WIRELESS INDUSTRIAL PERSONAL PROTECTIVE EQUIPMENT THROUGH INTERNET-OF-THING TECHNOLOGY IN HEAVY INDUSTRIES

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WIRELESS INDUSTRIAL PERSONAL PROTECTIVE EQUIPMENT THROUGH INTERNET-OF-THING TECHNOLOGY ADVISOR: ASST. PROF. DR. WIMOL SAN-UM, 60 PP.

This paper presents the design and implementation of wireless industrial personal protective equipment (PPE) through internet-of-thing (IoT) technology. Since modern digital technologies have been introduced into the industry, this paper has designed personal injury protection equipment by installing sensors for real-time monitoring of operator health conditions. The proposed system so-called "Smart PPE" includes a warning system when problems or irregularities occur to hazardous operators to protect lives. It is also a tool to prevent or reduce risks of harm to industrial plants. This paper employs Raspberry Pi as a controller to collect data from various sensors, and installed on PPE to send the integrated information over the wireless networks. The data were analyzed in the database system on the cloud server, and will report to the central agency for notification and collect information to keep a record. It is expected to be useful for heavy industries where operators are working in high risk areas.

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Introduction

1.1 Introduction

This chapter introduces backgrounds of research approaches, including the design and implementation of wireless industrial personal protective equipment (PPE) through internet-of-thing (IoT) technology for Industrial hazardous conditions, Motivations, statement of problem, research objectives, expected outcomes, and definition of technical terms are also included

1.2 Backgrounds

The current economic and social conditions make it difficult for occupations to work in a competitive, rushed and competitive environment, regardless of occupation. Everybody must keep up with the rapid change with new technologies. Business owners only focus on productivity but do not care about safety, which is the cause of the danger of the accident of operators, injury or risk of illness. This can cause illness, both physical and mental, until death has a long-term impact on families, society and the nation. In addition, operators' illnesses also have an impact on the workplace because those in danger are unable to work. When the lack of an operator results in higher production costs and the effect of panicking and morale. At present, enterprises are more interested in working on the safety of their work. At present, businesses are more interested in working on safety in their workplace, and at the same time, the employer considers the benefits of increased productivity and protection or reduce the loss of man-power with raw materials along the way. Therefore, the establishment or the owner will try to develop the technology to work by empowering operators with reducing accident statistics and job insecurity. The idea of bringing modern technology into the mix, combined with a new approach in the industry today. This can bring advanced computer systems and intelligent electronics to help solve industrial plant for safety problems by transforming traditional industrial plants into intelligent industrial plants. Intelligent industrialization is the new evolution of information in the factory. Connecting devices together through the network is the first step towards the Smart

Industrials. However, the equipment and machinery used in the manufacturing industry are diverse and varied. So, developing a system that can monitor the status of equipment is extremely difficult for finding effective ways to collect production status data from individual brands that use different connection protocols to use them for analysis for remote monitoring to reduce maintenance and operational costs, optimize production monitoring. It also protects against hazardous industrial conditions. This thesis incorporates all potential hazardous conditions in the industry and implement industrial PPE to Smart PPE for operators to wear while working to prevent short- and long-term hazards that may affect the wearer. These will help prevent accidents or reduce the risk of heavy injuries to light, such as if using safety equipment, it will reduce the risk of work more than ever. PPE is potentially the last barrier might as well be the final option to alleviate the effects of a possible accident. Despite accident causation and prevention techniques, motivating and controlling workers to wear PPE needs its own efforts. Employers may address the use of PPE in three ways: (1) education and training, (2) incentives, and (3) enforcement. Some operator not prefer to wear PPE because they either forget or find it uncomfortable to wear PPE. Other factors (a) PPE may impact productivity, (b) exposure to a hazard is short and thus PPE is not needed, and (c) inadequate or not available education and training for using PPE. To solve these issues, employers can improve the consistency of PPE use by applying best practices assisted through novel technology. These could then meet the employer's responsibility of enforcing safety rules by undertaking changes in controlling PPE and related processes.

Employers (enterprises or business owner) can potentially improve the rate operators wear PPE on production sites by putting more value on safety education, training, and enforcement. One way is a system that might not be too intrusive, but reminds workers daily or at the beginning of hazardous work that appropriate PPE must be worn at all times. This could be emphasized by erecting a PPE control gate at the entry of or close to hazardous work spaces at or within production sites.

1.3 Motivations

Today's factories do not have the ability to use Internet technology to find, track, and link all information within a plant. Particularly for safety reasons, the researcher realized this problem required the creation of a human resource package with all the Internet technology for industrial hazardous conditions. To collect information and to prevent or reduce the risk of hazards in the factory. And for the industrial model to be applied to intelligent industrial plants in the near future as well. According to a survey of production line staff at a factory in Eastern Seaboard Industrial Estate, Rayong, there were resignations or requests to replace the station in the production line because they had health problems. For example, back pain often causes inability to work, frequent flu, lack of or frequent job loss including various diseases, etc. At present, this problem also occurs regularly. Researchers have installed a Motion Sensor (Gyro Sensor and Accelerator Sensor) into the Smart PPE to measure the movement of employees that are follow "the Ergonomically" and install a gas sensor to measure the amount of toxic gases around the wearer to checks for long term health problems. And from inquiries to the safety department at a factory in Eastern Seaboard Industrial Estate, Rayong, it was found that most of the accidents in the factory were from employees who were not ready to work, such as flu, not enough rest. So, the Heart Rate Monitor Sensor was installed for real-time heart rate monitoring, and then analyzed and monitored whether the wearer was in a working state to protect himself. Accuracy will happen to the wearer if not in working condition.

1.4 Objective

1.4.1 To design a personal protective equipment design with Internet technology in all things for industrial hazardous conditions.

1.4.2 To develop a prototype of a personal protective equipment kit containing various sensors that can be displayed and measured in real time.

1.5 Research Scope

Development of personal protective equipment consists of a Heart Rate Monitor Sensor, a Gyro Sensor, Accelerator Sensor; a sensor used to detect movement of an object and Magnetic Sensor. The 4 sensors are connected to a wireless transmitter by using a 3 ~ 5 Volt lithium battery system. To send data through a flammable system to display on the web application. Including a system to alert you when something is wrong with a real-time monitoring hazardous worker.

1.6 Expected Outcomes

1.6.1 Develop personal protective equipment kit with internet of thing technology in industrial hazardous conditions.

1.6.2 Develop a prototype of a personal protective equipment kit that includes various types of sensors that can be displayed in real time.

1.6.3 Design Web application that alerts the user of a real-time personal injury protection kit.

Chapter2

Related Theories and Literature Reviews

2.1 Introduction

This chapter gives information of related theories including Safety Management System theory, Heinrich's Domino Theory and Personal Protective Equipment. The literature reviews of Publications on Recent Advances on IoT-Based PPEs, Related Technology and Commercially Available Smart PPEs are also included.

2.2 Related Theory

2.2.1 Safety Management System [1]

The need for improved safety handling has been obvious since the first accidents in aviation. The more complex aircraft became, the more complex their associated safety topics became. This factsheet describes the aviation industry's Safety Management Systems as they address the needs of modern day flight operations. A Safety Management System is a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures (ICAO, 2013). The objective of an SMS is to improve safety performance through a structured management approach that reduces the risk of accident. An SMS consists of four main activities – pillars that consist of multiple elements as depicted in Figure 2.1. They are: Policy and Objectives; Safety Risk Management; Safety Assurance; and Safety Promotion.

The first pillar of an SMS is Safety Policy and Objectives. This pillar consists of three elements: management commitment, safety accountabilities, and the appointment of key safety personnel. The ICAO Safety Management Manual (SMM) states that the coordination of emergency response planning and a documentation of the SMS are part of the Safety Policy and Objectives . The management of an organization must commit to safety if the SMS is to work properly. This includes providing the necessary resources for the SMS and its implementation, following procedures for reporting incidents and accidents, and supplying employees with information regarding behavior standards for aviation activities (as well as stating the kinds of risk deemed acceptable and unacceptable). Management commitment should be signed by a 'responsible executive' and then communicated throughout the entire organization. The management or responsible executive should also ensure that the document stays accurate and relevant. An executive should be appointed with final responsibility and accountability for the SMS' implementation and maintenance. They should be supported by a line of safety-accountable managers, with a pre-determination of which managers (and at what level in the organization) have the authority to make decisions regarding safety risk tolerability. Aside from accountable managers, a safety manager is also needed to implement the SMS and keep it up to date. This safety manager should have direct access to the responsible executive, and a position above the line managers in the organization – as shown in Figure 2.2.

Figure 2.1 The Four Pillars of Safety Management

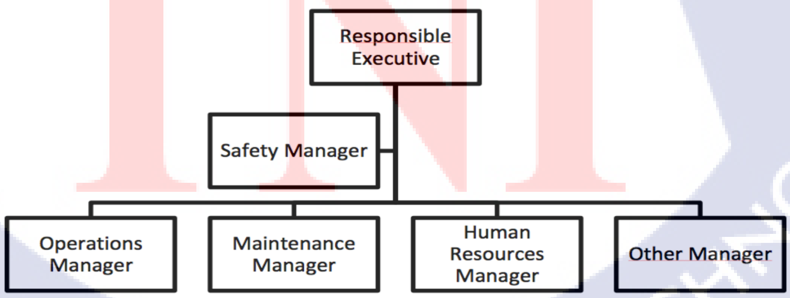


Figure 2.2 Structure tree showing the position of the safety manager

The second pillar of an SMS is Safety Risk Management. This part consists of hazard identification and risk assessment. A hazard is defined as a condition or an object with the potential to cause death, injuries to personnel, damage to equipment or structures, loss of material, or reduction of the ability to perform a prescribed function Ideally, hazards should be detected before they lead to accidents or incidents. Reporting systems, inspections and audits are used to achieve this. However, some hazards can be identified from the study of accident investigation reports. There are three methodologies for hazard identification: the reactive way (an analysis of past events); the proactive way (an analysis of real-time situations); and the predictive way (the use of data gathering to identify possible negative future events). Risk assessment is the projected likelihood and severity of the consequence or outcome from an existing hazard. Due to the endless number, Responsible Executive Operations Manager Maintenance Manager Human Resources Manager Other Manager Safety Manager SAFETY MANAGEMENT SYSTEM FACT SHEET of different hazards, a wide variety of risks emerge. Not every risk can be mitigated or excluded, so safety risk must be categorized. These categories are specified in the Safety Policy, which assesses the broad range of risks in aviation, their probability, and their severity. There are five different grades of likelihood, ranging from extremely improbable to frequent (see Figure 3). Every grade has its own number, from 1 (extremely improbable) to 5 (frequent).

There are five different grades of severity, ranging from negligible to catastrophic Every grade has its own letter, from A (catastrophic) to E (negligible). These letters are also used in the risk assessment matrix. This leads to three different regions: the intolerable region (red), the tolerable region (yellow) and the acceptable region (green). Risks assessed in the red region are unacceptable under any circumstances, and operations associated with them must stop immediately. Risks assessed in the yellow region need appropriate mitigation strategies. Risks assessed in the green region require no further action

Safety Assurance is the third pillar of the SMS, and is the part that shows whether an organisation is safe. This is done by monitoring the identified risks and measuring safety performance in the organisation. Safety Assurance also contains a feedback system for the SMS when processes change or new hazards are identified. In such cases, this new information is incorporated into the SMS is to keep it complete – and the organisation safe. Safety must be measured and monitored to know if the SMS is working. This can be done by: - Introducing a reporting system for hazards and occurrences. The reporting system can be made mandatory or voluntary (mandatory reporting systems tend to collect more information about high consequence technical failures than other operational activities). In all cases, it is advised to educate personnel on the needs of the reporting system, as well as on how the reporting system is to be used. - Using safety studies that are conducted mostly by large organizations or government institutions, which provide information to improve safety. - Conducting safety reviews when a new technique or procedure is introduced, to show how they might influence safety in the organization. - Conducting safety surveys to create an expanded view of an organization's safety, and where potential problems may lie. - Conducting audits for the assurance of safety management functions, such as training or staffing. - Conducting internal investigations when serious (or minor) incidents or accidents happen.

The fourth pillar of the SMS describes Safety Promotion. A safety culture must always exist in an organisation, and it should be promoted with positive supporting practices. Safety Promotion includes training, education and communication to create a safety culture across all levels of an organisation. A written SMS policy in an organisation is not enough for success. Management should convey, enhance, and emphasize the organization's safety policy by exemplifying it in their daily work and in their one-on-one leadership styles. Managers must make sure that the safety policy is continuously promoted and enhanced. Employees must be provided with training and education to promote safety awareness, and safety information systems accessible to all employees should form part of the educational approach. A good safety culture depends on effective communication of the SMS policies, existing processes, tools and other related information. The SMS aims to ensure that all employees in an organisation have sufficient SMS awareness and that important information is transferred. Clear explanations regarding specific actions and safety procedures must be conveyed.

For the SMS to work properly, all four pillars must be stable, and more importantly, the interaction between the pillars must be managed. A proper safety policy that defines an organization's commitment to safety helps ensure that risk management is conducted properly, making known which risks are deemed acceptable and which are not. The same goes for the safety assurance and the safety policy – clear safety goals must be stated. Interaction between the pillars as shown in Figure 2.3

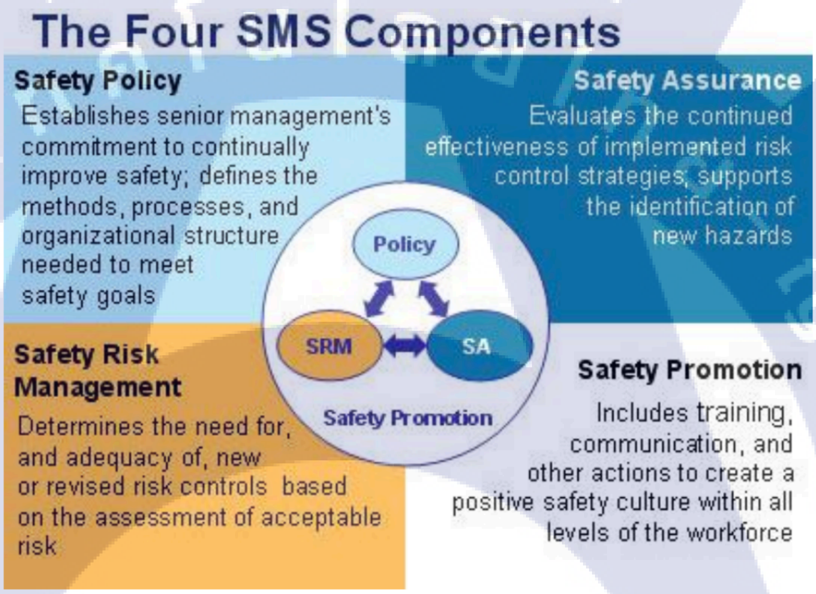


Figure 2.3 Interaction between the four SMS pillars

Safety Risk Management and Safety Assurance are the active pillars SRM starts with an analysis of the system, followed by hazard identification and risk analysis. Then a risk assessment is made: if deemed unacceptable, it must be controlled, after which the process starts over. If deemed acceptable, then safety assurance kicks in, first with the regular system operation, from which data is acquired and analyzed. Then an assessment of the system is made: if it conforms to the planned safety, no further action is required and the system can continue to operate under supervision of the SMS. If it does not conform to the planned safety, corrective actions are taken, after which the system can continue to operate. If new hazards are identified, the system starts from the beginning with a new analysis for the risk management. Without the safety promotion pillar, the workforce would be inadequately trained and would not have proper safety education. This would mean that safety is only managed from the top of the company, with less priority on the work floor, and potential hazards could be missed

2.2.2 Heinrich's Domino Theory [2]

Heinrich's Domino Theory states that accidents result from a chain of sequential events, metaphorically like a line of dominoes falling over. When one of the dominoes falls, it triggers the next one, and the next... but removing a key factor (such as an unsafe condition or an unsafe act) prevents the start of the chain reaction. According to Heinrich, all incidents directly relate to unsafe conditions and acts, which he defines as “unsafe performance of persons, such as standing under suspended loads ... horseplay, and removal of safeguards”; and “mechanical or physical hazards such as unguarded gears ... and insufficient light.” These have been described in detail in human behavior and errors in Module 7. Heinrich posits five metaphorical dominoes labelled with accident causes. They are Social Environment and Ancestry, Fault of Person, Unsafe Act or Mechanical or Physical Hazard (unsafe condition), Accident, and Injury. Heinrich defines each of these "dominoes" explicitly, and gives advice on minimizing or eliminating their presence in the sequence.

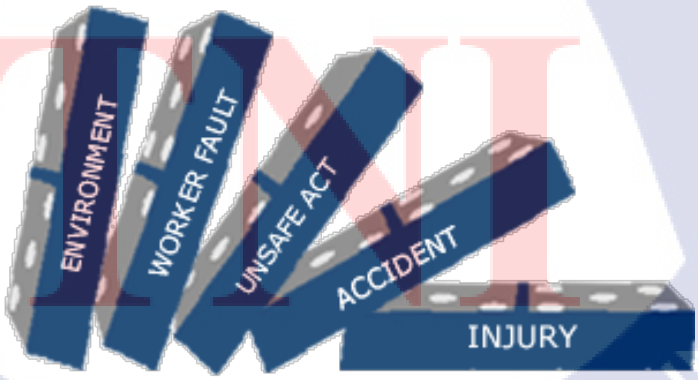


Figure 2.4 Heinrich's Domino Model of Accident Causation

(1) Social Environment and Ancestry: This first domino in the sequence deals with worker personality. Heinrich explains that undesirable personality traits, such as stubbornness, greed, and recklessness can be "passed along through inheritance" or develop from a person's social environment, and that both inheritance and environment (what we usually refer to now as "nature" and "nurture") contribute to Faults of Person. (2) Fault of Person: The second domino also deals with worker personality traits. Heinrich explains that inborn or obtained character flaws such as bad temper, inconsiderateness, ignorance, and recklessness contribute at one remove to accident causation. According to Heinrich, natural or environmental flaws in the worker's family or life cause these secondary personal defects, which are themselves contributors to Unsafe Acts, or and the existence of Unsafe Conditions. (3) Unsafe Act and/or Unsafe Condition: The third domino deals with Heinrich's direct cause of incidents. As mentioned above, Heinrich defines these factors as things like "starting machinery without warning ... and absence of rail guards. " Heinrich felt that unsafe acts and unsafe conditions were the central factor in preventing incidents, and the easiest causation factor to remedy, a process which he likened to lifting one of the dominoes out of the line. These combining factors (1, 2, and 3) cause accidents. Heinrich defines four reasons why people commit unsafe acts "improper attitude, lack of knowledge or skill, physical unsuitability, [and] improper mechanical or physical environment." He later goes on to subdivide these categories into "direct" and "underlying" causes. For example, he says, a worker who commits an unsafe act may do so because he or she is not convinced that the appropriate preventative measure is necessary, and because of inadequate supervision. The former he classifies as a direct cause, the latter as an underlying cause. This combination of multiple causes, he says, create a systematic chain of events leading to an accident. (4) Accident: Heinrich says, "The occurrence of a preventable injury is the natural culmination of a series of events or circumstances which invariably occur in a fixed and logical order." He defines accidents as, "events such as falls of persons, striking of persons by flying objects are typical accidents that cause injury." (5) Injury: Injury results from accidents, and some types of injuries Heinrich specifies in his "Explanation of Factors" are cuts and broken bones. To be fair to Heinrich, he does insist that "the responsibility lies first of all with the employer." Heinrich specifies that a truly safety-conscious manager will make sure his "foremen"

and "workers" do as they told, and "exercise his prerogative and obtain compliance ... follow through and see the unsafe conditions are eliminated." Heinrich's remedy for such non-compliance is strict supervision, remedial training, and discipline.

2.2.3 Personal Protective Equipment [3]

Personal protective equipment (PPE) ; protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection. The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter. Protective equipment may be worn for job-related occupational safety and health purposes, as well as for sports and other recreational activities. "Protective clothing" is applied to traditional categories of clothing, and "protective gear" applies to items such as pads, guards, shields, or masks, and others. The purpose of personal protective equipment is to reduce employee exposure to hazards when engineering controls and administrative controls are not feasible or effective to reduce these risks to acceptable levels. PPE is needed when there are hazards present. PPE has the serious limitation that it does not eliminate the hazard at source and may result in employees being exposed to the hazard if the equipment fails. Any item of PPE imposes a barrier between the wearer/user and the working environment. This can create additional strains on the wearer; impair their ability to carry out their work and create significant levels of discomfort. Any of these can discourage wearers from using PPE correctly, therefore placing them at risk of injury, ill-health or, under extreme circumstances, death. Good ergonomic design can help to minimize these barriers and can therefore help to ensure safe and healthy working conditions through the correct use of PPE. Practices of occupational safety and health can use hazard controls and interventions to mitigate workplace hazards, which pose a threat to the safety and quality of life of workers. The hierarchy of hazard controls provides a policy framework which ranks the types of hazard controls in terms of absolute risk reduction. At the top of the hierarchy are elimination and substitution, which remove the hazard entirely or replace the hazard with a safer alternative. If elimination or substitution measures cannot apply, engineering controls and administrative controls, which seek to design safer mechanisms and coach safer human behavior, are implemented. Personal protective equipment ranks last on the hierarchy of controls, as the workers are regularly exposed to the hazard, with a barrier of protection. The hierarchy of controls is important in acknowledging that, while personal protective equipment has tremendous utility, it is not the desired mechanism of control in terms of worker safety.

Figure 2.5 Personal protective equipment

Personal protective equipment can be categorized by the area of the body protected, by the types of hazard, and by the type of garment or accessory. A single item, for example boots, may provide multiple forms of protection: a steel toe cap and steel insoles for protection of the feet from crushing or puncture injuries, impervious rubber and lining for protection from water and chemicals, high reflectivity and heat resistance for protection from radiant heat, and high electrical resistivity for protection from electric shock. The protective attributes of each piece of equipment must be compared with the hazards expected to be found in the workplace. More breathable types of personal protective equipment may not lead to more contamination but do result in greater user satisfaction.

(1) Respirators (*Main article: Respirator*) Respirators serve to protect the user from breathing in contaminants in the air, thus preserving the health of one's respiratory tract. There are two main types of respirators. One type functions by filtering out

chemicals and gases, or airborne particles, from the air breathed by the user. The filtration may be either passive or active (powered). Gas masks and particulate respirators are examples of this type of respirator. A second type protects users by providing clean, respirable air from another source. This type includes airline respirators and self-contained breathing apparatus (SCBA). In work environments, respirators are relied upon when adequate ventilation is not available or other engineering control systems are not feasible or inadequate. In the United Kingdom, an organization that has extensive expertise in respiratory protective equipment is the Institute of Occupational Medicine. This expertise has been built on a long-standing and varied research programmed that has included the setting of workplace protection factors to the assessment of efficacy of masks available through high street retail outlets The Health and Safety Executive (HSE), NHS Health Scotland and Healthy Working Lives (HWL) have jointly developed the RPE (Respiratory Protective Equipment) Selector Tool, which is web-based. This interactive tool provides descriptions of different types of respirators and breathing apparatuses, as well as "dos and don'ts" for each type. In the United States, The National Institute for Occupational Safety and Health (NIOSH) provides recommendations on respirator use, in accordance to NIOSH federal respiratory regulations 42 CFR Part 84. The National Personal Protective Technology Laboratory (NPPTL) of NIOSH is tasked towards actively conducting studies on respirators and providing recommendations

(2) Skin protection Occupational skin diseases such as contact dermatitis, skin cancers, and other skin injuries and infections are the second-most common type of occupational disease and can be very costly. Skin hazards, which lead to occupational skin disease, can be classified into four groups. Chemical agents can come into contact with the skin through direct contact with contaminated surfaces, deposition of aerosols, immersion or splashes.[6] Physical agents such as extreme temperatures and ultraviolet or solar radiation can be damaging to the skin over prolonged exposure. Mechanical trauma occurs in the form of friction, pressure, abrasions, lacerations and contusions. Biological agents such as parasites, microorganisms, plants and animals can have varied effects when exposed to the skin. Any form of PPE that acts as a barrier between the skin and the agent of exposure can be considered skin protection. Because much work is done with the hands, gloves are an essential item in providing skin protection.

Some examples of gloves commonly used as PPE include rubber gloves, cut-resistant gloves, chainsaw gloves and heat-resistant gloves. For sports and other recreational activities, many different gloves are used for protection, generally against mechanical trauma. Other than gloves, any other article of clothing or protection worn for a purpose serve to protect the skin. Lab coats for example, are worn to protect against potential splashes of chemicals. Face shields serve to protect one's face from potential impact hazards, chemical splashes or possible infectious fluid.

(3) Eye protection A paintball player wearing appropriate eye protection against impact. Each day, about 2000 US workers have a job-related eye injury that requires medical attention. Eye injuries can happen through a variety of means. Most eye injuries occur when solid particles such as metal slivers, wood chips, sand or cement chips get into the eye. Smaller particles in smokes and larger particles such as broken glass also account for particulate matter-causing eye injuries. Blunt force trauma can occur to the eye when excessive force meets the eye. Chemical burns, biological agents, and thermal agents, from sources such as welding torches and UV light, also contribute to occupational eye injury. While the required eye protection varies by occupation, the safety provided can be generalized. Safety glasses provide protection from external debris, and should provide side protection via a wrap-around design or side shields. Goggles provide better protection than safety glasses, and are effective in preventing eye injury from chemical splashes, impact, dusty environments and welding. Goggles with high air flow should be used to prevent fogging. Face shields provide additional protection and are worn over the standard eyewear; they also provide protection from impact, chemical, and blood-borne hazards. Full-face piece respirators are considered the best form of eye protection when respiratory protection is needed as well, but may be less effective against potential impact hazards to the eye. Eye protection for welding is shaded to different degrees, depending on the specific operation.

(4) Hearing protection Industrial noise is often overlooked as an occupational hazard, as it is not visible. Overall, about 22 million workers in the United States are exposed to potentially damaging noise levels each year. Occupational hearing loss accounted for 14% of all occupational illnesses in 2007, with about 23,000 cases significant enough to cause permanent hearing impairment. About 82% of occupational

hearing loss cases occurred to workers in the manufacturing sector. The Occupational Safety and Health Administration establishes occupational noise exposure standards. NIOSH recommends that worker exposures to noise be reduced to a level equivalent to 85 dBA for eight hours to reduce occupational noise-induced hearing loss. PPE for hearing protection consists of earplugs and earmuffs. Workers who are regularly exposed to noise levels above the NIOSH recommendation should be furnished hearing protection by the employers, as they are a low-cost intervention. This form of PPE is all-encompassing and refers to the various suits and uniforms worn to protect the user from harm. Lab coats worn by scientists and ballistic vests worn by law enforcement officials, which are worn on a regular basis, would fall into this category. Entire sets of PPEs, worn together in a combined suit, are also in this category.

(5) Ensembles Below are some examples of ensembles of personal protective equipment, worn together for a specific occupation or task, to provide maximum protection for the user. Chainsaw protection (especially a helmet with face guard, hearing protection, Kevlar chaps, anti-vibration gloves, and chainsaw safety boots). Bee-keepers wear various levels of protection depending on the temperament of their bees and the reaction of the bees to nectar availability. At minimum, most bee keepers wear a brimmed hat and a veil made of fine mesh netting. The next level of protection involves leather gloves with long gauntlets and some way of keeping bees from crawling up one's trouser legs. In extreme cases, specially fabricated shirts and trousers can serve as barriers to the bees' stingers. Diving equipment, for underwater diving, constitutes equipment such as a diving helmet or diving mask, an underwater breathing apparatus, and a diving suit. Firefighters wear PPE designed to provide protection against fires and various fumes and gases. PPE worn by firefighters include bunker gear, self-contained breathing apparatus, a helmet, safety boots, and a PASS device.

The situation of using PPE in Thailand; From economic and social prosperity, working conditions in various occupations. Including statistics of People who suffer from dangers of work. This may be due to working in an incorrectly designed workplace. Work in an unsafe workplace or in an unsafe working environment, both physical, biological, chemical and social psychologically because disease caused by work. Including accidents, injuries or disabilities to the point of dying from work, there is a chance at all times. Although sometimes the establishment will have a planned structure. The engineering design is good, but some work has limitations that cannot be used in engineering to solve the problem. Therefore, it is necessary to design the device, facilities to assist in the control and prevention of personal injury, the operator must use such equipment to prevent hazards that may occur while working, along with other control and preventive measures as necessary in operation to ensure maximum safety. The most important occupational protection devices are personal protective equipment.

2.3 Related Technology

2.3.1 Arduino [4]

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) to load new code onto the board – you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package. Arduino makes several different boards, each with different capabilities. In addition, part of being open source hardware means that others can modify and produce derivatives of Arduino boards that provide even more form factors and functionality.

(1) Arduino Uno (R3) ; the Uno has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a USB connection, a power jack, a reset button and more. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

Figure 2.6 Arduino Uno (R3)

Figure 2.7 LilyPad Arduino

(2) LilyPad Arduino ;this is LilyPad Arduino main board! LilyPad is a wearable e-textile technology developed by Leah Buechley and cooperatively designed by Leah and SparkFun. Each LilyPad was creatively designed with large connecting pads and a flat back to allow them to be sewn into clothing with conductive thread. The LilyPad also has its own family of input, output, power, and sensor boards that are also built specifically for e-textiles. They're even washable!

(3) RedBoard; at SparkFun we use many Arduinos and we're always looking for the simplest, most stable one. Each board is a bit different and no one board has everything we want – so we decided to make our own version that combines all our favorite features. The RedBoard can be programmed over

a USB Mini-B cable using the Arduino IDE. It'll work on Windows 8 without having to change your security settings (we used signed drivers, unlike the UNO). It's more stable due to the USB/FTDI chip we used, plus it's completely flat on the back, making it easier to embed in your projects. Just plug in the board, select "Arduino UNO" from the board menu and you're ready to upload code. You can power the RedBoard over USB or through the barrel jack. The on-board power regulator can handle anything from 7 to 15VDC.

Figure 2.8 RedBoard

Figure 2.9 Arduino Mega (R3)

(4) Arduino Mega (R3); the Arduino Mega is like the UNO's big brother. It has lots (*54!*) of digital input/output pins (14 can be used as PWM outputs), 16 analog inputs, a USB connection, a power jack, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The large number of pins make this board very handy for projects that require a bunch of digital inputs or outputs (like lots of LEDs or buttons).

(5) Arduino Leonardo; the Leonardo is Arduino's first development board to use one microcontroller with built-in USB. This means that it can be cheaper and simpler. Also, because the board is handling USB directly, code libraries are available which allow the board to emulate a computer keyboard, mouse, and more!

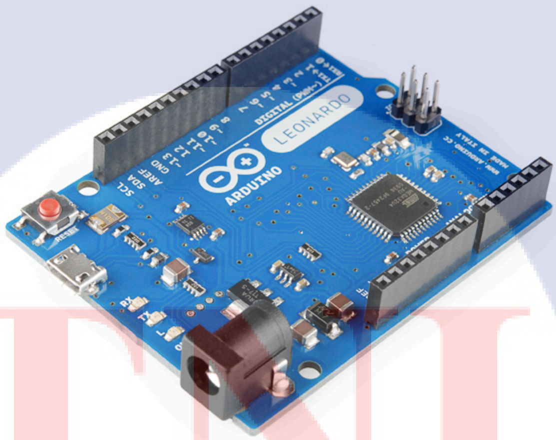


Figure 2.10 Arduino Leonardo

The Arduino hardware and software was designed for artists, designers, hobbyists, hackers, newbies, and anyone interested in creating interactive objects or environments. Arduino can interact with buttons, LEDs, motors, speakers, GPS units, cameras, the internet, and even your smart-phone or your TV! This flexibility combined with the fact that the Arduino software is free, the hardware boards are low cost, and both the software and hardware are easy to learn has led to a large community of users who have contributed code and released instructions for a huge variety of Arduino-based projects. For everything from robots and a heating pad hand warming blanket to honest fortune-telling machines, and even a Dungeons and Dragons dice-throwing gauntlet, the Arduino can be used as the brains behind almost any electronics project. There are many varieties of Arduino boards that can be used for different purposes. Some boards look a bit different from the one below, but most Arduinos have the components in common as shown in Fig 2.9

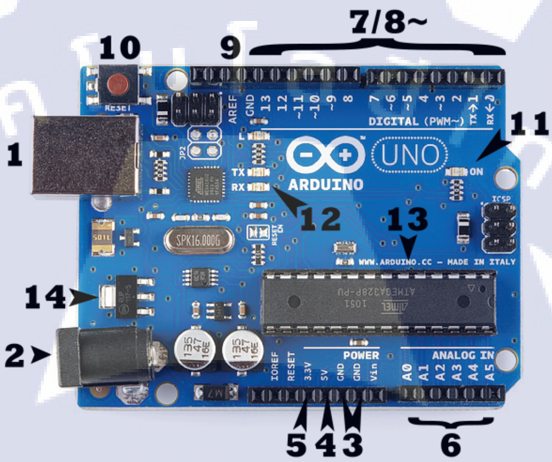


Figure 2.11 the components in common

(a) Power (USB / Barrel Jack)Every Arduino board needs a way to be connected to a power source. The Arduino UNO can be powered from a USB cable coming from your computer or a wall power supply that is terminated in a barrel jack. In the picture above the USB connection is labeled **(1)** and the barrel jack is labeled **(2)**.The USB connection is also how you will load code onto your Arduino board. More on how to program with Arduino can be found in our Installing and Programming Arduino tutorial. The recommended voltage for most Arduino models is between 6 and 12 Volts.

(b) Pins (5V, 3.3V, GND, Analog, Digital, PWM, AREF); the pins on your Arduino are the places where you connect wires to construct a circuit (probably in conjunction with a breadboard and some wire. They usually have black plastic ‘headers’ that allow you to just plug a wire right into the board. The Arduino has several different kinds of pins, each of which is labeled on the board and used for different functions.

- GND (3): Short for ‘Ground’. There are several GND pins on the Arduino, any of which can be used to ground your circuit.
- 5V (4) & 3.3V (5): As you might guess, the 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the Arduino run happily from 5 or 3.3 volts.
- Analog (6): The area of pins under the ‘Analog In’ label (A0 through A5 on the UNO) are Analog In pins. These pins can read the signal from an analog sensor (like a temperature sensor) and convert it into a digital value that we can read.
- Digital (7): Across from the analog pins are the digital pins (0 through 13 on the UNO). These pins can be used for both digital input (like telling if a button is pushed) and digital output (like powering an LED).
- PWM (8): You may have noticed the tilde (~) next to some of the digital pins (3, 5, 6, 9, 10, and 11 on the UNO). These pins act as normal digital pins, but can also be used for something called Pulse-Width Modulation (PWM). We have a tutorial on PWM, but for now, think of these pins as being able to simulate analog output (like fading an LED in and out).
- AREF (9): Stands for Analog Reference. Most of the time you can leave this pin alone. It is sometimes used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

(c) Reset Button; just like the original Nintendo, the Arduino has a reset button (10). Pushing it will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino. This can be very useful if your code doesn’t repeat, but you want to test it multiple times. Unlike the original Nintendo however, blowing on the Arduino doesn’t usually fix any problems.

(d) Power LED Indicator; just beneath and to the right of the word “UNO” on your circuit board, there’s a tiny LED next to the word ‘ON’ (11). This LED should light up whenever you plug your Arduino into a power source. If this light doesn't turn on, there's a good chance something is wrong. Time to re-check your circuit!

(e) TX RX LEDs is short for transmit, RX is short for receive. These markings appear quite a bit in electronics to indicate the pins responsible for serial communication. In our case, there are two places on the Arduino UNO where TX and RX appear – once by digital pins 0 and 1, and a second time next to the TX and RX indicator LEDs (12). These LEDs will give us some nice visual indications whenever our Arduino is receiving or transmitting data (like when we're loading a new program onto the board).

(f) Main IC ;the black thing with all the metal legs is an IC, or Integrated Circuit (13). Think of it as the brains of our Arduino. The main IC on the Arduino is slightly different from board type to board type, but is usually from the AT mega line of IC's from the ATMEL company. This can be important, as you may need to know the IC type (along with your board type) before loading up a new program from the Arduino software. This information can usually be found in writing on the top side of the IC. If you want to know more about the difference between various IC's, reading the datasheets is often a good idea.

(g) Voltage Regulator; the voltage regulator (14) is not actually something you can (or should) interact with on the Arduino. But it is potentially useful to know that it is there and what it's for. The voltage regulator does exactly what it says – it controls the amount of voltage that is let into the Arduino board. Think of it as a kind of gatekeeper; it will turn away an extra voltage that might harm the circuit. Of course, it has its limits, so don't hook up your Arduino to anything greater than 20 volts.

While your Arduino board sure is pretty, it can't do a whole lot on its own – you've got to hook it up to something. There are lots of tutorials here on learn as well as the links back in the 'What does it do' section, but rarely do we talk about the general *kinds* of things you can easily hook into. In this section, we'll introduce basic sensors as well as Arduino shields, two of the handiest tools to use in bringing your projects to life. (1) Sensors With some simple code, the Arduino can control and interact with a wide variety of sensors - things that can measure light, temperature, degree of flex, pressure, proximity, acceleration, carbon monoxide, radioactivity, humidity, barometric pressure, you name it, you can sense it! (2) Shields Additionally, there are these things called shields – basically they are pre-built circuit boards that fit on top of your Arduino and provide additional capabilities controlling motors, connecting to the internet, providing cellular or other wireless communication, controlling an LCD screen, and much more.

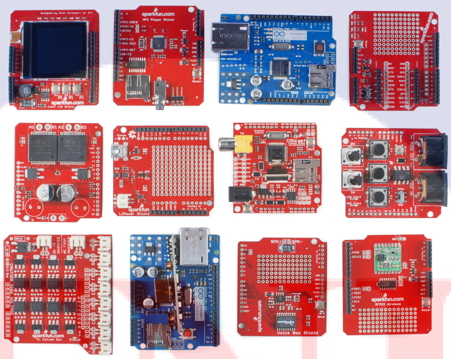


Figure 2.12 Sensors and Shields

2.3.2 Accelerometers

Accelerometers are devices that measure acceleration, which is the rate of change of the velocity of an object. They measure in meters per second squared (m/s^2) or in G-forces (g). A single G-force for us here on planet Earth is equivalent to 9.8 m/s^2, but this does vary slightly with elevation

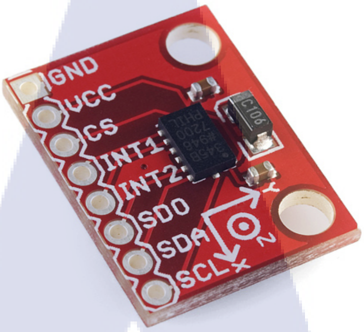


Figure 2.13 Accelerometers (*ADXL345 Breakout Board*)

Accelerometers are useful for sensing vibrations in systems or for orientation applications. Accelerometers are electromechanical devices that sense either static or dynamic forces of acceleration. Static forces include gravity, while dynamic forces can include vibrations and movement. Accelerometers can measure acceleration on one, two, or three axes. 3-axis units are becoming more common as the cost of development for them decreases. Generally, accelerometers contain capacitive plates internally. Some of these are fixed, while others are attached to miniscule springs that move internally as acceleration forces act upon the sensor. As these plates move in relation to each other, the capacitance between them changes. From these changes in capacitance, the acceleration can be determined. Other accelerometers can be centered around piezoelectric materials. These tiny crystal structures output electrical charge when placed under mechanical stress

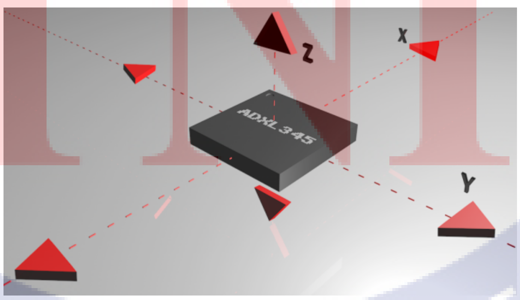


Figure 2.14 Axes of measurement for a triple axis accelerometer

For most accelerometers, the basic connections required for operation are power and the communication lines. As always, read the datasheet to ensure proper connections are made.

Accelerometers will communicate over an analog, digital, or pulse-width modulated connection interface.

- Accelerometers with an analog interface show accelerations through varying voltage levels. These values generally fluctuate between ground and the supply voltage level. An ADC on a microcontroller can then be used to read this value. These are generally less expensive than digital accelerometers.
- Accelerometers with a digital interface can either communicate over SPI or I^2C communication protocols. These tend to have more functionality and be less susceptible to noise than analog accelerometers.
- Accelerometers that output data over pulse-width modulation (PWM) output square waves with a known period, but a duty cycle that varies with changes in acceleration.

Accelerometers are generally low-power devices. The required current typically falls in the micro (μ) or milli-amp range, with a supply voltage of 5V or less. The current consumption can vary depending on the settings (e.g., power saving mode versus standard operating mode). These different modes can make accelerometers well suited for battery powered applications. Make sure that proper logic levels are matched, especially with the digital interfaces. Most accelerometers will have a selectable range of forces they can measure. These ranges can vary from ±1g up to ±250g. Typically, the smaller the range, the more sensitive the readings will be from the accelerometer. For example, to measure small vibrations on a tabletop, using a small-range accelerometer will provide more detailed data than using a 250g range (which is more suited for rockets). Some accelerometers include features such as tap detection (useful for low-power applications), free-fall detection (used for Active Hard Drive Protection), temperature compensation (to increase accuracy in dead reckoning situations) and 0-g range sensing, which are other features to take into consideration when purchasing an accelerometer. The need for these types of features on the accelerometer will be determined by the application in which the accelerometer is incorporated. There are also IMUs (Inertial Measurement Units) available, which can include accelerometers, gyroscopes and even, occasionally, magnetometers into a single IC package or board. Some examples of this include the MPU6050 and MPU9150. These are commonly used in motion tracking applications and UAV guidance systems, where location and orientation of an object is important.

2.3.3 Gyroscope

Gyroscopes, are devices measure rotational motion. MEMS (microelectromechanical system) gyros are small, inexpensive sensors that measure angular velocity. The units of angular velocity are measured in degrees per second (°/s) or revolutions per second (RPS). Angular velocity is simply a measurement of speed of rotation.

Figure 2.15 Gyroscope (The LPY503 gyro on a breakout board)

Gyros, like the one above, can be used to determine orientation and are found in most autonomous navigation systems. For example, if you want to balance a robot, a gyroscope can be used to measure rotation from the balanced position and send corrections to a motor. When things rotate around an axis they have what's called *angular velocity*. A spinning wheel can be measured in revolutions per second (RPS) or degrees per second (°/s).

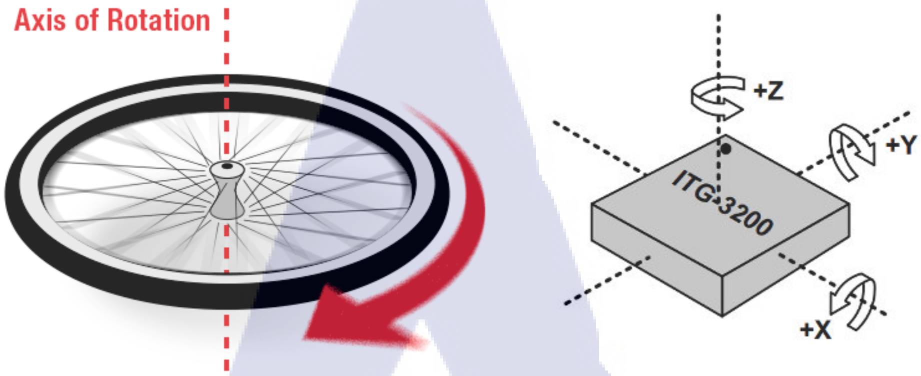


Figure 2.16 Axis of Gyroscope's rotation

If you attach the sensor to the wheel shown above, you can measure the angular velocity of the z axis of the gyro. The other two axes would not measure any rotation. Imagine if the wheel spins once per second. It would have an angular velocity of 360 degrees per second. The spinning direction of the wheel is also important. Is it clockwise around the axis, or is it counter-clockwise? A triple axis MEMS gyroscope, similar to the one pictured above (ITG-3200), can measure rotation around three axes: x, y, and z. Some gyros come in single and dual axis varieties, but the triple axis gyro in a single chip is becoming smaller, less expensive, and more popular. Gyros are often used on objects that are not spinning very fast at all. Aircrafts (hopefully) do not spin. Instead they rotate a few degrees on each axis. By detecting these small changes gyros help stabilize the flight of the aircraft. Also, note that the acceleration or linear velocity of the aircraft does not affect the measurement of the gyro. Gyros only measure angular velocity. The gyroscope sensor within the MEMS is tiny (between 1 to 100 micrometers, the size of a human hair). When the gyro is rotated, a small resonating mass is shifted as the angular velocity changes. This movement is converted into very low-current electrical signals that can be amplified and read by a host microcontroller. The primary hardware connections to use a gyro are *power* and a *communication interface*. As always, refer to the sensor datasheet for all of the information on specifications and example connections. Gyros can have either a *digital* or *analog* communication interface.

- Gyros with a *digital* interface usually use either the SPI or I2C communication protocols. Using these interfaces allow for an easy connection to a host microcontroller. One limitation of a digital interface is max sample rate. I2C has a max sample rate of 400Hz. SPI, on the other hand, can have a much higher sample rate.
- Gyros with an *analog* interface represent rotational velocity by a varying voltage, usually between ground and the supply voltage. An ADC on a microcontroller can be used to read the signal. Analog gyros can be less expensive and sometimes more accurate, depending on how you are reading the analog signal.

MEMS gyros are generally low power devices. Operating currents are in the mA and sometimes &micro A range. The supply voltage for gyros is usually 5V or less. Digital gyros can have selectable logic voltages or operate at the supply voltage. For any digital interface, remember to connect 5V to 5V lines and 3.3V to 3.3V lines. Also, gyros with digital interfaces can have low power and sleep modes that allow them to be used in battery powered applications. Sometimes this is an advantage over an analog gyro. There are many specifications to consider when figuring out what type of gyro to use. Here are a few of the more important useful ones: The measurement range, or full-scale range, is the maximum angular velocity that the gyro can read. Think about what you are measuring. Do you need to measure the spin of a record player, which is very slow or a spinning wheel, which could be very fast? The sensitivity is measured in mV per degree per second (mV/°/s). Don’t let the weird dimension of this value scare you. It determines how much the voltage changes for a given angular velocity. For example, if a gyro is specified with a sensitivity of 30mV/°/s and you see a 300mV change in the output, you rotated the gyro at 10 °/s.

2.3.4 Magnetometer

A magnetometer is a tool or instrument that measures the magnetization of an item or the force of a magnet. The magnetometer typically looks at the Earth's magnetic field and local magnetic field to determine the location and vector of a magnetic force. There are two basic types of magnetometer measurement. *Vector magnetometers* measure the vector components of a magnetic field. *Total field* *magnetometers* measure the magnitude of the vector magnetic field. Magnetometers used to study the Earth's magnetic field may express the vector components of the field in terms of *declination* (the angle between the horizontal component of the field vector and magnetic north) and the *inclination* (the angle between the field vector and the horizontal surface). *Absolute magnetometers* measure the absolute magnitude or vector magnetic field, using an internal calibration or known physical constants of the magnetic sensor. *Relative magnetometers* measure magnitude or vector magnetic field relative to a fixed but uncalibrated baseline. Also, called *variometers*, relative magnetometers are used to measure variations in magnetic field. Magnetometers may also be classified by their situation or intended use. *Stationary magnetometers* are installed to a fixed position and measurements are taken while the magnetometer is stationary. *Portable* or *mobile magnetometers* are meant to be used while in motion and may be manually carried or transported in a moving vehicle. *Laboratory magnetometers* are used to measure the magnetic field of materials placed within them and are typically stationary. *Survey magnetometers* are used to measure magnetic fields in geomagnetic surveys; they may be fixed base stations, as in the INTERMAGNET network, or mobile magnetometers used to scan a geographic region.

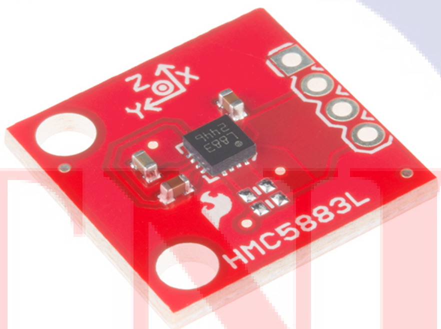


Figure 2.17 Triple Axis Magnetometer Breakout - HMC5883L

The performance and capabilities of magnetometers are described through their technical specifications. Major specifications include

- *Sample rate* is the amount of readings given per second. The inverse is the *cycle time* in seconds per reading. Sample rate is important in mobile magnetometers; the sample rate and the vehicle speed determine the distance between measurements.
- *Bandwidth* or *bandpass* characterizes how well a magnetometer tracks rapid changes in magnetic field. For magnetometers with no onboard signal processing, bandwidth is determined by the Nyquist limit set by sample rate. Modern magnetometers may perform smoothing or averaging over sequential samples. achieving a lower noise in exchange for lower bandwidth.
- *Resolution* is the smallest change in a magnetic field the magnetometer can resolve. A magnetometer should have a resolution a good deal smaller than the smallest change one wishes to observe.
- Quantization error is caused by recording round off and truncation of digital expressions of the data.
- *Absolute error* is the difference between the readings of a magnetometer true magnetic field.
- *Drift* is the change in absolute error over time.
- *Thermal stability* is the dependence of the measurement on temperature. It is given as a temperature coefficient in units of nT per degree Celsius.
- *Noise* is the random fluctuations generated by the magnetometer sensor or electronics. Noise is given in units of , where frequency component refers to the bandwidth.
- *Sensitivity* is the larger of the noise or the resolution.
- *Heading error* is the change in the measurement due to a change in orientation of the instrument in a constant magnetic field.
- The *dead zone* is the angular region of magnetometer orientation in which the instrument produces poor or no measurements. All optically pumped, proton-free precession, and Over Hauser magnetometers experience some dead zone effects.

- *Gradient tolerance* is the ability of a magnetometer to obtain a reliable measurement in the presence of a magnetic field gradient. In surveys of unexploded ordnance or landfills, gradients can be large.

2.3.5 Temperature Sensor

Temperature Sensors measure the amount of heat energy or even coldness that is generated by an object or system, allowing us to "sense" or detect any physical change to that temperature producing either an analogue or digital output. There are many different types of Temperature Sensor available and all have different characteristics depending upon their actual application. A temperature sensor consists of two basic physical types: (1) Contact Temperature Sensor Types – These types of temperature sensor are required to be in physical contact with the object being sensed and use conduction to monitor changes in temperature. They can be used to detect solids, liquids or gases over a wide range of temperatures. (2) Non-contact Temperature Sensor Types – These types of temperature sensor use convection and radiation to monitor changes in temperature. They can be used to detect liquids and gases that emit radiant energy as heat rises and cold settles to the bottom in convection currents or detect the radiant energy being transmitted from an object in the form of infra-red radiation (the sun).

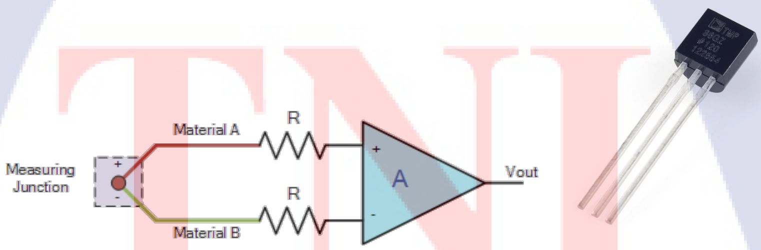


Figure 2.16 Circuit and example Temperature Sensor (TMP3)

2.3.6 Humidity Sensor

A humidity sensor (or hygrometer) senses, measures and reports both moisture and air temperature. The ratio of moisture in the air to the highest amount of moisture at a particular air temperature is called relative humidity. Relative humidity becomes an important factor, when looking for comfort. Humidity sensors work by detecting changes that alter electrical currents or temperature in the air. There are three basic types of humidity sensors: capacitive, resistive and thermal. All three types of sensors monitor minute changes in the atmosphere in order to calculate the humidity in the air. Capacitive: A capacitive humidity sensor measures relative humidity by placing a thin strip of metal oxide between two electrodes. The metal oxide's electrical capacity changes with the atmosphere's relative humidity. Weather, commercial and industries are the major application areas. Resistive: Resistive humidity sensors utilize ions in salts to measure the electrical impedance of atoms. As humidity changes, so does the resistance of the electrodes on either side of the salt medium. Thermal: Two thermal sensors conduct electricity based upon the humidity of the surrounding air. One sensor is encased in dry nitrogen while the other measures ambient air.

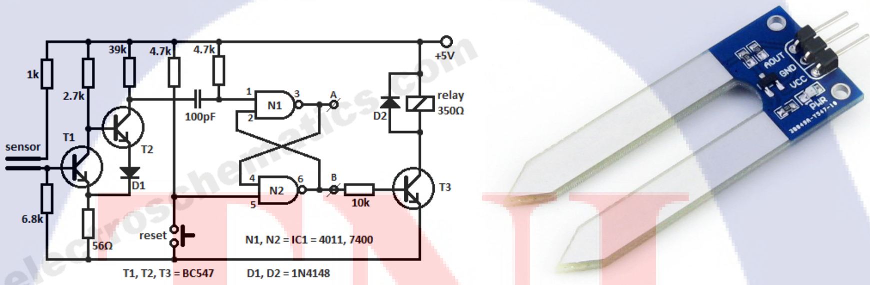


Figure 2.18 Circuit and sample of Humidity Sensor

The applications of humidity sensor range far and wide. People with illnesses affected by humidity, monitoring and preventive measure in homes employ humidity sensors. A humidity sensor is also found as part of home heating, ventilating and air conditioning systems (HVAC systems). These are also used in offices, cars, humidors, museums, industrial spaces and greenhouses and are also used in meteorology stations to report and predict weather.

2.3.7 Heart Rate Monitor

The Heart Rate Monitor Interface (HRMI) is an intelligent peripheral device that converts the ECG signal from Polar Electro Heart Rate Monitor (HRM) transmitters into easy-to-use heart rate data. It implements a sophisticated algorithm for computing an average heart rate even with noisy or intermittent data from the transmitter. The HRMI also provides analog inputs and a digital input/output utility port to ease integration into custom applications.

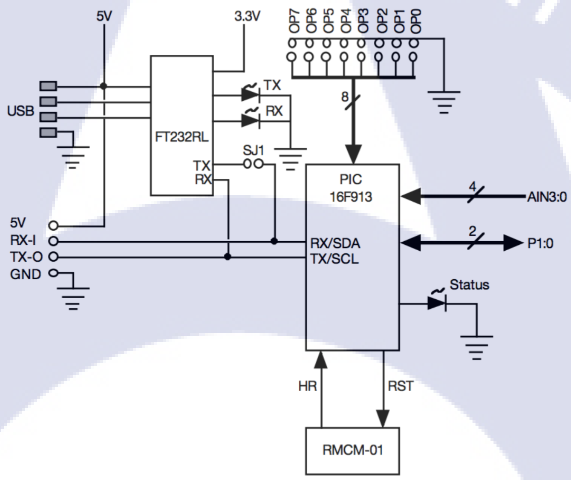


Figure 2.19 Heart_Rate_Monitor Circuit Diagram

The HRMI receives power and data through a communication interface. It provides two interface connectors: USB and a Logic-level header. Use of the two physical interfaces is mutually exclusive, only one can be in use at a time. The HRMI communicates using either a serial interface or an I2C interface. The HRMI is configured at power-on reset to use a interface with the OP0 - OP7 jumper block as described in section "Configuration Jumpers" of this chapter. It communicates using a serial interface through either the USB connector or the Logic-level header. It communicates using the I2C interface through the Logic-level header. A USB Mini-B connector allows quick connection to a host computer. The USB interface provides both power and a data connection to the HRMI. The USB interface uses a FTDI FT232RL interface IC that exposes the HRMI as a serial device to the host computer. FTDI provides royalty free drivers for Microsoft Windows, Apple Macintosh and Linux operating systems.

Figure 2.20 Heart_Rate_Monitor Sensors

Heart rate data can be really useful whether you're designing an exercise routine, studying your activity or anxiety levels or just want your shirt to blink with your heart beat. The problem is that heart rate can be difficult to measure. Luckily, the Pulse Sensor Amped can solve that problem! The Pulse Sensor Amped is a plug-and-play heart-rate sensor for Arduino. It can be used by students, artists, athletes, makers, and game & mobile developers who want to easily incorporate live heart-rate data into their projects. It essentially combines a simple optical heart rate sensor with amplification and noise cancellation circuitry making it fast and easy to get reliable pulse readings. Also, it sips power with just 4mA current draw at 5V so it's great for mobile applications. Simply clip the Pulse Sensor to your earlobe or fingertip and plug it into your 3 *or* 5 Volt Arduino and you're ready to read heart rate! The 24" cable on the Pulse Sensor is terminated with standard male headers so there's no soldering required. Of course, Arduino example code is available as well as a Processing sketch for visualizing heart rate data.

2.4 Publications on Recent Advances on IoT-Based PPEs

M. Jutila *et al*. [5] have presented a prototype of wearable vest for improving the safety and well-being of children in nursery as shown in Fig.2.18. The IoT-based vest is composed by LilyPad Arduino and Adafruit Flora platforms with Xbee radio module, GPS module, temperature and accelerometer sensors. The proposed vest early suggested the digital safety applications and services for parents and teachers.

Figure 2.21 Safety vest with the Arduino LilyPad for children in nursery [5].

Figure 2.22 PPE tagged with RFID and ID card for construction zone access [6].

A. Kelm et al. [6] have used RFID technology to monitor PPE to access into the construction zone by mounting an RFID receiver plate on a PPE as shown in Fig. 3. It can record the time in and out, which can effectively control and automatic site access, time recording, and completeness control. These improve the logistics of the existing compliance checking process and provide users with timely feedback. Meanwhile, S. B. Torres et al. [7] brought cyberphysical (CPS) to monitor real-time PPE usage by using Zigbee and RFID technology for prototype as shown in Fig. 4 that supports the deployment of both kinds of networks. The user must have a device that uses a microcontroller to check the status of the PPEs and send the report to the central authority for notification and collection of data for recording.

Table 2. 1 Summary of researches related to the proposed approaches

Author	Year	Proposed Schemes
M. Jutila et al. [5]	2014	Implementation of a Wearable Sensor Vest for the Safety and Well-being of Children
A. Kelm et al. [6]	2013	Smart Vest: Wearable multi-parameter remote physiological monitoring system
S. B. Torres et al. [7]	2012	Real-time personal protective equipment monitoring system
Y.D. Lee and W.Y. Chung [8]	2009	Wireless sensor network based wearable smart shirt for ubiquitous health and activity monitoring
P.S. Pandian et al. [9]	2008	Smart Vest: Wearable multi-parameter remote physiological monitoring system

A. Kelm et al. [6] have used RFID technology to monitor PPE to access into the construction zone by mounting an RFID receiver plate on a PPE as shown in Fig. 2.19. It can record the time in and out, which can effectively control and automatic site access, time recording, and completeness control. These improve the logistics of the existing compliance checking process and provide users with timely feedback. Meanwhile, Santiago Barro-Torres et al. [7] brought cyberphysical (CPS) to monitor real-time PPE usage by using Zigbee and RFID technology for prototype as shown in Fig. 2.20 that supports the deployment of both kinds of networks. The user must have a device that uses a microcontroller to check the status of the PPEs and send the report to the central authority for notification and collection of data for recording.

Figure 2.20 The Prototype CPS PPE for worker [7].

Y.D. Lee and W.Y. Chung. [8] have designed and developed the smart shirt which measures electrocardiogram (ECG) and acceleration signals for continuous and real time health monitoring as shown in Fig. 2.21. The smart shirt consists of sensors for continuous monitoring the health data and conductive fabrics to get the body signal as electrodes and sends data to the server computer for real-time remote monitoring via an ad-hoc network in IEEE 802.15.4 communication standard to a base-station and server PC for remote monitoring.

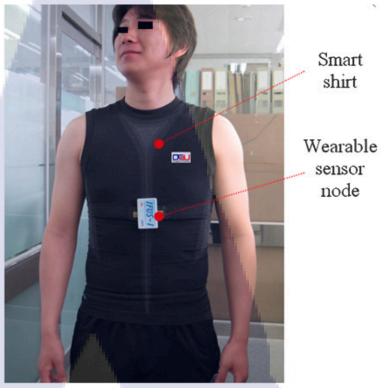


Figure 2.21 An integrated wearable sensor node for physical exercise monitoring [8].

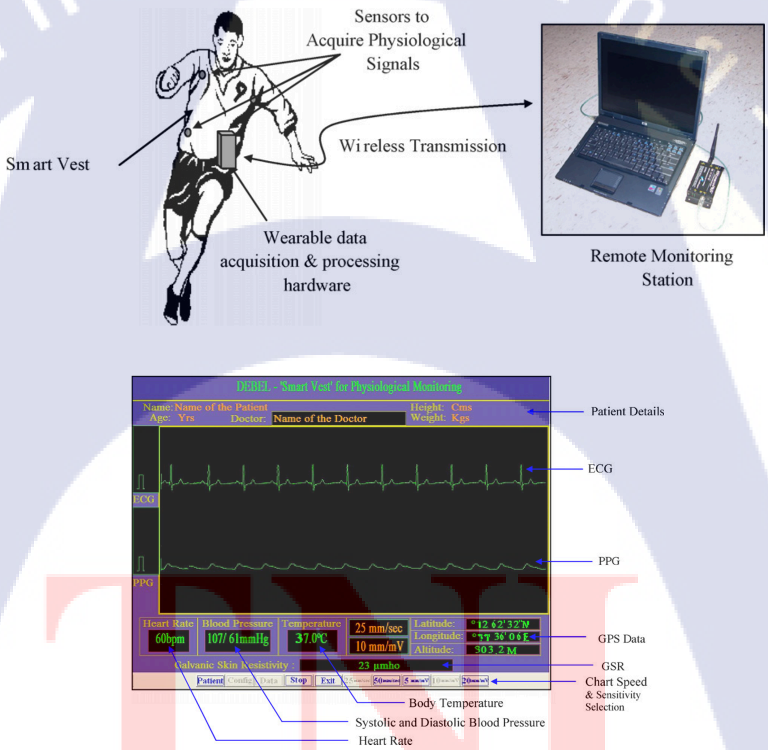


Figure 2.22 Overall architecture of wearable physiological monitoring system

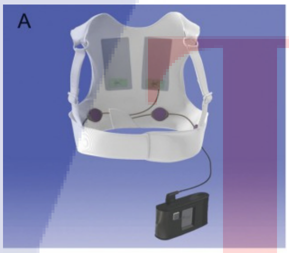
In addition, P.S. Pandian et al. [9] have creates a shirt with a physiological examination system that can be washed for physiological parameters monitoring system called “Smart Vest” Used for remote monitoring of physiological parameters and medical examination. The Smart Vest’s data acquisition system is designed using microcontroller and interfaced with wireless communication and global positioning system (GPS) modules. The Physiological signals monitored are electrocardiogram (ECG), photoplethysmogram (PPG), body temperature, blood pressure, galvanic skin response (GSR) and heart rate sensor as shown in Fig.2.22. The acquired physiological signals are digitized at 12-bit resolution and transmitted wireless to a remote physiological monitoring station along with the geo-location of the user.

2.5 Commercially Available Smart PPEs

In recent years, many research institutes and companies have been working on PPE and Personal Protective Systems PPS projects, in some cases supported by the European Union or national or regional agencies. Smart PPS by KAN-Commission for Occupational Health and Safety and Standardization Company [10] has created smart PPS as shown in Fig. 2.23. communication and localization devices are available in the wearer, consisting of various sensors for body functions and environmental monitoring, e.g. for fire-fighters. It has cooling and heating functions that operate only when necessary based on measured body and external temperatures. Active PPE acting as an emergency stop, for example for laser devices or chain saws when they endanger the safety of the wearer of the PPE and installed light-emitting flexible materials that provide high visibility. But this Products not yet ready for the market soon.

Figure 2.23 Smart PPS designed by KAN company [10].

Table 2.2 Summary of commercially market related to the proposed approaches

Company Name	Features
KAN - Commission for Occupational Health and Safety and Standardization, Company [10] https:/www.kan.de/en/ 	• Can communicate between devices with limited space devices for wearers. • There are sensors for measuring the body and the environment. • Increase / decrease the temperature of the time required based on the outside temperature. • Automatic emergency stop signaling In conditions where the wearer is dangerous. • Good reflective material.
Virginia Tech and VDOT [11] http://www.vt.edu/ 	• There is a GPS to identify the wearer's location to prevent hazards in different locations. • A warning system for the wearer if there is a danger of a car accident. The shirt will be contacted with cars running through the radio.
Pittsburgh Company (Zoll Manufacturing Corp.) [12] http://pittsburgh.cbslocal.com/ 	• The shirt can generate electrical waves to pump the head immediately as the body is experiencing problems such as heart failure, etc., so that the patient or the wearer returns to normal. • The shirt will contact the vet facility registered by the wearer when it detects a wearer's fatal injury.

Smart Safety Vest by Virginia Tech and VDOT [11] has teamed up to create a vest that can communicate with cars in the area as shown in Fig. 2.24. Early tests show the vest can give workers a five to six-second warning of a possible collision with cars travelling less than 40 miles an hour. The driver would also receive a warning on the dashboard. The vest is part of the broader vehicle connectivity research that has been going on for several years. This technology could soon be launched that would tell roadside workers when a car might hit them.

Figure 2.24 Smart Safety Vest that can communicate with cars [11].

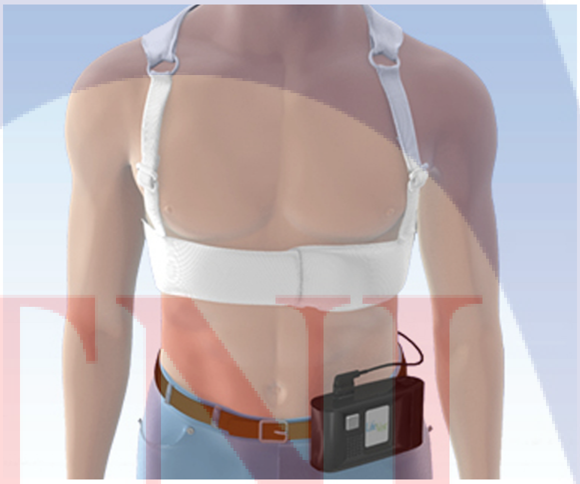


Figure 2.25 The LifeVest Appearance [12].

A LifeVest produced by Pittsburgh Company (Zoll Manufacturing Corp.) [12] has created smart vest that called "LifeVest wearable defibrillator", which is worn by patients at risk for Sudden Cardiac Arrest (SCA), providing protection during their changing condition and while permanent SCA risk has not been established. The LifeVest can generate electrical waves to pump as shown in Fig. 2.25. The head right away such as heart failure, etc., so that the patient or the wearer returns to normal. The LifeVest will contact the hospital where the wearer registered when detecting abnormalities of the wearer at risk to life. The LifeVest is covered by most health plans in the United States, including commercial, state, and federal plans.

2.6 In conclusion

This chapter has provided the information of related theories including Safety Management System theory, Heinrich's Domino Theory and Personal Protective Equipment. The literature reviews of 5 Publications on Recent Advances on IoT-Based PPEs, 5 Related Technology and 3 commercially available smart PPEs are also included.

Chapter 3
Research Methodology

3.1 Introduction

This chapter describes research methodology of this thesis, involving research process, data collection, and research tools.

3.2 Research Process

3.2.1 Study the basics of Arduino systems and IoT.

3.2.2 Study Industrial Personal Protective Equipment (PPE)

3.2.3 Design Prototype Personal Protective Equipment

3.2.4 Implement for Test and improve PPE and application kits.

3.2.5 Update and modify the program based on the feedback received.

3.3 Data Collection

The data in this thesis is the set of results by measuring and recording the data of 5 sensors (Accelerometers, Gyroscope, Temperature sensor, Humidity Sensor and Heart Rate Monitor Sensor) recorded by Node MCU controller. All sensors are connected to a wireless transmitter by using a 3 ~ 5 Volt lithium battery system. To send data through a flammable system to display on the web application. Including a system to alert you when something is wrong via Line application with a real-time monitoring hazardous worker.

3.4 Research Tools

Research tools in thesis are MATLAB R2013a, Arduino Studio Version 1.8.3, and Computer Device.

3.5 Conclusions

This chapter has presented research methodology of this thesis, including research process data collection, and research tools.

Chapter 4
Research Result

4.1 Introduction

This chapter presents the research results for Wireless Industrial Personal Protective Equipment through Internet-of-Thing Technology in Heavy Industries. The researcher infers the worker activity in 3 type (1) Heavy job is running (2) Medium job walking and (3) Rest is do nothing.

4.2 Experimental Results

4.2.1 Multi sensors system design

Figure 4. 1 Multi Sensor installed in Smart PPE

Many different body movements can be recognized based on the accelerometer data to provide and gather information about, e.g., a worker's activity level and behavior to implement numerous applications. The basic identified modes can usually be categorized as walking, running, sitting/staying still or using a form of transportation. Implementation of the vest has some limitations concerning the way the movement data is gathered compared to those wearable systems that have sensors, e.g., in the arms and/or legs. With arm and leg sensors other more specific activities can also be recognized such as eating, using stairs, falling and lying down etc. The researcher designed to use Accelerator and Gyro Sensor to keep recording the data of wearer's backbone for analysis their health condition in the future. In order that a suitable place for the sensitive components can more easily be tested to guarantee the best functionality and wearable. In the future to apply intelligent reasoning, context-awareness and functional accuracy. The temperature sensor and humidity sensor in the vest is used for environmental monitoring purposes. These sensors can assist to monitor during extreme weather to control, when and for how long, to do their job during working time. Also, knowing the heart rate are important for the well-being of those worker suffering from diseases, e.g. Temperature information is also valuable for the worker suffering from the diseases, e.g., to be able to pick them earlier from the work site and take care of their health condition.

Figure 4. 2 The warning notification when abnormal case happened

4.2.2 Smart PPE design

For our safety vests, we chose platforms: Uno Arduino board (ESP-32S Node MCU ESP- WROOM-32 Wi-Fi and Bluetooth Module Dual Core) to test the basic functionalities. They are micro-controller boards designed for wearables and e-textiles and outputs a steady voltage of 3.3 volts. The Uno has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a USB connection, a power jack, a reset button and more. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The physical communication between the vests and the gateway is handled by Wi-Fi, which are based on the IEEE 802.15.4 standard. ESP-32S Node MCU ESP- WROOM-32 The maximum range is 100 meters the micro-controllers are running CoAP (Constrained Application Protocol) servers, which offer temperature, accelerometer and gyroscope sensors depending on the configuration of the vest. Programming was done using Arduino IDE and Mat lab as the programming language. The sensor data is read from the analogue pins of the microcontroller and appended into a payload to be sent to the gateway. All components are connected and sewn together on the fabric with a conductive thread. It turned out to be easier to connect the components to the Arduino board, because it has more ground and voltage pins. The power consumption of the systems is using a lithium polymer battery with a capacity of 650 mAh at 3.7 volts, the vest can be operational for approximately 8 hours. By putting. Approximately the same battery life can be achieved with the Safety vest by using the Wi-Fi for one second every 30 seconds. The Heart Rate Monitor module consumes a lot of power. Further improvements in battery life can be achieved by using sleep modes within the micro-controllers themselves.

4.3 Conclusion

A smart PPE with wireless sensor network compatibility is designed for continuous monitoring of physiological ECG signal and physical activity signal from an accelerometer simultaneously. To collect physiological ECG data and activity of the smart PPE wearer simultaneously, the performance test is done on a treadmill by a wearer who is resting, walking and running on a treadmill with various speeds. The motion artifact included in the stress ECG signal was well removed by the proposed adaptive filtering method using the accelerometer as a source of noise reference. A wearable smart shirt with both physiological ECG and physical activity detectible sensors transfers the signals without any troubles in wireless sensor network environment at the performance test on a treadmill. Thus, the developed smart shirt system can be applicable to improve the accuracy of the wearer diagnosis by the continuous monitoring with non-invasive, comfortable and convenient shirt to wear in wireless sensor network environment.

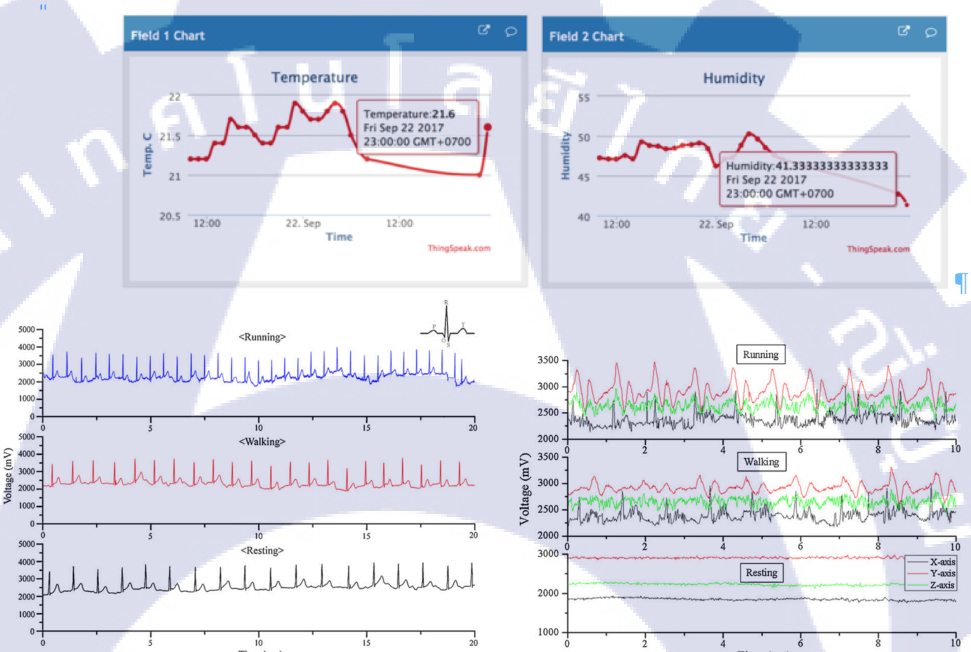


Figure 4.3 The result of ECG and acceleration signal variations

Chapter 5
Conclusion and Suggestion

5.1 Conclusion

This work presented wearable safety vests with 5 sensors (Accelerometers, Gyroscope, Temperature sensor, Humidity Sensor and Heart Rate Monitor Sensor) to be used heavy industries. The current prototype vest or smart PPE is designed to mainly provide safety, behavior and activity-related information, but as a future work, the vest could be made more appealing from the worker's point of view and include some applications in addition to safety issues. The basic functionalities of the vest have been tested but more concrete real-time measurements and analysis will be done as a future study. The technicalities of the vest do not restrict adding other sensors as well, or having other end users besides worker and their safety and well-being issues. Researcher is also aiming for more intelligent reasoning and context-awareness using the input from many sensors to assist in decision making. The situation-aware application will be based on the earlier work on run-time context management with the context ontology. The applications and services around the system will be more valuable.

5.2 Suggestion

Employers (enterprises or business owner) can potentially improve the rate operators wear PPE on production sites by putting more value on safety education, training, and enforcement. One way is a system that might not be too intrusive, but reminds workers daily or at the beginning of hazardous work that appropriate PPE must be worn at all times. This could be emphasized by erecting a PPE control gate at the entry of or close to hazardous work spaces at or within production sites. The industrial model to be applied to intelligent industrial plants in the near future as well. According to a survey of production line staff at a factory in Eastern Seaboard Industrial Estate, Rayong, there were resignations or requests to replace the station in the production line because they had health problems. For example, back pain often causes inability to work, frequent flu, lack of or frequent job loss including various diseases, etc. At present, this problem also occurs regularly. Researchers have installed a Motion Sensor (Gyro Sensor and Accelerator Sensor) into the Smart PPE to measure the movement of employees that are follow "the Ergonomically" and install a gas sensor to measure the amount of toxic gases around the wearer to checks for long term health problems. And from inquiries to the safety department at a factory in Eastern Seaboard Industrial Estate, Rayong, it was found that most of the accidents in the factory were from employees who were not ready to work, such as flu, not enough rest. So, the Heart Rate Monitor Sensor was installed for real-time heart rate monitoring, and then analyzed and monitored whether the wearer was in a working state to protect himself. Accuracy will happen to the wearer if not in working condition.

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Appendices

Research Conferences

1. 4th The TNI Academic Conference 2017 on the topic of "Managing innovative researches to drive Thailand 4.0

2. The 2017 International Conference on Embedded Systems and Intelligent Technology


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This is to certify that

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has successfully presented a paper entitled

"Perspectives on Recent Advances on IoT-Based Industrial Personal Protective Equipment"

at the 2017 International Conference on Embedded Systems and Intelligent Technology (ICESIT2017)

2nd – 4th August 2017, Thai-Nichi Institute of Technology, Bangkok, Thailand

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