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Voice Enabled Indoor Localisation

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Abstract
The ability to track objects in real time offers a wide range of beneficial applications that include safety, security and the supply chain. The problem with location based systems is that they can be inconvenient and time-consuming to locate an object. A user has to access a computer and log onto a location system to locate an object. There are several problems with current location determination interfaces. Firstly a user has to log on to a computer; this can be inconvenient and time consuming as the user may have to locate a computer (which may be in another area of a building) and then log onto the system. The user has to look at a map that is displayed on screen to see where the object is located; the problem with this is that the user could make a mistake by looking at the wrong object or the wrong area of the building. Incorporating a voice control function into the system can solve interaction problems with some location based systems. This paper provides an overview of integrating voiceXML with an indoor location positioning system to locate objects through voice commands.

1. Introduction
Positioning is a process to obtain the spatial position of a target (Küpper, 2005). Any positioning system has at its core the measurement of a number of observable parameters. These include angles, velocity, ranges and range differences. These parameters usually measure the spatial relationship between some fixed point and the target whose position is to be determined. These measurements utilise the fundamentals of Radio, Infrared (IR) or Ultrasound signals. The positioning systems can be classified as radio-location or non-radiolocation, e.g. acoustic, optical. Position is determined by various mathematical methods including Angulation, Lateration, Dead Reckoning and Pattern Matching. For a positioning system to be implemented, various hardware and software components are needed. These physical infrastructures contain components such as Base Stations (BS) and Terminal Devices (TD). The base stations could be Satellites, GSM towers or Wi-Fi Access points. The terminals are usually small mobile pieces of hardware like a mobile phone, Wi-Fi enabled tag, laptop, PDA or a handheld GPS receiver. Other important elements of positioning systems include a Geographical Information System (GIS) database, some sort of server and/or control unit and various protocols applied between the control units and the BS and the BS and terminal devices (Curran and Hubrich, 2009).

Mobile devices are associated with network technologies that have the potential to provide user location and context cues to the services they offer. Location data alone has little value, but when it is used to expand the variety of mobile applications through timely, personalised content reactive to dynamic environments, it offers great return for very little additional bandwidth use. Integrated positioning infrastructures are those whose primary function is not positioning. This is usually some form of wireless network whose main purpose is communication. The positioning software runs on top of the standard communications hardware. A cellular network is an example of this.
The base stations (cell towers) and terminal devices (mobile phones) can facilitate positioning even though it is not their primary function. An advantage of this type of approach is that roll-out and operating costs are manageable. A disadvantage is the extra traffic produced by the positioning network. A second disadvantage is because the hardware and software protocols used for communication were not originally designed for positioning so it can be difficult to integrate a positioning system with them. Standalone positioning infrastructures operate independently of the communications networks. They use their own base stations and terminal devices. Examples include GPS satellites which are only used for positioning. In an indoor environment, systems using ultrasound or infrared are sometimes set up in locations such as airports. These systems have a number of disadvantages including high roll-out and operating costs and the need for non-standard mobile devices. In addition, communication between the positioning systems and the communications network requires separate interfaces to be designed. Advantages include more straightforward design and less competition for bandwidth from the communications network (Curran and Furey, 2007).

Positioning infrastructures may also be classified as terminal or network based. This refers to where the actual position fix is carried out. In terminal based positioning systems, all the positioning (measurement, calculations and mapping) is conducted on the mobile device. For network based positioning systems, all the measurements and calculations are conducted by the network. For both of these options, the “fix” may be sent on to the network or back to the mobile device. A third option exists where the measurements are taken by the terminal device and then uploaded to the network for processing which is known as terminal assisted. The type of positioning infrastructure used depends on the type of location based service to be used. If further processing of the data is to be carried out at the target location, e.g. on a laptop, then the terminal-based approach may make most sense. However, with the network based approach, upgrades to the system can be carried out without the need for new terminal devices such as phones. This can assist cellular companies with “smooth migration”.

Current indoor location based systems can be prone to human error as a human has to look at a map and work out the position of an object. With a voice controlled location base system many of the disadvantages of location based systems could be addressed. The overall objective of this research is to have a voice controlled location based system. This would allow scenarios such as a user lifting a phone and ‘speaking out’ what object they would like to locate. The system should send the user back the location information via voice. For instance, if a user wanted to locate their laptop bag (which contained a tag) then they would lift a phone and dial a specific number to put them through to the system. Once the user is connected a voice will ask the user to state the object that they would like to locate. The system will send the location information to the user in voice output.

2. Location Determination Technologies

Radio Frequency Identification is a tracking technology that is used to track people, animals and objects. Radio Frequency Identification has three main components these are a “scanning antenna, a transceiver with a decoder (to interpret the data) and a transponder (RFID tag) that has been programmed with information”. Radio Frequency Identification works by the scanning antenna sending out radio frequency signals. These signals are used as a mean of communicating with the transponder (RFID tag).
When an RFID tag receives the Radio Frequency signals sent out from the scanning antenna it transmits its information stored on the chip so that information like tag number can be checked with a database to identify who or what has entered a particular area. Tags are a fundamental element of any location position system. There are two main types of tags, passive tags and active tags. A passive tag is one that seldom moves. A passive tag has no batteries so it relies on radio waves from an access point to power it up. This works because there is a coiled antenna inside the tag that generates a magnetic field that powers the circuits when it receives a signal. Passive tags have their disadvantages which include very short reading distances. However passive tags have lots of advantages including the absence of batteries, long tag life, cheap to manufacture and very small size. An active tag is used for tracking objects. An active tag is equipped with a battery that is used as its main source of power. It is possible to connect a tag to an external power source. Active tags are regularly used as they can be read at great distances and can improve the utility of a device. However the active tag has a lot of draw backs such as a short lifetime as the tag relies on a battery for power, cost (active tags are quite expensive to buy), the active tag is much larger than the passive tag this may limit some applications, long term maintenance costs as batteries have to be replaced, the possibility of misreads due to battery failures.

Bluetooth is a short range technology that is used to connect two devices together wirelessly (Open Wireless Protocol). Bluetooth uses a radio technology called frequency-hopping spread spectrum, which chops up data being sent and transmits chunks of it on up to 79 frequencies (Ali et al., 2008). Nowadays all mobile phones and laptops have Bluetooth capabilities, which enable the transfer of files from one device to another device as well as a range of other uses. It is fundamental that devices wishing to be connected both have Bluetooth capabilities or else connection is not possible. Infrared radiation (IR) is commonly used in remote controls for TVs and other consumer electronic products (Kolodziej et al., 2006). IR-based positioning systems use short-range transmissions of modulated IR light to transmit the identity of a mobile device (tagged object) to a fixed receiver in a particular known location. Ultrasound technology is mostly used in positioning systems for improving the accuracy, as it provides the finest granularity (Kolodziej et al., 2006).

Wi-Fi works by a computers wireless adaptor transferring data into radio waves which then get transmitted by an antenna (Marshall et al., 2001). The signal is then sent to a router which then decodes the signal and sends information to the internet using a physical connection. Ultra-Wide-Band is a communication method used in wireless networking to achieve high bandwidth connections with low power utilization. UWB operates by emitting a series of extremely short pulses across a very high broad of frequencies simultaneously. The accuracy of time measurements for time-of-flight range estimations is a direct function of signal bandwidth. Particularly in the case of indoor location and short range systems in general, range, and position accuracy on the order of 1m demand pulse widths or rise times of several nanoseconds, and bandwidths of several hundred megahertz, with equivalent clock rates (Bensky, 2008).

Finally, cellular networks are a major platform for wireless location-based services (LBS). This is natural considering the widespread distribution of handsets. Position accuracy demands and the methods used for positioning are dependent on the nature of these services (Bensky, 2008). The main reason for adding location determination to cellular communication was the physical security for users. Some of the most common
location based services are navigation, identification of nearby commercial institutions, tracking objects and fleet manager and intelligent transport systems. There are two main categories that describe location based systems: Network based and Handset based. A Network-based system determines the position of a handset by cellular base system measurements. In a Handset-based location system, special software and hardware may be built into the handset to allow position determination to take place.

2.1 Location Determination Applications

There are a number of location determination applications available which often can be classified as applications for users who do not want to disclose their position to anyone else, applications for users who display their position to a selected group, or applications for users who want to disclose their position to everyone.

Mappoint\textsuperscript{15} is an example of an application for users who do not disclose their position to anyone else. It displays the user’s position on a map and nearby points of interest. Dodgeball\textsuperscript{16} is an example of an application for users who display their position to a selected group. It is used by mobile users and works by users telling dodgeball who their friends are. Then when a user is out and about they send a text message to dodgeball with their location; dodgeball then send a text message to all their friends and reports back if there are any of their friends in the vicinity. LocateMobiles.com\textsuperscript{17} is a service for people wishing to find the current location of their family or friends. Average accuracy of the location determination is about fifty meters albeit depending on the number of towers within the cell at the location and other factors such as interference from large buildings and the terrain.

The Skyhook hybrid positioning system (XPS) is a hybrid location determination system that uses the location data from GPS, mobile cellular masts and nearby Wi-Fi access points to calculate the position of a mobile device, such as a dual-mode mobile phone, laptop or PDA. When calculating the position using Wi-Fi, a Skyhook database is utilised that contains millions of access point records from across Asia, Europe and North America. The records are collected by a fleet of vehicles that drive around the roads detecting the signal from access points. From an access point the Media Access Control (MAC) address is read, recorded and time stamped along with the vehicle’s location at the time of detection. This means that the actual physical location of an access point is not recorded but rather a signal fingerprint from the access point. Then later when required to calculate a location it is the fingerprint that is actually used not the actual access point location\textsuperscript{18}. The use of Wi-Fi location determination technology could be utilised in a number of applications namely:

- **Prisoner Monitoring** - A system using tamper-proof Wi-Fi tags can be worn by prisoners for instance to restrict prisoners to certain areas of the prison by notifying prison wardens if prisoners enter restricted areas. This will also help to prevent escape attempts and allow prison guards to monitor prisoner whereabouts at all times.

\textsuperscript{15}www.mappoint.com
\textsuperscript{16}www.dodgeball.com
\textsuperscript{17}www.LocateMobiles.com
\textsuperscript{18}www.skyhookwireless.com
• **Child Safety** - A Wi-Fi based system could be used by children in a school, crèche or theme park environment, some of the Ekahau tags have a call-button which a child could activate if they were distressed or in need of help. The system could be configured to notify the nearest teacher, carer or park staff about the issue.

• **Indoor gaming** - A large scale version of Pac-man could be played with people equipped with tags playing the roles of Pac-man and the Ghosts.

• **Security** - If valuable equipment is no longer detected in its normal area this action could activate an alarm for the security staff and then allow them to track and find it while it is in the range of the WLAN.

• **Supply Chain** - Wi-Fi tags could be attached to product in a warehouse to enable stock or inventory level tracking.

• **Healthcare** - Patients could wear wristband tags that allow them to be tracked throughout the hospital. If a patient tries to leave without being discharged, nurses are alerted to the situation and are able to get them and return them to their ward. This would be particularly useful for patients suffering from dementia or Alzheimer’s disease. Additionally, important staff may wear tags so that in an emergency situation they can be quickly located (Stantchev, 2007).

## 2.2 Location-based Systems

Cricket is an indoor location system for pervasive and sensor-based computing environments. Cricket provides the hardware, software based algorithms, and a software API for location-aware application running on handehlds, laptops and sensor nodes (Hjelm 2006). MIT Cricket uses both radio frequency and ultrasound signals to provide location information to both mobile devices and static nodes in a decentralized, uncoordinated architecture. Active beacons are placed on walls and ceilings throughout a building sending out Radio Frequency location information. A device such as a laptop and PDA would have passive listeners attached to them that run application software.

Place Lab uses map-based pinpointing approach. In Place Lab, each wireless access point transmits an ID which can be used to uniquely identify a particular location. Place Lab uses a device’s embedded 802.11 interface, but does not rely on precalibrated fingerprints. It determines its position by using the location of access points that a device has detected.

AeroScout provide unified asset visibility solutions for healthcare, manufacturing, logistics and other industries. AeroScout’s Wi-Fi positioning technologies use the wireless infrastructure to locate any standard 802.1b and g mobile station, including laptops, PDAs, bar code scanners, and RFID readers, in addition to battery-powered AeroScout tags attached to people or any other assets and equipment. AeroScout have many different products including, AeroScout MobileView and AeroScout tags. AeroScout uses two different algorithms to determine the location of an object. These algorithms are known as TDOA and RSSI. AeroScout’s Wi-Fi based active RFID tags and/or Wi-Fi devices send a brief signal at a regular interval, adding status or sensor data. The signal is received by standard wireless access points (or AeroScout Location Receivers), without any infrastructure changes needed, and is sent to a processing "engine". The engine uses signal strength and/or time of arrival algorithms to determine location coordinates, and sends location and status data to AeroScout MobileView.
2.3 Ekahau

Ekahau is a leading indoor positioning system. Their solution tracks 802.11 (Laptops, Mobile Phones, Wi-Fi tags) enabled devices. The Ekahau Positioning Engine provides a software-based system that enables location-based applications for wireless LANs. The complete positioning system includes the Ekahau Client, Ekahau Positioning Engine and Ekahau Manager. Each user device that the system tracks, such as a laptop or PDA, must be running the client software. The Ekahau Positioning Engine is Java-based server software that calculates the user device locations, and the Ekahau Manager is a platform for creating positioning models, tracking devices, and analyzing positioning accuracy (Geier, 2002). Ekahau achieves accuracy of 1 to 3 m, and calibration that requires up to 1 h/12000m$^2$.

Ekahau Vision is an end-user software application enabling a full asset and process visibility by turning location of assets into valuable information. It delivers the data required to streamline business processes and optimize asset utilization. Ekahau Vision application is web based and is a gateway to critical data. The Ekahau Positioning Client is a software tool for tracking mobile devices with Ekahau RTLS. The software runs as a system service. It is by default started automatically at system start-up and runs in the background. The Ekahau Positioning Client works by scanning compatible Wi-Fi-devices for RSSI-data and transmitting this data over the wireless network to an Ekahau Positioning Engine (EPE) running on a remote server. Ekahau API is a web service that can merge with enterprise systems. The tag configuration, management and locating functions can be embedded into an external application. So the users of enterprise applications do not have to learn a new system. The Ekahau Manager is a stand-alone application tool that is used for creating models of an area. It can perform site calibration, drawing and editing of rails. Site calibration is used to increase accuracy. Basically it works by walking around the area you wish to calibrate stopping every few feet so that the system can compare against the server to find out the accuracy of the system (See Figure 1).

![Figure 1: Calibration on Block MG Second Floor @ University of Ulster, Magee](image)

The Ekahau planner can be used to intelligently simulate the initial access point placement settings, walls, and thus predict the expected network performance, prior to installing any Wi-Fi infrastructure (Ekahau, Planner data sheet). It provides a drag-
and-drop GUI for access point and wall placement on a facility floor map (Ekahau, Planner data sheet). The Ekahau Planner provides real-time visualizations for displaying RF coverage shown in Figure 2 and a variety of performance parameters. The software supports multiple different wall material types and antenna types for the best possible calculation of RF signal propagation (Ekahau, Planner data sheet).

![Figure 2: Shows RF coverage](image)

The Ekahau planner presents an innovative approach that streamlines Wi-Fi network design and deployment (Ekahau, Planner data sheet). It can be used to intelligently simulate the initial access point placement settings, walls, and thus predict the expected network performance, prior to installing any Wi-Fi infrastructure (Ekahau, Planner data sheet). An easy to use drag-and-drop GUI is included for access point and wall placement on a facility floor map (Ekahau, Planner data sheet). The Ekahau Planner provides real-time visualizations for displaying RF coverage and a variety of performance parameters. The Ekahau Software Development Kit (SDK) is an application that contains Java package, Javadoc, and code example for quickly connecting to the Positioning Engine (Kolodziej, 2006).

3. **Voice Technologies**

Interactive Voice Response (IVR) is a term for automated telephony applications. There are a lot of systems that use IVR. When someone rings an insurance company or a mobile phone company there is usually a voice asking a question. IVR applications are created by VXML. For example if a user lifted a phone and dialled a number, the application would pick up and say “Please tell me what you are looking for” The user would then say what they were looking for (e.g. Laptop Bag) The system would then go to the back end database, look up the location of the “Laptop Bag” and send the location back to the VXML application: The VXML application would then use that information to plays back “The Lap Top is located in MF124”.

As shown above the system has to go to the back end of the database. The proposed system will be different in that it will be working alongside the Ekahau system and will be in real time, therefore if an object is moved it will still be possible for the user to receive a very accurate location of their requested object. A Spoken User Interface is one in which both machine presentation and user input take the form of human speech. Speech replaces the video display, indicator lights, buttons and knobs of the more traditional user interfaces. The machine presents output through digitized or synthesized speech – in effect, “reciting” information to the user-and accepts and
interprets spoken user input through the use of speech recognition technology (Becchetti and Ricotti, 1999).

When a machine speaks to a user, the spoken machine output serves five functions.

- Prompts – Indicates User must provide input.
- Feedback – Returns result of users input.
- Instructions – Help user understand task.
- Help – Instructions that will coach the user.
- Application Data – e.g., weather, stock information – that the machine states to the user as part of the application task itself (Balentine et al., 2001).

ASR technology allows an application to identify human speech. The aim of ASR research is to allow an application to recognise human speech with 100% accuracy regardless of pitch, accents and noise. Despite several decades of research in this area, accuracy greater than 90% is only attained when the task is constrained in some way. Depending on how the task is constrained, different levels of performance can be attained; for example, recognition of continuous digits over a microphone channel (small vocabulary, no noise) can be greater than 99%.

VXML technology allows a user to interact with the internet through voice recognition. Instead of a traditional browser that relies on a combination of HTML and keyboard and mouse, VXML relies on a voice browser and/or the telephone. Using VXML, the user interacts with voice browser by listening to audio output that is either pre-recorded or computer-synthesized and submitting audio input through the user's natural speaking voice or through a keypad, such as a telephone. There are a lot of similarities between VXML and HTML, for example a user would write VXML to describe to a VXML browser (or interpreter) on what to say to the caller and what to expect in response from the caller in the same way that a user would write a HTML page that IE or Firefox uses to display information to the user.

SSML is one of three types of mark-up language used to create voice enabled functionality with Internet browsers and email programs. Sometimes used as a standalone approach, SSML is also sometimes used in tandem with Spoken Text Mark-up Language (STML) and Java Speech Mark-up Language (JSML). The ultimate goal of SSML is to provide applications that allow persons to use voice commands with various online tasks such as searching the Internet, receiving and responding to emails, and enjoying the content of various web sites. SSML applications are mainly used in conjunction with telephony applications, this type of XML mark-up provides exceptional sound clarity. Spoken Text Mark-up Language (STML) is a set of mark-up codes and symbols for text-to-speech (TTS) synthesis for voice-enabled Web browsers and voice enabled e-mail. STML provides text description tags that describe the structure of the document, and speaker directive tags that control the emphasis, pitch, rate, and pronunciation of the text (Balentine & Morgan, 2001).

The Java Speech Mark-up Language (JSML) is a text format used by applications to annotate text input to speech synthesizers. JSML elements provide a speech synthesizer with detailed information on how to speak text and thus enable improvements in the quality, naturalness and understandability of synthesized speech output (Hunt, 2000). JSML defines elements which in turn define the structure of a document,
pronunciations of words and phrases, speaking rate, speaking pitch and word emphasis. JSML is portable across different platforms, supports lots of languages throughout the world and was designed to be straight forward to learn.

4. Voice Enabled Location Determination Prototype

This system aimed at allowing users to request the location of a tagged object on campus through telephony. The first phase of this project involved creating a list of key words (e.g. laptop, Keys, MF124 etc) and linking each keyword with speech. The next phase would involve mapping the area that objects will be placed in; this will be done using Ekahau Manager. The final phase involved linking the voice keywords with corresponding tags, so that whenever a user asks where a certain object is, the response will be correct accurate. The system works as follows:

- The user makes a request to the application
- The application translate the request so it’s understood by the main system
- The main system queries the database.
- The database returns the query result.
- If object does not exist the main system translates message back into voice form to the voice application
- If the object does exist then the main requests information from the location engine.
- The location engine returns requested information
- The voice application then responds to the user with relevant message

The system allows a user to not only find the location of an object but also the user can find out specific data of the object such as the charging status, the battery life, the map ID, the tag number and the MAC number of an object using VoIP calls anywhere in the world. In addition the user can connect to the application via an instant messenger client that will allow the user to interact with the application and receive the desired results effectively and efficiently; this is a great addition for user with speech problems and also allows users with mobile phones to connect to their instant messenger client and communicate with the application, anywhere and at anytime.

VoiceXML was integrated with the Ekahau SDK (Software Development Kit) for retrieving the data of objects and parsing that data to a text file. To get the real time data of the tags, the following command was run “example –h 193.61.190.42 stream ALL >laptopinfo.txt”. This placed the real time information of the tags into a text file called “laptopinfo.txt” as shown in Figure 3.

![Figure 3: Data output](image)

Now that the real time data has been saved, it must be uploaded to a hosting account before the application can utilise the data. Another way of obtaining tag data is to run a query in the browser that will produce the tag stream data such as
“http://193.61.190.42:8550/epe/pos/tagstream?tagid=105463684135”. This query will get the tag stream data for tag number “105463684135”. The output is in xml so no parsing is required. This provides all the data that the application needs, in order to produce accurate results. If the user says laptop, and then asks for the battery life, the application will read the text between <batterylevel>26</batterylevel> which is 26 and produce an output for the user.

Voxeo provide platforms and tools for developers specialising in voice and IVR applications. This application and all the files required to run it can be stored in a Voxeo developer account. The application has an instant messaging feature as well as voice interaction. We show the interaction between the application and the instant messenger client.

Figure 4 shows the user calling the application by typing “main into the chat box”. The application responds and asks the user what object they would like information on. Figure 5 shows the user requesting for the details of the battery life. The application returns the details and takes user back to the main menu.

The voice location system underwent performance evaluation as a way of testing accuracy of words. Skype was quite useful as testing could be performed for free. In summary, users found the speed of the system was acceptable. The response and interaction with the system was reasonable. A problem however was found with the accuracy of the system as some users had to repeat their input several times before the system recognised what they said. It is important to remember that speech recognition systems still have fundamental errors. Recognition errors and ungraceful error handling is currently hindering the progress of systems such a proposed here.

5 Conclusion

Common approaches to determining location were discussed in this section. GPS (Global Positioning System) is able to show ones position on the Earth mainly in
outdoor locations. GPS satellites, 24 in all, orbit at 11,000 nautical miles and float in geosynchronous orbit above the Earth. They are continuously monitored by ground stations located worldwide. GPS Receivers are cheap but the downside is that you need a line of sight to a satellite hence you need to be outdoors. Cellular Triangulation is a process by which the location of a radio transmitter can be determined by measuring either the radial distance, or the direction, of the received signal from 2 or 3 different points. The distance is determined by measuring the relative time delays in signals from the mobile set to 3 base stations. Most people carry mobile phones, however in reality most readings are quite coarse and can only be relied on to roughly pinpoint one to a geographical region. Wireless location determination systems consist of radio beacons, databases holding beacon location information and clients which estimate their location from the signal strength measurements. Leaders in the field include Ekahau, Trapeze Networks and Ubisense. It is a useful method as access points now exist in many residential and public buildings but it can be difficult to achieve accurate readings and intense planning/fingerprinting needs to be performed. RFID has seen widespread use across many different applications with the vast majority of these applications only using the data contained in tags within the reader’s zone, rather than the location of the tag at any given time. Tags are quite cheap but it is relatively new and the distance for measurements can be quite restrictive. Ultra Wide Band (UWB) is precisely timed by short bursts of RF energy to provide accurate triangulation of the position of the transmitting tag. Since the short time UWB signal is very broad in frequency spread (typically 1 to 2 GHz wide) the system can operate on a very low power output and is robust against interference. It can be accurate to centimetres but deployment can be expensive and many systems only work in limited wide area spaces.

The system presented here which integrates voice and location positioning however was able to recognise interactions such as which object we wished to locate e.g. laptop or phone. It also allowed us to then speak which function (e.g. location, battery level). There is merit indeed in systems such as proposed here.

References