter codes for treatment, as well as the tasks of co-workers. For healthcare assistants, the list is presented as a time schedule while for nurses it is a to-do list with no exact times. For each client or patient in the list (and on the map) there is an icon indicating his or her status of treatment for the day (e.g. done, ongoing, pending, unavailable, emergency, etc.). The order of the list is determined ahead of time but can also be altered ad-hoc by dragging an entry to a different position. Changing the order of visits immediately changes the suggested route on the map accordingly, and hence this can also be used as a dynamic planning tool for obtaining an optimal sequence of visits. In the bottom part of the control panel the user can monitor which colleague is closest by in case of need for assistance. Next to the control panel, short predefined or free text messages may appear from colleagues reporting, for example, that they are done with the treatment of a particular patient. The control panel in the bottom of the screen contains a timeline enabling the user to "fast forward" into the scheduled plan or "rewind into the past" to see where people have already been today.

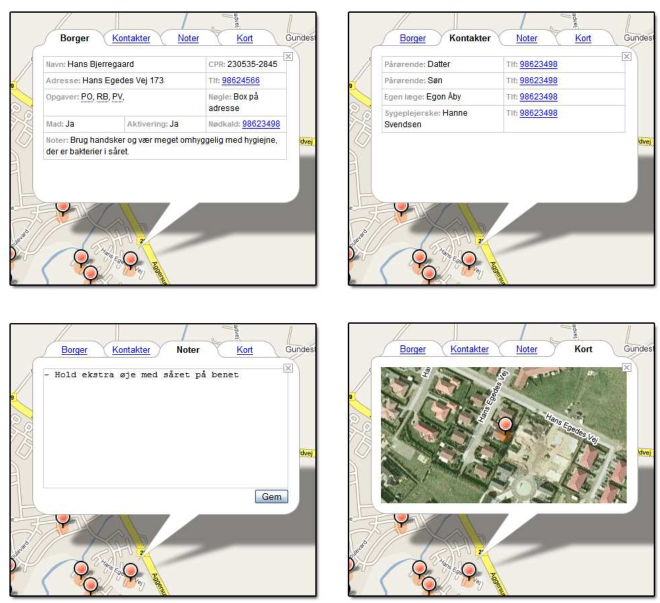

Figure 2. Four different views of client/patient information: 1) medical record, 2) contact information, 3) notes on treatment, and 4) satellite image and map details of home location

4.2 Information tailored to location

In addition to facilitating information "pull" about the work domain through the map representation and call-out boxes, the system also "pushes" information on the basis of location and assigned work tasks. However, rather than prompting the user with intrusive information screens, information push is done gently through changes to the map representation and appearance (and disappearance) of information. Firstly, the map view moves automatically when the user comes close to the edges, and icons change automatically in accordance to co-workers progress throughout the day. Secondly, when a healthcare worker drives into the vicinity of an assigned client or patient, the call-out box for this client or patient automatically pops up on the map (figure 3) making information about the upcoming visit ready at hand. In addition to the information currently available on paper, one of the tabs contains a close-up satellite image of the client or patients' address (figure 2, bottom right) facilitating way finding through reference to physical attributes of the environment (e.g. the colour of roofs, density of houses, presence of trees, etc.). Leaving vicinity of a client/patient makes the box disappear again.

Figure 3. Information box appearing automatically when a healthcare worker drive into vicinity of a clients' home

4.3 Ad-hoc exchange of work tasks

Apart from facilitating reshuffling of ones' own work tasks, the GeoHealth system also facilitates easy ad-hoc exchange of work tasks from one healthcare assistant or nurse to another during a workday. Exchange of a work task is done in the map view by simply dragging a client or patient icon onto the icon for another healthcare worker and then dropping there (figure 4). By doing this, the visit to that particular client or patient will disappear from one healthcare workers' list of tasks and appear on the other's. Moving a work task on to a co-worker also triggers a predefined text notification to appear on this person's screen. Hence, rather than forcing users through tedious formalized procedures for negotiation and confirmation, this design relies on trust, professionalism and social conventions for collaboration. Although not technically necessary for reassigning a work task to another colleague, this process of ad-hoc exchange is thought of as combined with a Skype call for verbal agreement between the healthcare workers involved.

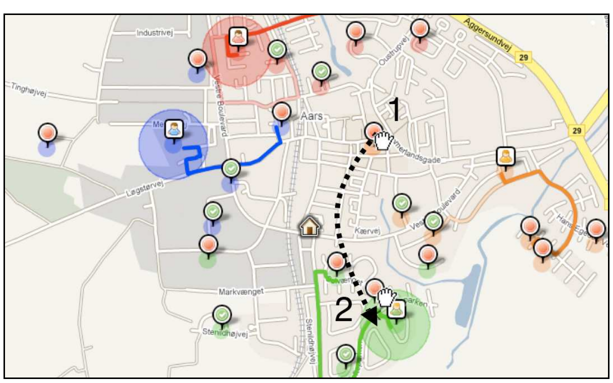

Figure 4. Ad-hoc exchange of work tasks by dragging a client or patient symbol onto another healthcare worker

4.4 Alarms directed to the closest person

Replacing the use of mobile and landline phones for negotiating responds to alarms, GeoHealth embeds alarms into the spatial view of the work domain, and uses the ongoing GPS positioning of the healthcare workers to automatically direct the alarm to the nearest person. Hence when an alarm is triggered, the closest healthcare assistant or nurse receives a pop-up message on their screen, and the location of the alarm and nearby colleagues is highlighted on the map (figure 5). If assistance is needed, the nearby colleagues can then be contacted via Skype. For the co-workers further away, the alarm is indicated by means of its location on the map, and a notification of which person the alarm has been delegated to. In the event that the closest healthcare worker is not able to respond, he or she can reject the alarm by which it is directed to the second closest person, and so forth.

Figure 5. Home alarm appearing as a pop-up message on the closest healthcare worker's screen along with information about location of nearby colleagues

4.5 Implementation

The prototype system was implemented using web technologies and languages such as XHTML, CSS, JavaScript, and Ajax, thus allowing the healthcare workers to interact with the system through a web browser. The server-side component was implemented on a Debian Linux system, an Apache web server, a MySQL database server, and the PHP scripting language engine.

The user interface is built on top of Google Maps embedded into a web page in full screen. The floating palettes are made from layered XHTML, which is dynamically updated using JavaScript. The engine used to run the interface was created using object-oriented JavaScript and asynchronous XML requests, which makes the user interface independent of page reloading and improve possibilities for interactivity and system responsiveness to user interaction both locally and remote. In popular terms, Ajax provides a framework that allows developers to create desktop-like application for the web by relying on XML for data transport "behind the scenes" of the graphical interface and thereby enabling the user to interact with a web-application while it is requesting or processing data in the background.

The information layers superimposed onto the map are constructed from markers and polylines. The locations of clients on the map are calculated on the basis of their addresses' latitude and longitude coordinates provided through a look-up in the

Address Web Service (AWS) provided by The National Survey and Cadastre of Denmark, which contain the geographical coordinates of all addresses and in Denmark. Routes between addresses on the map are generated on the basis of a look-up in the Google Maps directions service, which return a KML file with coordinates following the road network. All requests to AWS and Google Maps directions are done through the Ajax engine.

The client parts of the application communicate with each other via a central database and a web server. However, unlike a conventional web site or web application, all requests to the web server are done through the Ajax engine and are requests for XML data rather than whole pages of XHTML.

Applications based on Google Maps, like this one, are quite demanding on download bandwidth for graphics. For a map of 1700 x 1200 pixels, each zoom level requires 200Kb-1Mb of data depending on view mode (map, satellite or hybrid). Since bandwidth on the mobile Internet is still a rather scarce and expensive resource in areas covered only by GPRS or 3G networks, the GeoHealth prototype system caches all data from the Google Maps imagery server locally on the client through a proxy server set-up. Thereby, maps and satellite images are only downloaded to the client once (until updated on the server), and the response time of the application is improved significantly.

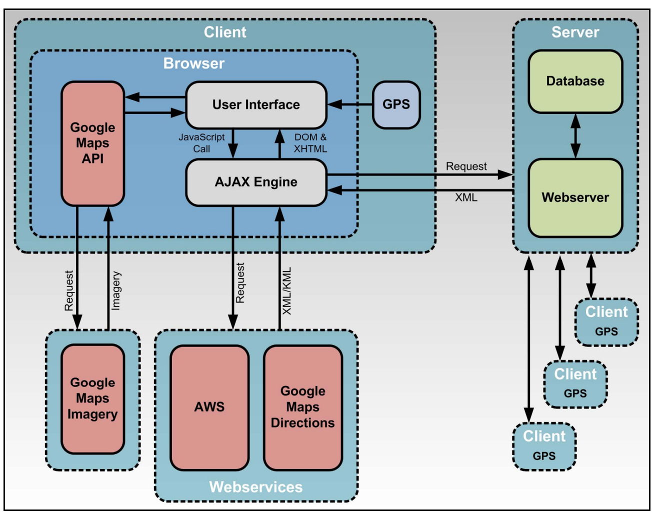

Figure 6. The technical architecture of the prototype system

5. EVALUATIONS

The GeoHealth prototype system was evaluated through field and laboratory studies involving nine healthcare workers. The evaluations took place in the municipality of Aars, Denmark. The evaluation sessions were structured by task assignments prompting the users to interact with particular parts of the system. During the evaluation sessions, the users were asked to think-aloud and respond to a series of interview questions about their perception, interaction, and use of the system.

The purpose of the field evaluation was to investigate into the use of the prototype system in realistic surroundings spread around the municipality. For this purpose, we installed a laptop computer with GPS in a minibus equipped with video and audio recording equipment (figure 7), and then let the healthcare workers use this vehicle to visit locations on their normal routes. As we were not interested in the issues related to interacting with the system while driving at this time of the project, all interaction took place while the vehicle was not in motion. The time used to drive from location to location was spent on follow-up questions and general discussions about the use of the system. Due to lack of resources in the healthcare domain for the purpose of exploratory studies like this one, we were only able to conduct three sessions in the field. In response to this, we carried out a series of laboratory studies with the purpose of supplementing the field evaluation with more empirical data without interfering with the work activities in the municipality, and without demanding too much of the healthcare workers' time. For this purpose, we set up a temporary laboratory in a dedicated room at the healthcare workers' central office, in which they could interact with the prototype system while seated at a desk.

Figure 7. In-car field evaluation of prototype system

The nine participating healthcare workers were all women and either employed as nurses or healthcare assistants. They were between 32 and 53 years old, and had 6 to 28 years of experience with their job. Most were experienced users of IT but one user characterized herself as a novice and one as an expert. All evaluations were recorded on digital video showing the users and their interactions with the system. In addition, the prototype screen was captured to a movie file through a screen logging utility. The evaluation sessions in the field took 30-40 minutes while the sessions in the lab took 25-30 minutes. For ethical reasons the evaluation did not involve real patients or patient data but was based on fictive data and scenarios informed by our ethnographic studies of the domain. Video data from the evaluation sessions underwent content analysis by two independent researchers, who then merged their observations into a coherent set of codes. These codes were subsequently affinity diagrammed into themes on higher levels of abstractions leading to the creation of 8 overall categories of findings. Below, we present and discuss highlights from these.

6. FINDINGS AND DISCUSSION

From our evaluations it was clear that the users understood the basic design of GeoHealth and were able to interact with its basic functionalities after very short time. The users understood the map representations and the floating control panels (icons, colour coding etc.), as well as the close relationship between them. They also expressed that the spatial and temporal/sequential representations of work tasks complemented each other very well, and that the spatial representation gave them a good and useful overview of their own work activities and supported awareness about their co-workers without requiring too much attention. On the down side, some concerns were voiced in relation to difficulty in separation of similar coloured routes and tasks on the map (i.e.

the ones coloured red and the ones coloured orange). Obviously, this problem would increase if even more healthcare workers were to be represented at the same time, and great care should be taken when selecting a palette of possible colours. Some users also had problems with navigating and zooming on the map.

In relation to tailoring information to location, the healthcare workers were very happy with the way GeoHealth automatically presented information about assigned clients when entering vicinity of their home. It was expressed that the change of visual appearance on the screen caught attention without being intrusive, and that it was “natural” that the call-out box automatically disappeared when leaving vicinity. Nobody expressed, and it was not observed, that this use of context-awareness information push took control away from the user. However, concern was expressed that the status of a client/patient could change simply by driving past their house, and that such automatic change should require a certain “dwell-time” at the physical location of the house. Making information and note taking facilities about clients/patients available electronically directly through call-outs on the map was received very positively, and it was confirmed that the use of satellite imagery aided navigation by means of prominent physical properties of the surroundings. However, it was also observed that the strong colours of satellite imagery sometimes interfered with the colour coding of work tasks and routes (Denmark is a very green-looking country).

In term of support for ad-hoc exchange of work tasks, all healthcare workers were able to use the drag-and-drop technique with icons on the map. The simplicity of the procedure was appreciated, and one user even expressed that doing this within a spatial representation of the work domain helped her assess which colleague to exchange tasks with based on vicinity to planned routes. On the negative side, however, some healthcare workers expressed that although they were able to understand and use the implemented interaction technique, it felt odd to be moving the icons of clients/patients to the healthcare workers on the map, since this did not match the corresponding effect in the real world (where the healthcare workers are the ones who go to the clients/patients). A suggestion was to reverse the technique, so that it is dragging a healthcare worker icon to a client/patient icon that pairs the two.

In dealing with alarms, the healthcare workers were very positive towards the visualisation and automatic prompt of the closest person. Combined with the representation of nearby colleagues, it was expressed that this would significantly ease the amount of time as well as cognitive efforts spent on coordination. In extension of the new way of communicating in relation to alarms, the healthcare workers also found that the use of text-based messages constituted a significant advantage over current practice because it eased their need for making phone calls about every little detail. However, it was also stressed that text messages should not replace verbal communication, and that access to a verbal communication channel (e.g. Skype) would be essential for complex coordination as well as for the social purposes.

7. CONCLUSIONS

We have described a geographical information system, GeoHealth, for physically distributed and nomadic home healthcare workers that combine Google Maps, GPS positioning, and Web 2.0 technology. The system is location-based, represents live contextual data about a shared work domain on an interactive map displayed in a web browser, and has facilities for communicating and coordinating work tasks among distributed users. Through a series of user-based evaluations, we have verified the overall design and functionality of the prototype system as well as identified a number of areas for improvements to its interaction design. Further work will experiment with these areas of improvements, and will also seek to apply our general design ideas, and technical platform, to a different domain of nomadic collaborative work, and to use in non-work settings.

8. ACKNOWLEDGMENTS

The authors thank the home healthcare unit of Aars for their participation throughout the project.

9. REFERENCES

[1] Aaltonen, A. and Lehikoinen, J. (2005) Refining visualization reference model for context information. Personal and Ubiquitous Computing, 9(6): 381-394.

[2] Bardram, J. (2004) Applications of Context-Aware Computing in Hospital Work – Examples and Design Principles. Proc. SAC’04, pp. 1544-1579.

[3] Barkhuus, L. and Dey, A. K. (2003) Is Context-Awareness Computing Taking Control away from the User? Three Levels of Interactivity Examined. Proc. UbiComp 2003.

[4] Beyer H, and Holtzblatt, K. (1998) Contextual Design. Morgan Kaufmann, San Francisco.

[5] Brown, B. and Randell, R. (2004) Building a Context-Sensitive Telephone: Some Hopes and Pitfalls for Context Sensitive Computing. CSCW, 2004(13): 329-345.

[6] Cheverst, K., Davies, N., Mitchell, K., Friday, A. and Efstratiou, C. (2000) Developing a Context-Aware Electronic Tourist Guide: Issues and Experiences. Proc. CHI 2000.

[7] Dey, A. and Mankoff, J. (2005) Designing Mediation for Context-Aware Applications. TOCHI, 12(1): 53-80.

[8] Edwards, W.K. (2005) Putting Computing in Context: An Infrastructure to Support Extensible Context-Enhanced Collaborative Applications. TOCHI, 12(4): 446-474.

[9] Erickson, T., Halverson, C., Kellogg, W. Laff, M. and Wolf, T. (2002) Social Translucence: Designing social infrastructures that make collective activity visible. Communications, 45(4): 40-44

[10] Jones, Q., Grandhi, S.A., Terveen, L. and Whittaker, S. (2004) People-to-People-to-Geographical-Places: The P3 Framework for Location-Based Community Systems. CSCW, 2004(13): 249-282.

[11] Kaasinen, E. (2003) User Needs for Location-Aware Mobile Services. Personal and Ubiquitous Computing, 7(1), 70-79.

[12] Kjeldskov J. and Paay J. (2006) Public Pervasive Computing: Making the Invisible Visible. IEEE Computer 39(9): 60-65.

[13] Lemmelä, S, and Korhonen, H. (2007) Finding Communication Hot Spots of Location-Based Postings. Proc. CHI 2007 work-in-progress, pp 2549-2554.

[14] Millen, D.R. (2000) Rapid ethnography: time deepening strategies for HCI field research. Proc. DIS 2000, 280-286.

[15] Paay, J. (2007) From Ethnography to Interface Design. In J. Lumsden (Ed.), Handbook of Research on Mobile User Interface Design and Evaluation. Idea Group, Inc.

[16] Paulos, E. and Goodman, E. (2004) The Familiar Stranger: Anxiety, Comfort and Play in Public Places. Proc. CHI 2004, pp 223-230.

[17] Skov, M. B. and Høegh, R. T. (2006) Supporting Information Access in a Hospital Ward by a Context-Aware Mobile Electronic Patient Record. Personal and Ubiquitous Computing, 10(4): 205-214.