Sudan University of Science and Technology

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Human Detection Techniques

تقنيات الكشف عن الإنسان

A Project Submitted In partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) In Electrical Engineering

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الآيـــــة

قال تعالى:

﴿ وَمَنْ أَحْيَاهَا فَكَأَنَّمَا أَحْيَا النَّاسَ جَمِيعًا ﴾

سورة المائدة، الآية رقم 32

DEDICATION

To community of science and knowledge: we dedicate the responsibility of reform and change, not certificates of appreciation. To workers on the ground, adventurers who save other's souls from under the rubble. For those who really & honestly care about human life: we dedicate apologies for our default. To those who lost their lives under the rubble: we dedicate our prayers for them to win paradise. And to all of those how pray for ALLAH from under the ashes to facilitate them to survive, to every children grew up among the debris hopeful: we dedicate them this research with a hope to be a start of new life to thousands of innocence lives. To our families who were patient until we reached our destination. To our Muslim Ummah: we dedicate greeting from our hearts, its title: My succour is only with Allah.

ACKNOWLEDGMENT

Praise and thanks to ALLAH that the extension in our lives and we ask blessed in our works. Then thanks to the team work, classmates. And thanks to all of those who revived the love of knowledge in our hearts. Thanks to project supervisor Mr. Omar Mohammed Salama. And the praise and thanks to ALLAH first and foremost.

ABSTRACT

With the development of civic life details of humans and the enormous boom technological and architectural huge growing of population and increasing of the effects of global warming to touches the details of everyday reality, a new kind of problems which in the past were not significant or extreme gravity appeared. Wars and natural disasters steadily rising and left many trapped under the rubble of developing life who are unable to help themselves waiting for helping hand to stretch them.

Detecting survivors under the rubble became an urgent demand. Varied ideas and mechanisms were developed, in this research some of them have been discussed; representing, analyzing and comparison. The study concludes that the research and development in the human detection systems still need a lot of effort from researches institutions, studies centers and governmental agencies concerned with. The results of earlier efforts are still insufficient to achieve the required speed and efficiency. Connectivity of applications of this type of systems with the security and the lives of people directly, doubles the responsibility of who are able to help.

مستخلص

مع تطور تفاصيل الحياة المدنية للإنسان، والطفرة التكنولوجية والعمرانية الهائلة، والإزدياد السكاني الضخم، وطفوا آثار ظاهرة الإحتباس الحراري لتلامس تفاصيل الواقع اليومي ظهر نوع جديد من المشاكل لم تكن في السابق ذات أهمية أو خطورة قصوى. الحروب والكوارث الطبيعية شهدت إزديادا مضطردا وخلفت الكثير من العالقين تحت ركام الحياة المتطورة العاجزين عن مساعدة أنفسهم ينتظرون يد العون لتمتد إليهم.

ومن هذا المنطلق فقد أصبح الكشف عن الناجين تحت الأنقاض مطلباً مُلحاً، وقد تنوعت في ذلك الأفكار والآليات، نناقش في بحثنا هذا بعضا منها عرضاً وتحليلاً ومقارنةً. وتخلص الدراسة إلى أن مجال البحث والتطوير في أنظمة الكشف عن الإنسان ما يزال بحاجة للكثير من الجهود من المؤسسات البحثية ومراكز الدراسات والجهات الحكومية المعنية على حد سواء، فنتائج الجهود السابقة ما تزال قاصرة عن تحقيق السرعة والكفاءة اللازمين. إن مساس تطبيقات هذا النوع من الأنظمة لأمن وحياة الناس مباشرة يضاعف من المسؤولية على عاتق القادرين على المساعدة.

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LIST OF ABBREVIATIONS

ADC	Analogue to Digital Converter
BPF	Band Pass Filter
CO_2	Carbon Dioxide
FCC	Federal Communications Commission
FET	Field Effect Transistor
FMCW	Frequency Modulated Continuous Wave
GPR	Ground Penetrating Radar
GPS	Global Positioning System
IR	Infra-Red
LCD	Liquid Crystal Display
LFSR	Linear Feedback Shift Registers
LWIR	Long-Wavelength IR
MLBS	Maximum Length Binary Sequence
MLDS	Millimeter-Wave Life Detection System
NB	Narrow-Band
PC	Personal Computer
PIR	Pyroelectric Infra-Red
PN	Pseudo-random Noise
RRR	Rubble Rescue Radar
SFCW	Stepped Frequency Continuous Wave
SNR	Signal-to-Noise Ratio
USAR	Urban Search And Rescue
UWB	Ultra Wide-Band
VOCs	Volatile Organic Compounds

LIST OF SYMBOLS

W	Emitted energy, watt
ε	Emissivity
σ	Stephan-Boltzmann constant, watts/cm^{2}K^4
T	Absolute temperature of object, K
b_f	Fractional bandwidth, Hz
f_u	The upper cut-off frequency, Hz
f_l	The lower cut-off frequency, Hz
f_m	The centre frequency, Hz
B	The absolute bandwidth of the signal, Hz
T_0	Chips duration, sec
T_p	The duration of a complete period, sec
R	The unambiguity range of the radar, meter

CHAPTER ONE

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 Overview

From the beginning of the civilization, the human being tried to extend his senses' range. He developed types of sensors which can sense what he couldn't; seeing in the dark or behind obstacles and so on. Development of a sensor which can detect the human based on one or more of his characteristic properties is essential demand for many applications. Detecting the human for teasing him from the danger is the most important and obsesses all the tension. Rescuing him may make the rescuers other victims, so looking for an alternative to human rescuers is needed [8].

Since the past century, many efforts have been done in researching, studying, designing products and developing the methods for the human detecting issue either in free space or behind obstacles. Some of these efforts had not recorded any useful results, some others have different detection tolerance depending on the environment but some important details aren't mentioned. There are many techniques have been used in the field of human detection depending on the radiated heat from his body, the carbon dioxide from breathing operation, the human's smell, his body shape recognition, his voice discovering or the oscillations of his chest and abdomen by using different kinds of sensors like: infrared sensor, CO_2 sensors, also camera with specific image processing technology, microwaves and ultra wideband radar technology [1].

Any method has its certain advantages and disadvantages and that limits the domain of its using. Some methods are not the most sensitive but they are least cost and have a simple structure. According to the environment where the detection is going, the method of detection is chosen. The problem is increasing in the complex environment where the dynamic variables make it difficult to treat with. When the detection is for a target behind obstacle, the method should depend on penetrating by waves which have special properties. Despite the huge number of studies, there is no method which can detect human efficiently. Therefore, detecting human has always been a great challenge and still an open, very wide and evolving research area [18].

1.2 Problem Statement

Every year, thousands of people live their last minutes under the debris of collapsed buildings so their situation demands a high sensitive and a very fast detection system. Besides that, human detection techniques are very useful tools for many civilian and military applications. As a consequence, studying the different methods and analyzing them play an important and essential role to understand the concept of human detection and supply with the main points about the system mechanism.

1.3 Objectives

- Presenting related previous studies.
- Studying the different methods of human detection.
- Analyzing and comparing the various techniques.
- Designing appropriate system for detecting human under debris.

1.4 Methodology

Display human body detection methods, systems and studies related, taking scientific sources from books, research or scientific papers with a focus on the ways in which we believe is a faster, more efficient and effect, and briefly speaking about the ways that we believe it is less important, aiming to shorten the time for researchers by identify the available methods and make a comparison between them to determine the most appropriate one to be a subject for interested parties efforts.

1.5 Project Layout

- Chapter one contains overview, problem statement, objectives and methodology.
- Chapter tow contains previous related studies in the field of human detection.
- Chapter three contains presentation of some various methods for human detection in different applications.
- Chapter four contains studying and analyzing the methods presented in chapter three.
- Chapter five contains the conclusion and the recommendations.

CHAPTER TWO

RELATED STUDIES

CHAPTER TWO

RELATED STUDIES

2.1 Introduction

The studies which have been reviewed about human detection are classified into the following:

- Heat-based detection using infrared sensors.
- Voice-based detection.
- CO_2-based detection.
- Shape-based detection.
- Small-scale movements-based detection using radars.

The followings topics are some related studies for some of those methods:

2.2 The Detection Using Infrared

Disaster sites are complex and dangerous. They are a great threat to rescue workers and survivors. In such confused scenarios, the rescue workers' lives can be put at a risk. In order to avoid unnecessary losses, a rescue robot can be of great help to detect human beings as well as save the rescuers. There are a lot of researches which proposed a system carried by a robot. In [3], the authors suggested a system consists of a robot section and control section. Robot section consists of a movable unit, which has Bluetooth module, GPS receiver, an LCD display, PIR sensor (its detection angle is 120°) and a microcontroller Atmega-328. Control unit consists of a manual control using a remote to control the movement of the robot and a PC interfaced with the robot section using Bluetooth to get the output of GPS receiver i.e. to find the exact location of the human. The robot will navigate in the search area and the PIR sensor will check for alive human. If there is a signal, then it will determine the location using the GPS and sent it to the PC.

In [6], the authors constructed what they called 'sensitive life-detection system' using infrared radiation which, as they mentioned in their paper, can be used to locate and obtain valuable information regarding human subjects which are buried under earthquake rubble. They alleged that their system can detect the distance at which the human is detected and can measure the heartbeat signals of the person under the earthquake rubble. Their infrared life-detection system comprises of a light emitting diode which generates and distributes infrared signals to various infrared components, a phototransistor and a light dependent resistor which is used to detect the IR signals, an Op-amp as amplifier and comparator and a microcontroller which controls the system and provides the output on an LCD as the output signal.

According to their paper, when an infrared beam is aimed at a portion of earthquake rubble covering a human being, the beam can penetrate the rubble to reach the human subject. The IR light reflected back from the skin of a human subject due to blood passage is captured by the detector. This reflected light has intensity variations which occur as the blood volume changes in the tissue and it results in voltage variations. This voltage variation determines the heart rate.

Although the insufficiency of using the infrared for the application of detecting human in search and rescue operations, there are a lot of amazing applications which use the principle of detecting human under normal circumstances to do any useful action. Here is one of these applications. In [2], the researchers used the radiated infrared from the human to do an automatic control of car to save the human who is invisible to the driver. The next two paragraphs show more details about this project.

The authors from Nissan Motor Co., LTD developed a prototype blind spot pedestrian warning system for a Nissan car. This system helps alert the driver to the presence of a pedestrian in a blind spot by detecting the infrared radiation emitted from the person's body. The system can also prevent the vehicle from moving in the direction of the pedestrian. According to the research, the results showed that in a low temperature range of 10°-22°, the detection distance was 6-8 m, which would cover a large portion of the rearward blind spot. On the other hand, the detection distance decreased to 3-3.5 m in a temperature range of 24°-30°C. Under a condition of a temperature difference ΔT = Tt (surface temperature of a pedestrian) - Te (background temperature) $\geq$ 5°C (i.e., the atmospheric temperature (background temperature) is no more than 27°C), a detection distance of 3 m or greater was obtained with the prototype system specifications. Additionally, it was also confirmed in actual vehicle tests that the system detected the presence of a human body and prevented the vehicle from moving in that direction.

They also did another experiment using a visible camera and infrared sensors to alert the driver to the presence of a pedestrian in a rear blind spot (rearview system). An image processor combines the image signal from the visible camera with the detection results of two IR imaging sensors to produce a rearview image that is shown on a dashboard display screen.

2.3 The Detection Using CO_2

Somehow, we will review two projects carried out by some of the scientific community in this field. The first one is a project called " SGL FOR USAR" by an European Commission's, and the other is a scientific paper about " Field Chemical Analysis and Technology: For Locating Entrapped People" from School of Chemical Engineering, National Technical University of Athens (NTUA), Athens, Greece.

- SGL FOR USAR (Second Generation Locator for Urban Search and Rescue Operations):

It's obvious that the European Commission's efforts to approach that goal are one of the greatest. In fact they started a project call it SGL FOR USAR (Second

Generation Locator for Urban Search and Rescue Operations), and many reports of their experiment had been published in many scientific journals.

The ChemPro 100i chemical detector (aspiration-type ion mobility spectrometer) was used for the detection of selected volatile organic compounds known to be potential indicators of human presence [45].

- Field Chemical Analysis and Technology: For Locating Entrapped People:

The theory proposed attends to classify the types of entrapment based on physical, metabolic and neuroendocrine responses. It determines phenomena occurring in entrapment and defines the status of entrapped people as a function of time. It also qualitatively predicts the type of compounds (permanent gases and VOCs) expected in each case. The main categories of entrapped people are described as type A, type B and type C. In the frame work of this theory compounds such as CO_2, acetone, isoprene, ethanol, pentane and phenol are predicted as candidate compounds for the chemical method. To test the theory and convert it to a real technological detecting system, a device called "CHAVI-med (Chemical, Audio, Visual, Medical device) " to make some lap and field experiment. The device integrates the principles of synergism (more than one search and locate methods), multiplicity (includes more than one device) and is based on the fundamental characteristics of a field device (i.e. ergonomy, energy autonomy, portability). The term synergism declares the ability of the device to combine three basic rescue methods in different combinations: optical, acoustic and chemical. Multiplicity defines the capability of the system to act as a communication device, to detect environmental hazards and to provide early medical support [46].

2.4 The Detection Using Narrowband Radar

The history of effective system to detect human being buried under the rubble starts with K. M. Chen who brings out the concept of detection of buried victims using microwave beam in 1985 [7]. After the detailed study of microwave signals and Doppler’s effect, K. M. Chen had been proposed including the basic principle for the operation of life detection system in 1991.

A low power hand-held microwave device for the detection of trapped human has been done by W. S. Haddad in 1997. This device, called the Rubble Rescue Radar (RRR) incorporates micro power impulse radar technology which was developed at Lawrence Livermore National Laboratory over the few years. In 2003 P. K. and A. S proposed the basic block diagram for the clutter cancellation system [7]. In 2004, there was a concept of three band radar system proposed by M. B.

In the past, when victims were trapped under earthquake rubble, there was a little chance that they would found. This was due the fact that rescue techniques such as optical devices, acoustic devices or robotic systems were found limited application for the detection buried victims. If victim was unconscious and was unable to shout for help then the existing rescue system found to be failed. With the help of microwave signals the life signs can be detected as it is able to sense the heart beat and breathing signals of human being trapped under collapse debris. A life detection system based on microwave frequency detects the human body vibration by Doppler shift effect. The life detection system has been implemented with simulated rubble and several humans by illuminating microwave beam on their different body position and it is found that phase shift occurs in the illuminated beam on front side of human body was maximum at chest and minimum at forehead. This phase shift may help rescuer to saves human lives [8].

In 2012 Huey-R Chuang and others have reported experimental study of a 60 GHz MLDS for noncontact human vital-signal monitoring is presented. This detection system is constructed by using V-band millimeter-wave waveguide components. A clutter canceller is implemented in the system with an adjustable attenuator and phase shifter. It performs clutter cancellation for the transmitting power leakage from the circulator and background reflection to enhance the detecting sensitivity of weak vital signals. The noncontact vital signal measurements have been conducted on a human subject in four different physical orientations from distances of 1 and 2 m. The time-domain and spectrum waveforms of the measured breathing and heartbeat are presented. This prototype system will be useful for the development of the 60-GHz MLDS detector chip design [10].

Also, K. Zhao and others from China, [9] have developed and constructed a new sensitive microwave life detection system which can be carried by special rescuing robots. The system can be used for rescuing, antiterrorist and law-enforcement purposes. The design is recited in details. Experiments have been conducted to verify the effectiveness of this system. The recorded signal frequency spectrums for heartbeat and respiration of a man behind an obstacle (wall) are presented.

2.5 The Detection Using Ultra Wide-band Radar

Using UWB radar for human detection applications that require penetrating obstacles is rather new direction due to the late availability of this kind of radar techniques. There are a lot of researches and thesis belong to this field, a lot of them used a ready product and tried to enhance the signal processing algorithms for different scenarios using different obstacles in indoor or outdoor environment.

In [18], the author used P410 PN-UWB radar produced by Time Domain in his experimental studies in indoor environment. The main objective of his thesis was to explore different ways to enhance the performance of a human breathing detection system. For the reflected signal processing, he used a technique called ‘Singular Value Decomposition’ combined with other techniques to detect a human behind a wall. He was able to detect a target standing 1.5 m behind a 20 cm gypsum wall, distinguish between two targets separated by a distance equals to 0.3 m between each other and distinguish between lying down posture and sitting or standing posture in specific environment.

According to [19], there are four commercially available UWB radar technologies and it is not clear which radar technology is the most suited one for the purpose of detecting trapped victims. Also, there is very little available knowledge on the two target features that enable detection of a trapped human body using radar (respiratory and cardiac motion). For his researches, he used various products from Geozondas, Meodat, HP and Agilent companies. His results showed that the respiratory motion responses stronger than the cardiac motion responses and the position such that the chest is turned toward the receive antenna produces strongest respiratory motion responses due to larger chest displacement and reflective area than the other positions. One of the problems discussed in this thesis is the attenuation as function of frequency for specific rubbles. However, realistic rubble thicknesses and types of rubble can heavily increase the attenuation and thereby lower the probability of detection. One of the fundamental tasks of this thesis is the development of a respiratory motion detection algorithm.

Jürgen Sachs with his team published some papers related with using UWB sensor for applications such as human detection for rescue, security or medical care. Their researches were to develop a radar device and software suited for the human detection under rubble which is one of the goals of the EU-project RADIOTECT (project invested by the European Union). In [25], they described M-sequence ultra-wideband radar as a tool for the detection of people buried beneath rubble. Their system depends on the fact that any strong enough motion of the victims will modulate the signals detected by the radar. Because the target maybe unconscious, breathing is the most beneficent type of motion besides, the periodical nature of breathing makes it possible to distinguish it from noise and clutter components. Of course the received signal will be full of noise and clutters so some appropriate processing can applied to enhance the signal to noise ratio. The basic diagram of this system is slightly discussed in chapter three.

CHAPTER THREE

PREVIEW AND STUDY THE MAIN METHOD

CHAPTER THREE

PREVIEW AND STUDY THE MAIN METHODS

3.1 Heat-Based Human Detection

All objects with a temperature over absolute zero transmit thermal energy, infrared radiation. The higher the object's temperature is, the more radiation it transmits. Infrared sensors capable of detecting such radiant energy are an extremely useful means of human body detection because they can detect the presence of a person even at night without any illumination. Depending on the IR radiation that emitted from the human; it is possible to detect him for the applications of rescue operations, security systems and so on [2, 5].

3.1.1 Infrared radiation

Infrared (infra is the Latin prefix for "below") is a type of light that we cannot see with our eyes. Our eyes can only see what we call visible light. Infrared light brings us special information that we do not get from visible light. It shows us how much heat something has and gives us information about an object's temperature. Everything has some heat and puts out infrared light. Even things that we think of as being very cold, like an ice cube, put out some heat. Cold objects just put out less heat than warm objects. The warmer something is the more heat it puts out and the colder something is the less heat it puts out. Hot objects glow more brightly in the infrared because they put out more heat and more infrared light. Cold objects put out less heat or infrared light and appear less bright in the infrared. Anything which has a temperature puts out infrared light. Because IR radiation is generated by heat, it is called thermal radiation. Infrared radiation is a form of electromagnetic radiation exists in the electromagnetic spectrum at a wavelength that is longer than visible light (see Figure 3.1). It cannot be seen but it can be detected. Infrared radiation has wavelengths from 0.78 µm to 1,000 µm (1 mm). The IR region is generally divided into three sub-regions: near IR (NIR) with a range of 700–1400 nm, mid-wavelength IR (MWIR) with a range of 1400 nm–3 µm, and long-wavelength IR (LWIR) with a range of 3 µm–1 mm [2, 13].

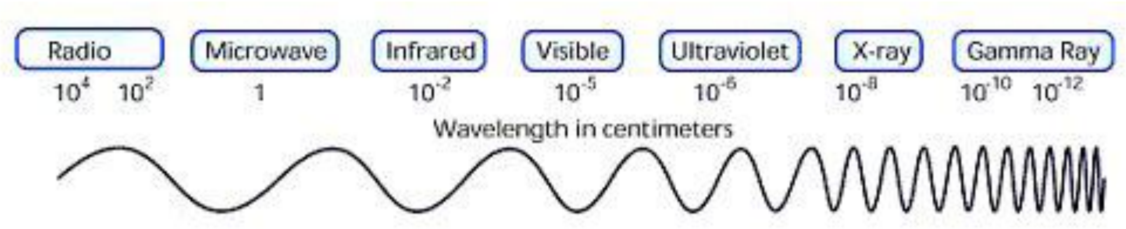

Figure 3.1: Electromagnetic spectrum

3.1.2 Infrared radiation producing

Infrared can be used as a way to measure the heat radiated by an object. This radiation produced by the motion of atoms and molecules in an object. The higher the temperature, the more the atoms and molecules move and the more infrared they produce. Any object which has a temperature i.e. anything above absolute zero (-459.67 degrees Fahrenheit or -273.15 degrees Celsius or 0 degrees Kelvin), radiates in the infrared or generally emits electromagnetic radiation. Absolute zero is the temperature at which all atomic and molecular motion ceases. This radiant energy is in accordance with the Stephan-Boltzmann equation [11]:

$$W = \varepsilon\sigma T^4 \tag{3.1}$$

where:

W= emitted energy (watt)

ε = emissivity

σ = Stephan-Boltzmann constant (5.67×10^{-12} watts/cm^2K^4)

T = absolute temperature of object in degrees Kelvin.

If the object is hot enough then some of the radiant energy will be in the visible light range. When an object is not quite hot enough to radiate visible light, it will emit most of its energy in the infrared. When the temperature increases, the wavelength decreases so, the emitting light becomes visible light like the sun.

3.1.3 Human's body temperature

Warm-blooded animals, like human, try to keep the same body temperature during both the day and the night. Their body temperatures do not change when it gets dark or cold outside and their heat remains about the same. They emit IR radiation or visible light corresponding to their temperature. In humans and in warm-blooded animals, the temperature of the central part of the body is stabilized by a physiological thermoregulatory function, and the deep tissue temperature at the central part of the body is called core temperature or deep body temperature. The term “body temperature” is often used to indicate the core temperature, even though the temperature of the body is not uniform but can vary from site to site. The core temperature always remains in a range from 35°C to 40°C. The skin temperature depends on the heat produced by the core and the external temperature, also the skin itself produce a small amount of heat that distributed over the whole skin surface [2, 32].

The skin temperature varies from 20° C to 40° C depending on environmental conditions. Between 32°and 36° C, the skin surface emission is mainly in the IR. It is therefore possible to measure, at a distance, the skin surface temperature by its IR radiation or to just detect and make decision that there is a human. Death usually occurs when the core temperature reaches above 43° C or bellow 26° C. According to [2], the maximum radiation intensity wavelength of the IR radiation emitted by the human body is about 9.5 µm. The emissivity (ε) of human skin is very close to unity (0.98). A typical human gives off somewhere between 80 and 100 watts of radiant energy with a peak wavelength around 10 µm, thus producing a distinctive thermal signature [33, 11].

3.1.4 Detecting the radiant infrared from the human

Objects that generate heat also generate infrared radiation and those objects include animals and the human body. Since the maximum radiation intensity wavelength of the IR radiation emitted by the human body is $\lambda_m \approx 9.5$ µm then, using LWIR radiation in a wavelength range of 8-13 µm is suitable for human body detection. Infrared in this range will not pass through many types of material that pass visible light such as ordinary window glass and plastic (classical glasses do not transmit wavelengths greater than 2.5 µm). However it will pass through, with some attenuation, material that is opaque to visible light such as germanium and silicon. An unprocessed silicon wafer makes a good IR window in a weatherproof enclosure for outdoor use. It also provides additional filtering for light in the visible range. 9.5µm infrared will also pass through polyethylene which is usually used to make Fresnel lenses to focus the infrared onto sensor elements. For the purpose of human detection, IR camera, pyroelectric sensor, thermopiles sensor may used. The following sections will spot the light more on the first two techniques [2, 34].

3.1.5 Infrared cameras

Infrared camera **(**also called a thermographic camera or thermal imaging camera**)** gives a complete picture of the environment heat which is very useful in human detection. Although infrared cameras are very expensive, they seem the best solution to make the discrimination between human and non human presence and, as such, seem to be essential to a robust and efficient solution for human finding. According to Wikipedia, IR camera is a non-contact device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the 400–700 nanometer range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm). IR camera detects infrared energy (heat) and converts it into an electronic signal, which is then processed to produce a thermal image [1].

Thermal infrared images let us see heat and how it is distributed. By using special infrared cameras, we can get a view of the infrared world. These cameras are very useful and have even helped save people's lives. In the infrared, you can "see" in the dark. Even if the sun is down and the lights are off, the world around us still puts out some heat. The infrared picture shown in Figure 3.2, from ‘coolcosmos website’, shows a deer in a forest during dark night. Notice how we can clearly see the heat from the deer, especially from areas not covered with thick fur like the ears, face and legs. The trees and the ground put out less heat than the deer, but can still be seen through an infrared camera.

Figure 3.2: Infrared image for a deer in a forest

The general architecture of the infrared camera is shown in Figure 3.3 [34]. Here are some details and explanation for the components mentioned in the figure, from [34] and [35] with some editing and rearrangement:

- An optical system that can form an image of an external scene using radiation in the thermal wavelength range. Its function is the same as for radar antennas. The optical system is constituted of lenses or mirrors where each type of component has its own advantages and disadvantages. The lens focuses waves from the infrared energy present in all objects onto an infrared sensor array.

Some systems require a scanning mechanism that scans the thermal image in a regular pattern across the detector element(s), although most modern imagers do not require this, since they use large detector arrays that completely cover the field of view of the imager.

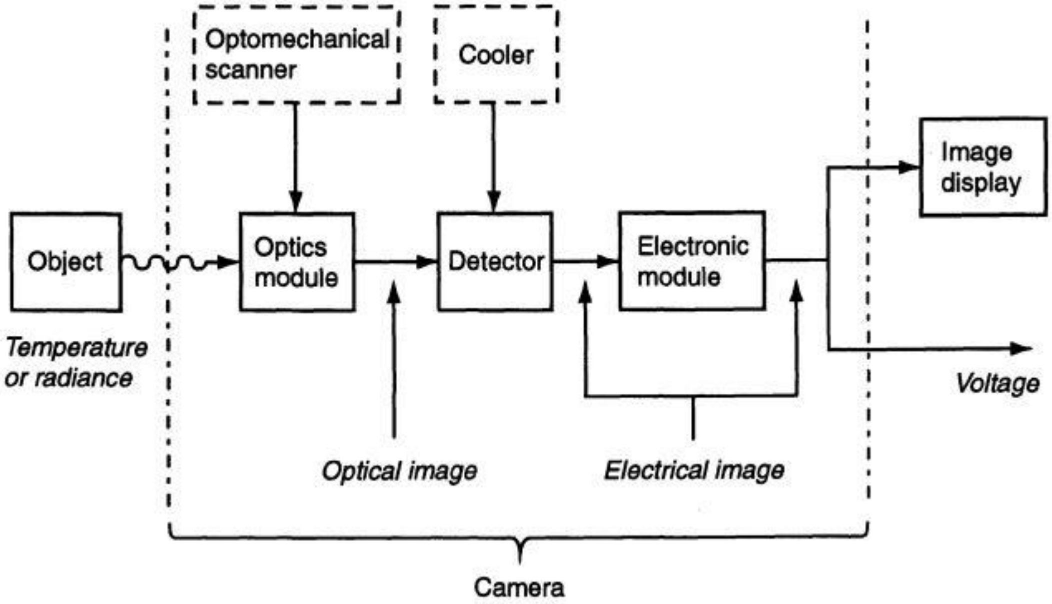

Figure 3.3: Block diagram of an infrared camera

- Thousands of sensors (detector elements) on the array convert this radiation into electrical signals proportional to the radiation falling on them. Most of the detectors used in thermal imaging require some form of cooling or temperature control. Liquid nitrogen or thermoelectric cooler (using Seebeck effect) may used.

- An electronic processor that can process the detector outputs, and can convert them into a thermal image.
- A display unit that generates a visual image from the electrical signal.

The materials used in the infrared can be germanium, silicon, selenium sulphide or zinc sulphide... All of these materials have a high refractive index. It is therefore absolutely necessary to pre-treat with antireflective coatings to improve the transmission [34].

3.1.6 Pyroelectric "passive" infrared sensors

PIRs are another type of heat-based human detectors. These sensors are designed specifically for human detection. They are often referred to as PIR, "Passive Infrared", "Pyroelectric", (“pyro” means fire from Greek) or "IR motion" sensors. The term “passive” means that sensor is not using any energy for detecting purposes; it just works by detecting the energy given off by the other objects [1].

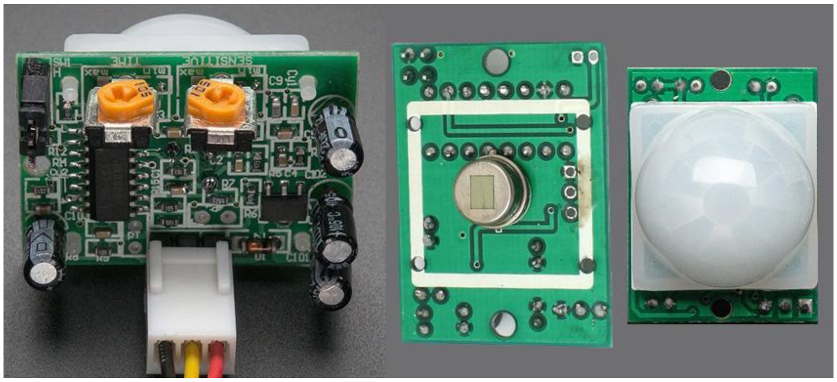

Figure 3.4: PIR (motion) sensor (adafruit.com)

PIR sensors allow us to sense motion, almost always used to detect whether a human has moved in or out of the sensors range. They are composed of two infrared sensors (or two sensing elements), so they detect humans only if the human or the sensor is moving. This arrangement cancels signals caused by vibration, temperature changes and sunlight. A body passing in front of the sensor will activate first one and then the other element whereas other sources will affect both elements simultaneously and be cancelled. Instead of using germanium or zinc sulphide, they are rather expensive; more recent devices take advantage of high-density polyethylene Fresnel lenses, which are 60 to 80 percent transmissive at the wavelengths of interest (see Figure 3.4) [1, 11].

According to Edmundoptics website “IR Fresnel lenses are molded in a flexible, 0.457mm thick, milky white plastic with grooves molded into one surface, the surface that faces the PIR sensor. Advantages of this product are: least absorption loss in the 8-14μm region, extremely thin with consistent thickness across the lens, large apertures and minimal thermal expansion”. In general, PIR sensor consists of (see Figure 3.5):

1- Fresnel lens; to captures more IR radiation and focuses it to a small point, this is can extend the range of the PIR and the detecting angle. The sensor shown in fig.3.4 has a view angle 110°.

2- Filter window; to limit detectable radiation to the 8 to 14mm range.

3- Two sensing elements; this cancels signals caused by vibration, temperature changes and sunlight. It is made of lithium tantalate which is very sensitive in the 8-14 mm range

4- FET; measures the charge produced by the sensing elements and passes suitable current to the amplifier.

5- BISS0001 IC; consists of: the amplifier, the comparator and the ADC.

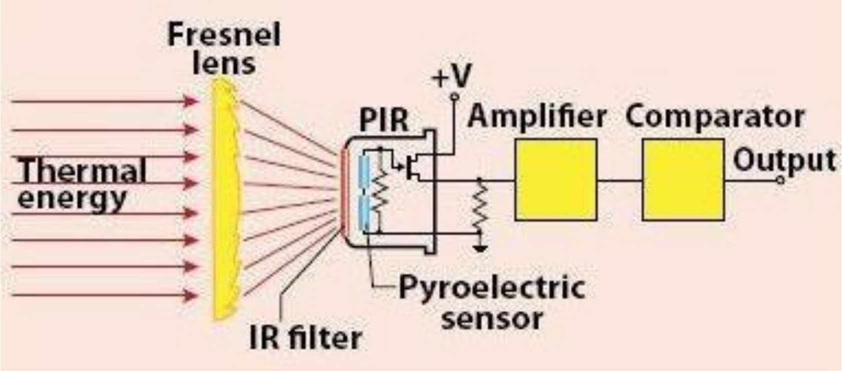

Figure 3.5: Internal construction of the PIR sensor (twinschip.com)

Theses sensors are made of a crystalline material that generates a surface electric charge when exposed to heat in the form of infrared radiation. They are calibrated to be sensitive to human heat wavelength (8 - 14 μm) using filter window. The charge can then be measured with a sensitive FET device built into the sensor. The FET source terminal connects through a resistor to ground (this is to convert the charge into voltage) and feeds into a two stage amplifier having signal conditioning circuits. Then the comparator compares the sensor's signal voltage with a reference voltage, after that ADC used to convert the difference signal to a digital output [1].

3.2 CO_2-Based Human Detection

Carbon dioxide (CO_2) is a very familiar gas to human being, it's directly or indirectly involved in our life details, in our food or drink, manufacture, and even as a natural result of breathing (see Figure 3.6). So it was a logical thing for man to make use of CO_2, especially after the industrial revolution when the carbon dioxide (CO_2) dynamic characteristics have been discovered. One of the new generations of carbon dioxide applications is the detection, because carbon dioxide (CO_2) generally has certain saturation according to the environment, so when it increases or decreases the carbon dioxide detection system alert the person in charge to check the parameters and fix any error can be probably happened. However, although of the great technological development in modern life, detecting vital signs of human body still a very hard and complicated thing, in this field many theories and experiments did flow to the surface, one of them is about locating vital signs of humans by analyzing carbon dioxide (CO_2), in this part we will study this theory and see how useful it can be [47].

3.2.1 CO_2 properties

Carbon dioxide (CO_2) is a triatomic molecule with a molecular weight of 44 Da. It is a gas at room temperature and pressure. At atmospheric pressure it sublimes directly from a solid to a gas at 78ºC. Carbon dioxide is a relatively inert gas which is neither explosive nor flammable and which does not support combustion. Therefore, it is widely used in fire extinguishers and fire suppression systems, though some care is needed especially in confined spaces as it asphyxiates and has a density (1.98 kg/m3 at 0ºC) greater than that of air.

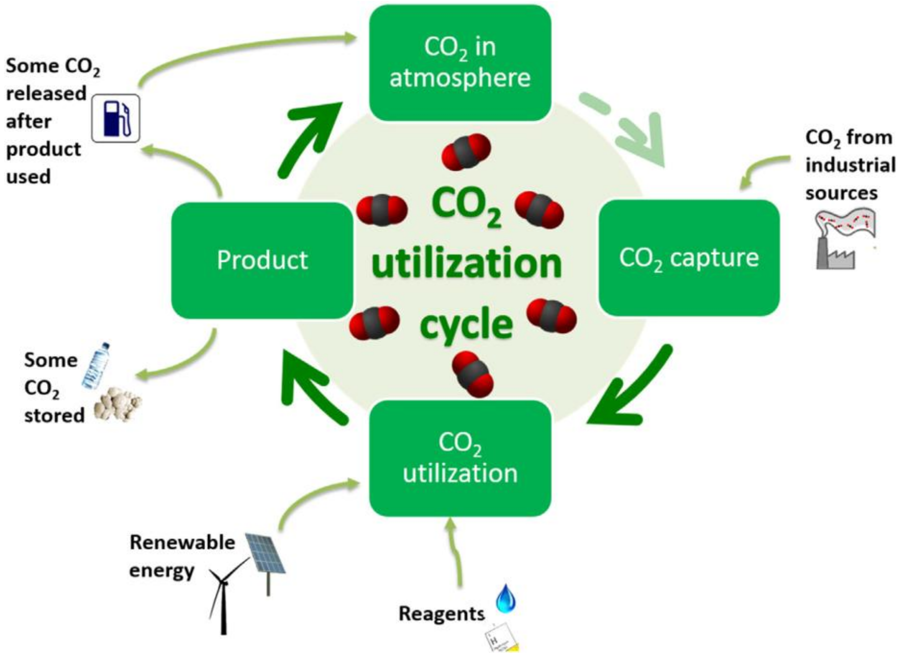

Figure 3.6: Schematic representation of a carbon dioxide capture and utilization

Carbon dioxide occurs naturally in the Earth’s atmosphere as a result of volcanic eruptions, forest fires and plant and animal respiration. It is essential to the growth of green plants which use photosynthesis to convert carbon dioxide and water into sugars. These are key parts of the natural carbon cycle which controls the level of carbon dioxide in the Earth’s atmosphere and hence the surface temperature of the planet. Prior to the start of the industrial revolution, atmospheric carbon dioxide levels were around 270 ppm by volume [47].

3.2.2 Locating trapped victim by analyzing CO_2

In fact, the idea of locating the trapped victims by analyzing the concentration of chemical compounds like CO_2 as a theory is acceptable, but as a technological device still need more of improvement to reach the required efficiency. All the available information about any experiment in this field still either incomplete or unhelpful, and there is no scientific research institution did deploy any scientific and engineering papers schemes that explains their experiences to develop an electronic device able to monitor the chemical effects of the victims trapped under the rubble yet [46].

3.3 Voice-Based Human Detection

To record sound and to detect the direction of the emitting sound source a microphone array is used. The microphone is connected to a speech recognition toolbox. The speech recognition toolbox analyzes the sound stream, searches for common voice pattern and fits words to the sequence in a probabilistic way. The speech recognition is based on dictionaries containing words and phonemes. The words and phonemes are recognized and interpreted to detect human voice. The detection result is submitted to a higher instance [38].

3.3.1 Sound properties

Sound is a pressure wave which is created by a vibrating object. These vibrations set particles in the surrounding medium (typical air) in vibrational motion, thus transporting energy through the medium. Briefly, any vibrating body in contact with the atmosphere will produce sound waves. Since the particles are moving in parallel direction to the wave movement, the sound wave is referred to as a longitudinal wave. The result of longitudinal waves is the creation of compressions and rarefactions within the air. The alternating configuration of crests and troughs of particles is described by the graph of a sine wave as shown in Figure 3.7. The speed of a sound pressure wave in air is

331.5+0.6Tc (m/s), where Tc is temperature in Celsius. The particles do not move down the way with the wave but oscillate back and forth about their individual equilibrium position [36].

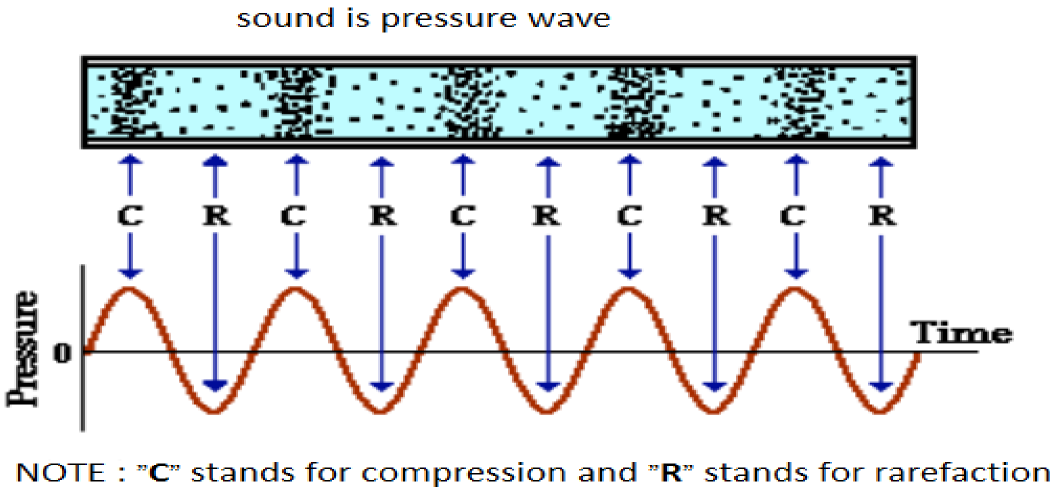

Figure 3.7: Configuration of crests and troughs of particles

3.3.2 Types of sounds

Sound waves are divided into three categories that cover different frequency ranges:

(1) Audible waves: lie within the range of sensitivity of the human ear. They can be generated in a variety of ways, such as by musical instruments, human voices, or loudspeakers.

(2) Infrasonic waves: have frequencies below the audible range. Elephants can use infrasonic waves to communicate with each other, even when separated by many kilometers.

(3) Ultrasonic waves: have frequencies above the audible range. You may have used a “silent” whistle to retrieve your dog. The ultrasonic sound is easily heard by dogs, although humans cannot detect it at all. Ultrasonic waves are also used in medical imaging [37].

3.3.3 Human's voice

The human's voice consists of sound made by a human being using the vocal folds for talking, singing, laughing, crying, screaming, etc. The human voice is specifically a part of human sound production in which the vocal folds (vocal cords) are the primary sound source. Other sound production mechanisms produced from the same general area of the body involve the production of unvoiced consonants, clicks, whistling and whispering. Generally speaking, the mechanism for generating the human voice can be subdivided into three parts; the lungs, the vocal folds within the larynx, and the articulators. The lung (the pump) must produce adequate airflow and air pressure to vibrate vocal folds (this air pressure is the fuel of the voice) [39].

The commonly stated range of human hearing is 20 Hz to 20 KHz. Under ideal laboratory conditions, humans can hear sound as low as 12 Hz and as high as 28 KHz. Humans are most sensitive to (i.e. able to discern at lowest intensity) frequencies between 2,000 and 5,000 Hz. Individual hearing range varies according to the general condition of a human's ears and nervous system. The range shrinks during life, usually beginning at around age of eight with the upper frequency limit being reduced [48].

3.3.4 Detection the human's voice

A human Sound is in audible spectrum so that it could be detected and measured. In a complex environment, it is very difficult to filter a human sound like a shout. However, to find a survivor, the rescue people sometimes stop all activity to listen to a shouting person. It is possible to hear some people in this condition ,but it's not practical at all [40].

Microphones are also a low cost sensor but not very easy to interface to process its data. Human detection based on his voice can be performed by positioning two microphones with known distance. Given an audio source left, right or between both microphones, the time difference, i.e. phase shift, is measured between both signals. This is carried out by the Crosspower Spectrum Phase (CSP) approach, which allows to calculate the phase shift of both signals based on the Fourier transformation. Using this approach, the bearing of the sound source can be successfully determined, if there is not too much background noise [1].

The most common way to do sound processing is to work under the frequency domain using the Fourier transform. A sampling rate of 8000 Hz for 30 ms (240 samples) is necessary to classify the human voice. A Fast Fourier Transform (FFT) with a 200 MHz processor and a buffer of 100 samples takes about 150 ms. It is better to do more simple sound processing in the time domain, which is fast enough to be used in real-time. Since humans are very good at sound processing, the best solution may be to transmit the audio to a computer so a human can determine whether or not the sound is human [40].

3.4 Shape-Based Human Detection

Since the first invention of the computer and its applications still in the development to make human life more easily, and man's care about developing artificial intelligence machines rapidly increased day after anther to reduce the daily tasks entrusted to him through by sharing them with intelligent machines.

With the advent of digital photography techniques began the talking about action recognition in computer vision. Recognition is defined by the trial to determine whether or not an input data contains or resembles some specific object, feature, or activity. In computer vision, action recognition is to decipher an action/activity component from a video or image scenes. The problem of understanding human actions is complicated by many issues, including the fact that actions are dynamic and may not typically be recognized by simple attention to single moments in time. Action recognition is further complicated by the variation between people and even between instances of a single person. Finally, successful action recognition demands either explicit or implicit background removal; motions in the background are distracting and should be ignored. There are various approaches for action or activity recognition and analysis [42].

Figure 3.8: A board level camera designed for integration in computer vision, multi-touch, and custom tracking applications

3.4.1 Applications

Understanding motions or activities from video sequences is a very important but difficult task. The field of action and activity representation and recognition is relatively old, yet still not much mature for many real-life applications (see Figure 3.9). Recognizing the identity of individuals as well as the actions, activities and behaviors performed by one or more persons in video sequences is very important for various applications. Diverse applications are already undertaken on this goal for proper video understanding, e.g., in:

- Human-robot interaction,
- Human-computer interaction,
- Intelligent video surveillance,
- Mixed reality,
- Face analysis,

- Object tracking,
- Video-processing and video-indexing,
- Video-conferencing,
- Obstacle avoidance,
- Smart aware-house and rehabilitation center,
- Robotics,
- The fields of biomechanics, medicine, and sports analysis,
- Film, games.

3.4.2 Categorization

Human motion analysis can be typified into three broad areas, namely:

- Human motion and activity recognition,
- Human tracking, and
- Human body structure analysis.

Two different types of techniques can be considered to recognize human posture:

- Intrusive, and
- Non-intrusive techniques.

Intrusive techniques usually track body markers to recognize the posture of a person, whereas non-intrusive techniques observe a person with one or several cameras and use sophisticated vision algorithms.

Recognition approaches can be divided into:

- Generic human model recovery,
- Appearance-based approaches, and
- Direct motion-based recognition approaches.

In another nomenclature, recognition methods can be divided into two main paradigms:

- Static recognition, and
- Dynamic recognition.

The video sequence can be analyzed either by using static representation of individual frames or by using dynamic representation of the entire sequence. An approach using static representation analyzes the individual frames first and then combines the results into the sequence, whereas an approach using dynamic representation treats the entire sequence (or a fixed length of it) as its basic analysis unit; i.e., the analysis unit is the trajectory information across the sequence. Most of static approaches have applied the method of template matching in recognition. Usually, dynamic recognition approaches employ Dynamic Time Warping (DTW), Hidden Markov Model (HMM), hierarchical Bayesian Network (BN), Dynamic Bayesian Network (DBN), etc [44].

Figure 3.9: Various applications of action understanding

3.4.3 General overview

It is clear that the computer vision is a behemoth subject and his staffs are many, as to clarify the mechanism of it work is complex and will require a lot of pages, but we'll just clarify some of the general concepts for the formation of the idea of it (see Figure 3.10).

- Image processing:

Image processing is the study of any algorithm that takes an image as input and returns an image as output. It's the very first step in the computer vision by striving to emulate the human visual system and interpret our 3D world from 2D images or video object recognition, motion tracking, 3D shape from multiple 2D images. The image processing mainly includes image enhancement, noise removal, restoration, feature detection & compression.

Feature detection cannot be clearly defined and hence, what constitutes a feature varies depending on the application. However, edges, corners, interest points, blobs, regions of interest, etc. are typically considered as image features and therefore, in image processing context, we try to extract one or more of these image features and analyze them for further processing. Note that in the presence of occlusion, shadows and image-noise, features may not find proper correspondence to the edge locations and the corresponding features [43].

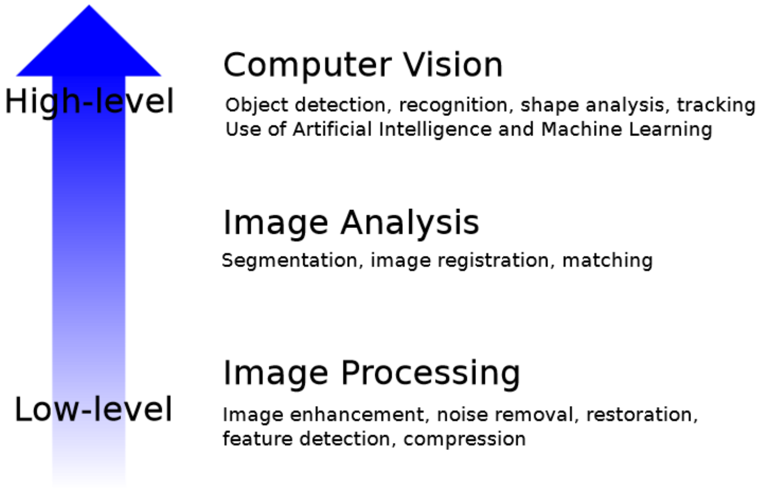

Figure 3.10: Relationship between image processing, image analysis and computer vision

- Digital image analysis:

  A method in which an image or other type of data is changed into a series of dots or numbers so that it can be viewed and studied on a computer. For example in medicine, this type of image analysis is being used to study organs or tissues, and in the diagnosis and treatment of disease. It is include three main operations: segmentation, image registration and matching. Segmentation of an object or an area of interest or interesting features in an image is done in many applications. Human detection aims at segmenting regions of interest corresponding to people from the rest of an image. It is a significant issue in a human motion analysis system since the subsequent processes such as tracking and action recognition are greatly dependent on the performance and the proper segmentation of the region of interest. The changes in weather, illumination variation, repetitive motion, and presence of camera motion or cluttered environment hinder the performance of motion segmentation approaches. Active contour, normalized cuts, graph cuts are some widely employed methods for region segmentation [44].

- Computer vision:

  A robot analogue of human vision in which information about the environment is received by one or more video cameras and processed by computer: used in navigation by robots, in the control of automated production lines, etc. It includes object detection, recognition, shape analysis, tracking use of artificial intelligence and machine learning (see Figure 3.11) [42].

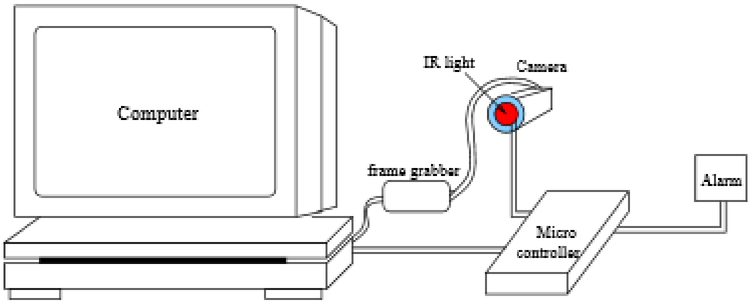

Figure 3.11: Typical hardware components of a computer vision system

3.5 Using of Trained Dogs (Canines) in USAR

Human beings knew the dogs from the beginning of the history. They used them for the hunting and guarding purposes. With the constructional development and population increasing, the problem of victims of collapsed disasters, even natural or man-made, has become an important issue to solve. The victims of these disasters usually buried under debris which make it difficult to detect them with the limited ability of human's senses. The human made a use of his relationship with animals (dogs especially) by using them for detection objectives. The strong sense of smelling of dogs gives them this ability of detection.

3.5.1 Canines for search and rescue operations

For the purpose of human detection under rubbles or debris, dogs were used in the past era, and still, because of their high sensitivity to any slight motion or human presence. In situations of survivors trapped under piles of rubble, Urban Search And Rescue (USAR) crews have a very limited or no knowledge on the presence and location of the survivors. The approach to localize trapped victims consists of three major steps. The first step is to gather all the related information from the local authorities, survivors, witnesses etc, which is later used for further USAR planning. The second step is to perform a confined-area search using specially trained USAR dogs, typically three in number. If at least two dogs mark a presence of a human being buried under rubble, the USAR crew needs to localize the victim. The dogs cannot provide the USAR crew reliable enough information on the location of the victim. Therefore, the USAR crews need to rely on other tools [3, 19].

In this step, the task for the canines is to find humans buried in rubble, or trapped inside blocked spaces. By using its superior sense of smell, the canine can detect the smell of a victim. To do so and not mix up the smell with something else, the canine trains to find a victim through the total model of scent from humans. The last step is to implement audio devices placed in direct contact with the rubble and listen for any sound coming from the trapped victim(s) or use combined audio-visual equipment that is inserted into the rubble (microphone, a video camera with a flashlight) then the operator that makes judgment on the possible location of the victim [5, 19].

3.5.2 Characteristic properties of canines

What we call smell is gas consisting of molecules or particles which is transported through the air. The particles in the air hit receptors in the nasal cavity that transform the gas to a nervous signal. The receptors send the information to the brain, which interprets them and transforms them to impressions. Therefore, logically it is the number of receptors that determine the sensitivity in the sense of smell.

A dog normally has around 200 million receptors. This is 20 to 40 times more receptors than a human being has. The dog's superior sense of smell makes it possible for the animal to detect far more complex and much weaker smells than humans can. There are several different types of dogs used in search and rescue operations. There are several different types of methods for the canine to mark a victim depending on the nature of the dog and there are also several different basic techniques for searching rubble with a canine [5].

3.6 Small-Scale Movement-Based Human Detection Using NB Radar

The demand for designing detection system for human victims buried under earthquake rubbles or collapsed building debris is getting larger, system which is more sensitive than the utilization of dogs, or optical devices. The urgency of task is defined by the ability of the system to detect the position of the victims in a very short time. The more time waste, their life goes more under danger. The system detects the breathing and heartbeat signals of human subjects [7].

3.6.1 The basic principle of operation

The system illuminates the human subject with a low-intensity microwave beam. The small amplitude body-vibrations due to the breathing and heartbeat of the human subject will modulate the back scattered microwave signal, it includes the breathing and the heartbeat signals. If the reflected wave from the stationary background can be cancelled and the reflected wave from the subject's body is properly demodulated, the breathing and heartbeat signals of the subject can be extracted. Thus, a human subject buried under the rubble or the debris can be located.

To achieve a high sensitivity for this special life-detection system, the clutter wave reflected from the rubble or the surface of the ground has to be cancelled as thoroughly as possible before it reaches the receiving microwave amplifier. Otherwise the clutter wave will saturate the receiving microwave amplifier. The clutter cancellation was performed by a slow manual-adjustment process (by two or more potentiometers). This is not practical for the field of rescuing robot operation which demands a fast process. A newly automatic clutter cancellation subsystem (that based on the technology of microchip controller) to control programmable microwave attenuation and a programmable microwave phase shifter for performing the real-time automatic clutter cancellation is developed.

The basic principle of this subsystem is to use the microprocessor-based control unit to scan the attenuator and phase-shifter to minimize the input signal to the microwave amplifier and cancel the clutter component [9].

3.6.2 Circuit description of the system

The schematics diagrams of microwave T/R system with microprocessor-based automatic clutter-cancellation subsystem are shown in the below figures [9, 10].

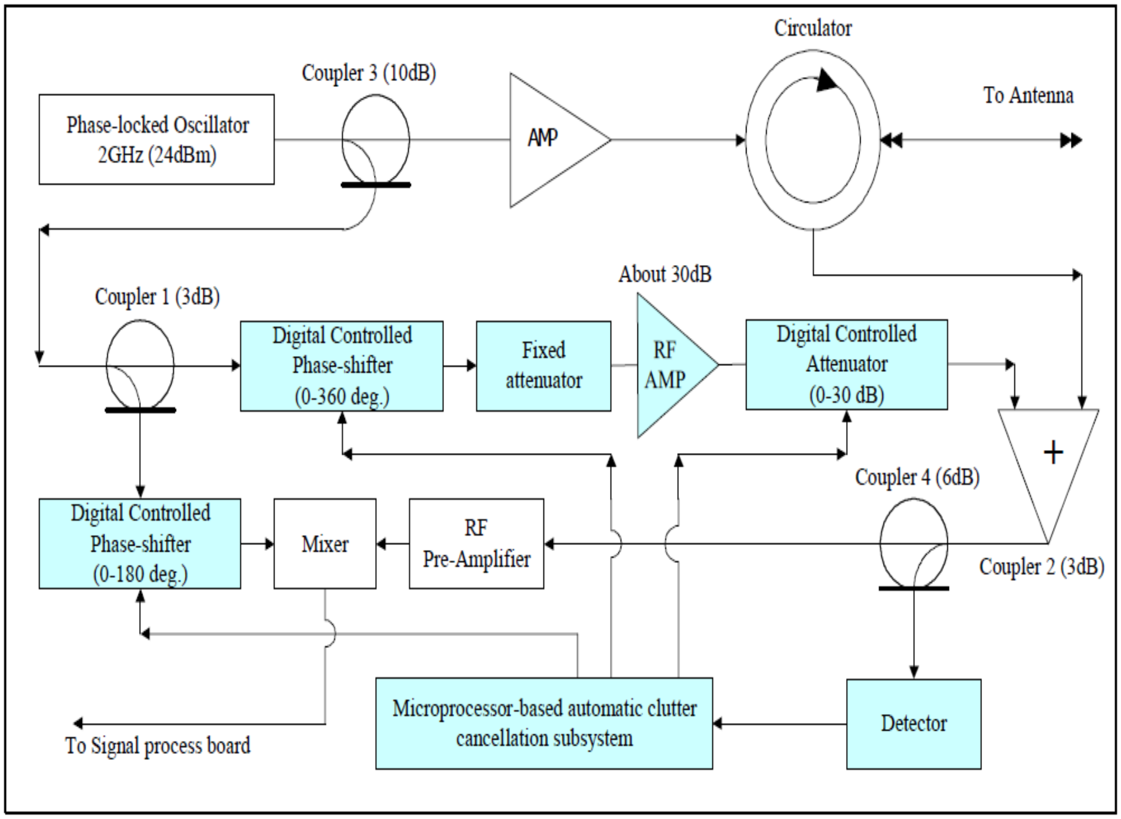

Figure 3.12: Schematic diagram of 2GHz microwave T/R system

The two systems have these components:

1- Phase-locked oscillator generators at 2/60GHz produce a stable output power.

2- A directional coupler gives 2 signals one signal is amplified by a low-noise microwave amplifier; the other signal is fed to other directional couple.

3- One of the directional coupler's outputs provides a reference signal for the clutter cancellation; the other one provides a reference signal for the mixer.

4- The element antenna radiates a microwave beam aiming at the human subject.

5- An automatic clutter cancellation subsystem that consists of two programmable microwave phase-shifters.

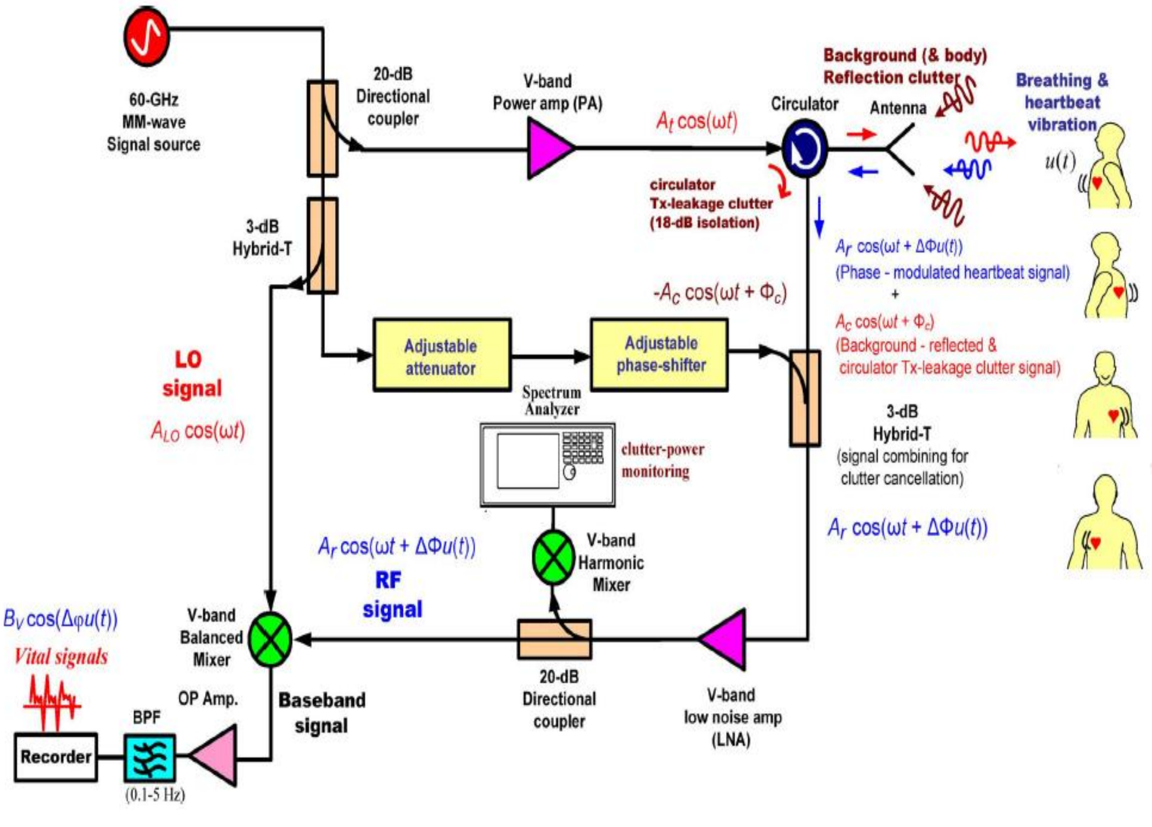

Figure 3.13: Schematic diagram of 60 GHz microwave T/R system

The received signal by the antenna consists of a large clutter reflected from background environments and a weak return signal scattered from the body. To be able to detect the weak signal modulated by the body breathing and heartbeat, the large background clutter needs to be cancelled and this is done by the above element, which consists of two systems:

a- Microprocessor-based control unit, which digitally controls the previous three components.
b- A programmable microwave attenuator.

Low-noise RF pre-amplifier is used to amplify the output of the directional coupler (coupler 4); mainly contains the weak signal scattered from the body, which is caused by the breathing and the heartbeat. This signal is mixed with the reference signal in a double-balance mixer. The mixer output provides the low-frequency breathing and heartbeat signals from the body. The mixer output is amplified by an operational amplifier and fed to the signal processing module [9].

3.7 Small-Scale Movement-Based Human Detection Using UWB Radar

The Ultra-WideBand (UWB) is a radio technology which can be used at very low energy levels for short-range high-bandwidth communications by using a large portion of the radio spectrum. UWB electromagnetic waves with frequencies of few Gigahertzes are able to penetrate through almost all types of materials around us. UWB technique has application in communications and radars systems. UWB radar is used in ground penetrating radar (GPR) for mine- for example- detection, also for through-wall radar applications for security and surveillance as well as for geology, medicine, military and civil engineering applications. For human detection in rescue or medical applications, UWB radar used to detect the movement of the chest and the abdomen resulted by the respiratory and the heart beats (the vital signs). For other applications like surveillance, tracking or security, the body movement used to be detected. It refers to as “UWB radar” or “UWB sensor” [15, 16].

The actual and intentional UWB research started in the 1950s and the 1960s. In February 2002, the Federal Communications Commission (FCC) gave the permission for UWB to be used for imaging and radar production. The corresponding technology is continuing to be developed furthermore, especially the radar applications of life detection [16, 17].

3.7.1 Ultra-wideband definition

A signal or device is called ultra-wideband if its fractional bandwidth exceeds a lower bound $b_f \geq b_{f0}$. This lower bound is typically fixed at $b_{f0} = 0.2$ in connection with a cut-off level of $L_{cut\text{-}off}$ =-10 dB. In order to avoid ambiguities with acoustic systems (audio devices, ultrasound or sonar sensors), one additionally requires an absolute bandwidth larger than a given value $B \geq B_0$ for UWB signals and devices: B_0 =50 - 500 MHz depending on the country. b_f takes values from 0.2 to 2 in the UWB case while in narrowband signals (bf ➔ 0)[17]. Fractional bandwidth:

$$b_f = \frac{B}{f_m} = 2\frac{f_u - f_l}{f_u + f_l} \quad b_f \in [0,2] \tag{3.2}$$

where:

f_u, f_l are the lower and upper cut-off frequencies.

$f_m = (f_u + f_l)/2$ is the centre frequency.

$B = f_u - f_l$ is the absolute bandwidth of the signal or device.

The spectral band occupied by UWB sensors is placed at comparatively low frequencies. Typical values are 100 MHz–10 GHz. UWB sensors must be restricted to low-power emissions (< 1 mW) [to avoid interference with other electronic devices because the very wide band] which entitles them to short-range sensing, that is up to about 100 m [17].

3.7.2 The idea behind using the UWB radar

The UWB radar system is used for scanning of the objects behind an obstacle. An electromagnetic wave is transmitted via antenna system, penetrates through the wall, it is reflected by the investigated object, penetrates again through the wall, and is received back via receiver antenna. The obstacle cannot be too thick, and may not be from to attenuating material in the used frequency band, to allow electromagnetic wave to travel through the obstacle and back. Every time the wave passes into (or from) a material, the reflection, refraction, diffraction, and absorption on the boundaries of these materials occurs. Also multiple reflections between antennas, obstacles, and all the objects in the scanned area arise. In addition, the wave changes the velocity of its propagation depending on the material properties.

As the result of all these factors, the radar receives a very complex signal, full of noise and clutters, which is very difficult to interpret. The main aim of the signal processing stages between the receiver and the radar display is to decompose the received interposed signals, use them for estimation of the scanned environment and represent this information for the end users in a human understandable and effective way. There exist no explicit method how to solve this complex problem, and that is why it represents a big challenge for researchers and engineers [15].

3.7.3 Types of UWB radars

UWB radar technologies can be broadly categorized as Impulse, Pseudo-random Noise (PN), Frequency Modulated Continuous Wave (FMCW) radars, and Stepped Frequency Continuous Wave (SFCW) radars [18]. Here is a brief explanation [19]:

- Time-domain impulse radar: transmits ultra-short pulses (thus obtaining ultra-wide bandwidth) with a fixed pulse repetition frequency.

- Pseudo-random Noise radar (PN): achieves ultra-wide bandwidth by periodically transmitting sequences consisting of pulses with pseudo random polarity and performing correlation in the receiver with the transmitted sequence.
- Frequency-Modulated Continuous Wave (FMCW) radar: transmits a chirp signal, which is a continuous wave signal whose frequency is gradually increased to cover the desired bandwidth.
- Stepped-Frequency Continuous Wave (SFCW) radar: transmits a sequential series of individual frequencies whose amplitude and phase are accurately known.

The PN-UWB technology is the fastest in data acquisition time. It is a readily available and inexpensive technology with wide dynamic range and low average transmitted power. Also, it is immune to interference and multipath problems. For these reasons it's the convenient technology for human detection behind obstacles [18].

PN-codes are periodic signals which constitute of a large number of individual pulses ostensible randomly distributed within the period. There are different types of binary pseudo-noise codes, for example Barker code, M-sequence, Golay-Sequence, Gold-code, Kasami-code and so on. They are applied in many fields, for example in the communication and (large range) radar technique or for global positioning systems and others [17].

3.7.4 M-sequence properties

M-Sequence is a special kind of pseudorandom binary code. It's called maximum Length Binary Sequence (MLBS). It has many desirable features: a short Auto-Correlation Function (ACF), an even distribution of energy over the whole stimulus period (thus avoiding high peak voltages), and very good reproducibility due to its binary nature. The period duration of the M-Sequence system is defined by the system clock f_c pushing the MLBS generator and the order of the MLBS. Another big advantage is the fact, that not only the stimulus, but also the sampling timing can be derived from the same single clock in a very stable manner without the need for slow ramps. It is based on another digital circuit called a binary divider. The first idea to use a very well known M-sequence in UWB radar was proposed by Jürgen Sachs and Peter Peyerl, US patent No. 6272441 in 1996 [15, 21].

3.7.5 M-sequence UWB radar basic circuit

The structure of the prototype M-sequence radar developed for under rubbles detection of human being by J. Sachs and his team is shown in Figure 3.14.

The operational mode of a M-sequence radar consists of a clock with frequency f_c periodically pushing a high-speed digital shift register, which generates so called m-sequence u(t). Each u(t) consists of (2^n - 1) pseudorandom rectangular waveforms, or chips, where n is an integer value (typically 9). Each m-sequence u(t) is passed through an anti-aliasing filter having $f_c/2$ cut-off frequency before being radiated by the transmit antenna into the rubble. Under the assumption of the presence of a victim, the radiated waveform is reflected from the trapped victim and the surrounding objects and is recorded by the receive antenna [19].

The received wideband signal directly pushes the ADC and the track-and-hold (T&H) circuit, where the T&H captures the wideband signal and provides it to the ADC which converts it to the digital domain. Obviously, the received signal is a pseudo-random one, and it cannot be further used directly. Thus, the time-domain radar signal is reconstructed by means of a correlation procedure. After that, the signal is available for further processing [19, 24].

The circuit can be divided into three main groups of components: the transmitting (Tx) part which generates the M-sequence signal and transmits it towards the target area, the receiving (Rx) part which receives the signal reflected from the target which will be in analog form and converts it to digital form. The third part is the processing stage and decision making.

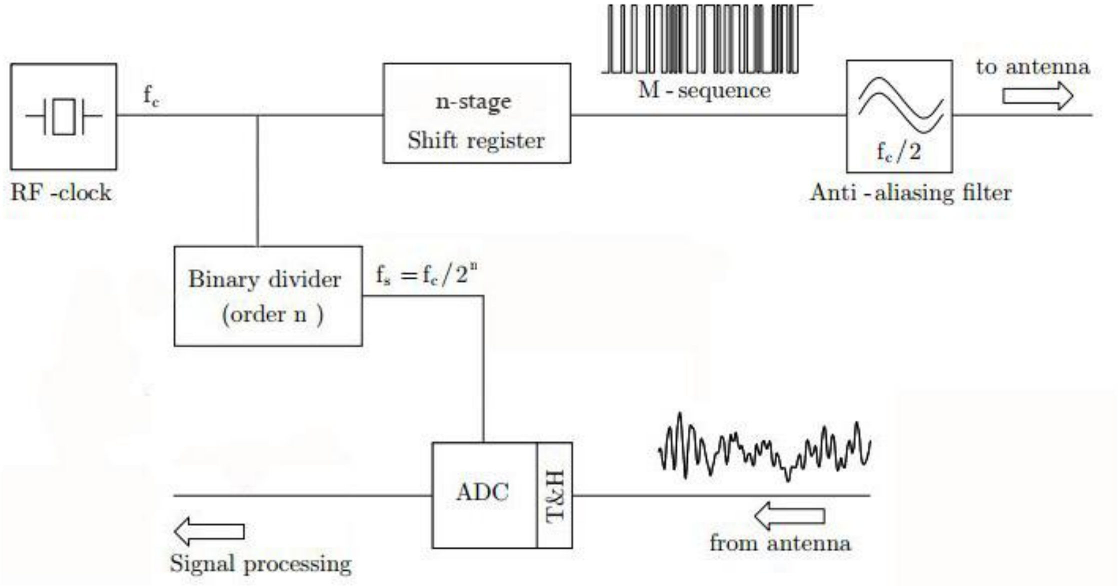

Figure 3.14: The basic circuit of M-sequence radar

- Transmitting part:

A fast 9-stage shift register with an appropriate feedback, which is driven by the RF-clock frequency f_c, generates the M-sequence. Since sensitivity is one of the key parameters of high resolution UWB sensors, a variable gain amplifier (VGA) helps to improve the dynamic range of the sensor by increasing the isolation between the Tx and Rx antennas. The transmitter circuit is operated by a single 5 V power supply and the power dissipation is less than 2 W. Since about 80% of the total signal energy concentrated from DC to $f_c/2$, then the sequence signal has to be low-pass filtered [26, 30]. For more details about M-sequence generating and its circuit (see Appendix).

- Receiving part:

Since we like to process our data in the digital domain, first we have to digitize the captured signal. Because the clock frequency is rather huge so it needs a huge sampling rate in order to meet the Nyquist theorem. Under-sampling “sub-sampling” can be applied. This is allowed due to the periodicity of M-sequence and will reduce the sampling rate. Only a few points or even less can be captured during each period of the stimulus signal. The function of the binary divider is to generate the sampling rate f_s where: $f_s = f_c/2^n$, this mean that we need 2^n signal periods to capture the whole data. A series of FFs between generator clock and ADC is all that is needed to implement such a divider. This leads to a sampling rate of 8.8 MHz [17, 28].

- Processing stage:

The role of radar signal processing is to extract required information from the received radar signals. As mentioned before, the received signal will be complex and full of noise and clutters (signals from the human, stationary clutter, non-stationary clutter and narrowband interference) beside that, a weak signal is what we are looking for. As a result, the signal-to-noise ratio (SNR) of the vital sign in radar signals will be low so in general, it is hard to identify a human's vital signs (breathing and heartbeat) in complex environments. Although a lot of studies have been done for the purpose of improvement the algorithms of human breathing detection, breathing rate estimation, posture detection and discrimination between multiple humans, the field of UWB radar signal processing for the human detection behind obstacles is still an open research area. According to M. Mabrouk in his thesis at 2015, there has been no system solve all the previous mentioned problems.

Before applying the algorithm of the received signal processing, the signal pre-processing algorithm applied. It prepares the data to be studied using the used technique (SVD for example). The pre-processing includes filtering data from the unwanted frequencies. Firstly, BPF (DC~2.25 GHz) applied to filter frequencies that are out of the transmitted frequency band and then to restrict the analysis to the breathing frequency, BPF (0.1~1Hz) applied. Butterworth filter can be used due to its flat magnitude response in the passband [18].

The basic required information is to make decision if there is a human behind the obstacle, the wall or under the rubble or not. For this purpose, the clutter and unwanted signal should be removed. Filtering can eliminate some clutter but there is still another. Singular Value Decomposition (SVD) and range gating can be used to remove clutter which has not been removed using the filtering and in order to detect human breathing as M. Mabrouk did in his thesis. The spectral analysis with the DFT, the STFT or wavelets can also be used to extract the breathing and heartbeat frequency. Artificial intelligence techniques can be used like Fuzzy logic in [28] or posture estimation using Neural Network in [29].

CHAPTER FOUR

METHODS ANALYSIS

CHAPTER FOUR

METHODS ANALYSIS

4.1 Analysis of Using Ultrasonic

Some researches used ultrasonic sensor and a camera with an autonomous robot to detect alive human for rescue operations. As mentioned in [4], they used a bomb (metal) sensor to detect the presence of suspected material in the search area, an ultrasonic sensor to detect human motion and obstacles come in the way of the robot, a temperature and fire sensor to measure temperatures, and a camera to record and display data when sensor trigger it. When the ultrasonic sensor detects a signal, the camera display the surrounding area .If a human is detected, the system sends its current location to the rescue team via a wireless RF transmitter.

It seems that the ultrasonic sensor is activated when the robot face any obstacle and then the camera turn on to confirm if there is a human or not. Because the ultrasonic can't distinguish between an obstacle and a human, can't penetrate the obstacles and the ordinary camera is not efficient in such as these scenarios, this system is not practical.

4.2 Analysis of Using Infrared

Infrared light can travels through thick smoke so firefighters are using infrared cameras to find people and animals in smoke filled buildings and to find the hot spots in a fire. Also for search and rescue operations, the rescuers can detect and locate the victims who are not visible to the naked eye, motionless and covered with dust or smoke in a total dark site using an infrared camera. On the other hand, the IR can't pass through the walls or even glass so we can't use IR camera for such applications that require detection of humans behind walls or under rubbles.

One of the problems related to the IR detection is that the IR detector detects the differences between the temperatures so if the temperature of the surroundings is close to the victim's temperature, it's difficult to distinguish and detect the victim. As mentioned in chapter three, the PIR sensors have some limitations one of them that the PIR sensors sense motion so, they detect humans only if the human or the sensor is moving. One of the solutions for this problem is to connect the sensor with a servo motor to create an artificial motion by moving the sensor itself as in [12]. Another solution is from OMRON Company (Japan); they have a thermopile sensor uses the Seebeck effect that can detect human heat even if the human is stationary. This product called D6T sensor and costs about 50$ (for more details see OMRON website).

Another limitation is that the PIR is not able to distinguish between the animals and the humans. Besides, the PIR is sensitive to the sunshine radiations for example and this may raise the false alarms. They also detect other heat sources from the electric devices for example. This is can mislead the sensor. By talking about the range, the IR cameras have a very suitable range, some IR cameras have a range reaches to 20km (FLIR products) used for border surveillance. The PIR sensors have a range up to 10m. The IR cameras are expensive but the PIR sensors are inexpensive besides, they are small, low power and easy to use [12].

The researches which used the idea of the infrared for the applications of detection the human behind obstacles or under rubbles and such like, didn't record any results. They talked about their circuit, its component, its simplicity and the cost efficiency but they didn't mention anything about its using in outdoor environment, under realistic conditions or even in indoor environment under simulated circumstances. Besides, there are a lot of limitations - discussed previously- when the infrared is used for such these application. The authors didn't discuss the limitations of the IR radiation. These reasons make these systems undependable and not practical.

Because the limitations of the PIR sensors, using them in the field of search and rescue operations is not practical. They nevertheless have wide applications in other fields. Energy consumption management in the buildings (smart homes, offices etc.) according to the presence of the residents is one of those applications. May the human detection achieved through using thermal and visual information sources that are integrated to do the mission. This system can be used with a mobile service robot in a home environment to provide different kinds of services like, cleaning, surveillance and so on.

Another application in outdoor environment is in [2], the authors designed a system which use the infrared radiates from the human to control a car and prevent accident with any human who is invisible to the driver. More details about this system discussed in chapter two. The field of human tracking is another application for the PIR sensor technology. Some systems used tracking algorithm based on wireless pyroelectric infrared sensors network and video analysis technologies to detect and locate the human target motion precisely.

With the development of the technology in the recent years, the infrared technology developers are trying to make more efficient and more practical sensors. Panasonic Company and its product which called Grid-EYE is one of the appearances of this development. The used technology made the Grid-EYE is around 70% smaller in size than competitor products. With this product, it is not only possible to detect moving people and objects but also the position and presence of motionless people and objects, the direction of movements and the accurate surface temperature from -20°C up to +100°C. More details on the company website.

4.3 Analysis of Using CO_2 Detection

The results of experiments in the studies in chapter two have proved useful in exploring the potential of using a chemical method for early location of entrapped people. Further work is needed for validating the theory and the model developed. VOCs in expired air of multi-fracture individuals also need to be investigated as this type is common in entrapment. The device developed is planned to be extensively tested in near-real situations [46].

The theory of locating vital signs of trapped victims under rubble by CO_2 and chemical component analyzing is a good field to do more research and experiments. Any success in the human body chemical activities locating devises will improve the search and rescue teams by making them focus in the areas with high chemical activities. But till now we still far from using this kind of technology practically in rescue missions.

4.4 Analysis of Using Voice Detection

Using voice detection method have many weak points, here they are:

- This method is computationally expensive and requires powerful hardware for use in real-time.
- Even if our processor is twice as fast, this is not possible in real-time.
- Reducing the sample number also reduces the quality of the Fourier transform.
- In a disaster area, rescue people sometimes stop all activity to listen for shouting victims.
- Basic voice recognition involves looking for a high amplitude noise during this time. This approach supposes that the voice of a shouting person is louder than environmental noise [41].

4.5 Analysis of Using Shape Detection

Human motion analysis is a challenging problem due to large variations in human motion and appearance, camera viewpoint and environment settings. The field of action and activity representation and recognition is relatively old, yet not well understood. Some important but common motion recognition problems are even now unsolved properly by the computer vision community. However, in the last decade, a number of good approaches are proposed and evaluated subsequently by many researchers. Among those methods, few methods show promising results with significant attentions by other researchers. We hope that more robust and smart methods will be developed and lead the computer vision field [44].

4.6 Analysis of Using Dogs for USAR

It is hard to totally depend on the canines since they can predict the presence of a living victim and dead victim although it is possible to train dogs to detect only living victims. Another limitation is that they are not able to expose the exact situation of the human and where exactly he is located. One major drawback is that dogs couldn't work independently; they need assistance of a human. It means, the need is totally or partially independent to human factor but still depends on human. The canines demand continuous care to work properly and they require high costs in training each canine and even when they are at rest. They can't work well in difficult climates with high temperature and high humidity. Besides, they have limited operational lifetime [3, 5].

Although all above, the respondents of the questionnaire in [5] mentioned that the canine is the most effective type of equipment used to detect trapped victims in rubble. The canine's mobility combined with its ability to detect hidden live victims makes it a valued asset. Due to the shortcomings of this method and with the accelerated development of the technology, more efficient and reliable methods are mightily needed. It seems that radar technology is the more suitable solution.

4.7 Analysis of Using Narrowband Radar Technology

Microwave techniques represent a promising technology for the applications of human detection behind obstacles, since electromagnetic waves within the lower GHz-range can penetrate most of building materials [25]. Generally, the radar that operates in the wavelength range of 3 - 30cm (frequencies correspond to 1 - 10 GHz) could be used for searching and rescuing human victims buried under earthquake rubbles or collapsed building debris. In this case, by subtraction of signals reflected from motionless objects it is possible to achieve high sensitivity at detection of objects [9].

It's very clear that increasing the thickness of the wall affects on the performance of the 2 GHz life-detecting system, it became marginal. Also, increasing the distance between the target and the wall affects the performance. Using (L-band, 2 GHz or X-band, 10 GHz) gives low sensitivity for detection human but it has a very large range for detection about (100 feet).

The microwave life detection system can work on different range of frequencies from L-band (2GHz) to X- band (10GHz). But X- band microwave is unable to penetrate deep into the rubble. It can penetrate rubble up to 1.5 ft in the thickness (5 layers of bricks) while L- band can penetrate the rubble of about 3 ft in thickness (10 layers of bricks). Due to the fact that lower frequency will be more capable of detecting vital signs through very thick rubble, so frequency of an electromagnetic wave needs to be in the L-band or S-band range. For this reason, the microwave life detection system should operates on the L-band frequency. This system is supposed to quite efficient to trap the breathing and heartbeat signals of victims who are completely trapped and too weak to respond [7].

4.8 Analysis of Using UWB Radar Technology

Beside that the lower microwaves frequencies have good penetrating properties, UWB radar has shown to be capable of detecting breathing and even heartbeat signals through wall along with the larger motion. One of the topics related to the electromagnetic radiations, in general, is the effects on the biological tissues .The physical impact of electromagnetic radiation on substances can be classified into heating, ionization and cracking of molecules. Short-range UWB sensing is an absolutely harmless sensing technique which can be applied for medical purposes and also in private homes. The radiated power of a cell phone is more than thousand times higher than that permitted for an UWB device according to the comparatively relaxed FCC rules. Typical power transmission levels for short-range UWB radar systems are in the milliwatt range. This leads to no effects on radio services, such as emergency radio or other devices [17, 19, 25].

In addition to the UWB radars have good penetration characteristics and use harmless radiation, UWB technology guarantees very fine range resolution due to its large bandwidth. This enables extraction of target features which are much smaller than the target size (e.g. respiratory motion), as well as increasing the ability of radar to discriminate between two or several closely located targets (humans), at least theoretically,. Furthermore, due to its large bandwidth, it allows for increased separation of the target response from the non-stationary clutter responses compared to narrowband radar. UWB radars also possess good immunity against narrowband interference and have the ability to operate indoor as well as outdoor areas [18, 19].

Although the large potential of UWB radar for human detection application, there are several major challenges that need to be treated for successful employment in real-life conditions:

- Low signal-to-noise (SNR) ratios which are the result of high material attenuation, low reflectivity of the human body, highly limited movements of the victim and low spectral power emissions.
- Presence of narrowband interference. Although UWB radars possess good immunity against multipath interference, this interference still affects detection and clutter is not completely eliminated in the detected signal.
- Presence of non-stationary clutter originating from moving objects in the area of the rubble site (rescue workers, radar operators, rattling leaves, construction machines etc) [18, 19].

The proposed bandwidth, for detection a human under rubbles, equals 2.25GHz and according to [31] any operational bandwidth exceeding 1 GHz is hardly to reach by commercial components. That is interprets why almost all the researchers used ready products. Another reason is that the most important point is the reflected signal processing which is very weak and need a lot of processing to extract the wanted information. This is a big problem and a great challenge because the ready products are very expensive and all the processing techniques are advanced topics.

As a conclusion, UWB radar has two main parts: the transmitting and receiving device, which responsible for generating, transmitting and receiving the desired signal, and the processing part which may includes hardware and software equipments. Researchers are using combination of advanced signal processing methods.

There are some companies using UWB technology to produce respiration sensors capable of measuring respiration of a person that sits or sleeps close to the sensor for monitoring, medical care or just presence detection like Novelda AS Company based in Norway (their product called “XeThru Impulse Radar”). Although their respiration sensor costs 150$, it isn't designed for working under rubbles or behind walls for applications like search and rescue, security and so on.

Some other companies have UWB radar products like Time Domain Company (America) has P440 Radar Development Kit and it costs about 5000$. For the purpose of development the algorithms of signal processing, a lot of researches used this product or another one of its family like [18], the researcher used it for human detection behind walls. Another product used by many researchers like J. Sachs in his researches and projects is m:explorer device (Ilmsens Company, Germany), its cost is 8000€.

Some other companies have ready products can be used in the field of rescue operations like Sensors & Software Inc. (Canada) has Rescue Radar costs about 20,000$!. Xaver 100 through-wall life detector is a product of Camero-Tech Ltd. (Israeli product!) can be used for military, law enforcement and search & rescue applications and costs about 9000$. Their other product “Xaver 400” is more efficiency, provides more information about the scanned area and costs only about 50,000$!. Most of these products aren't consumer products.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

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5.1 Conclusion

Human detection is a wide researching field and represents a great challenge due to various problems which must be considered. Always the human detection depends on one or more of his characteristics properties. In this study, some related previous researches in this aspect have been addressed and many major methods have been previewed and discussed in details. By analyzing and comparing the different techniques of detection, the results showed the domain for using each method, its advantages and its limitations.

The big trouble which have been faced is that the information belongs to the designing of appropriate system for human detecting is either more theoretical than practical, not effective under realistic conditions or the published researches are part of large projects which includes manufactured companies. From this point, it's clear that the designing of complete or just satisfactory system that can detect human under debris in realistic circumstances precisely demands large research institutions and a huge budget.

5.2 Recommendations

- Using combined of simple human detection sensors carried by a robot will be a helpful tool for many applications.
- Designing satisfying system based basically on the available cost.
- To be this search spring for designing systems for human detection.
- Get benefit from the available techniques and applications to get more suitable and practical applications in the future.

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APPENDIX

M-SEQUENCE GENERATING

APPENDIX

M-SEQUENCE GENERATING

A.1 Linear Feedback Shift Registers

M-sequence also called ‘shift-register sequence’ since it can be generated in so-called linear feedback shift registers (LFSRs) with appropriate internal feedback. An LFSR is a series of flip-flops controlled by a clock. Two or more of the flip-flop (FF) stages are connected back to the input of the shift register via a logic gate “exclusive-or (XOR) gate”. The number of FFs n defines the order of the pseudo-random code. The feedback is the distinguishing feature of the circuit. It allows the LFSR to generate patterns that are much longer than the shift register itself. For every clock pulse each FF outputs one bit, commonly called a ‘chip’. Since all FFs are directly connected, the output sequence can be taken from any FF with no consequence beyond a change in delay. In fig.3.6, the FFs are pushed by the master clock rate f_c and in each clock cycle, an elementary rectangular pulse is put out. The randomness lies in the polarity of the pulse, i.e. whether it represents a logical 0 or 1 (or -1 and 1, respectively) both states 0 and 1 usually represent the same (absolute) value V_{Ms} of signal voltage but they are of opposite sign [21-23].

A.2 Polynomial Generator

LFSRs are commonly specified by giving a characteristic or generator polynomial G(x). By looking at the Figure A.1 bellow, each clock time the register shifts all contents to the right. The sequence a_r -where r is any integer- propagates through each term generated linearly from the preceding r terms according to the formula:

$$a_r = c_1 a_{r-1} + c_2 a_{r-2} + \cdots + c_n a_{r-n} = \sum_{i=1}^{r} c_i a_{r-i} \qquad \text{(A.1)}$$

Here, all terms are binary (0 or 1), C_0 to C_m are connection variables (1 for connection, 0 for no connection), and ordinary multiplication rules hold, but addition is modulo-2 (or “exclusive-OR”), meaning that 0+1=1+0=1 but 0+0=1+1=0. With these rules, all operations are linear. Any LFSR can be represented as a polynomial of variable x, referred to as the generator polynomial:

$$G(x) = c_m x^m + c_{m+1} x^{m+1} + \ldots..+ c_1 x + c_0 \qquad (A.2)$$

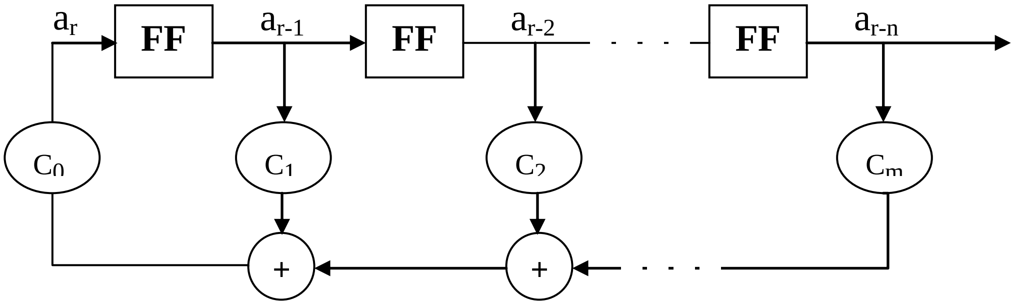

Figure A.1: General feedback shift register

The coefficients c_i represent the tap weights, as defined above, and they are 1 for taps that are connected (feedback), and 0 otherwise. The number of taps should be even. A necessary condition for $G(x)$ to generate a maximum length shift register (MLSR) sequence ($N=2^n-1$) is that the generating polynomial should be irreducible (not factorable) [22,27] or primitive polynomial and the initial state of the registers should be at least containing one state 1(not all of them equals 0). The LFSR will go through all states except the all zero. For n=9, the primitive polynomial is $x^9 + x^4 + 1$ (or it could be write as [9 4 0]).

A.3 9th Order M-Sequence Circuit

The MLBS generator circuit, which consists of a linear feedbacked shift register with 9 master-slave flip-flop stages, is shown in Figure A.2. To realize the feedback, the first flip-flop stage contains an embedded XOR gate.

For the application of human detection behind obstacles, the m-sequence order (n) =9, i.e. the impulse response covers 511 samples regularly spread over 114 ns. This corresponds to an observation window of 114 ns leading to an unambiguous range of about 16 m in free space [24]. Here are the rules [21]:

$$N=2^n-1 \quad (A.2)$$

$$T_0=1/f_c \quad (A.3)$$

$$T_p = N*T_0 = 1/PRF_{MLBS} \quad (A.4)$$

$$R = T_p*c/2 = c*N/2f_c \approx 2^{n-1}*(c/f_c) \quad (A.5)$$

Where

f_c=4.5GHz.

N is the total number of elementary pulses “chips” per period, =511.

n is the m-sequence order or the polynomial degree (no. of the shift registers), =9

T_0 is chips duration, =0.222ns.

T_p is the duration of a complete period (or the inverse of the equivalent pulse repetition frequency PRF_{MLBS}), ≈114ns.

R is the unambiguity range of the radar, and c is the speed of light, ≈16m.

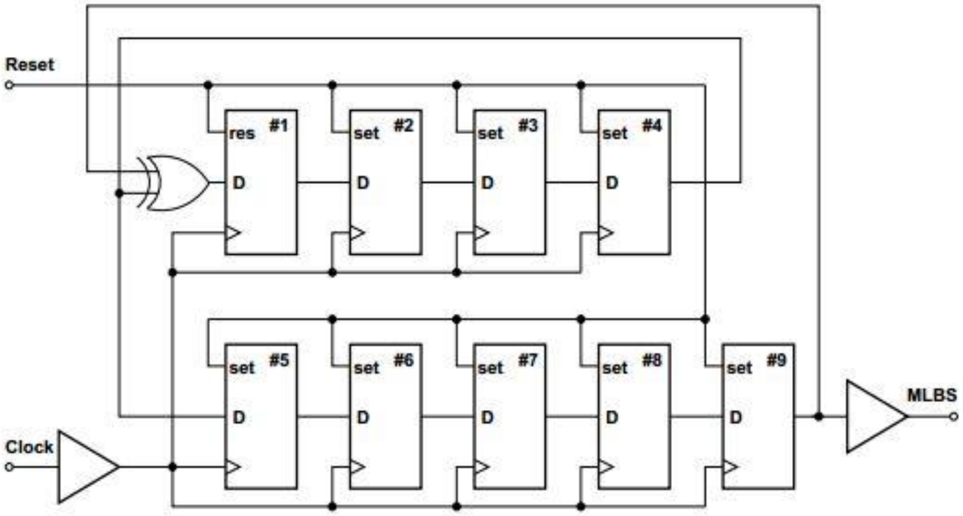

Figure A.2: Circuit diagram of the MLBS generator, n=9

A.4 Simulation Using MATLAB

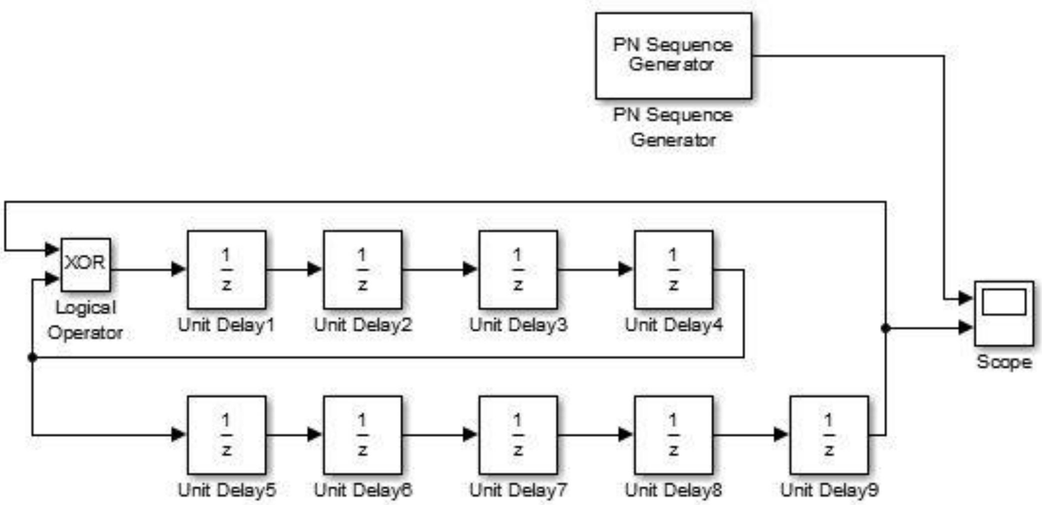

Figure A.3: Simulink model of the MLBS generator, n=9

The model shows two methods for generating M-sequence, one is directly by using PN Sequence Generator block and adjusting its characteristics (generator polynomial and initial states) to generate 9th M-sequence. The second method is by using 9 units delay which working as shift registers and XOR gate then connect them as shown after adjusting the initial state of every one.

Figure A.4 shows the resulted sequence. After 511chips, the sequence repeats itself; note the arrow.

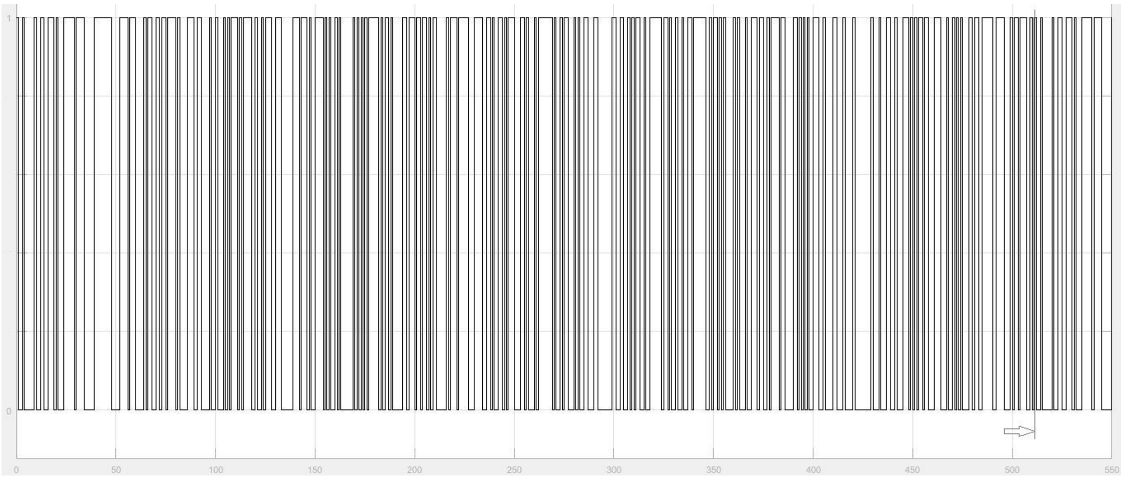

Figure A.4: The 9th generated M-sequence