DEVELOPMENT OF AN AUGMENTING NAVIGATIONAL COGNITION SYSTEM

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DEVELOPMENT OF AN AUGMENTING NAVIGATIONAL COGNITION SYSTEM

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SYSTEM

Ying Yang

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THESIS ABSTRACT

DEVELOPMENT OF AN AUGMENTING NAVIGATIONAL COGNITION SYSTEM

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Social isolation for persons with cognitive impairments due to aging and/or disease is common and widespread. Those people who have diseases such as early Alzheimer's and dementia tend to forget what they have to do to reach their destination and why they are going there when they go outside unaccompanied. The purpose of this research is to develop technical components of one device called Mobility Assistance (MA) for those persons with cognitive impairments. This MA device can store a pre-defined route and can also track the navigational route of a person. According to context (standing, running, walking, in vehicle) and position, the MA can detect likely deviations from the expected route. The MA device can give the lost user various cues to return to the route. If the user fails to resume the correct route or the user encounters an emergency (for example: falling down), the MA device can alert a caregiver.

There are three modules in this system: sensor, mobile phone and PC. The sensor module is composed of an analog accelerometer which provides information such as steps, distance and movement information, an analog compass which provides direction information, and a Bluetooth transmitter. The main use of the sensor module is for dead-reckoning navigation when GPS is unavailable. It is also used to detect context such as sitting, running, or riding in a vehicle. The mobile phone module can determine any deviations from a programmed route by using GPS and dead-reckoning navigation. The mobile phone can also prompt/alert the mobile user and communicate with a remote caregiver. The PC module can be used for route entry and can download the routes to a Mobile phone.

In this research we have developed and implemented the following components of the MA device:

1. System software to receive and store transmitted data from the inertial sensor.
2. System software to receive data from a GPS module.
3. Algorithms for direction determination.
4. Algorithms to interpret the sensed data to compute steps and distance of wearer traveled.

5. Interaction software, running on a PC, to present the data from PDA-phone appropriately.
6. Interaction software, running on a PDA-phone, that allows the user to setup conection between phone and PC.

So far, the communication between sensor and mobile phone and between mobile phone and PC work well. Furthermore, the analog compass can provide accurate direction information within a ±2° margin. However, the analog accelerometer still can not provide accurate step detection and stride length information. Future work will be needed to address these issues.

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MS Word

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CHAPTER 1.INTRODUCTION

1.1 Purpose

Social isolation for persons with cognitive impairments due to aging and/or disease is common and widespread. Conditions such as early Alzheimer's disease and dementia (incidence rates of 15 per 1000; projected incidence by 2020 is 7 million Americans) (Lauter, 1985) impair people's ability to journey outside their homes to access social and community resources. For example, some cognitively impaired people often forget their destination or how to get to their destination. Or when some people with conditions such as heart disease go outside unaccompanied, emergencies such as falling down can often happen. These situations are very dangerous for these people [1].

This research is part of a project to develop a Mobility Asistance (MA) device that can help these people with cognitive impairments. This device can store a pre-defined route before starting to travel. It can track the navigational route of a person. According to context (standing, running, walking or in vehicle) and position, this device can detect any likely deviation from the expected route. This device can also give the lost user various cues to return to the route. If the user fails to resume the correct route or the user encounters an emergency (for example: falling down), the MA device can alert a caregiver.

1.2 Related Work

Research in this area is widespread. Jovanov[2] introduces the wireless body area network (WBAN) of intelligent motion sensors. Continuous technological advances in integrated circuits, wireless communication, and sensors enable the development of miniature, non-invasive physiological sensors that communicate wirelessly with a personal server and subsequently through the Internet with a remote emergency, weather forecast or medical database server; using baseline (medical database), sensor (WBAN) and environmental (emergency or weather forecast) information, algorithms may result in patient-specific recommendations. The personal server, running on a PDA or a 3G cell phone, provides the human-computer interface and communicates with the remote server(s). Figure 1.1 shows a generalized overview of a multi-tier system architecture; the lowest level encompasses a set of intelligent physiological sensors; the second level is the personal server (Internet enabled PDA, cell-phone, or home computer); and the third level encompasses a network of remote health care servers and related services (Caregiver, Physician, Clinic, Emergency & Weather etc.). Each level represents a fairly complex subsystem with a local hierarchy employed to ensure efficiency, portability, security, and reduced cost.[2].

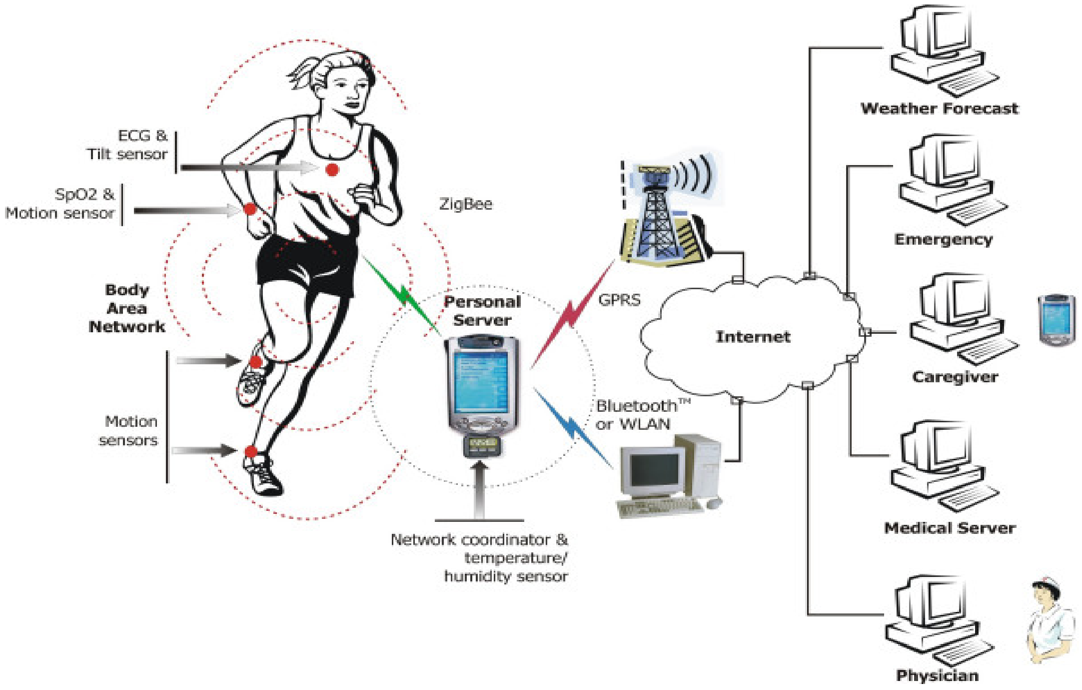


Figure 1.1 Architecture of WABN [2]

The group of Urs Anliker[3] developeded the advanced care and alert portable telemedical monitor (AMON), a wearable multiparameter medical monitoring and alert system targeting high-risk cardiac/respiratory patients. The system includes continuous collection and evaluation of multiple vital signs,intelligent multiparameter medical emergency detection, and a cellular connection to a telemedicine center(TMC). The idea is that by using an unobtrusive wrist-worn device,monitoring can be performed without interfering with the patients’everyday activities and without restricting their mobility. Thus, people currently confined to the hospital or their homes can lead nomal lives while knowing that any medical problems will be detected in time and help will be dispatched. Additionally, physicians are provided with a greater level of information about a patient’s condition-from a natural setting-thus enabling them to better tailor treatment[3]. Figure 1.2 shows the prototype of AMON.

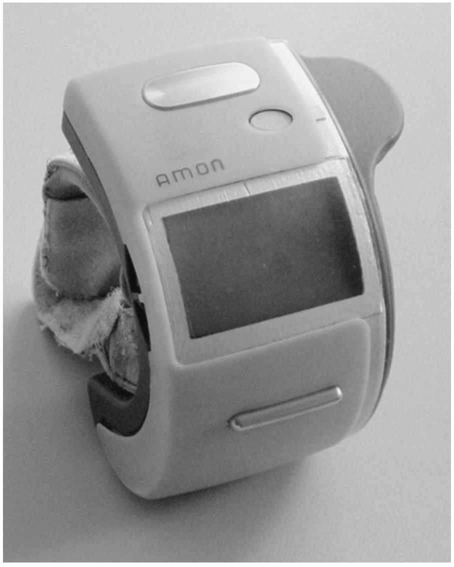


Figure 1.2 AMON prototype[3]

Compared with MA device, several unique features of AMON system are as following: First, the AMON system is capable of measuring blood pressure,SpO_2 , and a one lead ECG, all in a aingle device. There are currently no handheld or portable device which combines all of these measurements. Second, The AMON system combines all sensors,communiction, and processing devices in a single ergonomic wrist-worn enclosure. Third, the AMON system can perform an analysis of all measurements online, presenting them in appropriate form to both wearer and remote TMC. For emergency detection, the analysis can incorporate the patient's profile and activity information to reduce the number of false alarms. AMON system has similar features as MA device has. First, the cellular connection to the TMC features a flexible communication channel that can use a direct connection as well as short message system(SMS) services. It can also be easily extended to incorporate a tranmission control protocol(TCP)/Internet protocol(IP)-based link. Second, using a two-axis acceleration sensor integrated in the system, AMON is capable of detecting the context of user also. The AMON system requires only very simple activity analysis compared to other wearable activity detection application,e.g.,[4]. Thus, for example eating,drinking, or just talking and gesticulating involve arm motions that are not paricularly strenuous. AMON device only detected the activity associated with (fast) walking or running. Figure 1.3 shows the activity reading from AMON[3].Currently, we can not get accurately to detect context of the wearer of MA device. See Chapter 4 Experimental Results. So we can learn from AMON system about how to get correct context information of the wearer.

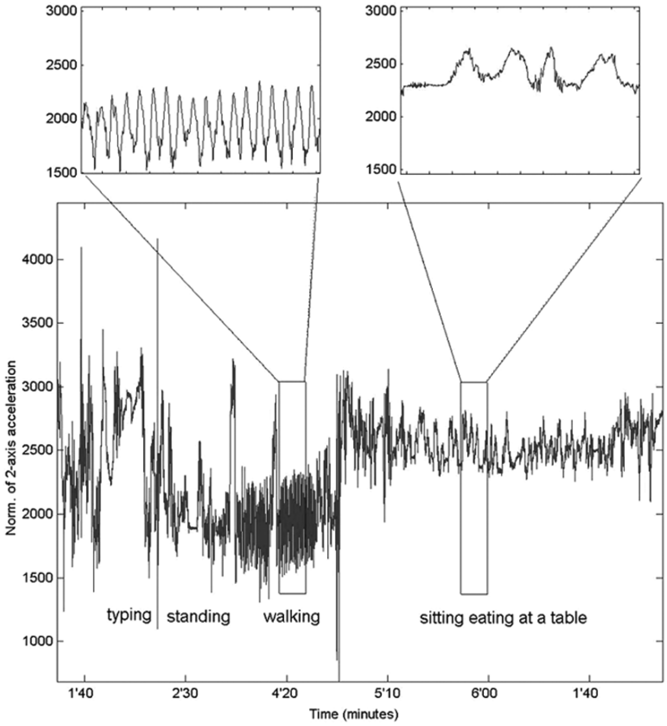


Figure 1.3 Activity readings:normal two-axis acceleration data from AMON system[3]

M-Health can be defined as “mobile computing,medical sensor, and communications technologies for health-care.“ This concept represents the evolution of e-health systems from traditional desktop “telemedicine“ platforms to wireless and mobile configurations[5]. Recently, there are many wireless communication and network technologies around mobile health systems. For example, development of smart intelligent sensors and drug delivery devices, some of them implanted, will allow communication with a personal server in complete mobility[6]. Physicians'access to patient history, laboratory results, and medical resources would be enhanced by mobile technology. Handheld devices can be used in home health care. A overview of some existing applications can be found in recent publictions in the area [7-11].

Currently, many wireless technologies are mainly depending on general packet radio service(GPRS) technologies. There are some limitations which can be summarized as following[12]: 1)There are no “m-health protocols“ as linkage of the different mobile telecommunciation options and standards for e-health services. 2)The high cost of communication links should be considered, especially between satellites and global mobile devices. Network security of mobile internet connection and information access especially for e-health system is another issue. 3)Currently, most physicans and health-care experts yet do not fully understand these technologies. 4) The software receiving paymant and reimbursement for m-health services are not fully developed and standardized. 5) The demostration projects so far failed to show that m-health sevices result in savings and have cost effective potential. Figure 1.4 shows the concepts of m-health system. It is very similar to Figure 1.1.

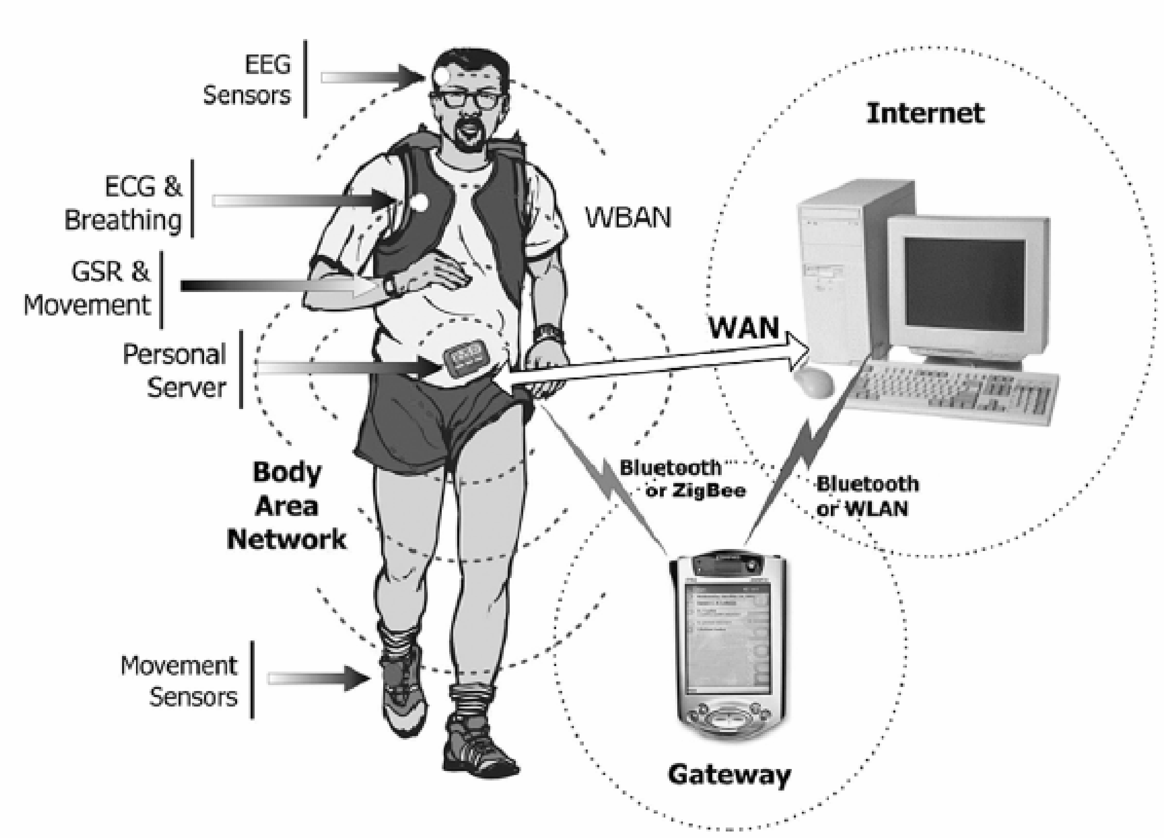


Figure 1.4 Typical system architecture of m-health monitoring systems[8]

The typcial application of m-health system includes the following[8]:

1) Wearable systems and personal heath-care mointoring[13],[14];

2) Monitorng of soliders in the battlefield[15];

3) Emergency medical care;

4) Home mointoring [16],[17],[18];

5) Computer-assisted rehabilitation and therapy[19];

6) Social networking of relatives and peers of chronically ill patients.

Fazlur Rahmn, Arun Kumar, Gangadharan Nagendra and Gourab Sen Gupta describe a system called physiological measuring and monitoring system (PMMS) which is able to record physiological parameters such as height,weight,body temperature,heart rate,and blood oxygen saturation level of a person[20]. A block diagram of the PMMS is shown in Figure 1.5. The system meaures and mointors the physiological parameters gathered from different type of sensors used for the purposed listed in Table 1.1.

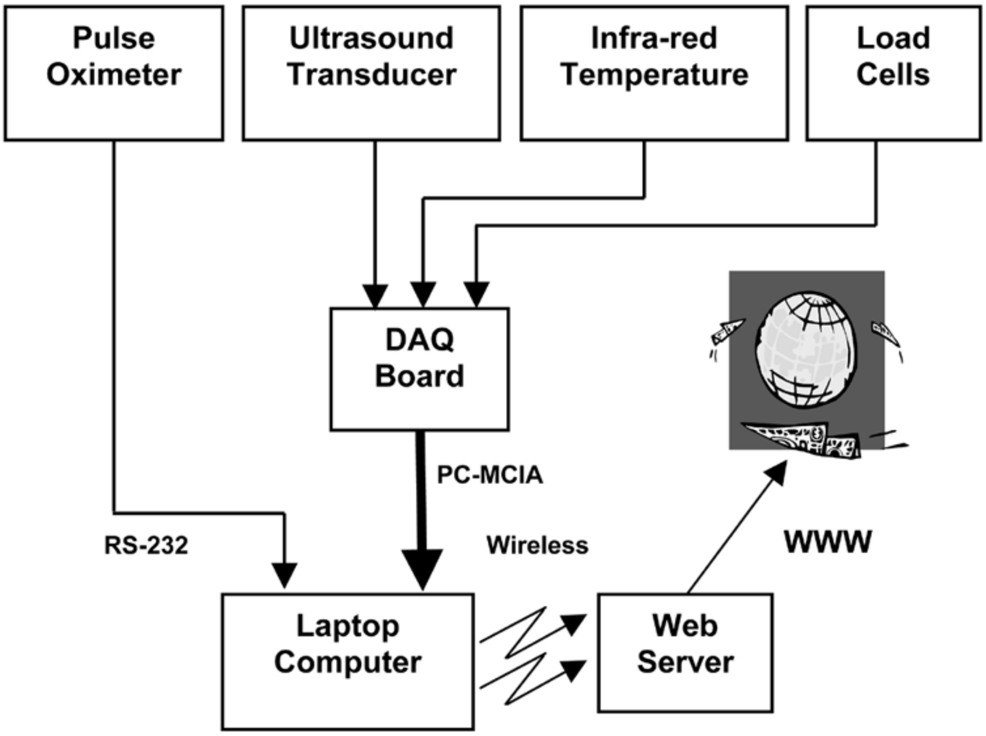


Figure 1.5 Block diagram of physiological measuring and monitoring system[20]

Table 1.1 Four Basic Sensors and their functions for physiological measuring and monitoring system [20]

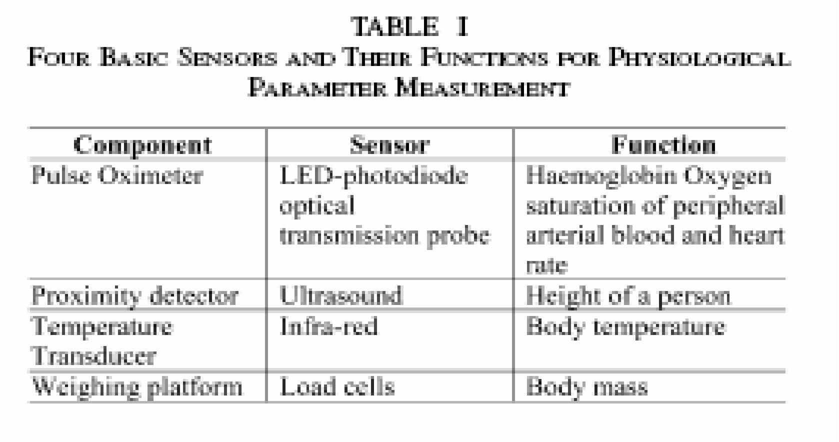


TABLE I

FOUR BASIC SENSORS AND THEIR FUNCTIONS FOR PHYSIOLOGICAL PARAMETER MEASUREMENT

Component	Sensor	Function
Pulse Oximeter	LED-photodiode optical transmission probe	Haemoglobin Oxygen saturation of peripheral arterial blood and heart rate
Proximity detector	Ultrasound	Height of a person
Temperature Transducer	Infra-red	Body temperature
Weighing platform	Load cells	Body mass

See Figure 1.5. The hardware system of PMMS consists of several individual sensors connected to the laptop computer through the data acquisition(DAQ) card, and one sensor is connected direclty to the RS232 port of the laptop computer. The laptop is interfaced with a PCMCIA 12-bit resoultion DAQ. External signals from physiological sensors are fed to the DAQ input channels. For each analog input channel, the DAQ card samples the signal at a rate of 200 samples/s. The main program is written using National Instrument’s LabVIEW software and is used to log the data onto the computers. The program captures, analyzes, displays and transmits the data to the central server[20].

Our MA device is a wearable computer. One important goal of wearable computing is to create digital devices that are as easy to don and as comfortable to wear as common articles of clothing such as blouses,pants and belts. New forms of woven materials such as conductive webbings, which incorporate durable electrical conductors directly into the matrix of the weave, offer exciting possibilites for closely integrating digital electronics with conventional clothing. However, many practical obstacles hinder the adoption of these materials, not the least being a lack of reliable electrical connectors for the interconnection of conventional electronics with conductive fabrics[21]. Michael M.Gorlick presents a simple and workable design for just such connectors and demostrate how a commonplace article of clothing-suspenders can be transformed into an effective power bus and data network for wearable digital devices[21].

An implementation of an unobstusive five-point acceleration sensing wireless body area network(WBAN) with mobile device data logging capabilities is presented, along with practical experiences on performance[22]. The tested device is a small, matchbox size device with sensing and communications capabilities,thus it is unobtrusive for measuring use activity. The basic board holds a realtime clock circuit, which provides timing reference precise enough for implementing a TDMA based MAC protocol. The Microchip PIC16LF877 is used as a mcirocontroller. RS-232 is used for serial communications with external devices. A single channel, 1mW license free radio (RF Monolithics TR 1001) is used for networking devices, providing 10 kbps bidirectional, half duplex wireless communciations. The standard sensor board of SoapBox ver. 1.0 includes five different types of sensors. Only the 3-axis acceleration sensor(two ±2g Analog Devices ADXL202JE) is utilized in the WBAN arrangement. In one node, a±10g derivative of the sensor is used. The test results show good communications performance in laboratory conditions. But field test performance is weak[22].

G.Edward Barnes and Steve Warren proposed “A wearable, bluetooth-enabled system for home health care“[23]. The portable personal monitoring system was designed to incorporate three devices that communicate wirelessly using Bluetooth. The device consists of the base station, data logger, and sensor unit. The monitoring system can have multiple sensor units that acquire physiological data from an individual. The system has a central control and storage component, called the data logger, to which all of the sensors on the piconet are connected. Finally, a connection to the network, called the base station, allows communication between the portable system and the outside world. This network access allows for processing, further data storage(e.g. in a patient's electronic medical record), and physician access to data. The prototype demonstrates that data can be taken by the remote sensor, stored and sent to the coordinating data logger, while the data logger can receive and store data from the sensor unit, control the sensor unit, and send data to the base station to be displayed[23]. Figure 1.6 depicts the layout for the personal monitoring system.

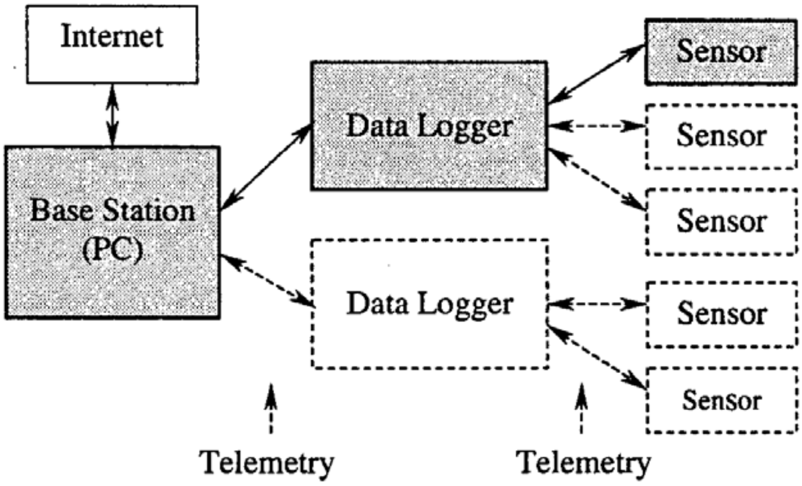


Figure 1.6 General layout for the prototype personal monitoring system[23]

Matthew B. Lau proposed a system called "The Snap!" in his master's thesis[24]. The Snap! is a cross-contry ski system which was designed to measure information about the interaction between a skier and a pair of skis. The goal of The Snap! is to correlate information about the skier(heart rate, GPS location, and local air temperature & pressure) and information about the ski equipment(boot flex, toe angle, heel pressure, etc.). The Snap! network was constructed with sensors on booth boots, both skis, and in the skiers backpack. Here, I want to mention that the author puts sensors on left and right skies to get toe angle, three axis acceleration and compass information. On the ski, two analog devices ADXL210[25] 10g, two-axis accelerometers were mounted perpendicular to one another to detect acceleration along three orthogonal axes. A Precision Navigaion Vector 2x[26] compass was mounted atop each ski to detect direction. These parts are capable of measuring acceleration small enough to show small degrees of tilt in the ski, and as large (±)10 g. The acceleration and boot angle are configured to measure at 20 Hz for 3.75 seconds out of every 30. The accelerometer module on the left ski was programmed to send out configuration packets to the other transducers to synchronize measurements across both skies. The compass sensor reported a single measurement every half minute. The x-axis of acceleration is in the direction of the ski. The y-axis shows lateral motion in the horizontal plane (side-to-side along the surface of the earth), and z-axis measures in vertical direction(with the positive-z direction measuring downward acceleration)[24].

A portable physical rehabiltation monitoring system based on a personal network of intelligent sensors is described in [27]. Rehabilitation is traditionally carried out in hospitals under the supervision of qualified personnel. So, using a PDA which can offfer large processing power, decent graphical user interface and compact flash based secondary memory can be helpful. Individual sensors are positioned on limbs to analyze movement using 2-axis MEMS accelerometers[28]. The system generates real-time warnings when predefined thresholds have been exceeded.The system also can be put on the hip and knee[27].

Jack M,Winters, Yu Wang, and Jill M. Winters write the paper which summarizes ongoing research on both mobile interfaces and therapies related to rehabilitation. They design a system called the mobile intelligent telerehabilitation assistant(ITA) which is a long-term project intended to provide an alternative for 21st-century rehabilitative telecare. The interactive, mobile ITA interfaces and telecommunications infrastructure are desribed[29].

In the MA system, a GPS receiver is used to locate a position outdoors. But an indoor position is also needed in our system. We use dead reckoning(DR) to estimate the position indoors or at locations where a GPS can not receive a signal from satellites. Dead reckoning is the process of estimating the current position by advancing a known previous position using course, speed, time and distance to be traveled. This is not only a domain for the humans, but also for primative animals like ants who do dead reckoning as well[30].The history of DR began with terrestrial or nautical navigation. Nowdays DR is needed to navigate outdoor and indoor positions. With much efforte the PointMan™ Dead Reckoning Module (DRM™) has been developed. This is a miniature, self-contained, electronic navigation unit that provides the user’s position(Latitude/Longitude) relative to an initialization point obtained by some other method. The PointMan™ DRM™ is the first practical implementation of a drift-free dead reckoning navigation system for use by personnel on foot. It is specifically designed to supplement GPS receivers during signal outages. It even works inside of many buildings but does not support a varying step length[31]. A recent solution for accurate navigation is the use of sensorfusion techniques to combine different sensor types to improve the performance of the navigation systems[32]. Military research centers are also implementing remarkable solutions[33].

In our MA devices, an acceleration algorithm is designed to get distance the wearer travels. Steps and strides of every step is computed from 2-axis ADXL202EB acclerometer data. Then, the distance is computed by adding all strides together. See Section 3.4.2 Acclerometer Algorithm. Fyfe[35] and Sagawa [36] proposed similar ideas.

The motion analysis sy`stem patented by Fyfe [35] in 1999 applies a biaxial sagittal plane accelerometer to measure foot acceleration. A third parallel offset accelerometer is used to allow measurement of angular acceleration which is integrated twice to yield the foot angle profile for the stride. The foot angle profile is then used to resolve the horizontal acceleration from the biaxial accelerometer measurements, and this horizontal acceleration is integrated twice to yield stride length. Drift is reduced by making use of the zero velocity reference during stance phase and removing the signal mean prior to integration. Accurate to within 3% over a wide population and without user calibration, this technique is valid for a complete range of gait velocities from slow walk to full run and has been applied in related consumer products such as the Nike SDM[34].

Sagawa [36] demonstrated a similar system in 2000 that applies a triad of accelerometers and a sagittal plane gyro. While the gyro requires only a single integration to measure the foot angle profile, this technique is otherwise functionally identical to Fyfe. Over multiple 30 m trials, this method had a maximum error of 5%[34].

As with some of the stride modelling techniques, the work by Sagawa and Fyfe relies on the assumption that the foot motion is primarily in the sagittal plane. However, these methods have a possible advantage in that they measure step length directly and work without making further assumptions about the user's height, gait, or walking environment. From a practical perspective, Fyfe's entirely accelerometer based method may be preferred to Sagawa's as accelerometers are currently less expensive, smaller, draw less power and drift less than gyros[34].

In Ross Grote Stirling's thesis[34], a pedestrian dead reckoning system is proposed that applies sensors mounted on the shoe.The technique of stride length measurement using shoe mounted accelerometers invented by Fyfe[35] is applied and analyzed. To get heading infomation, the magneto-resistive sensors are used. After treadmill tests and field trials, it was found that it is possible to navigate using shoe mounted sensors though the overall accuracy does not compare well at this point with conventional methods of pedestrian navigation and satellite positioning[34].

Making devices aware of the activity of the user fits into the bigger framework of context awareness, which also aims at awareness of environment and the state of the device itself[37]. Dey and Abowd[38] provided a survey of context and contextaware applications with handheld and ubiquitous computing requirements in mind:“Context is any information that can be used to characterize the situation of an entity. An entity is a person,place, or object that is considered relevant to the interaction between a user and an appplication, including the user and applications themselves[38].In order to get as much information on a context as possible, it is necessary to use a large number of different sensors. All of the raw sensor values would be used as inputs for the machine learning algorithms.Kristof Van Laerhoven and Ozan Cakmakci describe a combination of machine learning techniques such as Kohonen maps[39] and probabilistic models[37].

There are many algoirthms for predicting location and orientation as well. A.Elnagar and A.M.Hussein describe an algorithm for predicting future positions and orientation of a moving object in a time-varying environment using an autoregressive model(ARM)[40]. Yu.P.Grishin presents the structure and algorithms of fault-tolerant date processing in an integrated GPS-based airborne navigational equipment intended for enhancing the integrity of the whole navigational system[41].

1.3 System Design

There are three basic modules in the MA system. They are the sensor module, mobile phone module and PC module. The sensor module is composed of a Bluetooth transmitting device, an analog compass and an accelerometer. The analog compass provides direction information. The accelerometer provides steps, distance, and movement situation information. Figure 1.7 shows the sensor module architecture.

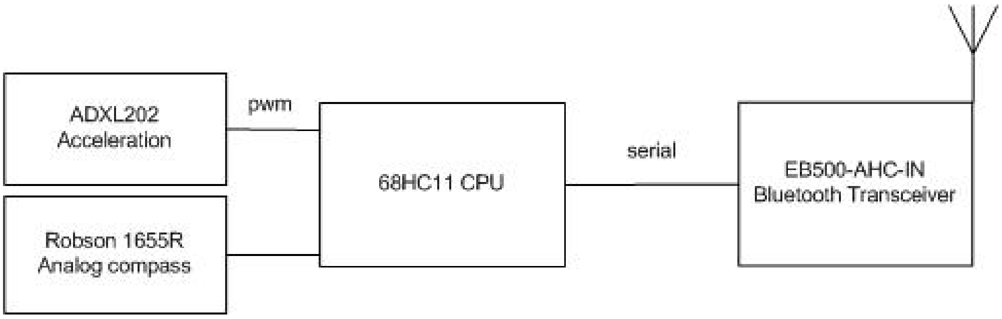


Figure 1.7 Bluetooth IMU module

The sensor module is used for dead-reckoning navigation when GPS is unavailable. It is also used to detect context such as sitting, running or riding in vehicle. The mobile phone module can detect context based on sensor data. It also is used to determine deviation from a programmed route using GPS and dead-reckoning navigation. The mobile phone module can cause the user interface to prompt/alert the mobile user. If the user needs more help, the mobile phone module will communicate with a related caregiver. The PC module permits route entry, and it can download a route to a mobile device. Figure 1.8 depicts the whole system's architecture.

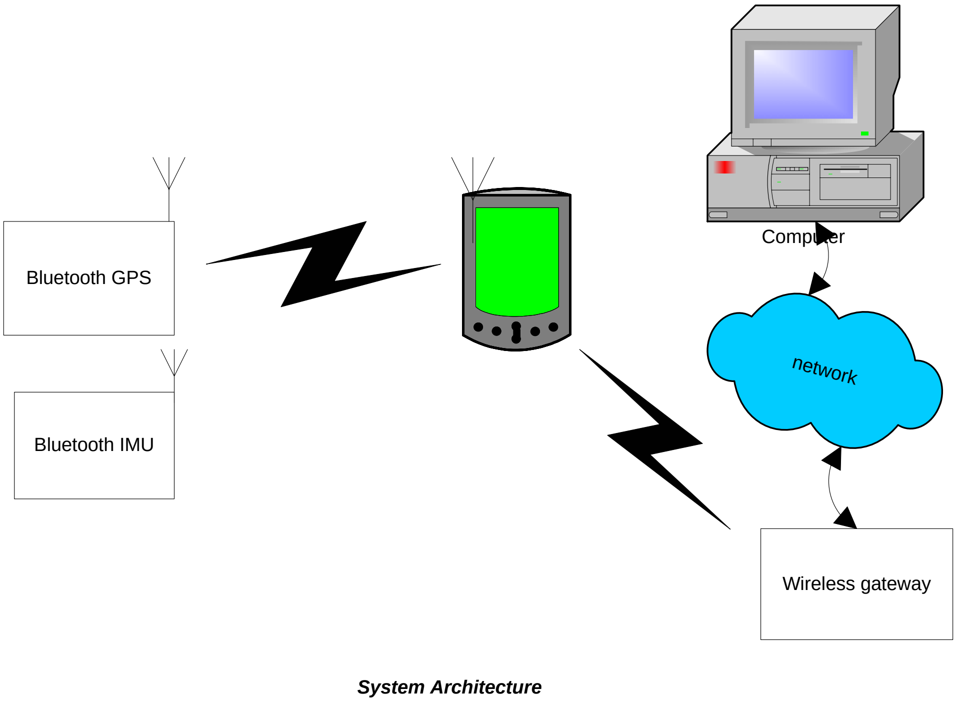


Figure 1.8 System architecture

Chapter 2 describes hardware setup and Chapter 3 is about the software implementation of the entire system. Chapter 4 analyzes the experimental results. Chapter 5 gives the conclusion and describes future work.

CHAPTER 2.HARDWARE PARTS

In this chapter, the specifications and application hardware setup details are described. Accelerometers, analog compass, and microprocessor are used in this MA system. Some positional reference equipment such as the GPS receiver is also described. Finally, since the evaluation of this method of pedestrian navigation depends on the quality of the data from the sensor, the experimental data is reviewed.

2.1 Hardware Components Introduction

2.1.1 Motorola 68HC11 CPU

The MC68HC11 is an advanced 8-bit MCU with highly sophisticated, on-chip peripheral capabilities. It can achieve a nominal bus speed of 2MHZ. On-chip memory systems include 8 Kbytes of read-only memory(ROM), 512 bytes of electrically erasable programmable ROM, and 256 bytes of random-access memory.

Major peripheral functions are provided on-chip. An eight-channel analog-to-digital (A/D) converter is included with eight bits of resolution. An asynchronous serial communications interface (SCI) and a separate synchronous serial peripheral interface (SPI) are included. The main 16-bit, free-running timer system has three input-capture lines, five output-compare lines, and a real-time interrupt function. An 8-bit pulse accumulator subsystem can count external events or measure external periods. A watchdog system protects against software failures. A clock monitor system generates a system reset in case the clock is lost or runs too slow[44].

2.1.2 Robson 1655R Analog Compass

The R1655 analog compass sensor made by the robson company,INC. (see Figure 2.1) requires a closely regulated 5.00 volts DC input and produces a ratiometric DC output. The input should be “spike” and polarity protected if operated from a vehicle power supply. The output closely resembles two channels of a sine-cosine set of curves which cross at approximately 2.5 volts and peak at approximately 3.1 volts and floor at about 1.9 volts. Each output will drive up to 4 mA.

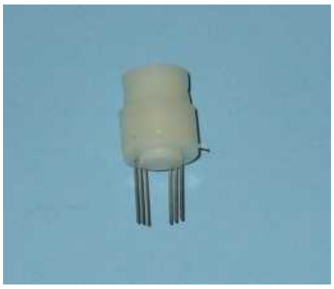


Figure 2.1 Robson 1655R analog compass

Table 2.1 shows specifications for the 1655 Analog compass.

Table 2.1 Specification for 1655R

Power	5-volts DC @ 19 ma. Since rise time is only 90 nanoseconds, input current may be pulsed to save power.
Outputs	Dual analog channels, 2.5v ?0.75v swing (total voltage swing rail to rail, aprox. 1.50v), 4ma DC signal. May feed direct to A-D front end of microprocessor.
Weight	2.25 grams
Size	12.7 mm diameter, 16 mm tall
Pins	3 pins on 2 sides on .050 centers
Temp	-20 to +85 degrees C

2.1.3 ADXL202E Accelerometer

ADXL202E was chosen for acceleration measurement because of its compact size, robust design, low-cost and low-power. It can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity).

The outputs of ADXL202E are Duty Cycle Modulated (DCM) signals whose duty cycles (ratio of pulse width to period) are proportional to the acceleration in each of the 2 sensitive axes. These outputs may be measured directly with a microprocessor counter, requiring no A/D converter or glue logic. The DCM period is adjustable from 0.5ms to 10 ms via a single resistor (Rset). If an analog output is desired, an analog output proportional to acceleration is available from the XFILT and YFILT pins (see Figure 2.2 and Table 2.2) or may be reconstructed by filtering the duty cycle outputs.

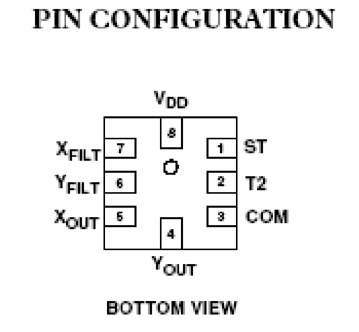
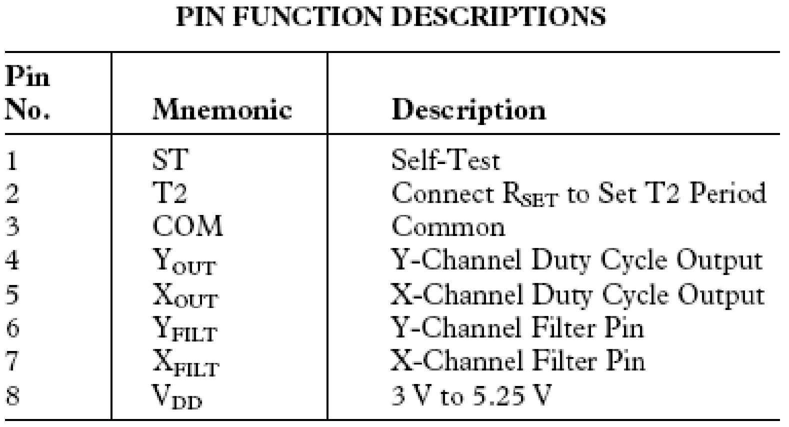


Figure 2.2 Pin configuration of ADL202EB[45]

Table 2.2 Pin function descriptions of ADXL202EB[45]



PIN FUNCTION DESCRIPTIONS

Pin No.	Mnemonic	Description
1	ST	Self-Test
2	T2	Connect R_{SET} to Set T2 Period
3	COM	Common
4	Y_{OUT}	Y-Channel Duty Cycle Output
5	X_{OUT}	X-Channel Duty Cycle Output
6	Y_{FILT}	Y-Channel Filter Pin
7	X_{FILT}	X-Channel Filter Pin
8	V_{DD}	3 V to 5.25 V

The bandwidth of the ADXL202E maybe set from 0.01Hz to 6 kHz via capacitors Cx and Cy. The typical noise floor is 100μg√Hz allowing signals below 2mg to be resolved for bandwidths below 60Hz.

Table 2.3 shows the specification of ADXL202E.

Table 2.3 Specification of ADX202E

Parameters	ADXL202E
# Axis	2
Range	+/- 2g
Sensitivity	12.5 %/g
Sensitivity Accuracy	±16
Output Type	PWM
Bandwidth	6kHz
Noise Density	200
Supply Voltage	3 to 5.25
Supply Current	0.6mA
Temp Range	-40 to 85°C
Package	E-8

Functionally, the ADXL202E is simple to use. Supply voltage of 3 to 5V is sufficient to power the chip, but since the analog output of the sensors is proportional to the supply voltage, 5V was used to maximize sensitivity. Capacitors placed on the output pins are used to limit the sensor bandwidth and reduce noise. In this application, the output was band-limited to 10-20 Hz, and the power supply was 5V.

2.1.4 EB500-AHC-IN Bluetooth Transmitter

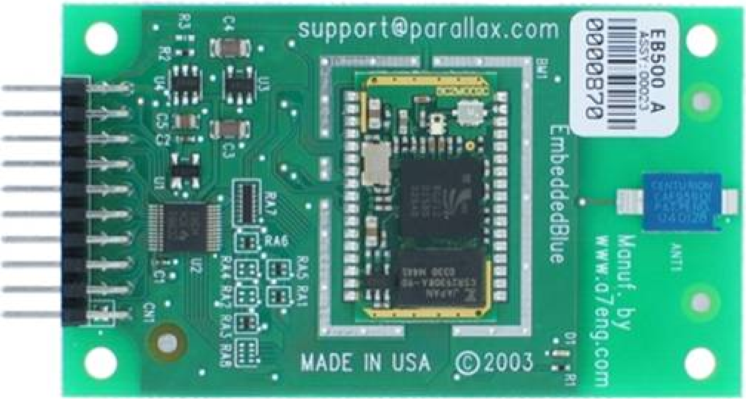


Figure 2.3 EB500-AHC-IN Bluetooth Transmitter

The communication between the Nokia 3650 and the Motorola 68HC11 is done by Bluetooth. We selected to use the EB500 Bluetooth Radio Module to connect with the Motorola 68HC11. The embedded blue Series EB500 Bluetooth radio module is ideal for enabling the Motorola 68HC11 with a widely supported industry standard wireless protocol. Monitoring and control applications will benefit from an integrated implementation of the serial port profile for seamless connectivity with PDA phones. Its low current consumption makes the EB500 ideal for use in standalone battery powered devices such as the Sensor model of this application.

The EB500 implements all components of the Bluetooth stack on board so that additional host processor code is not required. Once a connection to another Bluetooth device has been established, the link has the appearance of a cabled serial connection eliminating the need for special wireless protocol knowledge.

Simple UART communication facilitates the interface between the host processor and the Series EB500 radio. This UART interface may be used to discover, connect, and communicate with other Bluetooth devices. A LED indicator for connection status is provided.

2.1.5 Nokia 3650 Phone

Figure 2.4 Nokia 3650 phone

The Nokia 3650 phone is a mobile phone with PDA features. It has a big LCD screen (176x208 pixels), as well as support for infrared and Bluetooth wireless connectivity. This phone can combine picture, video, text and voice clips and send them by MMS or email to a compatible phone or PC. It can also send email over GSM data, HSCSD, and GPRS. In this system, we need real time connections between phone and PC. So a data transfer feature is necessary. The Nokia 3650 supports up to 43.2 kilobits per second in high-speed circuit switched data networks and up to 40.2 kilobits per second in GPRS networks. From a software development perspective, this phone supports J2ME MIDP 1.0 and can download new Java games and applications. It also has support for the Symbian 60 platform. The Symbian SDK 6.0 can be downloaded for free from the Nokia website.

2.1.6 Bluetooth GPS

Figure 2.5 Earthmate GPS receiver

The Earthmate GPS can be used for in-vehicle tracking purposes and also as a stationary sub-meter positioning device. With the Delorme Bluetooth PowerPack, the data can be transmitted to a laptop or Bluetooth-capable handheld computer. Messages from this device are complied with an NEMA 0183 v2.0 output standard. This device sends an NEMA message such as GGA,GSA,GSV,RMC For details of the message, see section 3.2.3 GPS parts.

2.2 Hardware Connections

Figure 2.6 shows the hardware architecture. The whole hardware is composed of an analog compass, an accelerometer ADXL202E, a 68HC11 microprocessor, and an EB500 Bluetooth Transmitter. The analog compass sends data to the 68HC11, and the ADXL202E sends sensor data to the 68HC11. A program is used to combine them together and the 68HC11 sends both of them to the phone over Bluetooth.

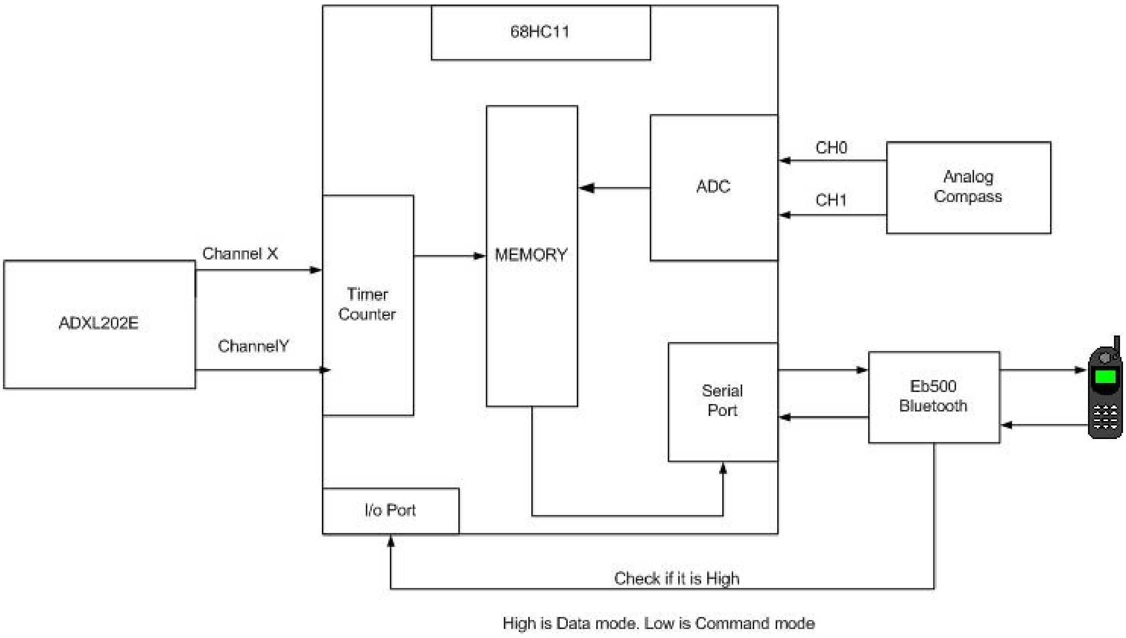


Figure 2.6 Hardware architecture

2.3 Direction Determination

We select the sensor called the R1655 Analog sensor from the Dinsmore Instrument Company to provide direction information. The sensor is connected with the 68HC11 as shown in Figure 2.6. Raw data are sent to the Nokia 3650 over Bluetooth. The algorithm program for direction determination is running on the phone. See Software Parts, Chapter 3 for details of the algorithm.

2.4 Context Determination

Context in this application is any information that can be used to characterize the situation of a person such as walking, running, standing still or riding on a vehicle. The accelerometer ADXL202E is selected to get the acceleration to detect the context of a wearer. The ADXL202E is connected with the 68HC11. The Motorola 68HC11 sends raw data to the Nokia 3650; the context recognition algorithm running on the phone will detect current context of the person. Currently, in order to detect correct context information, the ADXL202E is put on the hip of the person. For more information about the accelerometer algorithm mentioned here, see Software Parts, Chapter 3.

CHAPTER 3.SOFTWARE

In this chapter, software implementation is discussed. That includes the communication over Bluetooth between the Earth-mate GPS device and the Nokia 3650, the communication over Bluetooth between the Motorola 68HC11 and the Nokia 3650, the communication between the Nokia 3650 and the PC with a TCP/IP socket. The compass algorithm and accelerometer algorithm will also be discussed. The implementation GUI for the Nokia 3650 and server side program running on the PC to display data such as latitude/longitude, compass degree and distances is described in this chapter as well.

3.1 Software System Design Introduction

The entire software system falls into three categories: user interface(UI), communication and algorithms. Figure 3.1 shows the relationship between the three categories.

On the Nokia 3650, the UI consists of a TCP/IP setting dialog, a Bluetooth discovery dialog and a real-time data display list. The IP address and port number of the PC can be set in the TCP/IP setting dialog, and the Bluetooth discovery dialog is designed to display all of the Bluetooth devices in range. On the PC, a UI program is written in Java. The UI will display data transmitted from the Nokia 3650, such as latitude/longtitude, compass degree and distances etc.

Between the Nokia 3650 and the PC the communication is over a TCP/IP socket (using T-Mobile’s T-Zone wireless data service). And the Motorola 68HC11 communicates with the Nokia 3650 by using Bluetooth.

Algorithms play an important role in this system. In order to get correct direction information, one compass algorithm was developed to handle raw data from the Robson 1655R compass. Another algorithm is for the accerometer, and it has two functions: one is to get the correct context information of the user and another one is to get the position information for the indoors, where GPS data is usually unavaliable.

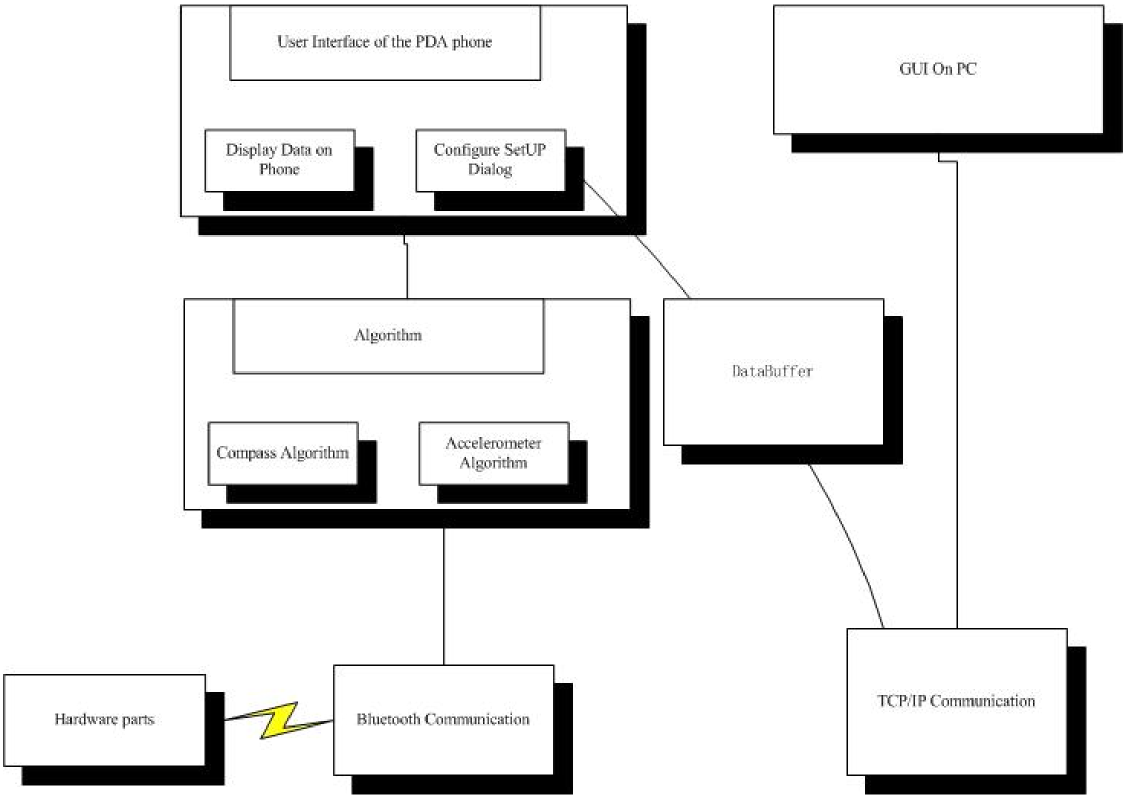


Figure 3.1 Software system design

3.2 Technologies Background

3.2.1 Bluetooth

Bluetooth is a short-range communication technology, standardized by the Bluetooth Special Interest Group (SIG).

The Bluetooth Stack is shown as below (Figure 3.2):

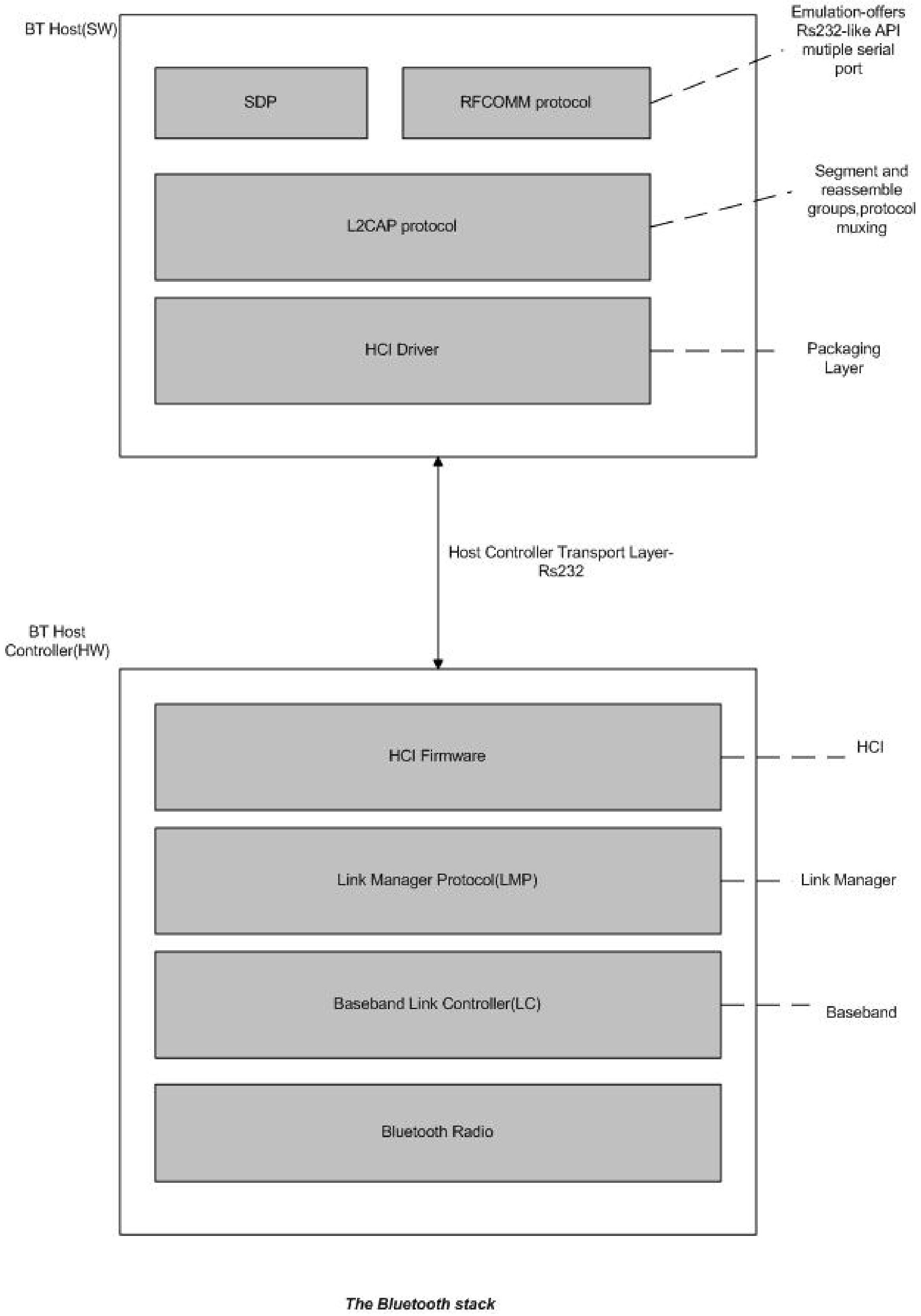


Figure 3.2 The Bluetooth stack

The Bluetooth Host Controller components provide the lower-level of the stack. It is typically implemented in hardware.

The Bluetooth Host components allow an application to send or receive data over a Bluetooth link, or to configure the link. It theoretically contains the following layers:

- RFCOMM: allows an application to treat a Bluetooth link in a similar way as if it were communicating over a serial port.

- Logical Link Control and Adaptation Protocol (L2CAP): allows finer-grained control of the link. It controls how multiple users of the link are multiplexed together, handles packet segmentation and reassembly, and conveys quality of service information.

- Service Discovery Protocol (SDP): used for locating and describing services provided by or available through a Bluetooth device. Applications typically use it when they are setting up communications to another Bluetooth device.

- Host Controller Interface (HCI) driver: packages the higher level components to communicate with the hardware.

3.2.2 Bluetooth on Symbian OS

The Symbian OS has a Bluetooth stack that is fully compliant with Bluetooth v1.1 specifications. The services that a Bluetooth implementation can offer are characterized by the Bluetooth standards as a number of profiles. The Symbian OS Bluetooth stack fully implements the Generic Access Profile, the Serial Port Profile and the General Object Exchange Profile. All other Bluetooth profiles are dependent on these three core profiles.

The Symbian OS implementation of this stack is made up of a Bluetooth Sockets module, Bluetooth Service Discovery Database, Bluetooth Service Discovery Agent, Bluetooth Security Manager and Bluetooth UI Module. Bluetooth Sockets encapsulates access to L2CAP and RFCOMM through a TCP/IP-like sockets interface. Bluetooth Service Discovery Database encapsulates one side of SDP: a local service uses it to record its attributes, so that remote devices may discover its presence, and determine if it is appropriate to use. Bluetooth Service Discovery Agent encapsulates the other side of SDP: it allows one to discover the services that are available on a remote device~~,~~ and the attributes of those services. Bluetooth security manager enables services to set appropriate security requirements that the incoming connections must meet. Bluetooth UI provides an API by which a dialog can be called that asks users for device selection information.

3.2.3 GPS

Global Positioning System (GPS) is a system of satellites and receiving devices used to compute positions on the Earth. GPS is used in navigation.

The National Marine Electronics Association (NMEA) is a standard protocol used by GPS receivers to transmit data. NMEA output is EIA-422A, but for most purposes, we can consider that it is RS-232 compatible. It uses 4800 bps, 8data bits, no parity and one stop bit. NEMA 0183 sentences are all ASCII. Each sentence begins with a dollar sign ($) and ends with a carriage return linefeed(<CR><LF>). Data is comma delimited. All commas must be included as they act as markers. Following the $ is the address field "aaccc". "aa" is the device id. For example, GP is used to identify GPS data. "ccc" is the sentence formatter, otherwise known as the sentence name[42]. The GPS device used in my research project is called the Earthmate GPS receiver. The Earthmate GPS's output is complied by NEMA 0183 v2.0 output standard. This device sends NEMA messages GGA,GSA,GSV and RMC whose formats are given as following:

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh

GGA = Global Positioning System Fix Data

1 = UTC of Position

2 = Latitude

3 = N or S

4 = Longitude

5 = E or W

6 = GPS quality indicator (0=invalid; 1=GPS fix; 2=Diff. GPS fix)

7 = Number of satellites in use [not those in view]

8 = Horizontal dilution of position

9 = Antenna altitude above/below mean sea level (geoid)

10 = Meters (Antenna height unit)

11 = Geoidal separation (Diff. between WGS-84 earth ellipsoid and mean sea level. -=geoid is below WGS-84 ellipsoid)

12 = Meters (Units of geoidal separation)

13 = Age in seconds since last update from diff. reference station

14 = Diff. reference station ID#

15 = Checksum

$GPGSA,A,3,19,28,14,18,27,22,31,39,,,,,1.7,1.0,1.3*35

GSA = GPS receiver operating mode, SVs used for navigation, and DOP values.

1 = Mode:

M=Manual, forced to operate in 2D or 3D

A=Automatic, 3D/2D

2 = Mode:

1=Fix not available

2=2D

3=3D

3-14 = IDs of SVs used in position fix (null for unused fields)

15 = PDOP

16 = HDOP

17 = VDOP

$GPGSV,4,1,13,02,02,213,,03,-3,000,,11,00,121,,14,13,172,05*67

GSV = Number of SVs in view, PRN numbers, elevation, azimuth & SNR values.

1 = Total number of messages of this type in this cycle

2 = Message number

3 = Total number of SVs in view

4 = SV PRN number

5 = Elevation in degrees, 90 maximum

6 = Azimuth, degrees from true north, 000 to 359

7 = SNR, 00-99 dB (null when not tracking)

8-11 = Information about second SV, same as field 4-7

12-15= Information about third SV, same as field 4-7

16-19= Information about fourth SV, same as field 4-7

$GPRMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,a,x.x,x.x,ddmmyy,x.x,a*hh

RMC = Recommended Minimum Specific GPS/TRANSIT Data

1 = UTC of position fix

2 = Data status (V=navigation receiver warning)

3 = Latitude of fix

4 = N or S

5 = Longitude of fix

6 = E or W

7 = Speed over ground in knots

8 = Track made good in degrees True

9 = UT date

10 = Magnetic variation degrees (Easterly var. subtracts from true course)

11 = E or W

12 = Checksum

3.2.4 Used GPS Sentences

In this project, only the latitude and longitude information which is contained in the GGA messages from the Earthmate Bluetooth GPS receiver are considered. This kind of information can be further passed into certain MAP SDK software running on a PC. And the MAP SDK can return address information to the Nokia 3650. If other positioning information is needed, other formats of messages may be considered.

3.3 Communications

This section will decribe all of the communications between the Motorola 68HC11 and the Nokia 3650, and the communciations between the PC and the Nokia 3650.

3.3.1 Bluetooth

3.3.1.1 Introduction of Use-cases

This section gives an overview of the interaction between the user, the Nokia 3650, and the GPS receiver/Motorola 68HC11 when the phone receives messages from GPS receiver or Motorola 68HC11. Figure 3.3, UML sequence diagram below, shows the interactions. The user powers on the Motorola 68HC11 with the EB500 or the GPS receiver. The devices will initialize the Bluetooth serial port service and advertise the service by adding an appropriate record to the SDP database. Then the user selects the “Discover“ menu on the Nokia 3650. The Nokia 3650 then displays a list of Bluetooth devices in range. The user selects one device (server device) from the list. The Nokia 3650 queries the SDP database to check that it is advertising the Serial Port service, and to extract necessary parameters of that service. Then the Nokia 3650 requests a serial port connection with the GPS/68HC11 over the Bluetooth. The Server bluetooth device informs the Nokia 3650 that the connection has been accepted. At the same time, the Nokia 3650 starts receiving message from the GPS or the 68HC11. After receiving messages, the Nokia 3650 handles these messages using the algorithms then displays the result to the user.

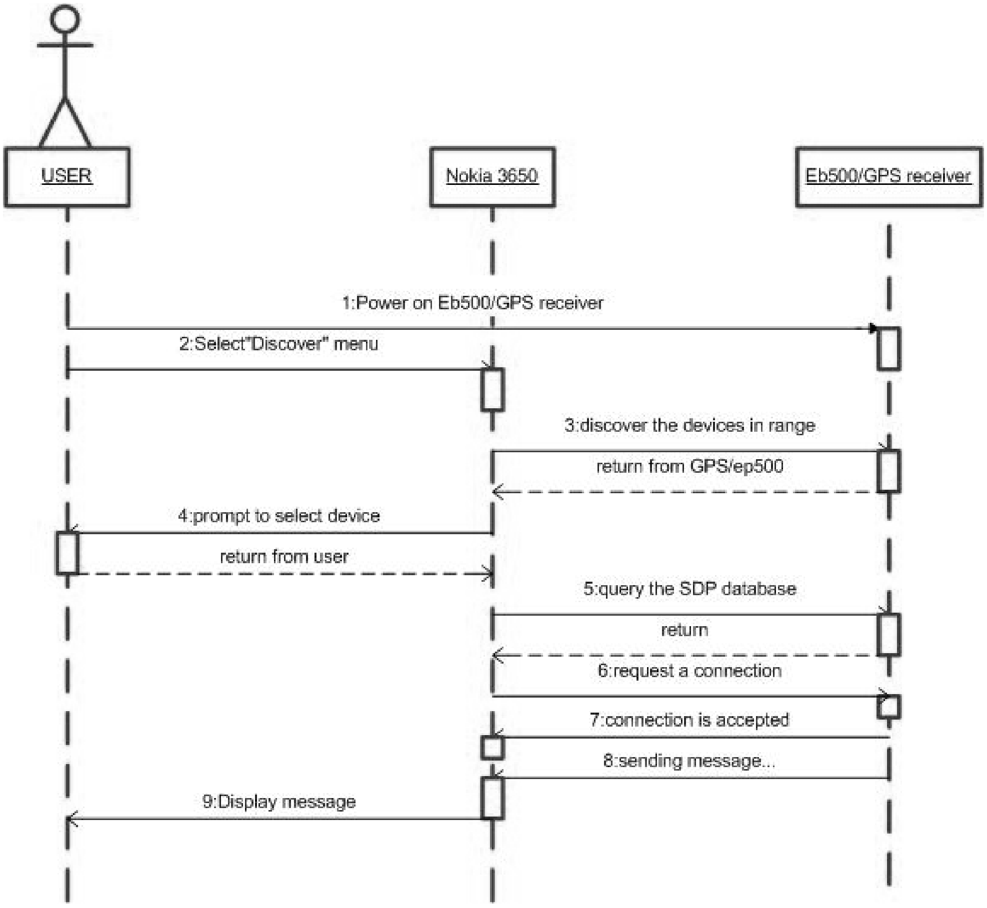


Figure 3.3 UML sequence diagram of bluetooth communciation

3.3.1.2 Design and implementation

Figure 3.4 shows the classes structure of the objects how to receive message from the GPS receiver or the 68HC11 over the Bluetooth.

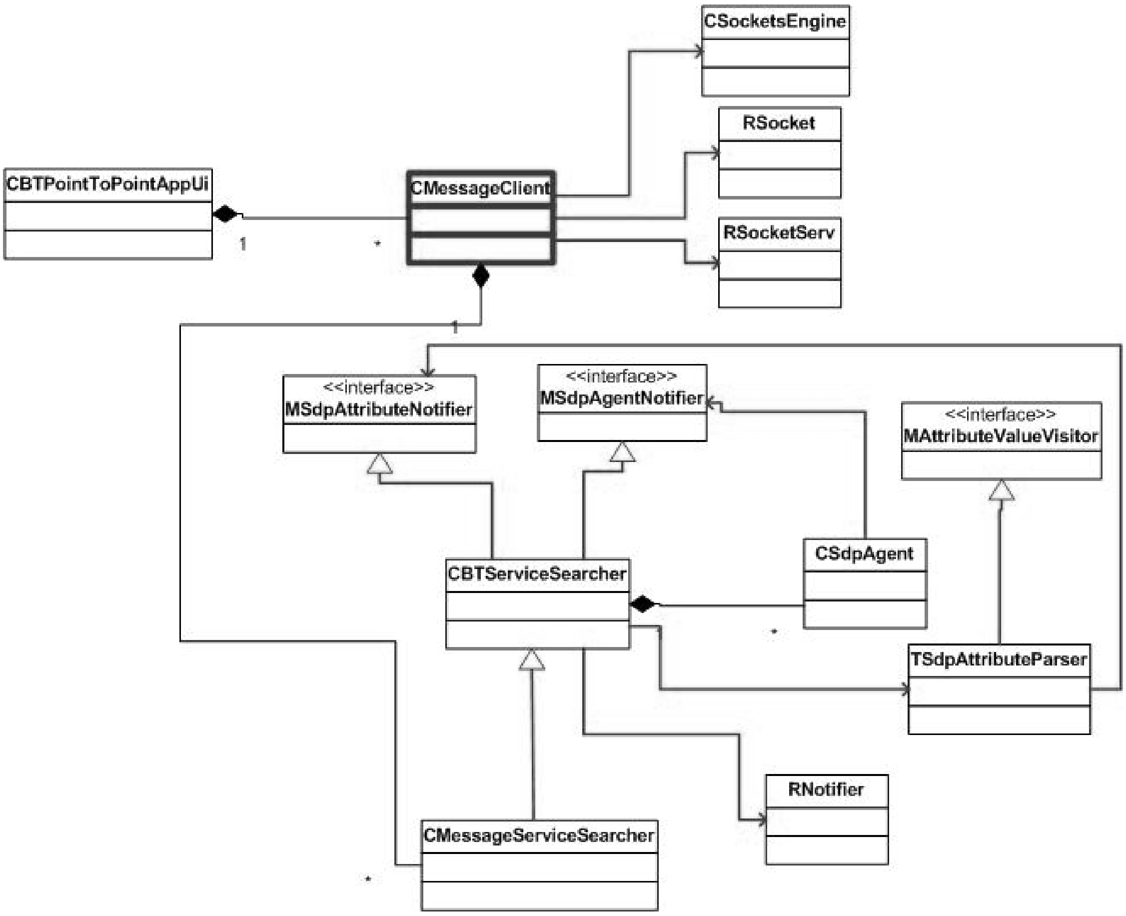


Figure 3.4 UML classes for Bluetooth communication

Class CBTPointToPontAppUI is the user interface class. It uses an object of CMessageClient to connect to another device and receive messages from remote devices. This class object uses the Symbian OS classes, RsocketServ and RSocket to open a socket to the GPS Receiver/68HC11. Before it opens the socket, the CmessageClient object needs to discover the Bluetooth device in its range and queries its SDP to find parameters relating to the Serial Port service. The Symbain OS class Rnotifier is used to discover the device. CmessageClient uses an instance of CmessageServcieSearch to query the server-side device’s SDP database and extract the port number to use for Serial Port service.

The CmessageServiceSearch class is derived from a general service searching object CBTService Searcher which connects to the server-side device’s SDP database. Class CsdpAgent can make Bluetooth SDP requests to another device. MsdpAgentNotifier handles responses to Bluetooth SDP queries. CBTServiceSearch uses TsdpAttributeParser to parse the SDP records. TsdpAttributeParser uses MsdpAttributeNotifier to notify CBTServiceSearch when it has found a specific value in an attribute.

3.3.2 TCP/IP Socket

3.3.2.1 TCP/IP Socket on Symbain OS

The Symbian OS provides TCP/IP communication services in conjunction with the Sockets Client API. The Sockets Sever defines a generic interface for all socket type communication services and defines a plug-in architecture for implementing particular providers. TCP/IP is such a plug-in. Clients access its services through the generic Sockets Client API, specifying protocol-specific behavior through TCP/IP specific utility types and constants. The API has three key concepts: TCP/IP socket, domain name resolver and internet address.

- TCP/IP socket: TCP/IP offers IP, ICMP, TCP, and UDP soket types. Socket services are provided through the generic interface *RSocket*.

- Domain Name resolver: Client programs make DNS queries through the generic host name resolution interface *RhostResolver*.
- Internet address: A socket address, IP address and port, is encapsulated in a *TInetAddr* object.

3.3.2.2 Design and Implementation

The UML diagram below depicts the classes of the TCP/IP socket commnuication. It makes use of the following three Symbian OS classes from the Sockets Client API:

- RsocketServ: This is used to create a session with the socket server that is providing a channel of communication with the socket server.
- RSocket: Each distinct connection to a remote server requires a RSocket subsession.
- RhostResolver: This can provide name resolution services.

And the core classes are as following:

- CsocketsEngine: This class creates the session with the socket server. It also creates and connects the socket to be used in communication with the server. This class can handle any feedback from the soket reader(CsocketsReader) and writer(CsocketsWriter). And reports any change in status and transfer status messages to the UI for display.
- CsocketsReader: This class is used to issue read request to the socket server. It reports any received data or error to the engine via the *MEngineNotifer* interface.

- CsocketsWriter: This class is used to issue a write request to the socket server. It reprots any errors to the engine via the *MEngineNotifer* interface.

The following figure 3.5 is the class diagram of the TCP/IP socket program of this application.

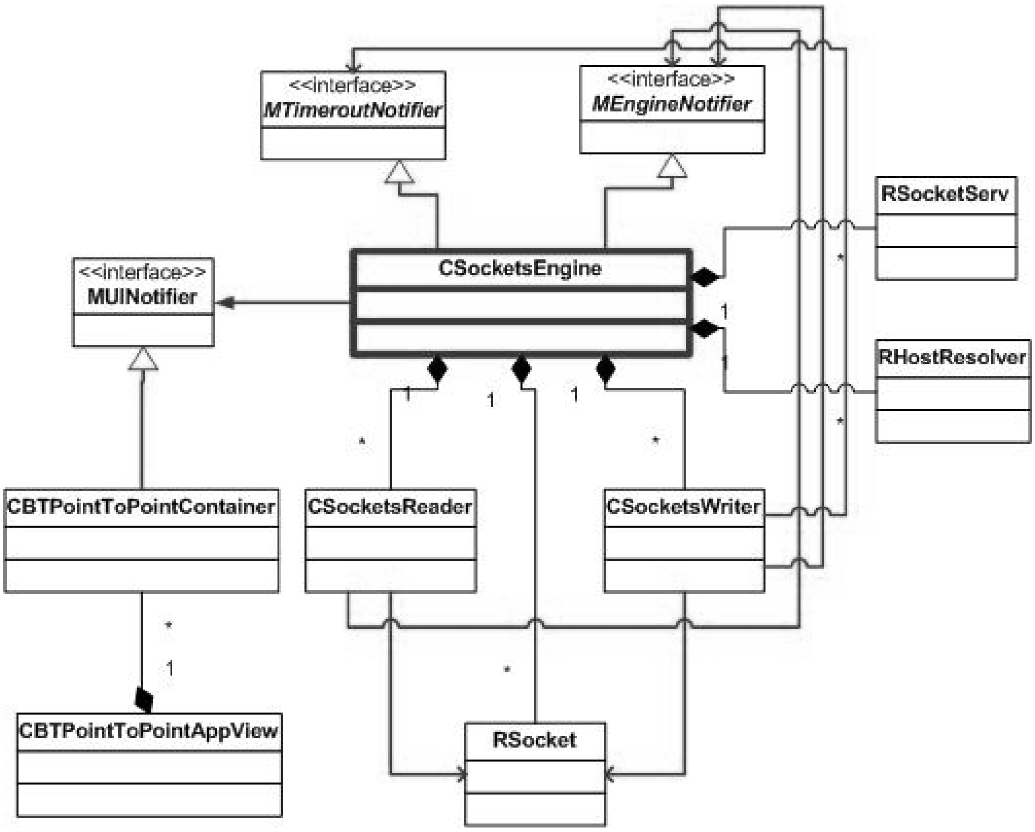


Figure 3.5 UML classes diagram of TCP/IP socket communication

3.4 Algorithms

3.4.1 Analog Compass Algorithm

A 1655R Analog compass output closely resembles a sine-cosine set of curves which cross at approximately 2.5 volts and peak at approximately 3.1 volts and floor at about 1.9 volts. Each output will drive up to 4mA. Figure 3.6 shows the two channels value after using an 8bits A/D converter. Samples are recorded every 5 degrees.

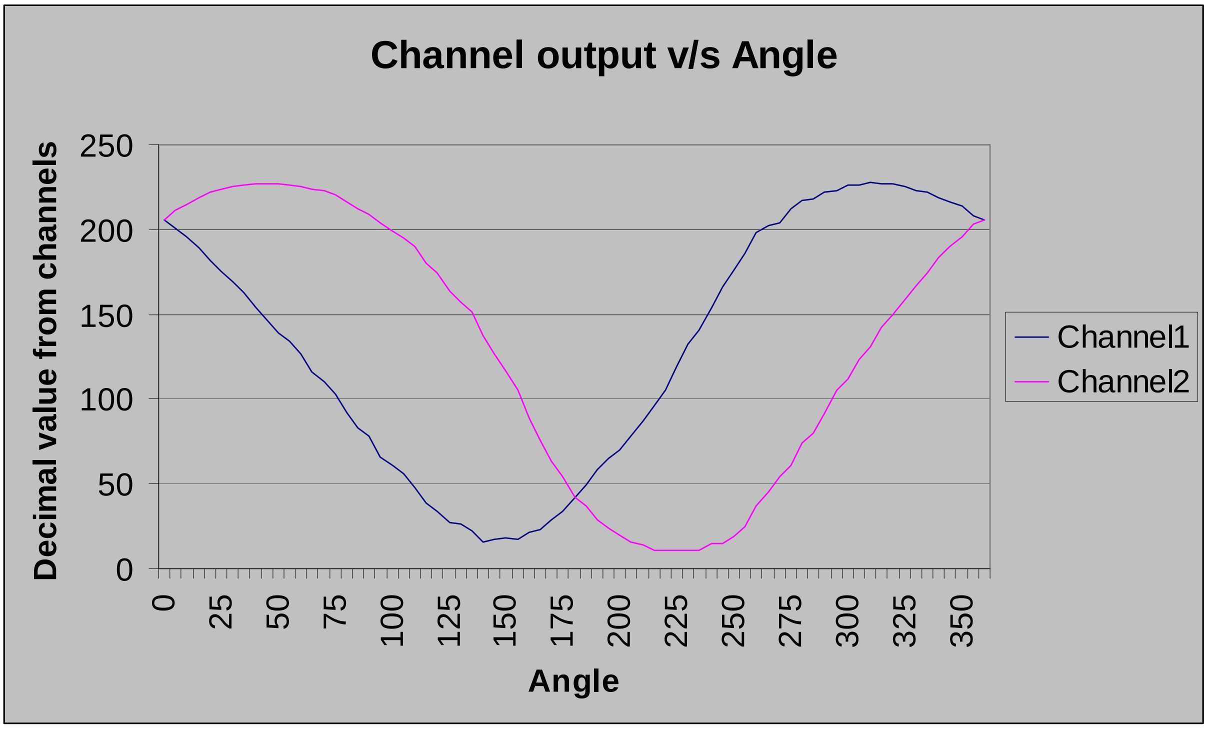


Figure 3.6 Outputs of two channels from 1655R compass

Table 3.1 Parts of reference table

Index	**Degree**	**Channel1**	**Channel2**
0	0	206	206
1	5	201	211
2	10	196	215
3	15	189	219
4	20	182	222
5	25	175	224
6	30	169	225
7	35	163	226
8	40	154	227
9	45	146	227
10	50	139	227
11	55	134	226
12	60	127	225
13	65	116	224
14	70	110	223

Table 3.1 is parts of the reference table. The whole table is attached in the Appendix A. This table is used in compass algorithm. The values in this table are tested by manually rotating the compass every 5 degrees.

Figure 3.7 shows how the Compass Algorithm works.

Input of algorithm is value1 which is from Channel 1 and value2 which is from Channel 2. Output of algorithm is degree.

```
if  ((ch1[0] –sigma) <value1<(ch1[0] + sigma)) &&
    ((ch1[0] –sigma) <value2<(ch1[0] + sigma))
degree = 0 or degree = 360;

if  ((ch1[37] –sigma) <value1<(ch1[37] + sigma)) &&
    ((ch1[37] –sigma) <value2<(ch1[37] + sigma))
degree = 180;

if (value1 < value 2)
```

```
{
    ch1Found = searchIndex(channel1,0,numSamples/2,value1,ch1Indexes);
    ch2Found = searchIndex(channel2,0,numSamples/2,value2,ch2Indexes);
}
else
{
    ch1Found = searchIndex(channel1,numSamples/2,numSamples,value1,ch1Indexes);
    ch2Found = searchIndex(channel2,numSamples/2,numSamples,value2,ch2Indexes);
}

if (ch1Found >0) && (ch2Found >0)
{
//Get maxim value of all slots in channel1
    ch1Slot = abs( channel1[ch1Indexes[i]] - channel1[ch1Indexes[i+1]]);

//Get maxim value of all slots in channel2
    ch2Slot = abs( channel2[ch2Indexes[i]] – channel2[ch2Indexes[i+1]]);
}

if(ch1Found < ch2Found) //normally, the smaller number is used to calculate
{
    return interpolate(ch1Indexes,…) //use channel1 to calculate degree
}
else
{
    return interpolate(ch2Indexes,…)//use channel2 to calculate degree.
}

//following is bad data correction, normally bit slot is used to calculate degree.

if (ch1Slot >= ch2Slot)
{
     return interpolate(ch1Indexes,…);
}
else
{
    return interpolate(ch2Indexes,…);
}

if (ch1Found >0 && ch2Found <=0) // ch2 Data is not correct.
{
    calculate biggest ch1Slot;
    use ch1 to calculate degree;
}
```

```
if (ch2Found >0 && ch1Found <=0) // ch1 Data is not correct.
{
    calculate biggest ch2Slot;
    use ch2 to calculate degree;
}

else return -1; //that means bad data can not be fixed.
```

Figure 3.7 Algorithm for getting direction

See Figure 3.6, from 0 to 90 degrees, we use channel 1 to compute the compass heading. From 90 to 180 degrees, we use channel 2 to compute compass heading. From 180 to 270 degrees, we use channel 1 to compute compass heading, or from 270 to 360 degree, we use channel 2 to compute compass heading. The reference table was tested manually every 5 degrees. So when we get the two values from channel 1 and channel 2, the range of the value in reference table should be computed first. Assuming the curve between every 5 degree of reference table is a line, we use the line solution function to calculate the degrees. Here is an example of how to calculate the degrees using this algorithm:

Example: value1 of Channel 1 is 199 and value2 of Channel 2 is 216, what's the output degree using this algorithm?

216 of value1 is greater than 199 of value2, so the degree should be between 0 to 180. The function of searchIndex is to search the reference table and find how many ranges (ch1Found/ch2Found) into which the value1/value2 fall. And the beginning indexes of each of range will be included in array ch1Indexes or ch2Indexes.

```
ch1Found = searchIndex(channel1,0,numSamples/2,value1,ch1Indexes);
```

ch2Found = searchIndex(channel2,0,numSamples/2,value2,ch2Indexes); here numSamples are 72 (360/5=72). The result is included in ch1Indexes and ch2Indexes. After looking up the reference table, ch1Found equals to 1 because only one range (201,196) is found and the index 5 will be stored into ch1Indexes. Ch2Found equals to 2 because two ranges are found. They are (215,219) and (216,212). And index 2 and 16 are stored into ch2Indexes. Obviously, the degree should be 0 and 90 degrees and channel 1 should be used to compute the degree.

Using line equation, x_0 =5, y_0=201 and x_1=10, y_1=196, we know y = 199(use channel1 to compute in this situation),

$$x= \frac{(y - y0) * (x1 - x0)}{y1 - y0} + x_0$$

So x = 7.00 degrees.

Sometimes, the outputs of channel 1and channel 2 are not stable because of the “bad data”, which normally caused by unstable circuit or environment with much noise interference. We need to find some ways to recover from that. In the above example, if ch1Found is also 2, and ch2Found is 2, we can not make a decision which channel should be used to compute. In this case we need to use ch1Slot and ch2Slot. The ch1Slot/ch2Slot is the y value range respectively with the same x value range in the reference table. Obviously, ch1Slot is much greater than ch2Slot which means that channel 1 is more linear than channel 2, so we should use ch1Index to calculate the degree.

3.4.2 Accelerometer Algorithm

The message format defined between the 68HC11 and the Nokia 3650 is as following:

$SENSORS,Ch1,Ch2,T1x,T1y,T2,#

Symbol“$“ is used to show the beginning of the message while symbol“#“ is used to show the end of the messge. “SENSORS“ is the name of the message. This is used to make it different from the GPS message whose name is “GPGGA“. Ch1 is the digital value from channel 1 of analog compass R1655 after one A/D converter. Ch2 is the digital value from channel 2 of the analog compass R1655 after one 8bits A/D conveter. T1x is the pulse width (T1) X channel output of the ADXL202.T1y is the pulse width (T1) Ychannel output of the ADXL202. T2 may be measured only once.

Acceleration experienced by the ADXL202 may be calculated using the following formula:

$$Acceleration\,(in\,g) = \frac{Duty\,Cycle - Duty\,Cycle\,at\;\;0\,g}{Duty\,Cycle\;per\;g}$$

The nominal duty cycle output of the ADXL202 is 50% at 0 g and 12.5% duty cycle change per g. Therefore to calculate acceleration from the duty cycle:

$$Acceleration\,(in\,g) = \frac{(T1/T2) - 50\%}{12.5\%}$$

The accelerometer algorithm will handle raw data from the accelerometer ADXL202. It will detect the distance and steps of the user. Currently we are testing the Weinberg Algorithm[43]. Harvey Weinberg proposed one method to get distance traveled using ADXL202 . The approximate distance traveled can be calculated by:

$$Distance = \sqrt[4]{\mathrm{A}_{\max} - \mathrm{A}_{\min}} * n * K$$

where: A_{min} is the minimum acceleration measured in the Z axis in a single stride. A_{max} is the maximum acceleration measured in the Z axis in a single stride. n is the number of steps walked. K is a constant for unit conversion (i.e.,feet or meters traveled). Weinberg describes in his results that the technique has been shown to measure distance walked to within ±8% across a variety of subjects of diferent leg lenths.

Figure 3.9 describes the whole algorithm used in this application.

```
// Put X and only X axis is vertical, Only use X axis to compute accerloration. Or put Y axis is vertical and use Y axis to compute accerloration
Read T1x, T2 value from microcontroller;
Get accerometer of X channel: Ax = (T1x/T2)/0.125;
Find a peak of one stride;//find Amax and Amin of one stride
Stride = $\sqrt[4]{A_{max} - A_{min}}$
Add all of strides togeter to get distance.
Return distance;
```

Figure 3.8 Algorithm for getting distance

3.4.3 Steps Algorithm

The Steps Algorithm is used to get the number of steps wearer traveled by analyzing the accelerations from ADXL202E. The main idea is to caculate the steps by counting all of the spikes from the accelerations of the ADXL202E.

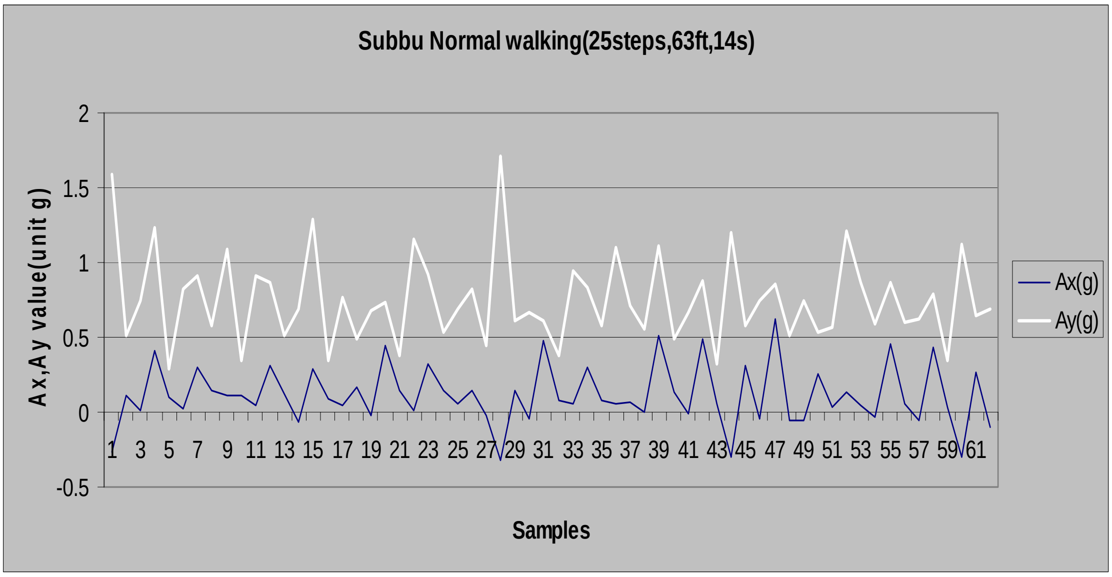


Figure 3.9 Accelerometer data used in step counting

For example, the total spikes in Figure 3.9 are 24 that represents the total steps the wearer traveles are 24. The original accelerations for Figure 3.9 are listed in Table 3.2 .

Table 3.2 Acceleration from Ax and Ay

Ax(g)	Ay(g)
-0.27	1.59
0.11	0.51
0.01	0.75
0.41	1.23
0.1	0.29
0.02	0.82
0.3	0.91
0.15	0.58
0.11	1.09
0.11	0.35
0.04	0.91
0.31	0.87
0.12	0.51
-0.07	0.69
0.29	1.29
0.09	0.34
0.04	0.77
0.17	0.49

-0.02	0.68
0.44	0.73
0.14	0.38
0.01	1.16
0.32	0.92
0.14	0.53
0.06	0.69
0.15	0.82
-0.02	0.45
-0.32	1.71
0.14	0.61
-0.04	0.67
0.48	0.61
0.08	0.38
0.05	0.94
0.3	0.83
0.08	0.58
0.05	1.1
0.07	0.71
0	0.56
0.51	1.11
0.13	0.49
-0.01	0.67
0.49	0.88
0.06	0.32
-0.3	1.2
0.31	0.58
-0.04	0.75
0.62	0.85
-0.06	0.51
-0.05	0.74
0.26	0.53
0.03	0.57
0.13	1.21
0.04	0.87
-0.03	0.59
0.46	0.87
0.06	0.6
-0.05	0.62
0.43	0.79
0.03	0.34
-0.3	1.12
0.27	0.64
-0.1	0.69

Let us consider samples of Ay colum as one example. First, we scan all of the accelerations from the Y axis of the ADX202E and create one intermediate table like Table 3.3. All of the samples should be sorted like this:

1.59>0.51<0.75<1.23>0.29<0.82<0.91>0.58<1.09>0.35<0.91>0.87>0.51<0.69>1.29> 0.34<0.77>0.49<0.68<0.73>0.38<1.16>0.92......1.12>0.64<0.69. We translate this list to Table 3.3. Each sample has two attributes beside its value. The Left colum lists the relationship between the current sample and the previous sample. The Right colum lists the relationship between the current sample and the next sample. 0 means “Start sample“. 1 means “End sample“. 2 means “Greater Than“. 3 means “Less Than“.

Table 3.3 Intermediate table for Figure 3.9

Ay Samples	Left	Right
1.59	0	2
0.51	2	3
0.75	3	3
1.23	3	2
0.29	2	3
0.82	3	3
0.91	3	2
0.58	2	3
1.09	3	2
0.35	2	3
0.91	3	2
0.87	2	2
0.51	2	3
0.69	3	3
1.29	3	2
0.34	2	3
0.77	3	2
0.49	2	3
0.68	3	3
0.73	3	2
0.38	2	3
1.16	3	2
0.92	2	2
0.53	2	3
0.69	3	3

0.82	3	2
0.45	2	3
1.71	3	2
0.61	2	3
0.67	3	2
0.61	2	2
0.38	2	3
0.94	3	2
0.83	2	2
0.58	2	3
1.1	3	2
0.71	2	2
0.56	2	3
1.11	3	2
0.49	2	3
0.67	3	3
0.88	3	2
0.32	2	3
1.2	3	2
0.58	2	3
0.75	3	3
0.85	3	2
0.51	2	3
0.74	3	2
0.53	2	3
0.57	3	3
1.21	3	2
0.87	2	2
0.59	2	3
0.87	3	2
0.6	2	3
0.62	3	3
0.79	3	2
0.34	2	3
1.12	3	2
0.64	2	3
0.69	3	1

After analyzing Table 3.3, every step detection happens at the maximum of acceleration (the peak of the spike). Therefore,

1). If the left colum value is 0 (Start sample) and the right colum value is 2

2). If the left colum value is 3 and the right colum is 1 (End sample)

3). If the left colum value is 3 and the right colum value is 2

They are all the step detections.

Figure 3.10 describes how to detect steps.

Input of steps algorithm is the acceleration of X or Y axis of ADXL202E, output of this algorithm is the number of steps that the wearer traveled.

```
//define attribute
Enum attribute
{
 START = 0,
 END = 1,
GREATER = 2,
LESS = 3
};

//every sample has three attributes, sample value, leftRelationship and rightRelationship
struct Sample{
double sampleValue;
attribute leftRelationship;
attribut rightRelationship
};
scan all of values from Ax or Ay;

//Create intermediate table
if (Is FirstSample), currentSample.leftRelationship =0;
if(Is LastSample), currentSample.rightRelationship = 1;
if (currentSample.sampleValue > previousSample.sampleValue)
currentSample.leftRelationship = 2;
else currentSample.leftRelationship = 3;
if (currentSample.sampleValue > nextSample.sampleValue)
currentSample.rightRelationship = 2;
else currentSample.rightRelationship = 3;

scan all of intermeditate table;

//step detection
if (currentSample.leftRelationship = 0 && currentSample.rightRelationship = 2)
stepNum ++;
currentSample++;
if (currentSample.leftRelationship = 3 && currentSample.rightRelationship = 1)
```

```
stepNum++;
currentSample++;
if (currentSample.leftRelationship = 3 && currentSample.rightRelationship = 2)
stepNum++;
currentSample++;

return stepNum;
```

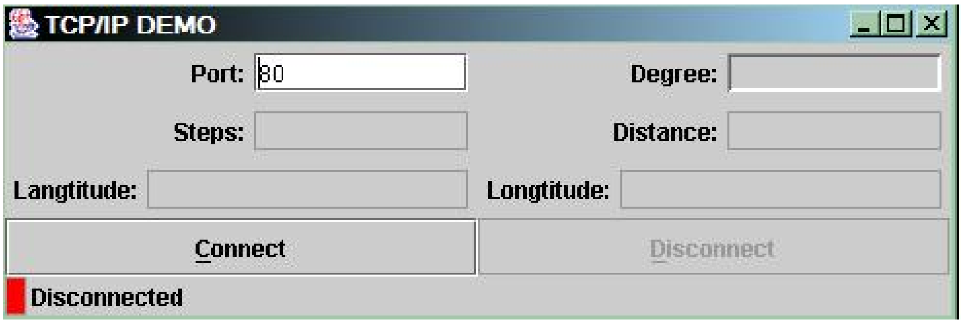
Figure 3.10 Algorithm for getting steps

3.5 User Interface

3.5.1 Server Program (On PC)

In this section, the GUI server program is described. The GUI can display data such as latitude/longitude, compass headings, and distances on a PC. The Java programming language is selected because Java comes with a large standard library. The library has packages for a platform-independent GUI, threads, sockets etc.

The following Figure 3.11 is the GUI written in Java Swing. Swing is a rapid GUI develpment tool that is part of the standard Java development kit. The Jframe, Jpanel, and Jbutton are mainly used for this program. The Port field is editable, the user can set up to which ever port server listens. The Degree field will display the direction of the compass headings. The Steps field is used to display how many steps the wearer traveled. The Distance field displays how far the wearer traveled. The latitude and longitude field are used to display the latitude and longitude of the GPS receiver. The two buttons are Connect and Disconnect. Press the Connect button to start the server, and the text of the staus bar is changed from“Disconnected“ to “Connecting...“ ; the tiny red rectangle will change to green. At the same time, the Disconnect button is enabled and the user can shut down the server by pressing this button any time.



Port: 80

Disconnected

Figure 3.11 User Interface of server side

3.5.2 Client Program (On Phone)

3.5.2.1 Menu

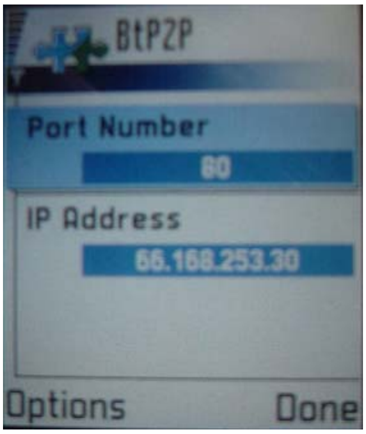
Figure 3.12 shows the menus of the client-side program. These menus provide the user functions to execute commands. All of the related commands are executed in HandleCommandL( ).

- “Discover“ discovers all of the Bluetooth devices in range.
- “Exit“ exits the application
- “ConnectPC“ connects the phone to the PC
- “DisconnectPC“ disconnects the phone from the PC
- “Settings“ displays the Setting dialog described below

Figure 3.12 Menus on the phone

3.5.2.2 Setting Dialog

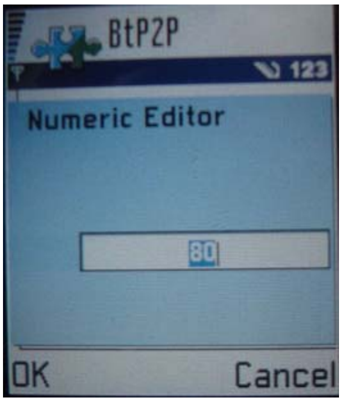
In order to enable a phone end user to set up the IP address and Port number to connect with server, one set up dialog is implemented with setting item lists. When the user selects a setting item, the item can be edited via a setting page. Sybmain OS 6.0 SDK provides different types of setting items. In this project, Figure 3.13 shows a setting item list with two visible setting items(Numeric editor and Ip address editors).



Port Number
80
IP Address
66.168.253.30

Figure 3.13 Setting dialog on the phone

By selecting an item, a setting page is shown, in which the user can manipulate the value. Figure 3.14 shows the setting page of a Numeric editor for a Port number. Figure 3.15 shows the setting page of an IP address setting.



Numeric Editor

80

Figure 3.14 Port number editor

IP Address

66.168.253.30

Figure 3.15 IP address editor

In this project, the setting item list is defined in a resource file. Figure 3.16 shows how the setting item list resource has to be created. A phone setting page consists of two items: A Numeric Editor and an IP address Editor.

```
RESOURCE AVKON_SETTING_ITEM_LIST r_settings
        {
        title = "Settings";
        items =
                {
    AVKON_SETTING_ITEM
       {
       identifier = ESettingNumeric;
       setting_page_resource = r_numericeditor_page;
       name = "Port Number";
       },
    AVKON_SETTING_ITEM
```

```
        {
        identifier = ESettingIp;
        setting_page_resource = r_ip_page;
        name = "IP Address";
        }
                };
         }
```

Figure 3.16 Phone setting page

The identifier *setting_page_resource* points to the resource of the setting page, which is displayed when the user selects a setting item. The setting page resource file is shown in Figure3.17.

```
RESOURCE AVKON_SETTING_PAGE r_numericeditor_page
        {
        label="Numeric Editor";
        type = EAknCtIntegerEdwin;
        editor_resource_id = r_numericeditor;
        }

RESOURCE AVKON_SETTING_PAGE r_ip_page
        {
        label="IP Address";
        type = EAknCtIpFieldEditor;
        editor_resource_id = r_ip;
        }
```

Figure 3.17 Setting page resource file

editor_resource_id is the attributes of the control. See Figure 3.18.

```
RESOURCE AVKON_INTEGER_EDWIN r_numericeditor
        {
        min = 0;
        max = 65535;
        //maxlength = 5;
        }

RESOURCE IP_FIELD_EDITOR r_ip
  {
  min_field_values = IP_FIELD
     {
     first_field = 0;
     second_field = 0;
```

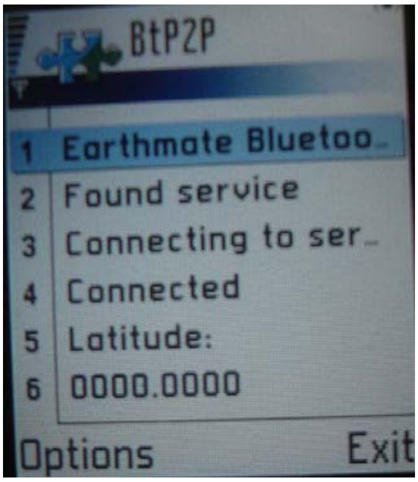
```
    third_field = 0;
    fourth_field = 0;
    };
 max_field_values = IP_FIELD
    {
    first_field = 255;
    second_field = 255;
    third_field = 255;
    fourth_field = 255;
    };
 flags = 0;
 }
```

Figure 3.18 Define the properties of port number editor and IP address editor

The Port number and IP address will be dynamically stored into the file "configFile1.dat". When the application is launched, a default value of the Port number and IP address will be given from "configFile1.dat". So the last updated values of the Port number and IP address are always kept. Note: the server must have an accessible Internet IP address with a certain port.

3.5.2.3 Display data

Figure 3.19 shows the LCD display when the Phone connects successfuly with the PC. The first line is the Bluetooth device name. If communication is set up ,"Connected" shows on the screen.



BtP2P

1 Earthmate Bluetoo...

2 Found service

3 Connecting to ser...

4 Connected

5 Latitude:

6 0000.0000

Figure 3.19 Display for connection

CHAPTER 4.EXPERIMENTAL RESULTS

Currently, the Bluetooth communication and TCP/IP communication are stable for transferring data. So, this chapter will analyze the two algorithms.

4.1 Compass algorithm

In order to check the performance of the algorithm, one test is designed here. The data selected from every 15 degrees from a 5-degree reference table is composed with a new 15-degree table. This is used as the reference table for this test. All of other degree values in the 5-degree reference table are used as input values of the algorithm, output value of the degree can compare with the ideal degree which is in 5-degree reference table. The following chart shows the result.

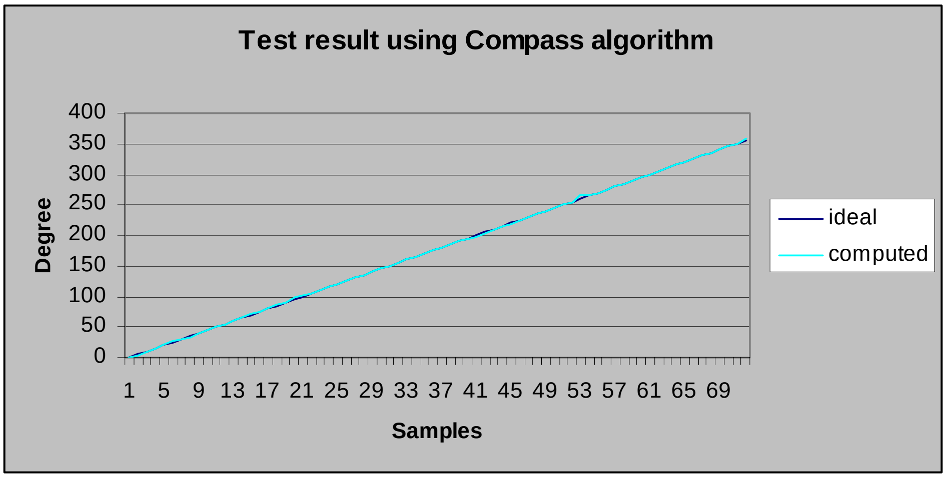


Figure 4.1 Compass test comparison between ideal values and computed values

From this chart, we can see the two lines are very close. So, the algorithm is acceptable. If we use a 5 degrees reference table, that will be more accurate.

The second test is a real time test. When rotating the compass one round, the angle data computed from output of the algorithm can change from 0 to 360. After testing, 0 degree is the North, 90 degrees is the West, 180 degrees is the South and 270 degrees is the East. Table 3.2 is the result of one test. We can see the degree is changed smoothly when the compass is rotating from North->West->South->East->North. So the compass algorithm is also acceptably accurate.Table 4.1 is the part of the results table. Please see Appendix for the full testing result.

Table 4.1 Parts of the real time test results

Channel1	Channel2	Degree
206	212	0
206	213	0
205	212	1
205	211	1
204	212	2
204	210	2
204	213	2
203	214	3
202	214	4
201	212	5
201	214	5
200	215	6

4.2Accelerometer algorithm

The results from this algorithm are not acceptable. The computed steps and distance have big differences from manually obtained values. Table 4.2 shows the difference between tested values and computed values according to the Weinberg algorithm. Here are two groups’ lists. One is a short trial test. Another is a long trial test. The X axis is put vertically, and the tester wears an accelerometer on the hip. The short distance is about 20 meters. The long distance is about 400 meters. The tester is required to walk normal, walk fast, or walk randomly.

Table 4.2 Result of short distance travel

Trial Name	Tested Steps	Tested distance(m)	Computed steps	Computed distance(m)	Error in computed steps(%)	Error in computed distance(%)
Subbu’s Normal walking	25	19.2	24	20.51	-4	6.8
Subbu’s Fast walking	27	22.25	20	20.12	-25.9	-9.6
Subbu’s Random walking	24	19.81	18	17.42	-25	-12.1
Bradley’s Normal walking	28	19.5	27	22.82	-3.6	16.9
Bradley’s Fast walking	23	19.5	21	19.74	-8.7	1
Bradley’s Random walking	26	19.5	18	17.42	-30.7	-10.7

We also have a long trial test. See Table 4.3

Table 4.3 Result of long distance travel

Trial Name	Tested Steps	Tested distance(m)	Computed steps	Computed distance(m)	Error in computed steps(%)	Error in computed distance(%)
Bradley’s Hip trial	525	400	485	459.312	7.6	-14.8
Subbu’s Hip trial	500	400	475	468.9957	5	-17.2
Subbu’s Torso trial	489	400	468	455.4601	4.3	-13.9

Whether a long trial or a short trial, the steps and distance are not correct. The main problem is that the step counting of both tests is wrong. The distance is computed by adding all of the strides together. If the step count is wrong, the computed distance must be wrong. So in future, we need to find another way to get steps accurately counted.

4.3 Steps algorithm

This algorithm considers that one spike represents one step. For short and long distance trips, I manually counted the spikes and then compared them with the results from steps algorithm. The number of steps was the same. For example, for short trip, I manually counted spikes of Ay(g) in the Figure 4.2 was 20. After using step algorithm, the number of steps was 20.

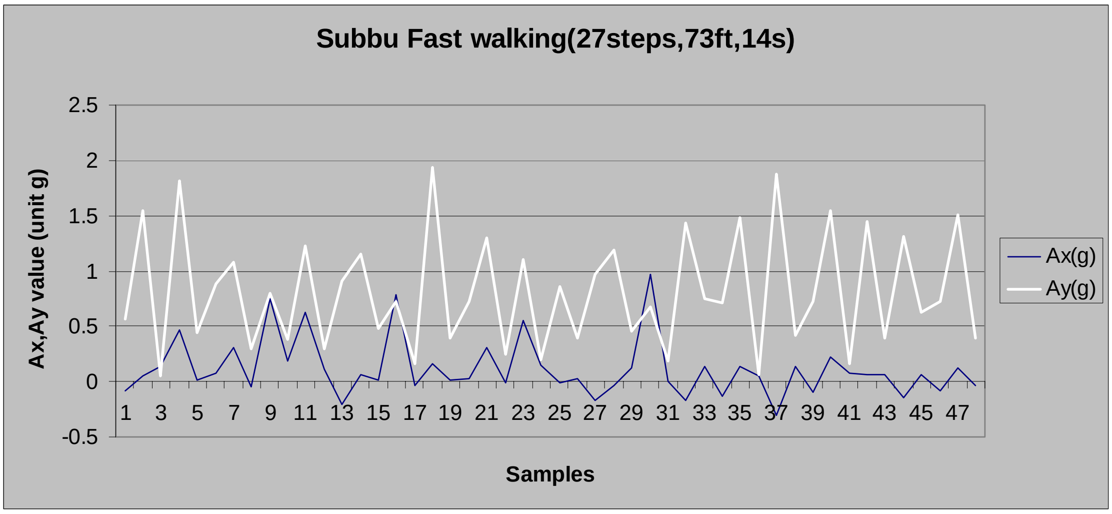


Figure 4.2 Short distance trip(20 meters)

Table 4.4 shows the results from other short distance trips.

Table 4.4 Comparison of steps from short distance trip

Trial Name	Tested Steps	Computed steps	Counted spikes	Error in computed steps(%)
Subbu's Normal walking	25	24	24	-4
Subbu's Fast walking	27	20	20	-25.9
Subbu's Random walking	24	18	18	-25
Bradley's Normal walking	28	27	27	-3.6
Bradley's Fast walking	23	21	21	-8.7
Bradley's Random walking	26	18	18	-30.7

I counted the spikes of Ay(g) in Figure 4.3 were 475. After using step algorithm, I got 475 also.

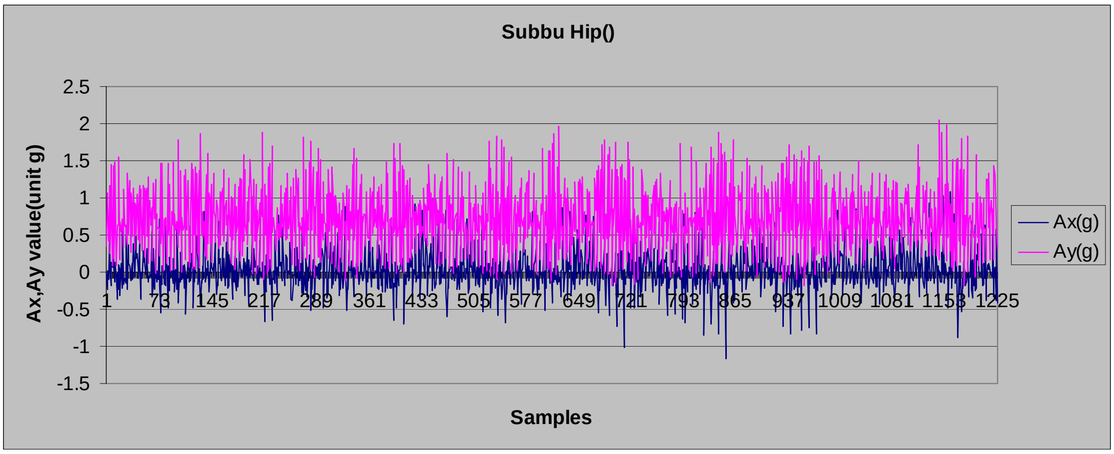


Figure 4.3 Long distance trip (400 meters)

Table 4.5 shows the results from other long distance trips.

Table 4.5 Comparison of steps from 400 meters distance trip

Trial Name	Tested Steps	Computed steps	Counted spikes	Error in computed steps(%)
Bradley's Hip trial	525	485	485	7.6
Subbu's Hip trial	500	475	475	5
Subbu's Torso trial	489	468	468	4.3

So if only considering one spike represents one step, this algorithm is accurate.

CHAPTER 5.CONCLUSION AND FUTURE WORK

A wearable Mobile Assistance device is very useful for those who have cognition problems. It has the potential to provide a better and less expensive alternative for the rehabilitation health care area. In this thesis, the architecture of Mobile Assistance is described.

Two algorithms were implemented to get local position by dead reckoning. The compass algorithm that we developed can provide good direction information, but when we rotate the compass very quickly, some invalid data can be still generated. The algorithm can not connect to recover from such data. In the compass algorithm, the performance of the algorithm depends on how good the reference table is. Normally, we create a reference table manually. And sometimes, if the compass is changed, the reference table needs to be changed too. So this is not very effective. In future, it is better to develop another algorithm without a reference table or one that can upload a reference table in real-time based on the pattern of use.

The performance of the accelerometer algorithm, which we adapted from [43], is not good. It can not provide an accurate stride length and step count. So, trying other methods including hardware change is needed to improve the accelerometer algorithm. When we use the following formula to calculate acceleration, $Acceleration\,(in\,g) = \frac{(T1/T2) - 50\%}{12.5\%}$ we assume the duty cycle output of the ADXL202 is 50% at 0 g and 12.5% duty cycle change per g. If the 0 g duty cycle output of the ADXL202 is other than 50%, and/or the duty cycle changes more or less than 12.5% per g, the acceleration calculation will be inaccurate. In fact, the 0 g output and the sensitivity of the ADXL202 vary somewhat from device to device. T2 value is nominally constant, but it does change over temperature and contains some jitter. For systems that do not require resolutions of better than 100mg, T2 can be measured only once. For more accurate measurements, several T2 measurements should be made and averaged. The average should be updated periodically to account for T2 drift over temperature. In order to make the computed acceleration more accurate, calibration should be implemented. The easiest way to calibrate the ADXL202 is by using the earth's gravity as a reference input. We assume that the sensitivity of the accelerometer is 12.5% duty cycle per g. One digital input may be used to tell microcontroller that it is in calibration mode. When in this mode, the accelerometer must be level with X and Y axes horizontal to the earth so both axes experience 0 g. When the microcontroller is told to calibrate, the microcontroller reads the duty cycle output (T1) and period (T2) of the accelerometer from each axis. Several readings of T1 and T2 may be averaged to improve accuracy. These values are stored as calibration constants and retained for use in calculating the acceleration after calibration[46].

Currently, the GPS receiver and Motorola 68CH11 transfer data to NOKIA 3650 by Bluetooth. The application can only handle point to point communication. This will be changed for point to multipoint communication in the future.

For the PC parts, because of time limitation, the data of longitude/latitude, compass heading angle, and distance are displayed on the PC. All of the data should be used to check the accurate address of the user. So, Map SDK can be installed on PC. And one could develop more complex application to return address information for the wearer by passing these parameters. This research is necessary in future to further realize the features of the MA device.

In summary, in this research we developed an architecture for the MA device, implemented sensor-phone-pc communication software with preliminary user interfaces, developed and tested a compass algorithm for heading calculation, adapted and tested algorithms for step counting and distance computation from accelerometer data. We found that the compass and accelerometer algorithms and the sensors need improvements in accuracy before they can be used in the MA device.

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APPENDIX A

Reference table used in Compass algorithm

Index	Degree	Channel1	Channel2
0	0	206	206
1	5	201	211
2	10	196	215
3	15	189	219
4	20	182	222
5	25	175	224
6	30	169	225
7	35	163	226
8	40	154	227
9	45	146	227
10	50	139	227
11	55	134	226
12	60	127	225
13	65	116	224
14	70	110	223
15	75	103	220
16	80	92	216
17	85	83	212
18	90	78	209
19	95	66	204
20	100	61	199
21	105	56	195
22	110	48	190
23	115	39	180
24	120	34	174
25	125	27	164
26	130	26	157
27	135	22	151
28	140	16	137
29	145	17	127
30	150	18	117
31	155	17	105
32	160	21	89
33	165	23	76

34	170	29	63
35	175	34	54
36	180	42	42
37	185	49	37
38	190	58	29
39	195	65	24
40	200	70	20
41	205	78	16
42	210	87	14
43	215	96	11
44	220	105	11
45	225	119	11
46	230	132	11
47	235	141	11
48	240	154	15
49	245	166	15
50	250	176	19
51	255	186	25
52	260	198	37
53	265	202	45
54	270	204	54
55	275	212	61
56	280	217	74
57	285	218	80
58	290	222	91
59	295	223	105
60	300	226	112
61	305	226	123
62	310	228	131
63	315	227	142
64	320	227	150
65	325	225	159
66	330	223	167
67	335	222	174
68	340	219	183
69	345	216	190
70	350	214	196
71	355	208	203
72	360	206	206

APPENDIX B

Results table in real time test for Compass algorithm

Channel1	Channel2	Degree
206	212	0
206	213	0
205	212	1
205	211	1
204	212	2
203	214	3
202	214	4
201	212	5
200	215	6
199	212	7
199	214	7
198	216	8
198	214	8
197	215	9
197	217	9
196	216	10
196	217	10
195	218	10.7143
194	219	11.4286
194	219	11.4286
193	219	12.1429
192	218	12.8571
191	220	13.5714
190	219	14.2857
189	218	15
188	221	15.7143
188	221	15.7143
187	211	16.4286

185	213	17.8571
185	221	17.8571
184	222	18.5714
183	223	19.2857
182	223	20
181	223	20.7143
181	222	20.7143
180	223	21.4286
179	225	22.1429
178	224	22.8571
177	225	23.5714
176	225	24.2857
175	224	25
174	226	25.8333
173	224	26.6667
172	227	27.5
172	224	27.5
171	227	28.3333
171	225	28.3333
170	227	29.1667
169	226	30
168	227	30.8333
167	227	31.6667
166	226	32.5
165	228	33.3333
165	226	33.3333
164	228	34.1667
164	227	34.1667
163	228	35
161	228	36.1111
160	228	36.6667
160	227	36.6667
159	229	37.2222
158	229	37.7778
157	229	38.3333
155	228	39.4444
155	229	39.4444
154	229	40

154	229	40
152	229	41.25
151	228	41.875
150	229	42.5
150	228	42.5
148	229	43.75
147	229	44.375
146	228	45
145	228	45.7143
145	229	45.7143
144	229	46.4286
143	230	47.1429
142	229	47.8571
142	227	47.8571
141	229	48.5714
140	229	49.2857
139	229	50
138	229	51
137	228	52
136	229	53
135	230	54
134	227	55
133	229	55.7143
133	229	55.7143
132	229	56.4286
131	229	57.1429
130	229	57.8571
130	229	57.8571
129	227	58.5714
128	227	59.2857
128	227	59.2857
127	227	60
127	229	60
126	227	60.4545
125	228	60.9091

124	229	61.3636
124	229	61.3636
122	227	62.2727
120	228	63.1818
118	229	64.0909
116	228	65
116	225	65
115	227	65.8333
110	226	70
110	226	70
108	227	71.4286
107	225	72.1429
106	227	72.8571
105	226	73.5714
105	225	73.5714
104	226	74.2857
102	226	75.4545
101	225	75.9091
100	225	76.3636
99	224	76.8182
98	225	77.2727
97	223	77.7273
96	225	78.1818
95	223	78.6364
95	220	78.6364
94	224	79.0909
92	225	80
91	224	80.5556
90	223	81.1111
88	224	82.2222
87	222	82.7778
86	223	83.3333
85	223	83.8889
84	221	84.4444

82	222	86
82	222	86
81	221	87
80	222	88
78	219	90
77	220	90.4167
76	221	90.8333
75	218	91.25
74	219	91.6667
72	218	92.5
72	217	92.5
71	219	92.9167
71	217	92.9167
70	218	93.3333
69	218	93.75
68	217	94.1667
66	215	95
65	215	96
64	215	97
40	201	98
40	201	98
39	200	99
61	214	100
60	214	101
36	197	102.5
58	211	103
36	196	103.75
57	211	104
56	212	105
33	195	105
55	212	105.625
34	194	106
53	210	106.875
31	193	107
52	208	107.5

31	192	108
51	208	108.125
49	206	109.375
29	190	110
28	189	110.5
46	207	111.111
28	187	111.5
26	186	112
44	204	112.222
44	203	112.222
24	184	113
42	202	113.333
24	183	113.5
23	181	114.5
22	178	116.667
21	177	117.5
18	175	119.167
19	174	120
19	173	120.5
18	172	121
18	169	122.5
16	168	123
16	167	123.5
15	166	124
14	164	125
13	162	126.429
14	161	127.143
13	157	130
14	157	130
14	156	130.833
13	155	131.667
13	152	134.167
14	149	135.714
13	148	136.071
13	147	136.429

14	145	137.143
13	141	138.571
14	140	138.929
14	139	139.286
13	138	139.643
14	136	140.5
13	135	141
14	135	141
14	134	141.5
14	133	142
14	132	142.5
14	131	143
13	130	143.5
14	129	144
14	128	144.5
14	127	145
14	127	145
14	126	145.5
14	125	146
13	124	146.5
14	122	147.5
14	121	148
14	119	149
13	118	149.5
14	115	150.833
14	114	151.25
14	111	152.5
13	110	152.917
14	109	153.333
13	106	154.583
14	105	155
14	103	155.625
13	99	156.875
14	98	157.188
13	95	158.125

15	93	158.75
14	92	159.063
15	90	159.688
15	88	160.385
16	87	160.769
17	85	161.538
18	83	162.308
17	82	162.692
18	82	162.692
18	81	163.077
16	79	163.846
19	78	164.231
18	76	165
21	74	165.769
22	72	166.538
22	71	166.923
20	71	166.923
19	71	166.923
22	70	167.308
20	70	167.308
20	70	167.308
20	70	167.308
23	69	167.692
23	69	167.692
20	69	167.692
23	68	168.077
21	68	168.077
20	68	168.077
20	68	168.077
19	67	168.462
24	66	168.846
22	65	169.231
22	64	169.615
23	63	170
23	62	170.556
23	62	170.556

28	61	171.111
24	60	171.667
17	60	171.667
23	59	172.222
16	58	172.778
20	57	173.333
16	56	173.889
13	54	175
33	37	175
19	49	177.083
33	35	180
42	18	180
45	16	182.143
46	16	182.857
48	15	184.286
51	14	186.111
54	13	187.778
55	12	188.333
58	11	190
61	12	192.143
63	12	193.571
65	11	195
68	12	198
70	13	200
71	11	200.625
76	12	203.75
79	12	205.556
90	12	211.667
92	12	212.778
94	12	213.889
98	11	216.111
103	12	218.889
106	12	220.357
107	12	220.714
108	12	221.071
109	12	221.429

111	11	222.143
112	11	222.5
112	11	222.5
114	12	223.214
118	11	224.643
122	11	226.154
126	12	227.692
130	12	229.231
134	10	231.111
136	12	232.222
139	12	233.889
142	14	235.385
143	14	235.769
145	15	236.538
148	17	237.692
149	18	238.077
151	17	238.846
155	20	240.417
159	23	242.083
161	26	242.917
166	29	245
166	30	245
166	30	245
167	29	245.5
167	30	245.5
168	29	246
172	41	248
175	40	249.5
175	44	249.5
178	53	251
179	48	251.5
182	49	253
187	61	275
186	62	275.385
187	62	275.385

189	65	276.538
190	66	276.923
190	69	278.077
189	70	278.462
199	89	289.091
200	90	289.545
200	91	290
202	97	292.143
200	98	292.5
202	100	293.214
203	105	295
206	118	302.727
207	121	304.091
207	129	308.75
207	132	310.455
206	133	310.909
207	137	312.727
208	145	316.875
207	146	317.5
208	148	318.75
207	151	320.556
205	155	322.778
206	158	324.444
202	174	335
207	179	337.778
204	181	338.889
203	184	340.714
203	188	343.571
203	193	347.5
203	194	348.333
203	194	348.333
218	198	351.429
218	199	352.143
218	200	352.857
217	201	353.571
216	201	353.571

215	202	354.286
214	202	354.286
212	204	356.667