The Design of a
Smart Rescue System for Private Swimming Pools

By:

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Supervisor: Dr. Raed Amro

Submitted to the College of Engineering
In partial fulfillment of the requirements for the
Bachelor degree in Mechatronics Engineering

Palestine Polytechnic University
Hebron, May 2018

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Collage of Engineering

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Supervisor Signature

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Testing Committee Signature

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Chair of the Department Signature

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Acknowledgement

The success and final outcome of this project required a lot of guidance and assistance from many people and we are extremely privileged to have got this all along the completion of our project. All that we have done is only due to such supervision and assistance and we would not forget to thank them.

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Abstract

The project aims to design and build a smart rescue system for private swimming pools that operates without human assistance. Using a safety rescue net driven by pneumatic system, and a Kinect sensing device associated with a raspberry pi microprocessor for analyzing and sensing. When a child is detected near the pool with no adults around, the first stage alarm is activated. Moreover, when he gets too close to a critical distance from the pool, the second stage alarm, along with the rescue system will be activated, alerting the parents and lifting up the net to the surface.

الملخص

الهدف الأساسي من هذا المشروع هو تصميم وبناء نظام إنقاذ ذكي للمسابح الخاصة يقوم بتحديد موقع الطفل وعملية إنقاذه في حال وقوعه في البركة دون الحاجة الي تدخل بشري، وذلك بإستخدام شبكة حماية تتم عملية رفعها بنظام هوائي ، بالإضافة إلى نظام إستشعار يعمل بالتوازي مع نظام تحكم للتحليل وتحديد موقع تواجد الطفل. عندما يقترب الطفل من البركة دون تواجد شخص بالغ معه، يتم تفعيل المرحلة الاولى من الإنذار كتنبيه اولي ، وعند وصول الطفل لمسافة قريبة جداً من البركة ، يتم تفعيل المرحلة الثانية من الإنذار وتشغيل نظام الحماية لتنبيه الأهل وحماية الطفل من الغرق.

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Chapter 1

Introduction

1.1 Overview of the Project

Drowning accidents happens mostly because of the lack of proper designs, safety mechanisms and lack of supervision, many parents who would otherwise build or buy such a swimming pool do not consider that when they are not watching, one of their children could accidentally drown in the pool. These facts have led to different ideas for a safety mechanism to be able to react and save lives in case of a drowning accident. Moreover, considering the fact that most of pool drowning accidents happens when no one's around to rescue the drowning individual, a non-human intervention in saving human's life is necessary.

In this project, the main idea based on the Kinect 3D optical sensor that works with a Raspberry Pi microprocessor to detect any children by themselves around the pool, in addition to an alarm system and a net mounted at the bottom of the pool driven by pneumatic cylinders for the rescue process.

The system has an alarming unit used to alert the parents in case of a child located near the pool by himself, or at a close distance from the pool edge. In addition to a rescue system activated in case if the child close to the pool's edge.

This project is considered to be challenging on many levels. The idea itself of using the accurate detecting capabilities of the Kinect sensor along with the smart algorithms used by the raspberry pi microprocessor to design a smart system that knows when to trigger the alarming and rescuing processes, preventing as much children drowning accidents as possible.

1.2 Problem statement

Swimming is an extraordinarily sport and an entertainment activity for millions of people around the world, especially during the warmer months of the year. However, in recent years, the number of families that have an in-ground home swimming pool increased, which increased the possibility of serious, or even deadly accidents for young children. A survey shows that among unintentional injuries, drowning is the leading cause of death for children below 4 years of age, the second leading cause of death for children 5-14 years of age and the third leading cause for children(15-17) years of age[1]. Another survey shows that 87% of the drownings occurred in private pools, where regulations and standards for pools are less rigorous than in public pools[2]. Noticing that sixty percent of pool drownings in (0-4) year old happened at their home, whereas for (5-9) year old about 40 percent occurred at either the child's or a friend's home (Figure 1.1).

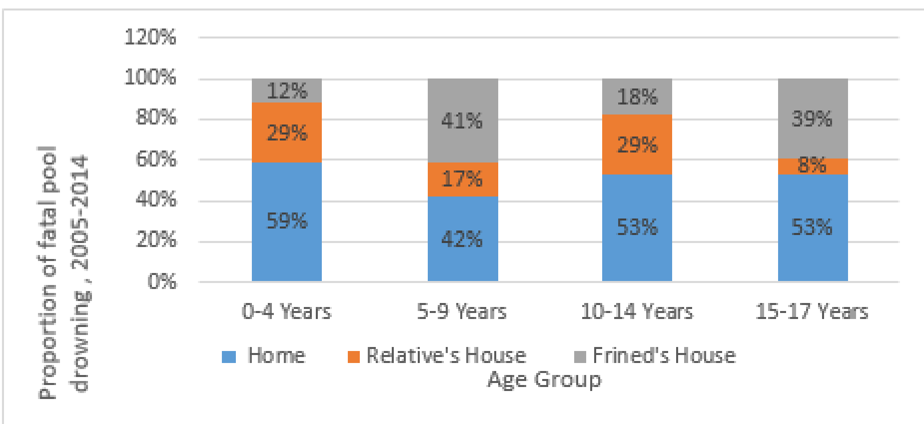


Figure (1.1) : Proportion of pool drowning to age 17[2]

Most of the parents thinks that if their child were drowning nearby they would hear him or her splashing, crying or screaming, but drowning can be quiet and quick when it occurs. In real life, something called instinctive drowning response kicks in[3]. children cannot wave their arms when they begin to struggle in the water because they extend their arms to the side and press down on the water trying to lift their bodies up so their mouth is above the water. Younger children do not even have the strength to do this so will remain with their face in the water with little to no movement in their arms and legs. Children mostly cannot even yell, they are struggling to keep their mouths above water and only have time to grab a quick breath. When it comes to parents, many distractions and social media, parents today often rely more on their sense of hearing than sight when supervising their children. As a result, parents expect they will hear something to signal that their child is in trouble. Particularly, it is not enough to supervise with your ears only.

1.3 Goals and objectives

What motivated to design and build this project is the fact that a lot of drowning deaths of young children occur at their own homes. Weather it is due to an unexpected event or because of the absence of adult's attention, it's still a horrible thought that the swimming pool that you brought to entertain your kids be the reason to put them in the danger of drowning.

The objectives of the project can be summarized as follows:

• Reduce the number of children drowning accidents in private swimming pools.

• Build a micro-computer-based rescue system using the raspberry pi microcomputer.

• Encourage people to build private swimming pools without worrying about their kids and the danger of drowning.

• Use modern electrical and mechatronics technology in buildings.

• Make private swimming pools much safer for children

1.4 Project description

In the beginning, and when the system is activated, the Kinect sensor will scan and whole area around the pool to detect any humans around the pool's area.

The data collected by the Kinect sensor will be transferred to the raspberry pi microcomputer, which represents the system's brain. The raspberry pi will analyze the data, determining if there are any humans in the area, their ages using their heights, and the location of each human. The microcomputer then controls the activation of the alarm unit and the rescue process.

As for the alarming unit, the first stage alarm will be activated when the system detects a child near the pool with no adults around, but without triggering the rescue process, so parents can be alerted before the child go any further towards the pool by himself. Moreover, when the child reaches a critical distance near the edge of the pool, both the second stage alarm and the rescue system triggers to alert the parents and start the rescue process.

The rescue system consists of four pneumatic cylinders at the corners of the pool, connected with a net that covers the whole bottom area of the pool. When the rescue unit activated, the cylinders extend to rise the net up to water surface, preventing the child from drowning in the pool.

1.5 Project Schedule and Time Plan

The followings are the distribution of the work for the first semester summarized in table (1.1), and the second semester summarized in table (1.2):

Task 1: Selection of project Idea

At this stage, the determination of the concept and the main idea of the project

Task2: Collecting the Data

Collecting information about the components and previous studies.

Task 3: Conceptual Design

Conceptual design that describes the system main concept and parameters.

Task 4: Components selection

In this step, selecting the hardware and software components and costs.

Task 5: Documentation

Writing and documenting the projects text.

Task 6: Order the components

Start to order all the components needed to build the prototype.

Task7: Assemble the machine

Start building modules, and then assemble parts of the prototype.

Task 8: installing, testing and calibration

For each module individually, then for the whole system.

Task 9: implementation and validation

Implementation and making sure there is no problem in the system operations.

Task 10: Documentation of graduation final report

Writing notes and making any necessary additions and modifications on the project documentation.

Table (1.1): Time Plane for the First Semester

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Task 1	■	■														
Task 2			■	■	■											
Task 3						■	■	■								

Task 4																
Task 5																

Table (1.2): Time Plane for the SecondSemester

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Task 6																
Task 7																
Task 8																
Task 9																
Task 10																

1.6Budget

Following are the parts and total costs of the project prototype:

Table (1.3): Budget for Parts and Prices

item	**quantity**	**price (JD)**
Kinect sensor	**1**	**80**
raspberry pi	**1**	**70**
net	**1**	**20**
prototype model	**1**	**200**
pneumatic cylinders	**4**	**80**
Total		**450**

Chapter 2

Previous Studies and Project Methodology

2.1 Overview

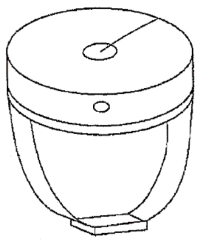
The drowning accidents of children has been a problem that deserves serious attention. Many methods and ways were found to reduce the numbers of drown kids. This chapter reviews the previous attempts and studies made to solve the problem, and samples of literature that relates to the subject. In addition, the methodology that shows what, why and how the components are going to be usedin the project to solve the problem.

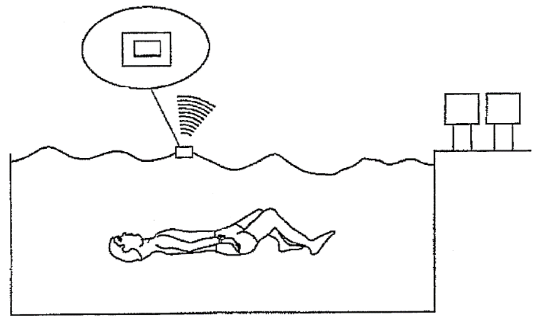
2.2 Literature Review

This section discusses the previous methods used to alarm and rescue the drowning children, advantage and disadvantage of these methods.

2.2.1 Wearable Apparatus

Eitan Weintraub (2009). Apparatus and Method for the Detection of a Subject in Drowning or Near-drowning Situation [4]: This article talks about using apparatus to identify a drowning person, sends an alarm to promote early rescue, the drowning person location, and attracts the people around.





Figure(2.1) : Wearable Apparatus [4]Figure(2.2): Apparatus Device Activated [4]

The device shown in figure (2.1) consists of a microcontroller, movement sensor, water sensor, battery, electro mechanical apparatus, loaded spring, buoyancy apparatus, elastic socket and a transmitter.

The detection process for the apparatus for drowning person situation, by comprising a detection unit adopted to detect at least one body movement related parameter and a controller used to receive data from the detection that subject is drowning.

The sensors utilized to measure one or more continuously external environmental parameters values, such as the type of the surrounding media (air or water), movement indication parameters such as body vibrations and so[4].

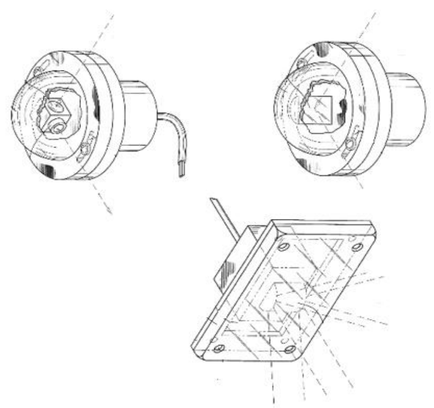
Values sensed and measured by the sensor are send to the microcontroller for suitable processing and transmitting. The microcontroller determines using to specific logical processing and algorithms and decides whether the subject is in a drowning situation according to the received values provided by the sensors.

Then the signal sent by the transmitter to begin the transition produces an alarm signal to the receiver, using radio frequency and ultrasonic, in order to alert the supervisor when the subject is drowning. In addition, a float unit for positive buoyancy filled with gas (air, nitrogen, helium) released to determine the subject’s location as shown in figure (2.2).

This detection method is not sufficient to use, because it requires that the subject wear the apparatus device, which is not reliable for kids and in an unexpected drowning event.

2.2.2 Laser-Beam Detection Safety Device

Jeffrey L. Rainey (2007). Motion Responsive Swimming Pool Safety Device [5]: The main concept of this system is a perimeter laser consists of a generated laser beam, reflectors, and a perimeter sensor to detect the laser beams reflections, shown in figure (2.3). the system detects in case anybody entered the pool so that an alarm and a rescue system driven by an electrical motors net are activated.



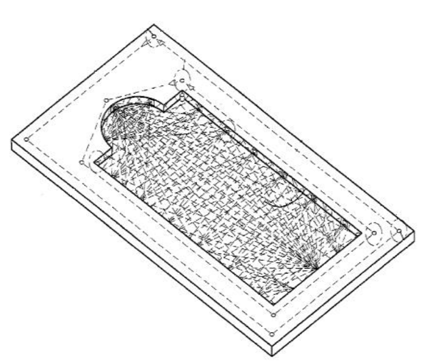


Figure (2.3): Laser shooter, Reflectors,Sensor[5]Figure (2.4): System With Laser Detection[5]

The system consists of a perimeter sensor connected to a control panel and located above the pool water line. In addition, a perimeter reflector located around the pool to ensure that all the pools area is covered, as shown in figure (2.4).

An alarm is electrically connected to the control panel, and capable of alarming upon interruption of the laser beam sent to the perimeter sensor. A safety grid included, using safety cable, driven by electrical motors, the rescue system also triggered when the laser beam interrupted.

2.2.3 Traditional drowning safety methods

The first line of defense against drowning in home pools is active supervision. In reality however, many distractions and lack of supervision occurs. Therefore, many people use some traditional methods to prevent children pool drowning accidents.

Some traditional methods used includes barriers like fencing, gates, alarms and door locks. Some fence include self-closing gates, surrounds and separates the pool from the rest of the house. Perimeter fencing, on the other hand, surround the pool and the house together. Still it is not as effective in preventing drowning.

Rigid pool covers can also provide additional layer of protection. However, it is not a substitute for adequate fencing. The most recent report on pool safety indicates that almost two-thirds of drowning deaths in children under age 5 in 2015 occurred when there was a lack in adult supervision and during that time the child managed to access the pool. Most commonly, inappropriately designed or poorly maintained fences were the problem, followed by gates and doors. Where a fence failure issues included a gap in the fence, the child climbing the fence, a damaged fence and not enough height, figure (2.5) shows the proportion of drowning accidents where these traditional methods where used.

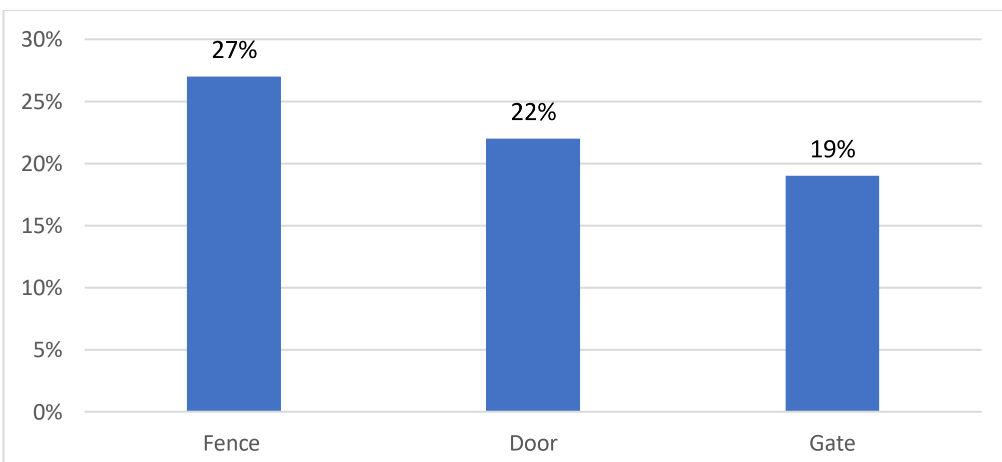


Figure (2.5): Proportion of all pool drowning where a barrier to access was in place and breached[6]

2.3 Methodology

The project presents a drowning detection rescue system consists of a smart children detection and sensing method, a control unit to process the possibility of children drowning when there are no adults around. The system does not only alarm adults that the child is near the pool by himself, but also has a rescue system used to prevent the child from drowning in case the child fell in the pool.

Many projects were made to satisfy the problem requirement as shown in the literature review, some detections methods and rescue system. a prototype of the system will be built to simulate real pool properties, and the following sections will show the main job for the main project components and why they were chosen over other methods.

2.3.1 Sensing Unit

The sensing unit is a very important component of our system, its main duty is to detect the children and adults around the pool, by their exact height and location, the data then sent to the control unit to decide whether to trigger the alarm or the rescue unit. As for a smart sensing unit, we can use one of the following devices:

1. Camera image processing

2. Kinect

3. Wearable apparatus

4. Laser-shooting columns

Many ways were created as detection systems, as shown in the literature review chapter, some used a reflected laser beam to detect anything enters the pool, but it is not sufficient because it cannot detect if what entered is even a human and would be triggered only after the subject is dropped in the pool.

In another way, a wearable apparatus is used. Which is not effective and require to be prepared for the accident. In another hand, some people used leaser-shooting columns with an optical sensor in the exit and entrance. This method defines a specific exit and entrance for the pool, and detects by interrupting the laser beam, which does not specify if it is a human or an object. Image processing camera can be used too that can detect the humans around the pool, but it has some unnecessary processing that can be done more accurate and sufficient. In addition, image processing camera can't specify the location of the subject. Table (2.1) shows an overview comparison.

Characteristics	**Laser-shooting columns**	**Wearable apparatus**	**Camera image processing**	**Kinect**
Humans detection	They give a signal in case any interruption happens whether its human or an object	Yes	Yes, but cannot differentiate between an adult far away and a child close to it.	Yes
Location detection	Only at the columns crossing line	Yes	Not accurate	Very specific, with the aid of its internal depth sensor
Installation	Requires suitable infra structure	Easy	Easy	Easy
Detection area	Only for one place	The pool surface	around the pool	around the pool
Cost	high	Medium	Low	Medium

Table (2.1): Comparison between Sensing Units

For the best performance **we chose to use the Kinect sensor**, unlike leaser-shooting columns and laser reflectors, the Kinect device is actually a group of sensors that can detect humans and identify their movements. The Kinect includes a depth sensor for the subject's location, a color sensor to specify humans from objects, an infrared ray's shooter. The sensor is originally designed to detect humans with a simple way and with the most efficiency, it does not require preparing like the wearableapparatus, and detects the humans with simple methods and sufficient performance unlike the complex camera image processing.

2.3.2 Control Unit

The control unit is the brain of smart rescue system in the project, the control unit is where all the data is collected and sent from the systems components, and where all the commands come from, to decides whether to trigger the alarm or the rescue process, by analyzing the data coming from the sensing unit.There are the following available options:

1. Arduino
2. Raspberry pi

Characteristics	Arduino Uno	Raspberry Pi 3 Model B
Complexity	Medium/High	Medium
Price	Low	Medium
Kinect compatible	Medium	High
Multitasking	No	Yes
Flash Memory	32KB	SD Card (2 to 16G)
USB	One, input only	Two, peripherals OK
RAM	2KB	1GB

GPIO pins	14 pins	40 pins

Table (2.2): Comparisonbetween Control Units

Some systems used Arduino microcontroller to decide and activate the system, but as for the project, **the selected controller is the raspberry pi microprocessor**. The Arduino has no interpreter, no operating system and no firmware, and its better suited for simple systems that does not require much processing. On the other hand, the raspberry pi is a single boar computer (SBC) that's very compatible processor with the data processing needed from the Kinect sensor. The raspberry pi microprocessor even has a possibility of an easy editing and can analysis complex data better than Arduino, which makes it better suited for projects that require more ram and processing power such as us. An overview comparison is shown in table (2.2).

2.3.3 Rescue Unit

The rescue unit is used to prevent the child from drowning in case of dropping in the pool. The unit receives its commands from the control unit to be activated, as the last line of defense if no one come to hold the child from dropping in the pool.

The rescue system used is a net mounted in the bottom of the pool, and the net lifting process can be achieved in three suggested methods:

1. Electrical Motors.
2. Hydraulic Cylinder.
3. Pneumatic Cylinder.

Table (2.3) shows an overview comparison, were some methods use electrical motors as a driver to lift the net up to the surface, others used hydraulic system as well, but for this project, a **pneumatic system is selected**. The pneumatic system is much safer unlike electrical motors, which are not suitable for water environments, especially around humans. In addition, any leakage in the pneumatic cylinders will not do any harm, unlike in hydraulic systems, where the leak might contaminate the pools water with oils due to faulty valves, seals or burst hoses. Moreover, the pneumatic is much simple, cheaper and gives the desired lifting process needed.

Table (2.3): Comparison between Mechanical System

Characteristics	**Pneumatic**	**Hydraulic**	**Electrical**
Complexity	Simple	Medium	Medium/High
Peak Power	High	Very high	High
Control	Simple valve	Simple valve	Electronic
Purchase cost	Low	High	High
Speed	Fast	Slow	Fast
Maintenance	Low	Medium	Medium
Dirt's	Low	High	Low

Rescue Net

The main purpose of the net in this project is holding the child breveting him from drowning in case the child fell in the pool. The net must be able to rise up fast to the surface, can withstand the child's weight. In addition, the net must have the ability to stay in water for long times. There are two options:

1. Plastic
2. GalvanizedMetal

Table (2.4): Comparison between Material of Rescue Net

Characteristic	**Plastic**	**Galvanized Metal**
Wight	Low	High
Corrosion resistance	resistant	resistant
Easy implementation	Easy	Easy
Cost	High	Low

The chosen component is the **Galvanized metal**because its endurance to rust and the ability to lift heave weights and its availability and manufacturing.

Chapter Three

Mechanical Design

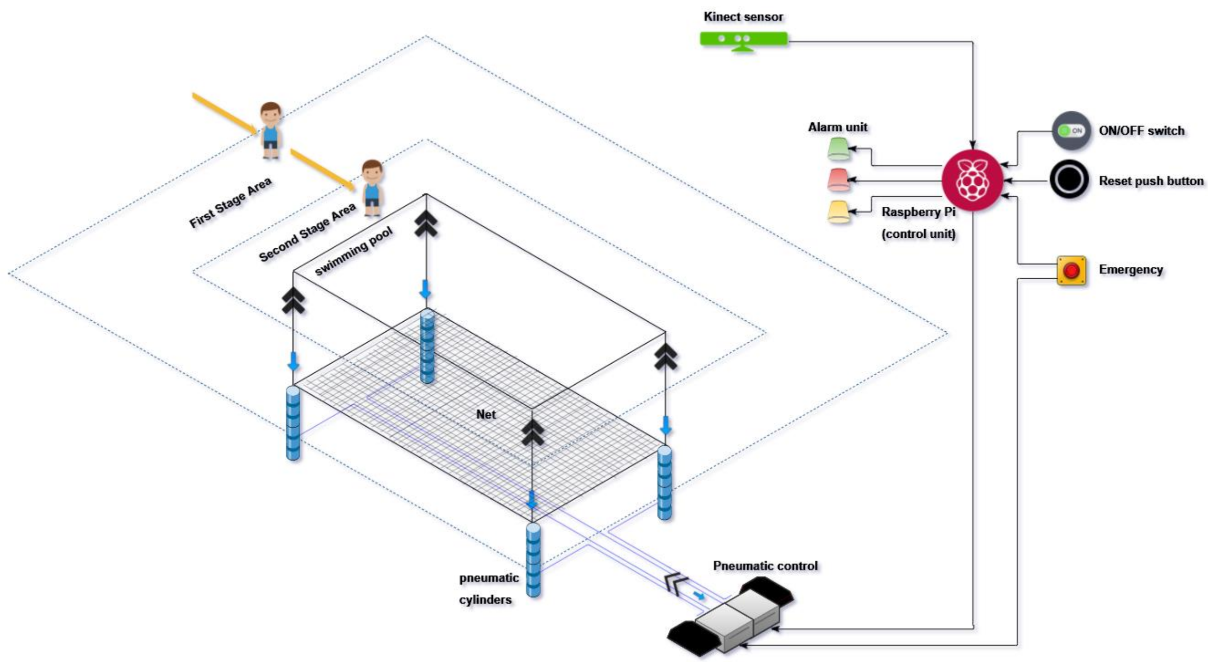
3.1 Overview

This chapter contains the conceptual design of the system, the mathematical model for maximum forces and conditions, operation flow chart and the mechanical design of the system, including the calculations for both the real pool and the prototype.

In addition, show all mechanical component that will use in prototype design and specification of them.the main connections for thepneumatic system and design the prototype on Catia program.

3.2 Conceptual Design

The following diagram in Figure (3.1) shows the coneptual design of the project, which provides a description of the project in terms of a set of integrated ideas and concepts about what it should do, behave and look like in a way that is understandable for users. Followed by a description of the system rescuing process.



Figure(3.1): Conceptual Design

When the system is still deactivated, the red-light alarm will be plinking to notify the user that the system is deactivated. Switching on the ON/OFF switch, which lights up the green light showing that the system is activated and starts the scanning process by the Kinect sensor mounted in a location that it is able to scan the whole area around the pool and detect if any human is around. The sensor detects the human's location, determine their heights, and send the data to the Raspberry pi.

The raspberry pi microprocessor then specifies whether the detected human is a child or an adult by their heights. In case of a child detected in the first stage area with no adults around, the control unit triggers the yellow light alarm to alert the parents. If the child reached the second stage area to a critical distance from the pool edge, the red-light alarm will be triggered along with the rescue process.

The rescue unit consists of a net located at the bottom of the swimming pool, attached to four pneumatic cylinders at its corners. The lifting process is controlled by a solenoid that receives its signals from the control unit, can also be activated by the emergency button for any unexpected cases. And when the rescue process is activated, the four cylinders extract, lifting up the net to the surface of the water, preventing the child from drowning.

When the rescue process is activated, the pneumatic cylinders keep the net at the surface of the water until the child is safe, and a reset button used to bring down the net to the bottom of the pool and the system as activated again.

3.3 Operational Flow Chart

The operationalchart shown in Figure(3.2) illustrates the algorithm and path that the control go throw to accomplish the desired goal of alarming the parents and preventing the child from drowning:

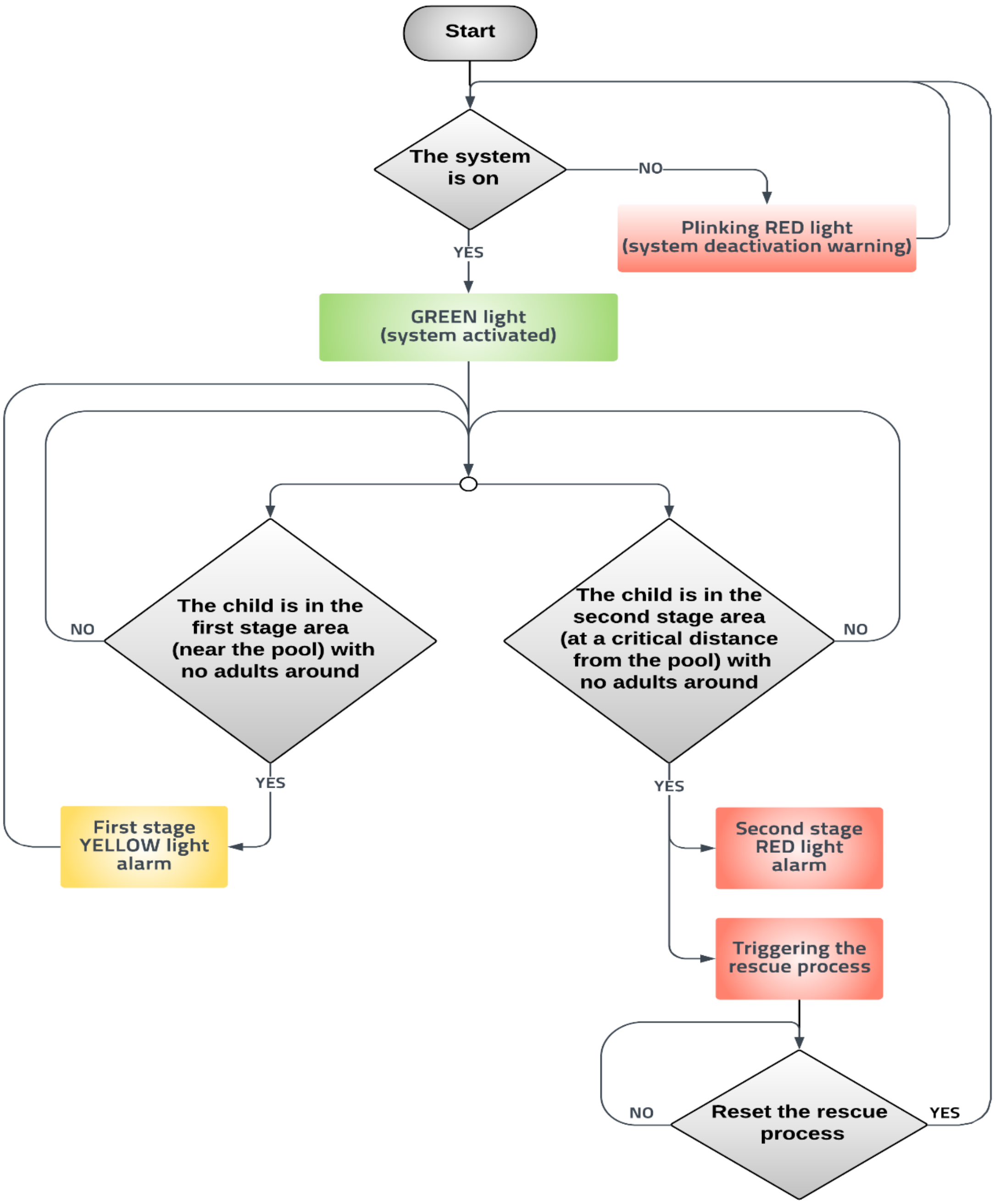


Figure (3.2): Operational Flow Chart

The operation starts by checking if the system is on or off. When the system is off, the red light will start plinking to warn the user that the system is deactivated.Switching on the system will turn on the green light showing that the system is activated.

When the system is switched on, the Kinect sensor starts scanning the area around the swimming pool searching for any child around and sends the data directly to the raspberry pi microprocessor.

The raspberry pi start checking for locations and heights. In case the system detects a child at the first stage area, a yellow light alarm is triggered to alert the parents before the child get closer to the pool, and the system keep scanning the area and operating while tracking the child, the alarm will be turned off in case of an adult interfaced to prevent the child from going any further. When the system detects the child reaching the seconds stage area to a critical distance from the pools edge, the red alarm light turns on and the rescue process is triggered to prevent the child from drowning.

The rescue process can be triggered by the raspberry pi, or by a direct signal from the emergency button, and the net will stay up at the surface of the water until a reset button is pushed to reset the rescue unit and the system.

3.4 Contents of Prototype Pool

The project's prototype simulates a simple model, to illustrate the real swimming pool attached to the rescue system, andprovide specifications for a real, working system.

The following figure (3.3) shows the prototype made for the project, and followed by a description for each part individually

Figure (3.3): Prototype pool

3.4.1 Main Frame

The main frame shown in figure (3.4) is made from metal with four legs connected together. The main frame carries the all parts of the system, such asthe pneumatic cylinders, solenoid valves, glass pool, the pool surrounding area, electrical box, alarm lights and the emergency button. The dimensions of the mainframeare 70 cm length, 40 cm width and 100 cm Hight.

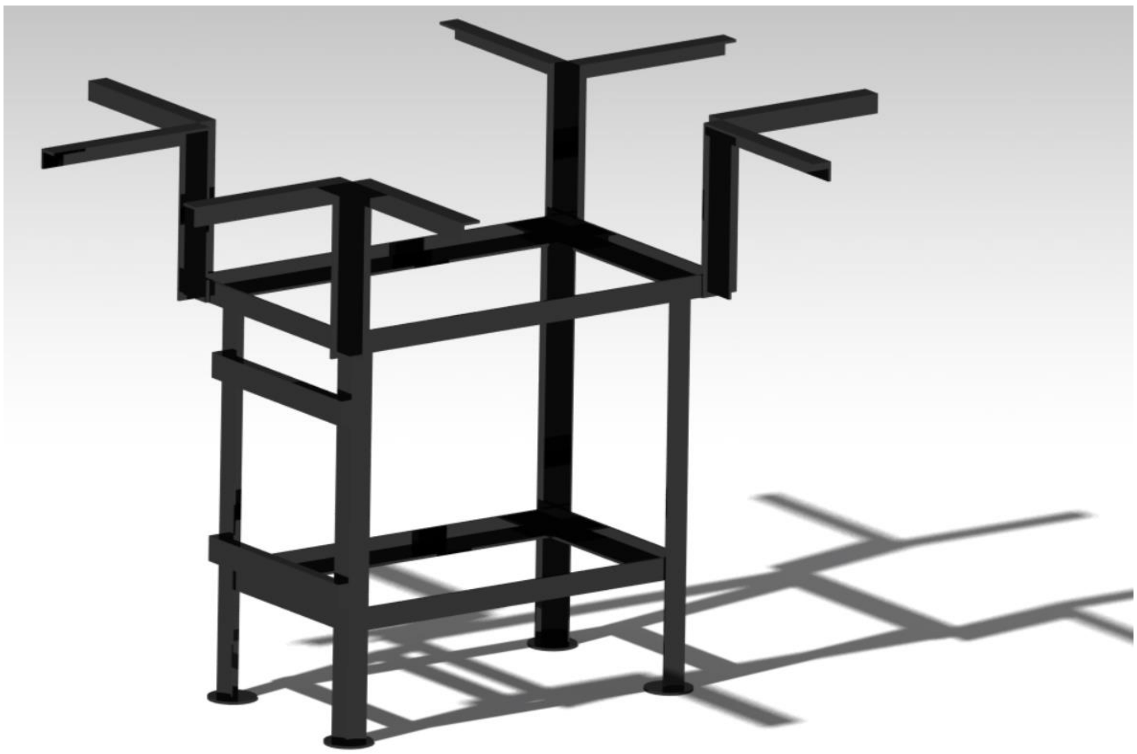


Figure (3.4): Main Frame of System

3.4.2 Glass Pool

A pool made from glass with 0.6 cm thickness with dimension 40 cm width, 70 cm length and 30 cm Highest as shown figure (3.5). The glass parts assembled using silicon.

The glass pool contains sealsused to prevent any leaking water in the system.

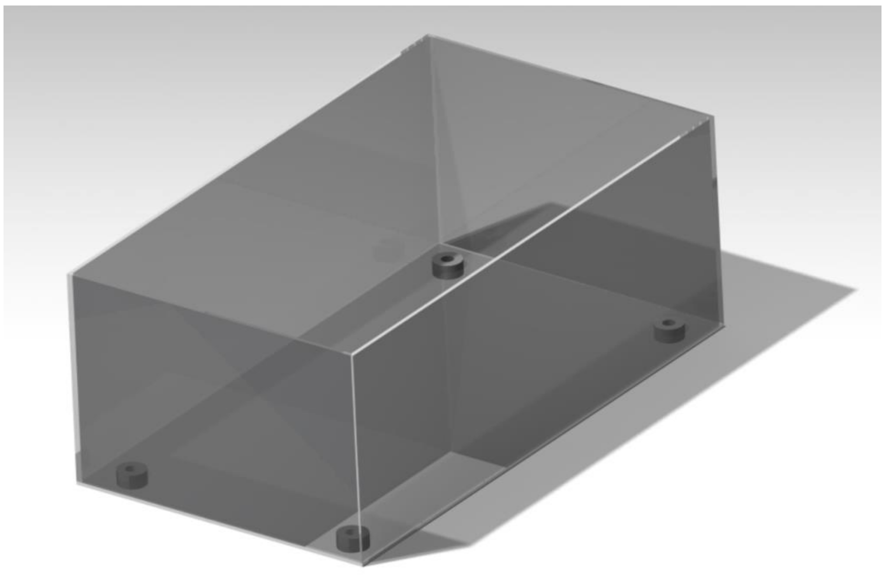


Figure (3.5): Glass Pool

3.4.3 Seals

A seal shown in figure (3.6) is a relatively soft, non-metallic ring, used to block any possible leaking water that may accrue due to the movement of the pneumatic cylinders shafts during the rescue process.

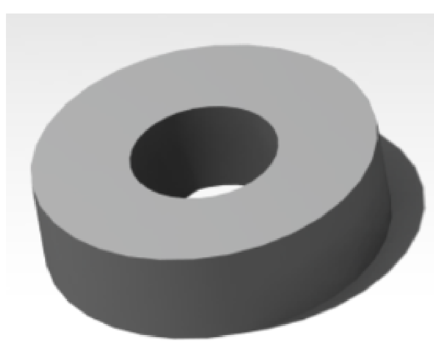


Figure (3.6): Seal

3.4.4 Rescue Net

The main function of rescue net it to save the child from drowning, it’s made from galvanized metal with dimension 65 cm length and 35 cm width as shown figure (3.7).

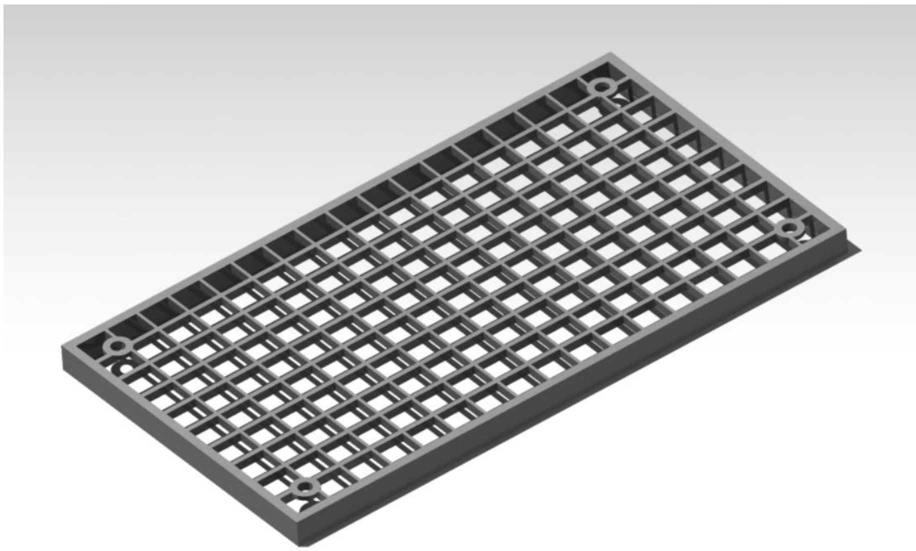


Figure (3.7): Rescue Net

3.4.5 Electrical Box

The electrical box shows in figure (3.8) contain all electrical parts, such as power supply, relays, transistors,microprocessor, the rest push button and the ON/OFF switch.

Figure (3.8): Electrical Box

3.4.6 Testing Area

Figure (3.8) shows the testing area that made from wood, contains the alarm lights and emergency button. The wooden frame illustrates the real area around the pool and divided to the first stage area and the second stage area.

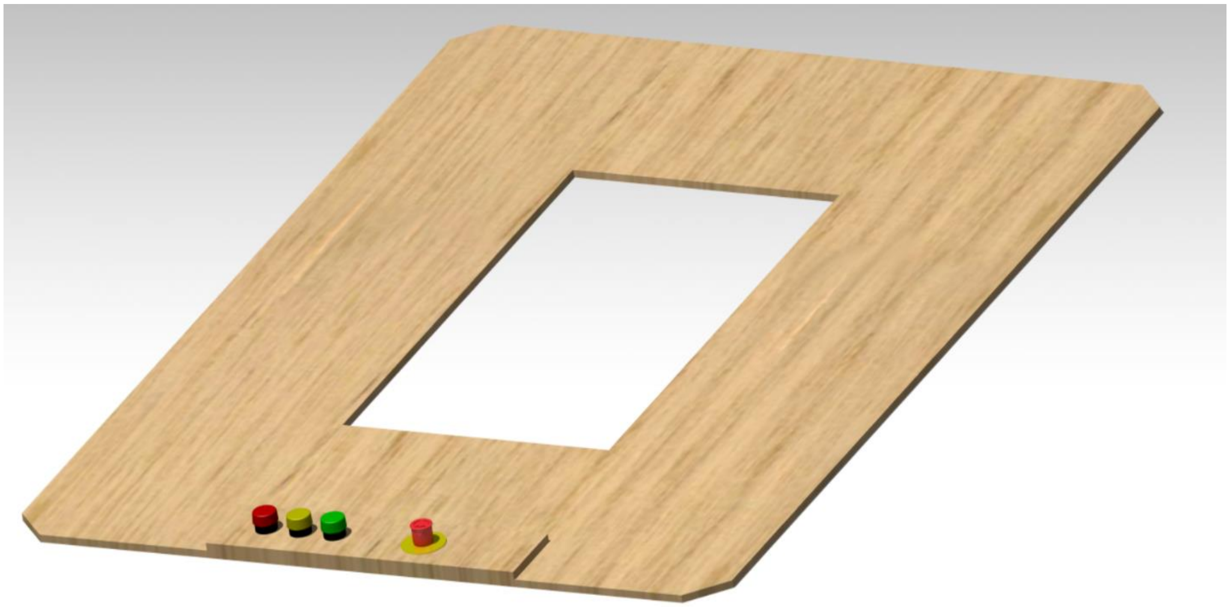


Figure (3.9): Testing Area

3.5 Fluid Theory:

A water is a collection of molecules that are randomly arranged and held together by weak forces and by forces exerted by the walls of a pool, any object inside it will be affected by a force perpendicularly on its surface as shown in the figure (3.10)

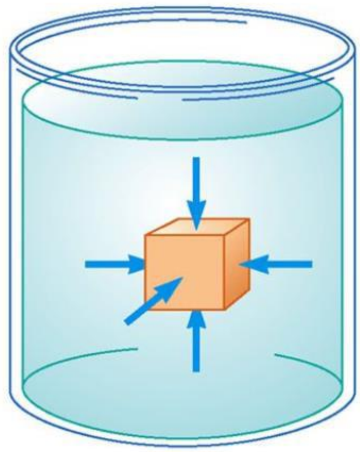


Figure (3.10): Perpendicular Forces

The pressure $P$of the fluid at the level to which the object has been submerged is defined as the ratio F/A.

The upward force exerted by water on any completely or partially submerged in a fluid is called a buoyant force ($\boldsymbol{F_B}$). The behavior of an object submerged in a fluid is governed by Archimedes Principle, which states that the magnitude of the buoyant force always equals the Wight of the fluid displaced by the object. The buoyant force acts vertically upward through the point that was the center of the gravity of the object.

In fact, the water on the top of the object it is pushing down, and the water on the bottom of the object is pushing up, we can find the total force on the object exerted by water pressure (which we call the buoyant force) by simply taking the difference between the magnitude of the upward force $\boldsymbol{Fup}$and downward force $\boldsymbol{Fdown}$**.**

$$F_B = F_{up} - F_{down} \quad (3.1)$$

This force can be clarified by using definition of pressure $P = {}^{F}/_{A}$

Where: A: cross section area   F: force

Which can be solved for force to get $F = PA$. So, the force exerted upward and downward:

$$F_{up} = P_{up}A \quad (3.2)$$

$$F_{down} = P_{down}A \quad (3.3)$$

Substituting these expressions in equation (3.1) to get

$$F_B = P_{up}A - P_{down}A \quad (3.4)$$

Using the formula for hydrostatic gauge pressure $P_{gauge} = \rho g \hbar$, to find expressions for the upward and downward directed pressures. So, the equation of buoyant force will be

$$F_B = \rho g \hbar_{up}A - \rho g \hbar_{down}A \quad (3.5)$$

Where:

ρ: density of fluid

$\hbar_{up}$: the height from surface fluid to the top surface of object

$\hbar_{down}$: the height from surface fluid to the bottom surface of object

Notice that each term in this equation contains the expression $\rho g A$. So, we can simplify this formula by pulling out a common factor $\rho g A$to get

$$F_B = \rho g(\hbar_{up} - \hbar_{down}) \quad (3.6)$$

Where

$$hobject = hup - hdown \quad (3.7)$$

and

$$v_o = A\hbar_{object} \quad (3.8)$$

So, the formula of buoyant force will be:

$$F_B = \rho g v_o \quad (3.9)$$

When the object is totally submerged in fluid of density ρ, the magnitude of the upward buoyant force is

$$F_B = (\rho_W - \rho_o)\ gvo \quad (3.10)$$

Where:

F_B: buoyant force

ρ: density of fluid

g: gravitational acceleration

A: cross section area

ρ_W: density of water

ρ_o: density of object

v_o: volume of object

$\hbar_{object}$: highest of object

3.6 Pneumatic cylinder

The pneumatic cylinders in figure (3.11) are mechanical devices that uses the power of compressed gas to produce a force in a reciprocating linear motion. The piston rod transfers the force to the object to be moved.

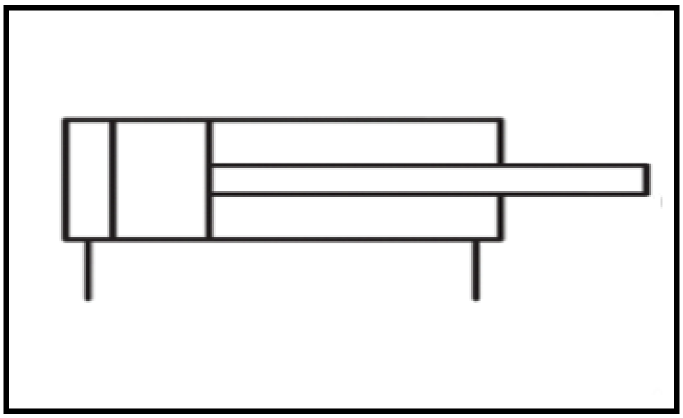


Figure (3.11): Pneumatic Cylinder

The piston force exerted by cylinder depends on the air pressure, the cylinder diameter and the frictional resistance of the sealing components. The theoretical piston force is calculated by the formula

$$F_{th} = AP \quad (3.11)$$

Where:

F_{th}: theoretical piston force (N)

A: cross section area (m^2)

P: applied air pressure (Pa)

In practice the effective piston force is significant so frictional resistance should be taken into consideration when calculating the force.

For double acting cylinder, the effective force due to extension stork is:

$$F_{ext} = (A_P \times P) - FR \qquad (3.12)$$

And the retraction stork is:

$$F_{ret} = (A_{ret} \times P) - FR \qquad (3.13)$$

The area of the piston surface calculated by the following equations:

Area in retraction stork:

$$A_{ret} = A_P - A_R \qquad (3.14)$$

Piston area:

$$A_P = \frac{\pi}{4} \times D_P^2 \qquad (3.15)$$

Rod area:

$$A_R = \frac{\pi}{4} \times D_R^2 \qquad (3.16)$$

Where:

F_{ext}:Effective piston force in extension stork (N)

F_{ret}:Effective piston force in retraction stork (N)

FR:Friction force $(approx. 10\%\ of F_{th})\ (N)$

A_{ret}:Retraction area (m^2)

A_P:Piston area (m^2)

A_R:Rod area (m^2)

D_P: Piston diameter (cm)

D_R: Rod diameter (cm)

3.7 Pneumatic valves

The control valve is a device which influence the path taken by air stream. Normally this involves one or all of the following: opening the passage of air and directing it to particular air lines, cancelling air signals as required by blocking their passage and/or relieving the air to atmosphere via an exhaust port.

A pneumatic system has a wide range of directional valves such as 5/3, 5/2, 3/2-way directional valves, flow control valve. the following shows a brief description of the appropriate valves for this project.

5/2-way valve

The 5/2-way valve has five working port and two switching position, by looking in the figure (3.5) it has one pressure port (1), ports (2) and (4) that connect to the device that needs to be controlled (cylinder in this project) and two exhaust port (3) and (5).

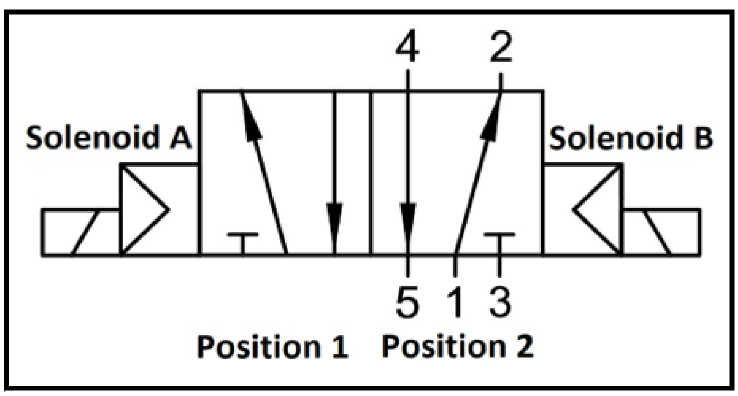


Figure (3.12): 5/2-Way Valve

The two states of the valve are:

- Pressure port (1) connects to port (2) while port (4) vents through exhaust port (5).
- Pressure port (1) connects to port (4) vents through port (3).

There are two solenoids on both sides of the valve (solenoid A and solenoid B), the main function of these solenoid is to switch between two positions of the valve, when valve is on position (1) it works as an extension mode, on the other hand; if it is on position (2) it works as a retraction mode.

3.8 Real Pool Fluid Design

As for the real pool, the equations of the pneumatic system are applied on the pool with following dimensions, 7 m length, 4 m width andhighest 1.25m

Calculation with taking the buoyancy force into consideration:

The volume of the Net is 0.002 m^3. And it's made fromgalvanized ironwith density of 7700 kg/m^3 and the water density is 1000 kg/m^3.Where thecompressor pressure is 6 Par ($600KPa$).

From equation (3.10)

$$F_B = (1000 - 7700) \times 9.8 \times 0.002$$

$$F_B = -132\ [N]$$

$$F_B = 132\ N\ Downword$$

Let us assuming the Wight of child 50 kg and the adult 100 kg (if he gets on the Net to pull out the child), so the total load on the Net will be equal 150 kg.

$$W = m \times g$$

$$W = 150\ kg\ \times 9.8\ m/s^2$$

$$W = 1470\ N$$

Where:

W: weight (the load on the Net).

The total load must be lifted up = weight + buoyancy force

= 1470 +132

= 1602 N

So, theextension force of a cylinder must be grater then (1602 N) for lifting up the Net.

Using equation (3.12)

$$F_{ext}=(A_P \times P)-FR$$

$$1602\ N = (A_p \times 600\ KPa) - 0.1(600\ KPa \times A_P)$$

$$A_P = 30\ cm^2$$

$$D = 6.18\ cm$$

According to the calculations shown, the system needs **Four Cylinders** at the pool corners, with a 7 cm diameter.

The previous calculations are in forward stroke. In downward stroke we need force lower than (132N) because the density of the Net material is greater than the density of the water.

3.9 Piston Velocity

There is no effective equation to find the specific speed of the pneumatic cylinders because the air is compressible, but the average piston speed can be classified as shown in figure (3.13) depending on the piston diameter.

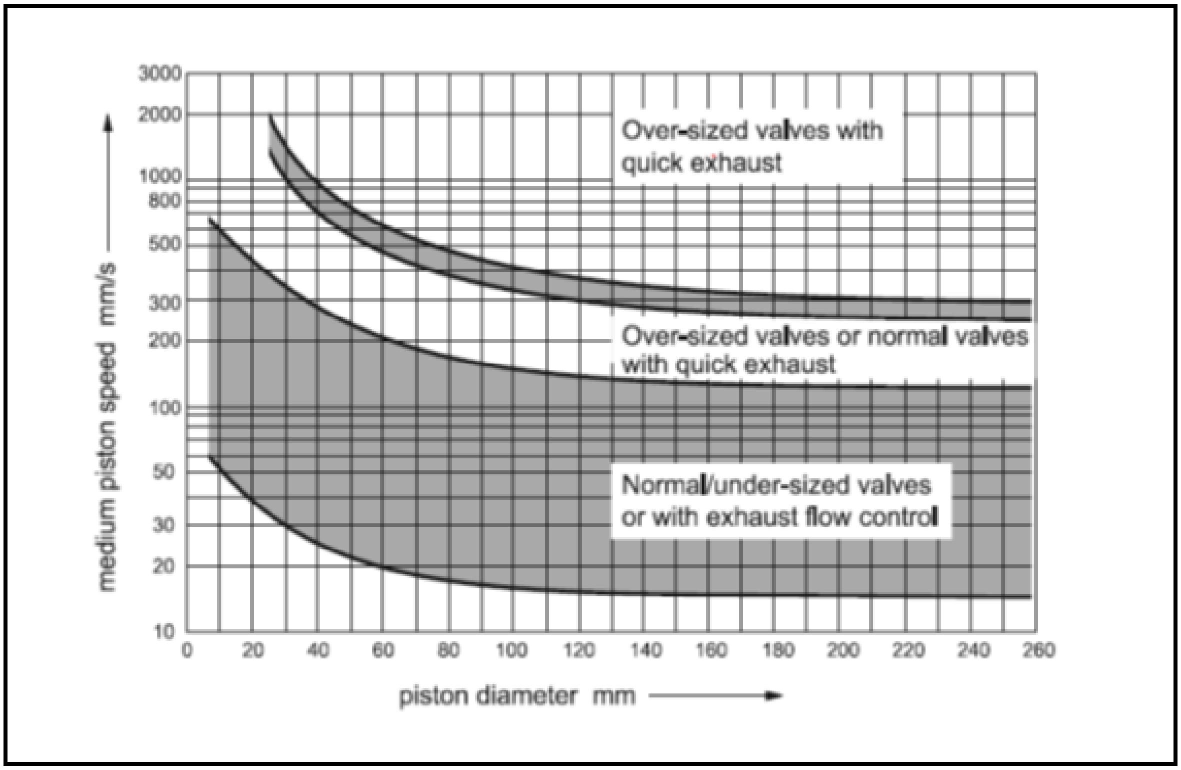


Figure (3.13): Average Piston Velocity

From Figure (3.13), the speed rang of the piston is 20 $mm/s$to 200 mm/s. Depending on this information the rang of lifting up process time is approximated to be ($6.25 s to 62.5 s$). To decreasing the time needed to lift up the net, a high pressure (8 par) compressor is used.

3.10 Prototype Design

The main object of this section is to show how determine the mechanical component, design the pneumatic circuit and electrical connection of the system.

3.10.1 Pneumatic Cylinder

By applying the equations of the pneumatic cylinder on the Prototype pool with the following dimensions, 70 [cm] length, 40 [cm] width andhighest 30[cm].

Calculation with taking the buoyancy force into consideration:

The volume of the Net is 0.0002 m^3. And it's made fromgalvanized ironwith density of 7700 kg/m^3 and the water density is 1000 kg/m^3.Where thecompressor pressure is 6 Par (600KPa).

From equation (3.10)

$$F_B = (1000 - 7700) \times 9.8 \times 0.0002$$

$$F_B = -13.2\ N$$

$$F_B = 13.2\ N\ Downword$$

In prototype pool there is no big load on the net, so let us assuming the load which lifted up equal 10 kg.

$$W = m \times g$$

$$W = 10\ kg\ \times 9.8\ m/s^2$$

$$W = 98\ N$$

The total load must be lifted up = weight + buoyancy force

= 98 + 13.2

= 111.2 N

So, theextension force of a cylinder must be grater then (111.2N) for lifting up the Net.

$$F_{ext}=(A_P \times P)-FR$$

$$111.2\ N = \left(A_p \times 600\ KPa\right) - 0.1(600KPa \times A_P)$$

$$A_P = 2\ cm^2$$

$$D = 1.5\ cm$$

According to the calculations shown, the system needs **Four Cylinders** at the pool corners, with a 1.5 cm diameter.

The previous calculations are in forward stroke. In downward stroke we need force lower than (111.2N) because the density of the Net material is greater than the density of the water.

3.10.2 Piston Velocity

From Figure (3.13), the speed rang of the piston is 40$mm/s$to 400 mm/s. Depending on this information the range of lifting up process time is approximated to be (0.75sto7.5s). To decreasing the time needed to lift up the net, a high pressure (8 par) compressor is used

3.10.3 Pneumatic Circuit

A pneumatic circuit is an interconnected set of components that convert compressed gas (air) into mechanical work.

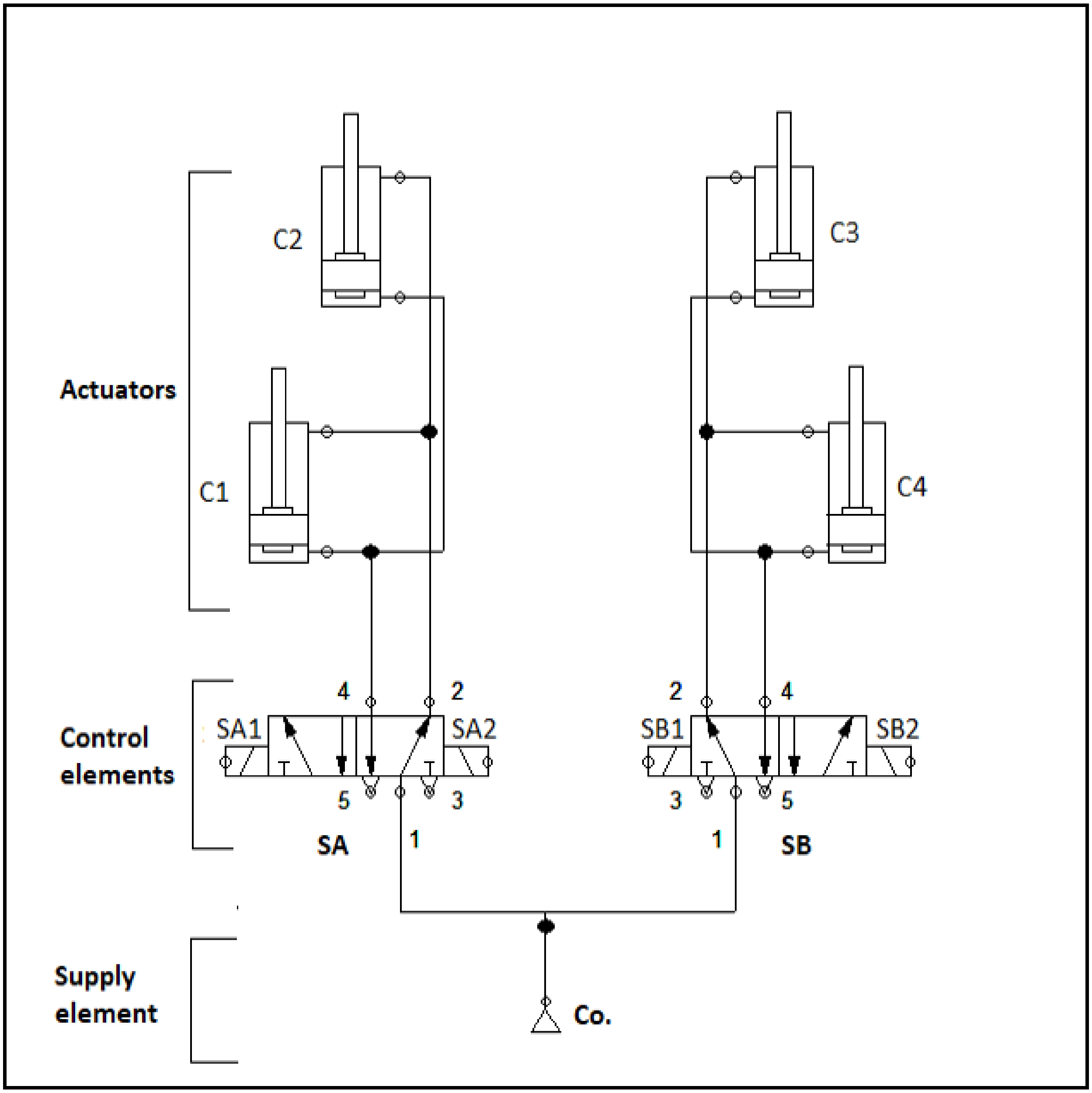


Figure (3.14): Pneumatic Circuit

Where:

C1, C2, C3, C4: Pneumatic cylinders

SA, SB: 5/2-way valve

Co.: Gas compressor

SA2, SB2: Solenoid for retraction mode

SA1, SA2: Solenoid for extension mode

Figure 3.14shows how the pneumatic system works in order to rescue a drowning child in the pool. First, the compressor compresses the air into the valves (SA, SB) in port 1, then the raspberry pi microprocessorcontrols its mode (extinction or retraction).

The piston rod of a 4 double-acting pneumatic cylinder extinct if the controller activatesthe two solenoids (SA1, SB1). As a result, the net rises with the drowning child to the surface of the water. Then an adult moves the child to safety,and then presses the rest push button. Which retracts the cylinder to bring the net back to its starting position at the bottom of the pool.

Chapter 4

Electrical Design

4.1 Overview

This chapter discusses electrical components that will be used in the project. and the connection diagram of the electrical component.

Figure 4.1shows the hardware components that are used in the system and relations between them.

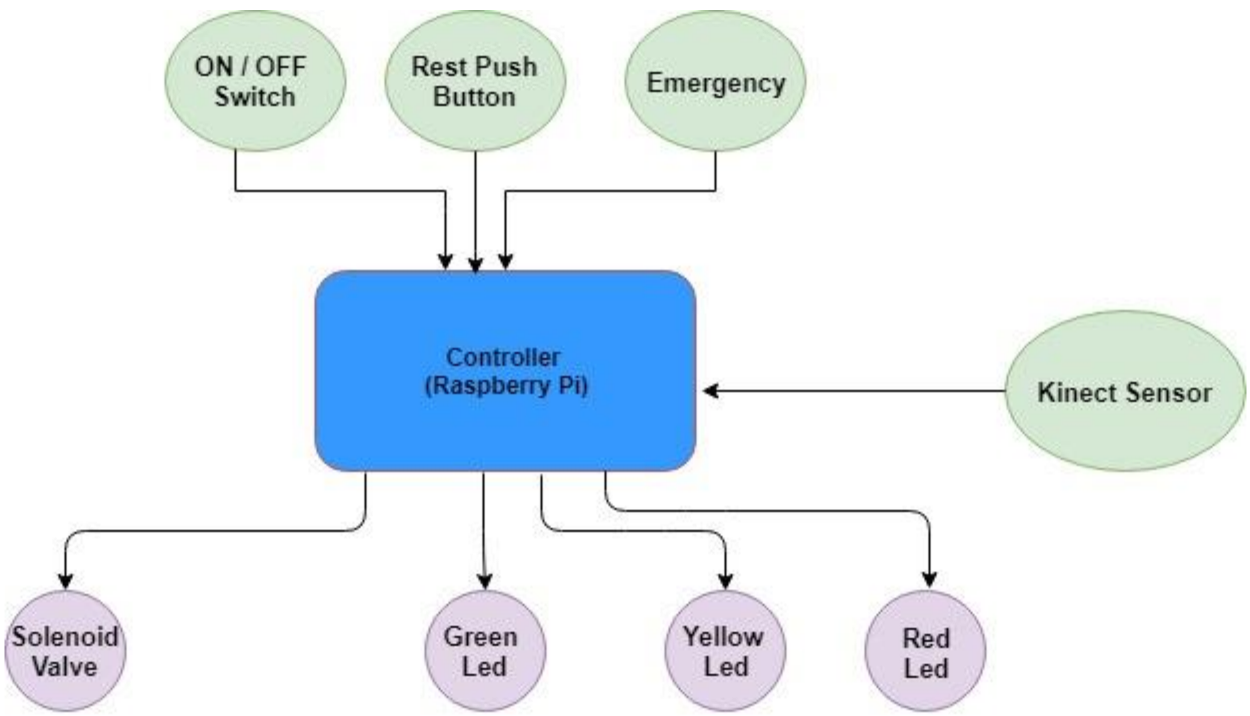


Figure (4.1): Electrical block diagram

The followingsections explain the functions of each part and what role it plays in the whole system

4.2 Sensing unit

Kinect figure (4.2) was originally designed as a gaming tool.In the last few years, studies have shown that this sensor can be used for real-time environmental scanning, classifications and scene understanding. As for our project, we used the Kinect as a detection tool to classify humans from objects and adults from children, specifying their exact location.

Figure (4.2): Kinect sensor

4.2.1 Kinect specifications

The Kinect sensor is connected by USB, with additional power supply and features a standard RGB webcam and a depth sensor shown in figure (4.3).

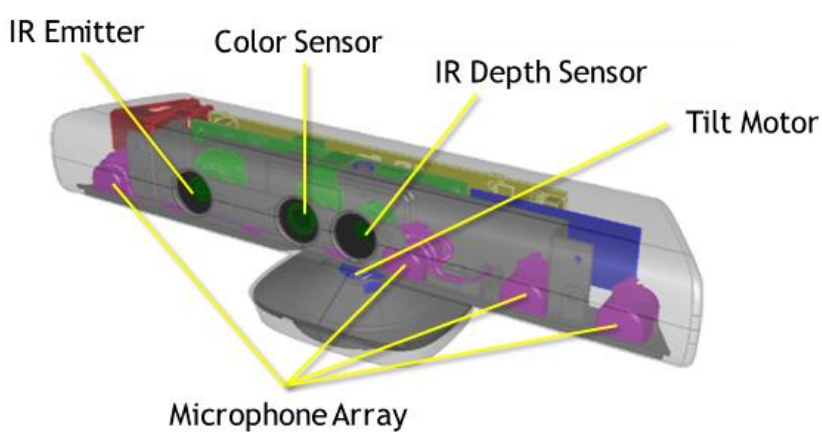


Figure (4.3): Position of the sensor

4.2.2 Depth sensor

The depth sensor consists of an infrared laser projecting a specific dot pattern onto its field of view as in figure (4.4). An infrared camera records these patterns on the objects and an on-board Digital Signal Processor (DSP) computes the distance by correlating the live image with stored reference patterns.

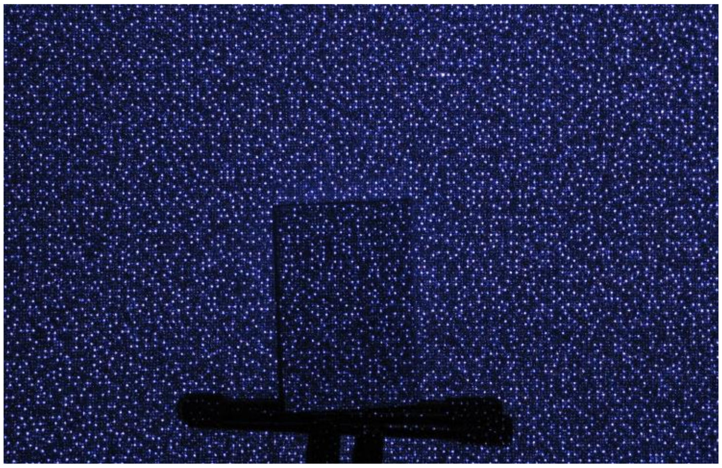


Figure (4.4): Infrared dot pattern

4.2.3 The range of the Kinect depth sensor

Covers approximately 0.7 to 7 meters. The manufacturer gives the optimum range from 1.2 to 3.5 meters. The field of view covers 58° horizontal, 45° vertical and 70° diagonal.

4.2.4 Using multiple Kinect devices

For the real swimming pool, multiple Kinect devices might be needed to cover the whole area around the pool but using multiple Kinect devices onto the same scene can cause unrecognized regions in the depth image due to overlapping infrared dot patterns.

A possible solution by adding independent motion to each of the sensors is proposed. Applying vibration to the Kinect sensors results in a blurry dot pattern of the interfering Kinect sensors. This can be done by attaching a motor with an eccentric mass to the bottom of the Kinect. The rotation of the motor and its attached mass induces a tiny vibration in the device. As the infrared laser and camera are attached to the same housing, they see their own pattern clearly and undistorted. The depth value can be estimated and recognition is not disturbed by other Kinect sensors.[8]

Figure (4.5) shows A -Depth map of room using a single Kinect. B - Depth map with 5 Kinect sensors overlapping the view, causing interferences and failures in estimation. C - Depth map with 5 overlapping Kinects while applying motion to every sensor.

Figure (4.5):Multi Kinect sensors depth data

The average latency of the sensor is 72.98ms. the latency indicates about two frames delay at a framerate of 30 images per second.

4.3 Controller

The Raspberry Pi microprocessor shown in figure (4.6) is a single computer board, developed to encourage and aid the teaching of programming and computing. It is also a fantastic starting point for the development of the projects. The low cost and 'plug and play' nature of Pi makes it a board that is accessible to all and has numerous connectivity options. Pi is the perfect experimental tool, whether you want to use it as a desktop computer, server or monitoring/security device within your home. Linux-based operating systems run on the Pi with plenty of access to free software and downloads[9].

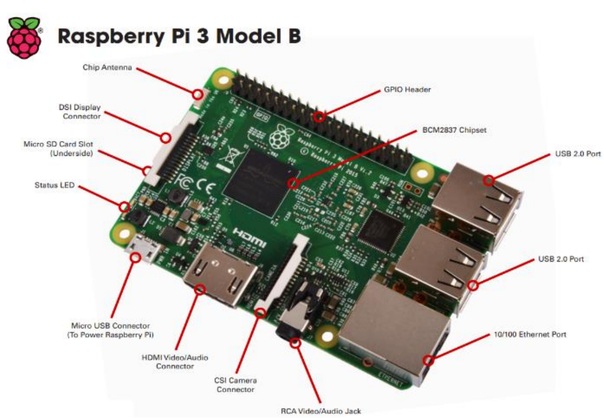


Figure (4.6): Raspberry Pi

4.3.1 Features of the Raspberry Pi 3

•Broadcom BCM2837 chipset running at 1.2 GHz

•64-bit quad-core ARM Cortex-A53

•802.11 b/g/n Wireless LAN

•Bluetooth 4.1 (Classic & Low Energy)

•Dual core Video core IV® Multimedia co-processor

•1 GB LPDDR2 memory

•Supports all the latest ARM GNU/Linux distributions and Windows 10 IoT

•microUSB connector for 2.5 A power supply

•1 x 10/222100 Ethernet port

•1 x HDMI video/audio connector

•1 x RCA video/audio connector

•1 x CSI camera connector

•4 x USB 2.0 ports

•40 GPIO pins

•Chip antenna

•DSI display connector

•microSD card slot

•Dimensions: 85 x 56 x 17 mm

4.3.2 Integrating the Kinect with the Raspberry Pi

Figure (4.7) shows connecting the Kinect and its sensor drivers on the raspberry pi process is an important, accurate and critical stage of the project. Because the Kinect is a Microsoft product and works on windows, and to make it work on the Linux based operating system for the raspberry pi, that installing all the libraries manually and drivers associated with it is needed.

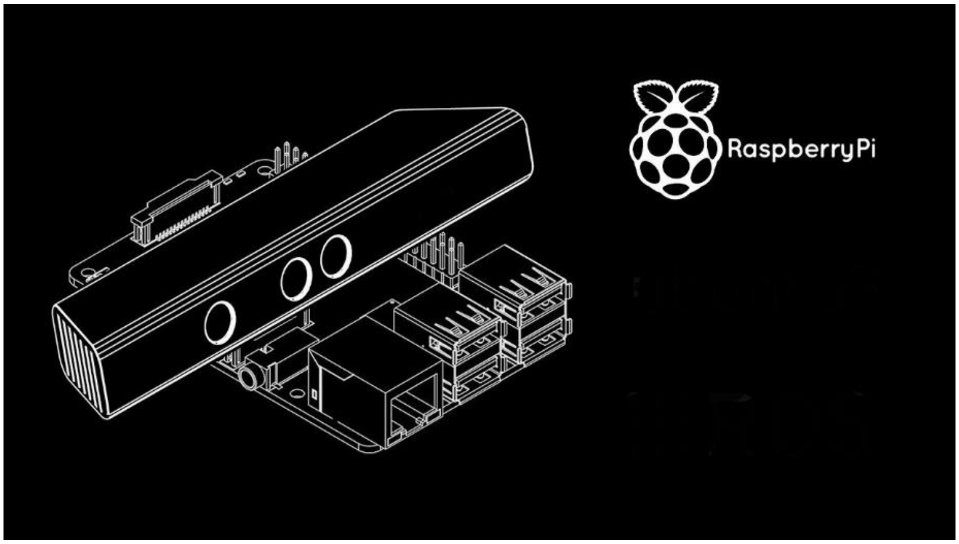


Figure (4.7): Integrating the Kinect with Raspberry

4.4 Power Supply

A power supply shown in figure (4.8) is an electrical device that supplies electric power to an electrical load.The primary function of a power supply is to converts the current from AC (alternating current) to DC (direct current), which is what the component of the system requires.

Figure (4.8): Power Supply

4.5 Transistor

Transistor used in this project as a switch, to active the solenoid of 5/2-way valve that depend on electrical signal from the microprocessor (raspberry pi). There are two types of transistors that can be used, the first one PNP 2N2907 and the second is 2N2222, there is no differencebetween them and both give the same result. So, the transistor used is **PNP 2N2907**.

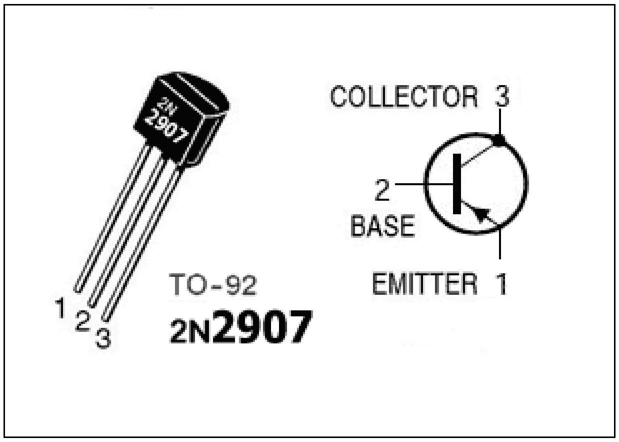


Figure (4.9): PNP 2N2907 Transistor

4.6 Relay

Relay is a switch that opens and closes the circuits electromechanically or electronically,and controls one electrical circuit by opening and closing contacts in another circuit. As relay diagrams shown figure (4.10), when a relay contact is normally open (NO), there is an open contact when the relay that is not energized. When a relay contact is Normally Closed (NC), there is a closed contact when the relay is not energized. In either case, applying electrical current to the contacts will change their state.

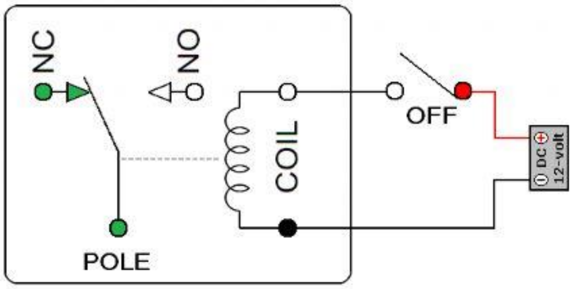


Figure (4.10): Electrical Relay

The input of the solenoid 5/2-way valve is 12V while the output of the controller is 5V, so we used the relay to control the solenoid form the controller.

4.7 ON/OFF Switch

This switch in figure (4.11) is used to turn ON or OFF the whole system, if user dose not want to activate the system he can turn it off.

Figure (4.11): ON/OFF Push Button

4.8 Emergency Push Button

The main function of emergency push button shown in figure (4.12) is lifting up the rescue net immediately if an unexpected situation occurred (for example an adult drowning).

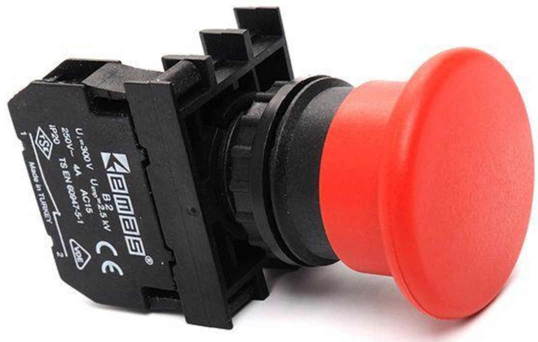


Figure (4.12):Emergency Push Button

4.9 Rest Push Button

In case of drowning, the rescue net will be lifted up. The net donot come down unless the reset bush button shown in figure (4.13) is pressed to confirm the rescue process and the child moved to safety. Then the net returnto the bottom of the pole.

Figure (4.13): Rest Push button

4.10 Electrical Connection

The figure (4.14) show the wiring connection of the system. The connection between the microprocessor and each part of system Relays, push button, Lads and solenoid valve.

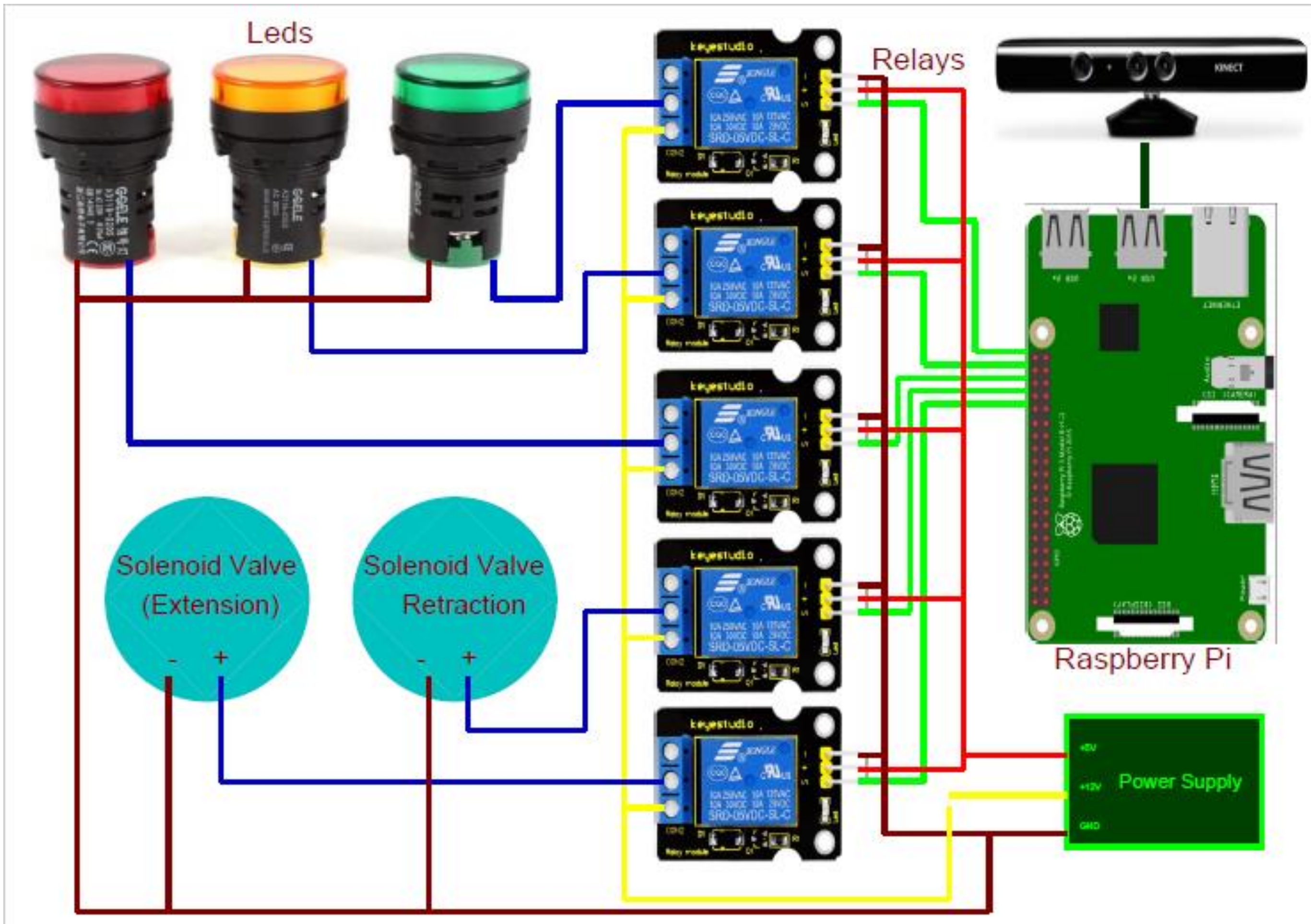


Figure (4.14): Electrical Connection

Chapter 5

Conclusion

5.1 Conclusion and Outcomes

The main points in the project construction are done, where the problem is carefully studied along with the methods used to solve the problem. The projects components such as the sensing unit, control unit and the rescue unit where selected to ensure the best performance, and to gain the desired results.

In addition, the whole system and process described in the conceptual design and the job of every unit, how and why the system components were selected.Then, a more detailed description of the Kinect sensor and the Raspberry pi controller features and main components. Moreover, a mathematical model of the pneumatic rescue process was made and calculated for the maximum estimated loads on both the cylinders and the net.

Moreover, a prototype is constructed that illustrates the real environment of the real swimming pool that uses the recue system to prevent drowning accidents. In addition to a software that can detect the humans around the pool and determine their age using their heights. Figure (5.1) shows the Kinect sensor scanning results (depth and RGB) for the area of the prototype.

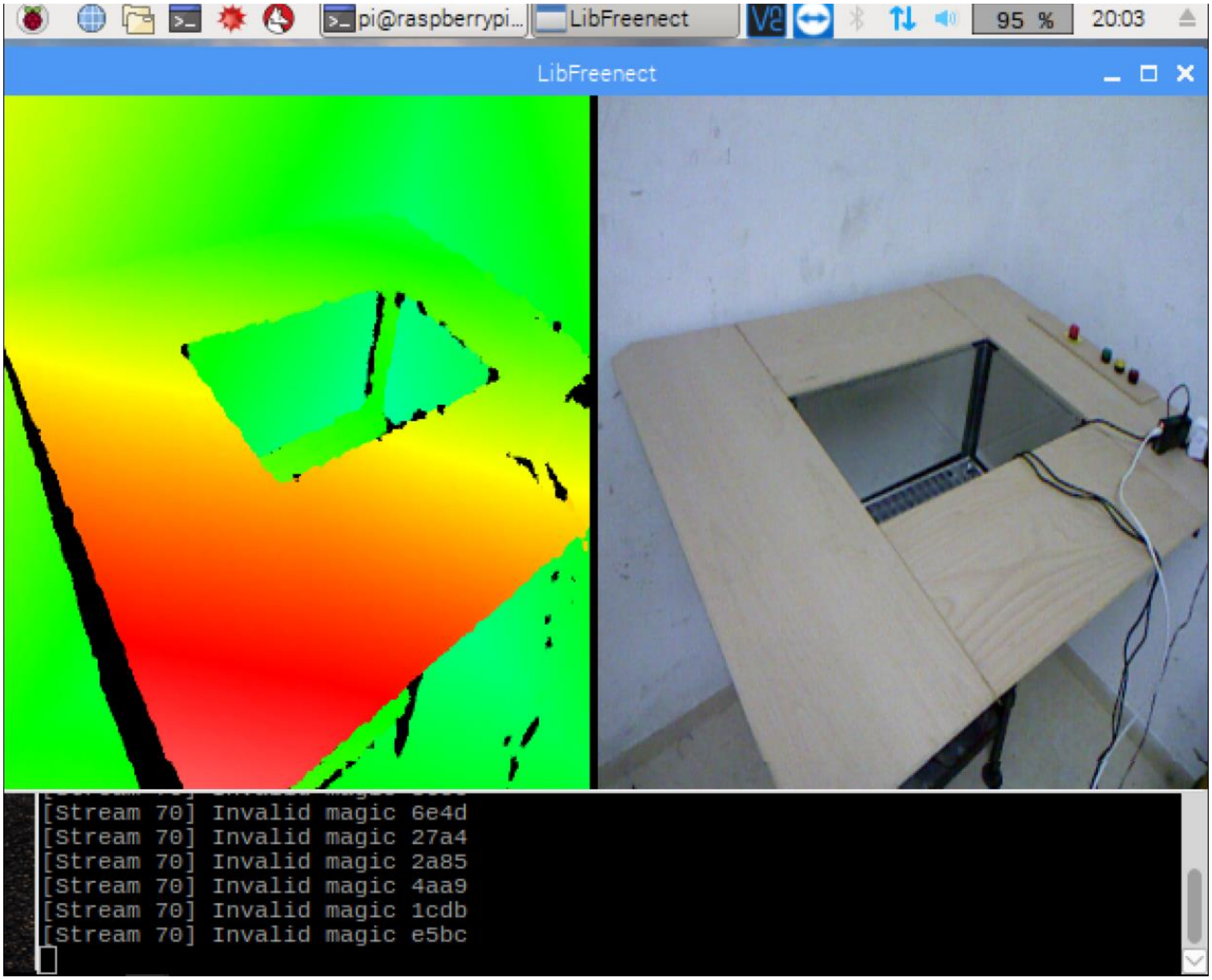


Figure (5.1):KinectScanning the Area

As for the experimental results, the system has been operated using a PC and an Arduino, and the system detected the humans in its frame and defined their heights as shown in Figure (5.3).The Arduino controls the system components activation, while the operating code is on the PC which signals the Arduino according to the code that illustrates the control algorithm.

Figure (5.2) shows the system experimented on a height 180, the person is out of the range of the first stage area, so no detection happens. Figure (5.3) shows the person entering the first stage area and triggers the first stage alarm. While Figure (5.4) shows the person getting closer and reaches the second stage area, to trigger the rescue process with the second stage alarm.

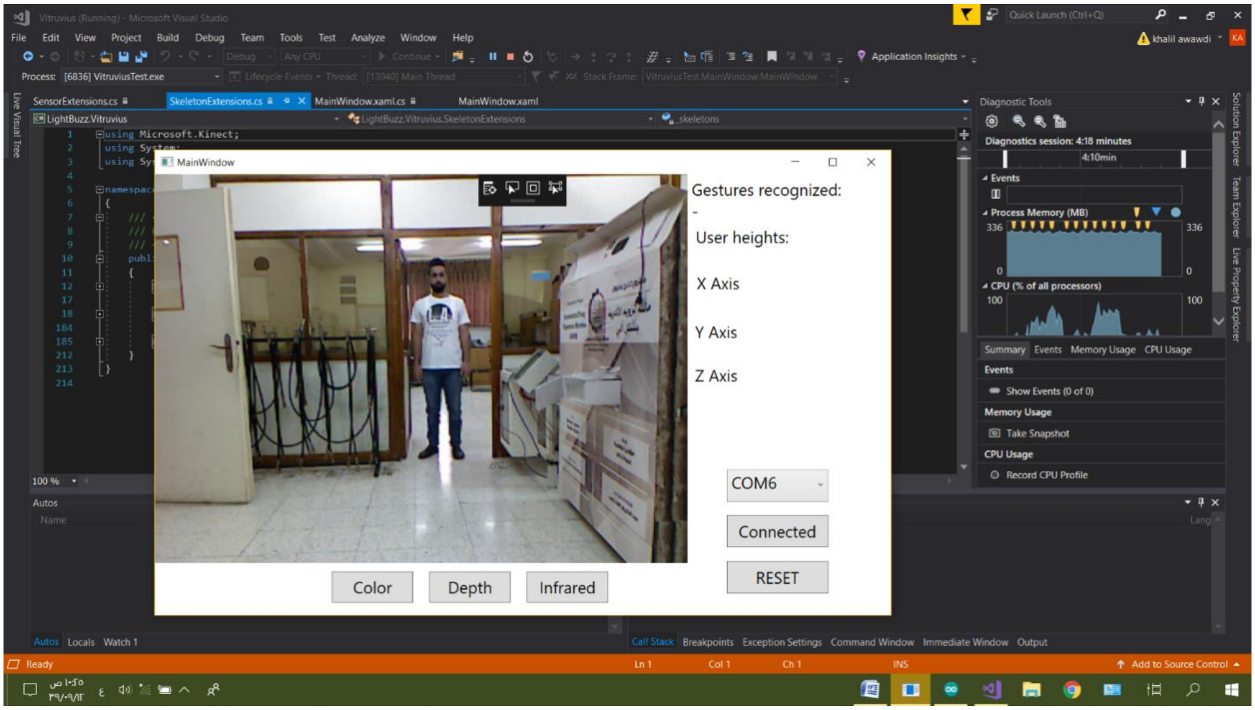


Figure (5.2): Out of the first stage

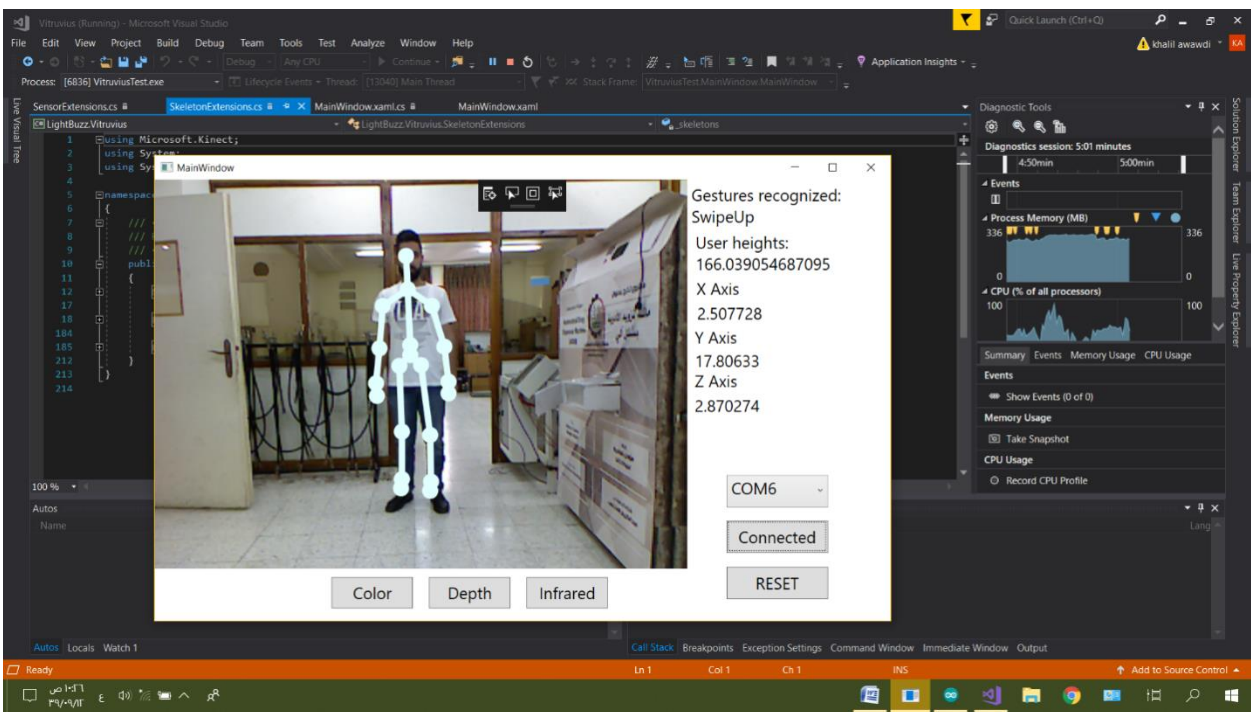


Figure (5.3): The first stage area

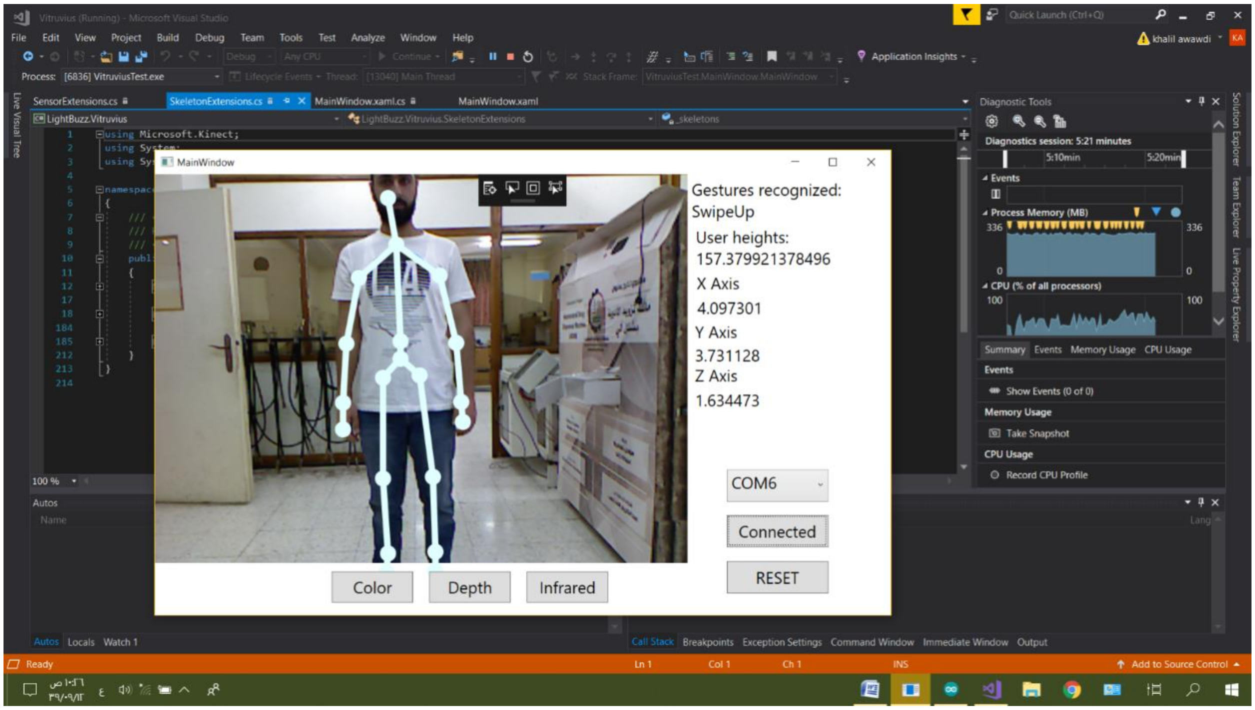


Figure (5.4):At the second stage area

5.2 Future work

This project is considered to be the cornerstone for many safety and rescuing projects, the system can use additional Kinect sensors for more accuracy and more surrounding area, it can also be improved to scan inside the pool to be able to differentiate between drowning or non-drowning by how much time they stay motionless in the water. A mobile application can be used to notify the parents in case anything happened in the pool.

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