Central Health-risk Alert System for the Elderly (CHASE)

An All-round-the-clock System That Protects Your Loved Ones and Sends Help to Them Whenever They Need It.

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Introduction

Aging population has been a growing threat to most developed nations during the recent years. Studies have shown that there is an increasing number of elderly living alone. The United Kingdom (UK), for instance has 16% of her population aged 65 and above in 2009, with 43% staying alone (Beckford, 2011). Given their age, the risk of them having various health problems is already much higher than the average adult. Staying alone allows these mishaps to happen without anyone noticing. In 1995, it was reported that a home-alone elderly, Clement Williams, passed away in his house and was left unnoticed for 3 years before till his neighbours found him (Encel et al, 1996). Tokyo's Bureau of Social Welfare and Public Health also reported that more than 2,200 people over age 65 died lonely deaths in 2008 and this number is expected to rise (Nobel, 2010). Study has shown that heart disease and stroke are the two main causes of elderly death (Veronique et al, 2011), with the former contributing

35% of deaths (Sahyoun et al, 2001). This problem can only worsen as people become less physically active and more dependent on technology.

While it would be more ideal to encourage children to live with their aging parents, we seek to come up with a technological solution to this problem. Hence, our group project – "**Central Health-risk Alert System for the Elderly (CHASE)**" aims to create a non-intrusive, all-round-the clock monitoring system, which is able to detect any anomalies in the vital signs of the elderly at risk, and dispatch emergency medical assistance to them at the fastest possible time.

The report will cover four main aspects. We shall closely examine the existing solutions, inspect their limitations and devise a new solution to tackle their shortcomings. We will also analyse the economic and managerial issues that will impact our system.

Defining the issue

Heart attacks and strokes can be easily triggered by falls, changes in mood, changes in weather, and even during sleep. When such attacks strike, it is imperative that they receive immediate medical attention. Pell (2003) explains that the sooner the patients are attended to and given the appropriate treatment, the higher the chances of survival and the lower the risks of long term implications. However, if staying alone, such attacks will leave the casualty incapacitated and unable to seek help.

The solution we envision utilises non-intrusive equipment that will monitor the vital signs, i.e. heart rate, of these elderly-at-risk consistently throughout the day. Thus, when health anomalies occur and are detected by the device, the CHASE system will automatically and immediately dispatch medical help to the casualty.

This system will need to comprise of the following high-level components.

1. **Monitoring system**
   The monitoring system will need to have two main characteristics: continuous monitoring and a non-intrusive nature that does not impede a user's lifestyle.

   There is also an issue of which vital sign to monitor. Our preliminary studies have indicated that the largest cause of death is cardiac arrest (World Resources Institute, 2012). Thus, we'll mainly focus on measuring blood pressure and heart rate, which is proven effective in covering multiple symptoms attributing to heart disease (Hjalmarson, 2007).

   a. **Heart rate**
      Most cardiac arrest cases are indicated by abnormal and increasing heart rhythms. Through heart rate monitoring, we will be able to detect the occurrence of an impending heart attack.

      However, circumstances such as exercising, changes in emotions could cause fluctuations in heart rate, thus hampering the reliability of monitoring heart rate as the only indicator.

   b. **Blood pressure**
      Vascular blockage results in higher blood pressure. This is often deemed as a premonition for heart diseases and strokes (University of Iowa Health Care, 2005). Thus, we can utilize the blood pressure measurement as a gauge to predict any potential heart attacks, in addition to heart rate.

2. **Data management**
   Heart rate and blood pressure readings must be analysed to identify the anomalies that are indicative of medical emergencies. Real-time measurements need to be constantly compared against thresholds and if they fall out of the safety limits, the data must be transmitted back to the hospital for evaluation and activation of emergency services. In addition, the thresholds will vary from people to people and from

time to time (myfit.ca, n.d.), thus there is a need for an intelligent system that will update the thresholds based on user patterns.

3. **Data Transmission**
When an emergency does happen, the CHASE system will place a distress call and at the same time transmit the measurements of the vital signs to the hospital.

Currently available solutions

From our research, we have discovered many systems available commercially which address the same issue that we are targeting. We will be evaluating these existing systems in terms of their strengths and weaknesses, particularly in two aspects: Monitoring of health /status, and Storage, Analysis and Transmission of Data.

1. **Monitoring of health status**
We evaluated systems which monitored heart rate and blood pressure, the mechanisms of the devices they used and their feasibilities. Detailed comparison of these devices can be found in **Appendix A**.

a. **Chest Belt (*Figure 1*)**
It comprises a transmitter and a receiver module. It detects the heart rate of an individual with 2 electrodes via electrocardiogram (ECG). Electric pulses generated from the heart can be detected by the transmitter which then sends the information wirelessly to a receiver module (Sirikham, n.d.).

Figure 1: Chest belt

b. **Hand Grip Electrocardiogram**
The Hand Grip device is based on the concept of electrocardiogram. By holding on to a pair of metal electrodes, the electric potential of the heart can be measured at the surface and information of the heart can be diagnosed. This concept has been applied to treadmills for sports usage. (Lin et al, Feb 2012)

c. **Head Band (*Figure 2*)**
By measuring the physiological signal (PPG) at the forehead, the smart Headband is able to calculate the heart rate of the user. Light is absorbed in body tissues and blood, then partially reflected and detected by a photo-detector. Different intensities measured can thus reflect the user's heart rate. Research has shown that obtaining signals from the forehead is proved to be more reliable since there is lesser noise due to motion (Sanghyun et al, 2008).

Figure 2: Headband

d. **Micro-Impulse Radar (MIR)**
Microwave signals are targeted towards the heart and information regarding heart diseases can be diagnosed by measuring the strength of the returned signal. The electromagnetic pulses are capable of transmitting through the human body and it can be detected from several meters away from body contact. Currently, this radar has been implemented in the form of a box-like module (*Figure 3*) and a radar gun (Azevedo et al, 1996).

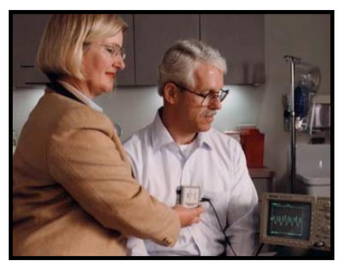

Figure 3: MIR

Evaluation: Convenience of usage of monitoring devices
Ideally, the device should not affect the lifestyle of its user. It should not require the user to consciously have to switch on and off. It must also be small and portable. The solutions presented above are either impractical to bring around (such as the hand grip), or intrusive to the user's daily activities (e.g. head band, chest belt and radar gun). The device should preferably be something people are comfortable and familiar with wearing, such as a watch.

2. **Data Storage/ Analysis/ Transmission**
   There are currently two methods of transmitting and managing data.

   a. **Uploading once a day automatically**
      One of such projects is the Artemist (Artemis, n.d.), an initiative for a 24-hour period data collection and analysis of blood pressure targeted at patients with cardiovascular risk. The data collection uses a web-based system that can interface with a recommended Microlife device. The device is installed with software that will transmit, analyse, and email the data to the person monitoring it, once a day.

   b. **Manual key-in from user**
      Another existing system that is currently used in the United Kingdom is the National Healthcare System Records Service (NHSCRS) (National Healthcare System, n.d.). The NHSCRS has a section on blood pressure and health rate section. The heart rate values that allow patients to manually key in are resting heart rate values, maximum heart rate and peak flow values. The blood pressure values that can be keyed in are systolic and diastolic blood pressure, blood type, blood sugar and cholesterol. The service has a summary record aspect that allows medical personnel to retrieve the electronic medical records, particularly in an emergency.

Evaluation: Continuous Real-time measurement of data / Power consumption
In many research projects, the detection system does not obtain continuous real-time data which is unsuitable for emergency situations. The system must both automatically and constantly monitor data from the measuring equipment. The current solutions presented above fulfil only one of the two criteria.

Another main consideration of implementing a real-time data collection system is power. Even though these systems have shown to have long battery life, they are only meant for periodic measurement and we should not expect the same performance under continuous usage. Transmission of data between modules especially in the case of long distance transmission can cause rapid power depletion. Thus, we need to implement a more power-efficient method of monitoring and transmitting the heart rate and blood pressure information.

Our solution
Our proposal, the CHASE system, seeks to un-intrusively monitor the vital signs of our users in real-time, and to provide a more robust response system. It can be broadly divided into five stages, as can be seen in *Figure 4*.

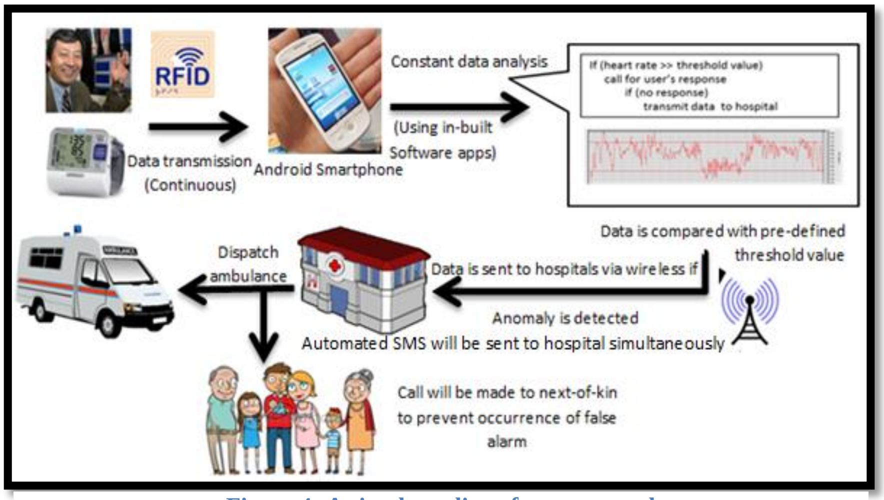

Figure 4: A simple outline of our proposal

Stage 1: Data Detection

We propose using a wristwatch device for detection. This is because monitoring equipment with the form of a watch would fulfil the criteria of being **convenient to wear for long hours and being non-intrusive**. A watch is also something most people already wear on a daily basis, and thus will allow the user to get used to the device more easily.

Suitable choices include the OMRON 7 series Wrist (Omron Healthcare Inc, 2010) or the wearable blood pressure monitor developed by MIT (Trafton, 2009), both of which can be seen in Figure 5. These devices will need to be re-programmed to constantly read the heart rate of the users, and take blood pressure measurements when the heart rate exceeds the limits.

Figure 5: OMRON 7 series Wrist-watch Monitor (left), Blood Pressure Monitor developed by MIT (right)

Both devices currently operate as standalone monitors. In order to transmit data out of these devices, we would integrate a Radio Frequency Identification (RFID) tag storing the monitored data and allowing it to be read by a RFID reader, which will be discussed further in the next stage. As an RFID tag is a passive device, we can **thus eliminate the need to have additional power supply** to the device to maintain the continuous transmission of data we require.

Stage 2: Data Management

The management of the monitored data will be performed on a smartphone that the user will carry with him/her. As smartphones are becoming more user-friendly and cheaper, more elderly people are starting to use them. According to a report from Nielson, 18% of those aged 65 and above owns a smartphone (Nielsenwire, 2011). Hence, by developing our product to be compatible with existing smartphones, we can **thus eliminate the need for users to buy additional equipment**.

The integration of smartphone technology into our system, allows us to address multiple issues concurrently. Firstly, data from the monitoring device can be retrieved using a **RFID-reader plug-in** module to the smartphone. The module will include the reader circuitry, an Omni-directional antenna and the interface to the smartphone. They will **be packaged as a phone casing**. The Omni-directional antenna will allow the phone to read the data from the device in the range of 5-10m without being directly in contact or in line-of-sight with it, thus reducing restrictions on the user's movements. (Rahman et al, 2011) This retrieval will be done automatically and constantly by a phone application. Similar ideas of adopting RFID readers have already been introduced by companies such as Wireless Dyanamics Inc. (MacManus, 2010) and Gentag Inc. (Gentag, n.d.) for other applications. It has been proven that RFID is an effective medium to transmit continuous data between two isolated devices, which is applicable to our proposal.

The recorded data will be stored in the phone memory or in the memory card in the phone for further analysis. To maintain the long reading range of the RFID reader, it is likely that we will need to include **a dedicated battery inside the plugin module** to provide the required power.

Stage 3: Data Analysis

Being an emergency system, we need to monitor the data all round the clock. It is impractical to transmit all the information to the hospital as it will simply take up too much bandwidth. Instead, the smartphone application will first analyse the heart rate and blood pressure information retrieved from the monitoring device, store them in the phone memory, and compare them against predefined threshold values. The application will detect any irregularities such as sudden spike in heartbeat or drastic drop in blood pressure, and only transmit and alert the healthcare centres if anomalies are observed.

As mentioned, these threshold values will differ from people to people. A former sportsman, for instance, might have a lower resting heart rate than one who was not. Thus, we will require first time users to seek medical evaluation and possibly have their heart rate and blood pressures monitored for a few days to determine their individual thresholds.

In addition, we can constantly update these threshold values by measuring the hourly means, daily (24hours) means, daytime and night-time averages and standard deviations. These readings are deemed necessary based on the European Society of Hypertension Guidelines (O'Brienm et al, 2003) to improve the reliability of the system. In addition to that, for every data entry, three consecutive blood pressure measurements should be recorded, analysed and weighted for more accurate and reliable results.

Stage 4: Data Transmission

When anomalies are detected, the information will be transmitted from the phone to the hospital database through an online messaging platform that will be created by us. The message will include the anomalous readings and the location of the patient. This can be done both via Wi-Fi or 3G networks. Most smartphones are not only able to utilise Wi-Fi networks to gain access to the Internet, but they can also automatically change to use 3G cellular networks when in the absence of Wi-Fi. This will ensure continuous connectivity to the hospital databases.

Stage 5: Emergency Medical Assistance

Our system will require a robust response system that eliminates false alarms as soon as possible. When an anomalous reading is registered, the phone will sound a loud alarm, which the user may deactivate if it was an erroneous reading. The alarm will also catch the attention of passers-by to come to the user's aid. An assigned care-taker, such as the user's neighbour, will also be contacted automatically by the phone's software to check on the patient. If no cancellation signal is sent within one minute, emergency services will be activated. The ambulance can then locate the user using the GPS readings from the smartphone.

Additional Features:

a. **Distress Call**
   In additional to using monitored data, we may also identify emergencies by implementing an emergency button on the device, which users may press to alert the hospitals. This can allow us to factor in events where our monitoring device cannot pick up, for example a broken ankle.

b. **Power management and Charging**
   We will include an inductive charging circuit, allowing users to have a more convenient, cable-free method of charging both the dedicated battery and the phone's battery as the same time.

Benefits of our solution over others

All-round-the-clock measurements
A feature of our system that differentiates from current telemedicine products is our ability to conduct all-round-the-clock monitoring of the elderly's health status. Hence, it can detect emergency situations such that in the occurrence of a cardiac arrest, the hospital and the user's next-of-kin will be notified in the shortest possible time and delayed treatment can be prevented. Studies have shown that for every minute interval between collapse and treatment, the survival rate decreases by 7 to 10% (Resuscitation Central, n.d.). Thus, our system can potentially save the lives of many since it deploys medical attention to them in times of emergency.

Automatic processing and transmission of measurements
Moreover, our system transmits data and analyses them automatically via a smartphone application. Unlike current systems whereby data needs to be uploaded manually and regularly in a day, the CHASE system offers greater convenience to the elderly as data is transferred to the smartphone via wireless and analysis of data is conducted automatically. This automatic service is especially useful for elderly as they might not be well-equipped with technological knowledge on uploading data.

Increased Convenience and Mobility
An important criterion that determines the elderly's receptiveness towards our system would be the product's ease of use and mobility. Most of the current products in the market are bulky and intrusive, which severely impedes the mobility of users. The device we chose to incorporate in our system is hence a wristwatch which allows minimal discomfort. Moreover, the use of smartphone technology, an increasingly common trend in society, further enhances the convenience of the product. Since most users already possess a smartphone, they are hence not required to purchase new equipment to enjoy the full benefits of the system.

Implementation plan (*Figure 6*)

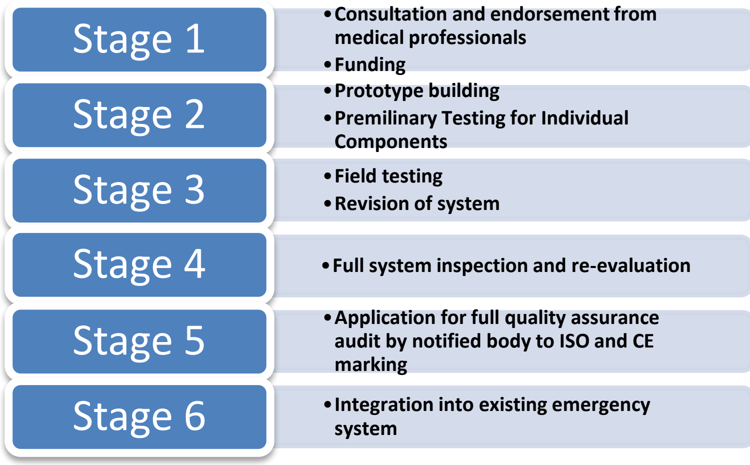

Figure 6: Implementation Plan

In the preliminary **Stage 1**, we will continue to consult medical professionals. This is to further ensure that our system is feasible and reliable from a medical point of view. We then need to seek for funding to create a prototype. The National Health Service (NHS) has a Health Services and Delivery Research Programme that provides funding for research that are relevant to improving the quality and effectiveness of NHS services (National Institute for Health Research, n.d.). This channel will be our primary source of funding for prototyping. The application is estimated to take two months, during which we will continue to apply for other relevant funding schemes, which are stated in further details in the **Appendix B**.

After acquiring sufficient sponsors, we will begin constructing a prototype in **Stage 2**. This will involve acquiring the required components, modifying the monitoring equipment, constructing the smartphone receiver module and writing the processing and communication software. We will also need to seek professional medical advice on how to evaluate and set the threshold values. The individual components will also be tested for their reliability, power consumption and integration with each other. Three months will be allocated for this stage.

In **Stage 3,** 10 volunteers aged above 65 will be invited to participate in a product trial. The purpose is twofold: to evaluate the medical and technical reliability of the system; as well as to obtain their opinions on the convenience of our product and easiness to adapt to the system. Further modifications will be carried out to remove any limitations observed. These trials will be carried out for one month.

Upon revision of the system, **Stage 4** will be carried out in collaboration with professional medical bodies on a larger scale. 50 elderly living near a target hospital will be invited to try on our system. Volunteers will pay home visits to them weekly to collate their feedback. At this stage, we also require assistance from NHS to integrate our project into their emergency system. This will involve us setting up a terminal in one of the hospital's A&E department, and our engineers will simulate the medical teaming manning the system. We will then test for the speed, reliability and false alarm rate/management for the system. Improvements to the system will be carried out constantly for the duration of this stage, which is estimated to be at least half a year.

Stage 5 will see the product undergoing a full quality assurance audit by an International Organisation for Standardisation (ISO) Notified Body, and European Conformity (CE) marking. The devices should also be inspected by contracted biomedical equipment technicians (BMETs). This application and inspection process is expected to last for five months.

Once we have gained approval from the relevant bodies, we are ready to integrate our solution into the current hospital emergency system in **Stage 6**. Healthcare workers and engineers will then be recruited and trained to be conversant with the operations and maintenance of our system in the A&E department. Distribution of the product will be done via general practitioners to introduce and teach the elderly who are keen to enrol into our health-monitoring programme. The project team will continue to manage the assembly process of the system and push it down to the end-users.

Economic Considerations

The feasibility of our solution is greatly dependent on the management of the costs involved. Many good projects have been unable to take off as they were unsustainable financially. In order to prove our project is economically viable and sustainable in the long run, we need to examine the overall cost of our project closely and weigh it against the benefits of our proposal.

Cost of implementation

Items	Cost (£)
Android SmartPhone	50.00
RFID tag	2.00
Software development	NIL
Heart rate monitor wrist watch	40.00
RFID kit (receiver, antenna and battery 3-in-1 pack)	110.00 (40.00 +50.00 + 20.00)
Total	202.00

Table 1: Implementation Cost Breakdown for Every Package

The table above shows the breakdown of the costs of the components that will be required for CHASE. For the manufacturing process, we intend to outsource production and assembly to external companies. Not only we can eliminate the need for factory setup, we can also push down the manufacturing cost through large-scale production. As a safety precaution to protect ourselves from non-negligible risk, it is necessary for us to apply for insurance against faulty devices.

We also have to account for other fixed cost such as assurance audits, CE marking, construction of data transmission infrastructure, recruitment and training of medical personnel to handle our emergency system, and of software and hardware engineers for maintenance work. These are estimated to sum up to £10 million per annum.

Justification

The main objective of our proposal is to save lives. Hence, it is our responsibility to ensure the cost is kept minimal and affordable for the end users to benefit from the programme. Where possible, we will look into bulk purchases to lower the cost price of the equipment. Through rough estimation, every user is only expected to pay **a small sum of £200** *(Table 1)* to be part of this healthcare system.

Given the nature of our product, our closest substitute would be hiring a caretaker. According to PayScale, an experienced caretaker in UK is projected to have an hourly rate of £6-10 (Payscale, 2012) . That would amount up to £336 a week. In comparison, our system is much more cost effective in the long run. There may be additional maintenance of the equipment, but we will try to keep it to a minimum by using more durable components.

The cost of providing medical support, coupled with increasing ageing population is one of the main cost drivers of NHS's annual budget. Last year, 4% (£4.23bn) of NHS's annual budget was dedicated to elderly social care and local authorities contributed another £7.21bn (Hill, 2010). Our project will potentially utilise this budget more efficiently, as it cuts down on social care from healthcare worker.

Ultimately, the key performance indicator of our product should be the number of lives saved. Through reducing the delay in medical response, we are potentially able to increase survival rates and save more lives.

Possible areas of further development

1. **User Interface**
   As many of our target users may suffer from high blood pressure or related diseases, being able to access the monitoring data will allow them to be able to better understand and manage their health condition. A smartphone application would be ideal for this purpose, as we would be able to display full-colour, summarised info-charts of the collect data on the LCD display of the phone. Through this process, users can play a more active role in monitoring their own physical health. Data stored in smartphones can also be accessed and analysed by doctor during their body check-ups.

2. **Telemedicine**
   Doctors and care-takers have long been using SMS to send appointment and medication reminders to their patients or wards. These messages can be integrated into the application, providing a one-stop system in which patients can self-review their health status, read reminders from their doctors as well as schedule for the next medical appointment.

3. **Compatibility with Future Devices**
   The CHASE system is designed to be modular and would be able to modify relevant sections to adapt to other uses or future technology. In particular, we foresee the possibility of replacing the wristwatch with a fabric-integrated MIR chip, which will be able to monitor heart muscle contractions with the user barely conscious of its presence.

Conclusion

In all, the CHASE system will maintain a continuous and uninterrupted measurement of the vital signs of elderly staying alone, thus allowing emergency services to reach them at the fastest possible time when any mishap occur. The team have put in extra consideration to ensure that the system will be reliable and user-friendly, yet at the same time affordable and economically sustainable. With aging population becoming a major problem worldwide, the system will allow families and friends to sleep more soundly at night, knowing that their elderly loved ones are being taken care.

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