Peripheral Display for Multi-User Location Awareness

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Abstract— **An important aspect of Ubiquitous Computing (UbiComp) is augmenting people and environments with computational resources which provide information and services unobtrusively whenever and wherever required. In line with the vision of UbiComp, we have developed a multi-user location-awareness system by following a user-centred design and evaluation approach. In this paper, we discuss the development of the system that allows users to share informative feedback about their current geographical location. Most importantly, the proposed system is to be integrated in the smart-home environment by portraying location-awareness information on a peripheral display. The proposed system can be used by various users, for example family members, relatives or a group of friends, in order to share the information related to their locations and to interact with each other.**

Index Terms— **Location awareness, Ubiquitous Computing, Calm Technology, Global Positioning System (GPS), Tracking, Focus group, Interviews**

I. Introduction

According to Mark Weiser's vision of Ubiquitous Computing (UbiComp), the trend is to move away from the traditional desktop computing paradigm, to integrate seamlessly with the environment, augmenting people and their environment with computational resources which provide information and services unobtrusively whenever and wherever required [1].

The UbiComp paradigm, where computers are everywhere, calls for new technology that prevents humans from feeling overwhelmed by information. 'Calm technology' implements this idea by putting computers in the periphery of our attention until needed [2]. Calm technologies easily and seamlessly move from the periphery of someone's attention and back again when appropriate. In this way, peripheral displays can convey non-critical information, but not distract or burden its users.

In line with this vision of ubiquitous computing and calm technology, several projects such as AMI [3], Interactive Workspaces [4] and CHIL [5] envisage systems that, rather than being used as a tool, support human-human communication in an implicit and unobtrusive way, by constantly monitoring humans, their activities and their intentions.

Traffic congestion is increasingly a problem around the world. So there is increasing scope for being delayed by congestion, due to the numbers of vehicles or due to an accident. When we are on a car journey, family members, friends and colleagues may want to know where we are. They may also wish to know if we are alright, making adequate progress and be able to interact (exchange messages) with us.

A few years ago we had to depend on our sense of direction and paper maps while travelling. Today many of us cannot imagine driving without a Satellite Navigation or a Global Positioning System (GPS). GPS is not only able to be used to locate unknown places, but also can be used to provide location-awareness information of its carrier.

This research raises some security concerns but we contend that there is a good tradeoff between the benefits we can get from this technology and disadvantages of being tracked by someone else. Within the family, tracking can be perceived as a positive step [6]. For instance when a member of the family is traveling at a busy time or in a bad weather, it is good to know that someone has reached their destination safely.

There are automatic algorithms and systems which use data gathered from phone calls, sensors embedded in, near or above the road surface or using GPS receivers in some cars themselves, called probe vehicles [7]. In addition there are a variety of Intelligent Transport Systems which attempt to help manage traffic and provide information to travelers [8]. However these systems are limited by the geographic spread of the

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sensors or the number of probe vehicles. So an entire country cannot be covered. In addition these systems do not cover a single person. This motivates our research and the development of the location-awareness system presented in this paper.

We develop a system which supports the sharing of positional data amongst users carrying GPS enabled devices. It is also possible to support non-GPS enabled devices if the user is prepared to input position data manually on an interactive map. Most importantly, the proposed system is to be integrated in the smart-home environment by portraying location-awareness information on a peripheral display. We have not been able to identify a product which would provide a similar level of functionality to that of our system. There are many GPS tracking solutions available on the market at present, but existing systems are mainly associated with some designated GPS receiver hardware which reports position to a server and then positions may be viewed using a computer browser, or are limited to given hardware. The scope of functionality in many cases is very limited and based on one-way communication. None of the systems we investigated was able to share positions with a smart display (in a smart-home environment) to display positions.

The rest of the paper is organised as follows: Section II reviews the technological background; Section III discusses the development of the proposed system. This section also describes the requirements captured using a user-centred design and evaluation method; Section IV presents the results of an evaluation of the system in terms of a user evaluation and a comparison of the system to other similar systems. Finally Section V concludes this paper and outlines our future work.

II. Review of Existing Systems

A Global Positioning Systems and Mobile Data Modems

Part of the technological infrastructure chosen to find location and time are Global Position System (GPS) receivers and mobile data modems. GPS receivers are increasingly being used in consumer applications such as navigation aids for walkers, navigation devices for boats and aeroplanes and in-car satellite navigation systems. The technology is getting increasingly cheap. In-car satellite navigation systems are fairly standard on luxury cars and are prevalent on top-of-the-range models in most categories of cars. Alternatively, in-car satellite navigation systems are available as an optional extra or can be bought as a separate item.

Mobile data modems using mobile-phone, packetised, data transmission technology using either General Packet Radio System (GPRS) (a second generation (2G) mobile phone technology) or third generation (3G) is also cheap. In addition mobile networks are widely deployed in the UK, covering most of the UK population and landmass, for example, Vodafone UK coverage map [9], Orange UK coverage map [10] and 3 UK coverage map [11].

B Incident Detection Systems and Intelligent Transport Systems

As has been outlined above there has been research and development of systems which detect incidents. There are a variety of approaches [7]: driver-based algorithms, for example correlating mobile phone calls [12]; roadway-based algorithms [13], [14]; probe-based algorithms which use GPS-equipped vehicles [15] and sensor-fusion-based algorithms using, for example, data from fixed detectors and probe vehicles [16].

As discussed above, the limitations of these systems are that they use only the extent of the deployment either of fixed sensors or the number and deployment of the probe vehicles. This cannot possibly cover a whole country. In any case they do not address the issue of the movements of a single vehicle. GPS and the mobile phone networks cover the vast proportion of the UK.

C Smart Home

There has been much research into the smart home. As will be seen below, the smart home is the embodiment of ubiquitous computing, because the computing integrates seamlessly with the environment. The smart home augments the people and the computational resources in the home provide information and services unobtrusively whenever and wherever required.

Smart-home projects falls into two types [17]:

- Non-healthcare
- Healthcare

Some examples of non-healthcare smart-home projects are briefly described, as these are the most relevant.

Mozer [18] describes the development of a system that learns the behaviour of the inhabitants of a building and controls the lighting and heating, water heating and ventilation.

Microsoft's EasyLiving project was concerned the production of an architecture and technologies for intelligent environments [19],[20]. An example is someone wants music to be played, then the system switches on the speakers, based on the location of the person [20].

The Ubiquitous Home project in Japan uses cameras and microphones in each room to record the residents; however pressure sensors are used to track the inhabitants and also to determine the position of furniture [21]. Other sensors are IR sensors which are placed in each room and at foot level in the kitchen and corridor and two radio frequency ID systems (active and passive) are used. There are appliances and visible robots in the home are controlled by the Ubiquitous Home system.

D Tracking Systems

Three systems have been identified that allow tracking of vehicles. The first is the En Route HQ app on the iPhone [22]. The second is Glympse which runs on iPhone and mobile phones running the Android and Windows Mobile operating systems [23]. The third is the TomTom Plus Buddies service [24]. Note that this paper was finalised in mid June 2010. The functionality, availability and hardware and operating systems relating to systems and software described in this subsection may have changed since mid June 2010.

At the time of writing, the En Route HQ app required an Apple iPhone 3G or 3GS [22]; the iPhone 3G and iPhone 3GS possess a GPS receiver. The trip can be viewed on any sort of Apple iPhone existing at the time of writing or on the En Route HQ web site [22]. Fig. 1 shows some screenshots of the iPhone app. En Route HQ has the ability to exchange messages between users of Apple iPhones or the En Route HQ website. The problem with the En Route HQ app, at the time of writing, is that it is limited to an iPhone 3G or 3GS for the tracking function [22]. Another problem, at the time of writing, is that only one trip can be seen at a time in a single web browser window or window tab [22].

The Glympse app requires an iPhone 3G or 3GS or a mobile phone running the Android or Windows Mobile operating systems and which have a GPS receiver for tracking [23]. In addition an iPod touch connected to Wi-Fi can be used to send a position. A person's location can be viewed, at the time of writing, using the app on an Apple iPhone, an Apple iPod Touch, Apple iPad or a mobile phone running the Android or Windows Mobile operating systems or on the Glympse web site [23]. Multiple people can be tracked using the Glympse app, which appear on different screens [23], [25]. Fig. 2 shows some screen shots of the Glympse app on an Apple iPhone. A problem with Glympse, at the time of writing, is that there is limited scope for interaction by sending messages. A message can be sent by a user of the app, when initially notifying his or her location. However in order to send another message, the location notification must be resent. There is no scope for viewers of a location either via the app or the Glympse website for sending messages back.

The TomTom Buddies service requires a TomTom satellite navigation device and linking the TomTom satellite navigation device to a mobile phone via Bluetooth. A screenshot of the TomTom is shown in Fig. 3. Two problems with the TomTom Buddies system are: the position update is not automatic and requires a user to request an update; and the system is tied to having the TomTom system.

In addition to the tracking applications mentioned above a there are a number of other multi-user location awareness systems, based around GPS-enabled mobile phones. Examples of these are as follows:

- Google Latitude [26]
- Centrl [27]
- Pocket Life and Pocket Life Lite [28]
- Look 8 Me tracking [29]
- Locus [30]
- Locc.us: [31]

Figure 1. Screenshots of the En Route HQ app from the En Route HQ website [22]

Figure 2. Screenshots of the Glympse app from the iTunes Store on the iTunes application [25]

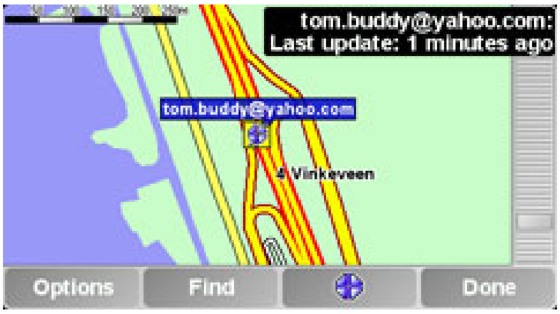

Figure 3. Screenshot of the location of a TomTom buddy [24]

III. Development of the System

We develop the location-awareness system by following a user-centred design and evaluation methodology [32]. We conducted a user study consisting of a focus group and interviews. The interest of this study was to inform the system design in order to design and develop a location-awareness system.

A Focus Groups

We established two focus groups consisting of 7 people in each with different age ranges to discuss the core requirements and most importantly, the usefulness of the system and whether they would use such a system. The merits and demerits of such a system were discussed and the participants' opinions were recorded for later analysis.

All participants of the focus group thought the idea was interesting and useful. However they all expressed concerns about the ethics and privacy of the system. The consensus was that tracking was to be on a case-by-case basis and they would not want to be tracked all the time. The results also showed that there would be some situations where users would not want to share position information and others where sharing position information would be very useful.

In addition the second focus group raised two interesting issues regarding the use of the system being used to track drivers. The first was concerns about safety using such a system while driving. The second concerned a person at home wanting to know when the driver (e.g., a family member or friend) was arriving back at home or a house where they were going to visit. This was so that the person in the house can schedule their activities, prior to the arrival of the driver.

B Interviews

The interviews were used to capture further user requirements. The interviews were held with three doctorate, two post-doctorate and two undergraduate students for one hour. A usability expert also participated in the interview sessions. The interviews were used to inform the system design and importantly, to record the missing functionality for the second stage of iteration of the user-centred design process.

C User Requirements and Design Considerations

The system provides three different user interfaces: a smart-phone solution, a web site solution and a smart-home display. The smart-phone and web solutions provide a similar level of functionality. The system allows the Web user to: register; confirm email address; invite friends; accept or refuse invitations; see friends' positions; send and receive messages, attach information to locations; set alerts on positional data; and manually set their own position. The smart-home display allows the viewing of positions messages, selection of the person to view and sending of messages from the person. As a source of GPS data, the mobile user uses the internal or external GPS receiver connected to his/her mobile device. The system protects the user against potential problems with connection and will re-establish connectivity if necessary.

During the registration process the users need to provide the system with a valid email address which is used to deliver a dynamically generated, unique link. This is required to fully activate the account and confirm ownership of specified email address. A logged-in user can use the system interface to invite friends with whom who the user would like to share positions.

The system provides a high level of privacy. Only an account owner should decide who will see his or her position. To achieve this level of privacy, the system uses invitations, which must be manually approved by the account owner. The user may see other users' positions from his friends' list only if those friends have agreed. If a mobile device malfunctions, it is possible to set the position manually using a web interface. Another functional requirement is that a user can create a number of locations with associated names which could potentially be used to create position related alerts. Additional requirements for the specific driver tracking application include information about estimated arrival time at location and reasons for delay to be supplied to the monitoring parties.

The non-functional requirements are related to cost, energy effectiveness, security and usability aspects of the system design.

Cost effectiveness - the smart-phone application requires the use of a network connection in order to work correctly. Mobile Internet is becoming more and more popular and in many cases it is included in contracts for free. The system also targets users who need to pay for their network use. Thus the amount of data sent between the client application and the server should be minimised. To further improve cost effectiveness, a periodical update should be used. This gives the user an opportunity to decide how often position data should be transferred to the server.

Energy effectiveness – because the system is operating on mobile devices, energy use is a very important matter. The system should not interfere with normal phone functions. When an application is using an internal GPS receiver it could easily lead to phone battery discharge. Because of that, periodical updates, used to save cost, could also increase battery life. The application should not use GPS hardware constantly, instead the normal state should be off with activation only for short periods of time to obtain position. In this way the system will give a user the opportunity to decide how often to update position.

Security – the system will handle confidential data, namely user position. Thus it should provide a high level of security and make sure that only selected users can have access to the data. To transfer data safely between client applications and server, SSL is used. As an additional security measure, a ticket authentication system is introduced. This reduces password traffic.

Platform compatibility – part of the system is targeted to be used on mobile devices. The system should be easily expandable to other mobile platforms available on the market. The requirement is achieved by using with XML and Web Services which are platform independent. The system stores all logic on the server side of the system. Thus all major changes are made in one single place.

Smart Home - The smart home will have Internet-connected screens in more than one room, for example in the kitchen, living room and dining room. The screens would be built into the wall. The tracking application could either be on a web page or be a web-service application. The application could display the current position, the intended route, the estimated arrival time and/or the estimated time to arrival and any messages sent by the driver. One of the major design considerations is that the display should be calm, unobtrusive and peripheral. The display could switch on by itself or display a message when one arrives. The home inhabitants could switch the display on or to the display when they wanted to check the location of the driver.

Another interaction of the system with the smart home is if there is no one home, then the heating could be automatically activated as the tracked individual is nearing home. Similarly the system on the smart-phone device could be integrated with a smart home's control system and thus at the same time as being able to reveal personal location, could also control the smart-home environment.

To be specific the requirements for smart-home display, in addition to those for the web page are that there should be that it should be calm and unobtrusive and in the periphery of someone's attention when there is no information to convey. When there is information to convey it should move to the centre of attention. So when there is nothing to report, the display should be switched off. The display could be used for other functions, for example watching TV or a DVD, playing video games or browsing the internet. Alternatively if the display is being used for anything else, then the tracking display should be minimized. When there is a message, then the display should switch on if it was off. Alternatively, if there is a message and if the display is on and it is being used for another purpose, then the tracking display should become more prominent. The information to be displayed is the position, speed and direction of travel of the driver. If known, then the destination and the intended route should be displayed. In these ways the display would be peripheral and unobtrusive.

The interactions with the display are as follows. The tracking display can be selected. There should be the option to select either the entire trip or centre the display on the current location. The display should be able to handle more than one driver, as there maybe more than one driver who is being tracked. There should be the option to switch between viewing individual drivers or see a map covering all drivers. There should be the ability to send messages to the drivers and to receive messages from drivers. The inhabitant of the home should be able to interact with the display using voice, keyboard or smart phone.

D Technologies Used

This section includes presentation of all main technologies used in the development. The system consists of three sub systems (as shown in Fig. 4) which represent different programming areas: web applications; web services; and mobile applications. All interact with each other so determination of the requirements and techniques of each was crucial to avoid interoperability problems. The sub systems and technologies used are listed below.

The System -.NET framework: There is a wide range of technologies and programming environments available, from open-source platforms to solutions provided by companies like Microsoft. Only two platforms meet the requirements of the three aspects of this development. One of them was an Open Source JAVA provided by Sun Microsystems and the other was .NET framework supplied by Microsoft. Each of them has a specific pros and cons. The system was built using .NET Framework, mainly to provide some level of similarity between code and functionality in different parts of system.

The Web Site - ASP.NET Framework 3.5: The web site was created using ASP.NET Framework 3.5 SP1 which was the latest available version released.

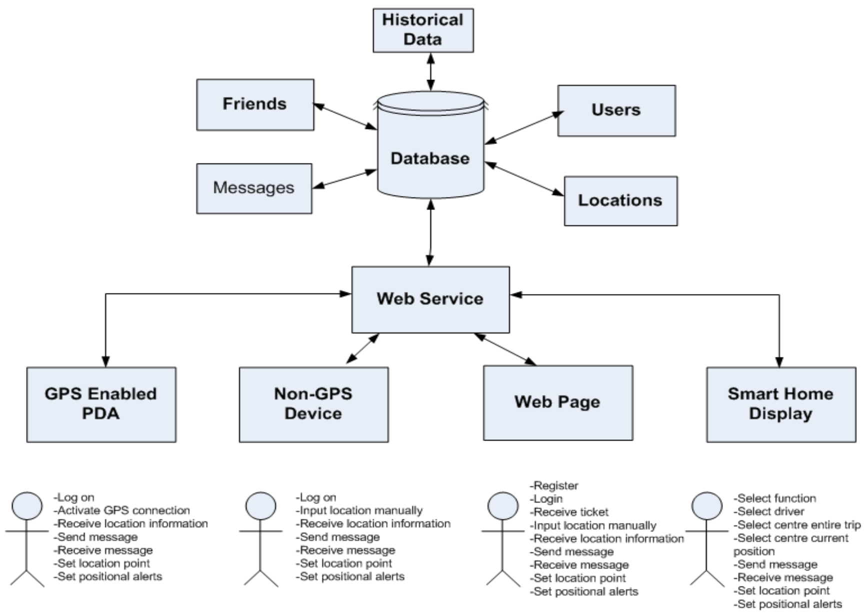

Figure 4. System Overview Design

The Mobile Application - Windows Mobile 6.1 SDK: The mobile application was developed using Visual Studio and C with Windows Mobile 6.1 SDK which brought a full mobile functionality to Visual Studio. The SDK includes a full documentation, code samples, libraries and tools – everything necessary to develop a rich mobile application. SDK libraries in conjunction with GPSID – GSP Intermediate Driver made it possible to access a GPS receiver and obtain GPS data [33].

GPSID works as an agent between the application and the GPS hardware. The main benefits of this solution are that GPSID enables use of a GPS receiver to handle multiple applications at the same time. To run the application on a smart phone, .NET Compact Framework 3.5 was necessary

The Server Functionality XML Web Services: The initial intention was to use Web Services provided by WCF – Windows Communication Foundation. WCF is an API introduced in .NET Framework 3.0 which is used to build distributed systems. Unlike past solutions WCF provides a single, unified and extendable programming object model.

Authentication - Microsoft Membership API: Security is an important aspect of the proposed system. Providing the user with a high level of privacy was one of the main concerns. Login facilities are very specific and provide almost the same scope of functionality for most of the applications. To save time and provide the developer with a high quality solution, Microsoft has included a Membership API with ASP.NET 3.5 [34]. The Membership API allows the developer to avoid repetitive implementation of authentication features and also to be sure that the used solution is bug free. It provides functionality for the most common activities like: registration, password change, password recovery, and login.

The Maps - Google Maps: This project uses Google Maps. Google Maps does not have a dedicated API for ASP.NET and so interfacing was achieved through Javascript.

The User Interfaces - ASP.NET AJAX: ASP.NET AJAX was used in this project to create user interfaces [35]. AJAX allows an application to retrieve data from the server while the user is interacting with the web site. In consequence only a selected part of interface is changed during user interaction and the user does not have to wait for the full web page to reload which creates a better experience.

Security - SSL (TLS Transport Layer Security)/SOAP Headers: Security is very important task in this project. The application will operate with confidential information such as actual user location. That why TLS was used to create a secure link between the client application and the server.

The Database - SQL Server: Visual Studio and the .NET Framework are well integrated with MS SQL Server. Use of MS SQL Server guaranteed a simplified access to diagnostics, database management and use of framework-provided security mechanisms.

Data Querying - LINQ: LINQ is a .NET Framework component developed by Microsoft that expands functionality of the .NET language by supporting the construction and compilation of data queries [36].

E System Interfaces

Fig.5 shows screenshot of the system website. As can be seen in the figure, the main content of a page is divided into two parts. On the left hand side there is a map showing users' positions; on the right hand side a vertical menu including a contact list, some additional features and messages. Graphics were limited to a minimum to reduce web page loading time. The whole layout is based on CSS (Cascade Style Sheets). Fig. 6 shows the main screen of the smart-phone interface.

In comparison with the web page, we see in Fig. 6, that the smart-phone layout is very simple, mainly due to limited amount of space provided by a mobile device. In the central point we can see a map and just below it there is a 'friend' list with scroll bar. On the top and bottom of the screen there are two status bars, 'message' and 'application'. It was not possible to provide all the functionality on the one screen. Most of the features use separate screens or partially cover the main screen.

Fig. 7 is the design for the smart-home display. The interface is designed to be interacted with by voice. It is a multifunction display; in the lower left there is the mechanism for selecting what is to be displayed, which is highlighted. The display has an area for the showing the position of one of the friends. There is also area for the messages received from the friend. In addition the text below the tracking area shows the friend list; the highlighted name is the one being the one being displayed. Below there is a means for selecting what is displayed on the map. Below that is a box for entering and sending a message to the friend. The is entered using speech input

In order to be peripheral when there is not a message and the display is not being used for other purposes, then the display could be blank. When a message arrives from the driver then an audio-alert would be played (similar to that when a text message arrives on a mobile phone). In addition the display could illuminate and the screen seen in Fig. 7 be displayed. If the display is being used for another function then the new message would appear on the screen in some way. For example the message could be superimposed in the middle of the display, or at the top or bottom of the screen. In addition the display could be integrated with a smart-home environment so that a system would sense in which room or rooms the occupants of the house were and only display the tracking screen on a display in those rooms. If the inhabitants of the house were not present in a room with a smart display, then some kind of audio alert could be played in those rooms, for example like the audio alert for a text message on a mobile phone. Alternatively something more meaningful such as a speech synthesised alert could be played for example "Message received from Adam". The inhabitants could then go to a room with a smart-home display. In these ways the display would be calm and move from the periphery to the centre of attention when required, as discussed above.

IV. EVALUATION

A Introduction

Two types of evaluation of the system were made. The first was a user evaluation of the system other than the smart-home display and separately an evaluation of smart-home display on its own. The second part was a comparison of the system to other existing systems identified in Section II D.

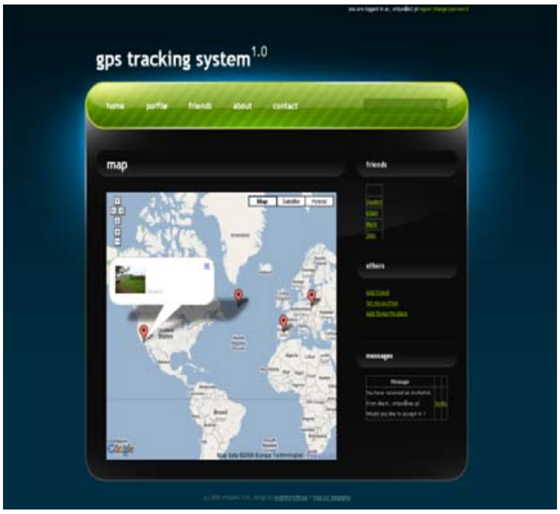

Figure 5. GPS Tracking System Web Page Main Screen

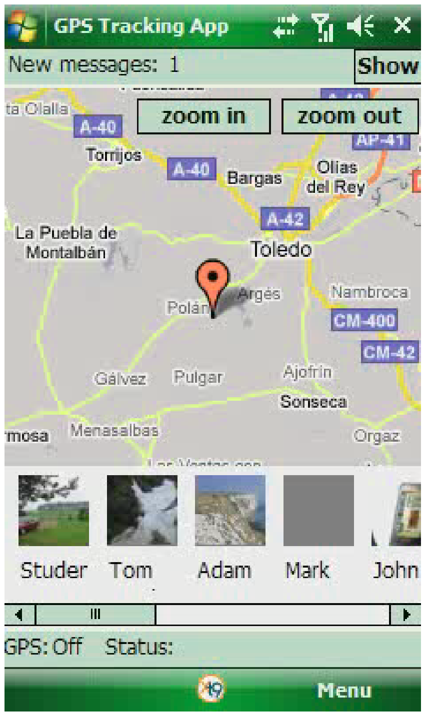

Figure 6. Smart-phone Main Screen

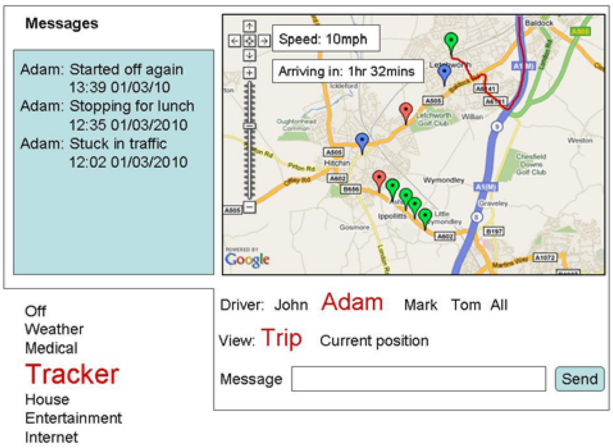

Figure 7. Smart-home Display

B User Evaluation

Both the qualitative as well as quantitative evaluation was carried out in order to test the functionality and behavior of the system as well as to test the usefulness of the system with the potential users.

The system apart from the smart-home display was tested with fifteen potential users. The users were from different age ranges. Age factor was very important to simulate potential user behaviour. All participants were from different academic and cultural backgrounds and represented various levels of IT skills.

For evaluation purposes, the system was deployed on a laptop computer and the users were connected to the same private network. In this way it was possible to test system using different computers and different browser versions. The system operated well and the user feedback was positive.

The second evaluation was conducted with ten users. All the participants were from the same academic department (Computer Science students) but from different cultural backgrounds. After the demonstration of the system (apart from the smart-home display), the users were asked the following questions. The results are shown in Fig.8.

- Is the system easy to use?
- Is the system useful?
- Would you use the system to track location and time of your family and friends?
- Would you let others track your location and time always?
- Would you let others track your location and time on a case-by-case basis?

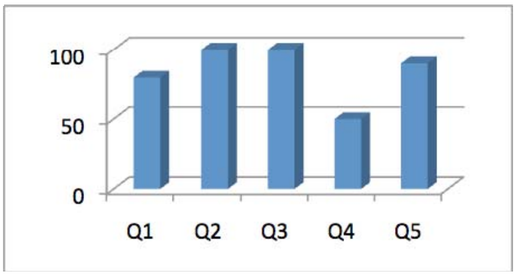

Figure 8. User Evaluation Results

The third part of the user evaluation was to interview separately a group of four potential users. The users ranged in age from 40 to 60 and consisted of three females and one male. The entire system was explained to the potential users. Then the users were shown the smart home display in Fig, 7, the functionality was explained and two potential scenarios were given involving journeys were described, which illustrate where the system may be useful. An alternate screen with a different driver just starting off, similar to Fig. 7 was shown as well as an alternative design to Fig. 7. The questions asked were:

- In general do you think all the information is there which you require?
- Do you think the idea of using speech input is a good idea?
- What do you like about the display and what don't you like?
- What do you think is best: Showing the route (planned) taken as:
  - A series of the position markers?
  - A solid path. There would be a difference in colour and a direction marker which would show where the driver is?
- Do you think it is useful to show the planned route so that the viewer can see where the driver is going or if the driver has deviated from the planned route?
- Do you think it is useful to show the current speed?
- Time to arrival:
  - Do you think it is useful to show the time to arrival?
  - Alternatively do you think it is better to show what the estimated arrival time is?
  - Do you think it would be good to have the option to select either of the time to arrival or the arrival time?
- Which do you think is best:
  - Showing the messages in a box?
  - Showing the messages as a speech bubble?
- Do you think showing the driver list in the way shown is a good idea?
- Do you think that showing the kind of map display (Referred to as View on the screen mock-up) is a good idea? Do you like it?
- What improvements would you like to see?

Speech input was thought to be good idea as the hands are not tied up interacting with the screen. Other activities were thought to be able to be performed while interacting with the screen, for example while cooking. Speech input was also perceived to be a more natural way to interact with a computer . Furthermore speech was thought to be a better way for people with disabilities to interact with a system and also good for people who are not adept at using a keyboard. However there was the worry that speech other than the commands could present a problem, due to speech not intended to be commands being misinterpreted by the system.

Another theme that emerged was the ability to have options and flexibility in what was displayed. For instance, to have a basic operating mode, but also to have a more flexible mode or a mode which was more complicated. One example was to choose to display the message box or not. Another example was to have different map display options. For example, to have the map occupying the whole of the top of the display, or perhaps the entire display area.

A further example of flexibility is the option of choosing to display either or both of estimated time to arrival and estimated arrival time. Yet another example of flexibility is either or both the current speed and a shortterm average speed (perhaps over the last five minutes). One idea proposed was to have speeds scrolling across the bottom of the screen in some way.

There were mixed feelings about the map display. Some liked the position markers, some did not. One interviewee thought that the position markers of the same size were confusing as it was not clear where the driver currently was or was going. It was suggested that there might be someway to distinguish what was the current position for example only having one position marker, or position markers decreasing in size as they get older. One idea mentioned in two interviews was to have a flashing position marker. It was also thought that having two lines showing where the driver had been a line in a different colour showing where the driver was going to go could be confusing. There were also mixed views about the usefulness of displaying the planned route.

C Comparison of System to Other Systems

This section shows a comparison of the proposed system and existing system in Table 1. As can be seen most systems allow many to many tracking. Some are available on more than one type of mobile phone hardware or operating systems. However no other system are integrated with the smart-home environment. The smart home is important, because of energy efficiency (for example [37]), health and safety (particularly monitoring the health of the elderly) and assisting people [17] and also government grants. As was seen in Section IIC there has also been work that monitors the behaviour of the inhabitants of a smart home for example [18], [19],[20] and [21]. So integration of systems with the smart home is important. Only the proposed system does this and the other systems do not. Note that this paper was finalised in mid June 2010. The functionality, availability and hardware and operating systems relating to systems and software in Table 1 may have changed since mid June 2010.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we have discussed the development of a multi-user location-awareness system, to be used to locate or track different people, especially family members and friends. The tracking is particularly important and the security and safety concerns are more in bad weather and when there are traffic problems. The proposed system integrates with the smart home and incorporates a context-aware peripheral display in the smart home.

The system is developed using a user-centred design and evaluation methodology. The evaluation results show that the system is useful and would be used by the users to track their family members and friends. However, it is also concluded that tracking would not always be permitted due to privacy concerns.

Changes could be made to the smart home display, following on from comments made by the interviewees in the user evaluation. For example to allow more flexibility in what is displayed, in terms of speed, arrival time and t the planned route ant the route taken, if messages are displayed if there are new messages and the area of the screen taken up by the map.

A future application is the use of Artificial Intelligence for the system alarm function. It could be designed in a way that would allow learning of user routines based on collected data. The system would then be able to react intelligently to changing conditions.

An additional feature that could be built around existing code is the display of past positions. That would allow user to see visited places, or for example to recreate a path of some trip. The system could potentially share this information with other users as recommendations of interesting places to visit. The system could be also integrated with social networking web sites and allow users to share their positions using the web site specific interface.

The system could be expanded to provide car navigation functionality. A community could be built around this to share information about road conditions such as road works, traffic or accidents. The system could be also adapted for a specific business use, to meet the requirements of that particular market. An additional possibility is the interfacing to systems that provide information on aircraft or train arrival times.

Furthermore the functionality of the smart-home display could be increased so that a user could set an alarm to alert the user when a driver was at the destination or was a user-specified time period (ie so many minutes) from reaching their destination. This functionality would be useful when a driver's destination was a home where the smart-home display is located. That way an inhabitant of the smart home could be ready for the arrival of a driver, for example have refreshments ready. The alert would mean playing an audio alarm and displaying the tracking screen on the smart-home display in the room where people were located.

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TABLE I.
COMPARISON OF PROPOSED SYSTEM TO EXISTING SYSTEMS

Software or System	**Tracking displayed on device**	**Other means of displaying tracking**	**Messages or Notifications**	**Compatibility with Hardware**	**Privacy**	**Integration with smart home**
Proposed system	Many to many	Web page and mobile phone	Anytime	All hardware types	Yes	Yes
En Route HQ [22]	Many to Many	Web page, or original iPhone	Anytime	iPhone 3G, iPhone 3GS, iPhone (original)	Yes	No
Glympse [23]	Many to many	Web page, iPod Touch, iPad	Anytime, but need to modify notification	iPhone 3G, iPhone 3GS, iPod Touch, mobile phone with Android or Windows Mobile operating systems	Yes	No
TomTom Buddies [24]	Many to many	No	Anytime	TomTom only. Mobile phone with Bluetooth required	Yes	No
Google Latitude [26]	Many to many	Web page	Anytime	Android OS mobile phones iPhone and iPod touch devices Most colour Blackberry mobile phones Most Windows Mobile 5+ devices Most Symbian S60 (Nokia)	Yes	No
Centrl [27]	Many to Many	Web page	Anytime	iPhone Blackberry Android Nokia	Yes	No
Pocket Life and Pocket Life Lite [28]	Many to many	Web page	Anytime	iPhone 3G/3GS, certain Nokia, Blackberry, Samsung, LG, Samsung, Sony Ericsson and HTC	Yes	No
Locus [30]	Many to many Location posting is manual	No	Only with a location post	iPhone 3G, iPhone 3GS	Yes	No

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