# Wrist Worn Device to Aid the Elderly to Age in Place

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# Abstract

The elderly population is increasing at a rapid rate each year, and with the increase in the elderly population there is a need for better medical assistance and devices. The greatest problem this demographic is facing is the ability to age in place. More elderly people are being placed in nursing homes, assisted living homes, moving in with relatives due to disabilities or fear of disabilities caused by a life threaten event such as heart disease, stroke, falling/fainting, or uncontrolled glucose levels. Falling is the number one leading cause of deaths, injuries and incapacity in the elderly. Stroke is the 3rd leading cause of death in the U.S; it is the 2nd leading cause worldwide. Rapid change in glucose levels is another leading cause of disabilities and deaths. Heart disease is the 2nd leading cause of death in the elderly. These life threatening events can be prevented and if treated early enough can allow the person to have a full recovery and continue to age in place.

A device was proposed that could monitor these four life threatening events: heart disease, stroke, falling/fainting and changes in glucose levels. This device will monitor the user continuously. Research was conducted to see what other products are on the market and how they detect these events and how reliable they are for the user. A literature review was performed to understand what other people are doing to solve the aging in place problem. Using this and needs assessment of the elderly, the system architecture for the wrist worn device was designed along with a testing plan and procedure.

More research needs to be done in certain areas to better improve solutions and technology in the area aging in place of the elderly. Before this device can bridge some of the gaps between the current issues and the solution the device will have to be tested for several things such as its ability to  differentiate between  stimulated falling/fainting and fall like activities such as sitting then lying. The orientation and position will be tested to see if the device can actually tell where the person is located. The device will have to be tested against well-known devices and see if it gives similar precise and accurate readings in real time.

# DEDICATION

I like to take this time to dedicate my thesis to God, my grandmommy, mommy, daddy, family, friends, and my church; the people who have always been there for me to encourage and kick me in the but when needed.

To God you are my foundation, the one I can lean on when nobody else is around. The one who directs my life and gives me love and encouragement, even when I don't deserve it. The one that is always there through it all, even my worse moments. The author and finisher of my life.

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# Chapter 1 Introduction

## 1.1 Motivation

There are over 300 million people in the United States, the elderly population makes up 13 percent of this population. This number is expected to increase as the life expectancy rate increases. With the increase of the elderly population many will be forced into living assistance homes or 24 hour home nursing care. The average annual cost of a living assistance homes is $106,000 with an expected 3-5% increase every year; the average annual cost of 24 hour nursing care is $85,000. The elderly are placed in living assistance homes or under 24 hour nursing care for several health concerns; four of which this paper will focus on these include heart disease, falling/fainting, stroke, and change in glucose level.

The proposed wrist worn device will collect and monitor specific parameters of the elderly, which should enhance their ability to better age in place. This device will be low cost, nonintrusive, low power, light weight, easy to use and wear, moisture proof, durable, and safe for the elderly. This device will be wirelessly linked to medical services and provide suitable warnings to the wearer and family.

The device will have sensors that will detect if the person needs immediate attention and have the ability to alert the appropriate party of the condition of the user. The device will continuously monitor the user's everyday vital signs. The data received will be stored for later use as it is continuously sent to the home base. The home device will be small enough to carry when traveling. The data from the device can be viewed and monitored by approved personnel through a secure network.

After doing medical research and a literature review it is clear that four conditions are preventing the elderly from aging in place properly; falling/fainting, heart disease, stroke, and change in glucose levels. These four conditions cause the most damage to the elderly causing them to be hospitalized, placed in nursing home, disabilities, and in some cases death. These conditions will be discussed in more details in the following section. Chapter 2 will discuss the literature review. Chapter 3 will discuss the system requirements of the device. Chapter 4 will discuss the interviews conducted. Chapter 5 will discuss the product's architecture. Chapter 6 will discuss the conclusion and recommendations for future work.

## 1.2 Background

### 1.2.1 Falling/Fainting

*a) Define*

Falling is the number one leading cause of deaths, injuries, and incapacities in adults 50 years of age and older. Falling patients over the ages of 60 with falling injuries have slower recoveries and most do not live 5-7 years after the fall; a third of this population will fall again within a year. Fifty percent of the elderly are placed in nursing homes due to a falls. As more people reach the age of 50 just under forty percent of them will have a falling accident; between the ages of 70-85 this number will almost double; with these accidents becoming more severe, and decreasing the chance of recovering properly [15,16]. The chance of falling again in the first 6 to 8 months is about two-thirds. Around 20 billion is spent every year on falling health care and treatment, this number will double with the rapid increase of the aging population [15,16]. Every 20 seconds there is a fall reported; one-third of these falls are severe enough to need medical attention. Four percent of the US death populations are due to elderly falling injuries [15,16]. A good portion of falls result in hip fractures. Majority of lifetime cost for the elderly is contributed to falls. Twenty percent of people residing in a living assistance homes will have a falling injury; half of the elderly that sustains a fall injury will get placed living assistance home.

*b) What are the causes?*

Some major causes of falls in the elderly include muscle weakness, blood pressure, slow reflexes, balancing and walking issues, foot pain, poor vision, sensory issues, medication, confusion, and environmental risks. As people get older they lose muscle tone and bone density, which is accompanied by the loss of flexibility and walking endurance. Constant standing and sitting can cause a person's blood pressure to drop which can cause temporary dizziness and disorientation. If a person's blood pressure spikes too high they can become unstable and fall. A good number of the elderly community deals with blood pressure issues; this number is increasing as the aging population grows. A person's reflexes become slower as a person gets older. This causes older people to miscalculate their movement, causing them to be momentarily off balance and potentially fall. As a person gets older, simple tasks such as balancing and walking become unpredictable and hazardous. Their balancing and gait changes drastically and many older people overestimate their walking ability, believing they can move the same way they once did. Most elderly people restrict their daily activities because they are afraid of the possibility of falling. Soreness in the foot and poor vision are other reasons for falling. How far or close things appear is underestimated, causing them to run into or miss objects. With the increase of medication intake, elderly people are more likely to fall. Many medication's side effects include dizziness and drowsiness, causing confusion and disorientation which can result in a fall.  Lastly, the environment in which they live can be hazardous and create falling risks.

c) *What are the symptoms?*

The main symptoms of falling include feeling weakness, lightheadedness, and dizziness. Falling can be sudden in the elderly and can occur during everyday activities.

d) *Death rate and recovery rate*

Elderly people account for 95 percent of hip fractures, most often caused by falls. Complication following a hip fracture accounts for  a large amount  of deaths in the U.S. One in five hip fracture patients die within a year of their injury. The most common form of treatment for hip fractures includes surgeries and hospitalization. After the elderly are discharged from the hospital they are often immediately placed in nursing homes or rehabilitation centers. Most elderly that use to live on their own frequently end up in a nursing home for a couple of years after a fall.

*e) Treatment*

After surgery the best type of treatment for falls are bone and muscle strengthening exercises. These exercises ensure the return of maximum function back to the injured area. The patient can also be given vitamin supplements such as Calcium and Vitamin D.

*f) Response time for best results*

Best recovery results from a fall require immediate action. When the elderly fall they can injure their heads or other parts of their body. If a body parts is fractured, dislocated, or broken, the best response time would be in the first day or so of the injury for best recovery results.

### 1.2.2 Stroke

*a) Define*

A stroke results for a sudden decrease or loss of consciousness, sensation, and voluntary motion caused by rupture or obstruction of blood flow to the heart. Stroke is the 3$^{rd}$ leading cause of death in the U.S and the 2$^{nd}$ leading cause worldwide [4,10,13,18]. It is closely related to heart disease and can be reoccurring. Stroke is one of the most undetected diseases and patients are less likely to call for help until hours after symptoms start, which can lead to severe side effects. There are 50.5 million deaths each year from strokes worldwide; a person dies every 3.3 minutes from a stroke [4,10,13,18]. It is the leading cause of disabilities. There are 700,000 reported cases of strokes each year; 500,000 are first timers and 200,000 are reoccurring [4,10,13,18]. Every 45 seconds a person has a stroke. Four million people live with side effects of strokes.

*b) What are the causes*

There are many factors that can cause a stroke. These include blood clots, cholesterol buildup, and blockage in the arties and veins. Other factors include unhealthy eating habits, drinking, smoking, lack of exercise and excessive weight gain, and poor heart circulation; as well as taking medications for things such as blood pressure and diabetes. Heart disease and mini strokes can cause major strokes, which can lead to disabilities. Some causes of strokes are unpreventable such as age, sex, race, and having a previous stroke. Elderly people are more likely to have a stroke, especially men.

### c) *What are the symptoms*

Depending on the type of stroke, symptoms can vary. Most times symptoms are sudden and only last a short while. Different strokes affect different parts of the brain, so depending on which area of the brain the stroke is affecting, one or several of these symptoms can occur; Loss of ability to perform movement on one side of the body, speech impediment such as stuttering or mouth drooping on one side, loss of sensory on one side, loss of vision in one or both eyes, loss of coordination and balance, and loss of memory or perception. Warning signals in the form of mini strokes (TIAs) are sometimes present before a full-on stroke occurs. These warning signs include weakness or numbness on one side of the body and face, problem communicating and forming speech, loss of vision or dimness, dizziness, disorientation or falling, sudden severe headaches, and confusion. This is when emergency care should be called.

### d) *What are side effects*

Side effects can result from not getting immediate attention once a stroke occurs, leading to severe permanent damage. These side effects include, but are not limited to: weakness or paralysis, lack of feeling or loss of awareness, swallowing difficulties, speech or language difficulties, perception difficulties, cognitive difficulties, behavior and mood changes, bladder or bowel difficulties, fatigue, post-stroke pain, epilepsy, and many more. These are some immediate side effects of a stroke.

### e) *Death rate and recovery rate*

Ten percent of stroke victims recover almost completely. Twenty-five percent recover with minor impairments. Forty percent experience moderate to severe impairments requiring special care. Ten percent of stroke victims require care in a nursing home or other long-term care facilities. Fifteen percent die shortly after the stroke. 7.5 percent of ischemic strokes and 37.5 percent of hemorrhagic strokes result in death within 30 days [4,10,13,18]. While subarachnoid hemorrhages (SAH) represent only about 7 percent of all strokes, they are the most deadly with more than 50 percent fatality rate. Of the survivors, approximately half will suffer permanent disability [4,10,13,18]. Twenty-two percent of men and 25 percent of women die within a year of their first stroke [4,10,13,18]. Fourteen percent of people who have a stroke or TIA will have another within a year [4,10,13,18].

### *f) Treatment*

The treatment of a stroke depends on two main factors: the type of stroke and the severity of the stroke. If it is an ischemic stroke, aspirin is given for two reasons: to reduce the risk of death and the risk of a second stroke. If the stroke was caused by a clot, a clot dissolving drug is given to the patient. Blood thinners can be given to prevent a future stroke and prevent new blood clots from forming. Depending on how long the stroke lasts and the severity of the stroke, rehabilitation and therapy can be a good recovery choice. Therapy can be used to help improve muscle control, coordination, and balance. Speech therapy might be needed to help with word formation, language, facial stability, and movement. Also, hand-eye coordination may be needed to help with everyday activities. The total cost of strokes in the United States is estimated at $43 billion per year. The direct costs of medical care and therapy are estimated at $28 billion per year. Indirect costs from lost productivity and other factors are estimated at $15 million per year [4,10,13,18]. The average cost of care for a patient up to 90 days after a stroke is $15,000 per year. For 10 percent of patients, the cost of care for the first 90 days after a stroke is $35,000 [4,10,13,18]. The risk of stroke doubles after age 55.

Table 1.1: Percentage breaks down of direct cost of a stroke for the first 90 days

The Stroke Center at University Hospital," 2013. [Online]. Available: http://www.uhnj.org/stroke/stats.htm. [Accessed 6 june 2013]

AHA, "Heart and Stroke Statistics," [Online]. Available: http://www.heart.org/HEARTORG/General/Heart-and-Stroke-Association-Statistics_UCM_319064_SubHomePage.jsp. [Accessed 8 July 2013].

C. Midey, "Response times play big part in Stroke patients' recovery," 24 February 2012. [Online]. Available: http://www.azcentral.com/news/azliving/articles/2012/02/24/20120224response-times-play-big-part-stroke-patients-recovery.html. [Accessed 8 July 2013].

CDC, "Stroke Facts," [Online]. Available: http://www.cdc.gov/stroke/facts.htm. [Accessed 8 July 2013] Used under fair use, 2014

| **Breakdown** | **Percentage %** |
|---|---|
| Initial hospitalization | 43 |
| Rehabilitation | 16 |
| Physician costs | 14 |
| Hospital Readmission | 14 |
| Medications and other expenses | 13 |

*g) Response time for best results*

If a stroke is treated fast enough, it can reduce the risks of long term side effects and damage. The sooner and faster a stroke is treated, the better chance of a full recovery. Eighty to 90 percent of strokes are caused by a blood clot which blocks a sufficient amount of blood flow to the brain, causing the brain to lose oxygen and start to shut down. Blood clots need to be treated immediately. The fastest way to treat a stroke before permanent damage occurs is to recognize the symptoms and call for help.

### 1.2.3 Blood Glucose/Diabetes

*a) Define*

The blood glucose level is the amount of glucose in the blood. Glucose is a sugar that comes from the foods we eat; it’s formed and stored inside the body. It’s the main source of energy for the cells in our body and it is carried to each cell through the bloodstream. If someone’s blood sugar is too low, the person has too much insulin in their body. If the blood sugar is too high, the person may have a disease known as diabetes, it affects the body's ability to produce insulin; this means the person doesn't have enough insulin in their body. Diabetics have to constantly monitor their blood sugar levels.

*b) What are the causes*

Low blood sugar can occur in anyone, but mostly diabetics. It can be caused from taking an excessive amount of diabetes medication and other medication, missing meals, waiting too long to have meals, over exercising, drinking alcohol, and other medical conditions. Having low blood sugar can be a real danger because a person's blood sugar could drop very suddenly and without any warning. High blood sugar is directly related to diabetes. When a person has high blood sugar it means they don't have enough insulin in their body. It is caused from diabetics not taking their medication, excessive eating, lack of exercise, having an infection, becoming sick, being stressed, or injecting too much insulin and not eating enough to offset the medication. Both high and low blood sugar can make a person become sick and both need to be treated immediately or they can cause serious damage.

*c) What are the symptoms*

The symptoms of low blood sugar include feeling weak, blurry vision, rapid heartbeat, pale skin, sudden mood change or nervousness, hunger, shakiness, sweating, sleeping problems, skin tingling, headaches, irritation, confusion, and lack of concentration. If the blood sugar gets too low, it can cause the person to pass out, have a seizure, or even cause the person to go into a coma. Symptoms of high blood sugar are similar to that of low blood sugar. They include frequent urination, fatigue, blurred vision, nausea, excessive hunger, drowsiness, and excessive thirst. If it is too high, it can cause your stomach to ache and become incapacitated. Some of these symptoms are easily detected, others are not. This is the reason that this condition has to be constantly monitored. Extreme glucose levels can cause sudden and unexpected changes that can lead to life threatening conditions if not treated properly or in a timely manner.

## d) *What are the side effects*

There are two types of side effects associated with change in glucose levels. Side effects of the disease include foot pain and trouble walking, impaired vision, kidney failure, nervous system trouble, gum disease, hearing difficulties, and blood vessel issues. These side effects do not happen suddenly. In most cases they are gradual and over a long period of time. These side effects are very silent when on-setting and most can't be detected until after they already exist. These side effects are also most likely seen in cases of uncontrolled diabetes. If the disease is left untreated or undetected, it can lead to serious life threating problems. This can include loss of a limb, kidney failure, blindness, trouble walking or moving, nerve damage, brain damage, comas, and even death. It is very important to detect and monitor this chronic disease before it gets out of hand.

## e) *What are the rate at which it occurs*

There are 26 million people in the United States with diabetes, with almost 2 million new cases each year [11,32,42,53]. Seven of the 26 million people who have diabetes are undiagnosed and or unaware of their condition. Seventy-nine million adults 20 years and older have pre-diabetes [11,32,42,53]. This means they meet most of the symptoms for diabetics but don't quite have the disease. These people are likely to get type 2 diabetes in a 5 year time span or other health issues such as heart disease or stroke. Type 2 diabetes accounts for 90 to 95 percent of all diabetes cases in the United States [11,32,42,53]. Eighty percent of these people die from heart attacks and strokes. One in 10 people suffer from diabetes in the age group of 20 years and older; in the elderly, that number increases to 1 in 4 [11,32,42,53]. Worldwide, 8 out of 10 diabetes related deaths are in the low and middle income countries. People in the age range of 40 to 60 accounts for the world's largest diabetic cases [11,32,42,53]. 10.9 million people aged 65 and older live with Type 2 diabetes.  Statistics of people with diabetes in the United States are listed below by age, gender, and race [11,32,42,53].

- 11.5 million US women (10.2 percent of all women age 20 years and older)
- 12 million US men (11.2 percent of all men age 20 years and older)
- 186,300 people under age 20
- 12.2 million adults over age 60

- 3.7 million African Americans (14.7 percent of all African Americans age 20 years and older)
- 2.5 million Hispanic/Latino Americans (9.5 percent of all Hispanic/Latino Americans)
- 14.9 million Caucasian Americans (9.8 percent of all Caucasian Americans age 20 years and older)

### *f) Death rate and recovery rate*

Diabetes is the 7$^{th}$ leading cause of death in the United States. There are around 70,000 deaths a year from diabetes related causes. If caught early and treated properly, it can be maintained and livable. If a patient takes medication, exercises, eats properly and takes care of their body, diabetes can be controlled and the person can live a long and normal life with the disease.

### *g) Treatment*

The main treatments of Type 2 diabetes include losing weight, eating right, and exercising. In some cases, medication is needed to keep the disease from getting worse and help stop long term complications. People with Type 2 diabetes have to have their blood sugar tested every 2 to 6 months, depending on how long the person has had the disease or how bad the person’s condition is. Treatments for people with Type 1 diabetes include insulin medication, exercise, and eating correctly. Their blood sugar needs to be checked regularly to make sure it is not too low or too high.

### *h) Response time for best results*

There is no response time for best results unless the person faints or goes into a coma. It is better to have too high blood sugar then too low blood sugar because it is easier to treat those symptoms.

### 1.2.4 Heart Disease

*a) Define*

Heart disease is the 2$^{nd}$ leading cause of death in the United States. Heart disease is a term to describe different types of diseases that affect the heart [1,10,17,32,44]. In the United States, the most common heart disease is Coronary Artery Heart Disease (CHD). This is when plaque builds up on the inside of the coronary arteries. These are the arteries that supply oxygen-rich blood to the heart muscle. This disease can lead to other serious diseases including heart attack, stroke, heart failure, and arrhythmias.

*b) What are the causes*

Heart attacks occur when the blood supply to the heart is hindered or blocked, or the heart does not get enough blood supply. This causes the heart cells to not receive enough oxygen, causing the cells to die. Heart attacks can be attributed to several factors. These factors include high blood pressure, high cholesterol, smoking, drinking, unhealthy eating habits, lack of exercise, age, having previous heart issues or heart attacks, family history of strokes, obesity, and diabetes.

*c) What are the symptoms*

The symptoms of a heart attack include pain or discomfort in the upper body, jaw, neck, back, chest, arm, and shoulder. Symptoms of a heart attack also include weakness or dizziness, being light headed, feeling faint, nausea, vomiting, anxiety, indigestion, coughing and wheezing, swelling in the body, sweating, and shortness of breath. The person could have several or all of these symptoms. Heart attacks and heart failure can be sudden and unpredictable. Other times, warning symptoms can occur weeks leading up to a heart attack.

*d) At which rate does it occur*

Heart disease is the second leading cause of death in the United States. 26.5 million Americans, 11.5 percent of the population, are diagnosed with heart disease each year [1,10,17,32,44]. 600,000 of these people die from heart disease each year; this is 1 in every 4 deaths [1,10,17,32,44]. 715,000 people have first-time heart attacks and 190,000 people have reoccurring heart attacks. Coronary Artery Heart Disease costs $108.9 billion a year. Cardiovascular disease costs $448.5 billion a year. Every 33 seconds someone has a heart attack [1,10,17,32,44]. Eighty million people have one or more types of heart disease. Forty-two percent of women and 24% of men die within one year of having a heart attack [1,10,17,32,44].

Table 1.2: 2008 chart of death for heart disease
"54 Random Facts About . . . Share on facebookShare on twitterShare on google_plusone_shareShare on pinterest_shareShare on stumbleuponShare on redditShare on tumblrMore Sharing Services," 25 March 2010. [Online]. Available: http://facts.randomhistory.com/heart-disease-facts.html. [Accessed 8 July 2013] Used under fair use, 2014

| Race of Ethnic Group | % of Deaths |
|---|---|
| **African Americans** | 24.5 |
| **American Indians or Alaska Natives** | 18.0 |
| **Asians or Pacific Islanders** | 23.2 |
| **Hispanics** | 20.8 |
| **Whites** | 25.1 |
| **All** | 25.0 |

*e) Death rate and recovery rate*

Fifty percent of people die suddenly from heart attack; many never knowing they had heart disease. Sudden cardiac death occurs on average around age 60. It takes four to six minutes after cardiac arrest before a person experiences brain death and then complete death. The survival rate outside a hospital is about 1-2%. Sixteen percent of patients treated in Seattle for cardiac arrest survived, compared to 3% in Alabama. Approximately 40% of people who have a heart attack die before they get to the hospital. Research suggests that 25% of heart attacks go unrecognized and are only discovered later when a routine ECG is performed.

### *f) Treatment*

To detect a heart attack either an ECG or blood test is performed, in some cases both are performed. An ECG show how the person heart electrical activities are behaving; how rapid the heart is beating and how often. A Blood test determines if the patient has blood clots, the location of the clots, if there is inflammation in the body, the level of the patient blood pressure, how much blood and oxygen a person heart is receiving, and other information to determine heart damage. Once heart damage is detected, depending on the severity several treatments are available. CPR is the first and most immediately treatment, then medical care is needed to stabilize the disease. Other treatments include surgeries to remove the damaged area or using stent to open the blocked or damaged area. Medication can be given to open the damaged area and to prevent a person from having a second heart attack. In extreme cases heart bypass surgery is need to open a new path to the heart to allow blood to flow. Often a change in diet and exercise is required. Treatment options can vary based on the damage and severity of the type of heart disease.

### *g) Response time for best results*

The average time from collapse to beginning CPR and providing Automated External Defibrillator varies widely across the country. Communities that train in CPR and strategically place AEDs in public buildings, arenas, and emergency vehicles significantly improve response times. Some studies show that police equipped with AEDs can cut response time to sudden cardiac arrest victims by about three minutes. This can improve the chances of the victim surviving. The average treatment time with heart disease is 56.8 minutes; this includes calling for help [1,10,17,32,44]. Calling for assistance in the first 5 minutes can increase survival rates. Facts about heart disease recovery are listed below [1,10,17,32,44].

- Brain damage can start to occur in just 4 to 6 minutes after the heart stops pumping blood.
- Death may be prevented if the sudden cardiac arrest victim receives immediate bystander cardiopulmonary resuscitation (CPR) and defibrillation within a few minutes after collapse.

- Ventricular Fibrillation (VF) sudden cardiac arrest can be reversed if the victim is treated with an electric shock to the heart within a few minutes. The electric shock can stop the abnormal rhythm and allow a normal rhythm to resume. This process, called defibrillation, is done using a defibrillator
- When bystanders perform effective CPR immediately after sudden cardiac arrest, they can double a victim's chance of survival.
- Survival is directly linked to the amount of time between the onset of sudden cardiac arrest and defibrillation. If no bystander CPR is provided, a victim's chances of survival are reduced by 7 to 10 percent with every minute of delay until defibrillation.
- The VF sudden cardiac arrest survival rate is only two to five percent if defibrillation is provided more than 12 minutes after collapse
- Early CPR and rapid defibrillation combined with early advanced care can produce high long-term survival rates for witnessed cardiac arrest. In some cities with public access defibrillation or "community AED programs," when bystanders provide immediate CPR and the first shock is delivered within 3 to 5 minutes, the reported survival rates from VF sudden cardiac arrest are as high as 48 to 74 percent
- No statistics are available for the exact number of sudden cardiac arrests that occur each year. However, about 335,000 people a year die of coronary heart disease without being hospitalized, about 918 Americans each day.

# Chapter 2 Literature Review

## 2.1 Literature Research

A literature review was conducted for the four events: heart, falling/fainting, stroke, and change in glucose levels to see how other went about solving these problems to better assist the elderly to age in place better. The research conducted was used to better enhance the development of this wrist worn device project.

### 2.1.1 Heart Disease

Many researchers are working on devices to detect heart issues. Many researchers are using marketed technology and trying to shrink them into a portable wearable devices for the user. This will make it easier for the user to detect heart issues earlier and get help sooner.

***A wearable wireless ECG sensor: a design with a minimal number of parts***

E.S Valchinov and N.E Pallikarakis made a prototype for a wireless ECG sensor. It can do continuous monitoring while the user goes about their daily activity. The device is small and comfortable. The design requires a minimal number of components. The hardware of the system contains two parts: the wearable ECG device, which measures, captures, and transmits ECG readings and the receiver which collects the ECG signal readings and stores them on the computer. The sensor device has a split design Pad-1, which is the digital and radio part of the sensor and Pad-2 which is the analog part of the sensor.

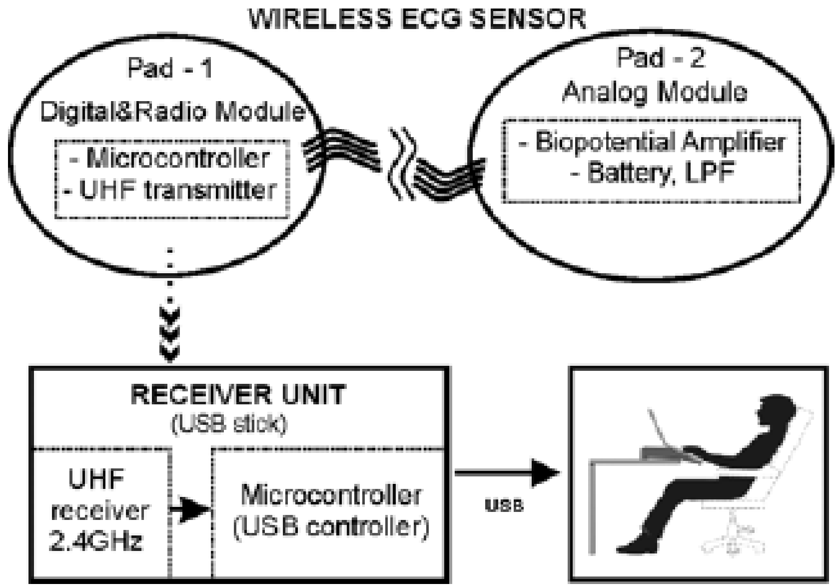



Figure 2.1: The components of the wireless ECG sensor and how it communicates

E. Valchinov and N. Pallikarakis, "A wearable wireless ECG sensor: a design with a minimal number of parts," *MEDICON,* vol. 29, pp. 288-291, 2010. Used with permission of springer, 2014

The ECG runs using a rechargeable coin cell Lithium-Ion polymer battery. The system uses an IEEE 802/ZigBee OEM Module, which is 2.4 GHz low power sensor controller. The controller is responsible for data acquisition, and radio communication. The sensor connects to the receiver by using 1 channel out of a possible 16. This is done by the IEEE scanning all the channels and picking the channel with the least amount of noise. Once the channel is chosen, the network coordinator triggers the timer and signals back to the sensor that the ECG is in use. The network is powered by a computer. When the sensor is monitoring the user, the embedded microcontroller samples the amplified ECG signal every 2ms at 500Hz sampling frequency. The data collected is transmitted every 500ms for a total of 15 seconds. The data is sent in 181 bits size packets; if the data is lost it is resent. The program was developed in LabView with the ability to change ECG sampling rates and the signal can be stored in Matlab.

The system was tested in three different ways using different transmitting powers. The first test was done with the amplifier inputs shorted at the snap connectors, the second test was done with placing a 22k resistor between the snap connectors, the third test was done with pre-gelled electrodes stack/shorted together. From these tests it was determined that the noise doesn’t depend on the measurement configuration. Limited tests were done on a human subject, the sensor was attached to the subject using adhesive foam electrodes. The maximum transfer distance for the data from the sensor to the receiver is 36m using a 0dB transmit power. The maximum operating time of the sensor was 49 hours of continuous monitoring.

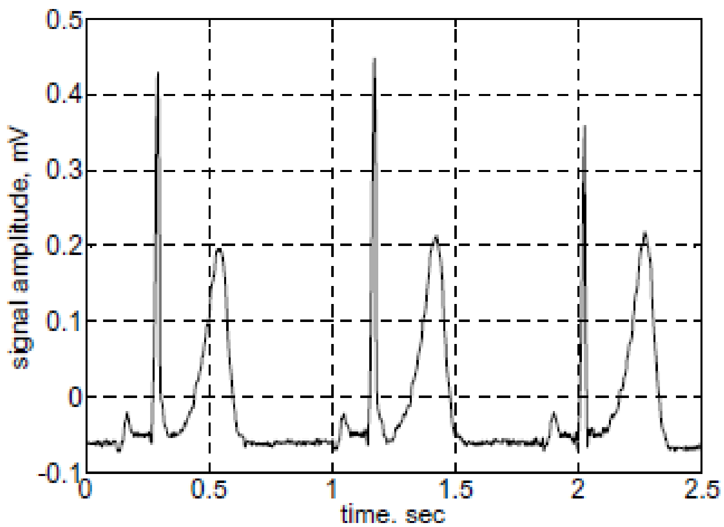



Figure 2.2: ECG signal recorded with the developed wireless sensor

E. Valchinov and N. Pallikarakis, "A wearable wireless ECG sensor: a design with a minimal number of parts," *MEDICON,* vol. 29, pp. 288-291, 2010 Used with permission of Springer, 2014

***<u>A Wireless Wearable ECG Sensor for Long-Term Applications</u>***

Ebrahim Nemati, M. Jamal Deen, and Tapas Mondal designed an ECG sensor that is a two lead system consisting of two parts. The first part of the system contains 3 PCBs that are used as electrodes for signal acquisition and common mode attenuation. The second part of the system contains a main board that is used for signal conditioning and transmission. Two of the electrodes are placed on the chest for signal acquisition, the third electrode is placed on the hip and this is considered the reference electrode.

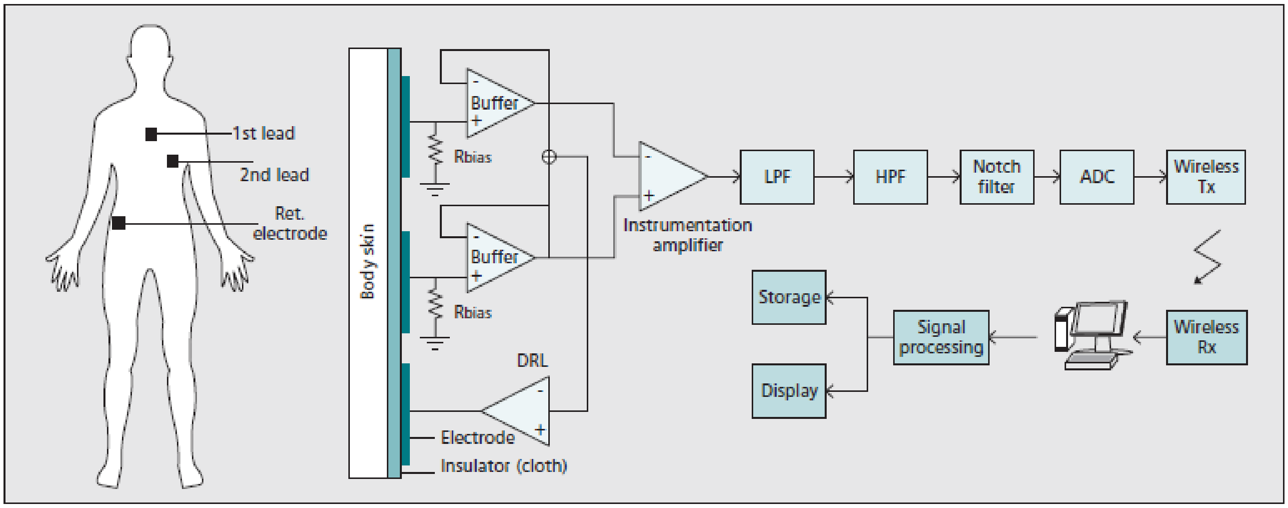



Figure 2.3: How the ECG sensor is set up on the user body and how it processes, communicates, and stores the information to the home based

E. Nemati, J. M. Deen and T. and Mondal, "A Wireless Wearable ECG Sensor for Long-Term Applications," *Communication Magazine,* vol. 50, no. 1, pp. 36-43, 2012 Used with permission of IEEE Communication Magazine, 2014

Once the electrodes are placed and start acquiring a signal the data is sent to the main board. The main board filters, amplifies, digitizes, and transmits the signal. A low and high pass filter is used to get rid of undesired frequency and to improve the signal-to-noise ratio. The new and improved signal is sent to the main station, which could either be the user's computer, or if used in the hospital, the hospital's network. From the computer or the network, the signal is farther processed and displayed on the screen. The signal can be stored for later use if desired. To power the sensor a 3V lithium battery with a capacity of 256 mAh is used, alone with a low power AC/DC voltage converter, to provide ±5 voltages to the system.

To test the setup of the system two of the electrode were placed on a subject, a piece of cotton was placed on top and lastly two metal plates, which modeled the human body were attached to the cotton. A Pressure was applied to the electrodes; this was used to test the frequency spectrum. The frequency was tested by applying a signal to the plate with a frequency between 0 and 10 kHz. From testing, it was determined the measured and simulated signals were similar. To test the time domain of the sensor, the electrodes were placed inside a stretchable belt and then placed on a male 24 year of age, two on the chest and one on the hip. One test was done while the subjected was motionless and the other test was done while the subject was moving.  The results showed that there was variation from pulse to pulse because of the change in coupling capacitance due to the electrodes becoming damp and wet. When the electrodes are directly glued to the body the pulse to pulse change is minimal. A test was performed to determine how the insulation affects the signal. This test was done by taking measurements when the electrodes were placed directly on the subject and insulation was in place. There were two different types of insulation, wool and cotton. When insulation was in place the electrodes signal was weaker. The wool signal caused the signal to be too unreadable and too distorted to analyze. With cotton insulation the signal was readable and able to be compared to the non-insulation results.

***Optical Sensor Based Instrument for Correlative Analysis of Human ECG and Breathing Signal***

M. Sundararajan designed a Photoplethysmograph (PPG) sensor, which measures the change in blood volume in the blood vessel through the skin. This method is used because the hemoglobin in the blood vessel absorbs infrared light extremely faster compared to the rest of the skin tissues. The best wavelength range to get a good reading is around 900nm. When the blood pressure changes, the blood vessel increase or decrease depending on if the blood pressure drops or rises. If the blood pressure decreases, the reflection of the light increases causing the PPG to increase; if the blood pressure rises, the reflection is smaller causing the reflection of the light to decrease.

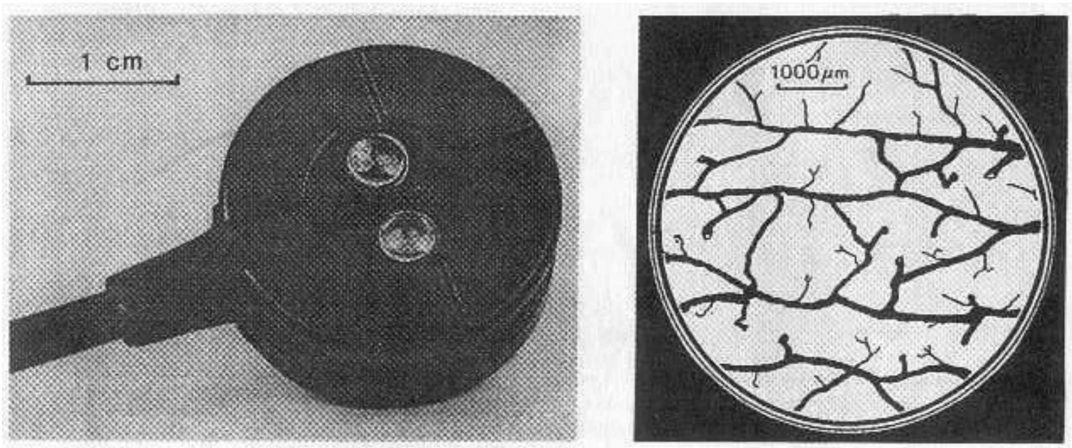



Figure 2.4: Left picture Optical sensor and right picture Optical sensor viewing blood vessels S. Lakshmi, "Optical Sensor Based Instrument for Correlative Analysis of Human ECG and Breathing Signal," *International Journal of Electronic Engineering Research,* vol. 1, no. 4, pp. 287-298, 2009 Used under fair use, 2014

The PPG sensors were placed on the left and right side of the head on the temples. The Tx and Rx have to be in line with the blood vessel. The two thermistors are placed in the right and left nostril. The ECG sensors are then placed on the body in the correct locations. Once everything is in place, data is collected simultaneously from the PPG and ECG at a sampling rate of 250Hz. The signals were processed using Fast Fourier Transform (FFT), Power Spectral Density (PSD), and graphing. The results determined that the PPG and ECG were close and the PPG sensors can be more reliable than other sensors.

### ***Revolutionary Optical Sensor for Physiological Monitoring in the Battlefield***

SRICO developed an optical based monitoring system that measures and monitors electrophysiological parameters such as EEG and ECG; the sensor requires no contact with the user and can be measured though the clothing of the user. The sensor uses an optical chip and a patent pending Photrodes. The Photrode uses a light as its medium and an innovative optical chip technology. The Photrode has high impedance which allows for non-contact though clothes sensing. With the Photrode being a light-based sensor it doesn’t have any signal loss and it doesn’t need a pre-amplifier, also the device has board range voltage sensitivity which allows the device to detect at the microvolt level an EEG signal. The Photrode sensor system contains a laser source, input and output Optical Fibers, and optical receiver and signal processing components.

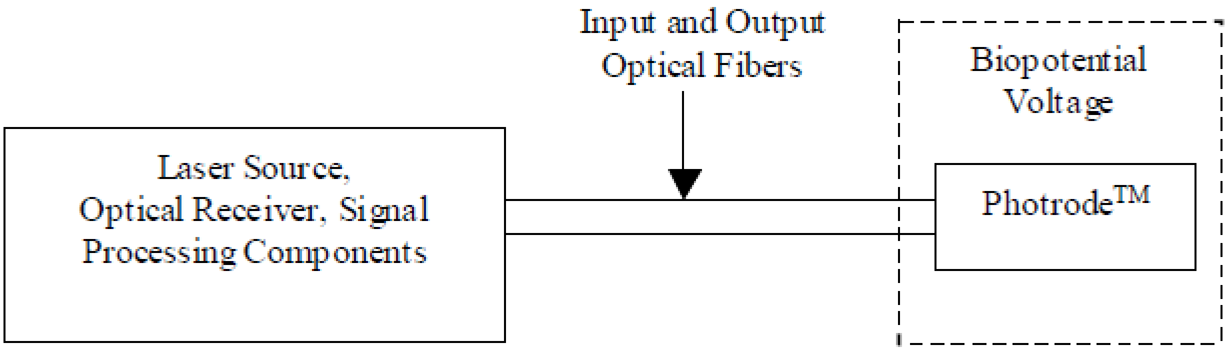



Figure 2.5: How the optical sensor communicates and transmit the signal
S. A. Kingsley, S. Sriram, A. Pollick and J. and Marsh, "Revolutionary optical sensor for physiological monitoring in the battlefield," *Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security and Homeland Defense III,* vol. 5403, no. Carapezza, Edward M, pp. 66-77, 2004 Used under fair use, 2014

The way the system works is that light from a continuous wave laser enters in the Photrode through Optical Fibers, from there the fiber becomes intense, after this the signal is detected and processed from an optical receiver. The design of the actual Photrode sensor consists of a Mach-Zehnder Interferometer (MZI), which is an integrated optical circuit. The MZI contains a light path which is y shaped and it splits the light into two different waveguides and the waveguide combiner, which is also y shaped allows the light to exit out the same path. The prototype design contains a ground tag, which is an extra ground reference and Bio-potential contacts, which can be place on the user clothes to take the ECG measurements.

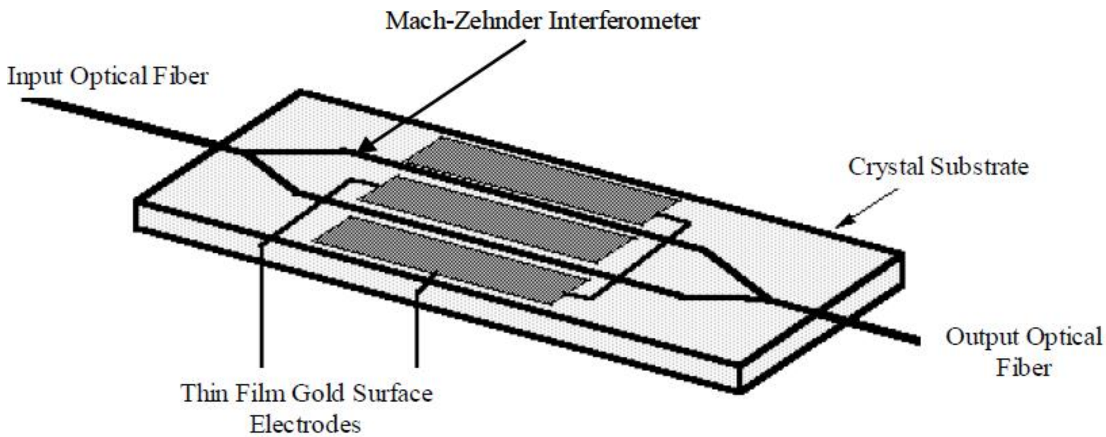



Figure 2.6: Optical sensor and it components

S. A. Kingsley, S. Sriram, A. Pollick and J. and Marsh, "Revolutionary optical sensor for physiological monitoring in the battlefield," *Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security and Homeland Defense III,* vol. 5403, no. Carapezza, Edward M, pp. 66-77, *2004 Used under fair use, 2014*

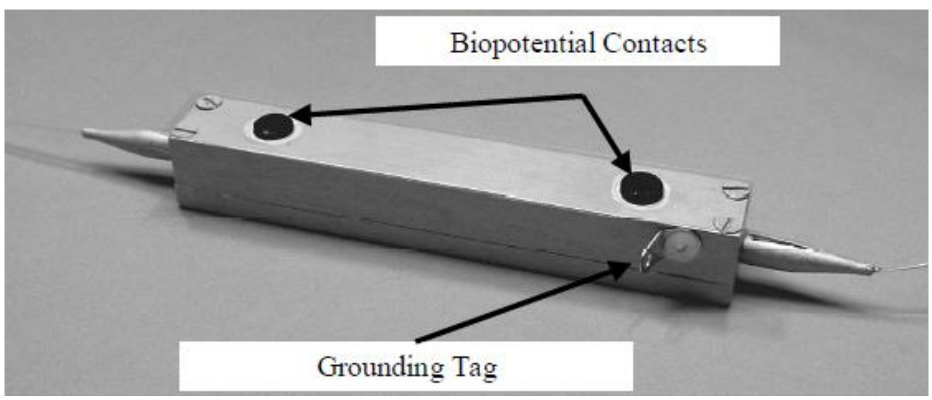



Figure 2.7: Prototype Optical sensor showing the Biopotential contacts and ground tag

S. A. Kingsley, S. Sriram, A. Pollick and J. and Marsh, "Revolutionary optical sensor for physiological monitoring in the battlefield," *Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security and Homeland Defense III,* vol. 5403, no. Carapezza, Edward M, pp. 66-77, 2004 *Used under fair use, 2014*

The Photrode was tested against EEG and ECG sensors that use wet contact electrodes, to see how the system stood up against well-established machine measurements. The EEG, ECG, and Photrode sensors were tested in the same general area at the same time at a rate of 1000 samples per second. Through testing, it was determined that measurements from the EEG, ECG, and Photrode sensors were very close and the difference in measurement came from the placement of the device. From this it can be determined that the Photrode can successfully and accurately detect EEG and ECG signals through non-contact with the user.

### ***Wireless Non-contact EEG/ECG Electrodes for Body Sensor Networks***

Yu M. Chi and Gert Cauwenberghs designed an EEG/ECG wireless sensor that requires no contact with the user. The system consists of a set of non-contact bio-potential daisy chained electrodes that are connected with a single wire. The EEG/ECG sensors can be placed directly on the user's skin or placed on the users clothing. The system consists of a base unit, which powers the whole system and a wireless transmitter that sends the data collected from the sensor to the user's computer or a device specified by the user. For the system to work a sensor needs to be placed near the base unit to establish a ground reference. The Electrodes are made up of two PCBs. The first PCB consists of a low noise differential amplifier and a 16-bit ADC, to reduce the amount of wires. The second PCB consists of an INA116 which functions as an ultra-high impedance amplifier.

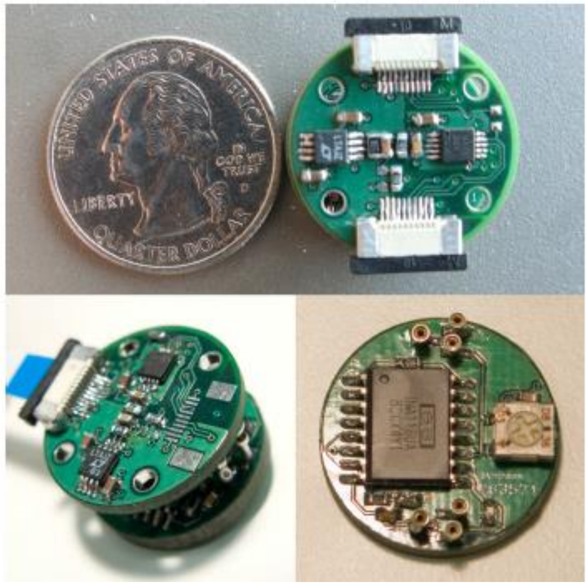



Figure 2.8: EEG sensor with it tow PCBs at the top pic bottom picture is the circuit of the sensor
Y. M. Chi and G. Cauwenberghs, "Wireless Non-contact EEG/ECG Electrodes for Body Sensor Networks," in *Body Sensors Networks* , Singapore, *2010 Used with permission of IRRR Body Sensors Networks, 2014*

They daisy chain of electrodes are connected to the wireless base unit, the base unit supplies the power. A low power microprocessor (PIC24) transmits the serial data from the ADC to a Bluetooth module (F2M03ALA), which is sent to the user's computer or other specified device. The system was tested several times to show the high signal quality taken with the electrodes. Alone with testing the signal, tests were performed to determine the performance quality of the device while taking EEG and ECG measurements. With direct electrode to skin contact the signal was very clear and the device performed well. With thin insulation, such as a t-shirt, the signal was less clear but still readable and the device still performed well. With thicker insulation, such as a sweater, the signal begins to experience noise; even with the noise the device signal was still readable.  Even with the subject moving the signal were readable and about to be distinguished.

## 2.1.2 Falling/fainting

Falling and fainting are the most researched medical devices to help the elderly age in place better. Since they are many devices on the market to detect falls and fainting researches are working on ways to better the technology that is already on the market to make them more accurate.

***<u>Privacy Preserved Fall Detection by an Infrared Ceiling Sensor Network</u>***

Shuai Tao, Mineichi Kudo, and Hidetoshi Nonaka used twenty infrared sensors to detect when falls occurs; they placed these sensors on the ceiling in the created testing space. The way these infrared sensors work are they detect an object with a different temperature from the temperature of the room. The detection range of the sensors can change depending on how big the area where the sensors are placed is located. The sampling rate of the sensors can range between 1Hz to 80Hz.

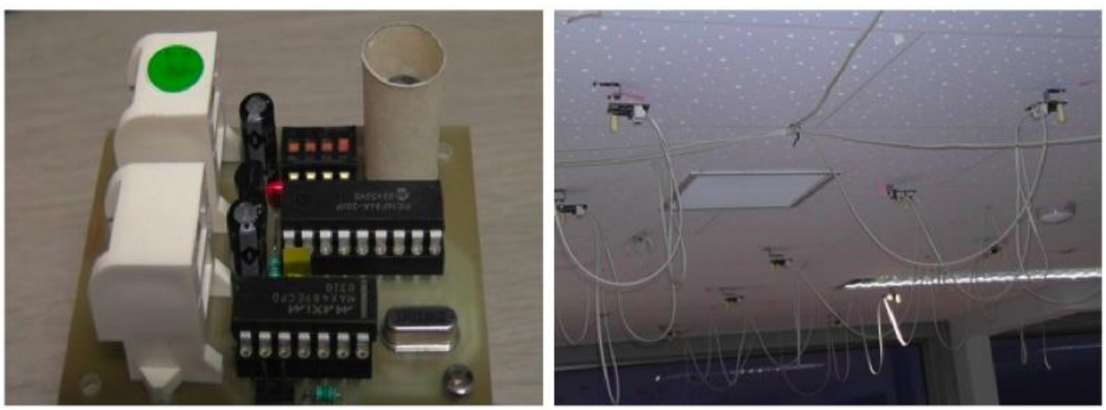


Figure 2.9: The infrared sensor on the left and the setup room with multiple sensors on the right
S. Tao, M. Kudo and H. and Nonaka, "Privacy-preserved fall detection by an infrared ceiling sensor network," *NCBI,* vol. 12, no. 12, pp. 16920-16936, 2012 Used with permission of *NCBI*, 2014 Used

The testing area was designed to simulate a small room. The sensors were place at an average of 75cm apart; this was done so that they could cover the whole area of the room. The sensors are designed to detect large motions and ignore small motions such as a person watching TV, reading, sitting, or standing. Once the person steps in the testing area, multiple sensors would detect their motion.

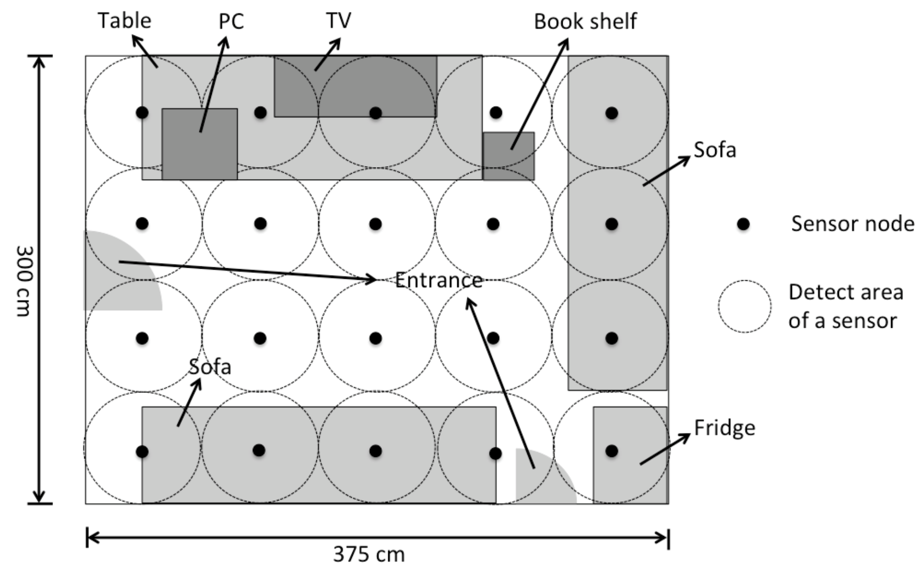



Figure 2.10: The layout of the test room

S. Tao, M. Kudo and H. and Nonaka, "Privacy-preserved fall detection by an infrared ceiling sensor network," *NCBI,* vol. 12, no. 12, pp. 16920-16936, Used with permission of *NCBI*, 2014

The infrared sensors produce a binary value at each independent time frame. The sensors function as a top view camera with a resolution of 4X5 pixel, with sensitivity of two. By tweaking the pixel values the sensor can pick up the location of the person. Also, using the pixel values can help to determine what activity a person is doing because of the difference in speed when doing activities. Walking and cleaning had a relative values of 7.5 (H cm/s) and 5 (H cm/s) and slower activities had a value of 1 (H cm/s). H stands for a sampling rate of 20Hz. To test the system, daily activities and simulated falls were performed.

Table 2.1: Results of the sensor with for each activity

S. Tao, M. Kudo and H. and Nonaka, "Privacy-preserved fall detection by an infrared ceiling sensor network," *NCBI,* vol. 12, no. 12, pp. 16920-16936, 2012 Used under fair use, 2014

| | Time period /Frames | Maximum Speed ($H$ cm/s) |
|---|---|---|
| Sweeping | 40.70s/814 | 6.88 |
| Walking | 31.55s/631 | 8.54 |
| Sitting | 23.95s/479 | 0.01 |
| Falling | 100.40s/2008 | 13.40 |

From these results, it was determined that activities with more movement had a higher speed. For fall simulation they tested 10 different falls in a 100 second time period, from this 13.40 (H cm/s) is the average. All of the falls were above 10 (H cm/s) and below 20 (H cm/s). To further test the system, the subject stayed in the environment for 30mins, doing normal activities, falling-like activities, and simulated falls. Regular activities include things such as reading and watching TV, fall-like activities include sitting down and lying down, and simulated falls included falling forward, backward, and sideward. From this testing, it was determined that the system could pick up on the falls were there was horizontally speed; it could not pick up on the speeds were the person falls vertically or falls at a low horizontal speed. Horizontal falls can be detected 85.71% and vertical falls 73.68%.

***Pyroelectric IR sensor Arrays for Fall Detection in the Older Population***

A. Sixsmith, N. Johnson, and R Whatmore developed a proactive system that detects falls called the Smart Inactivity Monitor using Array Based Detectors (SIMBAD). The SIMBAD system uses array based passive sensor technology, which is based on the Pyroelectric infrared detector array. The way the Pryoelectric device works is that it couples to the change of any input energy flux. For the Pyroelectric to work properly, it must be built from the correct material, ceramic. The electrical conductivity of the ceramics is a desirable thing to control because it affects the time constant. The Pyroelectric sensor is only sensitive to change in IR intensity, it has an array of 16X16.

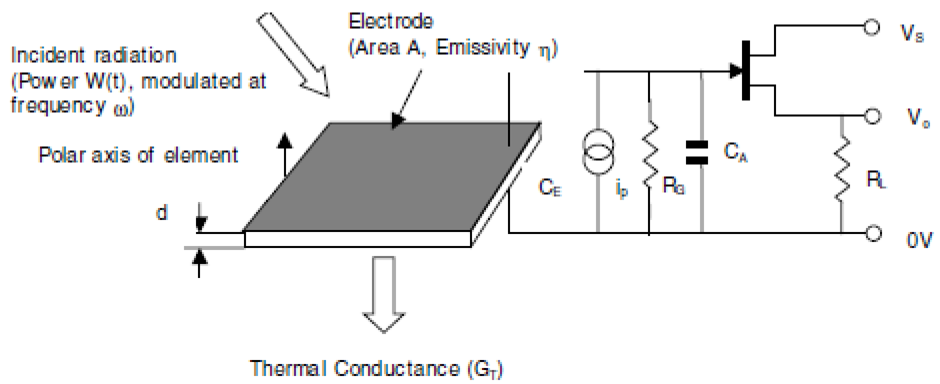



Figure 2.11: Pyroelectric IR sensor showing how it setup and works

A. Sixsmith, N. Johnson and R. and Whatmore, "Pyroelectric IR sensor arrays for fall detection in the older population," *EDP Sciences,* vol. 128, pp. 153-160, 2005 Used with permission of EDP Sciences 2014

The Pyroelectric is setup to only see moving warm objects, to do this it has to differentiate the object from the surrounding background. The sensor can also locate and track a thermal target that is in the sensor's field of view; it provides size, location, and velocity of the object. For the sensor to be able to detect a fall it must do two things: first the target motion must be analyzed to detect characteristics of dynamic falls and second the motionless activity is compared with a map of acceptable periods of motionless activity in different locations. If it is determined that motionless activity is in a location it shouldn't be the system will acknowledge this. The sensor communicates with a computer where the sensor sends the alerts and the user defined risk maps can be obtained. The sensor sends two different types of alerts one for long periods of motionless activity in a room or location that shouldn't have inactivity for long periods of time and the second is when a fall is detect. To test the system, a subject was monitored during several cases that could result in a fall from different angles and viewpoints. The results showed that only 30% of the falls were detected.

***Towards Automatic Detection of Falls Using Wireless Sensors***

Soundararajan Srinivasan, Jun Han, Dhananjay Lal and Aca Gacic designed a wireless system that detects different kinds of falls. This system consists of an accelerometer that the user wears and a motion detector, which is placed in the home. It will monitor the user and communicate to the central data processing station.

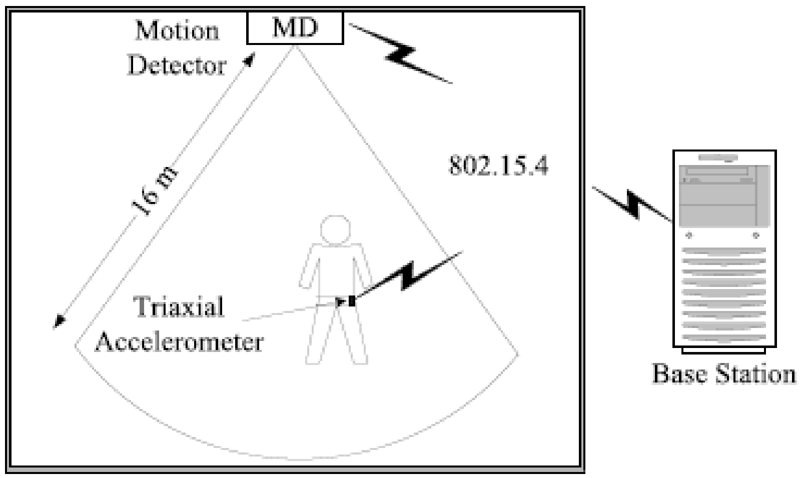



Figure 2.12: Wireless system setup in a typical room and base station

S. Srinivasan, J. Han, D. Lal and A. and Gracic, "Towards automatic detection of falls using wireless sensors," in *IEEE Engineering in Medicine and Biology Society*, Lyon, 2007 Used with permission of IEEE Engineering in Medicine and Biology Society Sciences, 2014

The way the system works is that the measurements from the sensors are sent wirelessly to the base station. The base station is connected to a computer through serial connection. The wearable mobile device contains a triaxial accelerometer, an MSP microcontroller, and a wireless transceiver. The mobile device is worn around the person center of gravity and records the user motion and detects falls. The passive infrared motion detector consists of an infrared sensor and Fresnel mirror, which collects infrared radiation within a range of about 16m. The motion detector transmits the signal to the computer in real time and provides other longitudinal information about the person's motion. The motion detector has an adjustable sensitivity level and Fresnel mirror orientation to adjust them to the area of the room to detect the most motion in room. The motion sensors are placed on the wall, when it detects motion it sends out a high signal and the signal remains high until it detects no motion. If the wall sensor thinks the user has fallen it will send a signal to the mobile device to check for movement or non-movement, if it is then confirmed from the mobile device of non-movement it will send an alert.

To test the system, the subject was told to sit, stand, walk, walk fast, hop, climb up, climb down, rotate in a chair and simulate falls. Simulated falls include falls backward, forward, and sideward. Result show that the system detects the sideward falls 94% of the time and backward and forward falls 100% of the time.

### ***VAMPIR an Automatic Fall Detection System Using a Vertical PIR Sensor Array***

Mihail Popescu, Benjapon Hotrabhavananda, Michael Moore, and Marjorie Skubic designed a fall detection system that has multiple passive infrared sensors, which are called VAMPIR that are in a vertical array. The pattern recognition algorithms are based on hidden Markov models. The system consists of four sets of two passive infrared sensors that are spaced 1 foot from each other vertically.

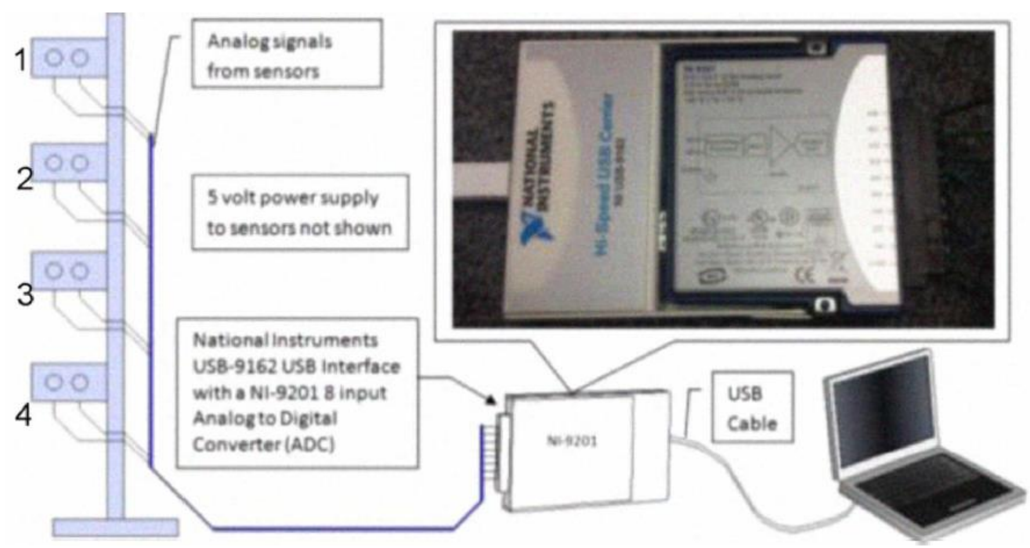



Figure 2.13: VAMPIR system and setup

M. Popescu, B. Hotrabhavananda, M. Moore and M. and Skubic, "VAMPIR- An Automatic Fall Detection System U sing a Vertical PIR Sensor Array," in *International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops pg163-166*, San Diego, 2012 Used under fair use, 2014

A Panasonic MP PIR motion sensor that has a 20 degree vertical field of view and 40 degree horizontal field of view was used, to allow infrared light with a wavelength of 10um, which is the wavelength of the human body; though the system. Once a person walks into the sensor's view the infrared energy from the human activates the left and right sensing surface. The right and left sensing surface does two different things; the right one activates a negative differential voltage and the left one activates a positive differential voltage. The signals are processed in real time to estimate the motion that the person is making. To test the system, several falls were stimulated, falls forward, backward, and sideward. From these tests, it was determined that the system has a high false positive rate and some falls remained undetected. The system was able to differentiate between falls, fall-like activity, and regular activity.

### 2.1.3 Stroke

Strokes are hard to detect outside of hospitals. Many researches are working on technologies that can detect stroke without a MRI or a blood test. Many of this technology consist of head gear that the user can wear. Most of these technology are easier to use and accurate in detecting strokes.

***Portable Brain Imaging System for Early Stroke Detection***

Jan Medical developed a device that can detect early signs of ischemic stroke. The way the device works is based on interesting principle of detecting the ultrasonic wave emitted by the skull. The device measures mechanical vibrations of the skull; these vibrations are caused by a pressure wave from blood rushing to the head from the heart. The device is designed to be worn for 5-10min; in this time frame, it can gather enough information to detect problems such as intracerebral or subarachnoid hemorrhage, epidural or subdural hematoma, intracranial aneurysm, arteriovenous malformations, ischemic stroke, and transient ischemic attack. The portable system has two main parts, the headset, which is covered with sensors and a controller, which is used to analyze the collected information.

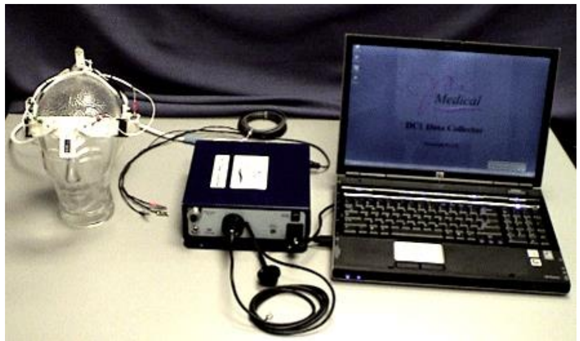


Figure 2.14: Early stroke detection and it setup. The computer used to monitor the brain waves V. Pikov, "Portable brain imaging system for early stroke detection," Nuerotech business , April 2011. [Online]. Available: http://neurotechzone.com/posts/344. [Accessed 21 January 2013] Used with permission of Victor Pikov, 2014

***__Portable Device Acts as Early Detector of Strokes__***

Figure 2.15: Early Detector device

D. Ferguson, "Scientists: Portable device acts as early detector of strokes," 27 December 2012. [Online]. Available: http://www.rawstory.com/rs/2012/12/27/scientists-portable-device-acts-as-early-detector-of-strokes/. [Accessed 9 september 2013] Used under fair use, 2014

Nathan Bornstein developed a device that detects early signs of stroke in at risk patients as well as people who have already suffered from a stroke. The device is automatic in detecting and wireless in sending the information to a computer or medical network. The way the device works is it measures the users brain wave, as the device is collecting the information it is being checked against an algorithm for stroke-like events. If the device detects a stroke-like event it will alert the user as well as a family member or medical personnel so the user is able to get immediate help.

***Eye Movement Analyzer May Diagnose Stroke***

GN Otometrics developed a device that can detect early signs of stroke using eye movement. The device is a Video oculograohy machine that can detect eye moment that doctors are not able to see or detect. This device detects if the person has had a stroke and who hasn't. The device consists of a set of goggles that the user wears, which has a webcam to continuously record the eye acceleration. The goggles are then connected to the computer where a picture of the eyes is displayed. Then a program that was developed, analyzes the eye movement by following how the pupils change position and the accelerometer measures the eye movement speed.

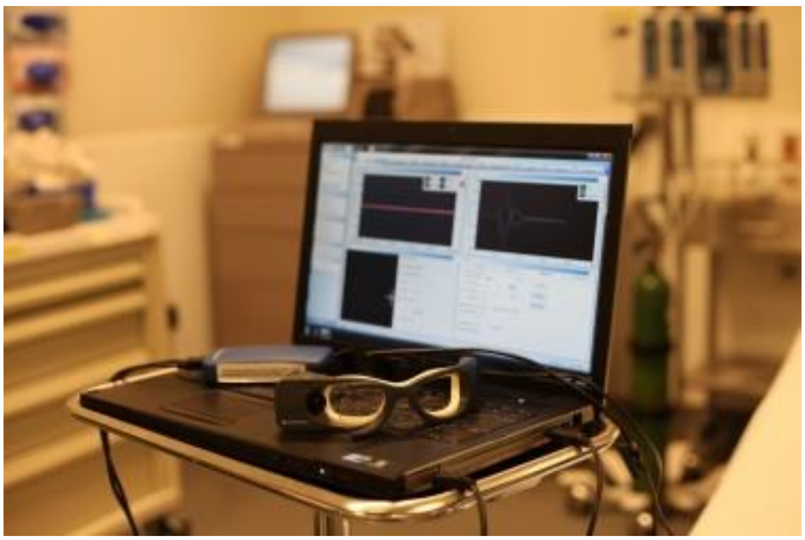


Figure 2.16: Video oculograohy machine device, the goggle used to monitor and capture eye motion and the computer used to see the eye motion and results

C. Paddock, "Eye Movement Analyzer May Diagnose Stroke," MNT, 7 March 2013. [Online]. Available: http://www.medicalnewstoday.com/articles/257312.php. [Accessed 9 September 2013] Used under fair use, 2014

To test the system they used 12 subjects that came to the hospital for dimness, vomiting, difficulty walking, and intolerance to head motion; the machine was placed on the subjects head and the computer recorded the results. The results were compared to a MRI, which is used to detect if someone has had a stroke or if something else is wrong. From the results 6 people were determined to have had a stroke and 6 people were determined to be benign. When later compared to the MRI all of the diagnoses were correct.

### ***Submarine Technology to Diagnose Stroke Quickly***

Retired U.S Navy radiologists sonar experts design a device that can monitor, diagnose, and detect stroke using submarine technology. The device consists of a headset and a laptop based home center.

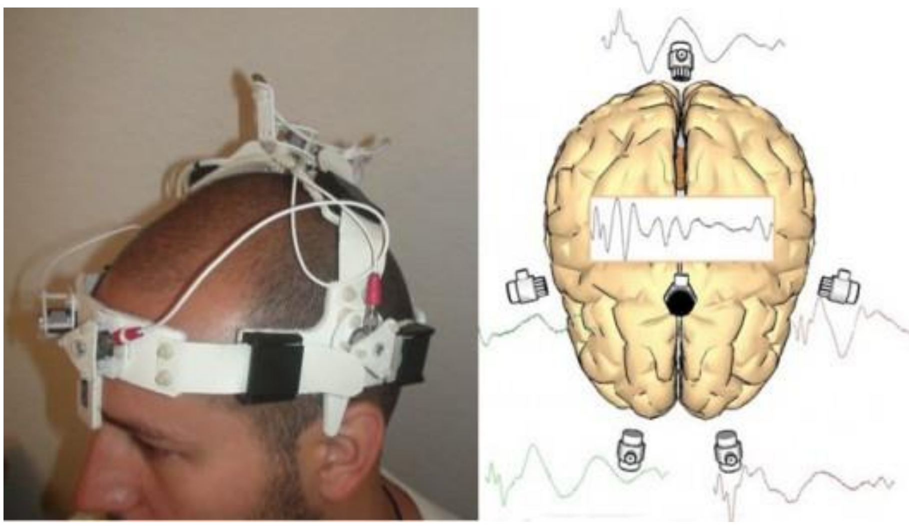


Figure 2.17: Submarine device in used on the left and where and how the sensors are setup on the right

ScienceDaily, "New device uses submarine technology to diagnose stroke quickly," Society of Interventional Radiology, 29 March 2011. [Online]. Available: http://www.sciencedaily.com/releases/2011/03/110329095434.htm. [Accessed 9 September 2013] Used under fair use, 2014

The device can monitor, diagnose, and detect stroke in a matter of minutes; the device can tell the difference between normal brain activity and abnormal activity such as swelling and bleeding of the brain. The device monitors the brain activity continuously and in real time. It then sends the data to the base computer. The way the device work is that is measure the brains complex brain pulsation; if it finds something is wrong it provides the location and type of abnormality. The device uses an array of sensors to measure the brain movement, then it generates a signal to be processed and analyzed by the computer. The computer then matches the signal to a type of abnormality such as an aneurysm, which is an abnormal connection between the veins and arteries in the brain. The device measures the skull acceleration to separate the acoustic sound caused by the rush of blood from the heart to the head and records the waveform of the pulse. To test the accuracy and reliability of the device 40 subjects were chosen who had different cerebrovascular conditions and 30 subjects who were fine. The device was tested and checked against a CT magnetic resonance imaging. From the results the device was able to diagnose each person with their perspective cerebrovascular conditions as well as the location of the problem, and the subjects that were healthy.

### 2.1.4 Glucose levels

Glucose levels are hard to detect accurate without the user having to prick their finger. Researchers are working on technologies that can detect glucose through the skin, which is non-invasive. Most of these technologies use a type of light sources that can penetrate the skin and get a reading of the person's glucose levels.

***PENDRA: The Once and Future Noninvasive Continuous Glucose Monitoring Device***

SA. Weinzimer designed a device that measure glucose noninvasively. The device measures the glucose level at the forearm of the user continuously. The way the device is used is that the adhesive tape has to be placed on a shaved arm every 24 hours and calibrated every 3 days. When it's placed on the user forearm it has an equilibration time of 1 hour to get used to the area where the device was placed and it needs a baseline adjustment every time it is placed on the forearm.

Figure 2.18: The adhesive tape for the PENDRA used to detect the blood glucose

F. Flacke, "Practical aspects of using the Pendra® device," 9 May 2004. [Online]. Available: http://www.diabetes-symposium.org/index.php?menu=view&id=136. [Accessed 9 September 2013]
Used with permission of NCBI, 2014

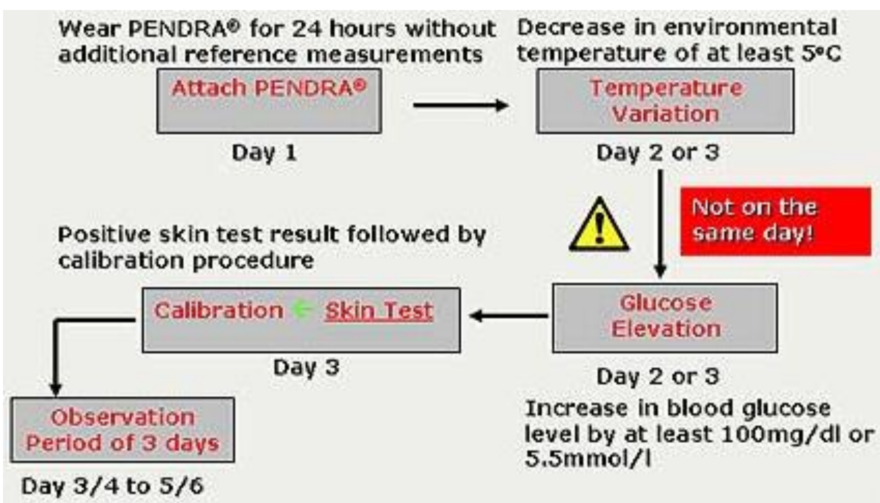



Figure 2.19: How the PENDRA is calibrated

F. Flacke, "Practical aspects of using the Pendra® device," 9 May 2004. [Online]. Available: http://www.diabetes-symposium.org/index.php?menu=view&id=136. [Accessed 9 September 2013]
Used with permission of NCBI, 2014

The device displays important information such as glucose measurements, a measurement indicator to say if the glucose it too high or low, and what time the measurement was taken. Also the device indicates if it is communicating properly with the base. The device is able to store past glucose readings and the user is about to set how often the device checks the glucose level, as well as set the region the user would like his glucose level to stay and an alarm to indicate if this level is reached.

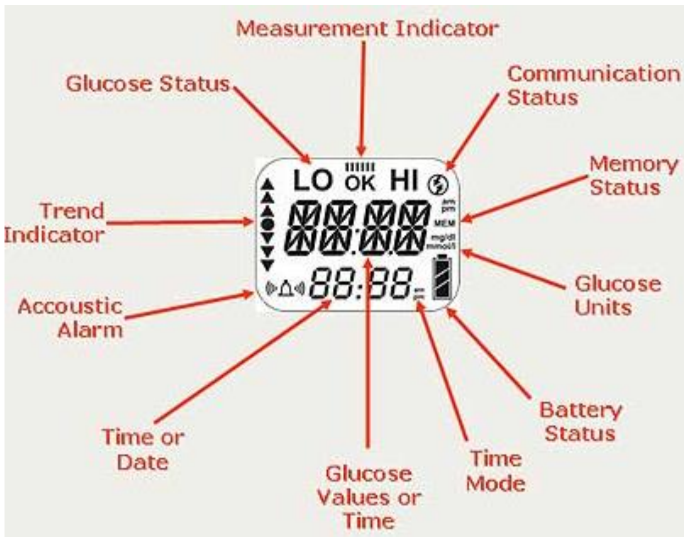



Figure 2.20: Display of what the PENDRA monitors

F. Flacke, "Practical aspects of using the Pendra® device," 9 May 2004. [Online]. Available: http://www.diabetes-symposium.org/index.php?menu=view&id=136. [Accessed 9 September 2013] Used with permission of NCBI, 2014

The alarms are also triggered in the following scenarios: if the user is within a risk of hypoglycemic state, 20 minutes before the state is actually reached; the user glucose level is lower than the given threshold for hypoglycemia; the user glucose has been in a hyperglycemic state for longer than 30 minutes; and if the user glucose level increase or decrease rapidly. The information from the device is sent to the base computer where either the user or medical personnel can analyze the data. The device measures glucose every minute unless otherwise changed by the user. The device can store data of glucose reading up to one month.


Figure 2.21: PENDRA system

F. Flacke, "Practical aspects of using the Pendra® device," 9 May 2004. [Online]. Available: http://www.diabetes-symposium.org/index.php?menu=view&id=136. [Accessed 9 September 2013]
Used with permission of NCBI, 2014

Figure 2.22: PENDRA in use

F. Flacke, "Practical aspects of using the Pendra® device," 9 May 2004. [Online]. Available: http://www.diabetes-symposium.org/index.php?menu=view&id=136. [Accessed 9 September 2013]
Used with permission of NCBI, 2014

To test the device reliability and accuracy it was tested against alternate site technique where the subject were tested at the fingertip, using a normal glucose measuring device, that is well known and used. The glucose level was measured every 15 minutes. From this test it was determined that with increasing glucose level they was no difference between measurements of the well know device testing at the fingertip and the PENDRA testing at the forearm. Once the glucose level begin to decrease either gradually or rapidly whereas the alternate site technique showed a systemic shift, the PENDRA device did not. The precision and accuracy of both the PENDRA and alternate site technique showed a decline and deterioration in measurement results over time.

### ***Sensor Detects Glucose in Saliva and Tears for Diabetes Testing***

Researchers have designed a biosensor device that measures glucose level from saliva, tears, and urine. The device is noninvasive and it can detect glucose level in a minute's time. The sensor is broken up into three main parts: layers of nanosheets which are made of grapheme and look like petal, platinum nanoparticles, and the enzyme glucose oxidase. The way the device works is that the edge of the petals of grapheme has dangling incomplete chemical bonds. These are where the platinum nanoparticles can attach to the defects of the chemical bonds. When the nanosheets petal and platinum nanoparticles are combined they form electrodes. From there the glucose oxidase attaches to the platinum nanoparticles. The enzyme then converts glucose to peroxide creating a signal to the electrode. The device can detect glucose levels concentration as low as 0.3 micro molar. The device is also able to differentiate between glucose and signals that can cause interference in sensors.

### ***GlucoTrack DF-F Noninvasive Glucose Meter***

Israel has designed a device that can measure the user glucose level. The device is nonivasive glucometry instrument. The GlucoTrack consists of a sensor that can be clipped to the ear which is connected to a monitoring system, which is a handheld control and display screen.


Figure 2.23: GlucoTrack system

W. Stomp, "GlucoTrack DF-F Noninvasive Glucose Meter Receives CE Mark," medGadget, 4 June 2013. [Online]. Available: http://www.medgadget.com/2013/06/glucotrack-df-f-noninvasive-earlobe-clip-glucose-meter-receives-ce-mark.html. [Accessed 9 September 2013] Used under fair use, 2014

The way the system works is that the device uses three main techniques to achieve the blood glucose reading. The device uses ultrasound, electromagnetic, and thermal technologies. The device uses these three technologies to independently measure glucose levels simultaneously in a time span of one minute. The measurements from each technique are then correlated and averaged using Israel designed algorithm. The GlucoTrack can measure continuously and detect changes in glucose levels; the results are then displayed on the handheld device. The GlucoTrack is required to be re-calibrated each month; the calibration is done for each individual user. To calibrate the system it is tested against invasive basal and postprandial capillary fingertip glucose measurements. The calibration takes about 1 hour and 30 minutes. The ear clip is designed to be replaced every six months. The device can be hooked up to a computer through a USB port to download the data and also recharge the device.

***New Non-Invasive Blood Glucose Measurement and Continuous Monitoring Device: The Glucoband***

Calisto Medical designed a blood glucose monitoring device. The device is based on the Bio-Electric Impedance Spectroscopy (BEIS) technology. Glucoband is non-invasive measuring and monitoring blood glucose patient pending device. The Glucoband is an electronic scanning device that uses bio-electromagnetic resonance phenomenon; it is worn on the wrist and reads blood glucose level every six minutes. The device consists of a LCD screen which is touchscreen, electronic circuits which function as a computer, an embedded microprocessor, electrodes, a battery, flash memory, and a wristband.


Figure 2.24: Glucoband and it display area

New Non-Invasive Blood Glucose Measurement and Continuous Monitoring Device: the Glucoband(R)," MINT, 10 June 2005. [Online]. Available: http://www.medicalnewstoday.com/releases/25926.php. [Accessed 9 September 2013] 2014 Used under fair use, 2014

The device meets FDA requirement for correlation and accuracy. The way the device works is that it measures the electrical impedance in the human body; this impedance is caused by glucose specific electromagnetic wave also known as the glucose signature, which is caused by Bio-Electromagnetic Resonance. The device can detect trends in the user’s glucose because of its continuous monitoring ability.

## ***New Non-Invasive Continuous Glucose Monitor Will Talk to You Smartphone***

C8 MediSensors design a device that continuously measure blood glucose, and it has the capability to communicate with a smart phone. The HG1-c is a device that is worn on the belt on the user and it sits very closely to the skin to get a glucose measurement. The device used a camera called the Raman spectrometer insides the sensor which uses light to identify and analyze glucose level inside the skin through interstitial fluid.


Figure 2.25: C8 MediSensors

A. N, "New Non-Invasive Continuous Glucose Monitor Will Talk to Your SmartPhone," 3 October 2011. [Online]. Available: http://www.diabetesmine.com/2011/10/new-non-invasive-continuous-glucose-monitor-will-talk-to-your-smartphone.html. [Accessed 9 September 2013] Used under fair use, 2014

Figure 2.26: C8 MediSensor worn on the user

A. N, "New Non-Invasive Continuous Glucose Monitor Will Talk to Your SmartPhone," 3 October 2011. [Online]. Available: http://www.diabetesmine.com/2011/10/new-non-invasive-continuous-glucose-monitor-will-talk-to-your-smartphone.html. [Accessed 9 September 2013] Used under fair use, 2014

Glucose molecules have their own glucose signature; the sensor can identify these signature, and then analyze and extrapolate the glucose values. The glucose values are then transmitted through Bluetooth to a smart device which could be a phone, computer, or other device with similar technology. The HG1- c is pre-calibrated; there is no need to change the device or sensors, and the device calculates and monitors in real time. The device can alert the patient, family, and medical personnel that the user's blood glucose is reaching a dangerous level.

### ***Soft Contact-lens Sensor for Monitoring Tear Sugar as Novel Wearable Device of Body Sensor Network***

M.K. Chu, K. Mitsubayashi, K. Miyajima, T. Arakawa, H. Kudo, and K. Mitsubayashi designed a device that monitors glucose using tears. The device continuously monitors glucose through the flexible amperometric biosensor made from Soft-MEMs technology. The sensor consists of gas-permeable membrane, non-permeable membrane, electrolytes, electrodes, and glucose immobilized membrane. The sensor is made up of a reed-shaped functional polymer and electrodes. The way the device works it that it measure the oxygen level and glucose change in the body. The signal received from the sensor is then transmitted to the user's computer to be processed and analyzed. The data can be stored for later use and also the device has its own body sensor network.

Figure 2.27: Soft Contact-lens flexible sensor

M. Chu, K. Mitsubayashi, K. Miyajima and T. and Arakawa, "Soft Contact-lens Sensor for Monitoring Tear Sugar as Novel Wearable Device of Body Sensor Network," *Knowledge Systems Institute,* pp. 54-57, 2011 Used with permission of Kohji Mitsubayashi, 2014

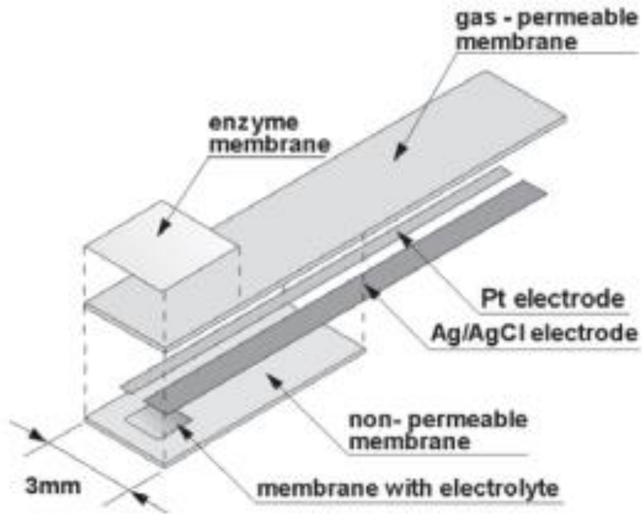



Figure 2.28: Soft contact-lens design

M. Chu, K. Mitsubayashi, K. Miyajima and T. and Arakawa, "Soft Contact-lens Sensor for Monitoring Tear Sugar as Novel Wearable Device of Body Sensor Network," *Knowledge Systems Institute,* pp. 54-57, 2011 Used with permission of Kohji Mitsubayashi, 2014

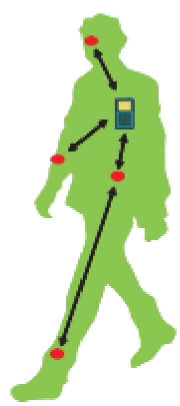


Figure 2.29: Soft contact-lens how it sensors throughout the body

M. Chu, K. Mitsubayashi, K. Miyajima and T. and Arakawa, "Soft Contact-lens Sensor for Monitoring Tear Sugar as Novel Wearable Device of Body Sensor Network," *Knowledge Systems Institute,* pp. 54-57, 2011 Used with permission of Kohji Mitsubayashi, 2014

The device was tested on rabbits. The sensor was placed on the pupil of the rabbits and then tested in two stages. The first stage measures the sensor output during steady state and the stability of the output current and the second stage measures the change in glucose levels. From this it was determined that there was a delay between the tear measurement device and the standard glucose devices.

# Chapter 3 System Requirements

## 3.1 Requirements

There are many devices on the market that detect heart disease, stroke, falling/fainting, and glucose level; the issue with these devices is they only monitor one or two of these given diseases. There is a real need for a device that can measure all these diseases at one time and give immediate feedback to the user and emergency care unit. For this to happen the device needs to have certain structural and sustainable requirements that are defined by the designer and users. The device needs to be able to measure the given parameters continuously and store the data for later use. The stored information can be used for doctor visits and other medical care facilities.

### 3.1.1 Reliability, robustness, and durability

a) Define

The device needs to able to withstand everyday use. It needs to last long term, as well as be impact-resistant. It needs to withstand being dropped from a high distance and being dropped constantly. The device needs to be able to withstand being stepped on and being hit against objects. It needs to be water resistant so that the user can wear it while in the shower or washing dishes. It needs to be reliable, that it even works in the harshest of weather conditions. It needs to be able to withstand everyday activities and extraneous activities and still function correctly. The device also needs to work continuously without any functional problems or bugs.

b) Why

The reason the device needs to incorporate all these features is because the user would be more willing to wear it at all times. Making the device more useful and beneficial to the user. With this device being target toward elderly who live alone, it is essential that the device be able to function correctly and continuously with accuracy reading. Since the device is measuring things such as heart disease, stroke, falls, and glucose the device will need to be worn at all times in case immediate care is needed and they are unable to call for help themselves. If the elderly wears the device while in a nursing home it will cut down the need to check on them constantly. The device will monitor their vitals and overall health; this is the reason the device need to be reliable, robust, and durable.

### 3.1.2 appearance/unobtrusiveness

a) Define

The device needs to be small and compact to fit in someone pocket, small purse, or handbag. The device needs to be able to be worn with everyday attire and not look out of place. The device needs to be discreet not to cause attention to it from others around the user. The device needs to be unobtrusive and not get in the way of everyday activities. The device needs to be comfortable enough that the user doesn't mind wearing it constantly. The device needs to be aesthetically pleasing to the user. The device also needs to be wearable not to cause any adverse reaction on the user skin. It needs to be comfortable and enduring. The device needs to be lightweight so that the user doesn't realize they are wearing it. With it being lightweight the user will not mind wearing and using the device for long periods of time.

b) Why

If the device is too bulky the user will not wear it because it will seem out of place. Also with the device being too bulky it can interfere with everyday activity. The more obtrusive the less likely the user is going to comply and wear it constantly. If the device is unaesthetically pleasing, the user may only wear it in the house or during the day when it is most convenient for them.

### 3.1.3 User information and scheduling

a) Define

The device needs to be able to take user input such as medical history, family health history, medical health such as: allergies, asthma, and medications information. The device needs to be able to be customized by the user, so the user and other personnel will know that it belongs to the user. The device needs to be able store information for the time and day the person needs to take their medication or do other medical need such as doctors appointment, and it should have an alarm to indicate these times and events.

b) Why

The reason it needs to have these specific requirements so if the user were to have a heart attack, rapid changing glucose levels, stroke, or falling/fainting, the health care provider will be able to pull up the medical history with ease and be able to treat the user more effectively. Also if the device has these specific requirements, it will be able to better monitor the user.

### 3.1.4 Communication

a) Define

The device needs to be able to continuously monitor the user even when the power is down, by using a back-up battery. It needs to be able to send and receive data to the base device wirelessly. The device needs to be able to receive and send messages to the user as well as the home base device continuously, no matter the environment or other factors that may prevent the signal from sending. The device needs to be able to continuously update the user location and time, no matter where they are located. It needs to be able to communicate with the user and home device when there is a problem or error with the actual device, and what the problem or error is so the person will know who to call to have it fixed. The device also needs to be able to send messages to the user from a health care provider, care giver, or relative. It also needs to be able to send messages from the user to a health care provider, care giver, or relative. The device communication needs to be wireless. It also needs to be Bluetooth capable and smart phone compatible, so that it can connect with any kind of system with no need for extra software.

b) Why

Being without power or other situations, the user could be in danger. If something were to happen during these times the device could alert someone the user needs help. The person will know to get in contact with the user to make sure they are okay and if they don't receive a message back they will know that the user is in need of help. If the communication is wireless and smart phone compatible, other people who have access to secure network can also monitor the user from remote locations. The user will know that a person is checking in on them because the device will send the user a message when someone logs onto their account.

### 3.1.5 Zero maintenance and fault recovery

a) Define

The device should need little to no maintenance. The user should be able to wear the device continuously without any problems. The device should have an extended battery life along with an extended back up battery. The only maintenance that the device should need is for cleaning because of everyday wear and damage. Also the device would need occasional software updates but this should be as simple as plugging it into the home base and letting it update on its own automatically. The device should be able to fix most of its own errors by restarting itself. The system can be recharged through USB by plugging it in the user's computer or using wall charger. The battery life of the system will be able to last 5 - 10 years of continuous use.

b) Why

The reason the device needs to have zero to no maintenance because the primary users will be 60 and older. It will make the device more users friendly and make the user more willing to wear it and use the device constantly. If the device is able to fix its own problems it will save on resources such as time and money to get someone to come out and fix the device. It will save on the user time trying to figure out the problem.

## 3.2 Measure and parameters

Certain vitals need to be monitored and detected in each of these events. Some vitals will be used to determine multiple events.

### 3.2.1 Heart disease

Heart disease is one of the main causes of death in the elderly each year. If it can be detected early enough or in the midst of the disease, many lives can be saved and prolonged. To detect symptoms of heart diseases, such as heart failure or a heart attack there are three main things that needs to be detected and monitored. The first of these is the heart rate/pulse to see if it is below or above the normal range. The second is the blood pressure to make sure that it is not to low or too high, which can cause other problems as well. Lastly is the blood flow to make sure the person is getting enough blood throughout their body, especially to and from the heart.

- Heart rate/ Pulse

  The device needs to be able to detect the heart beat to ensure that it is in a reasonable range. If the heart beat is to fast or too slow the device knows to alert someone. To prevent false alarms if the person is doing extraneous exercise or sleeping, there will be a place to input changes in activity or other information. For instant the person is 65 and goes for a run the watch knows that if the heart rate increases it doesn’t have to send a warning, but if they are exercising and all of a sudden collapse and the heart rate drops suddenly it knows to send an alert to someone.

- Blood Pressure

  The device needs to be able to make sure that the person blood pressure stays in the normal range for their age. Blood pressure is the contributing factor to many diseases. If Blood pressure gets too high or low it adds to the cause of having a heart attack, stroke, fainting, or diabetic coma.

- Blood Flow

  The device will need to be able to detect if the blood flow is normal. If the blood flow is too slow it means the body is not getting enough oxygen, which could cause someone to pass out. Also if it is too slow it could mean that something is obstructing its flow, such as a blood clot. If the blood flow is restricted, it can cause a heart attack or stroke.

**Other things to detect for heart disease**

- Time elapsed since last normal heart beat

  The device needs to detect and record the time of the last normal heart beat. This can be used in cases where they need to know how much time before the person becomes brain dead or how long the person heart stopped. So medical personnel can know what the person was doing when their heart stopped.

- Breathing

  The device would need to detect if the person is breathing normally; if there is an obstruction that occurred to hinder their breathing; if the person is breathing too fast from things such as hyperventilating, anxiety attack or other causes. If the person starts breathing abnormal or stops breathing the device can detect and record the time and what they were doing when the instance occurred.

- Oxygen levels

  The device will need to detect the oxygen level to make sure the person is getting enough oxygen. When a person is having a heart issues their oxygen level drops because the heart is not pumping correctly. This means that the oxygen rich blood is not getting pumped throughout the body.

- Units of measurement for the parameters for heart disease
  Pulse: BPM Beats per minute (Normal) 60-100
  Blood Pressure: mm Hg
  Systolic (top) below 120
  Diastolic (below) below 80
  Blood flow: velocity
  Aorta: 40cm/s
  Oxygen level: %

### 3.2.2 Falling/fainting

Elderly falling is another main cause of death in the elderly and it is also the main reason elderly are placed in living assisted home and 24 hour nursing care. The device would have to detect that a person has falling or passed out, which can be done by detecting their pulse, blood flow, and oxygen levels. The device would be able to alerts someone that the person is passed out and needs help. In case the person has falling and is not unconscious the person would be able to press a button to alert someone they need help.

- Motion/ Motionless
  The device will need to be able to detect that the person is moving and how they are moving. It needs to be able to detect if the movement of the person is unusual; if so send an alert to someone. It needs to be able to detect involuntary movements; for instance if the person is having a seizure, excessive twitching, spasms, Syncope, Tics, and Tremors. This way the device could possible detect things such as movement disorder, Parkinson’s disease, Cerebral palsy, and Tardive dyskinesia in an early stage, so that they can be prolonged.

- Position and orientation

  The device needs to be able to not just detect how the person is moving but where the person is located. Their orientation are lying, standing, bending, or sitting. Their locations are they in the living room, kitchen, bathroom, etc. So if they are lying down in the kitchen or bathroom the device will detect that something is wrong and the person requires medical care.

- Oxygen levels

  The oxygen level for falling/fainting will need to be detected for similar reasons as heart disease. The device will need to detect the oxygen level to make sure the person is getting enough oxygen. When a person falls their oxygen level drops because the heart is not pumping correctly and this means that the oxygen rich blood is not getting pumped throughout the body. Also with fainting the pulse becomes very faint and weak and in some instances there is no pulse. The medical team will need to know all this information before they get the scene so they know what to bring and what to work on once they get on the scene.

**Other things to detect for falling/fainting**

- Time elapsed since stopped moving

  The device needs to detect the time and place when the person stopped moving. It also needs to detect how long the person has been motionless and what they were doing before they became motionless. This is so the medical team can better assist the person.

- Breathing

  Depending on if the person falls or faint their breathing is different. The device needs to be able to detect both and it also needs to be able to detect the different between the two. It needs to be able to detect if the breathing is shallow or heavy. The device needs to be able to detect the difference between normal, abnormal, and lack of breathing.

- Units of measurement for the parameters for falling

Position and Orientation: Angular, Linear, and rotary. Displacement

Angular: up 90 degrees

Rotary: up to 360 degrees

Displacement: m

Linear: m

Velocity: m/s

Oxygen level: %

### 3.2.3 Body temperature

The device needs to be able to able to maintain continuous monitoring of the body's temperature in case it gets too high or low. The device needs to be able to withstand extreme temperatures and conditions and still be able to function correctly. The device needs to still be able to distinguish between that of the person's body temperature and other temperatures around the body in all environments and conditions.

- **Unit of measurement for the parameters for temperature**

  Celsius: degrees

  Fahrenheit: degrees

### 3.2.4 Stroke

Strokes are a little harder to detect since it only has a few symptoms, these symptoms can also be associated with other common problems. For the device to be able to detect stroke directly three things will have to be detect droopy face, speech impediment, and weak or slumping arm. With the placement of the device this cannot be done, so an indirect approach will be taken. With the indirect approach the device can detect symptoms and affects associated with the disease and combine them to accuracy detect stroke. The indirect way will be to detect heart rate/ pulse, blood pressure, blow flow, oxygen level, breathing, and waveform. Since heart disease and strokes are closely related they have some of the same symptoms and effects on the body. Strokes can lead to heart disease and the same goes for heart disease, it can lead to a stroke. The added symptom the device needs to be able to detect is waveform. When a person is having a stroke the blood flow changes a certain way causing the waveform to change. A person having a stroke has a distinguish waveform. It can only be seen under infrared level wavelength, which is not visible by the human eye.

- Waveform
  The device needs to be able to detect the change in waveform before the stroke become fully on-set and send an alert to the user, relative, or neighbor that the user needs medical attention. The device needs to detect the waveform while it is in changing form. The device needs to tell the different in waveforms and alert medical assistance for the user.

**Unit of measurement for the parameters for stroke**

Waveform: amplitude, hertz (Hz)

Wavelength: 800 to 1000nm penetrates to a depth of about 40mm and deeper

Pulse: BPM Beats per minute (Normal 60-100)

Blood Pressure: mm Hg

Systolic (top) below 120

Diastolic (below) below 80

Blood flow: velocity

Aorta: 40cm/s

Oxygen level: %

### 3.2.5 Glucose Levels

Sugar level is another disease that is hard to measure directly because most methods are invasive. It’s hard to measure sugars levels though a device because drawing blood is still the most accurate. To measure change in glucose level a near infrared spectrum will be used. The device needs to alert the user that it is time to take their medication and how much they need to take. It needs to alert them it's time to eat or exercise. The device will also have a place to input data such as what food they are eating and how much, how much exercise they are doing, or are going to do, so the device knows how much insulin the person needs to administer.

- Waveform
  The device needs to be able to detect the change in waveform on the near infrared level. A light will be shown on a desired area of the forearm. The device will need to detect the amount of light that is send back to determine is the blood sugar is too high or too low.

## 3.3 Interviews

Two interviews were conducted to better understand the needs for a device to help aid the elderly to age in place. The first interview was conduct with Phyllis Peachy a 71 year old lady that lives in the Blacksburg Virginia. The second interview was conducted with Julia Beamish and Eunju Hwang two professors who work at Virginia Tech.

### 3.3.1 Phyllis Peachy

To enhance this research project an interview was conducted with Phyllis Peachy a 71 year old lady. She has been confined to a wheelchair for the past 15 years from breaking her leg and never quite recovered; so a family member moved in with her to help with everyday living. A couple years ago she received a grant to remodel her home. She said "one of the biggest problems I faced was reaching the top and back cabinets, since I am wheelchair bound". "Another problem I had was taking a shower like a normal person without help form family member". Lastly she stated that just moving around in the yard was a challenge, she owned several animals and their leash would get caught in the wheels of the wheelchair causing her not to be able to move. She said "once I got stuck like that for several minutes until a neighbor and the mailman assisted me". She said "it wasn’t an emergency but I would like to have something that could alert someone I need help, but that is not immediate”. To help her live life easier and allow her house to be more accessible, the grant that she received helped her to add four draws that pull out in her kitchen to store things that would usually be stored in the top or back cabinets. Her bathroom was remodel to make the shower wheelchair accessible and have safety handles for her to grab. The toilet was also made handicap accessible. Her washer and dryer were moved up stairs. She said “these things needed to be done because they are an everyday needs”. She was very excited about the device concept saying “it would be very helpful and useful”. She stated the two biggest challenges that the elderly face when buying a device is the limitation to the networking range and the cost of being locked in a contract if something were to happen to her. “I don’t want my family to have to pay for something I’m not using” The limitation to the networking range includes having to be near the home base for the device to work properly. She said that even working in a yard is a hindrance because it’s too far from the home base. She would like to be able to go to the store or other places and the device still is able to detect her motion and vitals. She also liked the fact that the device would be wireless and unobtrusive. She was also excited about the fact that the device was non-invasive; she was stating that if the device was invasive, it would be an invasion of privacy to the user. She also liked the fact that the device could be worn on the wrist and also be about to get wet and still work properly. She stated several time that having the device be affordable and not contract based made the device more appealing, she didn’t like that fact that with some devices the families would get struck with the cost after the user no long used the device because the contract hadn’t ended. She also said “that this device would be very useful for the baby boomer era that is getting up in age”. She stated “some people are not as fortune as me and need to be monitored closely”. She said “many of my family have some of the same diseases that the device would be monitoring”. She stated that her daughter had had a stroke 10 years prior and another person had rapid changing glucose levels. She said “my family has been pushing me to get something that could monitor me but I’ve done tons of research and nothing had appealed to me until this device”. She also like that the device would continuously monitor the users vitals and that approved people could check in on the user to make sure they were okay. She was really excited about all the possibilities that the device could do and all the components that it would incorporate. She said " I take medicine and a device that could remind me to do so would be a good idea". She said that it is even good that the device could monitor her vital continuously because even though she is healthy now she never knows she might need it in the future. Right now she is more worried about falling risks for being in a wheelchair. She said to keep her posted on the progress of the device and would love to have one when it actual become available

### 3.3.2 Julia Beamish and Eunju Hwang

To enhance this research project from the academic side an interview was conducted with Dr. Julia Beamish and Dr. Eunju Hwang professors at Virginia Tech. They work with aging in place from the psychological stand point. They were very interested in the research of this project. The main things they were interested and concerned about were the ease of use of the product for the elderly; how would the elderly use the product, the cost of the device, and access range of the device. Since the elderly are older they wanted to know how easy it would be for them to use the device. She asked question like would they have to read a book of instruction or would it be as easy as putting it on and using it. The device is designed to be put on and used with no set up, but there will be instruction for how to input information, how to change setting, and other important information. The device is designed to be as user friendly as possible. The other question that was asked is how the elderly wear the device. The device is design to be used as a watch. The third major question was how much will the device cost. The device is designed to be cost effective for the elderly. The last question was what would be the range of the device. The device is designed to work anywhere. The home base device is small enough to fit in a pocket or purse to be carried. The research that the professors are working on is technologies to aid the elderly age in place. A kitchen was shown that students designed. It was designed to assist the elderly to be able to age in place better. The kitchen had pull down cabinet, a cutting board attached to the silverware draw. The dishwasher was wheelchair accessible. The counter tops were different colors and height from it surrounding, so that the elderly can feel and see the variance when gripping. The sinks were adjustable and the floors were wheelchair accessable. The cabinets were design to have pulled out draws for storage. The house was designed to be elderly friendly.

# Chapter 4 Sensors and Devices

## 4.1 Devices used in the medical field

Research was conduct to determine some devices that are used in other avenues. The devices where mainly used in the medical field. Other device found where devices that could be used a home.

### 4.1.1 Heart disease/ attack

#### a) Holter monitoring

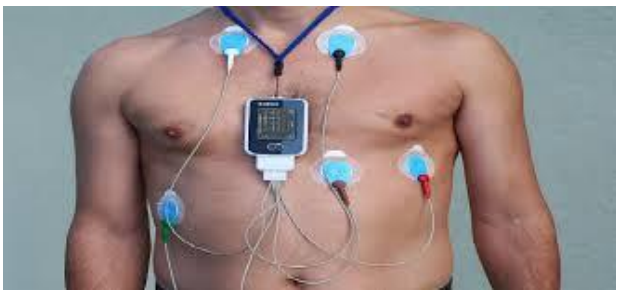


Figure 4.1: Chest holter monitor with a neck strap used to detect heart attack

[Online]. Available: http://directorsblog.nih.gov/2014/01/16/move-over-holter-heart-monitoring-in-the-mhealth-era/. [Accessed 9 September 2013] Used under fair use, 2014

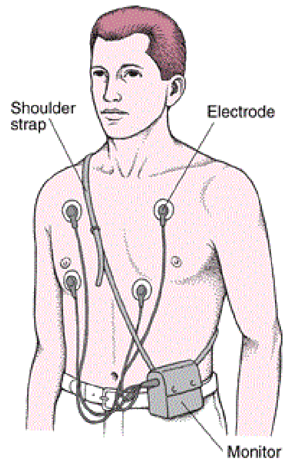



Figure 4.2: Belt Holter monitor

Merck Manual Home Health Handbook, edited by Robert Porter. Copyright 2013 by Merck Sharp & Dohme Corp., a subsidiary of Merck & Co, Inc, Whitehouse Station, NJ. Available at http://www.merckmanuals.com/home/. [Accessed 9 september 2013] Used with permission of Merick Manual, 2014

The Holter Monitoring is a 24 hour monitoring device that continuously records the heart rate. The user has to stick electrodes on their chest, which are connected to a monitor. The monitor can be carried in the pocket, worn around the neck, or wrist. The monitor power source is a battery.

b) Reliability

The device is very reliable, if it kept close to the body. The electrodes can become loose and fall off while wearing them. The device can be worn after a heart attack, after starting a new heart medication, and to diagnose heart problems. It can diagnose most heart issues. It can tell if a new medication is working and how well it is working.

c) Pros

The device can detect atrial fibrillation, flutter, palpitation, fainting problems, slow heart rate, ventricular tachycardia, multifocal atrial tachycardia, and paroxysmal supraventricular tachycardia. The device can detect abnormal heart problem such as if the heart is not getting enough oxygen. It can also detect blockage or if there is a delay in the heart beat.

d) Cons

The device can’t get wet and it has to be kept close to the body. When wearing the device the user has to keep away from things like: electric blankets, magnets, metal detectors, and high voltages areas. The user is not allowed to bathe while wearing the device and the device provides some discomfort if worn while sleeping. The device is very inconvenient to wear. The user has to keep a diary of everyday activities, and it has to be a detail diary for the doctor to be able to accurately determine the problem. The device is attached to the user using adhesive tape.

## a) VENDYS

Figure 4.3: VENDY device with home based device used to detect heart using a cuff and home base

[Online]. Available: http://www.endothelix.com/. [Accessed 9 September 2013] Used under fair use, 2014

The Vendys is a device that uses a cuff occlusion to measure heart disease. The device also measure how blood flow affects finger temperature. The way the device works, is it takes the user blood pressure using a blood pressure machine. The cuff is then placed on the left arm, for 5 minutes, during this time the blood circulation is decreased. Once the cuff is removed the blood releases back into the right fingertip, where the temperature clip is placed. The temperature change in the finger is directly related to vascular reactivity. Firstly, the device test to see if the users need further testing. It also, test to see if the user needs to start treatment or if they user needs further treatment. Secondly, the device tests to see if the user vascular is functioning correctly. Lastly, after the user has received or begun treatment they device is used to test if the treatment given is working effectively.

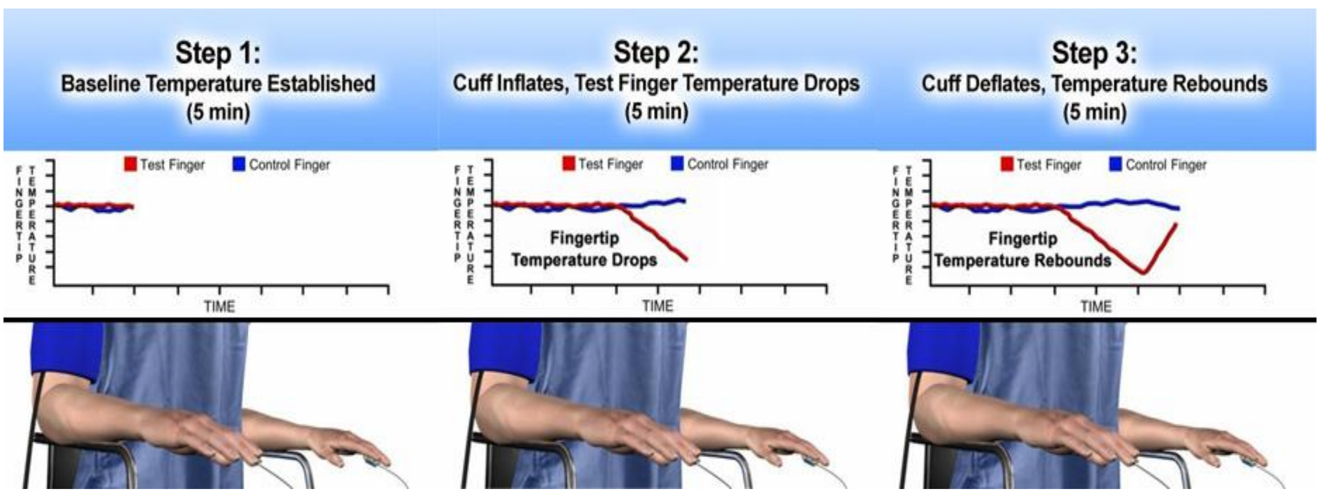



Figure 4.4: How the VENDY system is setup and calibrated

[Online]. Available: http://www.endothelix.com/. [Accessed 9 September 2013] Used under fair use, 2014

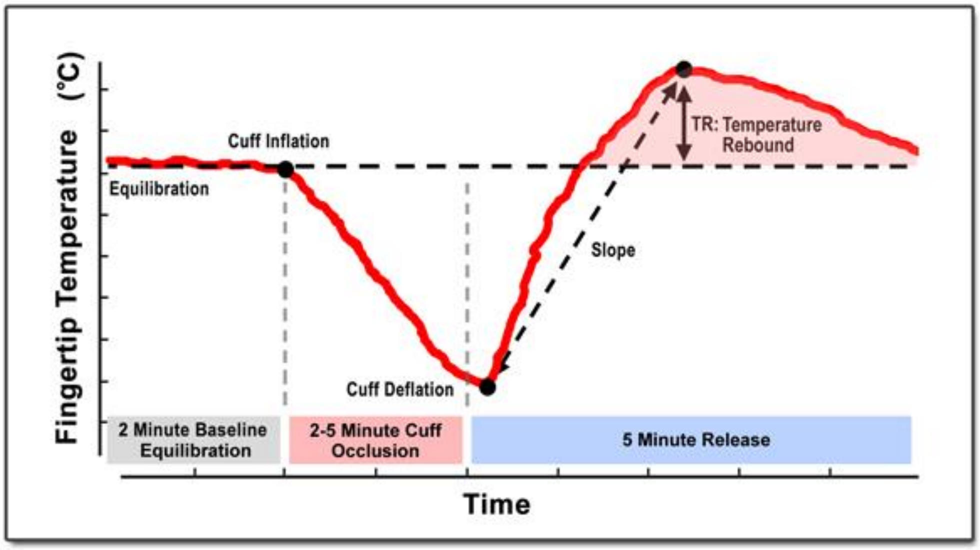



Figure 4.5: Test performed by the VENDY system

[Online]. Available: http://www.endothelix.com/. [Accessed 9 September 2013] Used under fair use, 2014

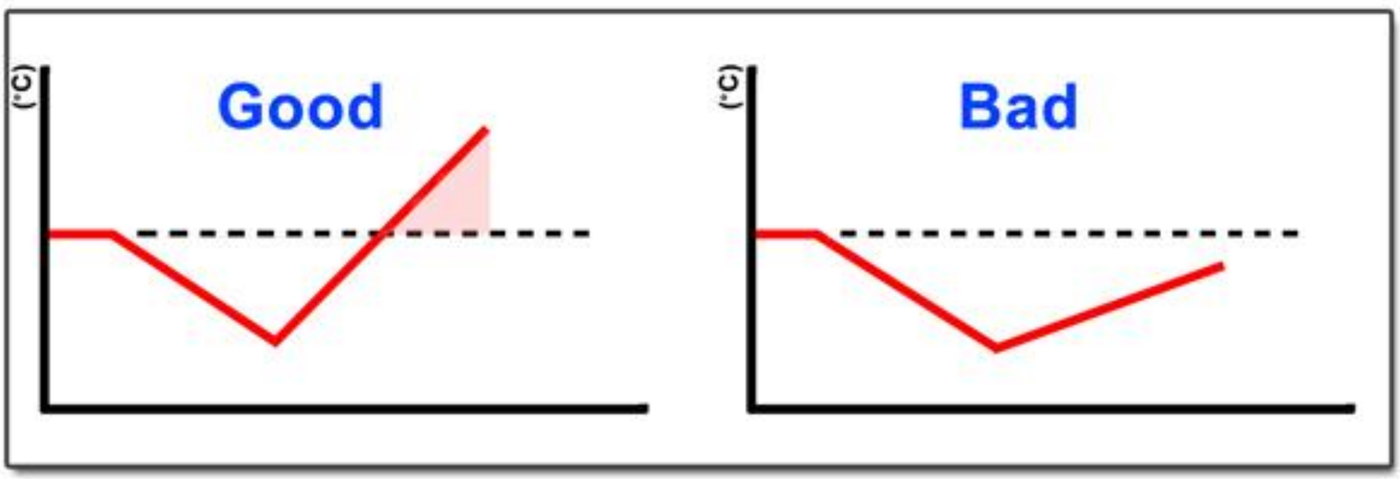



Figure 4.6: The higher the temperature rebound (TR), the better the vascular reactivity

[Online]. Available: http://www.endothelix.com/. [Accessed 9 September 2013] Used under fair use, 2014

b) Reliability

The test is very reliable. It is recommended to be used on patients because of its quickness and the changes can be seen in the cardiovascular system once a treatment is given.

c) Pros

The Vendys test is very fast and accurate and it takes about 15 minutes to complete the whole test. It poses minimal to no risks to the patient. The results are reliable. It recommended for people with vascular problems or receiving a new treatment that has to do with vascular disease.

d) Cons

There are some down falls to the system. One major drawback is that the user has to go to the doctor's office to get the test done. It doesn't monitor the patient continuously it's only a one time test for about 5 minutes. Also the devices used is very huge and it not portable. The device has to be connected to two places on the patient, the arm and the finger. They are a bunch of wires and it is not user friendly. Some patients experience mild skin bruising where the cuffs were placed. Other patients experience excessive pain and discomfort. If another test is performed they have to be performed at least 30 minutes apart.

### 4.1.2 Falling/ Fainting

#### a) myHalo

myHalo is a 24 hour falling monitoring system that monitors the user's heart rate and temperature. The device is worn 23hours, with a 1 hour charging period. It alerts someone that the patient has falling and needs assistance. It also allows family or other approved personnel to check on the user through a secure website. The device is wireless and when the person falls there is no button to press the alert is automatic. It cost 49 dollars a month for the chip. The chip doesn't monitor temperate or heart rate and it can't get wet. It doesn't notify someone if the device is not worn and can't be worn 24/7. The myHalo complete with everything cost 59 dollar a month and monitors temperature, heart rate, and can be worn in the shower.


Figure 4.7: How myHalo works and communicates when an alert is signaled [Online]. Available: http://www.lasplash.com/publish/LifesJourney/cat_index_golden_years/myHalo_Monitoring_Device_Review_Automatic_Fall_Detection.php. [Accessed 9 September 2013] Used under fair use, 2014

Figure 4.8: myHalo monitoring and home base device used to detect a fall [Online]. Available: http://www.lasplash.com/publish/LifesJourney/cat_index_golden_years/myHalo_Monitoring_Device_Review_Automatic_Fall_Detection.php. [Accessed 9 September 2013] Used under fair use, 2014

b) Reliability

The device is very reliable and accuracy with GPS tracking and 24 hour monitoring system. The device has a secure website and medical alert system. The alerts are fast and the alert is sent to the nearest medical assistant.

c) Pros

The device has wireless cellular technology. It has GPS tracking and easily mapping for medical personnel. The device has a personal identification, so the person's information is known by medical team sent to assist them. The medical history of the user is also known. The device is comfortable and lightweight. It can be worn around the neck or on a belt buckle. The device is water proof (myHalo complete). The device has an 18 month battery life. The button can be pressed any time for emergency assistance to be sent.

d) Cons

The downside to the system is the charging time and the monthly fees. Everything is not included in the service unless the myHalo complete is purchased. The myHalo chip can't be worn 24 hour or in the shower. It doesn't notify if the user is not wearing it.

## a) Life Call

LifeCall is a wireless medical system used in an event of a fall or pressing a button for other emergencies. LifeCall can be worn 24 hours a day and can be worn in the shower. It has a two way communicating unit from the user to the company and from the company to the user. The device can be worn on a bracelet, pendant, or belt clip. The way the LifeCall works is that once the button is pressed a signal is sent to the operators at the medical center. Once the operator receives the signal, they can communicate to the user through the voice communicator, to see what kind of help is need. Once the type of help is determined, appropriate help is sent; rather this is a friend, family member, neighbor, or emergency services. If the device detects a fall the operator automatically send for help.

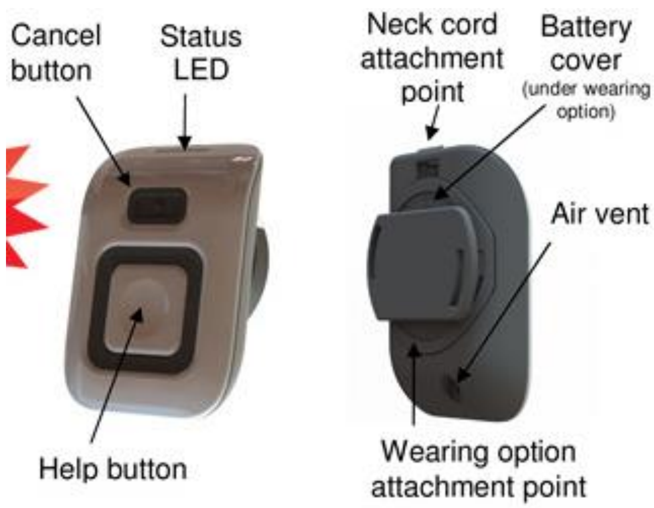



Figure 4.9: Lifecall medical device and its components used to detect and monitor falls [Online]. Available: http://www.lifecall.ca/. [Accessed 9 September 2013] Used with permission of Shirley Wilson, 2014

b) Reliability

The system is mostly reliable, although it can produce false positives. If the device gets too overheated or too moist it can stop working, and the user may have to get a whole new system put into place. If the device is hooked-up over the internet it can have security problems, if it is not set up properly or the user doesn't get a special type of installation.

c) Pros

The device is waterproof. The device sends automatic alerts to the monitoring center. There is a flashing LED and beeping signal to indicate that the alert was triggered. There is a button to cancel the alarm if the signal was false. There is a time delay to allow the user time to get up if it was a false alarm. The battery is replaceable. There is 24 hour monitoring with the device. You can push the button also if there is an emergency that is not related to falling. The device has a 5 year battery life. If the power goes out it has a 24 hour backup battery.

d) Cons

The system needs to be tested monthly by sending a test signal to the emergency center. The system works through a landline, if the person doesn't have a landline it need a special type of installation. The device can't get too hot or humidity or it will fail to work. The system can only be transferred to a new resident or alternate resident if the user calls the company and have them relocate the system. If the user doesn't want to go through all that is necessary for relocating, a note will be placed on the users account.

### 4.1.3 Stroke

#### a) BPro

BPro is a device that measure pulse wave acquisition using modified applanation tonometry. Using this technology it captures reliable and accurate real time reading for the arterial pulse waves. It measures disease such as hypertension, issues similar to hypertension, or have a relation to hypertension. The device measure blood pressure 24 hour continuously and displays the blood pressure patterns. The device identifies fluctuation in the blood pressure; it also identifies blood pressure drops during the night. The device assists with hypertensive condition and also allows for better treatment of the disease.


Figure 4.10: BPro medical device and its components used to monitor and detect stroke
[Online]. Available: http://www.healthstats.com/index3.php?page=homepage. [Accessed 9 September 2013] Used under fair use, 2014

Figure 4.11: BPro isometric view
[Online]. Available: http://www.healthstats.com/index3.php?page=homepage. [Accessed 9 September 2013] Used under fair use, 2014

b) Reliability

The device has ±5% accuracy for heart rate ranging between 40-180 beats per minute. Its pressure accuracy is between ±3mmHg with a range between 0-300mmHg. The operating humidity accuracy is <95% on the right hand with a range of 80-105kPa. The storage and transport humidity accuracy is <95% on the right hand with a range of -20-55˚C. The device is accurate and reliable enough to receive FDA approval from the USA, CE medical certification form Europe, and ESH certification from European Society of Hypertension.

c) Pros

The device is non-invasive and measures the blood pressure continuously. The user doesn’t even realize when that their blood pressure is being taken. With other software, the device can measure other bodily indicators such as heart rate, arterial pressure, and pulse. It measures these things in real time. It doesn’t interfere with daily activities or sleeping. It predicts heart attacks and strokes. The device is lightweight and comfortable. The device is a wrist worn device. It can also be used with IOS systems and if the user doesn’t have an IOS system they can download an app.

d) Cons

The pressure sensors are very sensitive. The device might not work properly, if the device is not secure enough or in the exactly right place. The user has to hold their arm perpendicular to the floor and at the heart level, when doing the initial reading. Blood pressure readings differ extremely depending on where the reading is taken; readings at the wrist are higher versus at the arm. The app has trouble receiving and sending data and sometime won’t turn on until it receives a correct reading. The device only works with IOS system or android devices. If the user wants to measure blood pressure without using the app the person has to turn on the offline mode on the device. The device can only be charged using a USB port.

### 4.1.4 Glucose Levels

#### a.) Grove

The Grove instrument optical bridge technology uses near infrared spectroscopy to measure the user's glucose levels. The device measures the user blood sugar in real time and it only takes 20 second. The device is non-invasive and design to be used on the earlobe or fingertip. The device uses a unique technology to get the device to work properly in the near-infrared spectroscopy.  The device doesn't take the glucose reading from interstitial fluid like other non-invasive device, it take its readings directly from the blood.

Figure 4.12: Grove medical device used to check blood sugar using the ear or fingertip
D. Pogrelc, "Bloodless glucometer uses light to check blood sugar in 20 seconds or less," MEDCITY, 28 June 2012. [Online]. Available: http://medcitynews.com/2012/06/bloodless-glucometer-uses-light-to-check-blood-sugar-in-20-seconds-or-less/. [Accessed 9 September 2013] Used under fair use, 2014

b.) Reliability

The device meets the ISO 15197 standards for accuracy. The device was tested against other on the market devices that are widely used. The device produced very accurate reading and was able to collect 4000 data pairs and able to stand-up against other devices.

c.) Pros

The device gives glucose readings in real time. The device is non-invasive. The device is waterproof and fast. The device doesn't have low signal-to-noise ratio problems. The device doesn't require a needle to pricking the user, so the device is painless and cleaner.

d.) Cons

The device is battery operated. The device doesn't monitor glucose continuously. The device is designed to be used on the ear or fingertip. The Mean Absolute Relative Difference (MARD) percentage can be off, which can limit the product. MARD is the percent between the false positives and false alarms.

## a) Sleep Well (concept)

Sleep Well is a device designed to be worn at night to monitor kid's blood glucose. The device is wireless and transmits a signal back to the monitor that can be carried from the device, so that someone can monitor the user blood glucose while they are sleep. There is an alert attached to the monitor, so the observer can be alerted if the user blood sugar spikes or drops.


Figure 4.13: Sleep Well conceptual medical device used to check blood sugar in kids

[Online]. Available: http://www.diabetesmine.com/2011/04/sleep-well-a-diabetes-design-concept-gone-viral.html. [Accessed 9 September 2013] Used under fair use, 2014


Figure 4.14: Sleep Well and it charging center also used as a screen monitor for parents [Online]. Available: http://www.diabetesmine.com/2011/04/sleep-well-a-diabetes-design-concept-gone-viral.html. [Accessed 9 September 2013] Used under fair use, 2014

b) Reliability

Hasn't been tested yet

c) Pros

The observer can review the user status throughout the night through the data that is stored on the home device. The data can be pulled up on the monitor or the observer's computer. When the alert is sound, the monitor displays what type of emergency care is needed.

d) Cons

It is designed to only be worn at night.

### a) Pancreum Vigil system

The Pancreum vigil device reads glucose level every 4 minutes. The device can record up to 1080 readings in a given three day period. The sensor measures glucose in the interstitial fluid found between the body cells. The glucose level is displayed on the device's screen. The user can set up alerts for danger zones. The device stores the data and can display graphs and trends in the person glucose levels. The user can see the data on the device or computer. The device has four main parts. The GlucoWedge, which is the CGM sensor; the BetaWedge, which is the wireless insulin pump; the AlphaWedge, which is the software that controls the device and the actual controller.

Figure 4.15: Pancreum Vigil device used to check blood sugar

[Online]. Available: http://pancreum.com/glu.html. [Accessed 9 September 2013] Used with permission of *Guilherme 'Gil' de Paula* , 2014

b) Reliability

The device is very accurate it has an intelligent filter. The glucose readings are measured in real time, every 4 minutes. The results are very constant and accurate. The device has a fast response time, if the blood sugar were to spike too high or drops too low. The user can set alarms and alerts to go off if their blood glucose is not between the given levels they desire.

c) Pros

The device is small and compact it can be stored. The device can last 7 days without having to recharge it. It checks glucose level every 4 minutes and records for three day and up to 1080 readings continuously before the strips has to be replaced. The device is wireless and communicates through Bluetooth technology.

The device is designed to be used for people who have type 1 and 2 diabetes. Users can set their only alarms and alerts, depending on what level the blood glucose level needs to stay.

d) Cons

The user has to calibrate the device twice a day, every 12 hours. It is only rechargeable by USB. The user has to change the pump after 3 days

## 4.2 Sensors that detect these events

There are other sensors that can detect the four life threaten events. These sensors are the initial choice for the conceptual design of the device. Most of the sensors chosen were discarded because of the complexity of the sensor and the work it would take when actually building the device. Many of the sensors original chosen would have been difficult to integrate into one standalone system. Another reason why these sensors were discarded was because many of them were not user friendly. Also trying to retrieving data from the chips would be difficult as well as trying to program the chips.

### 4.2.1 Body Motion sensors – falling/ fainting

The 3-Axis Gyro/Accelerometer IC - MPU-6050 is a sensor that detects motion. It is a MEM 3 axis gyroscope and a 3-axis accelerometer combined on one chip. The chip also has Digital Motion Processor (DMP); the DMP can process up to 9-axis motion fusion algorithms. This chip can be used to see how fast something is moving in the X, Y, and Z with the accelerometer. The Gyroscope can be used to tell where objects are located in the X, Y, and Z. By combining the two motions, the chip can tell which way the person fell and how fast. Also by combining the two motions the acceleration can sometimes have a little lag, with the gyroscope it makes up for this issue. The acceleration and gyroscope motions balance each other out when they are combined.

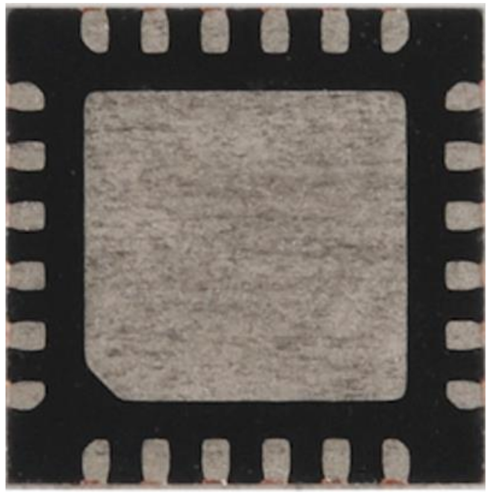


Figure 4.16: 3 Axis Gryo/Accelometer pins
[Online]. Available: http://www.invensense.com/mems/gyro/mpu6050.html. [Accessed 9 September 2013] Used with permission of David Almoslino, 2014

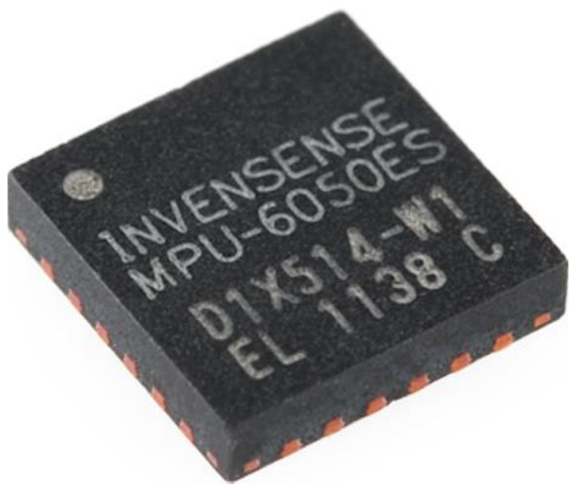



Figure 4.17: 3 Axis Gryo/Accelometer sensor chip
[Online]. Available: http://www.invensense.com/mems/gyro/mpu6050.html. [Accessed 9 September 2013] Used with permission of David Almoslino, 2014

### 4.2.2 Heart Disease

The AFE4400 is an integrated analog front end (AFE) chip. This chip can be used for a heart rate monitors and a pulse oximetry at a very low cost. The chip has a low noise receiver channel combined with an analog-to-digital convert. It also has a LED transmit and LED fault detection. Another important feature this chip has is the user can program a timing system. This can come in handy if the user needs to count the number of heart beat in a given time frame. This will help in calculating if the heart beat is function correctly or if it’s doing something abnormal. Lastly the chip has an operating temperature range of 0˚C to 70˚C which is a good range for what the chip needs to do.


Figure 4.18: AFE4400heart chip
[Online]. Available: http://www.ti.com/product/afe4490. [Accessed 9 September 2013] Used with permission of ti, 2014 Photo courtesy of Texas Instrument, 2014


Figure 4.19: AFFE4400 heart chip uses inside of a homemade built heart monitoring device
[Online]. Available: http://www.ti.com/product/afe4490. [Accessed 9 September 2013] Used with permission of ti, 2014 Photo courtesy of Texas Instrument, 2014

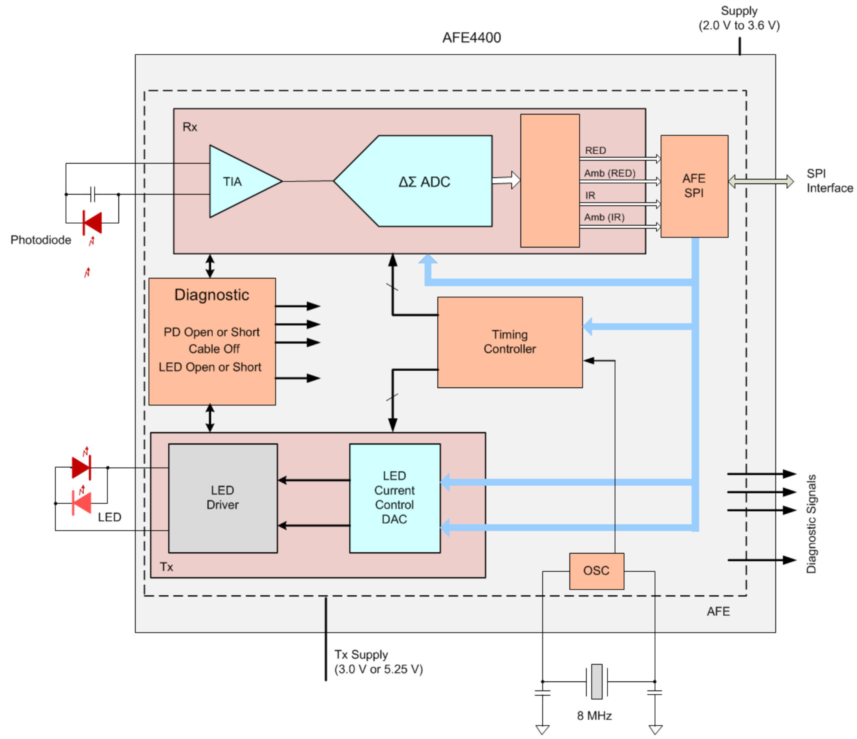


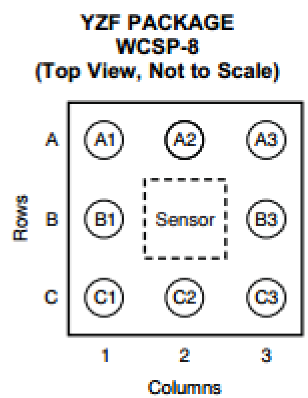

Figure 4.20: AFFE4400 internal setup
[Online]. Available: http://www.ti.com/product/afe4490. [Accessed 9 September 2013] Used with permission of ti, 2014   Photo courtesy of Texas Instrument, 2014

### 4.2.3 Temperature sensor

The TMP006 is infrared thermopile sensor chip that can measure the temperature of an object without make direct contact with the surface of object. The chip absorbs the infrared energy emitted from the object and uses a thermopile to get the correct temperature. How this work is the thermopile is one voltage to begin with then it moves over the object of the temperature that is being calculated, which causes a voltage change. The voltage change is what is calculated to get the correct temperature of the object. This is good because the chip would not be placed directly on the skin but inside the device, which is placed on the skin. Since this is an infrared chip the temperature range between -40˚C to 125˚C. This is more than enough for the application it is intended for. The chip is also low power consumption and low operating voltage. This is good, that once it connected inside the device, the battery won’t have to be charged or changed often.


Figure 4.21: TMP006 temperature chip
[Online]. Available: http://www.ti.com/product/tmp006. [Accessed 9 September 2013] Used with permission of ti, 2014 Photo courtesy of Texas Instrument, 2014

**PIN CONFIGURATION**




**PIN DESCRIPTIONS**

| PIN | NAME | DESCRIPTION |
|---|---|---|
| A1 | DGND | Digital ground |
| A2 | AGND | Analog ground |
| A3 | V+ | Positive supply (2.2 V to 5.5 V) |
| B1 | ADR1 | Address select pin |
| B3 | SCL | Serial clock line for SMBus, open-drain; requires a pull-up resistor to V+ |
| C1 | ADR0 | Address select pin |
| C2 | $\overline{\text{DRDY}}$ | Data ready, active low, open-drain; requires a pull-up resistor to V+ |
| C3 | SDA | Serial data line for SMBus, open-drain; requires a pull-up resistor to V+ |

Figure 4.22: TMP006 pin configuration and what each pin is design to do
[Online]. Available: http://www.ti.com/product/tmp006. [Accessed 9 September 2013] Used with permission of ti, 2014 Photo courtesy of Texas Instrument, 2014

### 4.2.4 Waveforms sensors/ blood flow – stroke

The CameraChip™ OmniPixel is a high performance 3.1 megapixel complementary metal oxide semiconductor (CMOS) CameraChip™. CMOS mean that it can do laser Doppler blood flow imaging, which is a technique that measure the total amount of local blood perfusion in the capillaries, arterioles, venules, and shunting vessels in the microcirculatory. The camera has 15 frames per second image array. You have to be able to get multiple pictures at a faster pace to be able to process the blood flow at a certain time. The camera chip has an image area of 3626 um X 2709 um, this area is big enough to ensure enough of the local blood perfusion is captured.

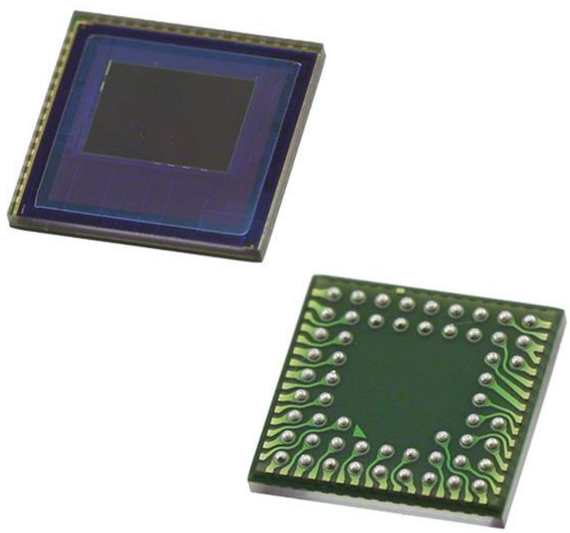


Figure 4.23: CameraChip™ OmniPixel sensor chip
[Online]. Available: http://www.ovt.com/uploads/parts/OV3640_PB(1.02)_web.pdf. [Accessed 9 Septemner 2013] Used under fair use, 2014

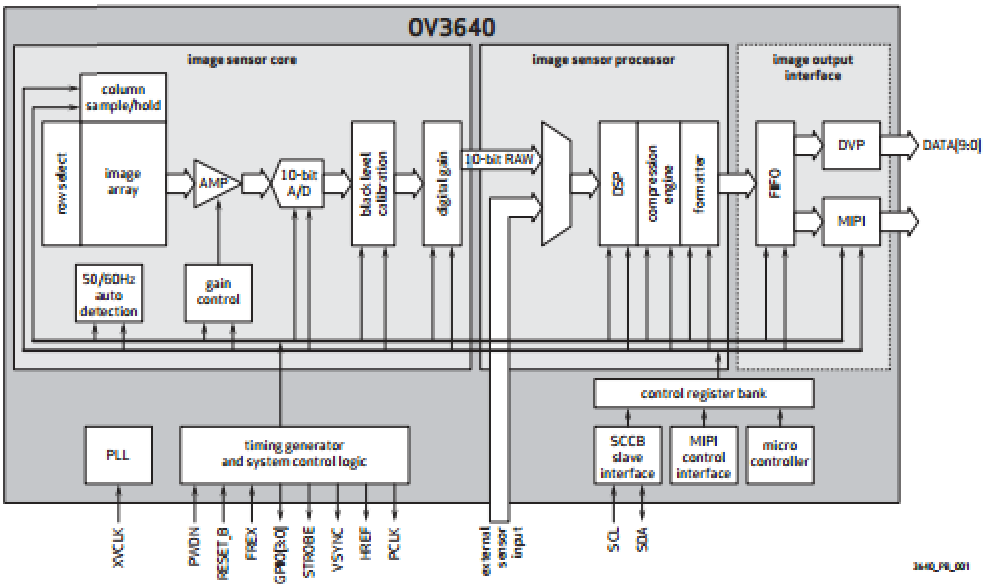



Figure 4.24: CameraChip$^{TM}$ OmniPixel internal setup
[Online]. Available: http://www.ovt.com/uploads/parts/OV3640_PB(1.02)_web.pdf. [Accessed 9 Septemner 2013] Used under fair use, 2014

### 4.2.5 Blood sugar sensors and temperature

The Near Infrared (NIR) camera captures visible and near- IR images at the same time though two individual channels. The reason for this camera is that the beam of light can penetrate the skin and measure the blood glucose level. It is not harmful or invasive and it is accurate. It reads the frequency and wavelength of the blood and tells if the blood sugar is low or high. The camera has high resolution and NIR sensitivity so it is capable of reading the glucose levels accuracy and is sensitive to the change in wavelength. This mean it will easily detect a slight change and be able to recognize earlier rather than later that something is wrong. The camera can capture 31 frames per second with full resolution and without full resolution it can capture up to 145 frames per second. This means that the data can be processed at a better and faster rate.

Figure 4.25: Near infrared camera
[Online]. Available: http://www.jai.com/en/products/nearinfrared. [Accessed 9 September 2013] Used under fair use, 2014

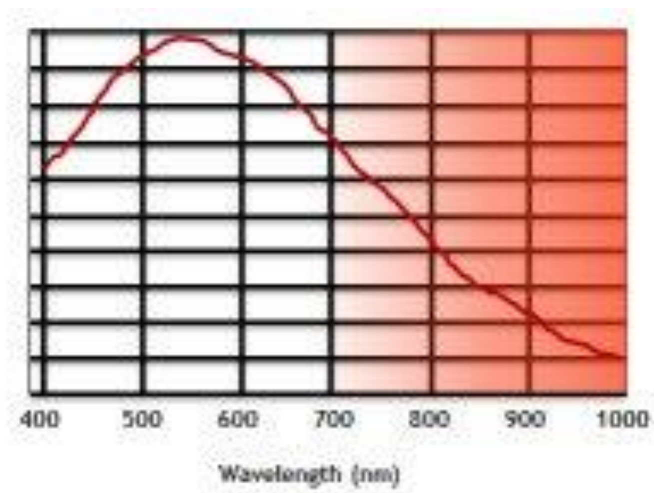



Figure 4.26: Near infrared camera wavelength visible range
[Online]. Available: http://www.jai.com/en/products/nearinfrared. [Accessed 9 September 2013] Used under fair use, 2014

# Chapter 5 Results

## 5.1 System architecture

After doing much research I found that four main areas heart disease, stroke, falling/fainting, and blood glucose are among that top rated disease that cause disability, incapability, and death in the elderly community as well as the world.  From these events it is important that a device is developed to monitor the elderly while in their homes to keep them safe and give them the ability to age in place better and longer. The device I proposal will be a wrist worn device that can monitoring, detect, and analyze the onset of heart disease, stroke, falling/fainting, and changes in glucose simultaneously as well as in real time. The device will have the ability for the user to set alarms for things such as time to take medication or doctor appointments.  The device will have the ability to notify the user, family member/ neighborhood, or medical personnel that the user is in danger and needs medical attention. The device will be able to give the medical personnel the user exact location, the type of illness, and the extent of the illness. The device will be water resistant, so the user can wear it in the shower or bath also it will be able to be worn 24 hour a day without the user noticing it. The device will be small compact, lightweight, long battery life, and portable with ease. It will be user friendly, non-irritating, fast, precise and accurate, and robust. The device will monitor, analyze, and process the data in real time. It will have the ability to store measurements for the user or medical personnel. The data will able to be stored on the base system and can be viewed through a secure network. This is so a family member or neighbor can check on the user without invading their personal privacy. Only the user will be able to give the network information to the people of their choosing. The device will also send an alert to the user when someone checks on them, so they can know when and who is checking on them. Other things that the device will be able to detect are the user's oxygen level, breathing, and body temperature to help determine what the person is doing. The device will have to differentiate between daily activity, extraneous activity, and when a life threating illness is occurring. This can be done by taking the measurements of all these threaten events and combine them to determine if something is wrong. For instance, say the person heart rate is high; their position is hunched over and barely moving; their body temperature is high; and their breathing is shallow it would be determined that they are having a heart attack. Whereas, if the heart rate is high, their position is upright and in a fast constant motion; their body temperature is high; and their breathing is fast the device would determine they are running or jogging. The device will communicate wirelessly to the home base and the secure network. The device will have bluetooth abilities to connect to other device that have this capability. The data can be stored and viewed through these devices. The wireless and secure network in the same manner that a cell phone works, it can work as long as nothing interrupts the signal it will send the information.

### 5.1.1 Heart Disease

For heart disease the device will monitor the pulse and blood flow. Below is a list of the follow ranges that the device will be set to, if more than one of these vitals are below or above the given range for a certain amount of time an alert and notification will be send to the appropriate people.

- Pulse: BPM Beats per minute
  Normal 60-100
- Blood Pressure: mm Hg
  Systolic (top) below 120
  Diastolic (below) below 80
- Blood flow: velocity
  Aorta 40cm/s
- Oxygen level %
- Temperature
  Celsius: degrees
  Fahrenheit: degrees

### 5.1.2Falling/Fainting

For falling/fainting the device will monitor the position, orientation, acceleration, and altitude of the user. The device will need to continuously monitor what the user is doing and how they are doing. If the user were to fall the device can alert someone the user needs help. The device will do this by measuring the criteria listed below. Also the device will time how long the user has been doing a certain activity, so that it doesn't send a false alarm. The device will need to know which room in the house the user is located, so it can send an alert when needed. For instance, if the person is lying down in the bed the device knows not to send an alert but if the person is motionless in the bathroom the device knows it needs to alert the correct people.

- Position and Orientation: Angular, Linear, and rotary. Displacement
- Angular: up 90 degrees
- Rotary: up to 360 degrees
- Displacement: m
- Linear: m
- Velocity: m/s
- Oxygen level %

### 5.1.3 Stroke

For stroke, the device will monitor the local blood perfusion in the capillaries, arterioles, venules, and shunting vessels in the microcirculatory using a beam of laser light that penetrates the skin. The Laser light beam is in the visible wavelength of 390nm – 750nm. To get a good view of the perfusion a wavelength with a range between 532nm – 800nm is desired. The waveform that the device will be detecting will be used for Laser Doppler Imaging (LDI). LDI is a technique that measures the total amount of local blood perfusion in the capillaries, arterioles, venules, and shunting vessels in the microcirculatory using a beam of laser light that penetrates the skin. The way the LDI works is that a laser light is direct to the area that is going to be test, some of the light distorts and some is absorbed by the tissue. The distorted light hits two different objects in the skin the dynamic blood cell and static objects such as tissue. The light causes the dynamic blood cells to change in wavelength and frequency, which is called a Doppler shift, and the static object remain the same. The change in wavelength and frequency determined the number of blood cells and velocity of blood cells in the measured area. The lack of blood allows more light to pass through and the deeper the light can penetrate the area. When a person is having a stroke the blood flow is restricted, this measurement can be used to determine if the person is having a stroke by the amount of light passing through the measured area. Combining this method along with blood pressure and BMP will help in determining if someone is having a stroke. The device will detect the changes that lead to a stroke. The device will combine this along with the criteria for heart disease to get a better reading and detection rate. Heart disease and stroke are closely related.

- Wavelength 390nm – 750nm
- Pulse: BPM Beats per minute
  Normal 60-100
- Blood Pressure: mm Hg
  Systolic (top) below 120
  Diastolic (below) below 80
- Blood flow: velocity
  Aorta 40cm/s
- Oxygen level %
- Temperature
  Celsius: degrees
  Fahrenheit: degrees

### 5.1.4 Glucose Levels

For Blood glucose the device will detect the change in wavelength in the infrared spectrum which is between 700nm - 1nm. The device needs to be able to detect the change in waveform on the near infrared level. A light will be shown on a desired area of the forearm. The light that is shown into the forearm some of the light will distort and some of the light will be absorbed by the tissue. The light will reflex a certain way depending on the way it interacts with different chemical components in the tissues. The light that is sent back will determine if the blood sugar is too high or too low based on the absorbance spectrum from the spectral signatures of tissue components: fat, water, protein, calcium, salt, phosphorous, and glucose. This is related to the blood vessel expanding and contracting. If the blood vessel is contacting or widen and how fast it's contracting or expanding is related how much tissue components are in the measured area. This is done by measuring how much infrared is sent back to the device once the light penetrates the skin. Below are the criteria vitals that will be monitored with an infrared signal to better detect a stroke.

- Wavelength IR 700 nm - 1 mm
- Pulse: BPM Beats per minute
  Normal 60-100
- Blood Pressure: mm Hg
  Systolic (top) below 120
  Diastolic (below) below 80
- Blood flow: velocity
  Aorta 40cm/s
- Oxygen level %
- Temperature
  Celsius: degrees
  Fahrenheit: degrees

## 5.2 Actual sensors chosen

The sensors that were actual chosen for the project will be discussed in this section. These sensors were chosen because of the ease of use they provide. The sensor can be integrated easily and can be programmed using arduino. Many of the sensors chosen are plug and play and don't requirement in-depth construction. Most important the sensor consisted of all the criteria needed to monitor and detect these events.

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### 5.2.1 Body Motion sensor

The Pololu AltlMU-10 v3 is an inertial measurement unit (IMU) and altimeter. This board has a build in gyroscope, accelerometer, magnetometer, and a digital barometer. The altimeter can be used to tell the altitude of an object at a given location and level. The gyroscope can be used to tell the orientation of an objects orientation with respect to an X, Y, and Z coordinate system. The accelerometer can be used to tell how fast an object is accelerating in a certain direction with respect to an X, Y, and Z coordinate system. The magnetometer can be used like a compass, it can tell if the person is turned, north, south, east, or west, etc. The barometer can be used to tell the air pressure. The board also has ten independent pressure, rotation, acceleration, and magnetic measurements. These measurements can be used to calculate the altitude as well as the absolute orientation. The reason for chosen this sensor versus others is that it is ease to work with. Also it can be more precise and accurate then similar products. When placed in the device it will be able to tell where the person is located, how fast they are moving, in what direction they are moving, at what altitude they are at and other information needed. Also this information will come in handy if the person wearing the device were to fall, the board would be able to tell what direction they fell in, how fast they fell, and how bad the fall. This will provide the emergency personnel with information such as; location, the orientation in which they fell, and other important information need to predict a fall. The barometer can be used to show the daily weather report, which can be a bonus feature. The board is able to output one 16-bit reading per axis for the gyroscope, accelerometer, and magnetometer. For the barometer it is able to output 24-bit pressure reading. The device is very accurate and precise, its sensitivity range is in an acceptable range for this application. For the gyroscope it has a sensitivity range of ±245, ±500, or ±2000°/s. For the accelerometer it has a range of ±2, ±4, ±6, ±8, or ±16 g. For the magnetometer it has a range of ±2, ±4, ±8, or ±12 gauss. For the barometer is has a range of 260 mbar to 1260 mbar (26 kPa to 126 kPa). The dimensions of the board are 1.0″ × 0.5

Figure 5.1: Pololu AltlMU-10 v3 chip
[Online]. Available: http://www.pololu.com/product/2469. [Accessed 9 September 2013] Used with permission of Derrill Hartley

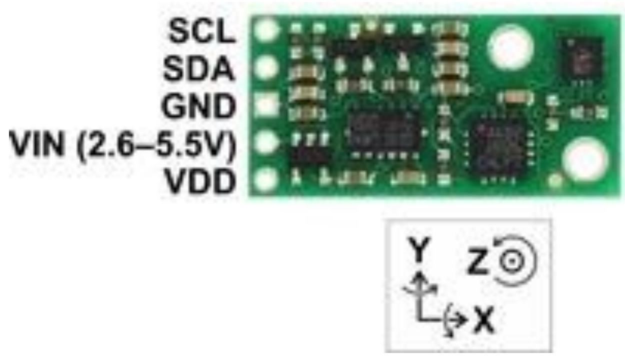


Figure 5.2: Pololu AltlMU-10 v3 and its coordinate system
[Online]. Available: http://www.pololu.com/product/2469. [Accessed 9 September 2013] Used with permission of Derrill Hartley, 2014

The way the IMU works is that it detects the acceleration of an object using an accelerometers and rotation with a gyroscope. The magnetometer helps with calibration for drift that the sensor gets from continuously measuring. It detects the change in the Pitch, Roll, and Yaw; using the accelerometers for change in position linearly and angularly and the gyro as a reference for absolute position angularly. Angular position measures the rotation of the object in space with respect to Pitch, Roll, and Yaw. Linear accelerometer measures all other acceleration of the object with respect to Pitch, Roll, and Yaw. From the acceleration velocity is calculated, which is used to determine the position of the object. When using an accelerometer and gyroscope alone the reading can be slightly off. To get the reading more accurate the measurements need to be filter through a complimentary filter, which is a high and low pass filter combined. Accelerometers are good for long term use but pick up on any and every forces that are being applied to it. Gyros are good for short term use but tend to drift with long term use. The complimentary tell the acceleration to ignore small or unnecessary force and only take in account the huge forces. For the gyro the complimentary filter fixes the drift problem.

### 5.2.2 Heart Disease

The sensor amped is a heart rate sensor. This sensor can get reliable pulse reading faster and easier. It can monitor and graph the pulse reading in real time. It comes with transparent stickers to prevent oily and sweaty fingering from interfering with the reading.  The sensor has a LED and light sensor. The light sensor shines into the skin to reads through to the capillary tissue. Once the light hits and gets a good reading on the capillary tissue the light bounces back to the sensor and gives the reading.  The light that hit the capillary is different than the sensor reads. The light changes based on fast or slow the pulse is beating. The LED on the back blinks to let the user knows when it has a good reading and the amount of time it blink indicate the number of times the pulse is beating. From the reading, the data that is sent back includes the heartbeat, pulse, heartbeat waveform, and time between heartbeats. This information can then be displayed for the user to see and analyze. The dimensions of the device are 0.625" Diameter and 0.125" Thick.

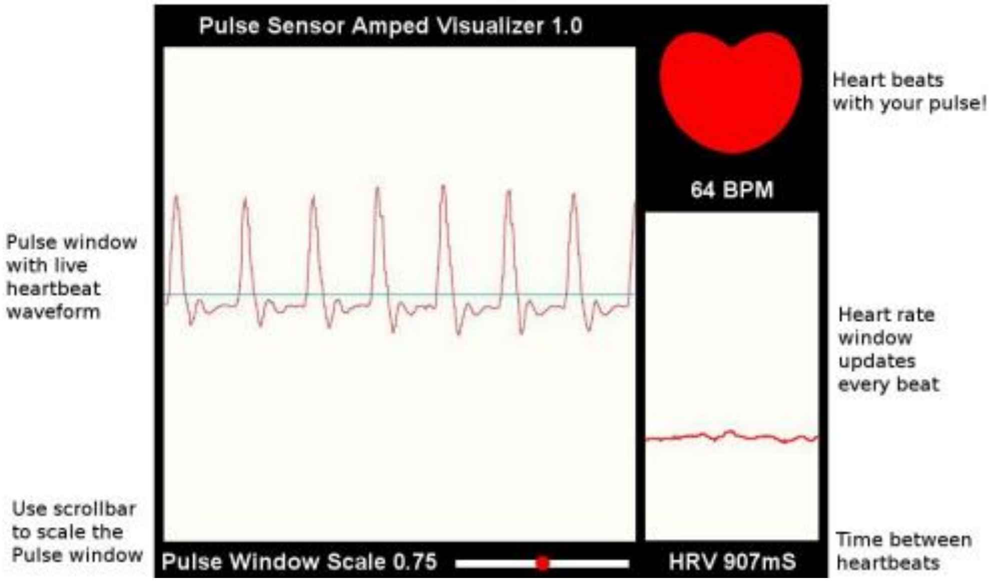


Figure 5.3: What is displayed on the computer screen that is received for the Amped sensor [Online]. Available: http://cdn.shopify.com/s/files/1/0100/6632/products/PulseSensorAmpedFinger-web_2_1024x1024.jpg?v=1348514131. [Accessed 9 September 2013] Used with permission of Yury Gitman, 2014

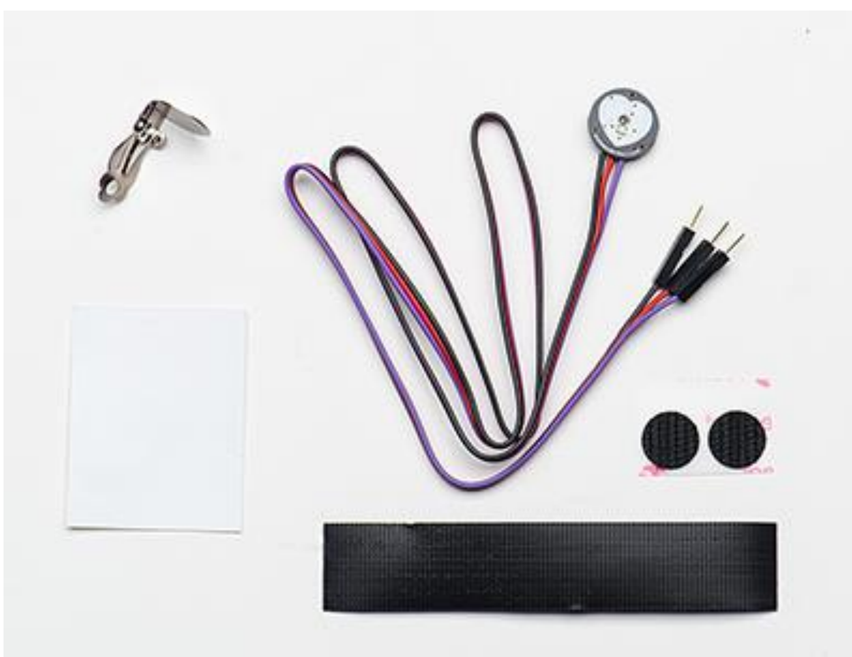

Figure 5.4: Amped heart sensor with wrist strap and earlobe sensors

[Online]. Available: http://cdn.shopify.com/s/files/1/0100/6632/products/PulseSensorAmpedFinger-web_2_1024x1024.jpg?v=1348514131. [Accessed 9 September 2013] Used with permission of Yury Gitman, 2014

How the Amped heart sensor works it is a photoplethysmograph which gives off a voltage of the measured pulse. The sensor measures the change in light intensity. The more light that is reflected back to the sensor the quicker the pulse and the smaller amount of light reflected back the slower the pulse.

### 5.2.3 Temperature Sensor

The TMP006 is a contact-less infrared thermopile senor breakout that can measure temperature of an object without having to touch the object itself.. The dimensions of the chip are Length: 20mm/0.8in, Width: 20mm/0.8in. The infrared sensor voltage range is between -40˚C and 125˚C. The device has low power consumption with a low operating voltage which means the device could be used for many applications, without using all the devices power.

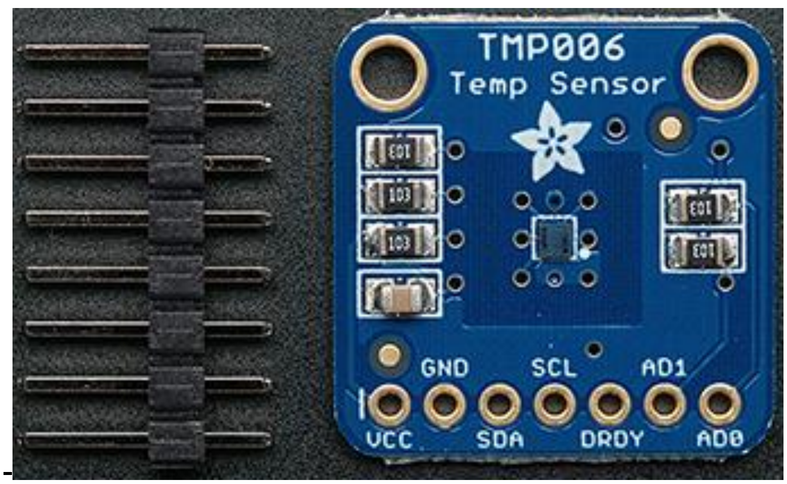


Figure 5.5: TMP006 temperature sensor
[Online]. Available: https://www.adafruit.com/products/1296. [Accessed 9 September 2013] Used with permission of adafruit, 2014

The way the sensor works is that the sensor is directed towards the object it is trying to measure. It then absorbs the IR waves emitted from the surface of the object. The change in thermopile is how the sensor tells the temperature of the object. Objects that are measured emit different amounts of IR voltage, depending on size and shape. It takes the average of the object IR voltage emitted, so that it can be more accurate in determining temperature.

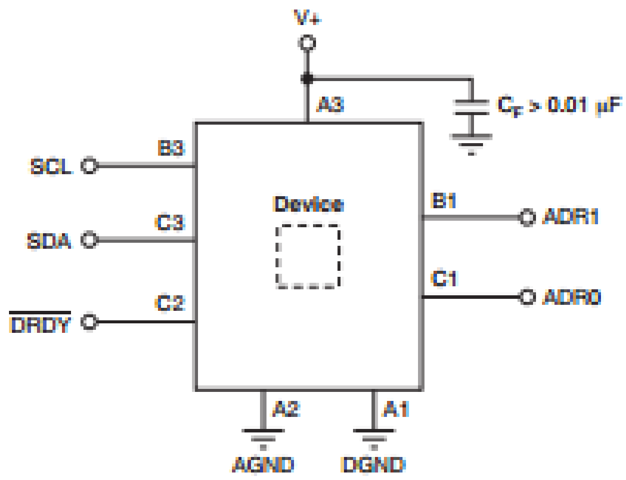


Figure 5.6: TMP006 internal setup
[Online]. Available: https://www.adafruit.com/products/1296. [Accessed 9 September 2013] Used with permission of adafruit, 2014

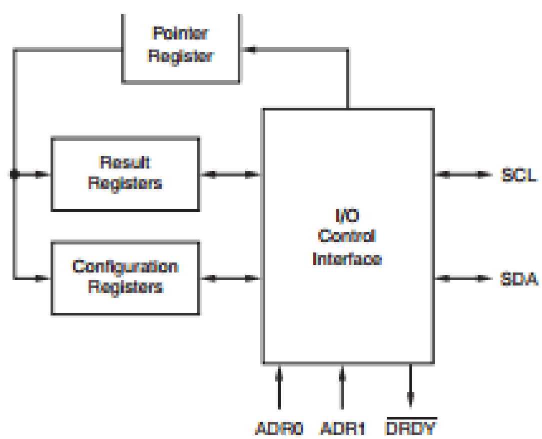


Figure 5.7: TMP006 signal setup
[Online]. Available: https://www.adafruit.com/products/1296. [Accessed 9 September 2013] Used with permission of adafruit, 2014

### 5.2.4 Stroke (Waveform sensor/ blood flow)

The VC0706 UART Camera is a camera that has CMOS and infrared capabilities. The image sensor CMOS is ¼ inches and the CMOS pixel is 0.3M. This camera has 3 different types of lens; 650nm, which is in the visible range; 850nm, which is in the near infrared range; and 940nm, which is also in the near infrared range. The camera can take up to 30 frames per second with a resolution of 640X480. It has a viewing angle of 120˚. The camera has a megapixel of 30 and a pixel size of 5.6umX5.6um. It has low power consuming and its operating temperature is 40˚C to 85˚C. The board has a built in high performance digital processing chip. The dimensions are 38 × 38 × 30mm. To do Laser Doppler Blood Flow imaging we would need a camera that has CMOS capability and that is able to view light in the visible range which is 380nm – 700nm. Cameras that can see a wavelength of 390nm – 750nm, are usual used for this type of imaging. The range most people try to aim for when doing Laser Doppler blood flow is between wavelengths of 532nm – 800nm. Since this camera has 3 different lens one of them begin in the visible range of 650nm and having CMOS abilities this would be a great camera to use for Laser Doppler blood flow imaging. This camera will have no problem measuring the total amount of local blood perfusion in the capillaries, arterioles, venules, and shunting vessels in the microcirculatory especially with the added bonus of 30 frames per second. At this frame rate the camera will be able to see small changes in the perfusion in the blood and be able to notify the user sooner that there is a problem. With the built in high performance digital processing chip the device will be able to process the information fast and have product reliable data, without having to go through a third party processing phrase. With pixel size being 5.6umX5.6um and viewing angle of 120, the camera will be able to get different angles of the same area and be able to analyze the area more precisely and accurately. The camera would be a go choice for detecting stroke using Laser Doppler blood flow.

Figure 5.8: VC0706 UART Camera
[Online]. Available: http://www.robotshop.com/en/vc0706-uart-vga-camera.html. [Accessed 9 September 2013] Used with permission of Eric Nantel, 2014

Figure 5.9: VC0706 UART Camera circuitry
[Online]. Available: http://www.robotshop.com/en/vc0706-uart-vga-camera.html. [Accessed 9 September 2013] Used with permission of Eric Nantel, 2014

The camera will work similarly for stroke and change in glucose levels. Two small lasers will be used as the light sources for the device. The lasers will use both near infrared and visible lighting. The near infrared laser will be used for change in glucose level and the visible laser will be used for stroke. The lasers will be used to penetrate the skin and the camera will process the light reflected back from the tissue to either detect stroke or change in glucose level. The CMOS ability will be used to convert the light received back from the tissue to electrons. The analog to digital converter will convert the pixel values to digital values to be process and analyzed. Once the data is converted the data can be displayed.

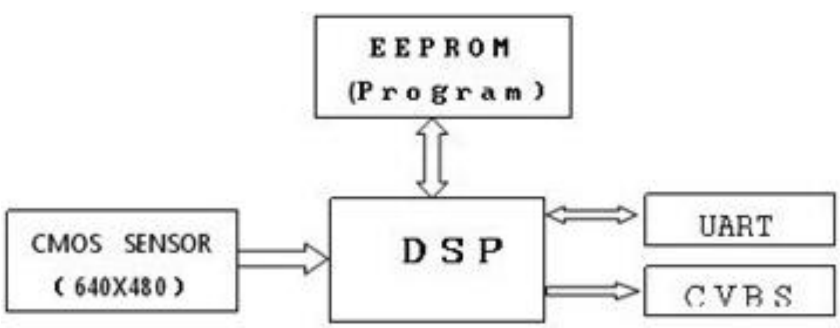


Figure 5.10: VC0706 UART Camera communication working
[Online]. Available: http://www.robotshop.com/en/vc0706-uart-vga-camera.html. [Accessed 9 September 2013] Used with permission of Eric Nantel, 2014

### 5.2.5 Glucose Level

The same VC0706 UART Camera that will be used for stroke detection will also be used for blood sugar detecting. The camera will be used for some similar reasons as the stroke detection such as 30 frames per second with a resolution of 640X480. It has a viewing angle of 120˚. The camera has a megapixel of 30 and a pixel size of 5.6umX5.6um. It has low power consuming and its operating temperature is -40˚C to 85˚C. The board has a built in high performance digital processing chip. The main reason that this camera will be used for blood sugar detection is the ability to use different lenses. The camera can use two lenses, which have wavelengths of 850nm and 940nm these are in the near infrared spectrum. With the near infrared lenses the cameras beam of light will be able penetrate the skin and measure the blood glucose level. This type of light beam is not harmful or invasive to the object and it's an accurate and reliable method. This camera will read the frequency and wavelength of the blood glucose and tells if the blood sugar is low or high. The camera has high resolution and a wide range of pixel area to capture the entire area needed for the glucose reading. With the built in high performance digital processing the camera will be able to process the change in glucose quickly and in a real time. With all these features combined the camera will easily be able to detect a slight change and be able to recognize earlier rather than later that something is wrong and alert the user.

Figure 5.11: VC0706 UART Camera

[Online]. Available: http://www.robotshop.com/en/vc0706-uart-vga-camera.html. [Accessed 9 September 2013] Used with permission of Eric Nantel, 2014

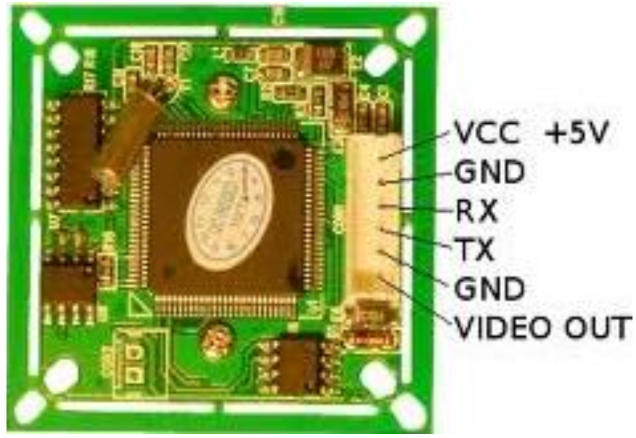


Figure 5.12: VC0706 UART Camera circuitry and signal inputs
[Online]. Available: http://www.robotshop.com/en/vc0706-uart-vga-camera.html. [Accessed 9 September 2013] Used with permission of Eric Nantel, 2014

## 5.3 System Design

The system design will be discussed in this section. This section will explain how the sensors will be ingrate together. The software and hardware needed. What the final device will look like. The placement of the sensors. The integration of the sensors and hardware. The cost of each component. The cost to build a prototype. The cost to build multiple prototypes. How the device will analyze and process the information. The testing plan for the prototype.

### 5.3.1 System setup

#### What are we going to build what is the final product going to look like?

The device will be in wrist watch form with a display screen, which will display the continuous reading of the measurements. It will contain a button to change the different settings and input information. The information can be loaded from the user's computer to the device through USB connection, Bluetooth technology, or wirelessly. The information can be taken off the device in the same manner. It will have a wrist band that can be easily adjusted to the user wrist size. The device will be compact and light for the user to wear. The home based which will be an arduino controller will be small and compact, it will communicate to the device wirelessly. It will be small enough so the user can place it in their pocket when they are traveling. It will be similar to how a cellphone works, a signal can be accessed anywhere. The home base will mainly be used to communicate with the secure network, so it’s able to alert the correct people in case of a threat to the user, even if they are not at home. The home base will also be used to store data to and from the network if the person doesn’t own a computer.

## The placement of the sensors

The laser light sources will be placed in the middle of the device to access the tissue clearly. The stroke and glucose cameras will be placed close to their respective light source. The laser light sources and cameras will be place underneath the arm where the tissue is located. The amped heart sensor will be placed on the side of the arm, where the ulnar artery is located. This placement will make it easier to detect the blood pressure and pulse rate. The temperature sensor can be placed on the back side of the wrist because it doesn’t require any contact with the user, so it can be placed anywhere. By having it place on the back of the wrist it will have more surface area to monitor, which will give a better average of the person’s body temperature.  The falling/fainting sensor will also be place on the back of the wrist. The reason for this placement is to make sure it doesn’t infer with the placement of the other sensors. The wrist device will have to be snug and form fitting on the users wrist, to get the desired accuracy and precision for the reading. It will fit like a band on the user’s arm. The display screen will be place on the back of the wrist for easy access to the screen.

## What is the cost to build one?

The cost to build a prototype of the device will be around a hundred dollars, most of the parts are between $5- $50 dollars. Each VC0706 UART Camera cost $31 from robotshop. The sensor amped heart rate sensor cost $25 from sparkfun. The TMP006 cost $15 from adafruit. The band cost 5-10 from any online store. The circuit board cost $5 -$15 from any store. The wires cost $5 – $10 from any store.

The analog to digital convert cost $10 - $50 depending on the type and size. The transducers cost $5 - $30, depending on the type and size. The Pololu AltlMU-10 v3 (IMU) and altimeter cost $50 from Pololu. The printed circuit boards cost $5 - $50 depending on the quality and what goes on the board. The arduino controller cost $20 - $30 depending on the board. Once the prototype is tested and determined to be accurate and reliable enough, multiple prototypes can be built. When the parts are brought in bulk the price decreases so it could be feasible to build more than one for around 300 – 500 dollars.

## Hardware and software integration

The hardware of the system consider of an arduino board as the controller. Multiple small circuit board to place and wiring the sensors. Eventually a printed circuit board will be used. Multiple transducers to convert the detected vitals and parameters into an electrical signal, to be processed and analyzed than eventually displayed on the display screen of the device. Two VC0706 UART Cameras one for glucose reading and one for stroke sensing. One TMP006 sensor to detect body temperature of the user. Two laser light sources, one that can be detected in the near infrared range and one that can be detected in the visible range.  One Amped heart sensor to detect: pulse, blood pressure, and blood flow. One Pololu AltlMU-10 v3 IMU and altimeter to detect falling and fainting. An analog to digital convert to covert the analog signal to digital signals for easier processing. A power source to power the entire system and a backup power source in case of emergencies. One wrist band to place the sensors for detection of this events. The software of the system consists of the arduino software, where each individual sensor will be coded. Code for each of sensors. The secure network, where the information will be sent and stored. LabView, where the signals will be send for display purposes. All of the sensors can be controlled and programmed through arduino, so there shouldn't be a problem with the sensor interfacing and communicating to each other. To prevent communication issues each sensor will have its own communicating pathway.

### 5.3.2 System Data analysis and processing

How do you record and process the information?

To record and process the information, a program will be written with arduino to transmit and send the signals and information to the appropriate locations to start: analyzing, recording, and processing the data continuously. The program will interface with LabView, which will allow the user to see the data collected on the computer. For instance, if the user would like to see their pulse or the trend in their blood sugar, the embedding program will be able to display these signals and information. This will be done in real time, so that the user can be informed constantly of their health.

### 5.3.3 System Testing Plan

The system will be tested initial to make sure it's sending, receiving, and recording the given signals and other important information. A program will be written to simulate different scenarios; some with normal health and other with abnormal health issues and see if the device is receiving the right information and able to read it. The device needs to be tested to see if the device can analyze and process the information and if it can process the information as the correct illness. The device needs to be tested to see if its records and stores the information in the right place for the right illnesses. If these tests show good results, a small clinical trial will be performed to see if the device can function correctly in a real life situation. One healthy subject will be used in the first clinical trial. The subject will be told to do normal activities and see if the device will be able to pick up on these events. The subject will have to stimulate falling/fainting and fall like activities, such as sitting then lying to see if the device can differentiate between them. The orientation and position will be tested, to see if the device can actually tell where the person is located. It is hard to simulated heart, attack, stroke, and blood glucose levels in a real life situation. Hopefully getting base information from a healthy subject will help in determining and setting thresholds. If the small clinical trial gives good results a larger scale trail will be performed, to see if the device can detect things on a larger scale with different types of people. Half of the subjects will be healthy and the other half will be less healthy, for instance subjects who have suffered a heart attack or stroke and subjects who are more at risk for heart diseases, stroke, or diabetes. The device will be tested to see if it can detect abnormal health issues and be able to sort and place each subject according to the diseases. The device needs to be able to different between healthy and unhealthy subjects, by their measurements and if the person has an illness it is able to pinpoint which illness and where. Lastly, if all the tests from the computer simulation, small clinical trial, and larger clinical trial give good results, the device needs to be tested to make sure the alert system works. The devices needs to be tested to see if it sends an alert to the correct people, in case of a life threaten event was detected.

# Chapter 6 Discussion

From literature research and medical research there are several factors that need to be taken into account when building a device to better assist the elderly to age in place longer. The main concern is the problems the elderly are facing everyday and making solutions to address these issues. A better understanding of what the elderly need is the first step to making better technology to assist them. This chapter will explain in details these problems and solutions.

## 6.1 Research issues to address

From research there were several main issues that needed to be adressed. The main issues that need to be addressed are life threaten events that hinder the elderly from aging such as falling/fainting, heart disease, stroke, and blood glucose levels. This issues were discussed in great detail thoughout this paper. If theses issues are not treated or caught early enough they can cause major problems in the elderly population ranging from disabilites to death, within 6 month to a year of the event occuring. One of the elderly's greatest fear is that one of these events will occur and will hinder their full capicity to live a normal because of this fear they will change their life style diasticlly to prevent these events from happening. When they change or hinder their everyday living it greatly increase the chances of these events occuring. This is because they don't move as often as they use to so when they walk they are at a greater chance of falling because they are not use to it. Also they may change their eating habit and stop exercising from fear of falling but this can increase they chance of heart disease or stroke. Also when they change there eating habit they may not be getting all the nutrients that they need to keep their bones strong so they become brittle, with brittle bones its easier to fall and if they fall a greater chance of a broken bone and taking longer to heal. With this being said there are issues that are addressed less frequently or over looked. These issues include after the event has occurred, how treatment effects the user ability to function normal. If the person falls and break a bone it affects how the person walks increasing the chance of falling also it can affect how fast the person is walking. With some treatments for heart disease or stroke like medication can increase the chances of falling because it may cause them to be disorient and dizzy. Medication for diabetic can cause similar affects and harm to the user. Lastly some medication taking for treatment can increase the risk of heart disease or stroke and it may cause the heart rate to become more irregular. There are not many solutions on the market for after these events have occurred, most products or solutions try and prevent the event from occurring or trying to detect it early enough so that treatment can be adminstered and the patient can heal faster and normally. Issues that need to be addressed are precaution and prevention in the home. Some of these life threaten events can be prevent if precaution are set in place before hand; Such as with falling and fainting many falls in the elderly occur because of vision, preception, sensory, and enviormental issues. If the elderly get their eyes check every 6 months to a year the amount of falls do to vision and preception issuses will decrease. If the elderly home is rearrange for ease and accessibty due to aging, falls do to sensory and enviormental issues will be greatly reduced. If the person changes thier eating habit to more healther choices while still getting the nutrients that they need this will cut down on if the person falling and increase the chance of recovering fully. Also by increasing the amount of exerice will increase the healing after a fall greatly. Eating healthy and exercising can also decrease the chances of health disease, stroke, and change glucose levels. More research needs to be done in prevention and precuation area to better access the elder to age in place.

## 6.2 How to address these issues

The are major gaps between the research that has be done and solutions. The main problem between the research and solutions are there are many devices that only monitor one or two life threaten events. The solutions produce many false positives and results can be ureadable. In addition to this if the person experince a fall like motion the device may think its an actual fall and send the alert. With heart disease if the person is doing vigourous activity the device may detect this and set off the alarm. The gaps between glucose devices are the reading can differ depending where the device is placed. Also the devices can be inaccurate with readings. The gaps with stroke are most of the solution on the market have to be placed on the person's head and uses eye moment or blood must be drawn. With many of the solutions the user may have to shave where the device is going to be place to get a good reading. Also there may be a period of time where the device needs to be changed, so the user is not wearing the device but there is still a chance that these event can occur. Many of the device has to be calbriated multiple time to make sure the reading is accurate and precise. The are few devices that detect multiple event and when the device can detect more then one event they are usually are related like heart disease and stroke but not falls and heart disease. To address this issues the wrist worn device will combined all these events, so the user only has to wear one device to monitor all these events. The device will have a long battery life so it doesn't have to charge they can just change the battery every 2-5 years without having to recalibrate during the time the battery is being changed; the device will use the back up battery so the device won't shut off completely. With the wrist watch device the user can wear it after an event occur so that it can continue to monitor the person. The specs and the information can be changed by the user to monitor a different ranges. This will prevent the device from having false postives after the user is treated for an event. With the new medication the doctor will give them the user can input the change that need to be made like change the heartbeat to a higher range because of the medication. The user can also tell the device that it took the medication at a cetian time and to ignore the iregular body conditions for a period of time or monitor the body conditions more closely for a period of time. To keep the device form having to many false postive it will be tested against other know device to see how accurate and precise it produces results. This will be dicussed in more details in the following section. Lastly for prevention and precaution issues. The device will have a place to set reminders such as the user needs to exercise, eat, or set appointments, such as eye exams and medication.

## 6.3 How to test the device

The wrist worn device will have to be tested for several components. The first thing the device will have to be tested for is its ability to work. The device will be tested to see if it will be able to read the user vital sign no matter the condition or the environment. To show that the device can read several vital signs the device will have to siminateously update each individual reading in real time. This will have to be done continuously to show that the signals are not inference with each other. The device will also have to be tested for accuracy and precision, for this to be done the device will have to be tested against other well-known device and see how the reading compares. The will have to be done several times throughout the day; for instance morning, midday, night. Also during this time the device will have to be tested before and after meals, during normal activity, during vigorous activity, and during lazy activity. In addition to test the accuracy and precision the device will need to be tested to see how it works in different condition especially extremes; such as extreme heat, extreme cold, extreme humid, extreme dryness, and normal conditions. The device will be tested in these conditions to see how the readings, battery life, accuracy, precision, signals and processing of the information, storing the information, and transferring of the information wirelessly are affected. After testing is done to insure that the device works consistently, continuously, accurately, precisely, and properly in all condition and environments the device will need to be test for each individual life threaten event. The first life threaten event that will have to be tested is falling/fainting. With many of the device on the market they produce false positives. To prevent false positives the Polulu AltlMU-10 v3 was chosen; which has a build in gyroscope, accelerometer, magnetometer, and a digital barometer. That can be used to determine the user orientation, location, acceleration, and magnitude. To test that this device is good enough to prevent false positives falls will be stimulated, such as sitting then lying to see if the device can differentiate between an actual fall and fall like activities. The thresholds and calibrations will be tighten or loosen based on how affective the device is at determining the difference. To prevent false positive with heart disease and stroke these events will be simulated, using the results from the simulations normal heart conditions thresholds and calibrations will be set. These calibrations and thresholds will change based on person's condition. This way the device will knows that if the person with heart disease or someone has had a stroke if their vitals become irregular this is the "normal" for that condition. Glucose levels are different where you don't get false positive, these devices focus on accuracy and precision of the readings. To make sure that the device will give accurate and precise readings it will be extensively test against many know device on the market, that are used on diabetics and calibrated and thresholded based off the reading of these devices.

# Chapter 7 Conclusion and Recommendations

## 7.1 Future Work

More research need to be done in certain areas to better improve solutions and technology for elderly aging in place. Prevention and precaution being one of the biggest areas not taken into acount when developing new technologies. Many of these life changing events can be prevented if small changes were made in the elderly home and life sytles. Another thing to take into account is the size of the technology that is on the market. The aging group wants technology that is smaller and non-invasive and that doesn't interfere with their every day living. Along with this they want device that wouldn't restict how far they can travel before it stops working. Many of the device on the market produce tons of false postive waste valuble resources such as time. Along with this they want the ability to stop using a device or product and not be stuck in a contract. With the wrist worn device some of these issues addressed. For future work on the device an actually prototype will need to be build and tested.

# REFERENCES

[1] "54 Random Facts About . . . Share on facebookShare on twitterShare on google_plusone_shareShare on pinterest_shareShare on stumbleuponShare on redditShare on tumblrMore Sharing Services," 25 March 2010. [Online]. Available: http://facts.randomhistory.com/heart-disease-facts.html. [Accessed 8 July 2013].

[2] "New Non-Invasive Blood Glucose Measurement and Continuous Monitoring Device: the Glucoband(R)," MINT, 10 June 2005. [Online]. Available: http://www.medicalnewstoday.com/releases/25926.php. [Accessed 9 September 2013].

[3] "Now, portable device to detect stroke," PTI Washington, 6 March 2013. [Online]. Available: http://archive.indianexpress.com/news/now-portable-device-to-detect-stroke/1084045/0. [Accessed 9 September 2013].

[4] "The Stroke Center at University Hospital," 2013. [Online]. Available: http://www.uhnj.org/stroke/stats.htm. [Accessed 6 june 2013].

[5] A. Caduff, E. Hirt, Y. Feldman, Z. Ali and a. H. L, "First human experiments with a novel non-invasive, non-optical continuous glucose monitoring system," *Biosensors and Bioelectronics,* vol. 19, no. 3, pp. 209-217, 2003 .

[6] A. Kumar, "Sensor detects glucose in saliva and tears for diabetes testing," *Advanced Functional Materials* , vol. 22, no. 16, 2012.

[7] A. N, "New Non-Invasive Continuous Glucose Monitor Will Talk to Your SmartPhone," 3 October 2011. [Online]. Available: http://www.diabetesmine.com/2011/10/new-non-invasive-continuous-glucose-monitor-will-talk-to-your-smartphone.html. [Accessed 9 September 2013].

[8] A. Serov, W. Steenbergen and F. and de Mul, "Laser Doppler perfusion imaging with a complimentary metal oxide semiconductor image sensor," *OPTICS LETTERS,* vol. 27, no. 5, pp. 300-302, 2002.

[9] A. Sixsmith, N. Johnson and R. and Whatmore, "Pyroelectric IR sensor arrays for fall detection in the older population," *EDP Sciences,* vol. 128, pp. 153-160, 2005.

[10] AHA, "Heart and Stroke Statistics," [Online]. Available: http://www.heart.org/HEARTORG/General/Heart-and-Stroke-Association-Statistics_UCM_319064_SubHomePage.jsp. [Accessed 8 July 2013].

[11] American Diabetes Association, "Statistics About Diabetes," 26 January 2011. [Online]. Available: http://www.diabetes.org/diabetes-basics/statistics/. [Accessed 8 July 2013].

[12] B. Grletens, "From micro to macro NIR sensors and imaging spectroscopy – a perfect match," *German in Photonik,* vol. 1, pp. 1-4, 2007.

[13] C. Midey, "Response times play big part in Stroke patients' recovery," 24 February 2012. [Online]. Available: http://www.azcentral.com/news/azliving/articles/2012/02/24/20120224response-times-play-big-part-stroke-patients-recovery.html. [Accessed 8 July 2013].

[14] C. Paddock, "Eye Movement Analyzer May Diagnose Stroke," MNT, 7 March 2013. [Online]. Available: http://www.medicalnewstoday.com/articles/257312.php. [Accessed 9 September 2013].

[15] CDC, "Falls – Older Adults," [Online]. Available: http://www.cdc.gov/HomeandRecreationalSafety/Falls/index.html. [Accessed 8 July 2013].

[16] CDC, "Falls Among Older Adults: An Overview," [Online]. Available: http://www.cdc.gov/homeandrecreationalsafety/falls/adultfalls.html. [Accessed 8 July 2013].

[17] CDC, "Heart Disease Facts," [Online]. Available: http://www.cdc.gov/heartdisease/facts.htm. [Accessed 8 July 2013].

[18] CDC, "Stroke Facts," [Online]. Available: http://www.cdc.gov/stroke/facts.htm. [Accessed 8 July 2013].

[19] D. Ferguson, "Scientists: Portable device acts as early detector of strokes," 27 December 2012. [Online]. Available: http://www.rawstory.com/rs/2012/12/27/scientists-portable-device-acts-as-early-detector-of-strokes/. [Accessed 9 september 2013].

[20] D. He, H. C. Nguyen, B. R. Hayes-Gill, Y. Zhu, J. A. crowe, C. Gill, G. F. Clough and S. P. and Morgan, "Laser Doppler Blood Flow Imaging Using a CMOS Imaging Sensor with On-Chip Signal Processing," *Sensors* , vol. 13, pp. 12632-12647, 2013.

[21] D. Pogrelc, "Bloodless glucometer uses light to check blood sugar in 20 seconds or less," MEDCITY, 28 June 2012. [Online]. Available: http://medcitynews.com/2012/06/bloodless-glucometer-uses-light-to-check-blood-sugar-in-20-seconds-or-less/. [Accessed 9 September 2013].

[22] D.-H. Nam, W.-B. Lee, Y.-S. and Hong and S.-S. and Lee, "Measurement of Spatial Pulse

Wave Velocity by Using a Clip-Type Pulsimeter Equipped with a Hall Sensor and Photoplethysmography," *Sensors* , vol. 13, pp. 4714-4723, 2013.

[23] E. Nemati, J. M. Deen and T. and Mondal, "A Wireless Wearable ECG Sensor for Long-Term Applications," *Communication Magazine*, vol. 50, no. 1, pp. 36-43, 2012.

[24] E. O'Malley and K. Rinne, "A Programmable Digital Pulse Width Modulator Providing Versatile Pulse Patterns and Supporting Switching Frequencies Beyond 15 MHz," *Applied Power Electronics Conference and Exposition. Nineteenth Annual IEEE*, vol. 1, pp. 53-59, 2004.

[25] E. Valchinov and N. Pallikarakis, "A wearable wireless ECG sensor: a design with a minimal number of parts," *MEDICON*, vol. 29, pp. 288-291, 2010.

[26] E. Venere, "Sensor detects glucose in saliva and tears for diabetes testing," IMPACT, 3 March 2012. [Online]. Available: https://engineering.purdue.edu/EngineeringImpact/2012_3/sensor-detects-glucose-in-saliva-and-tears-for-diabetes-testing. [Accessed 9 September 2013].

[27] F. Flacke, "Practical aspects of using the Pendra® device," 9 May 2004. [Online]. Available: http://www.diabetes-symposium.org/index.php?menu=view&id=136. [Accessed 9 September 2013].

[28] G. Uslu, H. I. Dursunoglu, O. Altun and S. and Baydere, "Human Activity Monitoring with Wearable Sensors and Hybrid Classifiers," *International Journal of Computer Information Systems and Industrial Management Applications*, vol. 5, pp. 345-353, 2013.

[29] G. Wang and M. P. Mintchev, "Development of Wearable Semi-invasive Blood Sampling Devices for Continuous Glucose Monitoring: A Survey," *Engineering* , vol. 5, pp. 42-46, 2013.

[30] Glelcher N, Confino E, Cofrman R, Coulam C, DeCherney A, Haas G, Katz E, Robinson E, Tur-Kaspa I, Vermesh M, "The multicentre transcervical balloon tuboplasty study: conclusions and comparison to alternative technologies," *Human Reproduction*, vol. 8, no. 8, pp. 1264-1271, 1993.

[31] H. Zeng and Y. Zhao, "Sensing Movement: Microsensors for Body Motion Measurement," *sensors*, vol. 11, pp. 638-660, 2011.

[32] Heart and Vascular Center, "Diabetes and Heart Disease," [Online]. Available: http://medicalcenter.osu.edu/heart/prevention/pages/diabetes-and-heart-disease.aspx.

[Accessed 6 June 2013].

[33] J. Chen, K. Kwong, D. Chang, J. Luk and R. Bajcsy, "Wearable Sensors for Reliable Fall Detection," in *Engineering in Medicine and Biology 27th Annual Conference Pg 3551-3554*, Shanghai, 2005.

[34] L. B. English, "In Pursuit of an Ideal – A Perspective on Non-Invasive Continuous Glucose Monitoring," *European Endocrinolog*, vol. 8, no. 1, pp. 18-21, 2012.

[35] L. Scalise, "Non Contact Heart Monitoring," in *Advances in Electrocardiograms - Methods and Analysis*, Shanghai, InTech, 2012, pp. 81-107.

[36] L. Xu, Q. Liang, X. Cheng and D. and Chen, "Compressive sensing in distributed radar sensor networks using pulse compression waveforms," SpringerLink, 2013.

[37] L. Z. Rubenstein and K. R. Josephson, "The Epidemiology of Falls and Syncope," *Clinics in Geriatric Medicine* , vol. 18, no. 2, pp. 141-158, 2002.

[38] M. Chu, K. Mitsubayashi, K. Miyajima and T. and Arakawa, "Soft Contact-lens Sensor for Monitoring Tear Sugar as Novel Wearable Device of Body Sensor Network," *Knowledge Systems Institute*, pp. 54-57, 2011.

[39] M. Popescu, B. Hotrabhavananda, M. Moore and M. and Skubic, "AMPIR- An Automatic Fall Detection System U sing a Vertical PIR Sensor Array," in *International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops pg163-166*, San Diego, 2012.

[40] N. Maneejiraprakarn, P. Panpho, D. Boonthong, P. Thitiwuthikiat, J. Koseeyaporn and P. Wardkein, "Low cost non-invasive instrument for heart disease and peripheral vascular disease detection," in *Biomedical Circuits and Systems Conference 49-52*, London, 2006.

[41] N. Tessler, V. Medvedev, M. Kazes and S. and Kan, "Efficient Near-Infrared Polymer Nanocrystal Light-Emitting Diodes," *Science*, vol. 295, no. 5559, pp. 1506-1508, 2002.

[42] National Diabetes Information Clearinghouse (NDIC), "National Diabetes Statistics, 2011," February 2011. [Online]. Available: http://diabetes.niddk.nih.gov/dm/pubs/statistics/. [Accessed 8 July 2013].

[43] P. Lim-Kong, "Wrist-based fitness monitoring devices". United States of America Patent 1250887 A2, 20 March 2002.

[44] P. Scarborough, P. Bhatnagar, K. Wickramasinghe, K. Smolina, C. Mitchell and M. and

Rayner, "Coronary Heart Disease Statistics," British Heart Foundation Health Research Group , Oxford, 2010.

[45] R. C. Seet, P. A. Friedman and A. A. Rabinstein, "Prolonged Rhythm Monitoring for the Detection of Occult Paroxysmal Atrial Fibrillation in Ischemic Stroke of Unknown Cause," *Contemporary Reviews in Cardiovascular Medicine,* vol. 124, pp. 477-486, 2011.

[46] S. A. Kingsley, S. Sriram, A. Pollick and J. and Marsh, "Revolutionary optical sensor for physiological monitoring in the battlefield," *Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security and Homeland Defense III,* vol. 5403, no. Carapezza, Edward M, pp. 66-77, 2004.

[47] S. Hondrogiannis, "Head-worn device uses sonar to rapidly diagnose stroke," gizmag, 31 March 2011. [Online]. Available: http://www.gizmag.com/submarine-technology-stroke-diagnosis/18277/. [Accessed 9 September 2013].

[48] S. Lakshmi, "Optical Sensor Based Instrument for Correlative Analysis of Human ECG and Breathing Signal," *International Journal of Electronic Engineering Research,* vol. 1, no. 4, pp. 287-298, 2009.

[49] S. Srinivasan, J. Han, D. Lal and A. and Gracic, "Towards automatic detection of falls using wireless sensors," in *IEEE Engineering in Medicine and Biology Society,* Lyon, 2007.

[50] S. Tao, M. Kudo and H. and Nonaka, "Privacy-preserved fall detection by an infrared ceiling sensor network," *NCBI,* vol. 12, no. 12, pp. 16920-16936, 2012.

[51] S. Weinzimer, "PENDRA: the once and future noninvasive continuous glucose monitoring device?," *Diabetes Technology and Therapeutics,* vol. 6, no. 4, pp. 442-444, 2004.

[52] ScienceDaily, "New device uses submarine technology to diagnose stroke quickly," Society of Interventional Radiology, 29 March 2011. [Online]. Available: http://www.sciencedaily.com/releases/2011/03/110329095434.htm. [Accessed 9 September 2013].

[53] T. V. Glotzer, D. E. G. and D. G. e. Wyse, "The Relationship between Daily Atrial Tachyarrhythmia Burden from Implantable Device Diagnostics and Stroke Risk: The TRENDS Study," *Circulation: Arrythmia And Electrophysiology* , vol. 2, pp. 471-473, 2009.

[54] V. Pikov, "Portable brain imaging system for early stroke detection," Nuerotech business , April 2011. [Online]. Available: http://neurotechzone.com/posts/344. [Accessed 21 January

2013].

[55] W. IM, H. JB, Z. A and a. D. JH., "Pendra goes Dutch: lessons for the CE mark in Europe," *Diabetologia,* vol. 48, no. 6, pp. 1055-1058, 2005.

[56] W. Stomp, "GlucoTrack DF-F Noninvasive Glucose Meter Receives CE Mark," medGadget, 4 June 2013. [Online]. Available: http://www.medgadget.com/2013/06/glucotrack-df-f-noninvasive-earlobe-clip-glucose-meter-receives-ce-mark.html. [Accessed 9 September 2013].

[57] Y. M. Chi and G. Cauwenberghs, "Wireless Non-contact EEG/ECG Electrodes for Body Sensor Networks," in *Body Sensors Networks* , Singapore, 2010.

[58] [Online]. Available: http://www.bkheart.org/index.php/services/holter-monitoring/. [Accessed 9 september 2013].

[59] [Online]. Available: http://www.endothelix.com/. [Accessed 9 September 2013].

[60] [Online]. Available: http://www.lasplash.com/publish/LifesJourney/cat_index_golden_years/myHalo_Monitoring_Device_Review_Automatic_Fall_Detection.php. [Accessed 9 September 2013].

[61] [Online]. Available: http://www.lifecall.ca/. [Accessed 9 September 2013].

[62] [Online]. Available: http://www.healthstats.com/index3.php?page=homepage. [Accessed 9 September 2013].

[63] [Online]. Available: http://www.diabetesmine.com/2011/04/sleep-well-a-diabetes-design-concept-gone-viral.html. [Accessed 9 September 2013].

[64] [Online]. Available: http://pancreum.com/glu.html. [Accessed 9 September 2013].

[65] [Online]. Available: http://www.invensense.com/mems/gyro/mpu6050.html. [Accessed 9 September 2013].

[66] [Online]. Available: http://www.ti.com/product/afe4490. [Accessed 9 September 2013].

[67] [Online]. Available: http://www.ti.com/product/tmp006. [Accessed 9 September 2013].

[68] [Online]. Available: http://www.ovt.com/uploads/parts/OV3640_PB(1.02)_web.pdf. [Accessed 9 Septemner 2013].

[69] [Online]. Available: http://www.jai.com/en/products/nearinfrared. [Accessed 9 September 2013].

[70] [Online]. Available: http://www.pololu.com/product/2469. [Accessed 9 September 2013].

[71] [Online]. Available: http://cdn.shopify.com/s/files/1/0100/6632/products/PulseSensorAmpedFinger-web_2_1024x1024.jpg?v=1348514131. [Accessed 9 September 2013].

[72] [Online]. Available: https://www.adafruit.com/products/1296. [Accessed 9 September 2013].

[73] [Online]. Available: http://www.robotshop.com/en/vc0706-uart-vga-camera.html. [Accessed 9 September 2013].

[74] Merck Manual Home Health Handbook, edited by Robert Porter. Copyright 2013 by Merck Sharp & Dohme Corp., a subsidiary of Merck & Co, Inc, Whitehouse Station, NJ. Available at http://www.merckmanuals.com/home/. [Accessed 9 september 2013]

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