

**DESIGN AND PERFORMANCE EVALUATION OF
DROWNING DEATH PREVENTION SYSTEM WITH
ARTIFICIAL INTELLIGENCE & IoT**

A Thesis

Submitted in partial fulfilment of the requirements for the
award of the degree of

DOCTOR OF PHILOSOPHY

in

Electronics and Communication Engineering

By

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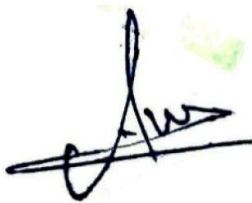
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CERTIFICATE

The thesis entitled “Design And Performance Evaluation Of Drowning Death Prevention System With Artificial Intelligence And IOT”, being submitted by Pillalamarri Laxman (Reg No-41800281), S/O Pillalamarri Amrutham to the Lovely Professional University, Phagwara for the award of the degree of Doctor of Philosophy is a bonafide research work carried out by him. He has worked under our supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree from the University. The content of the thesis, in full or parts has not been submitted to any other Institute or University for the award of any other degree or diploma.

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DECLARATION

I Pillalamarri. Laxman declare that the thesis entitled, “Design And Performance Evaluation Of Drowning Death Prevention System With Artificial Intelligence And IOT“ under the guidance of Dr.Anuj Jain, Professor, School of Electronics and Electrical Engineering, Lovely Profesional University, Punjab, India. No part of this thesis has formed the basis for the award of a degree or fellowship previously.

Submitted by

A handwritten signature in black ink, appearing to read 'Laxman', written in a cursive style.

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Pillalamarri Laxman

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Abstract:

Patrick Henry, an American patriot, once stated that we can't judge the future without looking at the past. We need to evaluate our current situation and look back to the past to find ways to increase safety in the future. The decisions we make will determine how we weather the challenges ahead. Those who die and are injured as a result of preventable causes do not include natural causes, such as illnesses, or intentional events, such as homicide or suicide. Drowning is the “process of experiencing respiratory (breathing) impairment (obstruction) from submersion/immersion in liquid, leading to loss of life or lasting health challenges” WHO estimates that unintentional drowning causes 0.7% of deaths worldwide each year (more than 500K deaths). As a result of extended oxygen deprivation, more drowning victims endure but experience permanent brain damage.

. The National Safety Council is America's leading nonprofit safety advocate [1] and has been educating people for over 100 years, a mission-based organization has published the article about **drowning** as the third major **preventable** death across the globe. It is a neglected issue, but one that is of major public health and safety importance. The most common unintentional injury death is drowning, followed closely by road traffic crashes. The researcher is working to design a robust, robust, flexible, and efficient system capable of predicting, avoiding, and autonomous/manual rescue of drowned victims. Various attempts were made to address this problem in literature explained in the following chapters most of them were wearable alerting devices. The present research mainly focused on prediction, prevention, and automatic rescue in a multi-layered approach. Using the system, predictors, alerters, and emergency responders can identify and rescue the victims in these challenging environments employing intelligent and cutting-edge technologies. The research suggests various available mechanical and electrical parts to design a reliable system. Typically, drowning occurs 20 to 60 seconds before the swimmer or drowning victim is spotted, which is the most difficult part of saving distressed swimmers and drowning victims from drowning. The study concludes the final design with practical validation data useful to reproduce the system for whoever is interested to protect their family from the said life threat. As a result, the system aims to replace and augment the efforts of trained rescue personnel, thereby preventing unnecessary human loss of life and minimizing trauma associated with drowning incidents.

There have been discussed several novel models of the system, IoT technology was chosen to design the proposed solution. The researcher has proposed an IoT (Internet of Things) based AI(Artificial Intelligent) System using popular reliable mechanical activators and a unique algorithm. Among the existing embedded system models, IoT has stood in first place in reliability, availability, affordability, and simplicity in designing and validating the proposed novel methods. The design of IoT devices is crucial to its success. Several appropriate components, sensors, processors, and actuators have been chosen by the researcher to address the problem. Systematic Literature Review (SLR) is used to process the data. An anti-drown safety system that is effective in real-time must be built upon a variety of components that have been identified, determined, robust, reliable, and rated in terms of their usefulness. IoT components, sensors, and devices have been selected based on their ability to be integrated into reliable drown detection, prevention, and auto rescue devices through SLR and incorporated into the device design. Various systems were planned and designed and tested by the researcher by incorporating suitable components. All the devices are examined for accuracy during the research. As well as current requirements and power consumption, the researcher has analyzed the components' properties. This report also examines the deployment costs associated with these devices. It is also possible for the installation location to affect the accuracy of sensed data. Considering a threshold in the risk assessment considers various parameters, such as size and depth, as well as other factors. Thus, the threshold is changeable in the design of the expert system. A System like the proposed one, which combines preventative measures with emergency management, will keep swimming pools safe for all.

CHAPTER-1

INTRODUCTION

Patrick Henry, an American patriot, once stated that we can't judge the future without looking at the past. We need to evaluate our current situation and look back to the past to find ways to increase safety in the future. The decisions we make will determine how we weather the challenges ahead. Those who die and are injured as a result of preventable causes do not include natural causes, such as illnesses, or intentional events, such as homicide or suicide. The National Safety Council is America's leading nonprofit safety advocate [1] – and has been educating people for over 100 years, a mission-based organization has published the article about drowning as the third major preventable death across the globe. Drowning is a largely neglected issue, but one that is of major public health and safety importance. The most common unintentional injury death is drowning, followed closely by road traffic crashes. WHO estimates that unintentional drowning causes 0.7% of deaths worldwide each year (more than 500K deaths). The epidemiology of drowning in India is very poorly understood. The vast majority of drowning deaths occur in low- and middle-income countries according to WHO and van Beeck (2005). Rescue of anxious, panic or drowning swimmers involves identifying the need for help from land as soon as possible after the swimmer is in distress. The rescue effort typically lasts 20 to 60 seconds and if not done so, leads to mild to serious health problems to permanent loss of life.

A higher percentage of the population dies by drowning in the South Asian countries than the average in the world as recorded by Szpilman D(2012). A majority (69%) of drowning survivors recover their neurological function, while 28% undergo some form of mental damage, and 3% have permanent brain damage revealed in an article by Fenner P(2000). Approximately 80 people drown in India each day, according to the National Crime Records Bureau, Accidental Deaths and Suicides (2012), which is around 7.4% of all abnormal deaths. Jaseena Nadu Veetil(2017) have published a study report on drowning epidemiology in India revealing 47.7% of children were drowned when they are happily playing with friends 21.6% were accidentally drowned while they are undergoing training in swimming and also 87.1% of the survivors reported that protective and preventive equipment was not

installed at the swimming site. Moreover, the Jaseena Nadu Veetil (2017) report found that 85.1% of survivors, who survived drowning, informed that there was no one overseeing closely on the site and 40.1% of them already knew how to swim. From the book named "Handbook on Drowning: Prevention, Rescue, Treatment" by Branche, Christine M et.al suggested that People's focus tends to shift towards identifying blame rather than finding cause and remedy when these incidents occur, as predominant emotions often come to the forefront immediately where there is death or serious injury. The goal of establishing the truth about accidents is not just to determine how they occurred, but also why they weren't prevented. Seventy-five percent of drowning deaths at residential pools in 2021 were caused by children under five years old, according to an op-ed in a blog in 2021 called "www.poolsafely.gov".

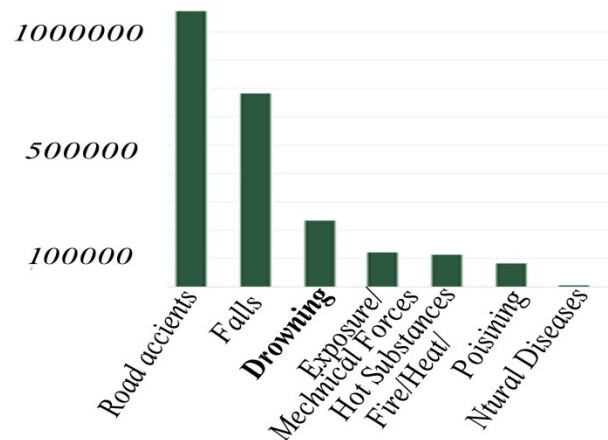


Figure.1.1: Statistics of Preventable death epidemiology worldwide according to WHO.

Source: World Health Organization. (2020). Global Health Estimates 2019: Deaths by Cause, Age, Sex, by Country and by Region, 2000-2019. Geneva: Author.

Table 1.1. Statistics of death epidemiology worldwide according to WHO

Leading causes of preventable death in the world, 2019	
Causes of death	Deaths
Road injury	1,282,150

Falls	684,277
Other unintentional injuries	631,108
Drowning	<u>235,642</u>
Exposure to mechanical forces	121,556
Fire heat and hot substances	114,144
Poisonings	84,278
Natural disasters	6,092
Source: Global Health Estimates 2019: Deaths by Cause, Age, Sex, by Country and by Region, 2000-2019. Geneva, World Health Organization; 2020.	

Swimming pools are great places where enjoyment mental relief under Fitness together happens at one place. Based on this point, usage of swimming pools is increasing in several tropical countries. Having swimming pools is not only a healthy choice but has also become a status symbol. Even reputed holiday destinations, Resorts, and holiday hotels are also providing large community pools and private small personal swimming pools to their customers. There are many applications for swimming pools, however, there are also very serious challenges that are popping up and affecting more families day by day by costing the lives of their loved ones. Despite taking precautions and technological developments, Statistics from the World Health Organization (WHO) indicate that unintentional drowning deaths are increasing exponentially in swimming pools. An adult drowns in 60 seconds, which you may believe is "quite rapid." However, the odds are significantly higher for children—according to the US Army Corps of Engineers, it only takes 20 seconds for a youngster to drown (USACE). In the United States, more than 2,500 kids suffer lasting brain damage as a result of near-drowning episodes. In the last two years, the number of residential swimming pools in the United States has increased by 11%.

1.1 Thesis Contribution: Problem Identification

In addition, the chapter includes a summary of the motivation for the research and the specific issues and objectives of the study. Diagrammatic representation of research objectives, methodologies used for research is shown lastly. Therefore, the contributions of the thesis publications and thesis organization provided a comprehensive understanding. It is essential to how machines influence and help our daily lives in a society that robotics and automation bring innovative dimensions to human practices for daily needs and security. Although different methods have been suggested, the research community has yet to address some of the challenges associated with understanding fatal accidents near swimming pools.

1. In every article, observations are partially focused on the proposed issue. To be able to automatically rescue someone in a risky situation, a multilayered approach is needed to identify the danger, alert the person, and also utilize an autonomous decision-making framework.
2. Using carefully chosen time thresholds and priority settings in the system, an efficient algorithm is needed to monitor the connected sensors and switches.
3. The availability of such programs on lightweight and convenient programming platforms like Raspberry Pi or the latest Arduino Micro-controllers prove to be a real match. PLC controllers are also another best alternative for programming these type of swimming pool anti-drown system.
4. Using cutting-edge and intelligent technologies, the predictors, alerters, and emergency autonomous rescue system can predict, identify, and rescue victims in these challenging indoor/outdoor swimming pools.

1.2 Motivation

The motivation for the proposal is a death statistic in my immediate surroundings and incidents across the world. Even though humanity invented many technologies, the problem of drowning-deaths is still uncontrollable, which prompted me to start researching in this issue. Furthermore, we all work in a competitive environment today, and we want to stay healthy physically and mentally suffering no side effects. Research presented in the current study has led to the development of a system with multiple drown detection, prediction, and

automatic rescue functions. It is never acceptable to lose a child or loved one because of small errors or ignorance and on any level to seek life security. Several methods and ways are proposed for the system to detect, prevent, and also act independently to rescue a victim from death in various ways in the present thesis with a complete choice of algorithms and components, and analysis of the fully functional prototype.

1.3 Research Issues and Objectives.

Our research is focused on real-time detection of swimming pool accidents, efficient preprocessing algorithms, detection of drowning incidents in real-time, alerting, and finally, providing a functional and reliable solution to society by comparing our research to other existing methods.

Specifically, the researcher seeks to address the following components in this study:

- 1) Closely identify stages of drowning accidents and the reasons behind the accidents.
- 2) Assess the existing methods, techniques, devices, and sensors that apply to the defined problem and find a unique solution
- 3) Propose a security system that can provide the most reliable service and provide multilevel life support with the least amount of human involvement at the time of the accident.

The investigator has compiled the following objectives by considering all points discussed above

1. To improve swimmer safety and security, a simpler and perfect preprocessing method can be designed.
2. To address the proposed challenges, identify a unique set of sensors, processors, materials, and actuators.
3. The goal is to apply computational intelligence, materials, and design techniques to predict, detect, and automatically react to proposed accidents in an automated or semi-autonomous system.

4. Validating the effectiveness of the project methods by comparing their performance against currently existing anti-drown safety systems.

1.4 Research Methodology

1. The first objective was accomplished by studying a good number of research articles, designing papers, and reviewing articles ,patents, commercial products to explore existing techniques and technologies to solve the drown deaths problems. During this research, it was recognized that there are a significant research gaps that need to be addressed effectively to reduce the intensity of the proposed issue.

2. Thanks to open-source programmable embedded processor technologies such as Arduino and Rasberry-Pi. The choice of an efficient sensor and embedded processor became much easier through studying a multitude of efficient sensors and embedded processors, but the key problem lies in using them underwater. Almost all sensors had characteristics that could be verified only in an open environment. We tested new sensors in an underwater environment to choose the right one with the right sensor.

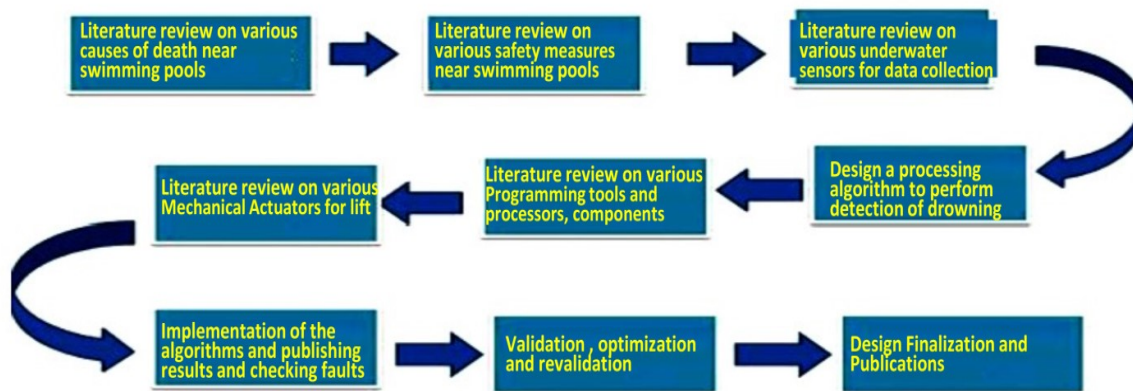


Figure 1.2. Organization of thesis.

3. To realize this objective, the proposed system is broken into several sub-programs and each sensor is fitted with a separate mini-processor (Arduino-Nano) to take a decision and seek the final response from the main central processor. It introduced the concept of

distributed edge-computing solving multi-threading problems. I have written the programs' efficient and direct logic methods facilitating a quick decision.

4. Accordingly, the fourth Objective has been achieved through the analysis of selected sensors, with a comparative analysis and correlation of both the complete system and the existing systems, so comparisons have been conducted with existing techniques.

1.5 Thesis Contribution

The research questions that were defined in this study were addressed in this study. It includes the following contributions:

A literature survey of all the statistical studies and design articles inspired to choose appropriate sensors and actuators to address the proposed challenges is done in detail.

1. Various existing methodologies and technologies, designs, and classification approaches revealed in patents, research papers, and conferences have been thoroughly investigated.
2. The recommended techniques are arranged in accordance with their common qualities.
3. The selected sensors were tested in various worst-case scenarios before finalizing them for the implementation of the proposed system.

A detailed literature survey has been done to select the appropriate algorithm

1. A detailed exploration has been done to recognize diverse stages of drowning and their impact on the human body considered to decide the final algorithm.
2. All the possible chances of the proposed problem occurrences to create a worst-case scenario are made and tried to address the worst-case situations.

The platform was chosen to construct a system capable of detecting drownings in real time, with unique characteristics such as those listed below.

1. The device needs to IoT enabled and multi-layered
2. The technology should be capable of identifying and anticipating worst-case scenarios.

3. The device needs to be cost-effective, low power, and reliable.
4. The device should be able to take decisions automatically and manually in real-time.

1.6 Thesis Organization

The flowchart in Figure 1.4 depicts the whole association of the thesis and its chapter-by-chapter structure.

Chapter 2 is primarily concerned with a survey of the literature on all available approaches, designs, metrics, and classifications relating to the described topic. Chapter 3 is about central ideas proposed concepts and various architectures. Chapter 4 explains the details of hardware and software coprocessors and actuators. Chapter 4 explains the detailed methodology and developed algorithms to implement a multi-layered system in real-time. Chapters 5 show the detailed Software and Hardware Development of the system including various choices available to choose sensors based on their tolerances and coverage. Chapter 6 Shows the Results and related discussions, and finally, Chapter 7 explains the Conclusion and future scope.

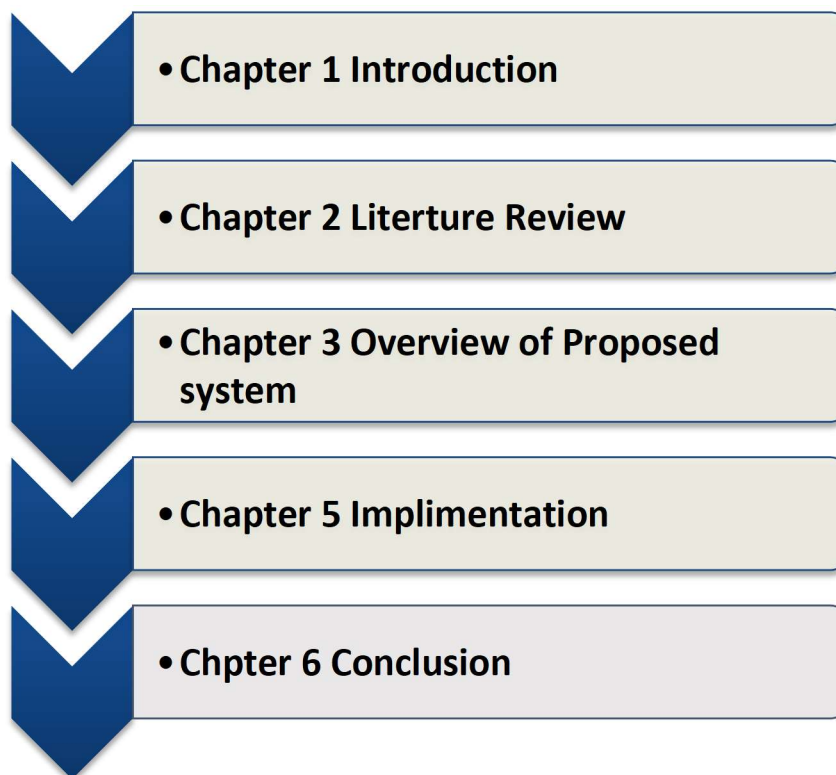


Figure 1.3. Chapter Organization

Chapter 2 represents the detailed methodological survey on existing methods and systems, algorithms addressing the challenges in the proposed area.

The outcome of the findings satisfies Research objectives as follows:

First Objective Achieved

- ❖ Pillalamarri.Laxman, Dr.Anuj Jain, “A review paper on Design And Performance Evaluation Of Drowning Death Prevention System With various technologies”, *Journal of Emerging Technologies and Innovative Research - UGC CARE*

Second Objective Achieved

- ❖ Pillalamarri.Laxman, Dr.Anuj Jain, "Robust Drown Alerting Preventing and Autonomous Rescue System", *The Scientific Bulletin of Electrical Engineering Faculty*.
- ❖ Pillalamarri.Laxman, Dr.Anuj Jain, "A Survey On Design And Performance Evaluation Of Drown Death Prevention Systems Embedded IoT"- **International Conference** On Advance In Computing Communication, IIMT University Meerut.
- ❖ Pillalamarri.Laxman, Dr.Anuj Jain, "A State of the Art of Drowning Death Detection and Prevention Systems with Various Communication Technologies and Discussion on their Performance"- SMART “MODERNISTIC in ELECTRONICS AND COMMUNICATION – Hyderabad **Conference**.

Third Objective Achieved

- ❖ Pillalamarri.Laxman, Dr.Anuj Jain “Drown Alerting Preventing And Autonomous Rescue System..”, *World Academy of Research in Science and Engineering(WARSE)* **SCOPUS INDEXED.**

Chapter 5 Explains the detailed methodology and also explains that the algorithm has been designed to implement real-time drown preventing an autonomous rescue system.

- ❖ Pillalamarri. Laxman, Dr. Anuj Jain, “Automation Of Swimming Pools To Prevent Drowning Deaths Using Iot , Sensors And Unique Algorithm”, Webology (ISSN: 1735-188X), Volume 18, No. 5, 2021. **SCOPUS**.

Fourth Objective Achieved

- ❖ Pillalamarri. Laxman, Dr. Anuj Jain, "Intelligent Swimming pool design with smart Embedded Drown Alerting Preventing and Autonomous Life Rescue System", International Conference on Computational Intelligence and Communication Technologies **IEEE. SCOPUS**

Fifth Objective - inventive step

- ❖ Pillalamarri. Laxman, Dr. Anuj Jain ,”ANALYSIS NOVEL ASSISTIVE ROBOTIC MULTI-STAGE UNDERWATER LIFT DESIGN FOR SWIMMER SAFETY” , The Journal of Engineering, ISSN:2051-3305 SCOPUS+ESCI.
- ❖ **Patent:** Pillalamarri. Laxman, Dr. Anuj Jain “an electro-mechanical anti-drowning autonomous rescue system for swimming pool”, Ref. No./Application No. 202111009202.
- ❖ **Under Publication Process Patent:** “Anti-drown construction for swimming pools inspired by buoyancy.” Recommended by LPU.
- ❖ **Under Publication Process Journal :** Pillalamarri. Laxman, Dr. Anuj Jain , “Intelligent Multi-Stage Drown Preventing, Auto-Responsive anti-drown System Using IoT, Biomedical Sensors ”, IETE Journal of Research.

This chapter provides a detailed account of the thesis. Its purpose is to provide a detailed description of the strategy that will help you decide on the research field, define the objectives, and achieve the objectives in an organized thesis.

1.7 Advantage and uniqueness:

- 1) The ubiquity of drowning was much higher than what appeared in government statistics. Public negligence and lack of intelligent systems lead to day by day increasing the number of deaths annually despite having so many gadgets and security systems . The people in the swimming pool will never guess or recognize if someone is in a panic

situation, so the security system demands a large number of options to express and alert the panic situation of victims by properly using programming and technology.

- 2) The algorithm developed to deal with drowning accidents is very novel simple to understand and simple to implement since the existing systems completely failed to reduce the annual death rate due to drowning.
- 3) The present algorithm does not depend on any complex image processing, image recordings, learning, or adaptation techniques.
- 4) The proposed system has tried two different strong automatic rescue methods such as elevator and draining the pool, and four different alerting methods simultaneously which was never been tried in any invention.
- 5) The Power-on self-test of the anti-drown systems were never been practiced in any invention so far.
- 6) The present invention leaves very little scope of fault in detecting and rescuing drowning victims.
- 7) The system exhibits a reliable and resilient architecture i.e if one subsystem fails, remaining systems won't get affected.
- 8) The proximity sensors used in the invention are immune to wear-and-tear since they were never been touched since the proximity sensor uses IR radiation to recognize newly arrived objects near to the sensor. Alternatively, any optical-shadow-detecting sensors or similar sensors can also be used in place of proximity sensors.
- 9) The screw-jack linear lifting mechanism used in this invention was approved to be a successful mechanical structure in moving extremely large weights to very light weights and very smooth 3d-printing technologies.
- 10) The total rescue operations can be directly initiated without consulting embedded Processor without disturbing automatic features, i.e initiating a manual rescue by simply giving bypass connection between 1)control panel panic switch, 2)push-to-break switches mounted underwater on pool walls, and 3)manual panic-switch that may be arranged anywhere outside the pool accessible to whoever watching the pool activities(a lifeguard or anyone witnesses the drowning accident) since there is a definite acknowledgment of drowning by a victim or another person.

LITERATURE SURVEY ON EXISTING SYSTEMS AND METHODS

2.1 Technology Transfer to Address the Challenge:

There were several classes of devices and systems proposed by various authors in reputed peer-reviewed journals. These methods and systems can be divided into categories as [2].

- 1) Drown alerting systems,
- 2) Drown preventing systems
- 3) Drown rescue devices (automatic and manual)

Alotaibi, Aziz (2020)[3] has presented an article by proposing a method to prevent the occurrence of such incidents by using IoT technologies and transfer learning with the help of IoT technology and Machine learning algorithm (Motion-detector, sensor, image processing) processing to identify and inform (Detection, Recognition, and alert) about falling of certain being (animal or human specifically) to the unsupervised home swimming pool through a cellular mobile phone message and claimed lower complexity and higher reliability. Alshbatat (2020) [4] introduced an IOT device set up to recognise and warn the panic drowning situation using a pre-trained mechanism powered by image sensors and complicated software components known as PC-based PixyMon software. His prototype works on several programmed IoT processors and imaging sensors (e Pixy camera) seamlessly capturing images of the underwater environment and comparing them with pre-stored images which are called a machine learning algorithm that requires pre-training. Eng, Toh, et al. (2003) [6] provided an efficient numerical model and software-based swimmer identification system that performs a variety of difficult image processing tasks, on running video frames to identify near-drowning incidents through modified Functional Link Network (FLN) and *generalized reduced multivariate polynomials network* (GRM) using only single training frame with a rate of 4 frames/second throughout the day and night as long as the system is turned ON achieving 5.5% of minimal error rates contrast to the existing other techniques.[5] Jan Dufek (2017) A strategy based on a single forward-facing monocular

sensor employing epipolar geometry in many perspectives, specifically an approach termed visual posture stabilisation of fotokite algorithm, is proposed to enable a tiny unmanned aerial vehicle become more resistant to environmental disturbances. It uses a 2.5 GHz Intel Core i7 Laptop computer taking an average time for one cycle was 206 ms with a fixed frequency of 4.85 Hz in the real-time testing environment. Nasrin Salehi and Maryam Keyvanara [7] introduced a real-time image processing system with an alert delay time of 2.6 seconds using a new method dubbed HSV-g with contour detection thresholding. Their experimental work done on ODROID-XU board processing as the processing environment, and Logitech HD Pro C920 webcam recording the video sequences by processing about six frames every second to detect contours and compare them by HSV algorithm which is limited to give alert on a successful detection of a drowning incident. Lei Fei (2009)[8] conducted explorations in a public swimming pool to capture a video sequence using a fixed underwater camera for Drowning Tracking Based on Background Correction and Shadow Inhibition, which appears to be one of the proven image processing techniques such as the Gaussian mixture model, EM algorithm, and defining a shadow mass SD motion segmentation to recognise drowning people in public swimming pools. With real-time photographs of the swimming pool under observation, Lei Fei has provided mathematical modelling of the suggested image processing technique. K. Hiratsuka and Y. Nishida (2007 and 2008) [9] devised a complicated floating transparent ball type equipment that may be maintained floating in bathtubs to forecast and alert unintentional child falls. This device uses a tri-axial accelerometer to detect abnormal water wave activity monitored by a micro-controller with sensor and radio communication device with 20 times per second signalling rate having an inbuilt battery. The device works as long as there is enough battery power as a major limitation and the algorithm is tested in a controlled environment and predefined objects placed in water. DEWS (Drowning Early Warning System) is based on a digital signal processing algorithm, a mathematical model with real-time trail, background subtraction, de-noising, data fusion, and blob splitting technique to identify various swimming behaviours such as anxiety, drowning, and treading, according to How-Lung et al. (2008) [10]. They have prepared and demonstrated a prototype in an onsite evaluation at a public pool. They have disclosed real-time images in various situations and simulation results to understand the proposed algorithm. This particular technique requires a powerful

DSP processor and high-resolution cameras to handle a large amount of running data. Roy and K. Srinivasan (2018) [11] published a design report on a drowning sensor module based on head-wearables that include safety glasses with a wireless radio that connects with a reception outside the pool. The system uses a simple wet-sensor and a timer set by Arduino processor, a siren as a part of head mount goggles and the receiver continuously checks for the signal which is around 40 kHz through an Ultrasonic sensor module. The trigger time is set for 10 seconds for kids and more than 10 seconds adjustable to adults. Sindhuja (2015) [12] proposes a garment for automated drowning victim rescue that uses a collection of accelerometers, pressure sensors, and a microcomputer. Inflating the airbag is carried out by a hand-held prototype that is attached to a controller. The micro-controller includes a mini-gas cylinder whose opening is controlled by a written program. As soon as the water depth reaches a certain threshold, the controller starts a timer to open the gas valve. This process happens once the timer value surpasses the set threshold time. Tamura et al. [13] and Tang, Z. (2014) [13] provided a pilot investigation on the performance of a sensor network supervised by a system that accumulated a significant amounts of data from multiple sensors and signals from multiple computers and warned people when the system detected danger. The system includes several Pyro-electric sensors attached to the ceiling of the proposed room, which would monitor sudden changes in human motion in the room, as well as an accelerometer attached to the bathtub to prevent accidental drowning of humans inside the bathtub if they breathe abnormally when bathing. The table 2.1 have summarize the research papers and their contribution in solving the proposed research gap.

Table 2.1: Comparison of existing research papers on drown prevention system designs based on reliability.

<i>S.No</i>	<i>Ref No's of existing systems</i>	<i>Sensing Method</i>	<i>Mode of action</i>	<i>System complexity</i>	<i>Cost efficiency</i>	<i>reliability</i>	<i>False Alarm</i>
1	Proposed system	Proximity, LDR, switches	Autonomous, manual	Moderate	Economic	More	LOW
2	Ref No [4]	Acceleration, pressure sensor	Detection and rescue	Moderate	Moderate	Moderate	High

3	Ref No [5]	Image Processing	Detection and alarm	High	Low	Moderate	Moderate
4	Ref No [6]	Pressure sensors	Detection and rescue	Low	High	Low	Low
5	Ref No [12]	Heart Beat Sensor	Detection and alarm	Moderate	High	Moderate	Moderate
6	Ref No [11]	RFID	Detection and alarm	Low	Moderate	Moderate	High

2.2. Patents published to address the proposed problem

The patent databases have numerous inventions registered on the issue of drain accident prevention. The study revealed that most of the inventions were focused on wearable alerting devices and very little progress is seen in autonomous robotic systems. The present researcher has published a patent on the current study results which is already motioned in chapter-2.

Table 2.2. List of available granted patents on the anti-drown devices and systems [28].

S No	Patent No	Title-description
1	CN103021135B	A kind of anti-drowning alarm
2	CN106428464A	Intelligent drowning-preventing rescue device and method
3	CN204965105U	The drowned monitored control system is presented to children's intelligence
4	CN102324167A	Anti-drowning alarming method and device
5	WO2016141859 A1	Anti-drowning system, method, and swimming pool, and construction method and reconstruction method of swimming pool -
6	CN1162364A	Self-locating remote monitoring system
7	WO2016023138 A1	Drowning help-seeking apparatus for improving underwater electromagnetic wave communications
8	CN105923124A	Intelligent drowning prevention self-rescue device – (neck airbag)
9	CN104367312A	Human body drowning monitoring method and drowning-prevention auxiliary device –(wearable neck belt case enclosing airbag)
10	CN205177096U	Intelligence watch with drowned alarming function
11	WO2007/015088A1	A portable bather monitoring device and a waterside monitoring

		system
12	WO2002023501 A1	Alarm apparatus (when contact with water, gives alarm)
13	EP1872151A1	Salvage system for life jacket – (useful in marine swimmers, also pools)
14	EP1915747A1	A portable bather monitoring device and a waterside monitoring system - wristband device with alarm in it.
15	EP2701130A1	Drowning prevention system: helmet detects that a user is submerged in water for a long time.
16	US2942247	Alarm warning for swimming fools
17	US5049859	Alarm warning system for swimming pools(sensors under pool pavement)
18	US5619187	Alarm to prevent drowning-transmitter attached to the body, actuatable when submerged in water.
19	US5959534	A swimming pool alarm detects a sensor if anything falls in the water.
20	US6064309	Swimming pool drowning prevention system (wrist band)
21	US6127930	Motion responsive swimming pool safety mat-actuated by a dependable microwave pattern which is disrupted when a person falls into the pool.
22	US6133838	System for monitoring a swimming pool to prevent drowning accidents(triangulate human in water –motion behavior learning)
23	US7019649	Pool monitoring-hydrophone generates a signal on the pressure threshold.
24	US 7218235B1	Motion responsive swimming pool safety device(perimeter laser)
25	US7642.921B2	Electronic swimmer monitoring system (heads are underwater for periods
26	US8164448	Security fence for swimming pools
27	US8659432B2	Security system for automatically detecting a person overboard using RFID tag
28	US9595178	Water safety monitoring devices, alarm devices, and related methods.
29	US20080218332 A1	Portable bather monitoring device and a waterside monitoring system(wrist band)
30	US20080266118 A1	Personal emergency condition detection and safety systems and methods(wrist bands with balloon inflatable)
31	US20110068933 A1	Personal water safety device(goggles with two electrical contacts by water entering between)
32	US20130106610 A1	Sentinel surveillance system with pre-alarms to avert drowning(mount cameras to observe the unauthorized entry of pool)
33	US20160314675 A1	Swimming aid to prevent drowning(wearable swimming aide having a plurality of wireless sensors including as an underwater depth transmit, an array of light, and an array of underwater bubble generator.)

34	WO1999057696 A1	Swimmer location monitors (pressure sensor depth sensor emit alarm signal to central processors outside water.
35	WO2009015060 A3	Electronic swimmer monitoring system(wearable e-device communicate with underwater receiver)
36	WO2015019360 A1	Wearable multi-sensory personal safety and tracking device(predicts danger by sensing changes in voice, pulse, emotions, impact, the motion of the wearer, and the device state)

The CN107134116A patent describes a swimming pool anti-drowning monitoring system that uses a sensor arrangement to detect the default hydraulic pressure given threshold; if the value exceeds, the timer transmits a signal to the controller, which then triggers ZigBee communication to submit positional information to the monitor terminal for presentation. This innovation, however, is for a wearable gadget and is not a viable option. The CN111502354A patent describes a smart swimming pool and an approach for observing an user's drowning via drowning prevention medical infrared matrix first-aid, in which the swimming pool body includes a bottom multipurpose device and sensors that detect whether an individual is drowning or not and make appropriate decisions. Moreover, no lift mechanism for an automated retrieval system is mentioned in this invention. The US20090126096A1 patent offers a lift assembly for a swimming pool that regulates the swimming pool's useable depth and gives a changeable platform across lowered, middle, and higher levels. This idea, on the other hand, does not address providing protection to a person within a swimming pool. According to the above-mentioned prior art, a mechanism that offers a powerful anti autonomous rescue system for the swimming pool is needed. The goal of this research is to develop an automated rescue system for a swimming pool in immediately to protect drowning.

Table 2.3. Few patents- and their limitations .

S N	Patent number	Abstract	difference
1	CN107134116 A	The CN107134116A patent describes a swimming pool anti-drowning tracking system that uses a sensor arrangement to detect the baseline hydraulic pressure threshold value; if the value reaches, the timer transmits an information to the control, which then activates ZigBee communication to transmit	The lack of a reliable rescue mechanism. It simply revealed a detecting technique. This innovation, however, is for a wearable gadget and is not a viable

		positional accuracy to the monitor terminal for presentation.	option.
2	CN111502354A	The CN111502354A intellectual property describes a smart swimming pool and a technique for tracking a person's drowning via drowning protection medical infrared matrix first-aid, in which the swimming pool framework includes a bottom multifunction gadget and sensors that detect whether a person is drowning or not and make appropriate decisions.	However, no elevator assembly for an automated rescue system is discussed in this invention.
	US20090126096A1	The US20090126096A1 intellectual property offers a lift mechanism for a swimming pool that controls the swimming pool's useable depth and gives a moveable platforms across lowered, middle, and higher levels.	This idea, on the other hand, does not address providing support to a person within a swimming pool.

2.3 Survey on Types of Elevator Systems

In the current research study, elevators are being used to rescue drowning victims from inside swimming pools. An elevator is a vertical transportation mechanism that properly and effectively transports passengers between levels of a structure.

Types of Elevators

- Traction with a machine room
- Machine-Room-Less (MRL) traction,
- Hydraulic
- Screw-Jack Actuators
- Scissor-Lifts

2.3.1 Traction with a machine room

Ropes travel across a (pulley) wheel attached to an electric motor positioned above the shaft to raise an elevator with traction. Pneumatic elevators are employed in high-rise applications and have substantially faster travel rates than lifts. By counterbalancing the weight of a

container car and its occupants, counterweights allow elevators to be more efficient by reducing the amount of weight the motor has to lift and drop down with uniform speeds. A gearbox attached to the motor drives the wheel of the gear traction elevator. The motor drives the wheel which moves the ropes through amplifying power by gearboxes between motor and car shown in Figure 2.1.A&B. A gearless traction elevator operates at a maximum speed of 2 mph. Traction elevators with geared motors can travel about 75 meters. Traction elevators, which are without gear, have the wheel directly attached to the motor. The only choice for high-rise elevators is the gear-less traction elevator, which has the greatest journey distance of 500 meters and a speed of up to 20 mph. As far as cost, maintenance, and energy consumption are concerned, gear-less traction elevators are in the mid-range. Compared to geared traction elevators, gear-less traction elevators are more expensive in the beginning, have average maintenance expenses, and use energy a bit more resourcefully. It is crucial to periodically inspect the ropes and sheaves of traction elevators for wear and tear damages that occur due to repeated usage on daily basis. Sheaves and cables lose their traction with wear and aging, resulting in more frequent slippage, dipping their efficiency and making them potentially dangerous if not taken care of.

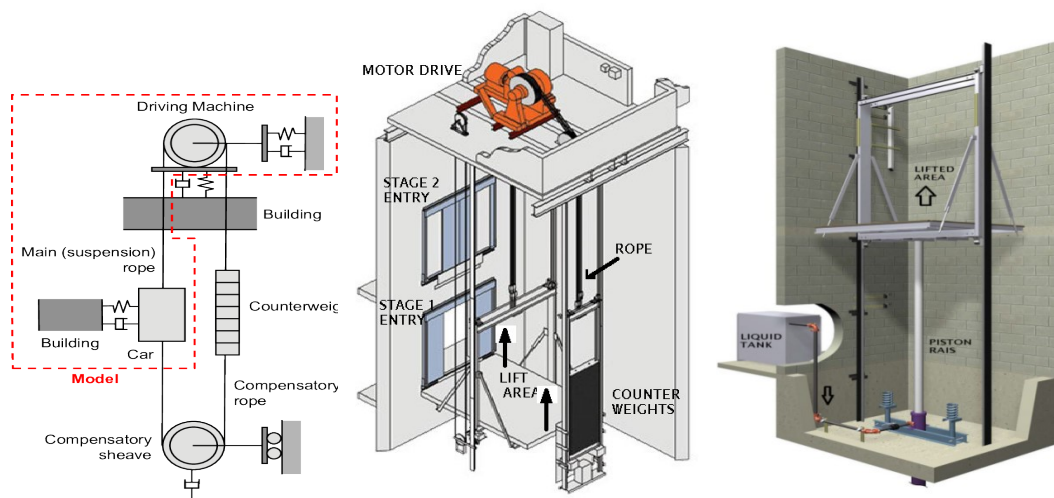


Figure 2.1. A,B) Illustration of Traction Elevator with a machine room; C) Hydraulic elevators

2.3.2 Hydraulic Elevators

Hydraulic elevators have a [14] piston underneath that forces hydraulic fluid into a piston as an electric motor drives the piston. This lifts the elevator upward. Once the oil is released, the piston descends, lowering the elevator, as illustrated in Figure 2.1-C. They travel at a maximum speed of 60 meters per hour and can be deployed on buildings with no more than four stories. Next to an elevator shaft, at the lowest stage, is the hydraulic elevator machine room. The hydraulic elevators that are conventionally used have a sheave that extends below the lowest bottom floor, which receives the retractable piston as the elevator descends. Depending on the configuration, telescoping pistons may collapse, creating a shallower pit below the pit. A maximum travel distance of 15 meters is achievable. Hydraulic elevators offer a cheaper initial investment and lower recurrent maintenance expenses than other elevator types. Hydraulic elevators, on the other hand, consume more energy than most other types of elevators since the hydraulic fluid fills the piston as the electric motor works against gravity, costing more electricity than traction elevators. It is a major disadvantage of hydraulic elevators that the hydraulic liquid may leak, putting the surroundings at risk. Hydraulic elevators are not installed as often as they once were because of the environmental risk and high energy requirements.

Advantages of hydraulic jack:

It takes up less room. They're also less prone to jam because the screw thread isn't rustproof. With big weights, it is quite effective. It lifts heavy things with minimal hassle. It is more convenient to utilise. It's a little less heavy than screw jacks.

Disadvantages of hydraulic jack:

Below are some disadvantages of Hydraulic Jack.

If the oil seals wear out, it is prone to failure, which can result in major complications. It moves at a snail's pace. When hydraulic oil becomes excessively heated as a result of usage, it can cause unhealthy odour. It has the tendency to overheat fast. A hydraulic oil spill can pollute the earth and water.

2.3.3 Screw-Jack Lift

A screw is a mechanical linear transducer that smoothly converts rotary motion into linear motion. In a screw jack, the load table is mounted on the top of the vertical screw. A threaded hole at the base of a stationary frame with a broad base accepts the vertical screw. These are Self-locking & overhauling of the screw. The handle, a metal bar, fits into holes in the rotating collar on the screw's head. The screw moves out of the base as the handle is turned clockwise, lifting the load on the load table. Screws are usually formed with Acme threads to accommodate large load forces. Using a horizontally oriented force, a screw jack can raise or lower a large load with a small amount of force. A screw jack's mechanical advantage is its load-to-effort ratio. Square threads, Trapezoidal threads, Summit threads, and Support threads are the thread types used in power screws[15].

Lever-Principle:

In the third century BC, Archimedes discovered this principle. The famous Line of Archimedes is quoted by Pappus in the 4th century: "Give me a fulcrum, and I will move the world." A uniform lever at equal distances from the fulcrum is found to reach equilibrium when two equal forces acting in opposite directions counterclockwise and clockwise are applied. It is the user's effort that multiplies the effect of levers. It's vital to remember that the effort force total distance from the fulcrum must equal the load force multiplied by that distance in order to raise and balance an object.

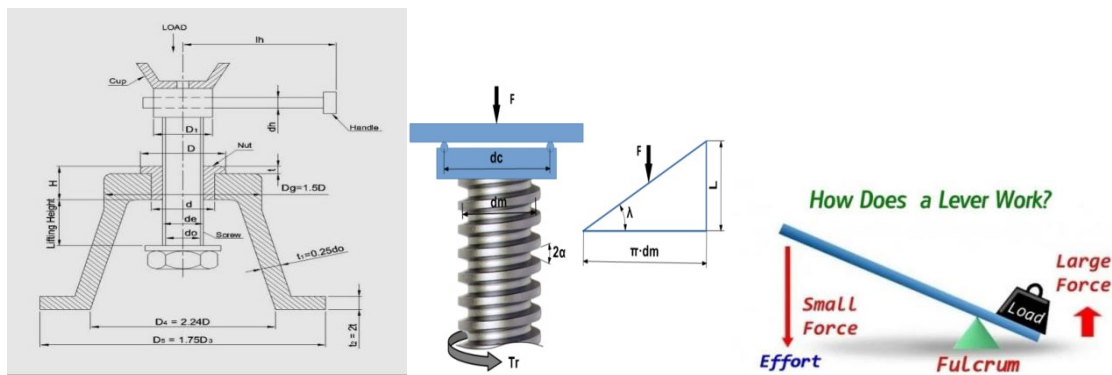


Figure 2.2. Illustration of Screw-Jack Lift and its principle.

You may vary the force given to the machine or the distance across which the force is delivered with the use of a lever, making work easier and giving you a mechanical edge. You can raise six pounds of weight for every pound you press on the lever. If the input lever arm

is six times the length of the output lever arm, the system provides a mechanical advantage six.

The machine designing technology makes it possible to manufacture the highly effective screw-jack with many advantages. Numerous precision all-direction movers utilized these screw-jacks. These are fundamentally safe, as opposed to hydraulic jacks, which would go backward if the strain on the hydraulic actuator is unintentionally removed [16]. The major drawback of screw-jack is the friction between screw threads, and in recent times, this loss is reduced by using highly intelligent "ball-screw jacks" whose efficiency is around 80%. In ball screws, threaded shafts support helical raceways that act as precision screws that support ball bearings. Aside from being able to apply or sustain enormous thrust loads, they can also do it with the least amount of internal friction [17]. The lifting capacity can be easily managed by gears and high torque motors. There are several simple linear elevators with 4 sided screw-jack (**Translating Screw Jack System**) connecting only one motor by the use of connecting gears in the market [18] [19].

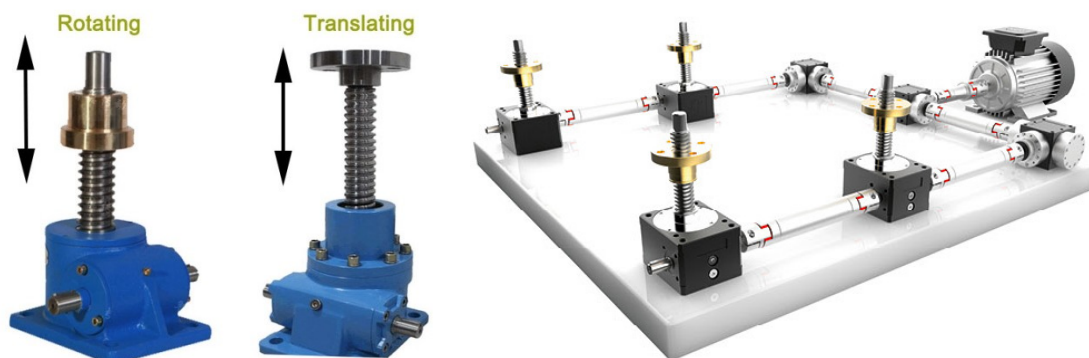


Figure 2.3. Illustration of commercially available Screw-Jack Lift with multiple jack operations by a single motor.

Advantages offered by power screws [20]:

- It has a huge load conveying capacity

- It's possible that it'll include a self-locking function. Screw jacks are a good illustration of this.
- A few sections of it make it modest and reliable
- The system provides smooth and quiet operation
- It does not require any support
- For applications such as machine instruments, it allows extremely precise movement
- Screw-jacks, clasps, valves, and indecencies are all made of this material since it has a great mechanical advantage.
- Putting it together is easy and doesn't require any specialized equipment. In general, the tightening of intensity aspects is minimal, resulting in a smaller development.

Disadvantages of power screws

- It has poor productivity
- Power screws are prone to wear due to high grating
- A situation in which high proficiency is desired. Examples include lead screws and presses
- In situations where low effectiveness is desired. For example, screws, jacks, braces, and indecencies.
- The sliding contact is reduced by moving grating to increase the competence of intensity screws. This component is used in the recycling of ball screws.

2.2.4 Buoyancy powered Lift

These types of lifts were never been implemented anywhere in the world to prevent swimming-related accidents. The proposed system utilizes the novel buoyancy-powered lift/elevator with automatically and manually operated levers. The author has published journal paper and a patent on the proposed buoyancy operated underwater lift which will be discussed in coming chapters

2.2.4 Comparison among various methods and techniques:

After careful examination of the state of the art lifting arrangements, the screw-jack system, and hydraulics system seem suitable for the proposed system. The advanced warm-screw-based jack seems much suitable for the proposed system since the proposed system is a short

distance lifting mechanism and will not have a continuous running business. The underwater screw-jack sinks the heat generated by the screw-jack friction. The hydraulic lift mechanism is also suitable for the proposed system since the hydraulic lift is best suited for short-length lifts. Due to similar advantages of the screw-jack and hydraulic lifts, screw-jack was selected to realize the final working prototype. Still, there is a gap in selecting a lifting actuator for a life safety arrangement. There is always a challenge in the people's mind that what if there is a power outage and how to rescue if there is a power outage. The researcher is trying to find out a solution where the power outage also not going to affect the proposed system. In the following chapters, various lifting mechanisms with mathematical modelling are provided, and practical comparison of the existing and the proposed system.

Table 2.4. Comparison table on the performance of lifting technologies.

Parameter	Screw-Jack with ball screw spindle	4-sided guided Scissor Lift with motor	Buoyancy based motorized Hoist
Novelty	Already existing system	Already existing system	Novel design and nowhere seen this design
Complexity	Single motor with 4 ways guided lifting require more locking jacks, gears needed. Complex	4-sided guided Scissor Lift with motor is not very complex. Moderate complexity	Simple to construct. No additional gears while traveling in the upward direction.
Wear and tear	More. Based on duty cycle. More parts are subject to wear and tear.	Moderate wear and tear. Stress on bearings is more.	Very less wear and tear.
Maintenance	Regular greasing and checkup is needed in several places	Regular greasing in joints of scissor-jack and regular checkup is needed	No greasing is required since the buoyancy force always pulls the load upwards naturally
Power Usage	Electric power is needed for traveling in either direction. Higher torque is needed always	Electric power is needed for traveling in either direction. Higher torque is needed always	Zero power is required when raising the elevator since the natural buoyancy is lifting the elevator.

Cost	Cost comparatively more than scissor-lift and hoist lift. Gearboxes,screw-pillars,connecting grooves,etc are expensive	Cost moderate due to comparatively less connecting machinery	Cost is very low comparatively. Since no actuator is required while raising the elevator. The main component is a motorized Hoist.
Weight	Overall weight is more.	Overall weight is less than screw-jack, more than hoist-lift	Very less when compared to scissor and screw-jack elevator
Effectiveness	Effective but complex and costly hardware	Effective but moderate complex and moderate costly hardware	Effective and better than other alternatives
Fail - probability	Moderate	Very less	Very less since no man made actuators were used while raising the elevator.

The following table displays the choices of various authors in their anti-drown systems. Components indicated in the architecture of the I List of available granted patents on the anti-drown devices and systems IoT device have discussed below:

Table 2.5. List of journals addressing drowning accidents with various technologies based on technologies complementation.

S N o	Author Name	Image processing Technique s	Wireless SONAR (Acoustic s) usage	Ther mal Imagi ng	IoT	Auto mati c Resc ue	We ara ble	Sign al to alar m
1	A. Roy & K. Srinivasan		Yes				Yes	
2	J. G. Ramani, J. Gayathri					Yes	Yes	
3	M. A. Hayat, G. Yang	Yes			Yes		Yes	
4	H. Liu, M. B. H. Frej	Yes	Yes					Yes
5	S. Sindhuja				Yes	Yes	Yes	Yes
6	Yaswanth Kumar S K	Yes	Yes	Yes				
7	Muhammad Ramdhan				Yes		Yes	Yes
8	A. Kulkarni				Yes		Yes	Yes
9	Y. Nishida						Yes	Yes

10	CAI Xiaoyang	Yes						Yes
11	L. Fei, W. Xueli	Yes						Yes
12	Soren Bonderup	Yes		Yes				Yes
13	Ahmad Ilham	Yes			Yes	Yes		
14	Wenmiao Lu	Yes						Yes
15	How-Lung Eng	Yes						Yes

This chapter has given an exhaustive literature survey on existing systems and their pros and cons and proposes a novel method and implementation in the following chapters.

CHAPTER 3

MULTI-LAYERED SAFETY SYSTEM – EDGE COMPUTING

3.1 Background: Anti-Drown Swimming Pool Management:

The proposed system after implementing achieved assumptions may play a crucial role, to minimize the impact of drowning. Drown prevention, prediction avoidance or its modelling is very tough for existing pools. However, some of the inventions and literature have suggested few models address the child drowning problem.

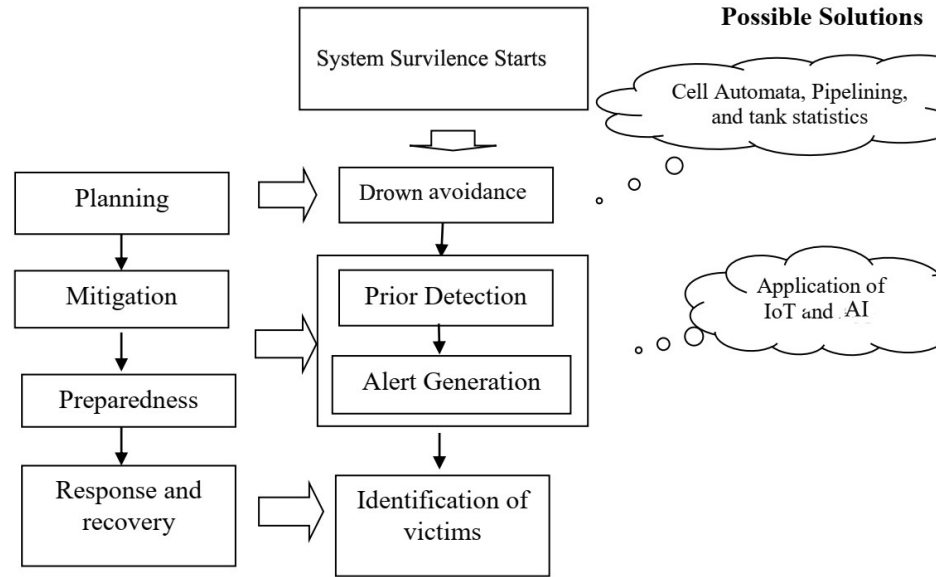


Figure 3.1. : Swimming Pool Safety Management:

3.2 Proposed anti-drown safety system:

In chapter 2, which described the literature survey, various authors proposed various methods addressing the drowning problem, such as wearable devices, water floating gadgets, image processing algorithms using underwater cameras and the patent database added a few pool covers and pool fences to control, avoid and prevent the swimming pool tragedies which are taking lives of kids and adults. The existing systems were partially covering the problem but not completely giving confidence to the users. Each article poses a different

disadvantage and reveals the need of proposing a novel multi-level safety device to give surety and safety to indoor pools

There are five kinds of techniques, which directly affect the swimming pool management process including:

- Techniques for Drown Avoidance,
- Techniques for Drown Detection,
- Techniques to deploy detection devices,
- Techniques to use sensed data,
- Techniques Take decisions manually,
- Techniques Take decisions automatically

Drown prevention and detection methods are briefly mentioned below:

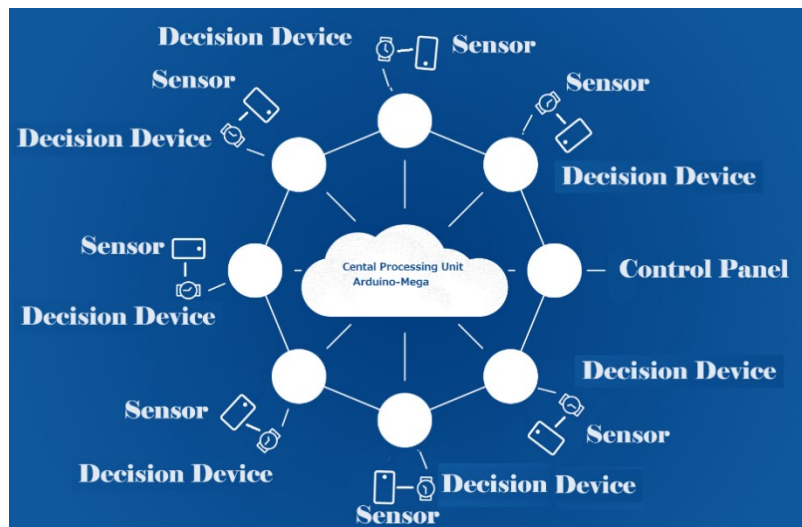


Figure 3.2. Sensors and computing device deployment strategy- Edge Architecture.

Edge computing is a distributed information and communication technology (IT) infrastructure in which client data is handled at the network's perimeter as near to the source as appropriate. Based on this technology, every sensor is attached to a decision device such as a Arduino -nano, to take appropriate decision reducing burden on the central processing unit(RASBERRY PI in present case).

The suggested Anti-Drown platform's functioning may be divided into four main categories, as follows:

1. Self-identified,
2. Noticed-by others,
3. Prediction by the system,
4. 4.Noticed by those who aren't in the pool.
5. Idle closedown.

Category 1: Self-identified

The swimmer may be an expert in swimming or semi-skilled might experience the helpless situation before he loses consciousness. Based on this fact, the researcher proposed numerous panic switches (push to break or any appropriate switches) to alert the central-processing unit (CPU) about the current helpless condition no matter where the swimmer is located. To do this, the scholar installed many panic buttons along the sides and bottom walls of the intended swimming pool, something that no current system indicated. This technique is going to avoid numerous drowning accidents around swimming pools. In this technique, they avoid the intervention of a second person. The swimmer will try to reach the nearest panic switch and invoke the intelligent system to initiate a rescue operation. The swimmer usually knows of the drowning death but does not speak about it or ask for help from fellow swimmers. In most cases, water blocks his mouth and the others are busy enjoying their swimming session.

Category 2: “noticed-by others”

The category “noticed-by others” is explained as the co-swimmer may also detect single or multiple persons drowning may be due to exhaustion or health condition. In this case, the co-swimmer in the same pool may be unable to save numerous victims at the same time, resulting in significant injury to the victims. In this circumstance, the co-swimmer can initiate the autonomous rescue operation by activating panic switches located throughout the pool on the sidewalls and bottom walls.

Category 3: The prediction by system

The two separate sensor configurations inside the swimming pool are included in the prediction by system category. The first sensor configuration involves deploying a matrix of proximity sensors over a robust, lightweight mesh mechanical activator whose depth is adjusted. The mesh subsystem is working as an elevator. Multiple proximity sensors cover the entire area of the swimming pool mounted on the mesh surface. These mesh sensors

continuously observe the occupancy of the mesh with the help of proximity sensors. If the user is intending to use the pool to access its full depth, the elevator mesh should remain at the bottom of the pool. Any swimming pool will have a depth varying from 1.5 meters to 5 meters based on the choice of the owner. The LASER-Trip-Wire sensor setup is another option (LTW). The horizontal 2D section of the pool 2 or 3 feet above the pool bottom will be monitored by this LTW. The proximity sensor system is designed to identify any new thing reaching and remaining for an extended amount of time extremely near to the planned pool's bottom, whereas the LTW would monitor and identify any thing hovering close to the bottom but not contacting it. This will be covering the pool's bottom, surface as well as 2 feet above the water's surface. The sensors and the LTW wall each have a specialised processor that counts the amount of time an incident object has been there and can initiate a relief effort by interacting with the CPU. All these sensors are integrated with a mini-decision device (Arduino nano) to take decisions without burdening central processing unit.

Accurate and timely drown detection is possible using three steps:

1. Choosing a Suitable Sensing Device(sensor);
2. Suitable Device deployment strategy(electrical and mechanical actuator selection)
3. Way of utilizing sensed data

Sensors and actuators are needed to connect IoT devices to their CPUs so they can sense their surroundings. As a result, finding the best-performing sensors and devices is a necessity when developing a solution using sensors. With the use of sensors and software, the Internet of Things can be used to detect events more easily. As the Internet of Things has progressed, tiny sensors have become more and more important. Since we are dependent on sensors more and more, we must select high-quality components, sensors when designing a detection device, yet choosing a good component may have consequences to make it more expensive to deploy. Devices coupled to the internet can send data to the server, which is vital to IoT mechanisms. In the future, IoT based on non-seamless connectivity might resolve this issue by using various sensors, boards, and communication protocols.

Category 4: Noticed by people outside the pool

This is another way to detect and prevent loss of life due to drowning. Anyone monitoring the swimming pool, who may or may not be a skilled swimmer, can activate the system's alerting and auto-rescue features by pressing panic buttons located outside the current

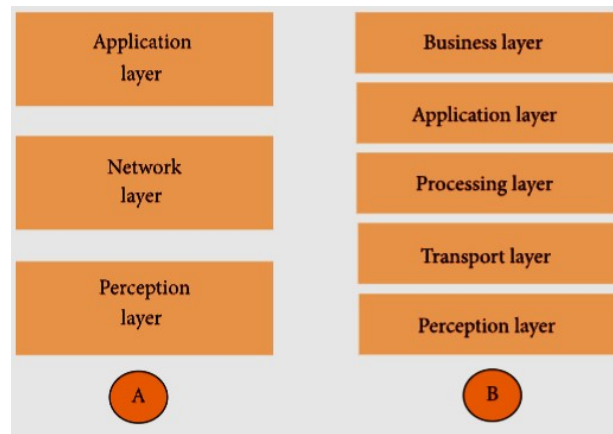
proposal. The watching person may be a vulnerable kid or a pregnant woman, or a sick old man who is incapable of saving the drowning victim by jumping into pool due to their inability can also have a definite option to save the drowning victim without getting any self-injury or labour. The researcher has set up many panic switches around the swimming pool that are wired to the CPU and trigger the rescue-alert procedure. This particular method has not been suggested in any of the existing literature such as in research papers, products or patents.

Category 5: When Idle-shutdown.

After all of these unique ways, this segment discusses an elevator feature that raises the elevator instantly when proximity senses no waves in the swimming pool water for a certain period of time. Generally, when someone is using swimming pool, there will be violent waves gets generated in the swimming pool naturally. The deployed simple proximity sensor will sense the still water state and initiate a raise of the elevator to close the opening of the swimming pool. By restricting the entry into a still swimming pool, this design will prevent any unexpected falls of kids and dogs in an unprotected swimming pool.

IOT DEVICES AND SENSORS FOR DROWN DETECTION

Despite widespread IoT adoption, there isn't a single, universally recognized IoT architecture. Depending on the specific business task, it can have a range of architectural layers. Thanks to its precision, aptness, compactness, and interpretation capabilities based on data analysis, the Internet of Things and compatible sensors are facilitating lifestyles in every sphere.



IoT World Forum Reference Model

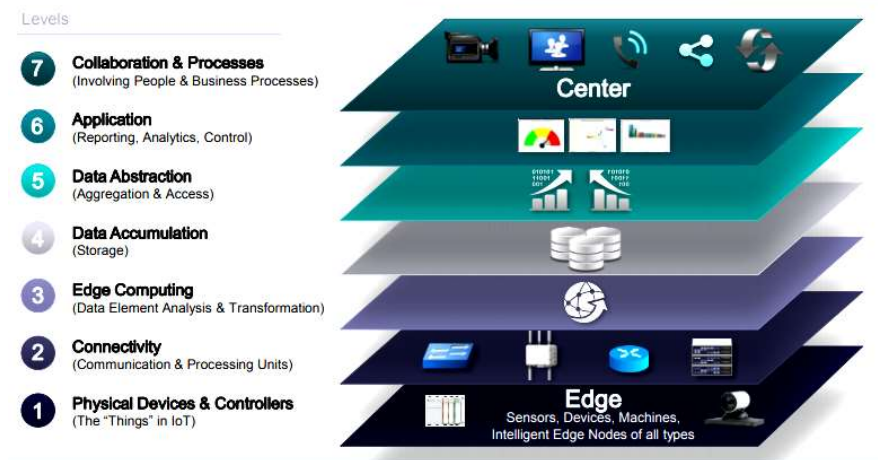


Figure 4.1. The layers of IoT device Architecture [24]

A variety of applications are being developed nowadays that incorporate IoT, including those for industries like production, Agro, healthcare, medical, transportation, administration, logistics, and safety, as Vongsingthong, S., and Smachat, S (2015)[21]. A report published by ITU-T [113] in 2005 defined IoT as "A network of items embedded with sensors connected to the Internet" [114], whilst an IEEE report published in March 2014 defined IoT as "A network of items embedded with sensors connected to the internet". According to these definitions, IoT networks can join at any time and in any place [22][23].

In the literature, three distinct architectures of IoT have been outlined, including those 1, 5, and 7 as per the article by P.Sethi [24].

4.2.1 Interfacing Processors, actuators and sensors

In an IoT model, devices and sensors are coupled with networks and analytics tools. Since sensing devices are attached to objects for supplying data, they are sometimes referred to as Things. It is through sensors that “Things” in the Internet of Things collect data, which is then transformed into wealthy information [25].

Figure 4.2 presents an overview of the architecture of an IoT device described by Elijah et al(2018).

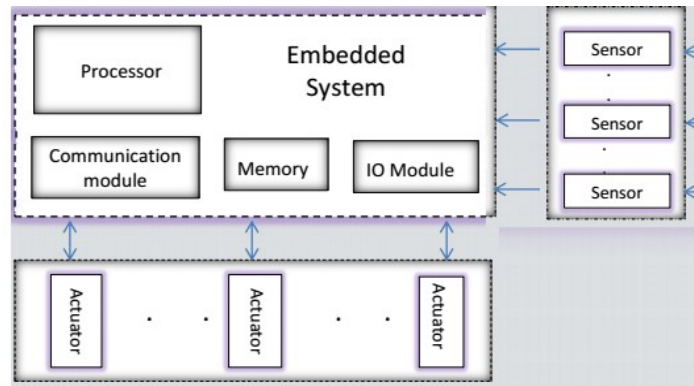


Figure 4.2. The IoT device Architecture

Sensor: It is a device used to sense physical parameters and produce useful data. However, it cannot form a solution on its own. The sensing node that is part of an IoT-based solution should be capable of communicating with computing devices and the internet, analyzing, organizing data, and decision making. Various protocols are available for establishing these

connections. Sensors are the inputs to the interactive devices developed for sensing parameters. Data is collected by using a variety of sensors, including but not limited to proximity, ultrasound, raindrops, water flow, light, temperature, humidity, flow, and pressure. While all of the sensors work differently, they are all capable of gathering and transmitting data to the central processing computer. [26] Researchers demonstrated laser communication using laser sources at different wavelengths from 407nm to 810nm in an analytical study. Different turbidities of water are transported by these lasers, including clear, low-turbid, and high-turbid samples. Compared to the other laser light sources, the blue laser light could be used as the carrier signal underwater because of its smaller absorption coefficient (3.0 cm^{-1}), greater transmission distance (78m), and least distortion. The researcher concluded that laser beams with different wavelengths experience different transmission distance Distances. The wavelength has a strong influence on transmission distance in the water. When turbidity increases in water, transmission is reduced, resulting in a decrease in received power and intensity peak values. According to another research article, underwater laser communication systems could transmit a variety of file formats including images, videos, text, audios, files, and processes at up to 80-100 kbps[27] He found A useful inverted TTL comparator and avalanche photo diode (APD) can be employed to increase the system's range (path length). There has been progressing in developing the basic architecture of underwater LASER sensor networks as well as the protocol stacks for such networks.

4.2.2 Central Processing and Controller Board:

Different companies were involved in producing the boards in the market. Data is composed, transferred, processed, analyzed, compared using these CPU boards. Computing paradigms known as edge computing refer to data collected at controller boards. Cloud computing is said to be fog computing if it's part of a network. In addition, cloud computing refers to a system that stores acquired data in data centers and analyzes the data on other systems. Controllers serve as gateways and processing units in such a system. Processors and transmission systems are used to process and transfer data to monitoring units for analysis. Controller types include Arduino, Raspberry, Netduino, Arm 7, and NodeMCU, among others. In IoT, such controllers function by utilizing a gateway based on different principles.

Display Unit: This essential part displays the data acquired via the gateway and can be integrated with any other device. Display units can be computer screens, laptop screens, Smartphone screens, or LCD units only.

Power Unit: Using a battery or a connecting device, such as a computer or laptop, the power unit provides the node with the power to do things. Power is the only thing that keeps the device functional, which is why it is considered a crucial part of the device.

Communication Methods LTE, GSM, and 3G, Zigbee where RFID, wifi, Bluetooth, etc to handle data.

4.3 Choice of Sensors and Devices

A sensor node may be connected to at least one transmitter and a processing unit in the IoT. In this system, the sensor is used to sense the ambient conditions, a processor is used to process the data, and a transmitter pumps the information to the Central Processing Computer. Two main factors in determining the system's efficiency are the design and the placement of these devices. Sensor nodes' cost varies with their design components and configuration. As the most frequent accident type that harms humans for a long time, drowning was chosen as the object of the investigation for its investigation and function. These devices have the potential to be of great help to society in the detection, prevention, and nullifying of drowning.

We explore a few basic queries in this chapter, including:

1. What components are the most appropriate for a drowning detection device?
2. Is there a design for drowning prevention and detection based on the Internet of Things?
3. What are the methods through which a Thing can retrieve a defined problem's data from its environment?

4.4 Drown Detection using Sensors interfacing with Processors

Researchers compared the devices developed by other researchers and found suitable components by studying devices developed by other researchers. The Internet of Things is comprised of single-board computers and sensors of various kinds that collect data at the monitoring station. When a device interprets data in itself, it is recognized on the edge. If it

is used to investigate a problem at another station by using the Internet, it is considered cloud computing. Through different communication technologies, including LTE, GSM, and 3G, data is collected from Things by the IoT and received at a data center or monitoring station, as discussed by Abu-Elkheir et al[29]. Devices developed for the IoT are regarded as nodes. In general, the nodes are designed by arranging various components in a particular order.

4.4.1. Component Selection

From the list of the most recent arrival sensors, the researcher could select a controller board and sensors based on suitability to the context. IR proximity sensor and laser array sensor are two of the most suitable sensors in building the existing drowning system after studying all the available robust sensors, which will accomplish the desired objective. There is a possibility to develop devices for both wired and wireless modes of communication with these sensors. Inspired by the experimental design paper by Liwei Shi(2012) [30], Satoshi Tsuji[31] has demonstrated the usage of proximity sensors on human cooperative robots (HCRs) with 24 sensors on various parts of the robot with a range of 300mm distance. Their experiment demonstrated the robustness and reliability of the proximity sensors in assessing real-time situations. Jiale Liang et.al have successfully demonstrated reliable performance of proximity sensors on a Nursing Robot with 16 proximity sensors and 64 piezoresistive pressure sensors to observe the surrounding. Their contributions to the research proved the reliability and robustness of sensors usage in assessing and decision-making in robotics. [32] Liwei Shi and Shuxiang Guo have proven the reliability of using proximity sensors for underwater obstacle avoidance while walking by using IR proximity sensors along with ten ionic polymer-metal composites (IPMC) actuators as a limb for transportation of the microrobot which is designed to travel, swim, and collect things in underwater conditions to monitor pollution detection in limited targeted areas in rivers and oceanic floors. L.Shi article has demonstrated the applicability of the IR proximity sensors for underwater sensing applications[33].

Table 4.1: Summary of the available proximity sensors with their coverage detection distances

Types	inductive	Optical	Magnetic	Capacitive	Ultrasonic	IR
Operating Distance	<50mm	<100mm	<80mm	<50mm	~15m	80 cm

The IR-Proximity sensor E18-D80NK appears to be the best-suited sensor for the proposed system among other sensors of its kind mentioned in the Table above and the comparison given in the article by Sasidharan [34]. In the underwater proximity sensing field, IR-Proximity sensors can be used with distance coverage of between 5mm and 15 meters[35]. For our needs, the sensors are coated with transparent adhesives to make them waterproof, so they can be used underwater as well. These sensors are generally intended for use in open-air conditions. IR sensors are currently widely used in automobiles for collision avoidance sensors (Parking Sensors E18-D80NK IR Proximity Sensor) for which the range is 10 to 15 meters [36].

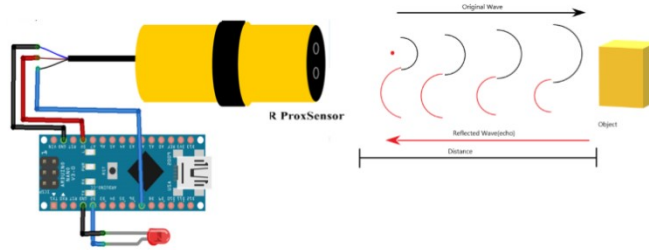


Figure 4.3. E18-D80NK IR- Proximity Sensor with Arduino-nano.

The matrix of sensors on the elevator floor is meant to inform any new object coming close to the bottom of the pool, in the vicinity of the sensor module is placed. Figure 4.4 is a perfect 2-dimensional sensor array inspired by my SD-RAM architecture. As soon as the objects come close to the proximity sensor, the timer in the Arduino-nano which is receiving the sensor data will send a trigger signal to the master RASBERRY PI processor to take the decision. The Arduino-nano is programmed to send a trigger signal only after 30 seconds of continuous contact with the obstacle.

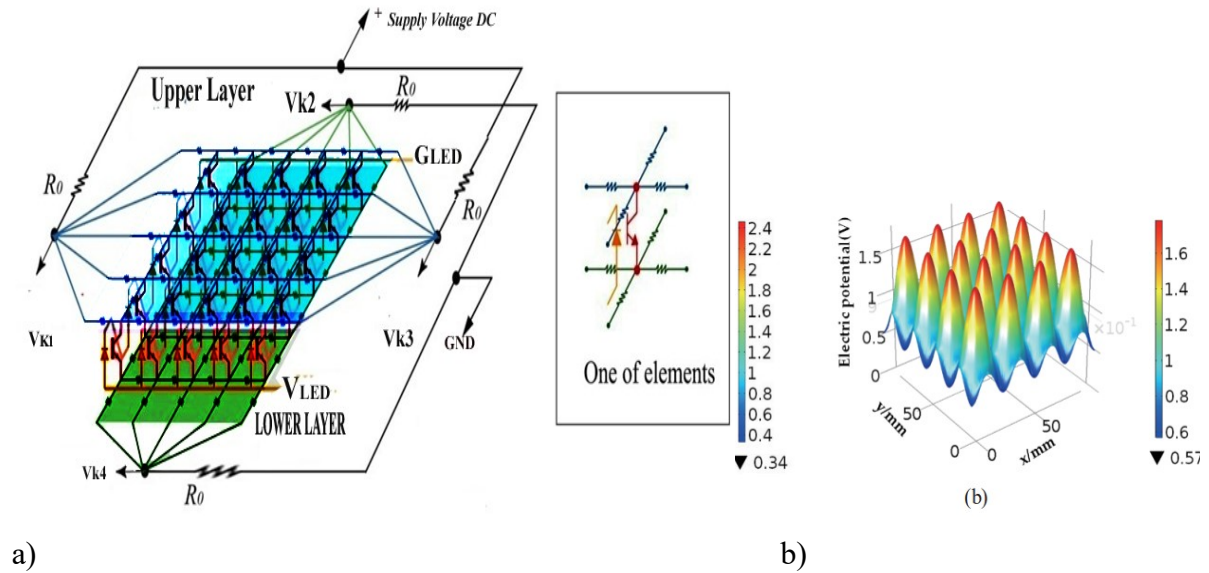


Figure 4.4: a) The arrangement of sensors underwater Corresponding b)Simulation graph of sensors

In the physical prototype experiment, the IR radiation from the proximity sensors can pass through the water between obstacles, and can reflect according to the principle of operation of proximity-sensor, the distance between the sensor and the object placed near the sensor as shown in Figure 4.4C and Figure 4.4D. The sensor's behaviour while scanning underwater for obstructions is shown in Table 4.2 (drowned objects). The experimental results verify the practical usefulness of the design for underwater object detection.

Several proximity sensors (JSN-SR044-2.0 waterproof ultrasonic) were installed as a mesh on the moving lift to monitor and identify the presence of any human body within the predetermined distance. The system will commence a rescue operation by activating the different subsystems of the proposed system depicted in Figure 4.6 when a proximity sensor identifies a foreign item or a human body within a predetermined (5cm) range, steadily unmoving during a delay of 40 seconds. The specimens were prepared for testing a proximity sensor underwater is shown in Figure 4.6. The distance between the obstruction and the proximity sensor was successfully detected by the proximity sensor. The sensor is a waterproof proximity sensor that produced consistent findings when used in wet environments. After performing trials, as indicated in Figure 4.6, proper calibration is carried out.

4.4.2 The proximity sensors arrangement on the elevator

The IR-proximity sensors were arranged like a matrix all over the surface of the movable elevator surface same as two car-parking sensors arranged backside of the car for collision advance. The matrix of sensors was continually scanned by the Arduino-Nano and the status of the sensors is communicated through a digital wire signal from Arduino-nano to RASBERRY PI(CPU) to initiate an urgent rescue routine to save a person from drowning. The arrangement of sensors is clearly illustrated by the Figure 4.5 below. The platform is made with wood having several apertures to support the water to flow in either direction of the table while moving upside and downside represented with circles and squares.

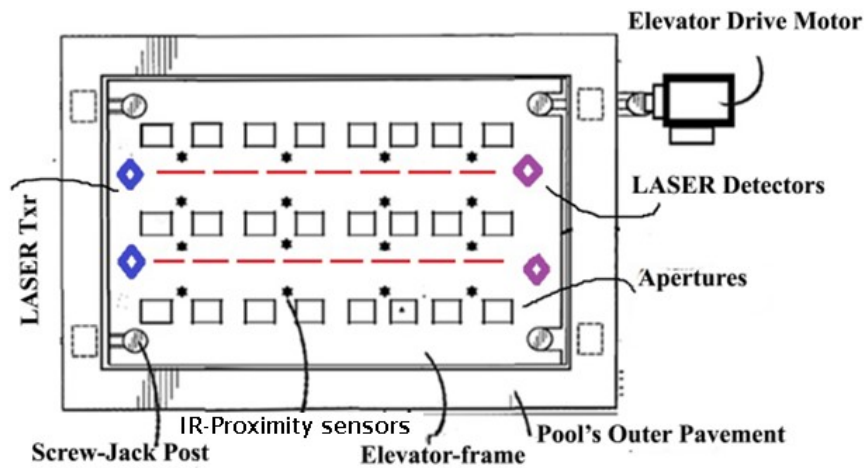


Figure.4.5. Showing 3d side view with apertures on the movable elevator floor and its top view showing sensors LASER sensor-detector (diamond), pairs, and proximity sensors (dot).

Based on the table given, the last sensor which is having the longest controllable proximity detection sensor chosen for the working prototype (real-time swimming pool). Table 4.2. When employing the Proximity sensor, the number of trials completed and the related success percentage.

Table 4.2. Proximity sensor trails.

S No	Underwater distance cm	Number of trails	No of success trails	No of errors detected	Rate of success of 100 trails
1	30	50	50	0	100%

2	40	50	50	0	100%
3	50	50	49	1	98%
4	60	50	50	0	100%
5	70	50	48	0	96%
6	80	50	50	0	100%
7	90	50	50	0	100%
The average success rate of detection					98.15%

When the distance between the sensor and the Obstacle (drowned object) is more than or equal to 30 cm, the success rate of identifying is higher, reaching an average of 99.625 percent, which meets the criterion of accurate obstacle identification as indicated in Table 4.2. The circuit schematic and Timing diagram is as follows in Figure 4.6. Figure 4.6 depicts the behaviour of the selected proximity sensors underwater, which demonstrates a tiny difference between real and measured values owing to the speed fluctuation of light in water as the medium of transit.

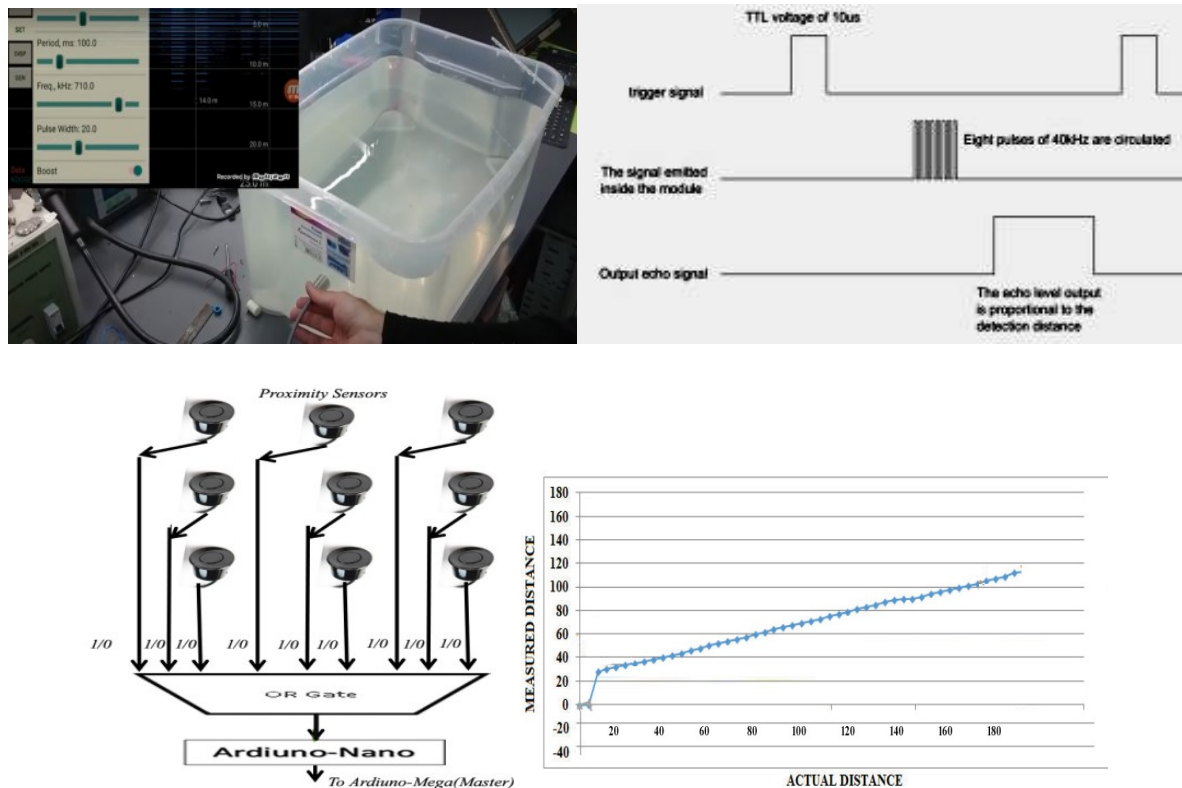


Figure 4.6. Plot of underwater distance fluctuation using proximity sensor in obstacle detection (Measured Vs Actual distance)

<pre> If { LDR is receiving LASER No risk repeat LDR is NOT-receiving LASER Count+1 If Count<50 seconds Function call Function { (digitalwrite pin==high) } </pre>	
--	--

4.4.3 LASER-LDR pair

Jailos Mrisho Nzumile Jailos Mrisho NzumileIsmail et.al has successfully tested the LASER-LDR pair for the obstacle detection and alerting phenomenon in an application useful in saving waiting time and paper usage. In another research finding, it is proven by Marhoon, Hamzah & Khalaf, the efficiency of LASER-LDR pair for obstacle detection related tasks accurately when combined with an embedded processor such as Arduino-Uno and Arduino-Nano in designing smart security and safety system [37].LASER technology is such a marvelous optical technology with which light signal can be sent to any amount of line of sight distance with absolutely good coherence and used in various barcode scanners also for decoding encrypted information. The LDR is an excellent light detecting sensor having a linear relationship with the intensity of light and internal resistance as shown below in Figure 4.7. It is observed in the Figure 4.7 below, a remarkable transition from dark to daylight and daylight to sunlight. Based on this graph, the consumer/designer has a broad range of freedom to choose sensitivity by properly associating LDR with embedded processors like Arduino based or higher capacity programmable on-chip CPU boards. LDRs were produced by several manufacturers and one among them is Silonex is one manufacturing various optoelectronic devices and LDRs with various specifications ranging from peak internal resistance 1M-Ohms to 20M-Ohms from lowest value 5K-Ohms[38]. A design research paper by Teja, P. S. R., Kushal, discloses an intelligent anti-theft alerting system using LDR as the major reliable source of sensing the events in real-world scenarios

accurately and reliably. The robustness, accuracy, reliability, and sensitivity made the LDR sensor a major photosensitive sensor device [39].

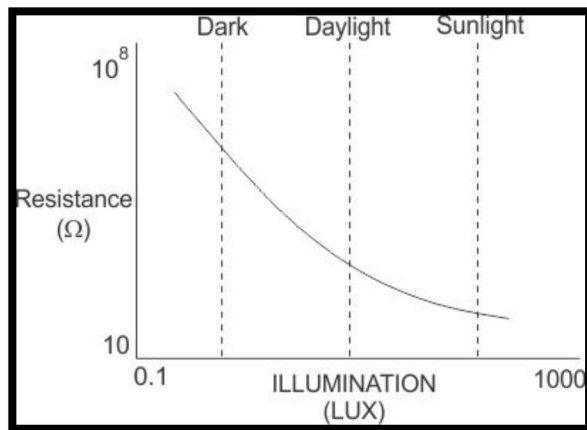


Figure 4.7. LDR response graph

Along with the proximity sensor, a LASER and LDR couple is also chosen to find the bodies floating close to the bottom and not lying on the bottom. These couples are working like laser-trip wires which work effectively sensing objects between the LASER and LDR. The light speed is similar in both air and water, the LDR responded equally in both air and underwater because the light intensity specially LASERS is well in both water and free space. The operational difference between the two media is indistinguishable because of the light speed similarities. Both these proximity and LDR sensors were having independent single-board mini-CPU which is Arduino-Nano to measure a short delay of 40 seconds with a program fed to the Arduino-Nano. This program can be modified to adjust the delay based on the requirement based on its response to light intensity as shown in Figure 4.7 and Figure 4.8. The 40-second delay is to tolerate the existence of a person in a danger zone and beyond this 40 sec time, the timer will overflow and the Arduino-Nano will send an emergency rescue command to the CPU. As soon as the Arduino-Nano sends the signal, The CPU will execute the emergency rescue routine to rescue the submerged body by energizing the alerting systems and actuators.

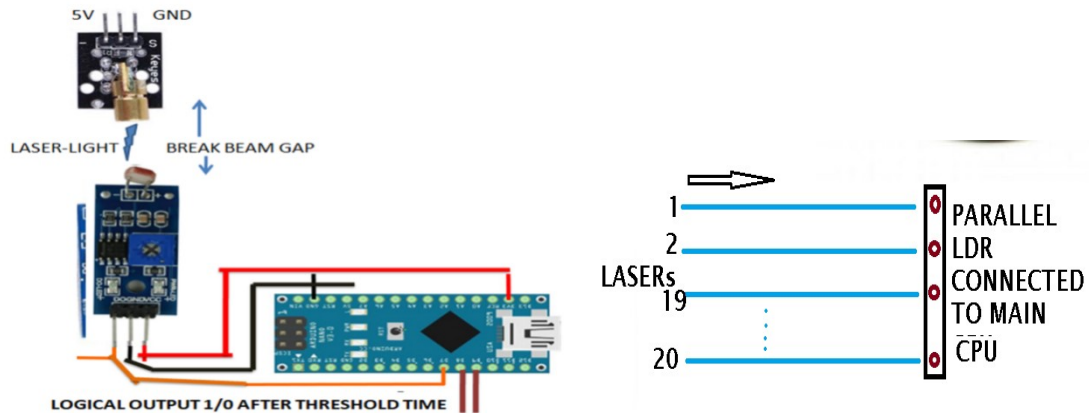


Figure 4.8. Configuration of Laser Diode Module (KY-008) coupled to LDR module.

Table 4.3. Comparison of the speed of light in various materials.

Material	Speed of travel	refractive index
vacuum	300,000 Km/S	1.0
Water H ₂ O	225,000 Km/S	the refractive index of 1.3
glass	200,000 Km/S	1.5
diamond	125,000 Km/S	2.4

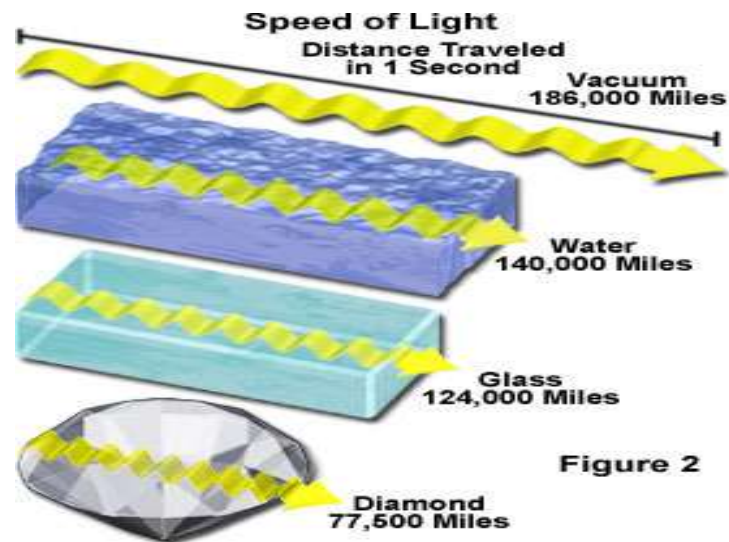
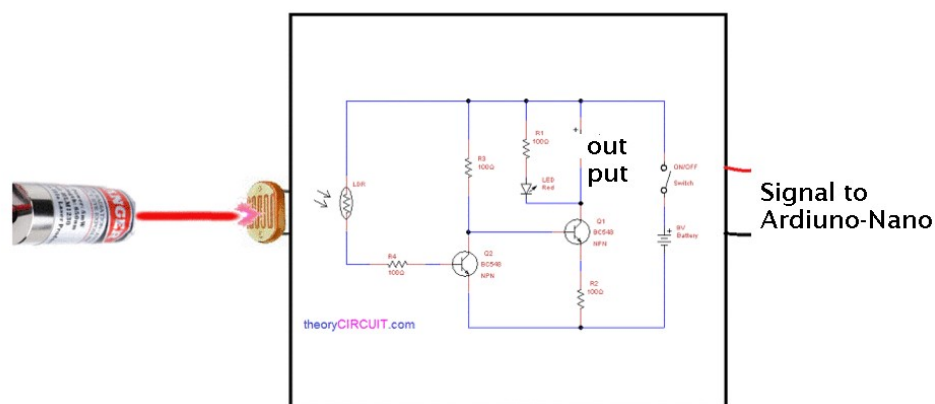


Figure 4.9. Illustration of light speed in various media/materials. [40]

A breadboard circuit featuring a 555 timer IC. The timer is connected to a series of red LEDs. The circuit is powered by a 5V supply, and the LEDs are connected in a chain. The breadboard is populated with various electronic components, including resistors and jumper wires. The LEDs are connected in a series configuration, and the circuit is powered by a 5V supply. The breadboard is populated with various electronic components, including resistors and jumper wires. The LEDs are connected in a series configuration, and the circuit is powered by a 5V supply.

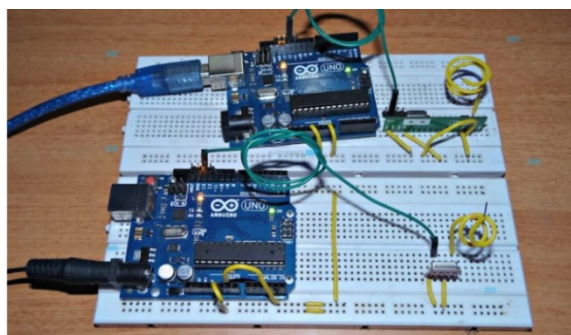


An article concluded that for distances ranging among 2.3 m, 6.9 m, 11.5 m, 16.1 m, 20.7 m, and 34.5 m, with a green LASER, transmitted real-time data rates are up to 4.60 Gbps, 4.20

Gbps, 3.93 Gbps, 3.88 Gbps, 3.48 Gbps, and 2.70 Gbps, respectively . This explains the efficiency of LASERs for data transmission for longer distances as shown in Figure 4.10. Anyhow, we are not transmitting high bandwidth data with LASERs, but using them to verify any anomaly happening underwater [43].

4.4.4 Wearable Wireless device

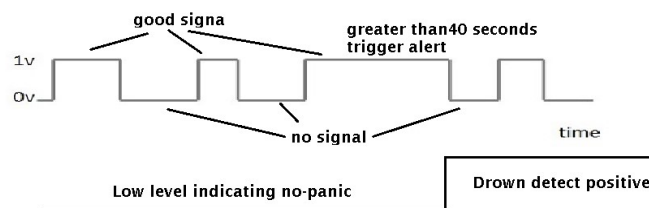
When the swimmer is floating on the pool's surface, data packet are continuously transmitted through the head-mount transponder to the Main Arduino device receiver, and if the signal is lost for more than 40 seconds, the Main RASBERRY PI recognises that the swimmer is in danger and activates a fully automated rescue procedure as shown in Figure 2 and Figure 10 main technique case-4. The fundamental approach includes a swimmer submerging into the water with a worn transmitter, causing microwaves to abruptly attenuate from passing through air to water. Microwaves are considerably attenuated by water. As illustrated in Figure 10, the 1xFS1000A 433MHz Transmitter and Receiver pair is an RF communication module with a speed of 1kbps to 10kbps serial communication and a range of 100 metres. Between the swimmer and the control unit, this module establishes a wireless link.



a)



b)



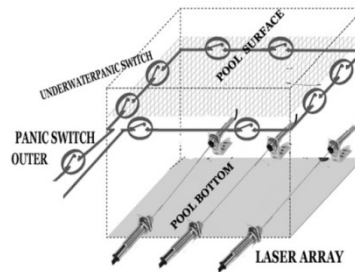
c)

Figure 4.11. A) RF transceiver testing at the main control panel and B) wearable reception module on-head C) Response signal at receiver section

Using the RF-communication modules, a seamless wireless communication channel is created as part of the proposed system. The receiver at the control unit (RASBERRY PI) continuously listens(receives) data packets from the wearable transmitter section and generates an interrupt as soon as the signal from the transmitter.

4.4.5. Panic Switches Mounting:

The manual rescue function of the swimming pool is given by the placement of many panic switches along the pool's sidewalls, bottom, and outside the pool. These switches are creating a loop connecting the CPU with a power supply of +5v. As soon as the power supply is removed by triggering panic switches will immediately inform the CPU to initiate the auto-rescue operation. The figure shows all the panic switches connected in series for simplicity of design. The designer can assign priorities and separate wires to individual panic switches based on the size and requirements. This figure also shows LASER-LDR couples arranged close to the bottom of the pool.



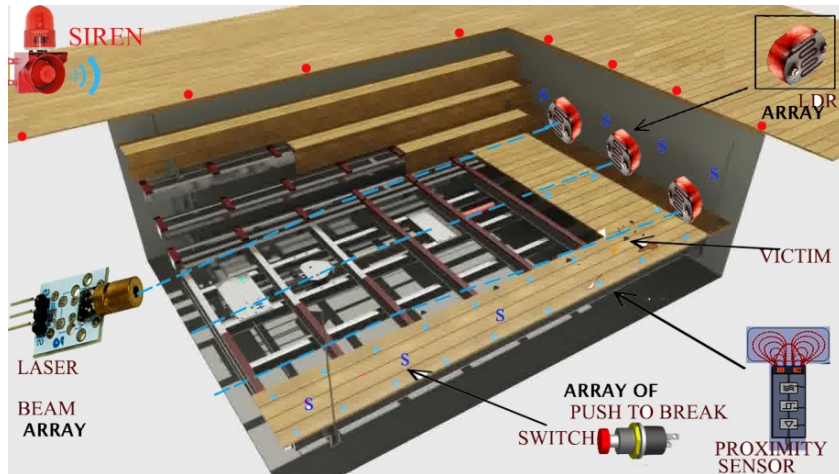


Figure 4.12. The LASER trip wire 3D drawing and 3D swimming pool cross-sectional view.

4.5 CPU Board and Software Selection

Essentially, it is a computer board with a microcontroller and a set of digital and analog links to serve as a gateway system for handing out and conveying data. It is a single-board computer that is based on a microcontroller that can be used to design digital devices. These programmable boards are all embedded systems based on microcontroller s, which offer low-cost performance compared to microprocessor-based systems. An Arduino Uno is an 8-bit microcontroller-based board with AVR technology. The board is low-cost and fast and easy programmable onboard computers. It utilizes the Arduino software IDE, which is a platform for producing and compiling programs. To operate this board, the computer must load an application program that instructs it how to process data based on the code dumped into the internal memory of the board. This device is used in our case to process information gathered from IR sensors and LDR sensors to inform our monitoring system.

4.6 Software Selection:

The proposed system can be programmed using any existing programmable embedded board with matching software tools. We picked Arduino and the accompanying software package named "IDE" from the official website of the Arduino and Rasberry Pi for efficiency and simplicity. IDE stands for Integrated Development Environment. It is an environment for writing code and compiling code to run on a micro-controller. The IDE facilitates the writing of program code for conducting research and for constructing micro-controller applications;

it helps compile the code on the micro-controller and provides help in writing code. IDE programs are designed as sketch files, and they are written in C or C++ following a few rules. The application is available on the web for free since it is open-source software. As per reviews and personal experiences, it has an easy-to-use interface and is friendly to its users. These systems enable digital and analogue I/Os to interface with the circuit. The board may be used to instructions from a computer in order to carry out certain tasks. The Arduino-uno is linked to the IR and LDR sensors, which send data to the computer. This Arduino IDE is written in Java and designed for new programmers to assist them in their development.

4.7 Block Diagram Description

- I. The "object detection sensors" block represents all the interconnected proximity sensors, LDR-LASER opto couplers mounted on elevator determined to sense the existence of any newly arriving objects inside the swimming pool; it will continuously send the status of the elevator surface to the embedded board.
- II. "Reset switch on control panel" and "Panic Switch around pool" block is determined to send the emergency signal such as PANIC signal to initiate rescue operation manually if the victim or person witnessed drowns accident.
- III. "Panic Switch on pool walls" block is a trigger switch directly connected to Embedded Board, which is a normally closed "push to break" switch mounted on the inner walls of the said swimming pool, which is a facility for a swimmer when the swimmer feel insecurity, panic, helpless. By pressing this switch, the swimmer himself can push and initiate a rescue operation. This switch when pushed was determined to initiate all the rescue and alert functions of the swimming pool. ALL the electric devices, SENSORS, SWITCHES are exclusively waterproof since the field of the system is dealing with waterside hazard handling.

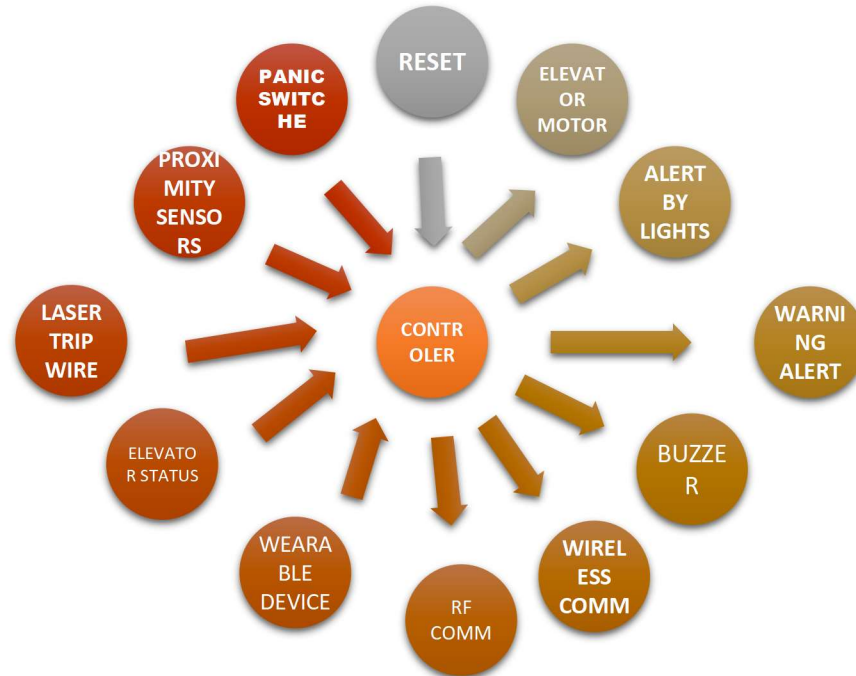


Figure 4.13: Block diagram representing various technologies involving the proposed system

- IV. "Elevator status proximity sensor" input block determined to control when to stop elevator drive motor. The proximity sensors sense whether the elevator reaches a fully lowered position or a fully raised position.
- V. "Elevator Motor" is the motor that will activate the elevator to move from one predetermined location to another by taking commands from Embedded Board.
- VI. "Drain Motor" is the motor with inbuilt dry-running protection which will activate the draining of water from the swimming pool by taking commands from the Embedded Board when there is a PANIC situation.
- VII. "Red Lights" are a series of several red color lights mounted on the upper edge walls of the swimming pool and will be glowing when there is a panic signal generated inside the System.
- VIII. "Orange Lights" block represents a series of orange lights mounted along with "red-color" lights determined to glow when there is a near-drowning situation.
- IX. "Buzzer" is a loudspeaker block, used as an alerting mechanism by ringing when there is the PANIC signal generated inside the Embedded Board.

- X. "Wireless Communication Device" block is a SIM-based GSM module, determined to make phone calls to pre-stored phone numbers with a pre-stored voice to alert and call help in the event of a drowning.

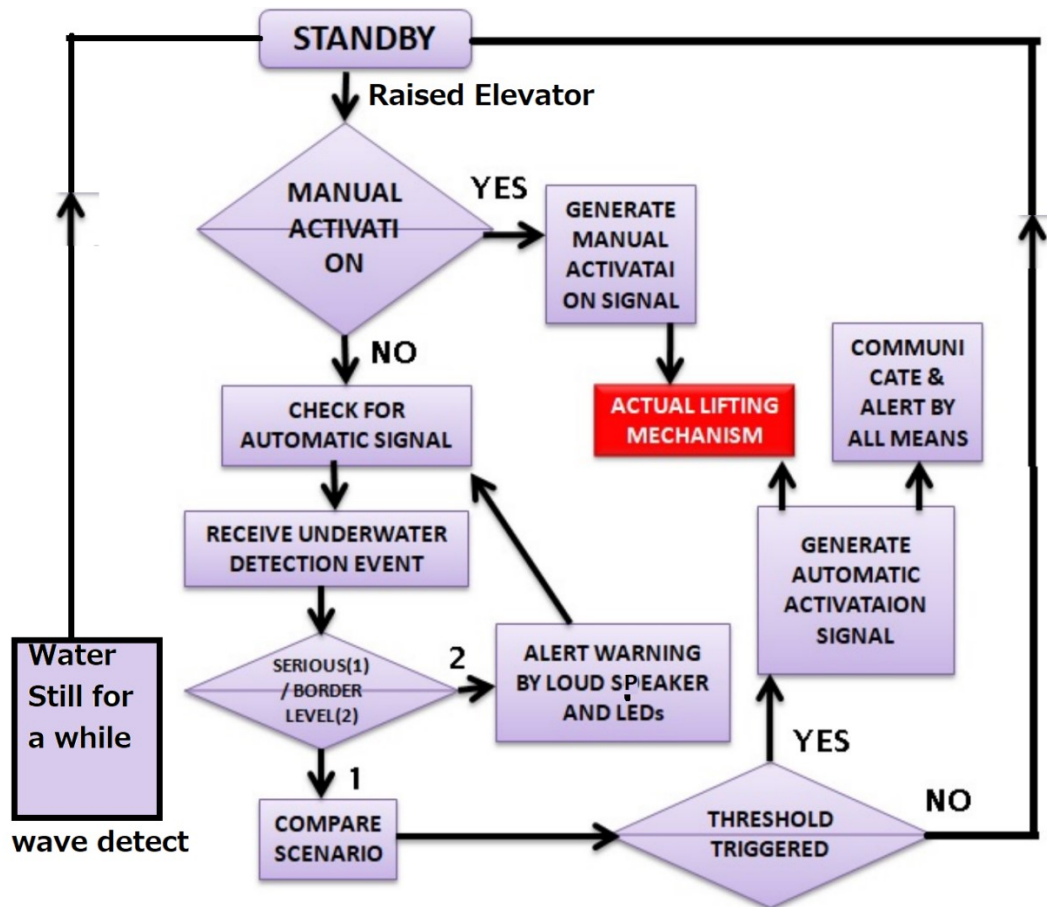


Figure 4.14: Flow chart of the proposed Intelligent swimming pool system

The Raspberry Pi 4 Model B is the newest member of the popular Raspberry Pi CPU family. In terms of CPU efficiency, graphics performance, RAM, and connectivity, it outperforms the previous-generation Raspberry Pi 3 Version B+ while maintaining backwards compatibility and power economy. The Raspberry Pi 4 Model B provides end users with desktop performance equivalent to entry-level x86 PC frameworks. Among the key distinguishing features are a higher CAPACITY 64-bit quad-core chipset, twin display support at resolutions up to 4K via a couple of micro-HDMI terminals, chipset video decode

at up to 4Kp60, up to 8GB of RAM, double band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capabilities (via a separate PoE HAT add-on).

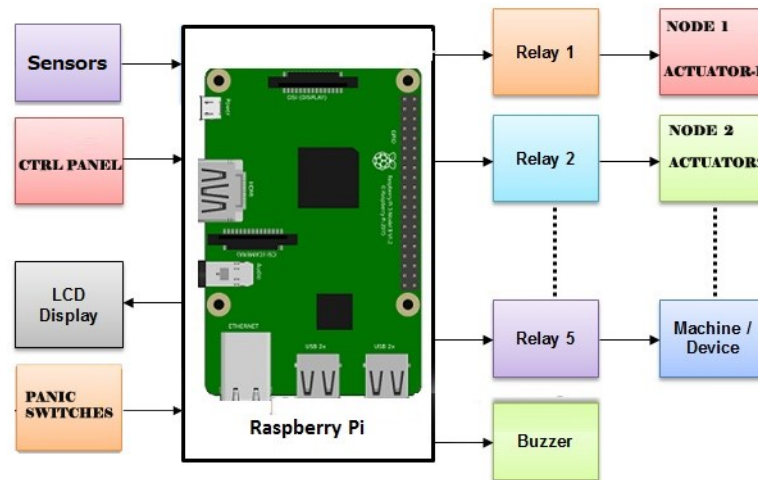


Figure 4.15. RASBERRY PI

The algorithm for the proposed system is as follows

Start: **Intelligent Assistive Robotic Pool**

POST operation //power-on-self test

{

Power-On Lift returns to the top to bottom

Switch On for 10 seconds and off alerting ed lights

Buzzer ON for 10 seconds and OFF

}

If (Alert Rxd from Proximity sensors=1)

Elsif(Alert Rxd from laser tripwire couples=1)

Elsif(signal from wearable RF wireless Txr =0 for 40 seconds)

Elsif(Panic Switch Signal Rxd)

Do

{

Turn on Lift to raise

Turn ON alert Lights

Turn ON Siren

Turn ON Motor

Waite for RESET

}

RESET function :

RUN lift motor to raise the depth of the pool

```

    Stop Buzzer and Lights
}

```

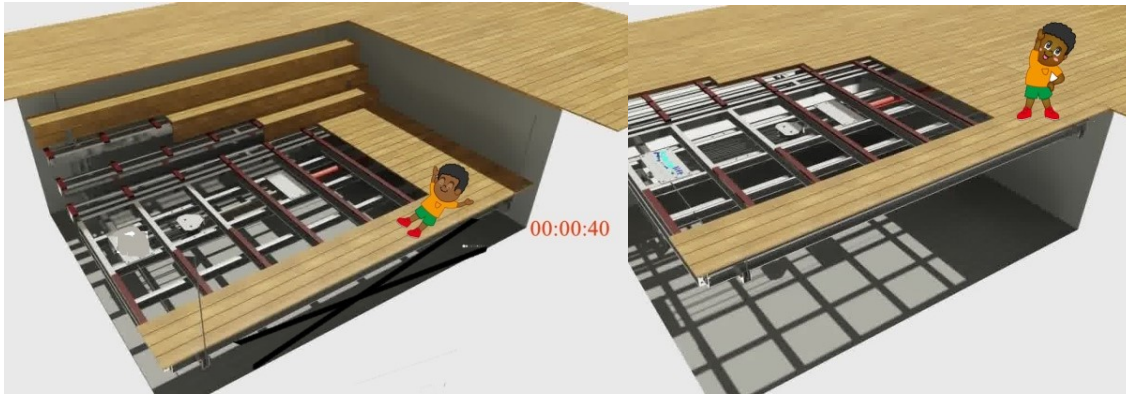


Figure 4.16. 3D imaginary graphic illustration of Lowered and Raised Elevator with the help of a Lift

4.8 Brief Description of the Research Project through Drawings

The swimming pool comprising meaningfully uniquely interconnection of an electronic computer(RASBERRY PI On-chip-CPU) to make logical decisions, an elevator assembly structured/determined to regulate accessible dept of the said swimming pool between two positions called as **lowered** and **raised** position when activated, the said elevator is housing a matrix of proximity sensors and push-to-break switches accessible to the individuals whoever are swimming, a manual trigger switch called as "the **panic**" switch on walls of the pool and control panel(outside the pool), a wireless software-enabled communication device, a drain motor, electric red-lights and alerting-lights on upper edges of walls of the swimming pool, and a buzzer. The computer system is going to turn-ON Orange lights when any sensor(s) detect the existence of any object or individuals for a shorter duration like 25 seconds and if the duration crosses a longer duration like 50 seconds or as specified in the computer program, a **Panic** signal is generated which will eventually alert the need of serious rescue operation by the proposed system. When the PANIC signal is generated, the said swimming pool elevator position is automatically changed from **lowered** position to the **raised** position, turns on the buzzer, alerts red lights around mounted, and makes phone calls to pre-stored phone numbers(which is called rescue operation) simultaneously.

The operation of the proposed system on a point by point basis as follows

- 1) an RASBERRY PI (CPU) is programmed as per the algorithm proposed, to take logical decisions based on the status of associated parts(such as sensors, push to break switches and control panel switches, GPS, etc.) of the swimming pool,
- 2) an elevator assembly determined to regulate accessible dept of the said swimming pool between two positions called as lowered and raised position based on commands received by the computer, several proximity sensors and PANIC-switches arranged across elevator surface and in communication with the RASBERRY PI (CPU),
- 3) Several pushes to break switches arranged/mounted on inner walls of swimming pool and said elevator surface in communication with the computer, PANIC-BUTTON accessible to victim On swimming pool sidewalls but not limited to sidewalls, mounted on elevator also, as a PULL-Buttons with same *pull-to-break* switches, since everyone pushes the ground when they do diving, and a drowned victim reaches bottom easily and the system is giving him a chance to catch a PANIC button to save himself. Unfortunately, no one identifies a submerged person (near-drowning victim) until his body floats on water after death.
- 4) **There are** Several manual trigger switches called "**the panic**" switch on the control panel of said computer and outside the pool,
- 5) a sound-producing, alerting electric buzzer and,
- 6) There are a series of electric red lights and orange lights mounted on swimming pool walls, and lastly.
- 7) a wireless cellular communication device(GSM module) that can make calls by taking commands from the said RASBERRY PI (CPU).

The said elevator assembly is kept in lowered position inside the swimming pool close to the bottom surface of the pool when in normal **“in-usage mode”**, and kept/raised above the pool water level when in "Turn-Off mode". A warning signal is generated in the computer if something sensed by sensors mounted on the elevator surface for a short

duration like 25 seconds (or a signed time) leads to turning-ON all **orange lights** which is indicating a less dangerous situation.

And a more dangerous **panic** event is defined in three different situations such as:

- 1) any one or several sensors which are mounted on swimming pool senses/detects existence/incidence of any object immovable for greater than a particular amount of time(eg. About 40 seconds) **AND**
- 2) a transition among the push to break switches which are mounted on the said elevator surface and inner swimming pool walls, **AND**
- 3) a manual command generated inside the said controlling computer through pressing the "panic" switch arranged outside swimming pool,
 - i) Upon generation of panic signal, the said computer determined to Force the swimming pool elevator position automatically shifted from lowered position to raised position (also called as rescue operation),
 - ii) Switch on said red-lights
 - iii) Buzzer and
 - iv) Make calls to pre-stored phone numbers simultaneously as per the program of the controlling computer. By doing so, any individual or object is prevented from falling and/or drawing into the swimming pool.
 - v) The proposed framework also comprises an automated **power-on self-test** routine to check its health whenever powered to operate including but is not limited to, checking elevator operation by operating the elevator between lowered and raised positions, connection to the loudspeaker, sensors, the status of panic buttons, etc, and indicate by glowing (switching ON) alerting lights so that the user can build up confidence on the proposed system and perform repairs whenever there is damage happened to the proposed system.

4.9 Devices required/used to build the proposed system

- Programmable Embedded Boards (Ex. Arduino-Mega,RASBERRY PI, Arduino Uno, Arduino Nano,)

- Elevator assembly (screw-jack model or scissor lift model)
- One motor for the elevator
- One conventional motor for the drain system.
- Loudspeaker
- Red and Orange Lights (any two different colored lights)
- Object detection sensors proximity sensors.
- Motor drivers for lift motor
- Push to toggle switches (or push to connect switches based on +/- connections preferences)
- Wireless communication device
- Reset buttons

4.10 Depth Control Actuators- Elevator Technologies- Selection &Construction

Humanity has invented several mechanical monsters with which one can lift heavy things including passengers to greater heights safely and securely through several means broadly called elevator or a lift which may be operated through various means such as cylinder assisted, or a hydraulic-powered or a roller track or a belt drive or a chain drive or a rope-wire assisted hoist or a screw-jack, etc. These lifts or elevators are used to transport items vertically between levels in buildings and for industrial material handling. In this chapter, the same technologies were explored and evaluated in terms of feasibility, appropriateness, and cost in order to close the research gap. [45] We can observe the analysis and design technique for an electric industrial lifting system employing a double-scissor in an article by Omar Y. Ismaela, which is commonly used for moving, transporting, and lifting routine maintenance. Omar Y. Ismaela has shown a complete hardware component selection procedure from the smallest component to the motor selection with mathematical modeling for complete accuracy and implemented the same in real-time for testing. [46][47] Soma Raghavendra¹ and Gaffar G Momin have described a complete list of lifting systems with scissors and hydraulics with mathematical modeling including their real-time applications. Soma Raghavendra¹ has designed and tested a 3.2 meters height carrying a maximum capacity of 500kg with existing mechanical engineering materials. Soma Raghavendra has

given a classification of scissor lifts such as Pit Mounted Scissor Lifts, Tandem Scissor Lifts, Floor Mounted Scissor Lifts, Vehicle Mounted Scissor Lifts, etc with an area of their application with relevant pictures of those lifts with a complete mathematical derivation supporting the choice of materials of fabrication.

4.10.1 Screw-Jack Lift: Design calculation to build a real lift

This section, discusses the detailed design and construction details with accurate mathematical justification covering losses and tolerances. The screw-jack and scissor jacks are equally capable power amplifiers in smooth lifting things horizontally and vertically with linear motion. For the simplicity and cost-effectiveness of preparing the prototype, a motorized scissor jack model is used to lift the elevator. The designed elevator is holding a mesh-like strong lightweight platform inside the swimming pool to control the depth of the swimming pool by taking commands from the CPU. The mesh closely resembles a continuous walking floor and contains multiple proximity sensors spread across the total upper surface of the mesh. When the mesh is kept close to the bottom of the proposed swimming pool, the sensors on the pool keep on monitoring incoming objects and send the data to the CPU. This elevator plays a major role in rescuing the drowned victims in the presented system. The underwater environment does not affect the specialized stainless screw-jack in the manufacturer database [48]. These stainless screw-jacks were rustproof even under the seawater.

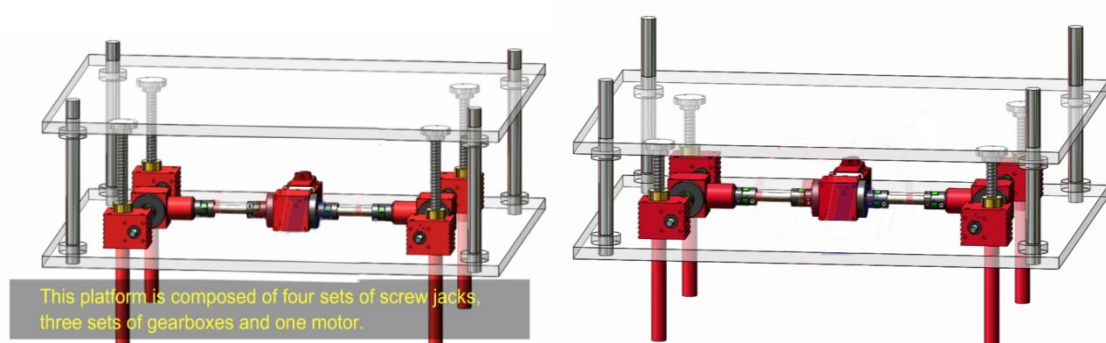


Figure 4.17. Screw Jack's multi-gear lift

4.10.2. Screw Jack and Scissor Jack Hybrid

Screw Jack Principle – Power calculations

Manufacturer of Screw-jacks Kelstone[49]

has given practical calculation examples which will be valid for all screw-jack power calculations by which a designer can choose the appropriate screw-jack motor.

$$\mathbf{Pin = Tin * Sin} \quad \text{-----}(1)$$

Input Power = Pin

Tin=Input Torque Nm

Sin=Worm-shaft input speed

Warm-shaft input speed is the actual speed of the motor employed in the system.

$$\mathbf{Sin = \frac{St}{Sr}} \quad \text{-----}(2)$$

St= Linear travel Speed mm/min

Sr= Travel rate mm/rev

Sr is decided by the ratio of worm wheel teeth to worm shaft starts and the pitch of the lead screw.

For a specific screw jack, Torque speed calculation made by

$$\mathbf{Tin = \frac{Tc*Ld}{Ln}} \quad \text{-----}(3)$$

Where:

Tin = Input torque for the customer-specified dynamic load (Nm)

Tc = Input torque for nominal capacity (Nm)

Ld = Dynamic load applied to jacks (kN)

Ln = Nominal capacity (kN)

the power requirement of a single *screw-jack*

$$\mathbf{Pin = \frac{Tin*Sin}{9550}} \quad \text{-----}(4)$$

Where:

P_{in} = Input power for a single screw jack (kW)

T_{in} = Input torque for customer-specified dynamic Load (Nm)

S_{in} = Worm input speed (Rotations Per Minute)

Screw Jack System Power Requirement:

The power requirements of the screw-jack decide the required drive motor and are calculated as follows:

$$P_s = \frac{P_{in} * (No\ of\ Jacks)}{\eta} \text{-----(5)}$$

Where:

P_s = Required power for a system of screw jacks (kiloWatts)

P_{in} = Input power for a single screw jack (kiloWatts)

Number of Jacks = The number of jacks in the system sharing the load

η = The system efficiency factor.

From the calculated system power requirements, an appropriate best suitable motor can be determined. For real-time prototyping, the present research has used a 10kW motor to move the scissor-lift elevator successfully.

The following mathematical analysis and decisions on choosing components are based on www.diequa.com [50], which is the manufacturer of the screw-jacks and associated machinery that is used in the proposed system. The following are the major challenges that are needed to solve to build a real screw-jack lift.

- 1) Data Essential to Design the Screw-Jack Lift For the Auto-Lifting Pool
- 2) Lifting Force in KN (Kilo Newton's)
- 3) Maximum Lifting Length and Effective Lifting Stroke
- 4) Lifting Speed

- 5) Duty factor, Work Cycle
- 6) Type of Jack to be used
- 7) Type of Power and /or Break mechanism
- 8) Operating Conditions
- 9) Operational Layout

The manufacturer datasets and the methods to find the appropriate machine parts are given such as type of jack, its associate components like bearings, connecting rods, gearbox, motor, etc.

The second point is the critical forces such as the minimum diameter of the screw which is lifting the total weight must not buckle (like bend or deform). The other one is whirling speed where the spindle and associated screw by motor torque rotates to lift the loaded weights so that the designed system won't exceed or lag behind the calculated critical speed. This analysis leads us to calculate the critical torque or force analysis.

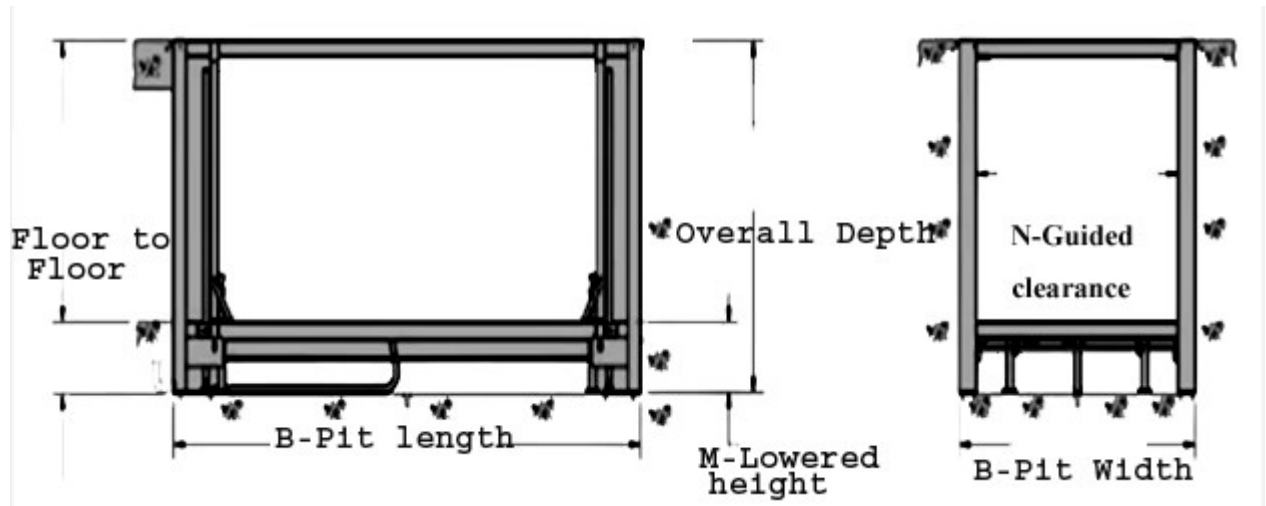


Figure 4.18. Side view showing pool width and length assuming the rectangular pool

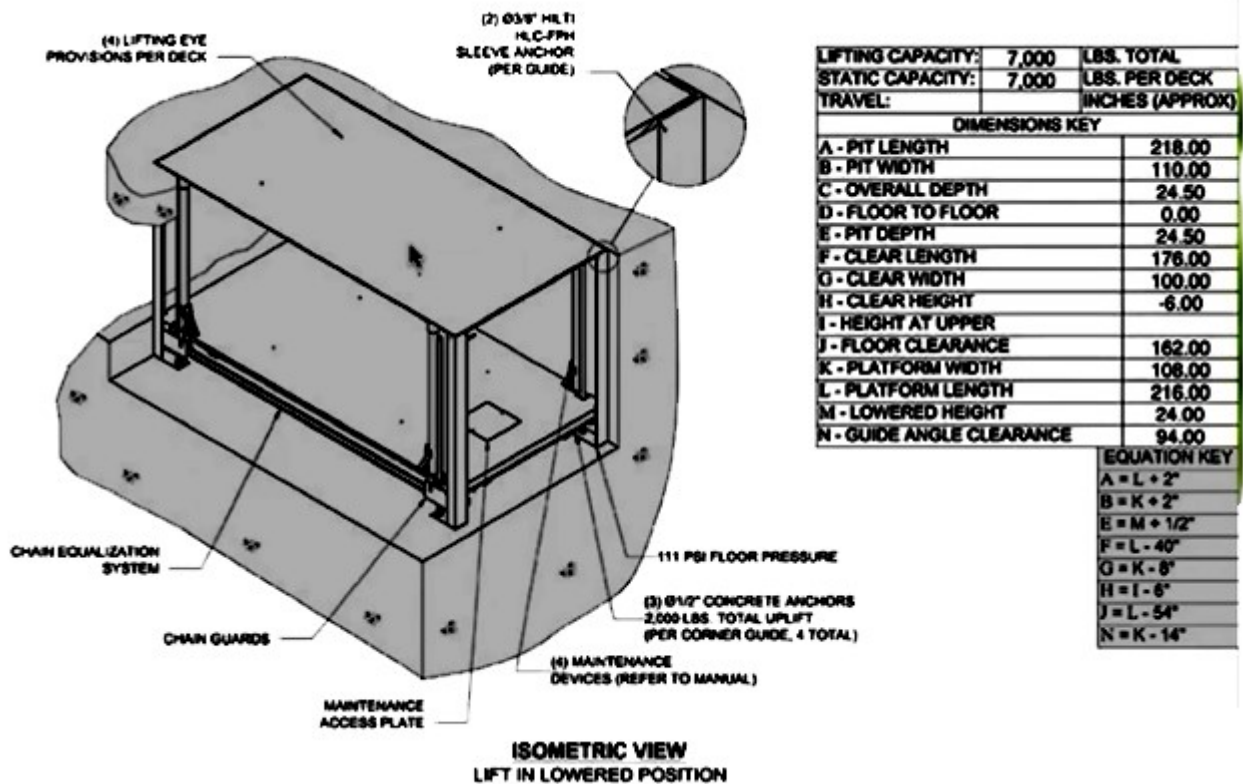


Figure 4.19. Screw-jack design specifications drawing with measurements.

The above figure 4.19 show the guide mechanism which does not rely on the jack screws, diminutions such as floor clearance, height, width, positions of the screw-posts, etc.

If we see the possible weights the screw has to lift are the weights of all the persons which is very less inside the water. As per the buoyancy calculations, human weight is only 5 to 10 percent experienced when inside the water. So the major loading weight is borne by the elevator floor which may be fabricated with a mix of wood or low-density fiber and stainless galvanic iron beams and pipes. So the ultimate weight calculation will lead to negative weight if we consider actual buoyancy forces. But for safety and security reasons, let us take a maximum weight loading onto the proposed lift would be 1000Kgs. The lift height may be chosen as 3 meters and floor clearance would be 8metersX10meters area and the speed should be 40 seconds to lift from bottom to top (3 meters). The duty cycle is assumed as 5 minutes. The duty cycle is defined as the amount of time the system is going to work in a day cumulatively. If one lift cycle takes 40 seconds then an average of six liftings will come

to a 5 minutes duty cycle for our requirement. In other words, the lift is operated 3 times up and 3 times downward directions in a day in normal operating conditions. Of course, the lift may be operated several times if the requirement raises like more people experience several drowning accidents in a day. But the accident won't happen very frequently and the average minimum duty cycle would be 5 minutes a day.

$$\text{Duty cycle} = 5 \text{ minutes} / (60 \times 24)$$

This will show the life expectancy of the screw jack. The jack will have a maximum life expectancy than specified in the manufacturer sheets due to the lower duty cycle.

$$\begin{aligned} \text{Total Load} &= \text{human} + \text{platform} \\ &= 1000\text{KN} + 100\text{KN} \\ &= 1100\text{KN} \\ &= 10.79 \text{ Kilo Newton's} \end{aligned}$$

So, for extra safety, let us choose a 50-kilo Newton jack

Gear Ration assumed to be 7:1,

Screw-pitch from the manufacturer sheet is 7mm/Rev is the vertical lift obtained from a single revolution of the screw. The best screw happens to be a 40mm screw with a 7mm pitch with trapezoidal-shaped threads. The spindle is chosen from the manufacturer sheet is an ACNE screw like the best spindle with ball screw is available out of 4 different spindles. From calculation below

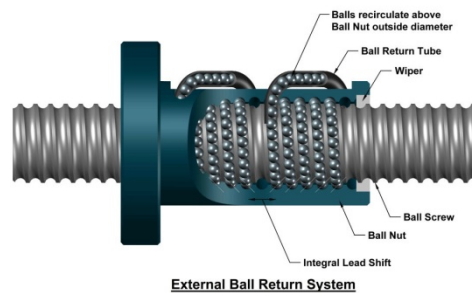


Figure 4.20. Ball Screw Spindle

Desired lift time = 10 feet/40 min for a 3 meters depth lift

$$= 0.25 \text{ ft/s}$$

$$= 76.2 \text{ mm/sec}$$

Gearbox speed = lifting speed(gear ration/screw pitch)

$$= 76.2 * (7/7)$$

$$= 76 \text{ Rev / sec}$$

$$= 4560 \text{ Rev/Min}$$

Which is too fast for any screw-jack, far beyond the screw-jack can withstand

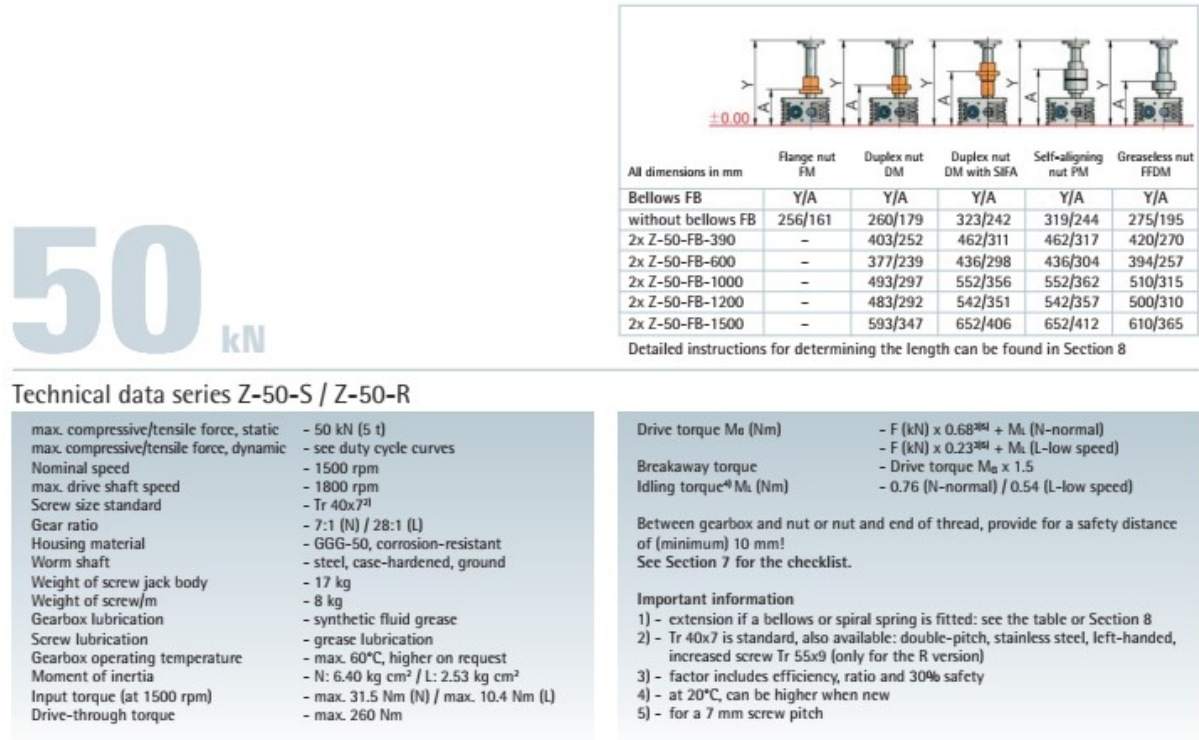


Figure 4.21. Manufacturer specification of Screw-Jack z-50 model.

Max speed of the gearbox is around 1800 RPM it is not possible to speed up to 4560 RPM

With these calculations, a normal screw-jack is not suited but we have another advanced type of screw-jack called BALL-SCREWS,

- **Spindle Selection**
- **Gear Ration Is Fixed**
- **Change The Spindle Pitch**

For the 50KN jack ACME screw pitch =7 mm/rev

ACME screws roll onto the lead screw with a trapezoidal thread. The threads push the shaft nut forward or backward depending on the direction of the rotating motion when the rotatory motor rotates. This converts the motor's circular motion into linear motion on the shaft.

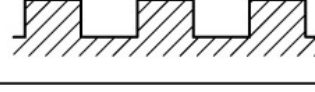
Thread Form	Figure	Uses
Unified		General use.
Metric		General use.
Square		Ideal thread for power transmission.
ACME		Stronger than the square thread.
Buttress		Designed to handle heavy forces in one direction (e.g. truck jack).

Figure 4.22. Types of Screw-threads popular in screw-jacks

Available Ball screw pitch = 5mm/rev to 40 mm/rev,

$$\begin{aligned}
 \text{Pitch} &= \text{speed} * 60 * (\text{gear ratio} / \text{max drive speed}) \\
 &= 76.2 \times 60 (7/1800) \\
 &= 17 \text{ mm}
 \end{aligned}$$

So the spindle selected from a Z-50 type with 20 mm pitch spindle Drive speed, 7 gear ratio, 20 pitch is

$$\begin{aligned}\text{Drive Speed} &= 4560 * (7 / 20) \\ &= 1596 \text{ RPM},\end{aligned}$$

The speed required for lifting the spindle

Buckling Force calculation

$$F = \text{Load Per jack in N}$$

$$V = \text{safety factor} = 3$$

$$L = \text{total length}$$

$$F = 10 \text{ KN}$$

Based on the data we have, the manufacturing datasheet suggested choosing a spindle diameter of 34 mm diameter which can bear 4 times the weight that we expected to lift.

Diameter of the proposed screw and spindle = 34mm

The manufacturer sheet suggests (27.54 min), a size z-50 jack

Whirling Speed Calculation:

Maximum permissible screw rotation speed= $1596/7$

$$= 228$$

max permissible speed= $0.8 \times \text{theoretical critical screw speed} \times \text{design correction factor}$

$$h \text{ actual} = \text{input drive speed} / \text{GearBoxRatio}$$

$$= 1596/7$$

$$= 228 \text{ RPM}$$

For the spindle length of 350 mm of 40 mm diameter spindle

$$H \text{ max} = 0.8 * 350 * 1$$

= 280 RPM max allowable speed of the selected spindle (29.4 min in video)

Therefore 228 RPM < 280 RPM

Drive torque is defined as

$$M_g = \text{idling torque} + F \text{ in kilo newtons} \frac{[Pitch \text{ in mm}]}{2\pi * Gear Box Efficiency * screw - efficiency * I gearbox}$$

$M_g = \text{idling torque} + F(\text{kN}) * P(\text{mm}) / (2 * \pi * GearBoxEfficiency * Screw-Efficiency * I gearbox)$

$$= 0.76 + 10 * 40 \text{ pitch} / (2 * \pi * 0.87 * 0.9 * 7)$$

$$= 0.76 + 400 / 34.452 = 0.76 + 11.59 = 12.35 \text{ Nm}$$

MR = OVERALL DRIVE TORQUE FOR THE ENTIRE SYSTEM

MG - Drive torque for a single gearbox

MA - Starting torque max 1.5xMR

Example

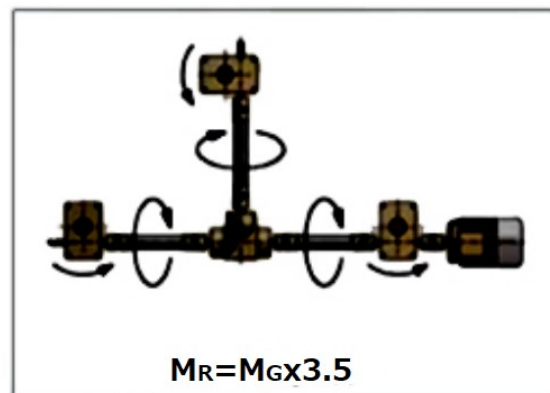
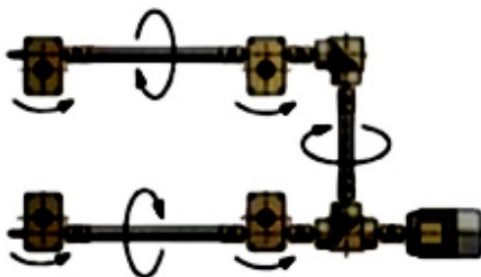


Figure 4.23. The arrangement of the 4-screw-jacks with a single motor drive

From the manufacturer sheet

System Drive torque

$$M_r = 12.35 * 4.9 * 1.4 \text{ safety factor}$$

$$=84 \text{ Nm}$$

Starting Torque including overcoming of the friction = $M_a = 84 * 1.5$

$$= 126 \text{ Nm}$$

The motor is supposed to drive 4 screw-jacks with associated connecting accessories; the factor suggested is 4.9 as the multiplication factor that includes 4 jacks and 0.9 for rotation of accessories

Required Motor Power = Starting Torque * drive speed /(9550)

$$= 126 * 1596 / 9550$$

$$= 21.057 \text{ K watt}$$

The final result shows a 21.05 k watts motor or for safety precautions, let us choose a 25Kw motor

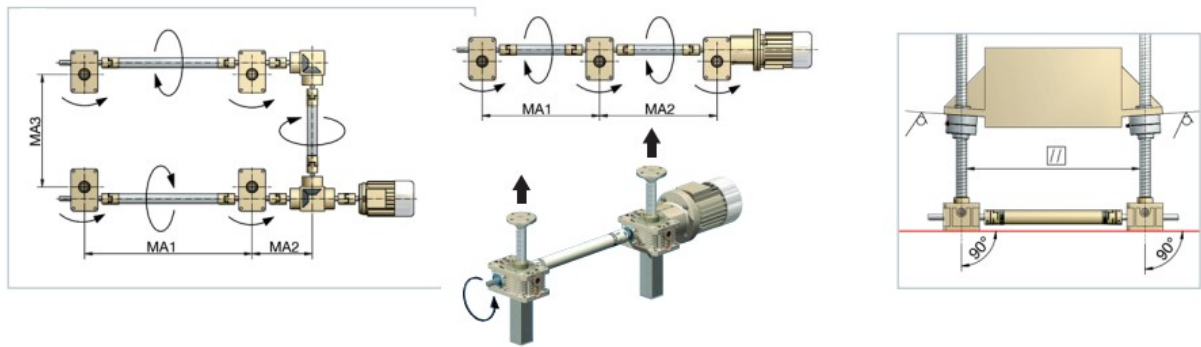


Figure 4.24. The arrangement drawings of the 4-screw-jacks with a single motor drive top view and side view

There is a necessity to have a break at the motor side of the gearbox side because the screw used is not a self-locking screw but a ball screw. Normal screw-jacks will have resistance to facilitate self-locking but the ball screw will rotate freely in both directions if there is a small force applied on either side.

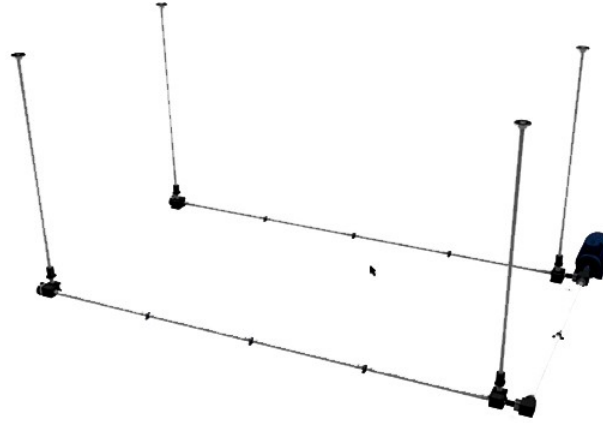


Figure 4.25. Isometric 3d view of the screw arrangements

Isometric 3d view of the screw arrangements along with the motor, gearboxes, connectors, etc. This includes a foot-mounted motor, driveshaft, gearboxes connecting ling drive shafts, and vertical screw posts pushing up the spindle. This is the conclusion to the deciding the motor required to drive the given load specific to the chosen lifting speeds, with the right kind of spindle diameter, and the number of other efficiency correction factors affecting the entire system to run as expected.

Table 4.4.Cost analysis

S No	Product Name	Quantity	Cost Rs	Total Rs
1	Motor 25 HP	1	10,000	10,000
2	Gear Boxes	6	15000	60,000
3	Screw Posts	4	5000	20000
4	Connecting Transmission Pipes	4	1000	4000
5	Spindle Ball screw type	4	1500	6000
6	Nuts and Bolts fasteners	40	50	200
7	Assembling Charges			3000
Total				1,03,200

The above figure illustrates a 4-skew-jack configuration in lowered and raised positions and the corresponding swimming pool depth control animation. It is clearly shown the operational view of the screw-jack as a linear depth control actuator. The main advantage of this configuration is the durability and noiseless operation with a single submersible motor. There are 4 screw pillars spun by 4 different screw-jacks and connecting worm gears and a gear-reduction box connecting a single motor. The spinning of the screws is maintained by a single motor with the movement of the flat surface in a perfectly uniform horizontally. The real fabrication picture is illustrated in the figure below showing the assembling of the mechanical and electrical parts to form a practical motorized screw-jack elevator.

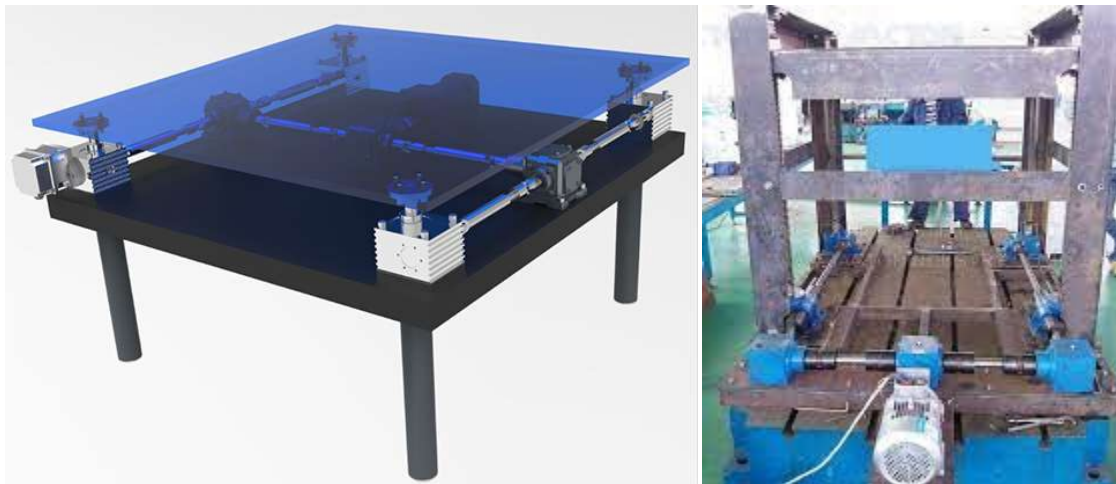


Figure4.26 Portable Screw-jack graphical representations with single motor supporting 4-screws and its realtime realization with the practical fabrication of elevator.

4.10.3 Rotating Pulleys run by electrical motor and rope HOIST method:

This is another method where two or one motors try to lift the pool floor with the help of ropes. Motor-Driven Hoist is another technical solution to lift heavy loads with a high-speed motor through a gearbox to increase torque. The torque is the most important parameter in lifting the weights quickly. So let us design a Hoist-system to lift the swimming pool elevator.

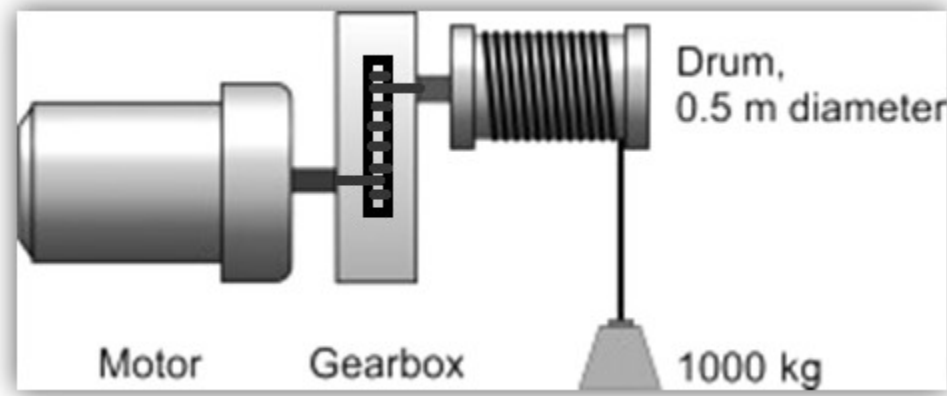


Figure 4.27. Hoist operation [51]

4.10.4 Water Physics Acting on the Provided Mechanism

Archimedes' principle [52], which states that anybody completely or partially submerged in a fluid (air or liquid) or at rest is drawn higher by a buoyant force equal to the weight of the liquid being removed, was uncovered by physicist and innovator Archimedes. In other words, when an item is buried in water, it loses a large portion of its weight, which is equivalent to the weight of water substituted by the submerged object volume, as shown in Figure 22 and Table 7. For instance –, a person weighing 100 kilogrammes (kilogrammes) occupies 99009.9 cubic centimetres in space [53], is submerged 100 percent in water (water volumetric weight is 100 kilogrammes taking up a volume of 100 000 cubic centimetres), and the human body substituting 100000 cubic centimetres of water from a well, river, or swimming pool due to the similar density of the human body mass and the water. Because of the concentration difference between the human body and water, the force acting on the human body upstream is equal to the weight of the water it replaces, and the human body promotes weight loss equivalent to the weight of the fluid it replaces. When fully submerged, an item whose weight is less than the displaced fluid would feel a buoyancy force larger than its own since the object's average density is lower than the liquid's.

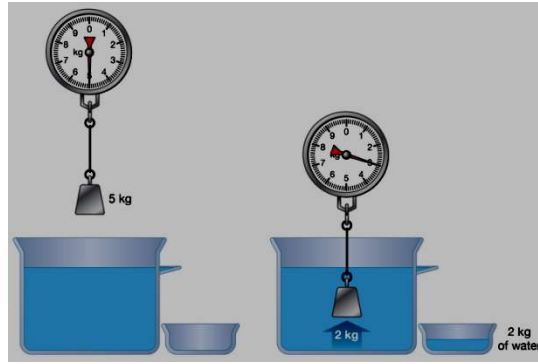


Figure 4.28. Archimedes buoyancy of liquids ' principle

Water has a density of 0.99970 g/cm³ at 10 degrees Celsius and 0.99222 g/cm³ at 40 degrees Celsius, according to textbook reference [54]. The density also changes or increases if any higher density solvents get dissolved into water. The resultant density will be equal to the sum of water density and solvent density. One cubic metre can hold 1000 kilogrammes [kg] of clean water. [55] According to the body density calculator on the internet, "Calculate the volume of compounds and materials per weight compounds weight to volume conversions," the human body weighs 1010 kilogrammes [kg] and fits inside 1 cubic[56]. According to these findings, the difference in water densities against human-body density is 10%, and the human body is 10% denser than pure water. Finally, we may deduce that when entirely immersed in clean water, a 1100 kilogramme human person appears to be a 10 kilogramme object[57][58],[59]. Owing to this density disparity, the normal person drowns fast due to a lack of swimming ability.

$$\text{Hydrostatic weighing} = \frac{\text{Weight in air} - \text{Weight in water}}{\text{Weight in water}}$$

Table 4.5. correlation of weights in different media of transmission [28]

Type	Density	Weight in air	Weight in water	Lung Capacity to hold air	Final weight in water	Behavior in water	Buoyancy Force
Water	1000kg/m ³	1000kg	1000 kg	NA	1000kg	Nil	Hovers
Human Body	1000 kg/m ³	110 Kg	10 Kg	1900-3300ml.	8.1 to 6.7	Slowly sinks	Acting Upwards

Teak wood	607 kg/m ³	1000Kg	400 Kg	NA	400Kg	Floats	Acting Upwards
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According to the reference paragraph [59], persons' lungs will carry air with a density of almost zero when compared to water density, which will reduce the human body's relative weight. The buoyancy force operates on the human body in the opposite direction of gravity, resulting in a reduction in body weight. According to this study, the human body's weight on the lift proposed in the provided swimming-pool safety system is minor. The relative weight of the elevator underwater can also be reduced by carefully choosing strong and low-density (lightweight) materials such as carbon fibers, low-density fibers, or wood in fabrication. The presented elevator platform is fabricated of teak wood (607 kg/m³ basic density) and the screw-jack is fabricated by rust-proof galvanic steel bars and a motor [60]. The teak wood bars are arranged by giving a small space to facilitate the transmission of water in either direction when in movement which will nullify water inertia and resistance against elevator movement. When fully immersed, the object has a density less than the displaced liquid, and if the object's weight is less than the displaced fluid, the object will experience a force higher than its weight. The table shows a density comparison between various building materials and the proposed elevator used a mixture of steel frames holding PE foam which is used as a movable cuboid elevator platform.

Table 4.6. Comparison of various building materials

S No	Material	Density (10^3 kg/m^3)
1	Aluminum	2.7
2	Bone	1.7 - 2.0
3	Cast Iron	7.2
4	Cement, Portland	1.5
5	Oakwood	0.72
6	Plywood	0.54
7	low-density polyethylene foam PE	0.91
8	Copper	8.79

9	High-density polyethylene foam	0.96
10	Pressed wood, pulp board	0.19
11	PVC - polyvinyl chloride	1.39
12	Rubber, foam	0.070
13	Steel	7.82
14	teak wood density	0.607

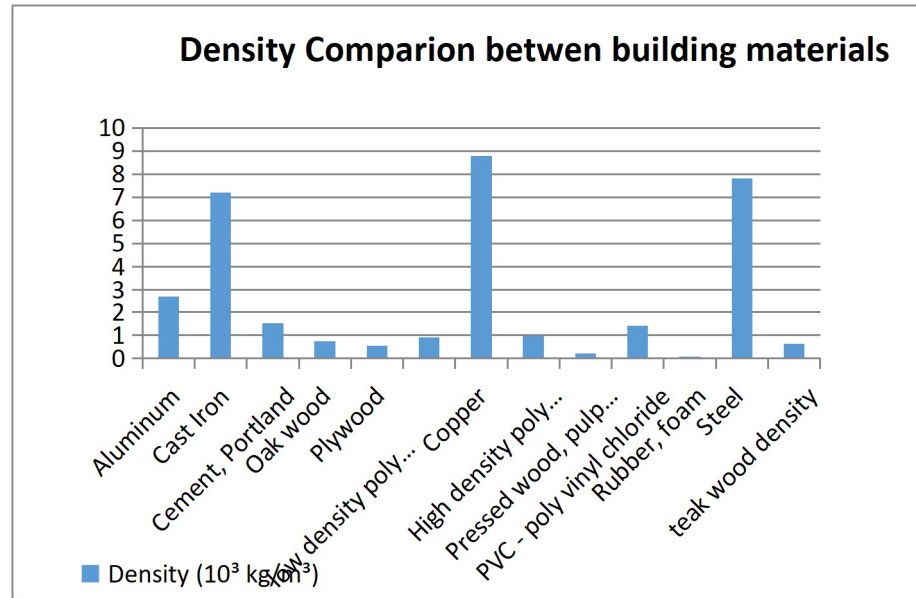


Figure 4.29. Chart showing the density of various building materials.

4.10.5 Mathematical Modelling Of Electric-Hoist for the Proposed System:

Case 1: In this method, the system needs to maintain a constant torque load, while lifting loads throw rotational forces through a motorized pulley.

If we assume a 1000kg load is lifted by a 0.5m drum pulley,

The tension on the rope is $F = 1000 \times 9.81 = 9810 \text{ N}$

Torque required on the drum = $0.25 \times 9810 = \underline{2500\text{N}}$

Assume the speed of the host = 0.5m/s

Typically most of the Motor speed = 1500 RPM

The gear ratio is assumed to be 80:1

Drum speed =19 RPM

Effective torque experienced by motor side= $\frac{2500}{80}=31.25$ Nm

Adding gearbox efficiency as 0.8 percentage

Then $\text{effective torque} = 31.25 \times 1.2$
 $=37$ Nm

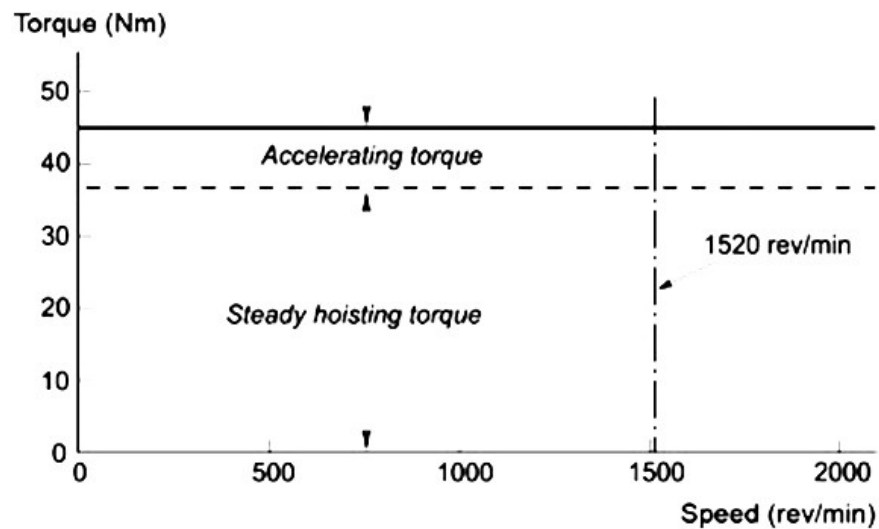


Figure 4.30. The steady-state torque-speed curve of the load is seen by the motor.

The steady-state motor power = torque (Nm) * angular velocity (rad/s)

Maximum continuous motor power for hoisting

$$P_{\max} = 37 \times 1520 \times \frac{2\pi}{60} = 5.9 \text{ KW}$$

This is including the power loss inside the gearbox due to friction.

Case 2: Let us assume the weight the elevator has to lift including the platform is 1000Kgs

The height assumed as 3 meters which is the depth of the swimming pool and the time we set to finish the lift is 30 seconds.

$$1 \text{ hp} = 75 \text{ m kg/s}$$

Work to be done,

$$W = \text{mass} * \text{gravity} * \text{length} = m * g * h$$

$$= 1000 \text{ kg} * 9.8 \text{ m/s}^2 * 3 \text{ m} = 3,266.66 \text{ joules}$$

$$\text{Power, } P = W/t = 29,400/30$$

$$= 980 \text{ watt /s}$$

$$\text{Horse Power} = 1470/75$$

$$= 13.06 \text{ HP} \quad , \quad \text{required motor capacity.}$$

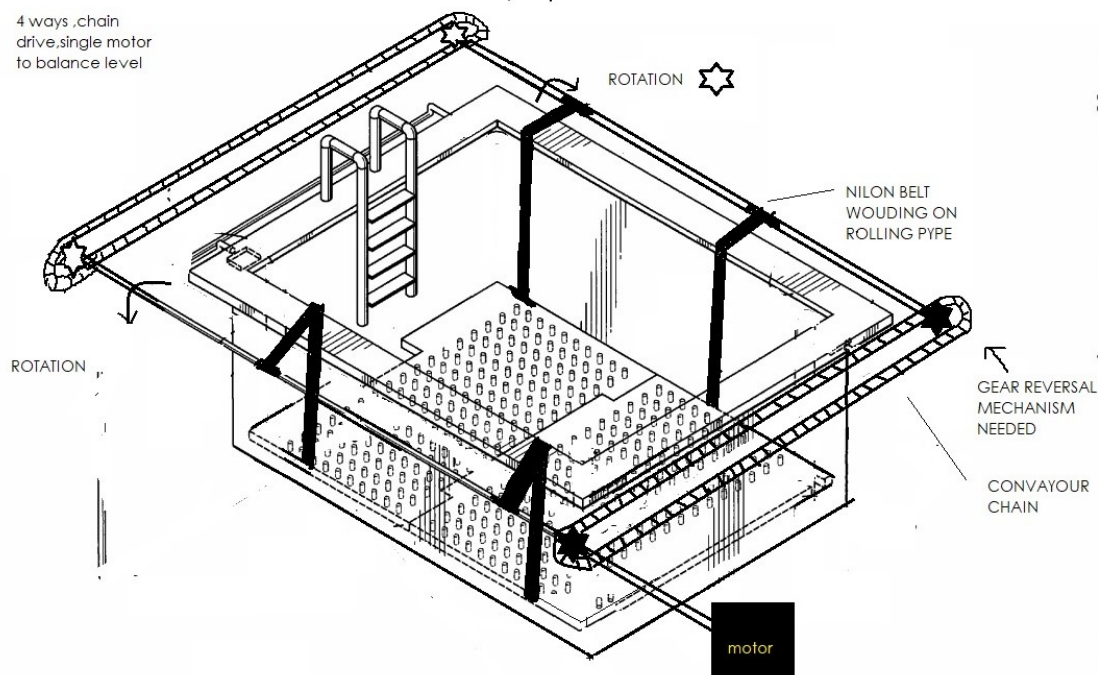


Figure 4.31. The illustration of the Motorized Hoist around the pool model with a chain drive and single motor.

4.10.6. Design of Proposed Novel Hoist Weight Carrying System

The moveable lift platform for the swimming pool is built out of iron frames and a thin layer of Thermocol with a low density. The lift deck will suffer immense buoyancy force as a result of Archimedes' concept, which is the motive force that will certainly hoist the victim automatic with increased speed owing to buoyancy. The arithmetic required in calculating the

resultant buoyancy is as below, taking into account the materials utilised in the proposed system's construction. As indicated in Figure 4.3.3, the reset procedure should return the elevator to the pool's bottom with a strong motorised hoist. Extra than natural buoyancy, no other war is required to elevate the lift. The stabilizing scissor frame will ensure that the lift moves horizontally without any imperfections. The ongoing mathematical analysis will provide a clear image of which components should be used to raise the lift back to the swimming pool's bottom.

The buoyant force formula is the product of (fluid's density),(gravitational constant g)and displaced volume of the fluid V_{dis}

$$F = d \cdot V \cdot g$$

$\therefore$ **buoyancy** force = loss in weight

When a body is partially or completely submerged in fluid, there is an up-thrust equal to the weight of the liquid displaced. The visible weight loss in the body is proportional to this up-thrust.

$$\text{iron Density} = 7,874 \text{ kg/m}^3 \text{ or } \text{m/v}$$

$$\text{iron frame Volume} = 106/7874 = 0.013 \text{ m}^3.$$

Volume of water displaced is equal to the volume of the frame.

Weight of water displaced by iron frame =

$$m = \text{volume} \times \text{density} = 0.013 \times 1000 \text{ kg} \times 9.81 \text{ m/s}^2 = 132 \text{ N}.$$

$$\text{Weight of the iron frame in water} = 106 \text{ kg} \times 9.81 = 1040 \text{ N}$$

When a body is partially or totally immersed in a fluid, Archimedes' principle asserts that the visible weight loss is equal to the weight of the fluid displaced by the submerged component of the body.

$$\text{Weight of the iron structure in water as a final outcome} = 1040 - 132 = 908 \text{ N}.$$

So the force needed to support iron frame in water is 908N

Thermocol Sheet Density [in kg/cubic-meter] = 14 - 32 Kg/Cubic Meter

The volume of the frame which is composed partially by Thermocol

$$= 8\text{m width} * 4\text{m length} * 0.2\text{m thickness} = 6.4\text{cubic m}$$

The acting buoyancy force on Thermocol pure sheet

$$= 8\text{m width} * 4\text{m length} * 0.2\text{m thickness} * 1000\text{kg/m}^3 * 20\text{kg}$$

$$= 128,000$$

RESULTANT Net buoyancy = 128,000 – 908 =
127,092 N

Weight felt by rope while pulling the elevator floor down is = 127,092 N

$$\text{Pulley Drum Diameter} = 0.25\text{m}$$

$$\text{Torque on drum} = 0.25 * 127,092 = 31,773 \text{ Nm}$$

$$\text{Assumed speed of the elevator} = 0.2 \text{ m/sec}$$

$$\text{Typical motor speed} = 1500 \text{ RPM}$$

$$\text{Gear Ratio} = 80:1$$

$$\text{Drum speed} = 50 \text{ RPM}$$

$$\text{Torque on drum} = 31,773 \text{ Nm} / 80 = 397.1625 \text{ Nm}$$

$$\text{Adding Gear Box efficiency correction} = 0.8\%$$

$$\text{Effective torque experienced by the motor side} = 397.1625 * 1.2 = 476.595 \text{ Nm}$$

Table 4.7. Illustrating power versus speed relation [61].

Power		Motor Speed (rpm)														
		3450			2000			1750			1000			500		
		Torque														
hp	kW	(lb _f in)	(lb _f ft)	(Nm)	(lb _f in)	(lb _f ft)	(Nm)	(lb _f in)	(lb _f ft)	(Nm)	(lb _f in)	(lb _f ft)	(Nm)	(lb _f in)	(lb _f ft)	(Nm)
1	0.75	18	1.5	2.1	32	2.6	3.6	36	3.0	4.1	63	5.3	7.1	126	10.5	14.2
1.5	1.1	27	2.3	3.1	47	3.9	5.3	54	4.5	6.1	95	7.9	10.7	189	15.8	21.4
2	1.5	37	3.0	4.1	63	5.3	7.1	72	6.0	8.1	126	10.5	14.2	252	21.0	28.5
3	2.2	55	4.6	6.2	95	7.9	10.7	108	9.0	12	189	15.8	21.4	378	31.5	42.7
5	3.7	91	7.6	10	158	13.1	18	180	15	20	315	26.3	36	630	52.5	71
7.5	5.6	137	11	15	236	20	27	270	23	31	473	39	53	945	79	107
10	7.5	183	15	21	315	26	36	360	30	41	630	53	71	1260	105	142
15	11	274	23	31	473	39	53	540	45	61	945	79	107	1891	158	214
20	15	365	30	41	630	53	71	720	60	81	1260	105	142	2521	210	285
25	19	457	38	52	788	66	89	900	75	102	1576	131	178	3151	263	356
30	22	548	46	62	945	79	107	1080	90	122	1891	158	214	3781	315	427
40	30	731	61	83	1260	105	142	1441	120	163	2521	210	285	5042	420	570
50	37	913	76	103	1576	131	178	1801	150	204	3151	263	356	6302	525	712
60	45	1096	91	124	1891	158	214	2161	180	244	3781	315	427	7563	630	855
70	52	1279	107	145	2206	184	249	2521	210	285	4412	368	499	8823	735	997
80	60	1461	122	165	2521	210	285	2881	240	326	5042	420	570	10084	840	1140
90	67	1644	137	186	2836	236	321	3241	270	366	5672	473	641	11344	945	1282
100	75	1827	152	207	3151	263	356	3601	300	407	6302	525	712	12605	1050	1425
125	93	2283	190	258	3939	328	445	4502	375	509	7878	657	891	15756	1313	1781

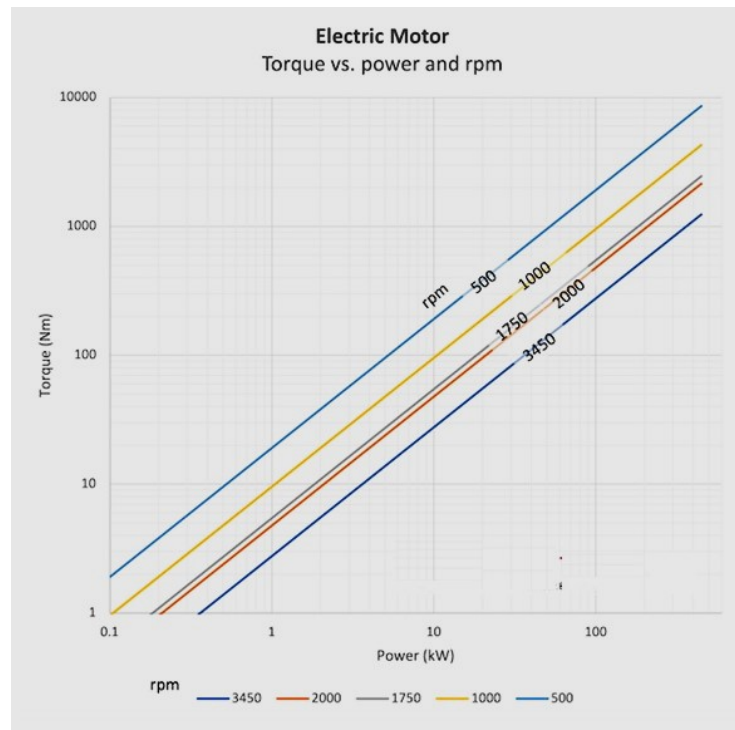


Figure 4.32. A)Based on the RPM of an electrical motor, there is a relationship between power and torque.B) the relationship between power and torque.

Based on the given Table 4, the appropriate suitable horsepower of the required motor is 90HP or **67Kwatt** is required. If two gearboxes are employed, the effective torque will be half of what it was previously.

Torque when 2 gearboxes used = 45 HP or 33Kwatt

Because the swimming pool lift is raised by natural buoyant force, the suggested solution uses a ready-made 1000kg electric hoist to pull the rope to lower the lift.

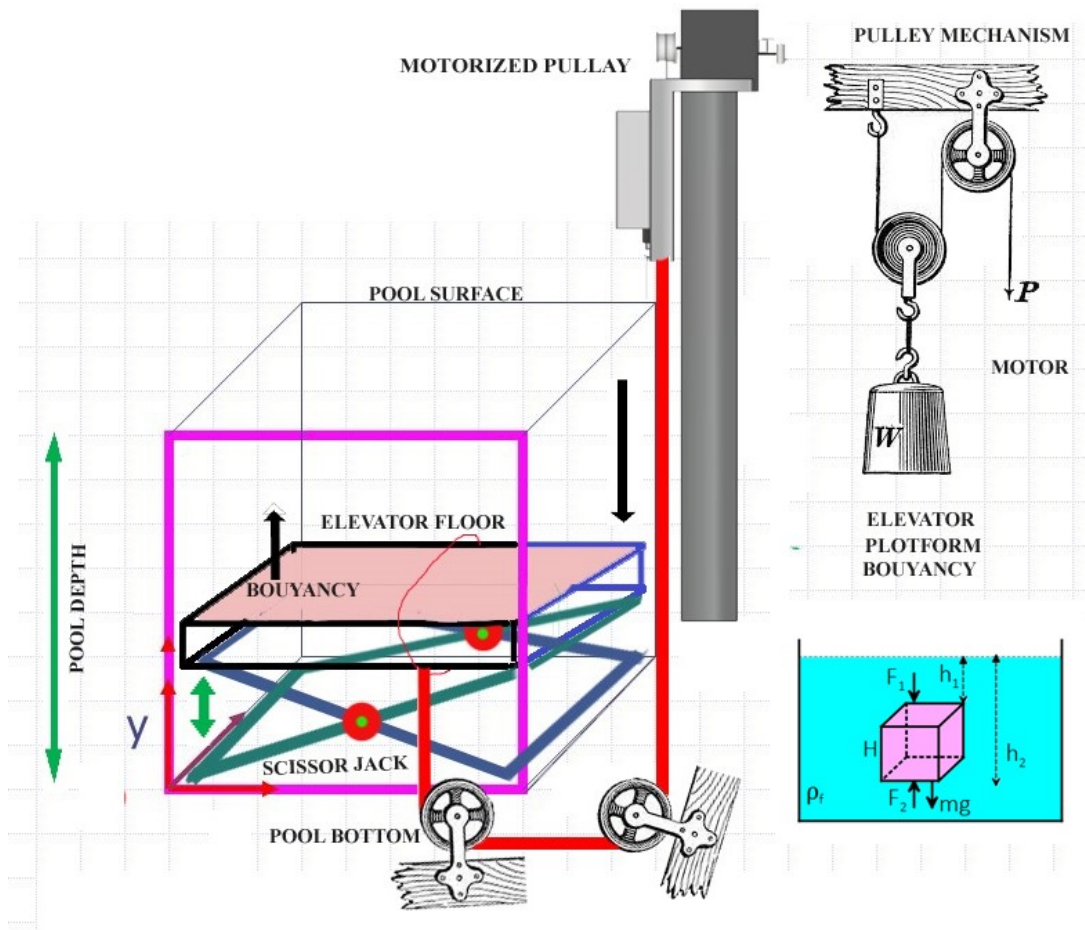


Figure 4.33: The construction and operation of a hoist are depicted in this diagram (Patented)

The presented novel- buoyant platform introduces a completely new, efficient, nature-inspired drown-rescue arrangement using purely buoyancy as the motive force. The design is as shown in figure 1, where the 3-dimensional cubical-shaped swimming tub comprises a properly fitted scissor-balancer which is supporting a platform structure made up of a rust-proof cuboid filled with ultra-light thermo-coal (or similar water-resistant low-density foam)

as movable swimming pool bottom floor. The movable cuboid novel- buoyant platform level can be adjusted by using a motorized hoist with a steel rope by an electric host pulley. The hoist is generally controlled by an electric motor whose operation can be controlled by a control panel. The elevator assembly can be released from the bottom level just by unlocking the lock as shown in the Figure and freeing the rope from the hoist, enabling the low-density novel- buoyant platform to float (raise) upward with the up-thrust of natural buoyancy force. The novel- buoyant platform is attached to the 4-sided-scissor to maintain perfect horizontal movement when the platform is in motion. The speed of the platform (novel- buoyant platform) floor may be controlled by hydraulic balancers inside the scissor jacks when raising the elevator floor. The hoist-motor may be arranged outside the pool to pull the hoist-rope with additional levers to rotate the hoist-pulley in the absence of electrical power similar to the *vehicle-jockey screw-jack*. The hoist motor is only useful in pushing the elevator floor from the raised position to the bottom and the elevator platform can easily rise without any labor with the help of buoyancy force simply by loosening the rope by releasing the lock at the hoist. The hoist can use a gearbox to amplify the power delivered by the electric motor. The electrical power rating can be calculated by measuring the resultant buoyancy force acting upwards on the deeply submerged elevator floor in water theoretically. Unlike conventional anti-drown lifts, the proposed method uses natural buoyancy as a motive force in raising an underwater elevator when activated by manually or automatically.

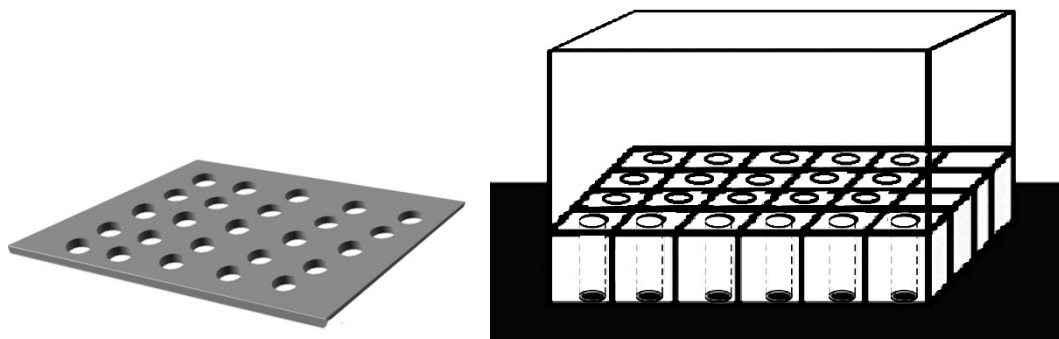


Figure 4.34. A) Apertures inside the long-cubic-shaped platform. B) 3-D view of the platform inside the pool

The thickness of the Platform is precisely calculated according to the required buoyancy force. The volume and effective density of the steel frame and contained foam were cumulatively estimated and the appropriate motor for the Electric-Hoist is chosen. There are several Electric-Hoist products in the consumer markets which are generally used by the small scale and large scale industries to lift, move operations for heavyweight materials.

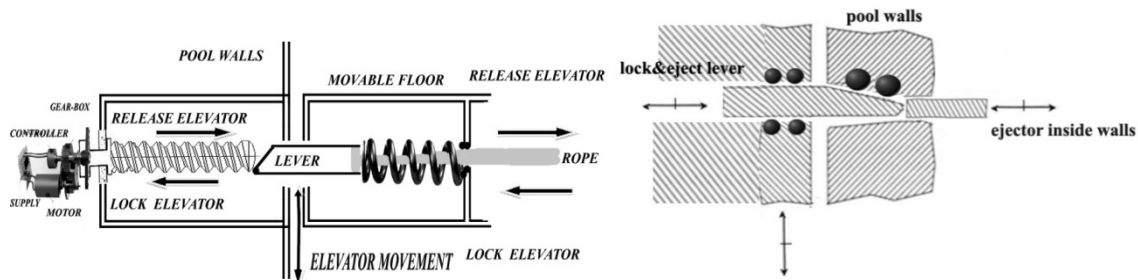


Figure 4.35. Elevator locking mechanism inside cuboid pull-to-release and inside pool walls push to release buoyant cuboid.

The elevator is locked on 2-opposite sides or all four sides with an interlocking system shown in the figure above. The locking lever is placed inside the groove carved at the edges of the elevator movable platform (cuboid) and connected to a common metal wire connected to manual clutch handles and electrical actuators. The lock can be operated manually by metal rope or by electrical actuators shown in the above Figure-4.

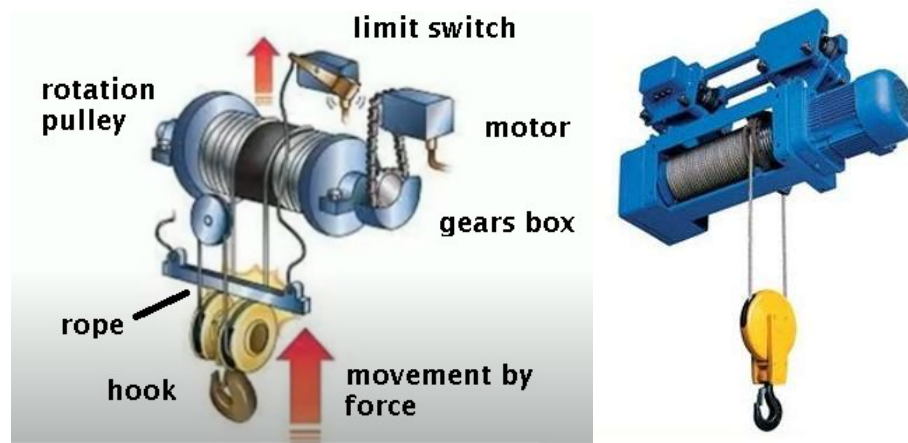


Figure 4.36. The standard commercially available motorized Electric Hoist and its internal parts and commercial electric hoist photo.

The hoist and lock may be controlled manually and/or automatically through wired or wireless means from near the system or from remote places with the help of IoT devices coupled with GSM technology, sensor networks, and programming techniques.

Locking the elevator level	The elevator level can be locked at the rotating motor gears or at the pulleys which are in contact with the rope movement or on the sides of the elevator platform. The gears and pulleys with an additional locking lever is an additional novel method that can control and lock the elevator in predefined stages/height but the ropes that are pulling the elevator will experience the weight of the elevator as long as the elevator platform is kept in the bottom of the pool.
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4.11 Problem Addressed By the Novel- Buoyant Platform:

- 1) The motive force behind lifting the elevator is depending on the natural buoyancy acting on the cuboid elevator floor and does not depend on any external forces.
- 2) The elevator works even in the absence of electrical power, so the user may not depend on electric power in the manual rescue operations.
- 3) Elevator release is provided by rope operated linked to levers accessible inside pool and outside pool. These levers free/loosen the movable "elevator cuboid platform" from underwater to the water surface with the forces of natural buoyancy.
- 4) This invention provides safety and confidence to swimming pool users.
- 5) The possibility of hitting the bottom in low depths of water is prevented while diving as the elevator platform is made up of low density foam.

4.12. Advantages of the Proposed Novel Buoyant Platform:

The invention uses natural buoyancy as a major force in controlling the depth of the swimming pool which is a novel method.

There is absolutely no power is used to lift the movable platform from bottom to top which is never been tried or tested in any invention.

Generally, the personal protection devices will fail if there are any electrical or mechanical problems arising due to aging or duty-cycles of the devices and might not work when there is a real emergency.

The proposed system is a movable-mesh type of float tied close to the bottom with a rope to an electric hoist, which is having ultra-light material packed inside a steel box resulting enormous amount of buoyancy up-thrust which will help the elevator in shifting positions upwards.

In the existing pool elevators, there are always some mechanical lifting actuators needed to lift the movable floor from bottom to top which is eliminated the proposed system.

4.13. Alternative Method- Double Scissor Lift Technology

A scissor lift is a platform that can only move vertically in most cases. A pantograph (or scissor mechanism) is a device that uses connected, folding supports in a criss-cross X pattern to achieve this. The work platform is propelled upwards by applying pressure to the outside of the lowest set of supports, elongating the crossing pattern, and applying pressure to the outside of the lowest set of supports. Because of the inherent limitations of vertical-only mobility, the platform may additionally feature an extending deck to give closer access to the work area.

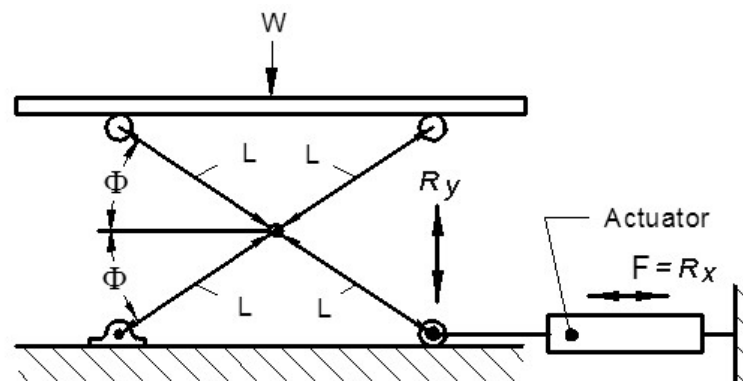


Figure 4.37. Criss-cross arrangement of two levers

The figure shows a rough sketch showing a criss-cross arrangement of two levers joined at the center and the variation of the platform height linearly laterally.

If we go to the mathematical analysis of the scissor lift to select the appropriate component selection.

Let us take the same case as calculated for the screw-jack and rope-lift, such as 1000kg weight to a 3 meters height swimming pool elevator.

A swimming pool covering a length of 10 metersX15 Meters indoor pool with a 3 meters depth desired.

$$\text{Scissor arm length} = \sqrt[2]{5 \times 5 + 3 \times 3} = 5.8 \text{ m}$$

Force analysis

the parameters are as follows

$$\text{Scissor lift desired capacity } M_c = 1000\text{Kg}$$

$$\text{Platform mass including table } P_M = 1000\text{Kg}$$

$$\text{Safety factor } S_F = 1.2$$

Total mass falling on the elevator after considering SF

$$T_M = (P_M + \text{Load}) \times 1.2 = 1200\text{Kg}$$

Total force acting on elevator arms

$$T_F = T_M \times g = 1200 \times 9.81 = 11,772 \text{ N} = 11.77\text{kN}$$

Screw-Spindle selection: The screw is going to create a movement of the scissor arms. The ball-screw spindle is the best spindle with maximum efficiency among other varieties of screw spindles. For this purpose, the SKF bearing selection tool was used to choose the best ball screw.

Designations	SL		TL		Support bearing Recommended thrust support bearings	Recommended support pillow block
	Basic load ratings dynamic	static	Basic load ratings dynamic	static		
	C _a	C _{0a}	C _a	C _{0a}		
kN						
SL/TL 25×20R	22,8	51,5	12,6	25,8	PLBU 25/FLBU 25	BUF 25
SL/TL 25×25 R	22,3	50,6	12,3	25,3	PLBU 25/FLBU 25	BUF 25
SL/TL 32×20R	25,4	65,2	14,0	32,6	PLBU 32/FLBU 32/FLRBU 3 ^(*)	BUF 32
SL/TL 32×32 R	26,1	69,3	14,4	34,7	PLBU 32/FLBU 32/FLRBU 3 ^(*)	BUF 32
SLD/TLD 32×32 R	26,1	69,3	14,4	34,7	PLBU 32/FLBU 32/FLRBU 3 ^(*)	BUF 32
SL/TL 32×40R	12,6	29,8	6,9	14,9	PLBU 32/FLBU 32	BUF 32
SL/TL 40×20R	41,3	128,8	22,8	64,4	PLBU 40/FLBU 40	BUF 40
SL/TL 40×40R	51,7	130,5	28,5	65,3	PLBU 40/FLBU 40/FLRBU 4 ^(*)	BUF 40
SL/TL 50×50R	92,9	235,1	51,2	117,6	PLBU 50/FLBU 50/FLRBU 5 ^(*)	BUF 50

Designations	Nominal diameter	Lead	Dimensions Shaft		Nut									
	d_0	P_h	d_1	d_2	L Max	L	L_1	L_3	L_7	D_1 g9	D_4 js12	D_5 H13	D_6	M_2 6H
mm														
SL/TL 25×20R	25	20	24,29	21,7	4 700	66,8	18	17,6	15	48	60	6×6,6	73	M6
SL/TL 25×25R	25	25	24,38	21,5	4 700	78,2	27	18,7	15	48	60	6×6,6	73	M6
SL/TL 32×20R	32	20	30,06	27,4	5 700	67,4	18	17,9	15	56	68	6×6,6	80	M6
SL/TL 32×32R	32	32	31,066	28,4	5 700	80,3	41	13	15	56	68	6×6,6	80	M6
SLD/TLD 32×32R	32	32	31,066	28,4	5 700	80,3	41	13	15	50*	65	6×9	80	M6
SL/TL 32×40R	32	40	29,58	26,9	5 700	54,8	17	12,2	15	53*	68	6×6,6	80	M6
SL/TL 40×20R	40	20	37,77	35,1	5 700	87,3	38	18	15	63	78	6×9	95	M6
SL/TL 40×40R	40	40	38,34	34,2	5 700	110,8	44	21,6	25	72	90	6×11	110	M8×1
SL/TL 50×50R	50	50	49,14	43,4	5 700	134	60	25,5	25	85	105	6×11	125	M8×1

Table 4.8. Ball bearing selection from the manufacturer datasheet SKF.

The force experienced by the ball screw when fitted at the bottom will be

$$F_e = (4 \cdot WB + 2 \cdot W) / \tan(q)$$

The angle at the lowest level is $q=5$ degrees

$$F_e = 51.5 \text{ kN}$$

From the table, $P_h = 50\text{mm}$ and $d_0 = 50\text{mm}$, So $\eta = 0.98$, But $\eta_p = 0.9$ $\eta = 0.88$

$$\text{So } T = (F \times P_h) / (2000 \pi \eta_p) = (51.5 \times 1000 \times 50) / (2000 \pi \times 0.88) = 455.2 [\text{N.m}]$$

$$\text{Speed} = 3\text{m} / 0.5\text{min} = 6\text{m/sec}$$

A reduction gearbox is necessary to provide a motor with high torque and low speed.

24V BLDC motor, Torque $T = 15$ [N.m], Power $P = 3$ [KW], , Speed $n = 2000$ [rpm] ,The gearbox used was a "Low backlash planetary gearbox" with a wide ratio range of $i = 3$ to $i = 100$.

For Mass (M)= 350 Kgs, Alloy steel 1010 Density (ρ) = 7868 kg/m³ , approx

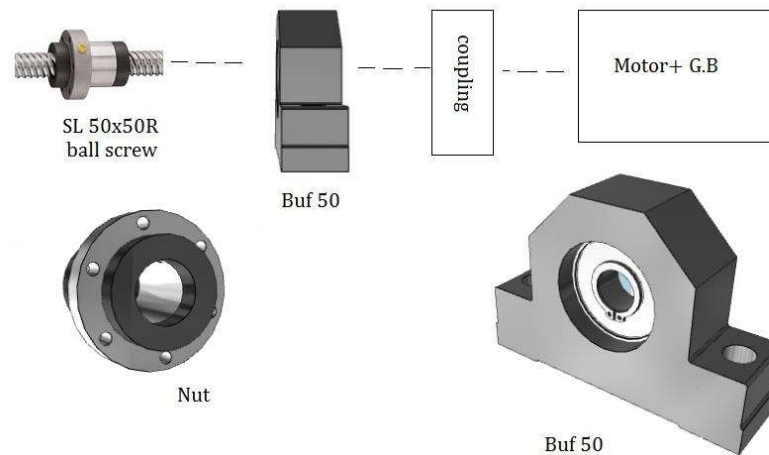


Figure 4.38: Ball-screw mounting.

Gearbox design

The British Gear Association (BGA) manual is used to conduct a "preliminary" examination of the gear design [62].

The Input requirements: Nominal input power, $P_n = 5.5$ KW, Nominal input speed, $n = 1500$ rpm.

For scissor motor Current for the motor $i = 53.25$ [A]

Transmission ratio, $i = 1500 / 70.7 = 21.22$ RPM

Gear Life (hours), $NL = 24 \times 7 \times 52 \times 5 = 43,680$ (based on 5 years life)

Reliability Required is 95%

To specify the ratio split, the overall Gear Ratio, $i=21.22$, should use 2 stages.

$KA = 1.3$, for the driven machine (moderate shock) and the prime mover, which is an electrical motor.



Figure 4.39. The Screw-jack scissor lift hybrid was used in the present experiment to lift the pool elevator.

The figure above displays the machinery used to construct the elevator underwater showing a single motor with a screw-jack lifting the 4-sided rectangular scissor-lift.

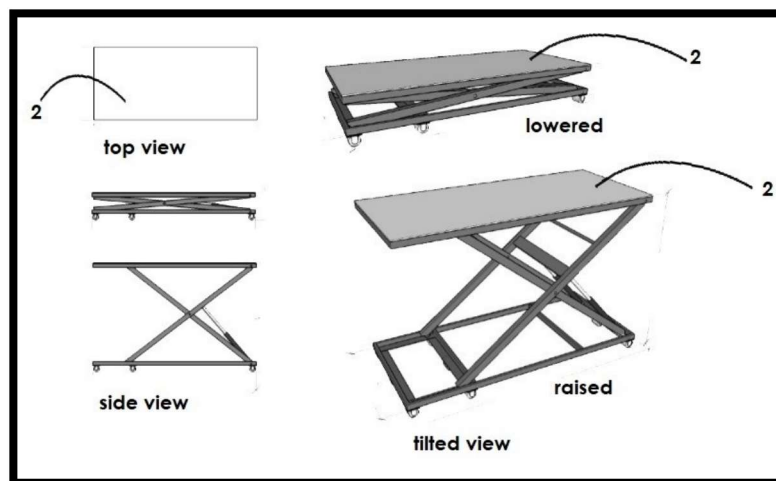


Figure 4.40. The mechanical structure of the scissor-jack and parts in different view angles.

4.14. Final Prototype:

The real-time prototype is tested in an indoor small swimming pool using the suggested algorithm and double scissor screw-jack framework. The project was successfully tested in real-time situations with pleasing outcomes. Several trials were conducted to test the reliability of the system assuming numerous conditions such as water turbidity, lighting conditions, and simulated scenarios.

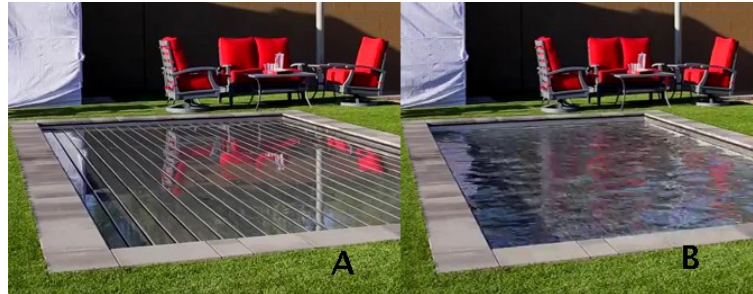


Figure 4.41. Experimental Pool with A) Raised Elevator (pool shut-down)B)Lowered elevator.

The table below illustrates the performance-based observations of the proposed prototype in real-time situations. After experimenting 50 times repeatedly, the designed prototype has given promising results. The different assumed scenarios were tested 50 times and noted its success rate. The wear and tear observed in the trails were also very less. The major advantage of this buoyancy-based elevator is when there is a panic situation, the elevator is released from the hoist so, there is no electrical power required to raise the elevator with the help of buoyancy power. The resetting requires the maximum power to push the elevator to the bottom and lock. The main difference is if the motor fails to elevate the elevator in an emergency, the total system is of no use. So, this innovative buoyant-based elevator is a breakthrough in underwater elevator designs. Other alternatives also work well but they are more vulnerable to failure. The buoyancy elevator has zero failures because zero power is used to raise the elevator.

Table 4.9.Practical observations of drowning identification by trails conducted on the prototype

S No	The situation of the risk	Success cases	Success	Type of
------	---------------------------	---------------	---------	---------

	identification	out of 50 trails	rate	operation
1	Self-identified,	50	100%	Semi-automatic
2	Noticed-by others,	50	100%	Semi-automatic
3	Prediction by the system,	47	94%	Fully automatic
4	Noticed by people outside the pool.	50	100%	Semi-automatic

4.15. Conclusion:

This chapter has illustrated and demonstrated the theoretical and practical measurements to construct an elevator for underwater lifting operation with mathematical proofs. All the methods are properly analyzed and designed by assuming real-time situations and the choice of method depends on the budget allocated by the consumer for the safety system construction.

RESULTS AND DISCUSSION ON TESTING AND VALIDATION

An in-depth practical case study of the testing and validation of fully automatic and manually programmable multilayered personal swimming pool safety architectures is presented in this chapter. This chapter reports the prototype performance to handle the proposed problem in detail. The sensor data is analyzed by the processors and takes the decision on reaching a critical time point and the signals are passed to the master controller to take the decision. The load on the master RASBERRY PI is shared among the LDR-connected mini-processors-connected processors. The buoyancy powered electric-Hoist has perf

5.1 LDR-LASER Module Data:

The LDR sensor detection of an obstacle

Table 5.1. Working on LASER-LDR Pair.

Test	Expected Output	Transmission	Remarks
Clear Water	Signal found in Arduino-Nano	Connected	Successful
Nacl Delusion	Signal found in Arduino-Nano	Connected	Successful
Potassium Permanganate Dilution 1Gram/100Liters	Signal found in Arduino-Nano	Connected	Successful
Potassium Permanganate Dilution 1Gram/10 Liters	Signal found in Arduino-Nano	Connected	Successful with lower intensity.

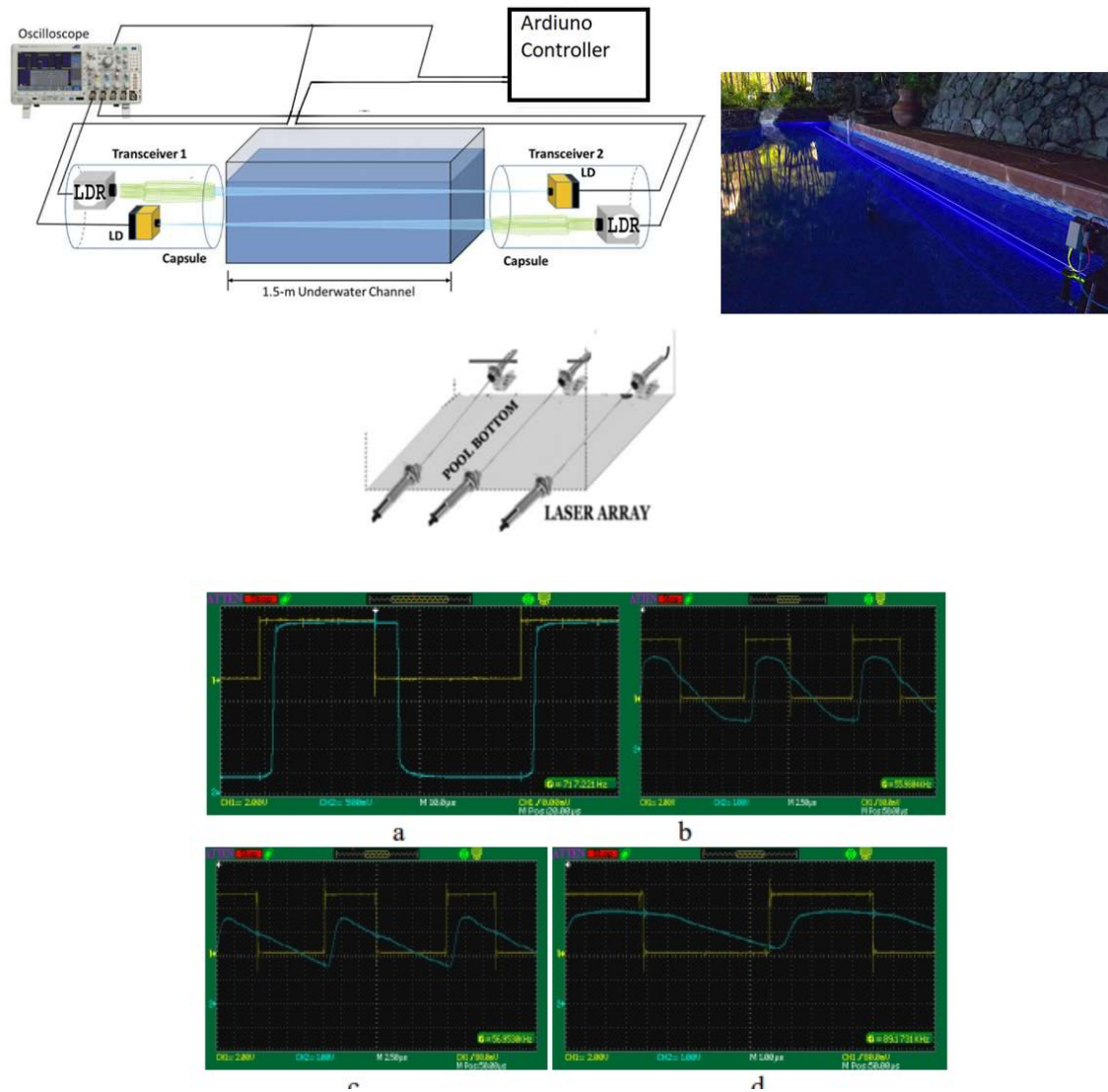


Figure 5.1. Rxd signal in the situations like a- no turbidity b- low c- middle d – high turbidity.

- 1- Varying turbidity levels of water result in different transmission lengths for laser beams. The turbidity has a strong influence on transmission distance in the water.
- 2- Any changes in water turbidity reduces the volume of water transmitted, resulting in a reduction in intensity peak and received power values.
- 3- Changes in the location of the laser light-spot over time as a function of turbidity and water flow rate
- 4- The optical signal is distorted by turbidity and flow velocity of water. Turbidity will have increasingly chaotic effects on the beam.

5.2 Proximity Sensor Success rate Calculation

The matrix of sensors on the elevator floor is meant to inform any new object coming close to the bottom of the pool, in the vicinity of the sensor module is placed. As soon as the objects come close to the proximity sensor, the timer in the Arduino-nano which is receiving the sensor data will send a trigger signal to the master RASBERRY PI processor to take the decision. The Arduino-nano is programmed to send a trigger signal only after 30 seconds of continuous contact with the obstacle. In the physical prototype experiment, the IR radiation from the proximity sensors can pass through the water between obstacles, and can reflect according to the principle of operation of the proximity sensor, the distance between the sensor and the object placed near the sensor. The sensor's behaviour while searching for obstructions underwater is shown in the table below (drowned objects). The experimental results verify the practical usefulness of the design for underwater object detection.

Table 5.2. The number of experiments undertaken and the success percentage associated with them

Lighting Condition	Laser Sensor Working	Proximity sensor	Trails conducted	Trails Success	Final Result
Fully Daylight	Yes	Yes,	50	47	Satisfactory
Fluorescent Lighting (Day)	Yes	Yes,	50	48	Satisfactory
Fluorescent Lighting (Night)	Yes	Yes,	50	46	Satisfactory
Medium Lighting(Evening)	5% Failures	Yes,	50	46	Satisfactory
Total Dark	5% failures	Yes,	50	39	Satisfactory

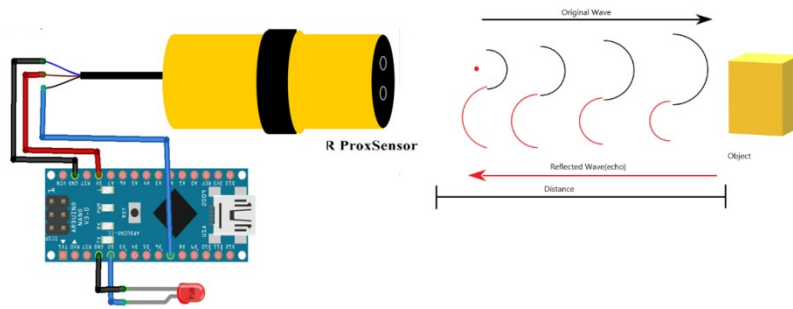
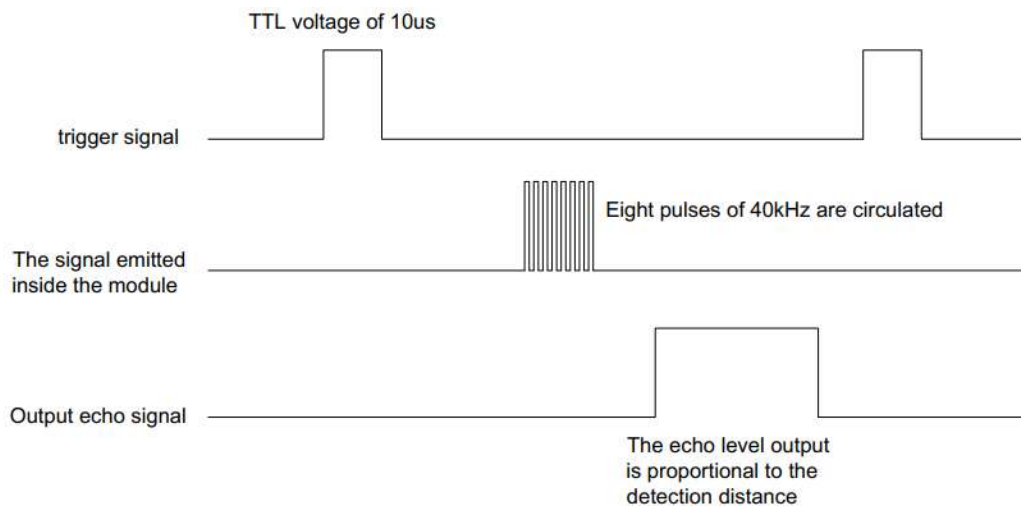


Figure.5.2. the sensor operation while interfacing with IR proximity sensor

Table 5.2 shows the experimental results on the complete finished prototype which is shown in Figure . The system prediction success rate can be improved by installing more sensors in the system in appropriate locations.

When the distance between the sensor and the obstacle (drowned object) is more than or equal to 30 cm, the identification success rate is higher, attaining an estimate of 99.625 percent, which meets the standards of accurate obstacle identification.



Graph 5.3. The ultrasonic sensor's sequence diagram when searching for an obstruction.

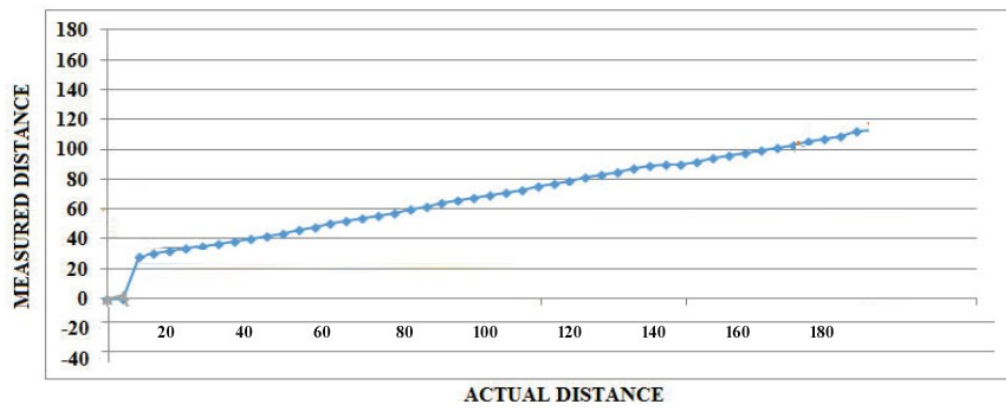


Figure 5.4. In obstacle detection, the distance variation underwater with the proximity sensor

5.3 Trails Conducted On The Prototype

Table 5.3.On the prototype, practical observations of drowning detection by trails were made.

S No	The situation of the risk identification	Success cases out of 50 trails	Success rate	Type of operation
1	Self-identified,	50	100%	Semi-automatic
2	Noticed-by others,	50	100%	Semi-automatic
3	Prediction by the system,	47	94%	Fully automatic
4	Noticed by people outside the pool.	50	100%	Semi-automatic
5	Idle closedown.	47	94%	Fully automatic

From my reading of the literature, I understood that swimming skills play no role in the prevention of drowning, and it is difficult to prevent unsupervised access to swimming pools by children and patients. In the proposal, a natatorium (swimming pool) is envisioned as a responsive, intelligent system that recognizes unforeseen drowning incidents and acts appropriately to save the victims of drowning. Methods such as the one used here are straightforward, reliable algorithms that work in conjunction with a powerful mechanical screw-jack and durable sensors to avoid drowning. By using the elevator mechanism with intelligent sensors and switches, the drowning victim will be rescued faster and be able to breathe again. Pool draining may be time-consuming, but it will allow the lifting process to be accelerated slightly reducing water level by removing water. Table 5.2 & Table 5.3 shows the optimistic results when the system performance is verified practically for about 50 iterations. By using the proposed design, the swimming bath could be not only health, sport, and leisure facility but also assure safety. This system presents a better system, overcomes all disadvantages, and incorporates revolutionary features. To address the deficiencies in the existing literature, it has introduced several new techniques. The proposed subsystems were tested individually and integrated to form the complete anti-drown system. The Comparison

between the Screw-jack and rope-hoist can be made and an economic choice may be choosing a rope-hoist and a luxurious choice may be the screw-jack or hydraulic elevator.

CHAPTER 6

CONCLUSION

Research groups bear a significant amount of responsibility for improving the quality and length of human existence. The researcher has chosen the provided subject for research in order to develop novel and sophisticated achievable system designs that may save many lives that are at risk of drowning all around the world. The purpose of this thesis is to encourage the avoidance of drowning incidents in swimming pools in order to safeguard live beings and assets. There are various causes why individuals and animals drowned to death in the thesis, ranging from newborns to adults at all ages. Drowning accidents can cause significant health problems and even death, according to several articles and reports reviewed in the literature review. The detection, prevention, avoidance, and automatic rescue of drowning deaths in swimming pools is a main aim of the thesis. It is feasible to address problems linked to drowning in pools by providing this system, which comprises drowning control techniques, drowning investigative techniques, deployment of detection equipment, and the creation of drowning risk-finding mechanisms, alerting, and automatic rescue. To evaluate drowning risks, researchers looked at real-time data from a range of scientific sources and used a variety of approaches. A completely autonomous and humanly controllable system has been designed to discover danger using electronic, electrical, computer science, and mechanical components, and it would be extremely helpful for both civilization and the real estate business to avoid all kinds of assets from drowning. The procedures required in developing a novel method for detecting drowning hazards have been thoroughly explained. The platform does not include all of the characteristics necessary to address drowning deaths in all types of water bodies, but it is expected to minimise drowning deaths in swimming pools. The researcher presented numerous strategies for detecting and avoiding drowning deaths, since it appears that dying from drowning is nearly impossible after implementing the recommended system. The authors have demonstrated numerous ways to design a low-cost and efficient gadget by selecting available components and intelligently connecting them. Device development success was reached by picking available components and effectively linking them, according to researchers in the area. The research team designed these devices to gather the information that can be used by the

system for avoiding drowning when possible and if that fails, to automatically rescue the individual and alert the appropriate authorities. Detailed contributions from this research are presented in the next section.

6.1 Major Research Contributions

The research presented presents a methodology for developing a fully or semi-automatic system for drowning death avoidance, alerting, and rescuing. In addition, it performs a comparative study of the workings of drowning detection devices and statistics to illustrate the importance of designing a novel intelligent system. In the aftermath, a transmitting device that can sense data was proposed. An analysis of the deployment of wired and wireless devices is presented in the research. The report presents a complete framework to use sensory data gathered by IoT in an intelligent way as an independent system, apart from analyzing different drown detection devices. A detailed description of the proposed system with real time implementation and animated illustration is shown in Figure 6.1.

6.2. Drown Avoidance Strategy

It has been attempted to avoid drowning at least in newly developing cities near indoor and outdoor swimming pools. The purpose of this thesis is to introduce a pattern for designing the swimming pool system to ensure drowning deaths are minimized. Mechanics, electronics, electrical, and computer science concepts are used to create the anti-drowning system. Research has been conducted on the structure of the anti-drowning mechanism to avoid accidents in many ways.

Chances of drowning in Various Patterns

The analysis revealed several numbers of drowning patterns. When the swimming pool is not attended by any lifeguard or skilled swimmer, kids and pet animals definitely approach the pool and might experience drowning accidentally. Another chance for drowning is when the swimmer might faint due to exhaustion or health problems. A person might fall into sleep while resting close to the swimming pool. A person who is learning to swim also

experiences frequent drowning and might die due to drowning when the supervisors fail to watch the scenario. A swimmer might encounter drown accident when alcohol drunken state.

6.3 Comparison between Devices for anti-drown systems

To make a comparison between devices for flood detection, the following steps have been taken:

- ♣ Design and development of existing **anti-drown** detection devices;
- ♣ Design and development of existing **anti-drown** rescue devices;
- ♣ Performance and design cost evaluation of devices of both modes for **anti-drown** detection and auto-rescue devices
- ♣ Comparison between proposed and existing wireless detection devices in dealing with the presented problem

At first, all the devices developed with advanced Arduino software were designed using breadboards that housed embedded single board computers and other components. The devices were compared on all dimensions, characteristics, and suitability for the application necessities. A low-cost device with high reliability was developed by the researcher based on the concept described in the literature. The accuracy, reliability, and robustness of the devices were tested with various samples. Breadboards, components, actuators, and Arduino Uno boards have been used to implement both kinds of devices. To verify the accuracy of these devices, the researcher collected data from all kinds of manufacturing sheets of sensors. To get a better understanding of the impact of such device deployment on the project budget, we used real-time prices to estimate the costs of materials. This exercise has resulted in comparison in chapter 4 between the cost of wired and wireless devices to conduct drowning detection and risk assessment, which impacts the budget. A cost comparison of individual devices in the chapter reveals that the proposed transmitting device and elevator lift were costly, but they suited the system's objectives and seem worth spending. Chapter 4 evaluates the advantages of the proposed automatic predicting, alerting, transmitting, and rescue

device with devices developed based on the existing concept based on assigning different scenarios to the system.

6.4. Deployment Strategies

It is important to find the right place to deploy the device because the deployment location, timing affect the performance, reliability, and cost of the proposed anti-drown system. The most important task is determining the best location when deploying devices since this determines how well and how much will be spent on the project. The researcher thus tried to figure out where to deploy, what devices to deploy at what timings in a variety of real-time scenarios in the swimming pool. The idea presented here is to develop an IoT system with a minimum cost, a minimum risk to life, maximum confidence in the reliability of the system, etc to achieve maximal benefits. The deployment strategy described here is based on exhaustively hunting the target in nearly all possible situations while assuming multilevel tactics. The design supports almost all possible drowning scenarios with multilevel detection scenarios and multi-level alerting mechanisms. The researcher attempted and succeeded in creating an autonomous system to predict the likelihood of drowning using data from things (sensors) after obtaining data from sensors. To calculate risk, a threshold is determined based on the different probabilities of drowning in different scenarios. By using this system, authorities can take appropriate steps to maintain public safety. In addition to automatic mechanisms to show risks and respond to them, this system also enables manual control and avoids false alarms. Based on the set timing for rules and the dependency of output on input, the proposed intelligent autonomous system will behave in different ways.

6.5 Significance of the presented thesis Work for the society

Statistical evidence shows that a lack of intelligent pool management systems, and intelligent decision-making strategies, contribute to drowning tragedies. According to reports, the automatic multi-level drowning avoidance systems are not well understood as to the nature of the technologies involved. The lack of drowning avoidance mechanisms, the lack of measurement, and the lack of perfection remain difficult problems. Identifying a suitable method of measuring drowning is challenging. By using an accurate risk finder system, this

study sought to investigate improving safety by minimizing loss by reducing drowning risk in advance. A suitable layer of a reference model that can detect drowning trends was found to be necessary for the development of an IoT-based mechanism to predict drowning risks. Following the successful development of low-cost, robust, and reliable recognition devices, the stages of a drown avoidance system were studied to determine what tasks needed to be accomplished in which way. Automated and manual phases consist of preparation, avoidance, detection, and recovery. The thesis' relevance can be understood through its application to drowning supervision in swimming pools. In the table below you will find the checklist indicating the tasks to be completed during each phase of the drown supervision system.

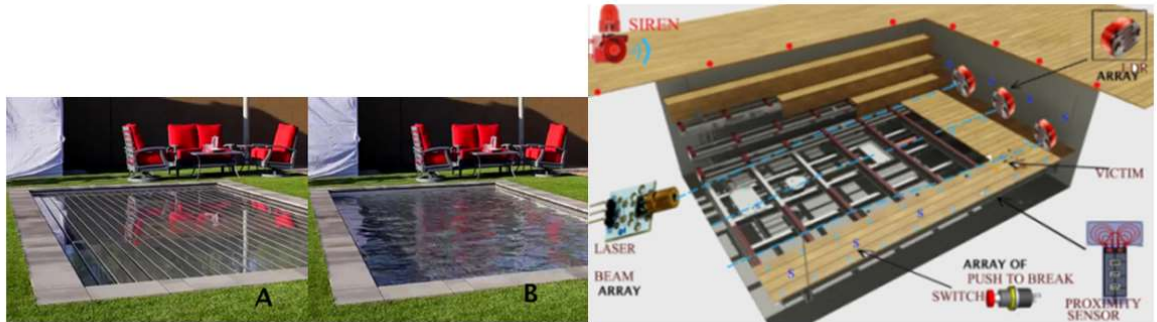


Figure 6.1. The real time prototype testing and corresponding graphical image illustrating cross sectional structure of the proposed system.

6.5 Performance Checklist

The following table shows how work is performed concerning the drown supervision and responsive System for any city (a checklist)

Table 6.1. List of innovative techniques implemented in the proposed design.

Phase	Checks	Tried in the Thesis	YES / NO
Avoid	Is there a barrier around the unattended pool?	Pool closes automatically after 60 minutes of no waves in the water.	YES

	Is the swimmer connected to a system that can alert authorities in the event of a suspected drowning disaster while swimming?	Inside the pool, a slew of panic switches are positioned to sound an alarm in the event of a suspected drowning.	YES
	Is there a plan to manually fence the pool?	By turning off the feature, the operator may manually close the pool entrance.	YES
	Is there any way to see if the system has any flaws before you use it?	The software now has a power-on self-test capability that allows it to run all of the available modules for a few seconds before settling into a ready-to-use state.	YES
Detection	Is there a sensor that detects the continuing drowning disaster automatically?	Inside the pool, proximity sensors are installed on the elevator surface to continually monitor the pool's bottom for the arrival of any drowned victims.	YES
	Is there another sensor that detects the continuing drowning tragedy auto?	A preset lateral horizontal cross-sectional region of the underwater space a few feet (selected) above the swimming pool's bottom is also continually monitored by LASER-LDR pairs.	YES
	Is it possible to use the sensors in unclean water (turbidity tolerant)?	Although lasers are not turbidity-tolerant, power loss in our application is minimal, and proximity sensors are trustworthy.	YES
Alert	Is the generating of alerts done automatically?	All of the sensors check for the condition on a regular basis.	YES
	Is it simple to manually	Manual triggering is possible in a variety of locations,	YES

	activate the alert?	thanks to panic switches installed both within and outside the deployments.	
	Is there more than one layer to the alert generation?	Multi-layered alert creation is possible thanks to two separate types of sensors and manual triggers.	YES
	Is the produced alert shown right away??	After reaching the threshold time, the created alarm is presented with alet lights and buzzer sounds..	YES
Response and recovery	Is a recovery procedure available once the alarm has been detected?	After the warning has been identified, the screw-jack lift system is offered.	YES
	Is there a multi-layered recuperation mechanism?	If the lift fails, a very slow drain mechanism is activated, which jointly informs the incident by sounding an alarm, flashing warning lights, and making a GSM mobile phone.	YES
	Is the recovery sub-system reasonably priced?	The screw-jack is the most expensive component of the system, although the hoist mechanism is inexpensive.	NO
	Is the expense of the recovery subsystem justifiable?	The screw-jack is costly, yet it raises the cost of building a swimming pool by 30%.	Yes

6.6 Significance of the presented thesis Work for the society

Research conducted will have significant implications, directly related to the following

- ❖ The proposed research work uses AI (Artificial Intelligence) and Embedded Processors (Like Raspberry-pie, PLC, IoT, etc) to prevent, avoid accidental drowning deaths.
- ❖ Focused on multilayered methods in saving drowning victims. Nothing is going to substitute the position of a lost person and only prevention of death is the best choice.

- ❖ Most vulnerable populations like old-age people, kids, and persons with seizures and fits disease will benefit from this system.
- ❖ Most of the existing drowning prevention avoiding, alarm systems were needed more improved AI, sophistication, and simplicity to construct.
- ❖ The ubiquity of drowning was much higher than what appeared in government statistics. Public negligence and lack of intelligent systems lead to day by day increasing number of deaths annually despite having so many gadgets and security systems. The people in the swimming pool will never guess or recognize if someone is in a panic situation, so the security system demands a large number of options to express and alert the panic situation of victims by properly using programming and technology.
- ❖ The algorithm developed to deal with drowning accidents is very novel and simple to understand and simple to implement since the existing systems completely failed to reduce the annual death rate due to drowning.
- ❖ The present algorithm does not depend on any complex image processing, image recordings, learning, or adaptation techniques.
- ❖ The proposed system has tried two different strong automatic rescue methods such as elevator and draining the pool, and four different alerting methods simultaneously which was never been tried in any invention.
- ❖ The Power-on self-test of the anti-drown systems were never been practiced in any invention so far.
- ❖ The present invention leaves very little scope of fault in detecting and rescuing drowning victims.
- ❖ The system exhibits a reliable and resilient architecture i.e if one subsystem fails, the remaining systems won't get affected.
- ❖ The proximity sensors used in the invention are immune to wear-and-tear since they were never been touched since the proximity sensor uses IR radiation to recognize newly arrived objects near to the sensor. Alternatively, any optical-shadow-detecting sensors or similar sensors can also be used in place of proximity sensors.

- ❖ The screw-jack linear lifting mechanism used in this invention was approved to be a successful mechanical structure in moving extremely large weights to very light weights and very smooth 3d-printing technologies.

6.7 Limitations Future Scope:

During the research, the researcher completed the task of developing an intelligent risk-finding system, the detection of drowning symptoms, and the automatic recovery for drowning victims. Among the limitations of this research are:

1. The system proposed cannot recognize living beings from non-living beings who are drowning. More research to find suitable thermal sensors which are effective in deep underwater environments. The researcher is trying with various thermal sensors in deep-water environments to identify living in the sensor proximity.
2. The researcher is working on LI-Fi technology to establish wireless sensors network in deep waters so the proposed system seamlessly communicates with the wearable reporting alerting devices on the human body transmitting body vitals such as heartbeat and blood glucose levels. So the system will automatically rescue the person underwater suffering from cardiac arrest or oxygen deprivation.
3. The cleaning of the elevator working under the swimming pool water is another challenge in the proposed system. Extra time and money are expected to maintain the proposed safety system.
4. Water turbidity is the major challenge to the effectiveness of the proposed system. More research is needed to solve the challenges involving opaque waters.

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	<u>JOURNALS & PATENTS PUBLICATIONS</u>
1	Laxman, P., Jain, A.: Analysis of novel assistive robotic multi-stage underwater lift design for swimmer safety. Journal of Engineering. 1–15 (2022). ESCI
2	Patent Name: “AN ELECTRO-MECHANICAL ANTI-DROWNING AUTONOMOUS RESCUE SYSTEM FOR SWIMMING POOL”, IN Patent App.No- 202111009202 ,Pillalamarri. Laxman , Dr. Anuj Jain
3	Pillalamarri.Laxman, Dr.Anuj Jain , “Intelligent Swimming pool design with smart Embedded Drown Alerting Preventing and Autonomous Life Rescue System”, International Conference on Computational Intelligence and Communication Technologies, IEEE. SCOPUS INDEXED
4	Pillalamarri. Laxman , Dr. Anuj Jain , “Automation Of Swimming Pools To Prevent Drowning Deaths Using Iot , Sensors And Unique Algorithm”, Webology (ISSN: 1735-188X), Volume 18, No. 5, 2021. SCOPUS INDEXED
5	Pillalamarri.Laxman, Dr.Anuj Jain “Drown Alerting Preventing And Autonomous Rescue System..”, <i>World Academy of Research in Science and Engineering(WARSE)</i> SCOPUS INDEXED
6	Pillalamarri.Laxman, Dr.Anuj Jain , “A review paper on Design And Performance Evaluation Of Drowning Death Prevention System With various technologies”, <i>Journal of Emerging Technologies and Innovative Research</i> , 2019 January 2019, Volume 6, Issue 1 - UGC CARE
7	Pillalamarri.Laxman, Dr.Anuj Jain , “Robust Drown Alerting Preventing and Autonomous Rescue System”, <i>The Scientific Bulletin of Electrical Engineering Faculty</i> .
8	Pillalamarri.Laxman, Dr.Anuj Jain , “A review paper on Design And Performance Evaluation Of Drowning Death Prevention System With various technologies”, <i>Journal of Emerging Technologies and Innovative Research</i> , 2019 January 2019, Volume 6, Issue 1 - UGC CARE
9	Pillalamarri.Laxman, Dr.Anuj Jain , “Swimming Pool Design with Drown Alerting Preventing and Autonomous Rescue System by Arduino-Uno array of Sensors with Multi-Layer Protected Intelligence”- ICICITES 2021 TN. SCOPUS INDEXED.
10	Pillalamarri.Laxman, Dr.Anuj Jain , “A Survey On Design And Performance Evaluation Of Drown Death Prevention Systems Embedded IoT”-Conference International Conference On Advance In Computing Communication , IIMT University Meerut.
11	Pillalamarri.Laxman, Dr.Anuj Jain , “A State of the Art of Drowning Death Detection and Prevention Systems with Various Communication Technologies and Discussion on their Performance”-Conference SMART “MODERNISTIC in ELECTRONICS AND COMMUNICATION - Hyderabad