Overview of mobile technologies enabling support of Alzheimer's patients

Contents

1 Introduction

With many approaches proposed by several research groups in the world to provide the localization of mobile targets, indoor/outdoor positioning became an important topic especially when dealing with pedestrian aiding technologies such as navigation, location based services, augmented reality and, more generally, ubiquitous computing to provide context aware services. Constrained environments, especially indoors, are places where positioning technologies, usually efficient outdoors, are well known to suffer from physical constraints on radio signals, such as attenuation, multipath and so on. There, the location service is not available. In order to ensure a continuity of service, many approaches focus on radio-based technologies since transceivers are already embedded in commercial nomadic devices. Moreover, based on a recent study the holder of smartphone is growing significantly (e.g. 56% people in 2013 in the US). It indicates the importance of nomadic devices on the market, which increases the interest in radio technologies. One can quote the various communication chipsets already embedded in smartphones, such as Wi-Fi, Bluetooth, 3G or GNSS. Besides, positioning technologies can be split into two main families: the one depending on infrastructure and the one being infrastructure less. The radio solutions previously quoted depend on a set of transceivers that constitutes an infrastructure. This may limit developments, due to construction costs, deployment and maintenance constraints. Furthermore, embedded devices, independent from any infrastructure, could be an interesting alternative for positioning.
Most of the time, the MicroElectroMechanical Systems (MEMS) are used in embedded devices as their power consumption, their price and their size allow an easy integration. Even if they are widely used, most of MEMS still suffer from measurement errors. At this point, the technology we chose to focus on should be infrastructure less and possibly embedded in a smartphone, in order to target the mass market.

This report categorizes all sighted indoor/outdoor positioning approaches into distinct technologies and describes the measuring principles of each individual approaches. Key performance parameters are characterized and quantified. For a better overview, these parameters are briefly compared in table form for each technology.

2 Localisation techniques for indoor/outdoor pedestrian applications

The following sections describe common technological solutions tackling the problem of the pedestrian indoor/outdoor localization.

2.1 Positioning requirements parameters definition

2.1.1 Accuracy

The accuracy of a system is an important user requirement which should be quantified in any description of an application. The term accuracy has been defined in the Joint Committee for Guides in Metrology

(JCGM) as the closeness of agreement between a measured quantity value and a true quantity value of a measurand.

2.1.2 Coverage

Describes the spatial extension where system performance must be guaranteed by a positioning system. One of the following categories should be specified:

- Local Coverage: a small well-defined, limited area which is not extendable (e.g. a single room or building). For this case, the coverage size is specified (e.g. (m), (m^2) or (m^3)).

- Scalable Coverage: Systems with the ability to increase the area by adding hardware (e.g. through deployment of additional sensors). In this report, the parameter 'coverage' is set to 'scalable' only if the scalability is not affected by a loss of accuracy.

- Global Coverage: system performance worldwide or within the desired / specified area. Only GNSS systems and celestial navigation belong to this category.

2.1.3 Availability

Availability is the percentage of time during which the positioning service is available for use with the required accuracy and integrity. This may be limited by random factors (failures, communications congestion) as well as by scheduled factors (routine maintenance).

2.1.4 Continuity

The continuity is the property of continuous operation of the system over a connected period of time to perform a specific function. The frequencies of acceptable outages should be given. The continuity requirement is usually similar to that of availability.

2.1.5 System latency

The system latency describes the delay with which the requested information is available to the user. The latency can have the following values:

- Real time: Does not tolerate 'perceivable' delays. It is the most demanding latency requirement. It is necessary for navigation and almost all indoor positioning applications.

- Sooner the better: Requires the system's best effort.

- Sooner the better with an Upper Limit: Requires the system's best effort but the system must be designed to limit the maximum delay to a specified threshold.

- Post processing: No specific time of delivery is defined.

2.2 Indoor positioning applications

The list of applications below demonstrates the omnipresent need for indoor positioning capability in our modern way of life. Moreover, along with an improvement of performance, future generations of indoor positioning systems will find even more applications which are at the present time not feasible.

2.2.1 Location Based Services in Indoor Environments

Commercially highly relevant applications for the mass market are the so-called Location-Based Services (LBS) which make use of the geographical position to deliver context-dependent information accessible with a mobile device. Such services are required indoors and outdoors. Examples of indoor LBS are obtaining safety information or typical information on cinemas, concerts or events in the vicinity. LBS applications include navigation to the right store in a mall or office in a public building. Within a store or warehouse, the location detection of products is of interest to the owner as well as to the customers. In particular, location-based advertisements, location-based billing and local search services have a high commercial value. At large tradeshows, there is a request to guide the visitors to the correct exposition booths. Applications at train or bus stations include the navigation to the right platform or bus stop.

Further examples of LBS are proximity-based notification, profile matching and the implementation of automated logon/logoff procedures in companies. There is also added value for the positioning provider, e.g. by resource tracking, fleet management and user statistics.

2.2.2 Private Homes

Applications at homes include the detection of lost items, physical gesture games and location based services at home. Ambient Assistant Living (AAL) systems provide assistance for elderly people in their homes within their activities of daily living. A key function of AAL systems is location awareness which requires an indoor positioning functionality. Applications at home are medical monitoring such as monitoring vital signs, detection of emergencies and fall detection, but also service and personalized entertainment systems, such as smart audio systems ([Zetik 2010]).

2.2.3 Context Detection and Situational Awareness

Mobile devices provide a large variety of useful functions where it is desirable to have an automated adaptation of the mobile device depending on a change of the user's context. Such functionality spares the user additional effort by providing assistance in individual situations. To enable such an automatic adaptation the mobile user's context needs to be determined by the mobile device itself. The most significant criteria to determine the user's context is the current geographical location. For example a smart conference guide can provide information about the topic discussed in nearby auditoriums.

2.2.4 Medical Care

In hospitals the location tracking of medical personnel in emergency situations has become increasingly important. Medical applications in hospital also include patient and equipment tracking, e.g. fall detection of patients. Precise positioning is required for robotic assistance during surgeries. Existing analytical devices can be replaced with more efficient surgical equipment.

2.2.5 Social Networking

As a member of the young generation participation in the network has become increasingly important because social integration is governed through the social network. Ubiquitous location plays a central role in social networking, such as locating friends for coordinating joint activities.

2.2.6 Environmental Monitoring

Environmental monitoring is used to observe some phenomenon such as heat, pressure, humidity, air pollution and deformation of objects and structures. To monitor these parameters over a certain indoor or outdoor space, multiple sensor nodes are organized as a Wireless Sensor Network (WSN). A WSN consists of small, inexpensive, spatially distributed autonomous nodes with limited processing and computing resources and radios for wireless communication. A comprehensive literature review on WSNs can be found in Yick et al. (2008). In order to retrieve the nodes' positions from ranging and proximity information among these sensor nodes, dedicated algorithms of cooperative localization have been developed, see Mautz et al. (2007a).

2.2.7 Police and Firefighters

Indoor positioning capabilities provide important benefits in law enforcement, rescue services, and fire services i.e. location detection of firemen in a building on fire. The police benefits from several relevant applications, such as instantaneous detection of theft or burglary, detection of the location of police dogs trained to find explosives in a building, locating and recovery of stolen products for post-incident investigations, crime scene recovery, statistics and training but also in the prevention of crime, e.g. with tagged devices for establishing so-called geofenceing i.e. alarm systems which can detect whether a person or an asset has left a certain area unauthorized.

2.2.8 Intelligent Transportation

A mass user application for vehicles will be the provision of seamless navigation through extension of road guidance inside parking garages (Wagner et al. 2010 [Wagner 2010]). In particular, it becomes possible to navigate the driver to a single parking spot and from there to the pedestrian destination (Gusenbauer et al. 2010 [Gusenbauer 2010]).

2.2.9 Industry

Mechanical engineering is developing towards intelligent systems for more or less fully automatic manufacturing. For numerous industrial applications indoor position awareness is an essential functional element, such as for robotic guidance, industrial robots, robot cooperation, smart factories (e.g. tool assistance systems at car assembly lines), automated monitoring and quality control. Indoor positioning capabilities can help to find tagged maintenance tools and equipment scattered all over a plant in industrial production facilities. The improvement of automatic safety systems, intelligent worker protection and collision avoidance is driven by the positioning capability of such a system.

2.2.10 Museums

There are several applications in museums, such as visitor tracking for surveillance and study of visitor behavior, location based user guiding and triggered context aware information services.

2.2.11 Logistics and Optimization

For the purpose of process optimization in complex systems, it is essential to have information about the location of assets and staff members. In a complex storage environment for example, it is important that requested goods are found quickly. Based on accurate localization, tracing of every single unit becomes possible. Positioning for cargo management systems at airports, ports and for rail traffic affords unprecedented opportunities for increasing their efficiency.

2.2.12 Guiding of the Vulnerable People

Systems designed specifically to aid the visually impaired should operate seamlessly in all indoor and outdoor environments. Navigation is generally required for vulnerable people to assist walking in combination with public transport.

2.2.13 Structural Health Monitoring

Sensors incorporated into steel reinforcements within concrete can perform strain measurements with high resolution. Strain sensing systems based on passive sensor-integrated RFIDs can measure strain changes and deformation caused by loading and deterioration (OKI 2011).

2.2.14 Surveying and Geodesy

Surveying of the building interior includes setting out and geometry capture of new buildings as well as for reconstructions. Positioning capabilities with global reference are needed for data input to CAD, GIS or CityGML. Accuracy requirements vary from centimeters to millimeters.

2.2.15 Construction Sites

Apart from surveying applications, large constructions sites require positioning capabilities that can support an information management system. The capability to localize and track workers is a crucial component to establish an automatic safety system.

2.2.16 Underground Construction

Special positioning requirements apply in dusty, dark, humid and space limited environments for tunneling ([Schneider 2010]) and longwall mining ([Fink 2010]).

2.2.17 Scene Modeling and Mapping

Scene modeling – the task of building digital 3D models of natural scenes – requires the precise orientation of the optical sensor. Indoor mapping systems need to know the camera's position in order to merge multiple views and generate 3D point clouds. Scene modeling is beneficial for several applications such as computer animation, notably virtual training, geometric modeling for physical simulation, mapping of hazardous sites and cultural heritage preservation.

2.2.18 Motion Capturing

Motion capturing relies on the detection of physical gestures and the capability to locate and track body parts. Such technologies are useful for medical studies and animated films. Location based gaming, such as exergaming (gaming as a form of exercise) relies on tracking body movement or reaction of the players.

2.2.19 Applications Based on Augmented Reality

Localization awareness is of fundamental importance for Augmented Reality (AR) applications – an increasingly powerful tool to superimpose graphics or sounds on the users' view, allowing the user to perceive overlaid information which is spatially and semantically related to the environment. An example of vision based navigation for AR is presented in Kim and Jun (2008).

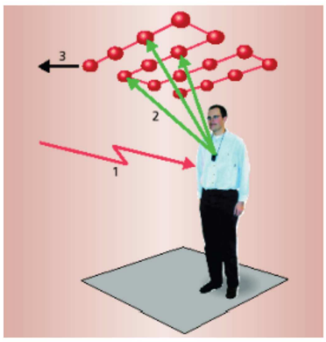
2.3 Indoor and outdoor localization technologies

2.3.1 Camera

Vision tracking pedestrians using multiple camera views is a well-researched problem, with techniques such as background subtraction and blob detection commonly used. Initially, the EasyLiving project Microsoft Research) used such algorithms together with two stereo cameras (i.e. four views in total) in order to track the users of an intelligent environment to an accuracy of around 10 cm in the horizontal plane. This was achieved without requiring a user to wear a tracking device or visual marker. Although this is a highly desirable property, it makes the identification of each user far more difficult. EasyLiving maintained color histograms of each user to ensure consistent assignment of unique identifiers to users during tracking, however these identifiers did not relate to the absolute identities of the users. A user previously tracked by the system would be assigned a new identifier when re-entering the environment after a sufficiently long absence. Camera-based tracking systems such as the one used in the EasyLiving project often perform poorly when users are partially or fully occluded and also when there are rapid changes in illumination (e.g. when a light is turned on or off, or when clouds obscure the sun on a sunny day).

2.3.2 Infrared

Infra-red light has been used to provide room-level location information (i.e. the room within which each tracked object is located). If an infra-red signal transmitted from one device is received by another then it is highly likely that they are located in the same room because infra-red light does not pass through walls. Furthermore infra-red light is strongly reflected by walls, meaning that a line-of-sight between the two devices is not required. Infra-red transmitters and sensors are cheap, power efficient and readily available, making them ideal for providing room-level location information.



The Active Badge is one of the first location system developed by AT & T between 1989 and 1992 [Cam02]. The mobile to be located is equipped with a tag infrared emitting an infrared signal periodically. Receivers are installed in the environment in the vicinity of the user. These receivers are interconnected to form an array for detecting the active tag. As the ultrasonic localization approach, the system emits a series of infrared pulses. The range of the sensors can reach 6 m. Infrared pulses are emitted every 15 s (for 0.1 s) in order to save energy, allowing multiple tags to be located and to avoid interference problems. This technology was used in this period because of its low cost. However, the disadvantage versus wireless technologies is that the infrared signals do not pass through walls, which reduces the scope of the system and requires deploying a dedicated network of receivers. Moreover, the presence of daylight affects infrared transmission between the transmitter and the receiver.

2.3.3 Wifi

Positioning using received signal strength indication (RSSI) measurements of signals received from WiFi access points has received much attention due to the number of access points that are already installed in many indoor environments. Such systems usually fall into one of two basic classes. In the first class signal strengths are used in conjunction with a radio propagation model in order to estimate distances between the receiver and multiple base stations in the environment. Multi-lateration algorithms can then be applied to estimate the receiver's position. The second class requires the construction of a radio map, in which surveyed signal strengths are recorded at known positions throughout the environment. During tracking a receiver can estimate its position by comparing observed signal strengths with entries in the map. This is known as fingerprinting and is the more accurate of the two approaches, however requires more effort because it is necessary to construct and subsequently maintain a radio map of the environment.

2.3.4 Radio frequency identification

An RFID (Radio Frequency IDentification) system consists of a reader with an antenna which interrogates nearby active transceivers or passive tags. Using RFID technology, data can be transmitted from the RFID tags to the reader (also known as RFID scanner) via radio waves. Typically, the data consist of the tag's unique ID (i.e. its serial number) which can be related to available position information of the RFID tag. The most frequently employed positioning principle is that of proximity, also known as CoO (Cell of Origin), e.g. the system indicates the presence of a person wearing an RFID tag. Thereby, the accuracy of an RFID system is highly depending on the density of tag deployment and the maximal reading ranges.

2.3.5 Ultra-Wideband

Radio has been used to develop several commercial indoor positioning systems. Ubisense or Decawave develop systems that are able to position small tags that emit pulses of UWB radio to within 0,1 m of their true positions 95% of the time in unobstructed line-of sight conditions (i.e. when there are unobstructed lines-of-sight between tags and receivers). This accuracy degrades to nearer 1m when some of the signals have passed through walls. The Ubisense positioning system uses both TDOA and AOA measurements to position tags. TimeDomain have developed a similar UWB positioning system called PLUS in which only TDOA measurements are used.

2.3.6 Other radio frequency technologies

Zigbee

ZigBee is a wireless technology standard which can be regarded as a low rate Wireless Personal Area Network (WPAN). It is particularly designed for applications which demand low-power consumption, but don't require large data throughput. The signal range coverage of a ZigBee node is up to 100 m in free space, but in indoor environments typically 20 m to 30 m. Distance estimation between two ZigBee nodes is usually carried out from RSSI values. Since ZigBee operates in the unlicensed ISM bands, it is vulnerable to interference from a wide range of signal types using the same frequency which can disrupt radio communication.

Bluetooth

Bluetooth is – like ZigBee – a wireless standard for Wireless Personal Area Networks (WPANs). But in contrast to ZigBee, the Bluetooth standard is a proprietary format managed by the Bluetooth Special Interest Group. The advantage of using Bluetooth for exchanging information between devices is that this technology is of high security, low cost, low power and small size. The most commonly specified power level (class 1) of the Bluetooth standard has a maximum power output of 1 mW (0 dBm) which enables communication ranges of 5 m to 10 m depending on the propagation conditions such as LOS, material coverage and antenna configuration. Class 3 however, which allows the transmission power to reach 100 mW (20dBm) provides communication ranges similar to WiFi. Since the Bluetooth sensor does not stay in inquiry mode for 5 s during its 10 s cycle, the off-the-shelf Bluetooth device has latency unsuitable for real-time positioning applications.

DECT phones

Phones based on Digital Enhanced Cordless Technology (DECT) are common devices for talking wirelessly around the house. DECT phones communicate with a single base station within a typical distance of 200 m to 500 m.
Kranz (2010) demonstrated the feasibility of using DECT phones for positioning in urban indoor and outdoor scenarios. His fingerprinting method on DECT RSSI outperformed that of WLAN due to the high number of DECT stations (12 to 17) which could be received at a single sub-urban location. After taking fingerprints of 1 to 3 m separation, a localization accuracy of up to 5 m was achieved.

Digital television

Broadcast signals of digital television stations can be utilized for positioning in urban areas including deep indoor environments with accuracy of about 10 m. Since digital television had started in 1998, most countries have established a network of terrestrial broadcast stations (10 km to 100 km distance between stations). The unmodified digital video broadcast is suited for pseudorange estimation and multilateration in indoor environments due to several reasons:

- digital television has a signal power advantage over GPS of 40 dB allowing reception in deep indoor environments
- the signals have a wide bandwidth of 5 MHz – 8 MHz facilitating multipath mitigation
- demodulation of the data is simplified by a guard interval in the message
- emitters of digital television are synchronized with GPS time allowing to timestamp the data and determine TOA pseudoranges.

However, the density of terrestrial emitters is low – causing the direct signal to arrive at low elevation angles near the horizon. With such a network configuration, only 2D positioning is feasible and multipath is severe since the direct signal is usually blocked.

Id Cellular

Wireless telephony is now widespread throughout large parts of the world. A wide range of measurements can be obtained to estimate the position of any device that is connected to such a network, including angle-of-arrival (AOA), time-of-arrival (TOA) and time-difference-of-arrival (TDOA) measurements of radio signals travelling between the device and multiple cell towers. The simplest approach is to estimate the position of a device as the position of the cell tower to which it is associated, with the accuracy dependent solely on the dimensions of the cell. More accurate approaches have received increased attention since the United States Federal Communications Commission introduced an E-911 mandate that required mobile carriers to provide the approximate positions of mobile devices making emergency calls. By 2012 carriers must provide positions that are accurate to within 50 m for 67% of calls and within 150 m for 95% of calls.

FM radio

FM radios represent a well-established broadcasting technology originally reserved for Frequency Modulation (FM) to convey information over a carrier wave by varying its frequency. FM nowadays refers to any radio wave operating in the frequency band 87.5 MHz to 108.0 MHz no matter what type of signal modulation is applied. The audio signals transmitted by FM radio broadcasting towers can be used for indoor navigation. ToA and TDoA methods have not been regarded as feasible because the FM signal lacks timing information. But signal strength based fingerprinting techniques which are independent of clock synchronization can be applied on broadcast FM signals. The employment of FM radios for positioning benefits from the existence of radio tower infrastructure providing almost ubiquitous coverage in indoor and outdoor environments, high received signal power and the possibility of using low-cost, low-power hardware. Due to the passive nature of the client devices, FM can be used in sensitive areas where other RF technologies are prohibited for safety or security reasons. On top of that, FM technology is readily available in many mobile devices.

Radar

Radar (RAdio Detection And Ranging) is a technique to determine the range and angle of incidence to an object. The original principle of radar was to measure the propagation time and direction of radio pulses transmitted by an antenna and then bounced back from a distant passive target (primary radar). If the object returns a tiny part of the wave's energy to the antenna, the radar device measures the elapsed time. The angle of incidence is estimated from a directional antenna. This original concept of radar assumes passive object reflection and involves only one station which comprises both, transmitter and sensor. This concept has two disadvantages: most of the signal energy gets lost by the reflection and the use of steerable directional antennas is impracticable. Therefore, the concept of radar has been extended to include more than one active transmitter (secondary radar). Instead of passive reflection, the single-way travel time of the radar pulse is measured by ToA and then returned actively.

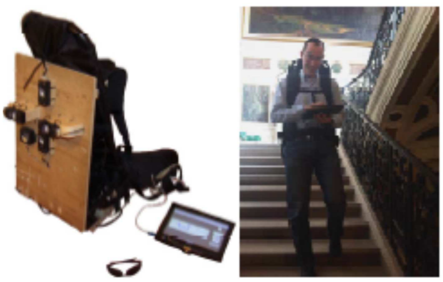
2.3.7 Global navigation satellite systems (GNSS)

The United States' Global Positioning System (GPS) and Russia's GLONASS allow mobile devices to position themselves worldwide when outdoors. To do this a receiver must track signals from four or more satellites, from which pseudo-ranges (distances to satellites that include possible errors due to an offset in the receiver's clock) can be obtained. Pseudo-multi-lateration algorithms (multi-lateration in which the receiver's clock offset is an additional unknown) are then used to resolve the position and clock offset of the receiver. The accuracy to which a GNSS receiver can compute its position is highly dependent on the local environment. With a clear view of the sky and when tracking all visible satellites in the GPS constellation, 1σ position errors of approximately 7m can be achieved by single frequency GPS receivers. This accuracy is significantly degraded when large parts of the sky are blocked from view, for example in an urban canyon. In such an environment the number of visible satellites is reduced, whilst multipath effects caused by reflections from nearby obstructions (e.g. buildings and trees) introduce additional error.

2.3.8 Inertial navigation systems

This approach uses one or more inertial sensors and/or gyroscopic sensors providing information about the mobile dynamics. From equations of mechanics, as the equation of motion, and gathered sensors information, the position of the mobile is estimated. This kind of navigation is often used in military applications. The sensor data are always available (suppressing the need of coverage problem of wireless technologies). Signal processing is locally performed, ie on the mobile, which provides a safe and secure operating process. In order to operate, the tracking system has to know in advance the starting position. Due to the numerical integration of digital accelerometer and gyroscopic data over time, noises led to a drift of the estimated position. Several research studies are currently carried out to bound the drift of sensors by hybridization methods for instance with other localization techniques.

2.3.9 Magnetic



Navigation technique that uses magnetic disturbances of the magnetic field for the location of a rigid body in motion has been studied recently, supported by recent developments in hall effect sensors with high sensitivity features. It is based on measuring the magnetic signature produced by the Earth's magnetic field close to the mobile. It is a very compact solution with regard to technological solutions described above. However, this solution requires prior magnetically mapping of the environment. This procedure is also repeated when the user environment is changed. Although the recent development of the demonstrator MINAV [Dorveau 2011] (figure against) based on a magneto-inertial approach has suppressed the calibration phase (magnetic mapping), the prototype still offers large dimensions.

2.3.10 Phase measurement

This technique consists on exploiting the phase measurements of the electromagnetic waves for estimating the distance between a point in space and the emission point. In this case the AM radio wave band is used. For this range of frequency, waves have good propagation properties, and transmit properly inside buildings. In order to operate, it is necessary that the distance between the reference receivers (transmitter) is smaller than the wavelength of the signal. The AM signals is well suited to these conditions because their wavelength is often high (λ = 150 m) for a signal whose carrier is 2 MHz. It is common that the buildings are seldom such heights in length or width, allowing the use of this technique in the context of indoor localization [Reynolds 2002]. The implementation of this system is not always easy because its needs accurate measurements of the signal phase. This issue can be relatively difficult to implement in hardware receiver. Thus, a second approach to determine the distance between transmitter/receiver using the phase of an electromagnetic wave is to measure the phase difference between the electric and magnetic components of the wave. The phase shift is related to the distance between transmitter/receiver providing that the receiver is in the near field of the transmitter [Siwiak 2004].

2.3.11 Ultrasonic

The ultrasonic localization based approach is commonly used to determine the position of a mobile. This technique was introduced in the 80s by the robotics field to address issues of telemetry. Most ultrasound localization systems are combined with another technology to obtain an estimation of the distance between a transmitter and a receiver. In the Cricket system [Priyanta 2000, Priyanta 2001], the information from an ultrasonic interface is combined with those delivered by an RF interface. This combination allows estimating the distance between transmitter/receiver and thus the position of the mobile. Based on the detection principle used in addition to time of flight measurement, further adjustment is needed since the technique suffers from generating a lot of multipath situation leading to an underestimation of the mobile position. In case of multipath, the wave path with highest sensor magnitude is not always the shortest travel. Obviously, the development of algorithms for estimating the arrival time of the first path is needed to minimize errors in the estimation of the distance between transmitter and receiver.

2.4 Localisation techniques (dead reckoning, triangulation, time of flight,...)

The Global Positioning System (GPS) is the most obvious technique that comes to mind when raising the question of “localization”. GPS is is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites [_Ref_link1]. It is broadly used for military scenarios as well as in civil and commercial applications.

Nevertheless, various localization techniques, or protocols, have been proposed, where nodes derive their location rather than equipping them with dedicated localization hardware such as GPS receivers, which increases node costs [_Ref_link1]. For a large number of sensor nodes, simply adding GPS to all nodes in the network is not feasible because [Schneider 2013]:

- In some situations, the presence of obstacles that block the line-of-sight from GPS satellites (e.g., dense forests, mountain, dense buildings), makes GPS inefficient.
- The power consumption of GPS will reduce the battery life of the sensor nodes and also reduce the effective lifetime of the entire network.
- In large networks, the production cost factor of GPS is an important issue.

Indoor localization is a particularly challenging problem [Kunz 2012] [Kuruoglu 2009]. Different methods for indoor localization have been designed, yet the localization accuracy problem is still to be solved. The common approach for indoor localization is to exploit/process RF signals sent from known positions. This localization methodology is also known as the network fingerprinting method. Indoor localization methods have largely surveyed in the literature. For instance in [Pal 2010], the indoor localization methods are organized into two categories: target/source localization and node self-localization. Target/source localization uses the measured distance/angle to estimate the location. Node self-localization uses the connectivity or pattern matching method to estimate the location. For the sake of simplicity, we will focus in what follows on the main measuring principles used throughout the state-of-the-art approaches. Those principles, or techniques, leverage distance and angular observations which form the basis for the positioning methods.

2.4.1 Received Signal Strength Indicator (RSSI)

RSSI measures the power of the signal at the receiver and based on the known transmit power, the effective propagation loss can be calculated. By using theoretical and empirical models, this loss can be used to derive/estimate the distance. This method has been used mainly for RF signals. RSSI is a relatively cheap solution without any extra devices, as all sensor nodes are likely to have radios. The performance, however, is not as good as other ranging techniques due to the multipath propagation of radio signals that may face physical obstacles (objects, people, walls, etc.) and radio interferences. This is why the RSSI is often combined with other algorithms to increases localization accuracy.

2.4.2 Time of Arrival (ToA) / Time of Flight (ToF)

The principle of ToA is based on measuring the absolute travel time of a signal from a transmitter to a receiver. The Euclidean distance between two devices can be derived by the multiplication of the signal travel time by the wave speed (i.e. speed of light in vacuum). Since the wave velocity depends on properties of the propagation medium, knowledge of the penetrated material is required. For all building materials the propagation speed depends on the square root of the dielectric constant k. For example, for glass and dry concrete k ≈ 5, slowing down electromagnetic waves by a factor of more than 2. For ferroconcrete k ≈ 9, resulting in a factor in travel speed velocity of one third compared to the speed of light. ToA relies on precise synchronization of transmitter and receiver clocks, as even one nanosecond error in synchronization translates into a distance error of 30 cm if radio frequency signals are used. During Line-of-Sight (LoS), a rule of thumb is that timing can be achieved down to a fraction of the chip duration. A chip is typically a rectangular pulse of +1 or -1 amplitude, multiplied by a data sequence. ToA is particularly difficult to apply in indoor environments where multi-path conditions are common, because the autocorrelation peak in the signal referring to the LoS beam may not be resolved. The usage of a wider frequency band is a way to address this problem.

2.4.3 Time Difference of Arrival (TDoA)

Taking time differences of ToA measurements has the advantage that a possible receiver's clock bias is not relevant. Any constant time offset of a non-synchronous receiver's clock is eliminated by subtraction. In contrast to ToA, the receiver does not need to know the absolute time at which a pulse was transmitted - only the time difference of arrival from synchronized transmitters is needed. With two emitters at known locations, a receiver can be located onto a hyperboloid. A receiver's location can be determined in 3D from four emitters by intersection of three hyperboloids. With this approach, very precise synchronization of all emitters is a precondition. For GNSS positioning based on TDoA is a useful approach, because the drift of a low-cost receiver's clock can be eliminated while the satellites are precisely synchronized by 'GNSS time'. Conversely, a mobile emitter can be located from multiple receivers. In this configuration the infrastructure is trying to determine the location of the mobile station.

2.4.4 Phase of Arrival (PoA) / Phase Difference (PD)

PoA uses the received carrier phase to determine the distance between two devices. In order to mitigate phase wrapping, the received signal phase is evaluated on multiple frequencies. The distance is then determined by the rate of phase change.

2.4.5 Fingerprinting (FP)

The standard quantity for Fingerprinting (FP) is radiofrequency RSSI, but FP can also be performed acoustically from audio or visually from images. Fingerprinting typically consists of two phases. First, in an off-line calibration phase, maps for fingerprinting are set up either empirically in measurement campaigns or computed analytically. In the first case, signal strengths received from fixed stations are measured at a number of points inside a building and added to a database. In the operation phase the current measured signal strength values (RSSItuples) are compared for the best agreement with a database. The second case of analytical model generation is used to avoid elaborating calibration measurements. Thereby, the signal strength reference values can be computed using a signal propagation model.

2.4.6 Dead Reckoning (DR)

Dead reckoning is the process of estimating a position based upon previously determined positions and known or estimated speeds over the elapsed time. An inertial navigation system is the main type of sensor used. A disadvantage of dead reckoning is that the inaccuracy of the process is cumulative, so the deviation in the position fix grows with time. The reason is that new positions are calculated solely from previous positions. In literature associated with the field of indoor applications the term Pedestrian Dead Reckoning (PDR) is used as an indication that accelerometers have been attached to the body of a person.

2.5 Technologies overview

A graphical overview in dependence of accuracy and coverage is given Figure 1. The coverage is to be regarded as the direct measuring range of a single node implementation, i.e. the spatial scalability which many system approaches offer has not been taken into account (e.g. deployment of additional sensor nodes). Most technologies rely on electromagnetic waves and a few on mechanical (sound) waves. As can be seen from Figures a large part of the electromagnetic spectrum can be exploited for positioning. High accuracy systems tend to employ shorter wavelengths (Figure 2).

Table 1 (extracted from [Mautz 2012]) characterizes the sensor technologies at high-level. The values specified for accuracy and coverage are given in form of intervals wherein most approaches reside. There are many exceptions exceeding these intervals. Similarly, only the main measuring principles and applications are mentioned in the table.

Technology	Typical Accuracy	Typical coverage (m)	Typical measuring principle	Typical application
Camera	0.1mm – dm	1 – 10	angle measurements from images	metrology, robot navigation
Infrared	cm – m	1-5	thermal imaging, active beacons	people detection, tracking
WiFi	M	20-50	fingerprinting	pedestrian navigation, LBS
Ultrasound	Cm	2-20	distances from time of arrival	hospitals, tracking
Magnetic	mm-cm	1-20	fingerprinting and ranging	hospitals, mines
RFID	dm-m	1-50	proximity detection, fingerprinting	pedestrian navigation
UWV	cm – m	1-50	body reflection, time of arrival	robotics, automation
Inertial	1%	10-100	dead reckoning	pedestrian navigation
GNSS	10 m	Global	parallel correlation, assistant GPS	location based services

Table 1: Overview of indoor/outdoor positioning technologies. Coverage refers to ranges of single nodes

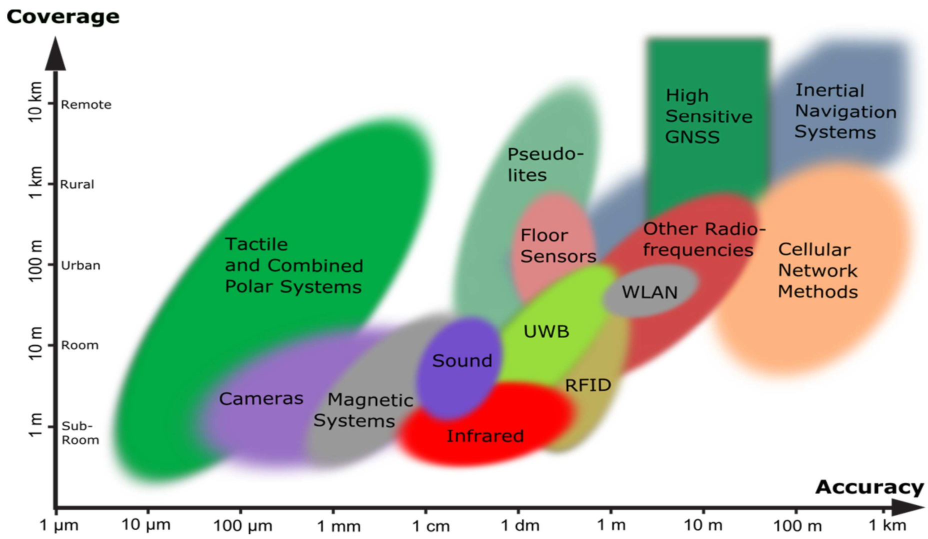


Figure 1: Overview of indoor technologies in dependence on accuracy and coverage

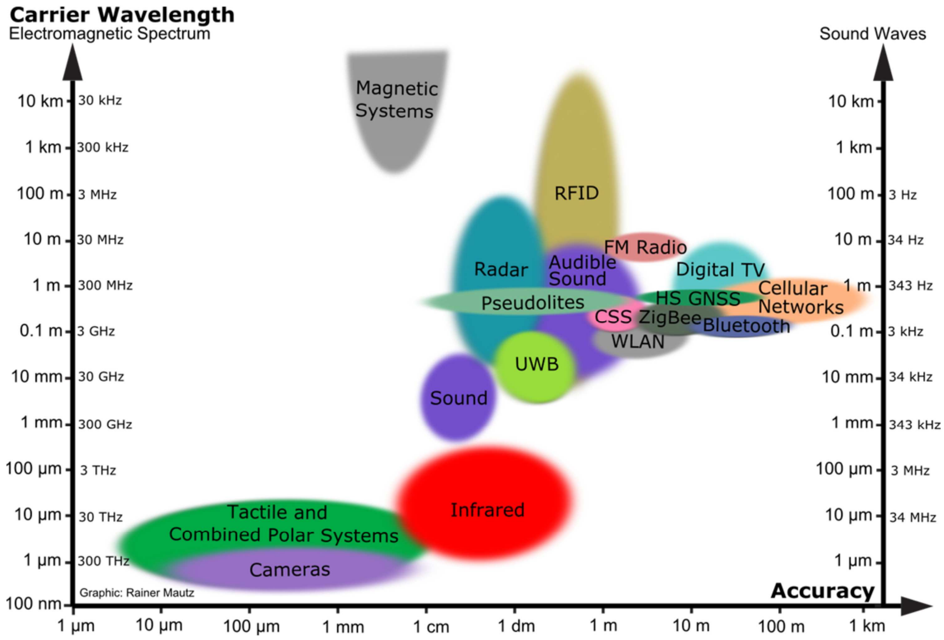


Figure 2: Indoor technologies in dependence on accuracy and carrier wavelength (extracted from [Mautz 2012])

2.6 Conclusion

The diversity of different technological solutions for indoor positioning and navigation shows how profoundly interdisciplinary the field is and reflects that almost any signal/sensor technique can be exploited for this purpose. Despite the abundance of approaches which exist to tackle the indoor positioning problem, current solutions cannot cope with the performance level that most applications require. In short, requirements for the mass market include 1 m horizontal accuracy, floor identification, absence of coverage-gaps, >99 % availability and minimal costs for local installations. Apart from insufficiency in position accuracy, coverage and availability, the need for extensive node deployment and maintenance is the main reason why system implementations are not sufficiently economical. A good fraction of research approaches are also missing appealing usability to enable wide-scale consumer adoption.

3 Ambient Assisting living Technologies (AAL)

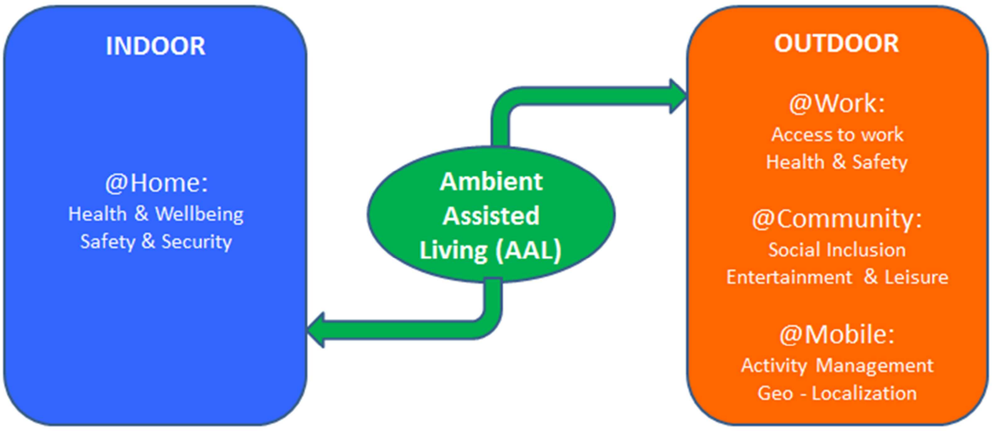
3.1 Context

Ambient Assisted Living (AAL) technologies offer a promising perspective on autonomous aging in place. This is in the interest of the older adults themselves, overburdened caregivers and policy makers who try to control health care budgets in the face of the ever growing older population. However, these technologies are still in their infancy and little is known whether the older adults are ready to adopt and use them. So far, most research efforts are of exploratory nature. While they identify factors which are important for the adoption and use of AAL technologies, only a few attempt to test and quantify the underlying relations between these factors. Furthermore, many studies focus on a pre-adoption stage (a technology has not been used yet) and do not consider post-adoption (users have used and experienced a technology).

3.2 User requirements

Ambient Assisted Living (AAL) is advocated as technological solutions that will enable the elderly population maintain their independence for a longer time than would otherwise be the case. Though, the facts motivating the need for AAL are indisputable, the inherently heterogeneous nature and requirements of the elderly population raise significant difficulties. One particular challenge is that of designing AAL systems that can evolve to meet the requirements of individuals as their needs and circumstances change. This demands the availability of an adaptive, open, scalable software platform that incorporates a select combination of autonomic and intelligent techniques. Given that the first generation of AAL systems will be deployed in the near future, it is incumbent on designers to factor this need for evolution and adaptability in their designs and implementations.

Ambient Assisted Living (AAL) requirements is multifaceted as shown in figure below, and is envisaged as supporting the person in their home, communities and work places.



Promoting social interaction is key objective of AAL. Unfortunately, isolation, social exclusion and depression are frequent results of the aging process in practice. Another key objective concerns the maintenance of the person's well-being in their own home, ensuring that the person is safe and capable of functioning independently. This later scenario has attracted significant research effort, possibly due a perception that maintaining independence and well-being in the home is essential and that all other benefits will accrue from this. Ref: [Peek]

3.3 Existing technologies and approach

3.3.1 Sensors

Today, most smart phones are equipped with various sensors such as accelerometer, gyroscope, proximity sensor, and global positioning system (GPS), which can be used for detecting user activity and mobility. Also, recent advances in epidermal electronics and MEMS technology (Micro-electro mechanical systems) promise a new era of health related sensor technology. Researchers have already developed noninvasive sensors in form of patches, small Holter-type devices, body-worn devices, and smart garments to monitor health signals. For example, blood glucose, blood pressure, and cardiac activity can be measured through wearable sensors using techniques such as infrared sensing, optical sensing, and oscillometric. Some other measurements such as EEG still require invasive sensors such as electrodes. Also, depending on the captured physiological signal, high or low data sampling rate might be needed. For example, accelerometer and gyroscope capture acceleration and orientation; therefore, a high sampling rate is required to detect activities such as running.

Ambient Sensors Used In Smart Environment

SENSOR	MEASUREMENT	DATA FORMAT
PIR (Passive Infrared)	Motion	Categorical
Active Infrared	Motion/ Identification	Categorical
RFID (Radio Frequency Identification)	Object Information	Categorical
Pressure	Pressure on mat, chair, etc.	Numeric
Smart Tiles	Pressure on floor	Numeric
Magnetic Switches	Door/ Cabinet Opening/ Closing	Categorical
Ultrasonic	Motion	Numeric
Camera	Activity	Image
Microphone	Activity	Sound

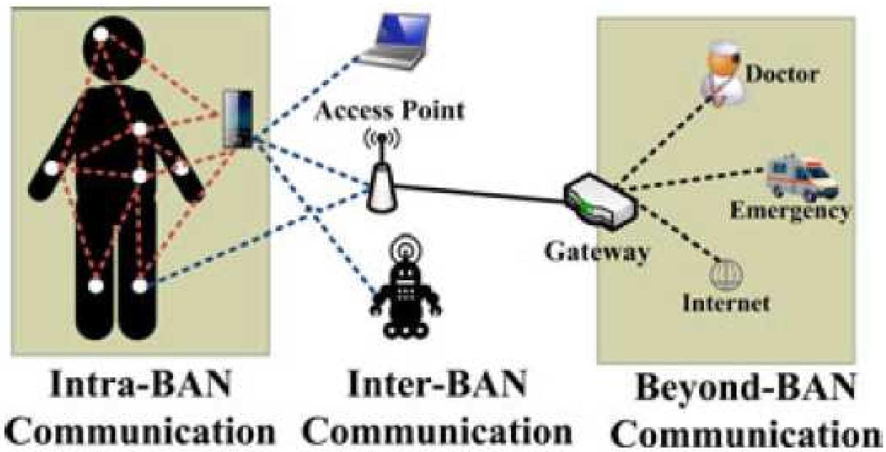
Wearable and Mobile Sensors

SENSOR	MEASUREMENT	DATA FORMAT
Accelerometer	Acceleration	High
Gyroscope	Orientation	High
Glucometer	Blood Glucose	High
Pressure	Blood Pressure	Low
CO2 Gas	Respiration	Very Low
ECG (Electrocardiography)	Cardiac Activity	High
EEG (Electroencephalography)	Brain Activity	High

EMG (Electromyography)	Muscle Activity	Very High
EOG (Electrooculography)	Eye Movement	Very High
Pulse Oximeter	Blood Oxygen Saturation	Low
GSR (Galvanic Skin Response)	Perspiration	Very Low
Thermal	Body Temperature	Very Low

3.3.2 Communication

Most sensors adopt a combination of TinyOS operating system and IEEE 802.15.4 (ZigBee) as the radio interface. Sensors generally rely on a network architecture known as the body area network (BAN) [M Chen]. BANs enable wireless communication in or around a human body in three different tiers, as depicted in figure below:



Intra-BAN communications refer to communications between body sensors. Several schemas have been proposed to achieve energy efficient communication with QoS provisioning, including MITHrill [A Ylis], SMART [C Poon], and CodeBlue [R Shah]. Recent advances such as inductive links and intra-body links promise alternative communication technologies by using body tissue as a transmission medium. To transmit data from on-body sensors to handheld devices, various IEEE 802.15 standards can be used. Popular choices include Bluetooth (IEEE 802.15.1) with a max data rate of 1 Mb/s and a range of less than 10 m, ZigBee (IEEE 802.15.4) as a low power and low rate protocol with a max data rate of 250 kb/s and a range of less than 20 m, and Wi-Media (IEEE 802.15.3) as a more recent technology with a max data rate of 480 Mb/s and a typical range of less than 10 m.

The inter-BAN communications include communicating data from personal devices such as smart phones to the access points, either in an infrastructure-based manner or in an *ad hoc* manner. Various technologies can be employed for inter-BAN communication, including WLAN, Bluetooth, ZigBee, cellular, 3G/4G, etc. The most popular choice is ZigBee protocol due to its ability to support mesh networks, low energy consumption, low duty cycle, low latency communication, and 128-bit security. More recent technologies such as "Bluetooth Low Energy" (BLE) will provide other alternatives in the future by decreasing the communication overhead.

Finally, the beyond-BAN tier connects the access points to the internet and other networks. A database is usually part of the infrastructure to hold collected data and information about users. A Web interface also might be provided to facilitate communication between users and care providers.

3.3.3 Application Areas and Projects

A large number of AAL systems aim to monitor daily activities for sustaining independent living, continual naturalistic assessment of health and cognitive status, automated assistance, and decreasing caregiver burden.

Application Area	Examples
Cognitive Orthotics	Daily Reminders, Medication Reminders, Navigators, Wandering Prevention Tools, Planners
Continous Health Monitoring	Vital Signs Monitoring, Sleep Monitoring, ADL (Activities of Daily Living) Monitoring
Therapy	Tele-health systems, Tele Rehabilitation Systems
Emergency Detection	Fall Detection, Medical Emergency Detection, Hazard Detection
Emotional Wellbeing	Social Connectedness, Facilitating Communication
Persuasive Applications	Well-being Promotion, Medical Compliance

Some researchers monitor a single activity such as walking or watching TV. Nambu et al. [Nambu] monitor watching TV for diagnosing health conditions. Wu et al. have developed a smart cane that classifies cane usage and walking patterns, and informs the elderly in case of high risk of falling [Smart Cane]

AAL tools can be useful for preventing wandering behavior of dementia patients. There are a number of outdoor wandering prevention tools. KopAL [KopAL] and OutCare [OutCare] support disoriented elderly by alerting the caretakers in case of deviating from predefined routes or daily signature routes. Comfort Zone [CZone], EmFinder [EmFinder], QuestGuard [QGuard], and GPSShoes [GPSShoes] are examples of commercial outdoor wandering prevention tools relying on GPS technology. In the case of indoor stray, Lin et al. [CCLin] use RFID technology to detect if an elderly person has approached a dangerous area, and Crombag [Crombag] proposes using virtual indoor fencing in potentially harmful situations.

Cognitive orthotics tools can prove very useful in case of older adults suffering from cognitive decline, as family members usually find it embarrassing and upsetting to provide cues and prompts to their loved ones, due to privacy invasion and role reversal issues [Mihalidis].

Some smart home projects in Europe include iDorm [iDorm], Grenoble Health Smart Home [GHSH], Gloucester Smart House [GSH], PROSAFE [PROSAFE], ENABLE [ENABLE], and CareLab [CareLab]. There are also related joint initiatives such as the “Ambient Assisted Living Joint Programme” supported by the European commission with the goal of enhancing the quality of life of older people across Europe through the use of AAL technologies [AALTech].

3.4 Alzheimer Tracking Devices

There are a variety of tracking devices available [AlzTrack]. Below two are recommended by Alzheimer's Association:

Medic Alert - This device was originally created to help emergency responders treat patients who could not speak for themselves. Today, the device also helps people with dementia who wanders. The devices is worn as a bracelet and when a loved one goes missing, caregivers can call the police and have the police call the 24-hour hotline to get the location of the missing person. Caregivers can also call the hotline themselves to get information. In addition to a tracking device, the bracelet has important medical information engraved upon it. [MedicAlert]

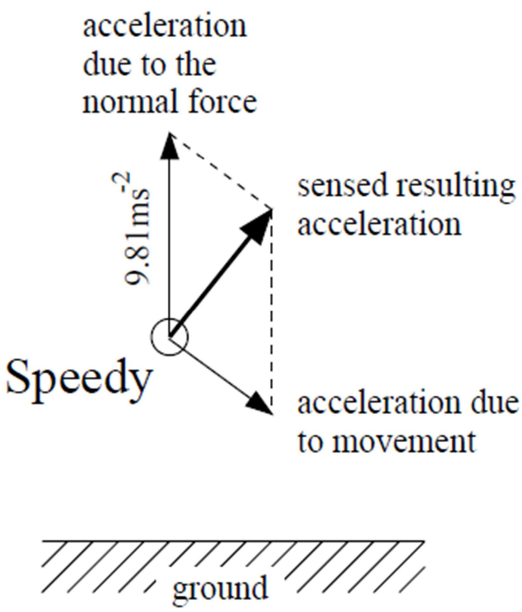
ComfortZone - The Comfort Zone Check-In is the wandering solution from the Alzheimer's Association. There are two options for tracking a loved one. One is a small device that can be carried in a purse or a pocket, the other is by tracking a Sprint cell phone that the person carries with them. Comfort Zone Check-In requires a monthly subscription that links the device to web-based software where caregivers can easily find the location of their loved one. [ComfortZone]

	DEVICE					APPLICATION							SERVICE				
	outdoor location	indoor location	Panic Button	2-way voice communication	Fall management	FIND (Current location)	FOLLOW (Constant tracking)	location history	Zone alert	network alert	battery alert	mobile application (Blackberry)	application support	24/7 location assistance	emergency health record	safety resources	care consultation
With COMFORT ZONE inside																	
PCD 8110 powered by Qualcomm inGeo™	x	x	x			x	x	x	x	x		x	x	x	x	x	x
Sendum PT200 Tracker	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x
CalAmp LMU2610 Vehicle Tracker						x	x	x	x	x	x	x	x	x	x	x	x
With Comfort Zone CHECK-IN inside																	
PCD 8110 powered by Qualcomm inGeo™	x	x	x			x	x	x	one				email only			x	x
GPS-enabled Sprint phone	x	x		x		x	x	x	one				email only			x	x

3.5 Fall detection technologies

In recent years, technological advances in micro electro mechanical system (MEMS) acceleration sensors have made it possible to design fall detectors based on a 3-axis integrated MEMS (iMEMS®)

accelerometer. The technique is based on the principle of detecting changes in motion and body position of an individual, wearing a sensor, by tracking acceleration changes in three orthogonal directions.



The data is continuously analyzed algorithmically to determine whether the individual's body is falling or not. If an individual falls, the device can employ GPS and a wireless transmitter to determine the location and issue an alert in order to get assistance. The core element of fall detection is an effective, reliable detection principle and algorithm to judge the existence of an emergency fall situation.

iMEMS semiconductor technology combines micromechanical structures and electrical circuits on a single silicon chip. Using this technology, iMEMS accelerometers sense acceleration on one, two, or even three axes, and provide analog or digital outputs. Depending on the application, the accelerometer may offer different ranges of detection, from several g to tens of g. Digital versions may even have multiple interrupt modes. These features offer the user convenient and flexible solutions. [3Axis]

4 Conclusion

Current AAL systems promise many opportunities for maintaining independence of older adults, as well as for monitoring and improving their health conditions. Several key emerging technologies have made it possible, such as the mobile and wearable sensors, assistive robots, smart homes, and smart fabrics. Meanwhile, advanced computational techniques have helped to unleash the full power of such technologies. But there are still many challenges that need to be addressed by the researchers in the future.

Sensor Technology: The new generation of mobile and wearable sensors should be more comfortable to wear and less obtrusive. To achieve this, such devices should take advantage of the future power harvesting and wireless power transmission technologies, as well as new human-tissue compatibles materials to achieve truly noninvasive solutions. Also, researchers need to address concerns regarding the absorption of electromagnetic energy by human tissue by employing devices with low transmission power and low duty cycles.

Assistive Robotics Technology: Currently assistive robots do not support a variety of daily tasks; rather, each robot is built to provide assistance with a very limited set of tasks [Smarr]. In the future, more user studies should be performed regarding the acceptance of robots by the older adults, as well as the older adults' expectations of such assistive robots. The future robots not only should be capable of assisting the older adults in their day to day life, but also should be able to adapt to their gradual physical and cognitive decline, as well as to their sudden changes such as a hip fracture.

Security and Privacy: Deployment of AAL technologies will bring along new concerns about security, as a multitude of personal data is collected. The future AAL systems should employ a variety of noninvasive user authentication methods based on biometric and physiological features to safeguard user privacy. Different levels of security should be granted to different users in such complex systems, and the communication links should be made secure and more reliable.

Algorithms: Most current techniques such as activity recognition and indoor location detection still need to be improved to become more reliable and more accurate for use in real-world settings. Also, some simplifying assumptions should be relaxed, such as the assumptions regarding single resident homes and availability of labeled data. Besides, there is a need for standard benchmark datasets.

Legal and Ethical: There are currently no structured regulations regarding reimbursement of AAL tools, or regarding malpractice in complex tele-health systems. Also, to protect their rights as consumers, the older adults should be well-informed about the possible consequences of AAL solutions.

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