TECHNICKÁ UNIVERZITA V LIBERCI
Fakulta strojní

Construction of manipulator for intelligent manufacturing system.

Diplomová práce

Studijní program: N2301 – Mechanical Engineering
Studijní obor: 2302T010 – Machines and Equipment Design

Autor práce: **Kaushik Pitty Surendranath**
Vedoucí práce: Ing. Radek Votrubec, Ph.D.

Liberec 2017

TECHNICAL UNIVERSITY OF LIBEREC
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Master thesis

Study programme: N2301 – Mechanical Engineering
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Author: **Kaushik Pitty Surendranath**
Supervisor: Ing. Radek Votrubec, Ph.D.

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DIPLOMA THESIS ASSIGNMENT

(PROJECT, ART WORK, ART PERFORMANCE)

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Rules for elaboration:

1. Describe basic principles of Industry 4.0.

2. Meet Arduino development board, its accessories and its shields.

3. Construct a manipulator for smart factory model controlled by Arduino which is able to move small subjects.

Scope of graphic works:	**as required**
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[1] BEQUETTE, B. Process control: modeling, design, and simulation. Upper Saddle River, N.J.: Prentice Hall PTR, 2003. ISBN 0133536408.

[2] Arduino Learning: Getting Started with Arduino. In: Arduino [online]. 2014 [cit. 2015-01-09]. available from: http://arduino.cc/en/Guide/HomePage

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Liberec, dated: 1 November 2016

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Současně čestně prohlašuji, že tištěná verze práce se shoduje s elektronickou verzí, vloženou do IS STAG.

Datum: 23-05-2017

Podpis: P. S. Kaufhold

TÉMA: KONSTRUKCE MANIPULÁTORU PRO INTELIGENTNÍ VÝROBNÍ SYSTÉM

ABSTRAKT:

V této diplomové práci jsou řešeny tři hlavní úkoly. První částí je návrh a výběr vhodného robota, který je schopen provádět požadované operace přemístění předmětu.Druhou částí práce je výběr vhodné desky Arduino podle počtu vstupních a výstupních pinů, které jsou potřebné pro danou operaci. Třetí částí práce je programování. Programování robota se provádí pomocí softwaru Arduino. Programovací prostředíArduino je jedním z jednoduchých programovacích jazyků pro práci robota. Pomocí programu lze zadat požadovaný pohyb robota.

Tato práce využívá koncepci průmyslu 4.0. V této práci byla provedena konstrukce manipulátoru - robotického ramene, které je komponentem ve smyslu průmyslu 4.0. Tato diplomová práce pomáhá modelovat situace dosažené v rámci koncepce Industry 4.0. Tento robot je součástí modelu platformy představující budoucí internet věcí v průmyslovém prostředí prostřednictvím koncepce Industry 4.0. Budoucí vývoj lze nastínit tak, že automatizace bude považována za faktor rozvoje průmyslu pro dosažení produktů s nižšími náklady a vyšší kvalitou bez ztráty času a výrobních ztrát.

"*Svět, jak jsme ho vytvořili, je proces našeho myšlení. Nemůže být změněn bez změny našeho myšlení.* "

-Albert Einstein

Klíčová slova: Průmysl 4.0, Inteligentní továrny, Kyber-fyzikální systémy, Internet věcí, Manipulátor - Robotickáruka, Automatizace, Arduino.

.

THEME: CONSTRUCTION OF MANIPULATOR FOR INTELLIGENT MANUFACTURING SYSTEM

ABSTRACT:

In this thesis, the work is based upon three parts of the tasks. First part of the task is selecting of the suitable design of the robot, compatible to the operation that we need to perform in the task. The second part of the thesis work will be selecting of the suitable Arduino board as per the number of inputs and output pins that are required for the operation. The third part of the thesis is the programming. The programming for the robot is done using the Arduino software. The Arduino lanuage of programming is one of the simple programming language for the working of the Robot. The coding will be reflected in the motion of the robot through the Arduino board connected to the robot.

This thesis develops a framework for the Industry concept 4.0. In this work, the construction of manipulator - Robot arm has been made which acts as the part of Industry 4.0. This dissertation helps to stimulate the needs of achievements within the concept of Industry 4.0. The results of this dissertation conclude the theme that this is only the beginning of the construction of the platform to present the future Internet of Things in the Industrial environment through the concept of Industry 4.0. The future development of the thesis can be prolonged in a way with considering automation as a factor of development in the indutry for the achievment of the products with less cost and higher quality without loss of time and production losses.

"The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking."

-Albert Einstein

Key words: Industry 4.0, Smart factories, Cyber Physical Systems, Internet of Things, Manipulator - Robot Arm, Automation, Arduino.

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It is with immense pleasure and gratitude that I acknowledge the support of my university for providing me this great opportunity to develop in the deepest manner my engineering skills for accomplishing this diploma thesis and help me to further develop the knowledge on the Industry concept 4.0 with the latest trends being used.

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IOT - Internet of Things.

CPS - Cyber Physical System.

ITS - Intelligent Technical System.

AI - Artificial Intelligence.

AC - Alternating Current.

DC - Direct Current.

1 Introduction

The world which is running in a competitive environment filled with day to day innovations and growth have seen a lots of transformations. By this phrase, I would like to quote that communication and transmission of knowledge has been made realtime through the usage of the latest technological developments. The developed countries has reached a position where they are able to frame the path of competitive industrial innovation through which the global market are developing in all the industrial sectors.

The concept behind this thesis work is to create a working robot for to be used as a part of the Industry concept Industry 4.0. The working concept of the industry 4.0 is based upon the automation achieved through computational techniques. Industry 4.0 introduced the term called as the "smart factory" which is based upon the complete automation. Smart factories, which will be the main frame for all the industrial sectors operating in Industry concept 4.0, will take over the information and communication technology for an evolution in the supply chain and production line that would help to achieve mich higher level of both automation and digitization. It refers to the machines using self-optimization, self-configuration and artificial intelligence to complete complex tasks in order to deliver vastly low cost efficiencies along with better quality goods or services.

The main aim of introducing the Industry Concept of 4.0 is to achieve the results that was not be able to achieve 10 years ago. This thesis work plays a part in the concept of Industry 4.0 helping in to create manipulator for the moving of subjects within the working environment of the industry. The manipulator which is being used in this thesis is the robot arm, is being placed at one place in the Industry and helps to move the objects by usage of the grippers and movement takes place by the activation of each servo at different positions or angles of the arm. The operation is carried out by the sequence given by the programming to the robot through the Arduino board. The manipulator functions as a pick and place robot for placing the objects into the vehicle. The reaching range of the arm is fixed by using the limit switches at the end, which helps to fix the manipulator's end position.

2 Evolution of the Industrial concept of 4.0

Industry 4.0 refers to the fourth industrial revolution which was arised for the improvement of the techniques and process in the industries. Industry 1.0 which was the outcome of mechanization lead its way to the Industry 2.0, which was majorly focused into mass production, finally came the introduction of automation into the industry through the concept of Industry 3.0, and now for the present generation comes the Industry concept 4.0, in which technologies influences the business and helps for the growth among the competitive environment with complete automation technologies[1].

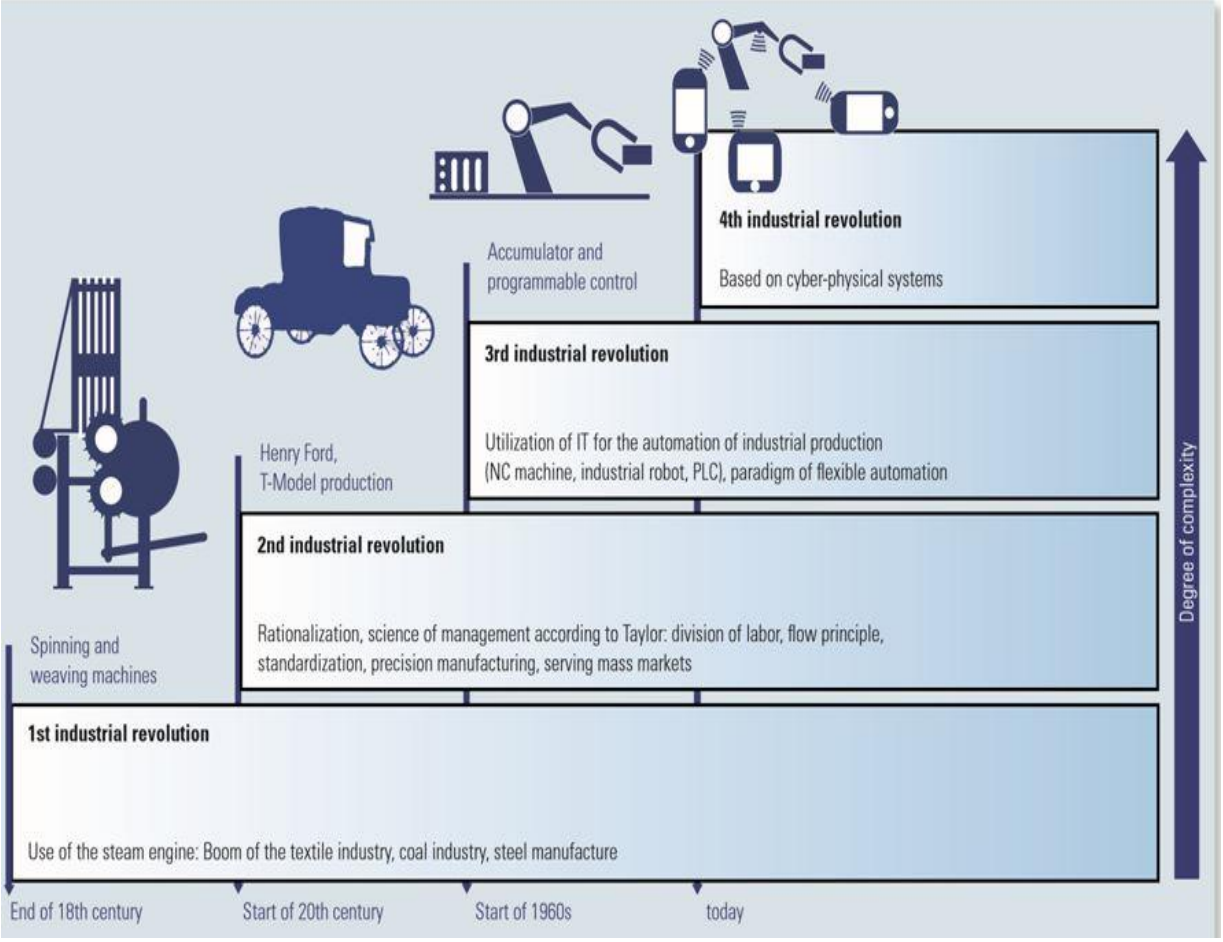

Figure 1. Historical Development of Indutrial Production[1]

2.1 Developments of Industrial Revolution - Overview

The development of industrial revolution started in stages as it began first from the first Industrial revolution which was brought up as the reason for the process of Mechanisation, which had a major impact on the manufacturing process, leading to the decline in the use of human labour, which was replaced by the machines[2].

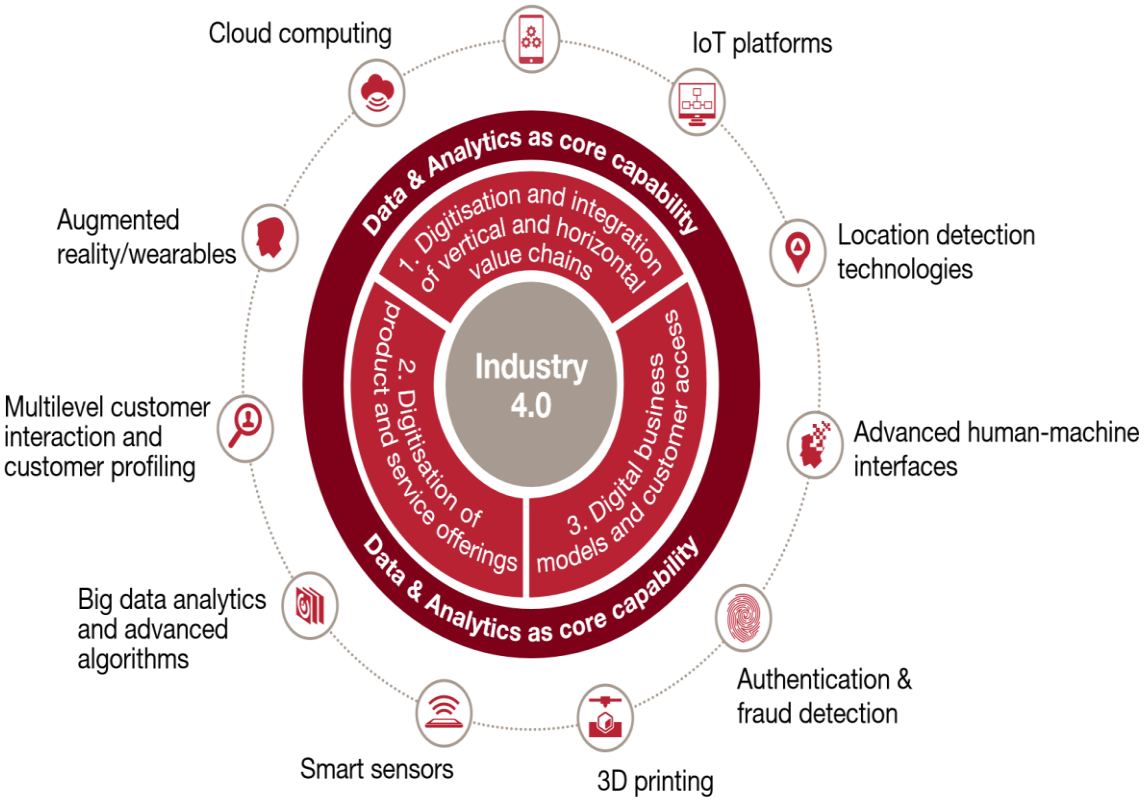

Figure 2. Framework of Industries contribution to Industrial revolution[2]

The Industrial revolution 1.0, was just a start for the revolutionary changes in the industries. The new method of producing more products in large number of batches, which was called as the Mass production came into existance. The mass production helped in a way to produce a lots of goods or products in a continual process. The introduction of mechanisation in the industrial revolution 1.0 was the key for the process of mass production through which the new methods were implemented. The Industrial concept 3.0 which was the next in the pathway was having a great impact in the manufacturing industry. The Industrial concept of 3.0 brought up the impact and the

concept of Automation into the manufacturing Industry, which was a very big change or revolution in the Indutrial concepts[1].

The major impact of Industry concept 4.0 puts its way into the industry of manufacturing systems after the Industry concept of 3.0 brought up the concept of Automation into the Industry[1]. The automation was further more developed into a more broader aspect called as the interlinking of the machines within a factory which was called as the, interlinking of the machines by the automation.

The main aspects for a factory or system to be considered Industry 4.0, are:[3]

- **Interoperability** — which is called in other word as the interconnection of the machines, devices, sensors and people that connect and communicate[3].
- **Information transparency** — It is the process in where a virtual copy of the physical world is created through a sensor data in order to summarize information between the systems[3].
- **Technical assistance** — It refers to both the ability of the system to support humans in decision making and problem solving and also ability to assist humans with tasks that are out of human control or unsafe for humans[3].
- **Decentralized decision-making** — The decentralizing here means the function of a cyber-physical systems to make simple decisions on their own[3].

  Industry4.0 has always been an added advantage in the industrial sector helping to reduce the loss in major factors like the time, things, people, cost within the industry. Industry 4.0 saw its biggest hype in the year 2013, which made a lots of people to invest and obtain the results. The level of digital production and technologies is highly being developed and it is expected to be at a postion twice than that of now by the year 2020[2]. Customization will be made very easy, all the products will be customer based. Customer will be at the center of the value chain that is being changed by the developments[2].

3 Smart Factory

Smart factory - It is the indutrial concept where the product innovations will be made from the creative use of smart manufacturing intelligence gathered from every point, from consumer preferences through production and delivery mechanisms.

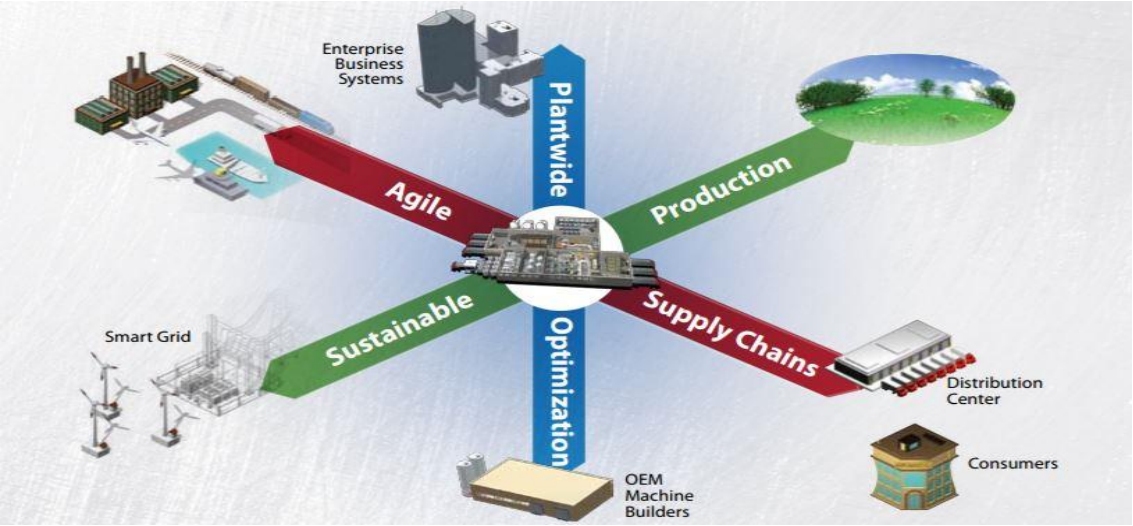

Figure 3. Representation of Smart manufacturing[4]

Charcteristics that are deisrable for smart factory[5]:

- Flexibility.
- Re-configurability.
- Low Cost.
- Changeability.
- Agility.
- Slenderness.

Based on the above mentioned characteristics, the conceptual definition for the smart factory can be stated as a factory that is able to provide manufacturing solutions that are flexible and adaptive production process, which helps in solving the problems arising from the production facility that is dynamic and rapidly changing in the competitive world of indutries[6].

3.1 Cyber physical systems - New era of Production

Cyber Physical System is the platform where the new generation of systems that are capable of integrating the physical abilities in a system with the computer. The industries that are using the cyber physical system are capable of providing the new revolution of Indutry 4.0, which is based on the access to the Internet and Physical Systems[7].

Basic Platform for the Cyber Physical Systerms are[5]:

- Integration of the Wireless System.
- Wireless control System.
- Machine learning.
- Production - based on the sensors.

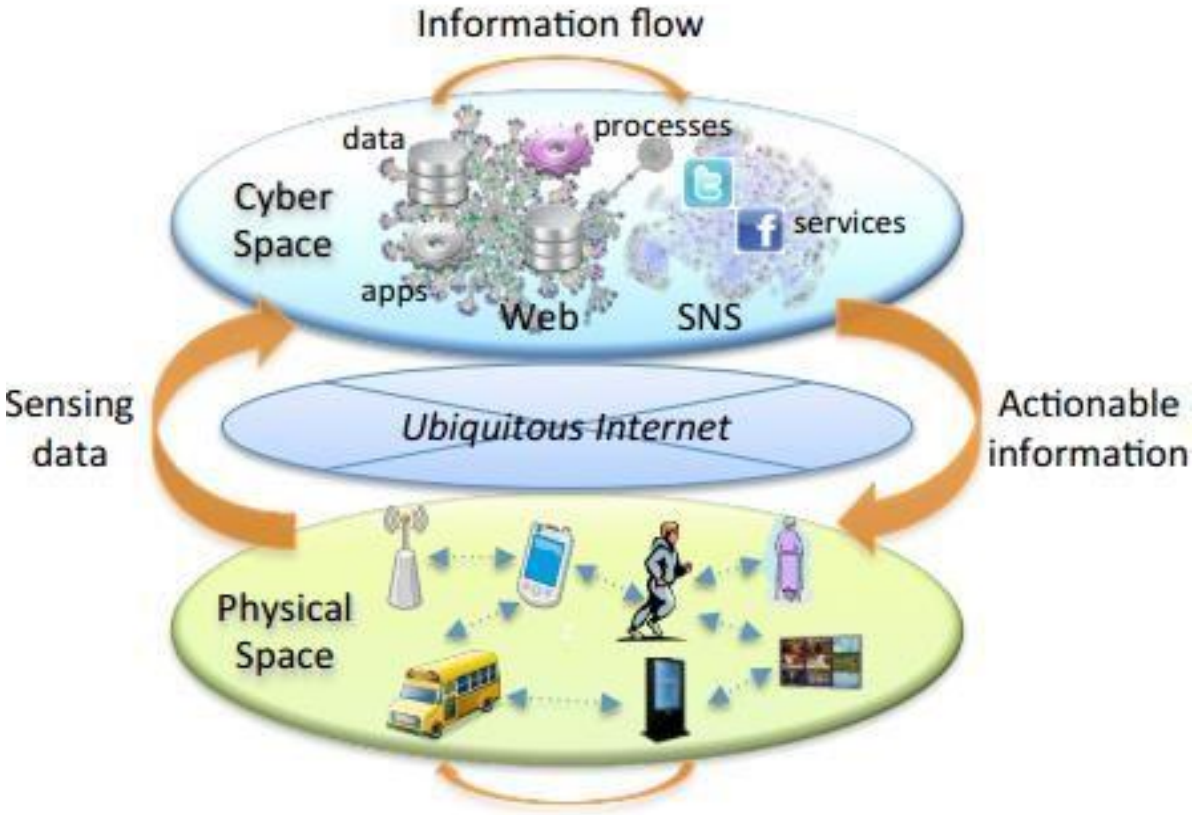

Figure 4. Flow of information between physical and Cyber world[5]

The charcteristic development of the cyber physical systems are [5]:

- Better usage of Computing power.
- Development in the Communication Technologies.
- Improved control mechanism.
- Improving Production process.
- Wider prospective view in the decision making process.

In a more better way the Cyber physical System(CBS) can be made clear as a method or process in which the man made systems and the natural systems are being integrated by the usage of computation, communication and control systems[8].

The various sectors which are influenced by the Cyber Physical System are :

- Automotive.
- Aerospace.
- Civil.
- Railways.
- Medical field.
- Manufacturing sector.

The recent development trends in the technology,when being taken into fact, then comes the technological developments like Sensors, data acqisition system, computer networks and cloud computing, which are a major part useful for the design and implementing of the cyber physical system in most of the indutrial sectors[8]. The integration of CPS in the fields of Production, logistics and services would provide a systematic way of approaching the shop floor with shear intelligence, helping to achieve loss of time and prevent production losses. The features that will be improved in the implementing of the CPS are, self awareness - which helps in the reducing of major production loss,

self - adaptability - helping for the changes that occur in the shop floor especially during changes in the design or process of production. These features when implemented in a perfect way, would tranform the today's factories into Indutry concept 4.0 factory[8].

3.1.1 Cyber Physical System Architecture:

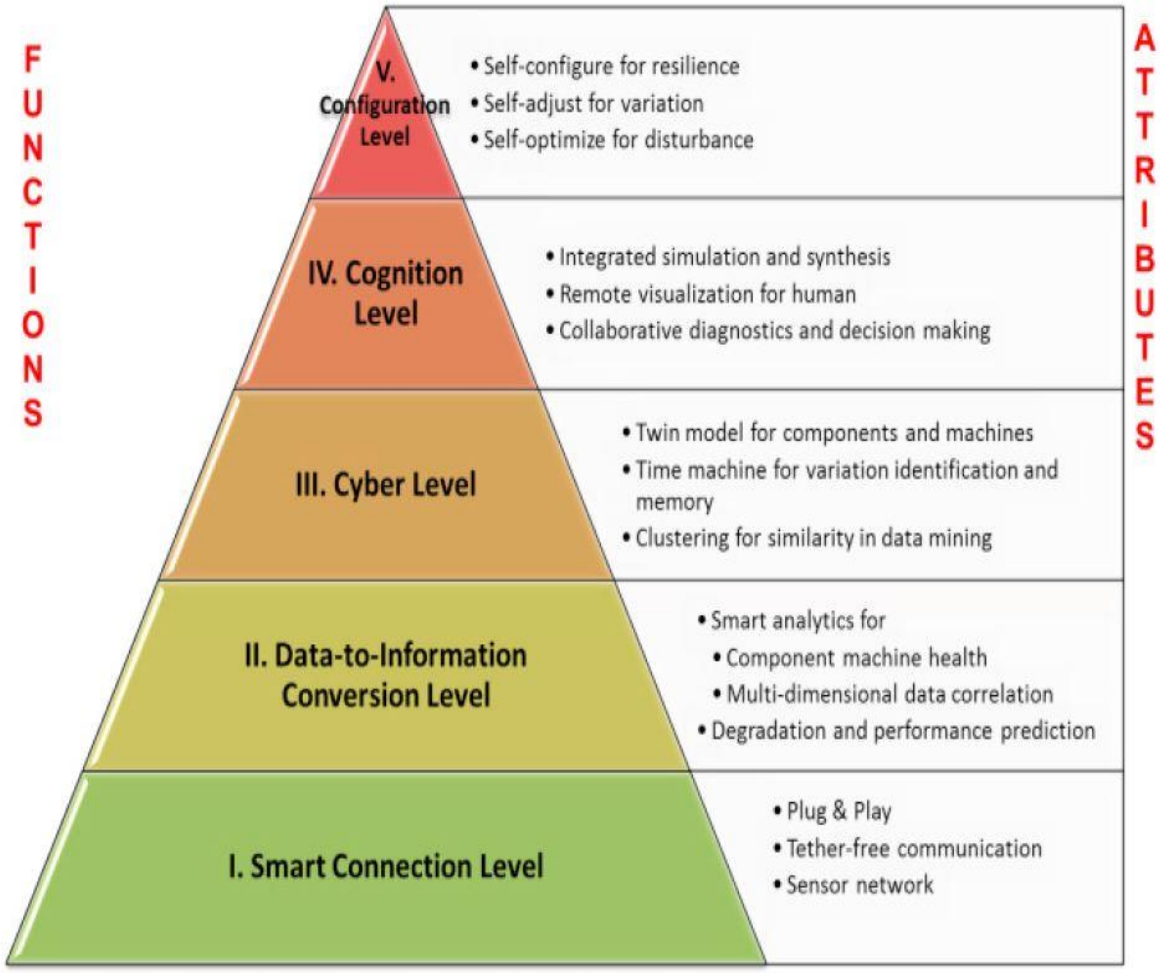

Figure 5. Cyber Physical system in Manufacturing[8]

The Figure above illustrates the methodologies used for the implementing the CPS into the factories.

SmartConnection - The data that is being measured by a sensor which is being controlled by a controller, forms the first and foremost procedure or step in the developing of Cyber physical systems. The major aspects that needs to be covered in the system are the various types of data that is being measured and also the type of sensor used to measure the data[8].

Data to informataion convesion - The data convesion plays a major role in the implementing of CPS into the factory. The data convesion is being done by using several methods and tools in present factories. The major aspect of data conversion is that, it brings Self-awareness to the machines[8].

Cyber - Cyber is the centre for the information that is being gathered in the previous step. The information gathered helps to do a better comparison of the machines in the environment, the comparison will be done based on the performance and the output information gathered from each and every machine. This comparison, helps in a better way to prevent the loss that may occur in the future, by the problems that may arise in the machinery, which will be helpful even to predict the future behaviour of the machines[8].

Cognition - From the previous level, since the comparative information and the invidual information of the machines are available, the prioritizing of the work to be done can be achieved easily for better maintenance. This level helps also to get a good knowledge about the monitored systems [8].

Configuration - This level acts as the supervisor for all machines to be self-configured and also self-adaptive to the changes that is being monitored in the cognition level. It also helps to apply the corrective and the preventive measures that needs to be implemented for the monitoring of the system[8].

3.1.2 Intelligent Technical Systems - Internet of things

The four main properties of the Intelligent Technical Systerm are:

- Adaptive.
- Robust.
- Preditive.
- User-Friendly.

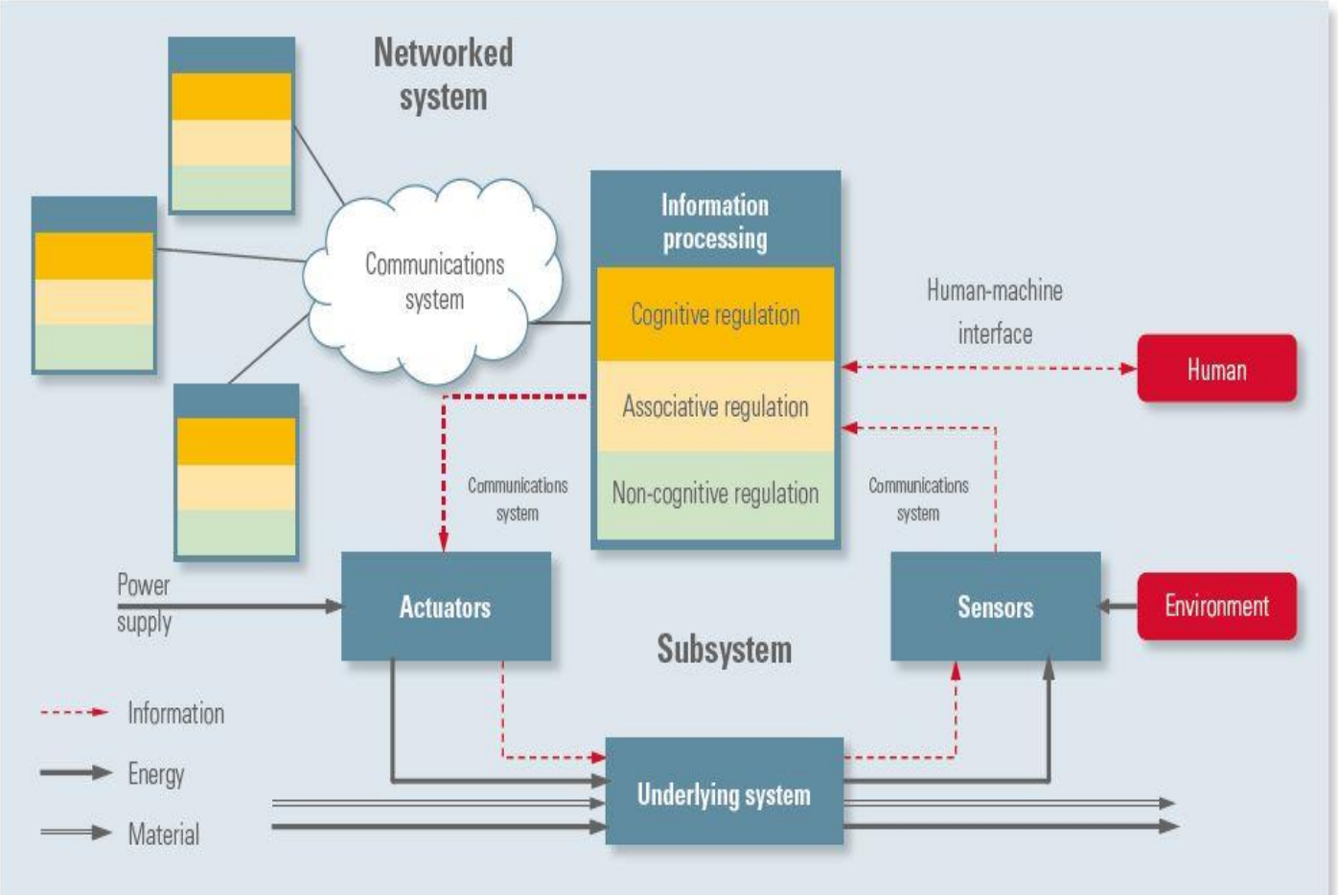

Figure 6. Technological Concept of Intelligent Technical System[1]

In the above mentioned figure, the major part of the system lies with the four units namely Underlying system, sensors, actuators an information processing technology. Information Processing Technology plays a major role here in the obtaining of the information via communication technolgy by the help of sensors. Mechanical Structures are always playing the role of underlying system[9]. The concept behind the technology of Intelligent Technical Systems is the capability of the system to adapt based on the funtionality and the process that has to be carried out. The individual systems are created in a way to support the networked system in the Intelligent Technical System[1].

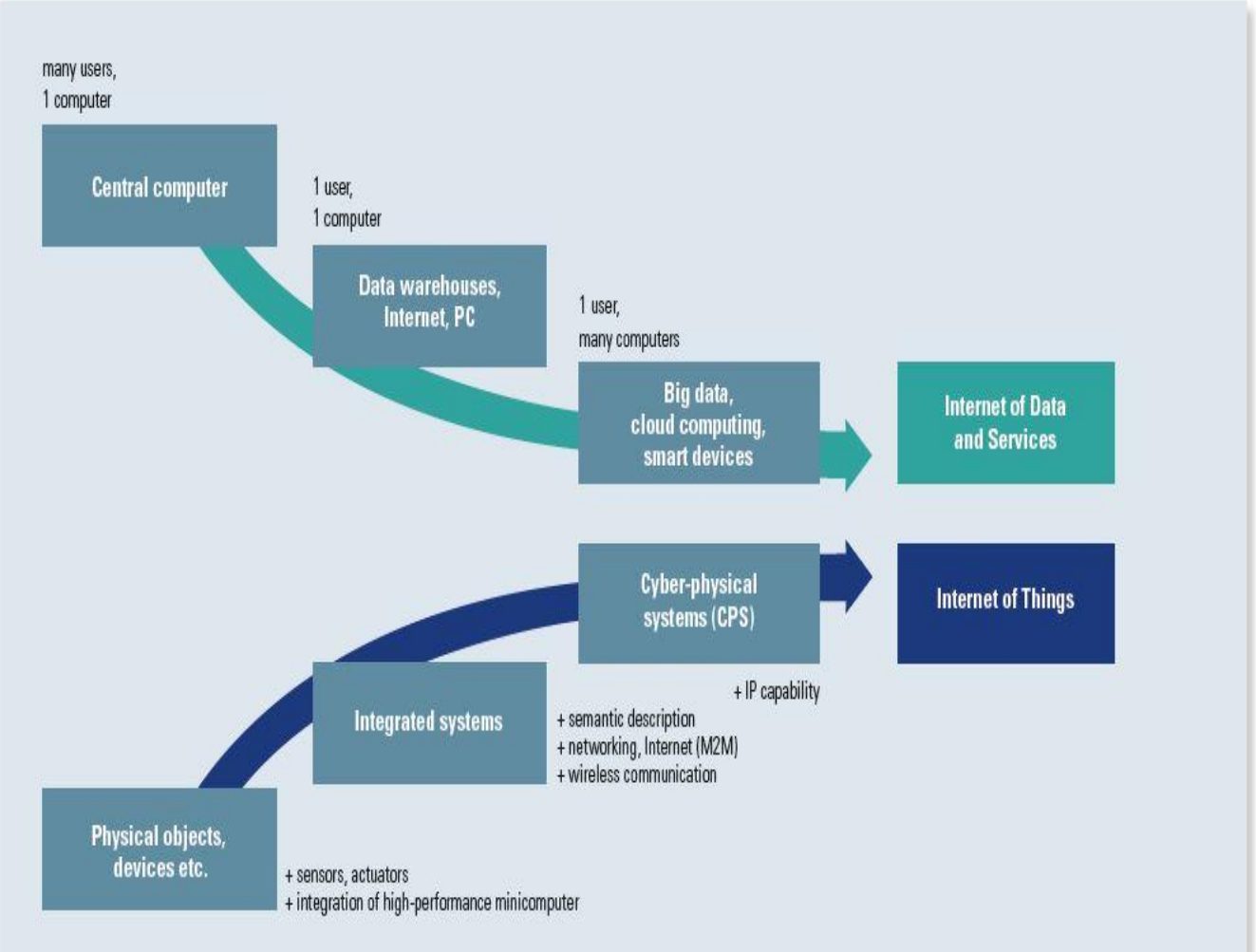

Figure 7. Implementing of Intelligent Technical System[1]

The above shown figure 7. shows in detail about the way and method in which two parallel converging development strands of innovation that are being merged together by the method of Intelligent Technical system and also with the help of Internet[1]. Internet of things is always the result of the concepts of technologies that has been mentioned above. The communication between the physical environment of the objects such as the various departments of a factory are taking place through Internet. The increasing demand and offers that are being provided by the internet based services can be done at a faster rate by implementing the Internet of things. Innovation in the services and also the opportunity growth can also be acheived by using of the technological concept of Internet of things[10].

Figure 8. Application of Smart/ Intelligent Systems[1]

4 Arduino - Electronic Platform

The term Arduino refers to the software platform, which is open in source for all its users. The operations in the Arduino board can be made by using the software provided by the Arduino company. The Arduino board can be controlled by sending a set of instructions by using the Arduino Programming Language. The simple method of

programming, has created a lots of interest among students and researchers to get binded with the Arduino[11].

Arduino came into the world existance with the main purpose of helping the students, who are not having a good knowledge and background in electronics and programming. The developed purpose of the Arduino was to help those students with fast prototyping, but with the opportunity of entering a wider community, Arduino started to adapt for the new challenges and needs that were arising in various Industrial sectors[11].

The major benefits of using Arduino over other softwares are[11]:

- The working process is simple and easily understandable.
- The low cost of the Arduino boards, helps to do the projects in a inexpensive way.
- The major benefit of the Arduino is that, it works on all the operating system platforms, which helps all the users, to work with Arduino in a easier way.
- The Arduino programming being simple and clear, is designed for people who are amateur in programming and also for the experts.
- The extensible software feature of the Arduino has added a great benefit for the users, who use a different proramming language. Arduino can also be expanded with the other programming language libraries, like the C and C++. This adds a special demand for Arduino among the experienced programmers.
- On the other hand, the extensible hardware usage of the Arduino boards is also a added value for the Arduino. The open source license of the Arduino, helps programmers and also Circuit designing experts to make their own customizable product of the Arduino board, which helps in improving and extending the growth of Arduino.

4.1 Arduino Board - A quick overview

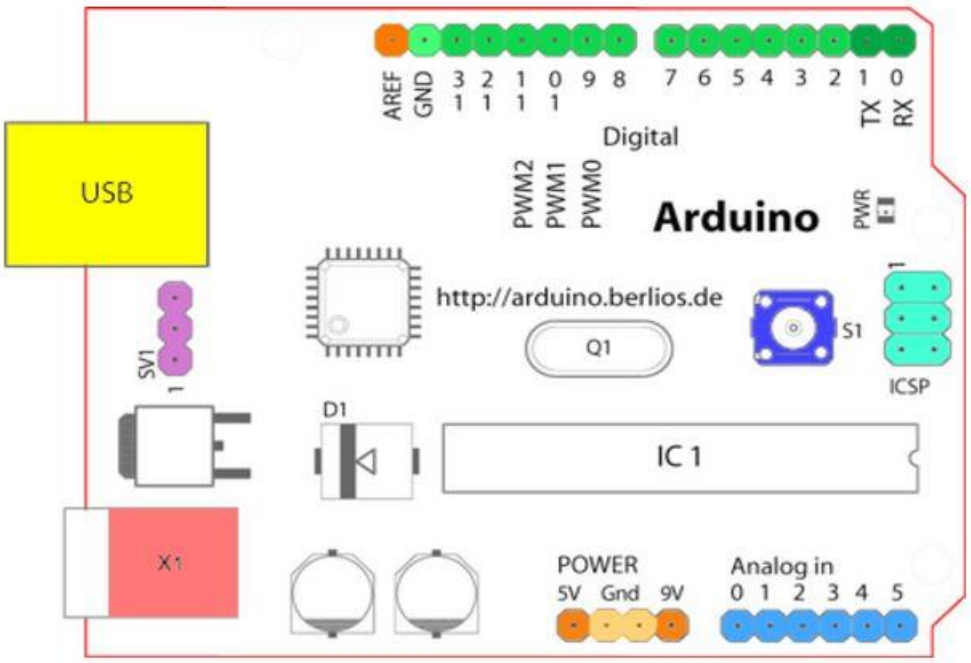

Figure 9. Arduino Board - Basic[11]

The basic overview of the Arduino board is being explained in the following points[11]:

- Analog Reference pin (orange)
- Digital Ground (light green)
- Digital Pins 2-13 (green)
- Digital Pins 0-1/Serial In/Out - TX/RX (dark green) - *These pins cannot be used for digital i/o (*digitalRead *and* digitalWrite*) if you are also using serial communication (e.g.* Serial.begin*)*.
- Reset Button - S1 (dark blue)
- In-circuit Serial Programmer (blue-green)
- Analog In Pins 0-5 (light blue)
- Power and Ground Pins (power: orange, grounds: light orange)
- External Power Supply In (9-12VDC) - X1 (pink)
- Toggles External Power and USB Power (place jumper on two pins closest to desired supply) - SV1 (purple)

- USB (used for uploading sketches to the board and for serial communication between the board and the computer; can be used to power the board) (yellow)

Digital Pins - The main purpose of the digital pins on the Arduino Board is that they are used for the switching ON and OFF, HIGH or LOW using the pinmode command and digitalread or digitalwrite commands, when the pin is configured. The powers supply that can be provided to the pin is about 40mA(maximum)[11].

Analog Pins - The main feature of the Analog pins are that they support 10-bit analog to digital convesion using the analogRead function. The analog inputs can also be used as the digital pins[11].

Power Pins - The normal input voltage given to the Arduino board using an external power supply is 5V by using a USB or a regulated power source, but for different boards the power supply varies according to the required input voltage of the boards[11].

Other Pins - These pins are used for providing a reference voltages for the analog inputs using the command analogreference(). It is also used to RESET the sheilds, which block one on the board[11].

4.1.1 Arduino Mega 2560

The concpet of Arduino Mega came from the ATmega2560. The 54 digital inut/output pins, out of which 15 can be used as PWM outputs, 16 analog inputs, a 16 MHz crytal oscillator, a USB connection, a power jack, an ICSP header and a reset button. The power source for the board can be given by using the AC - DC adapter or a battery. The advantage of the Mega 2560 board is that, its compatible with almost all the sheilds designed for other boards[11].

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

Table 1. Technical Specifications of Arduino Mega2560[11]

The programming, part of the Arduino can be done by using the Arduino Software. Additional feature of the ATMega2560 is that, it comes with the bootloader which enables the users with uploading of new codes without the usage of any external harware programme[11].

The safety feature of the ATmega2560 is that, it comes with a resettable polyfuse, which helps protecting the USB port of the computer , when the voltage excceds 500mA. The connection breakge is done by this safety feature, until the high

voltage or short circuit is removed[11].

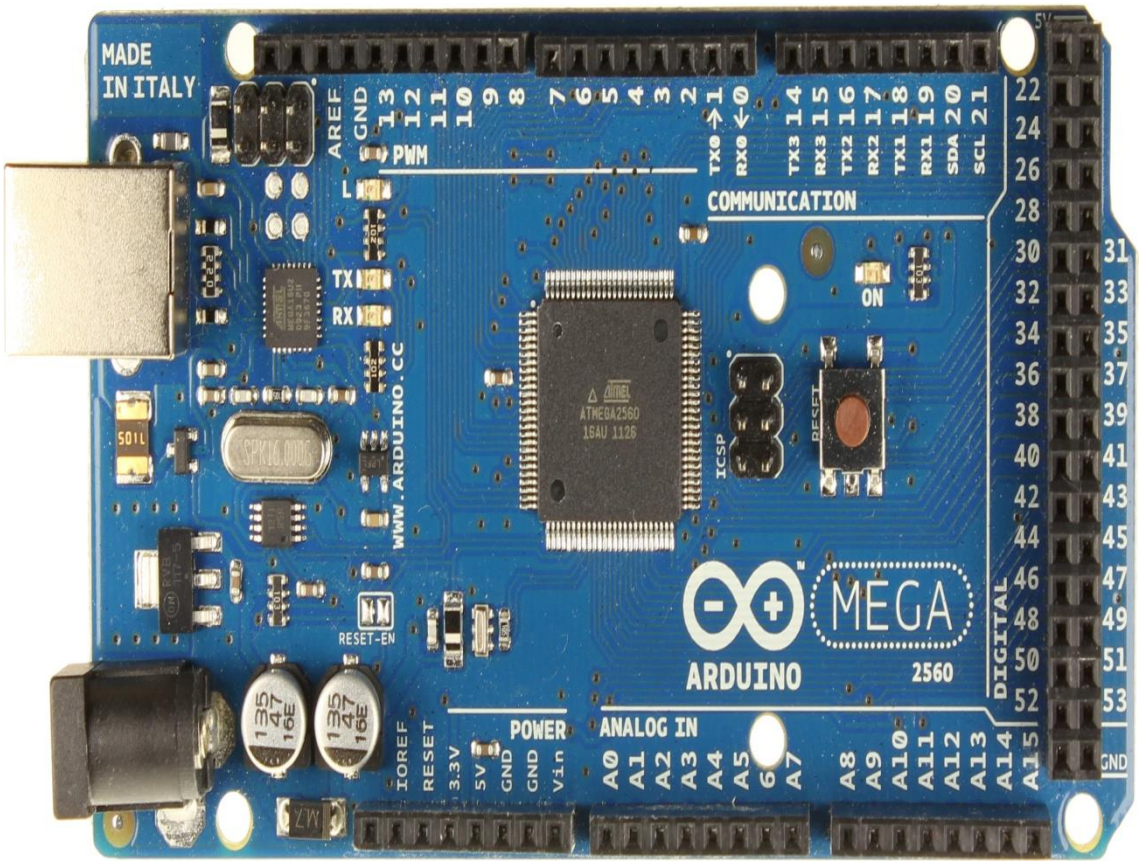

Figure 10. Arduino Mega2560[11]

The powersupply to the Mega2560 can be given using the USB power supply from a the PC and also the Mega250 also supoorts the power supply given by the external power source. The Mega2560 has the added advantage of detecting the power supply source, whether the power supply is being given from the USB or non USB source using the AC-DC adapter or battery. The operating power supply to the board can be from 6 to 20 volts[11].

There is also a condition where the board becomes unstable, if the power supply is given below 7V, and if the power supply is more than 12V. overheating occurs and the board is damaged[11].

The power pins of the board are:

- Vin - When using an extrnal power source such as USB or via a power jack, this pin can be utilised for suppying the voltage[11].
- 5V pin - The function of this pin is to regulate output of 5V from the regulator on the board. The power supply can be provided to the board through a DC power jack or through a USB connector but not through the 5V pin, which damages the board if power supply is given through the 5V pin[11].
- 3V3 - THe currect which can be drwan from this pin is maximum of 50mA[11].
- GND pins - Helps for the grounding[11].
- IOREF - This pin acts as a refrence in the board. This helps in acting as a voltage refernce at which the microcontroller operates. The sheid if properly configured, can select the appropriate power source needed or can even activate the voltage translators for the outputs working with 5V or 3.3V[11].

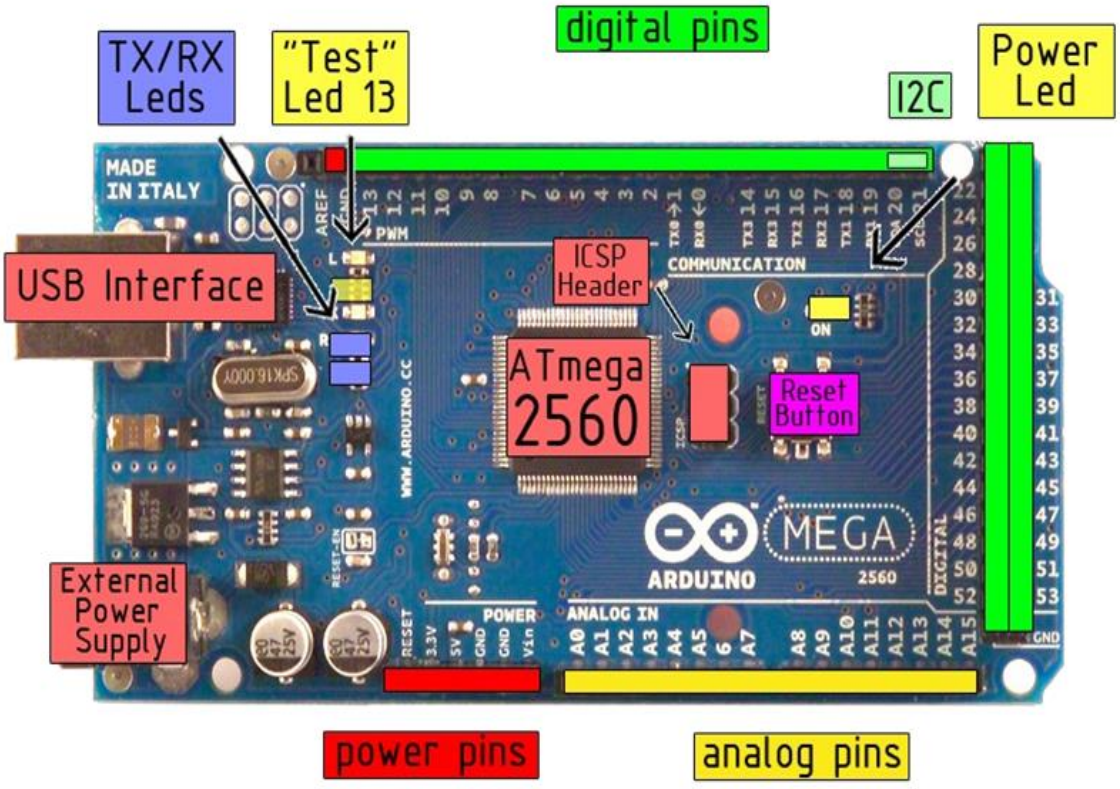

Figure 11. Arduino Mega2560 - Detailing of Pins[11]

The added advanctage of the Mega2560 is that all the 54pins can be used as the Input or Output, using the commands pinmode(), digitalwrite(), digitalread() functions[11]. The internal pull up resistor of 20-50 k ohm is being given with each pin in Mega2560 and the voltage each pin can recive or give is about 20mA, which is stated as the recommended operating condition. The safety value or the maximum value that must not exceed is 40mA[11]. The Mega2560 has also the 16 analog inputs, which act as provider of 10 bits of resolution. It is possible to change the upper end of the range using the AREF pin, although the default measuring is from 5v to Ground[11].

The board Mega 2560 consists of various ways of communicating with other devices like the computer and other micro controller board[11]. The hardware UARTs are four in number provided by the Mega 2560 helping to do the serial communication[11]. In addition to this, a software serial library allows for serial communication of any of the Mega 2560 pins[11].

The physical charcteristics of the Mega 2560 are[11]:

- Length of the board Mega 2560 PCB is 4 inches[11].
- The Width of the PCB board is 2.1inches[11].
- USB an power jack are extending beyond the length of the board[11].
- Attaching is made easy by usage of three screw holes provided[11].
- The distance between the digital pins are less 0.16 inch[11].
- Mega 2560 is compatible with most of the other sheilds designed for older boards[11].
- Serial Peripheral Interface(SPI) is available through ICSP header in the Mega 2560[11].

The major feature of the Mega 2560 is that it does not use a physical reset button before the upload, it has been designed in a way that it can be reseted by the software running on a connected computer[11]. The Mega 2560 when connected with the a PC running on any operating system, resets by itself each time when connected through USB[11]. There is a feature even to disable the auto reset by the help of connecting the 110 ohm resistor from the 5V to the reset line[11].

Advancements of latest Mega 2560 comapred to old ones[11]:

- The design of FTDI USB-to-serial driver chip is not being used in Mega2560[11].
- It has a resistor, which can be used for pulling uo the 8U2 HWB line to ground, helping it and making it easier for the Firmware updating[11].
- Stronger Reset Circuit[11].
- Tha additional of two more Pins have been placed near the Reset pin namely SDA and SCL pins[11].
- The future sheilds will be compatible both with the boards AVR and ATSAM3X8E that use 5V and 3.3V respectively[11].
- The replacing of the 8U2 has been done by the Atmega 16U2[11].

5 Function of the ROBOT ARM in concept of Industry 4.0

The entire concept of Industry 4.0 is being done as a prototype to show as illustration, how the real thing would be based on the new technologies used in the various sectors of the Industry. As a contribution to this proposed design, my part of the thesis is based on the function of the Robot arm used in the entire concept of Industry 4.0.

The basic frame work of this concept consists of a SQL server, which acts as the Cloud or the primary information center for the concept from which the information is passed to every part and vehicles operated in the entire concept of Industry 4.0. This SQL server even acts as the information storage system and also as the backup of all the data and details needed for the operation and also for the maintenance of the past records.

The major source of information like the operation of the vehicle in coordination with other vehicles and also the robotic arm are all stored in the server and acts as a data source when the operation is performed. During the functioning of the factory, these information is being sent to the vehicles and all other parts through wifi or by bluetooth

modules. These modules are the source of communication between the two ends where the information needs to be communicated at the right time.

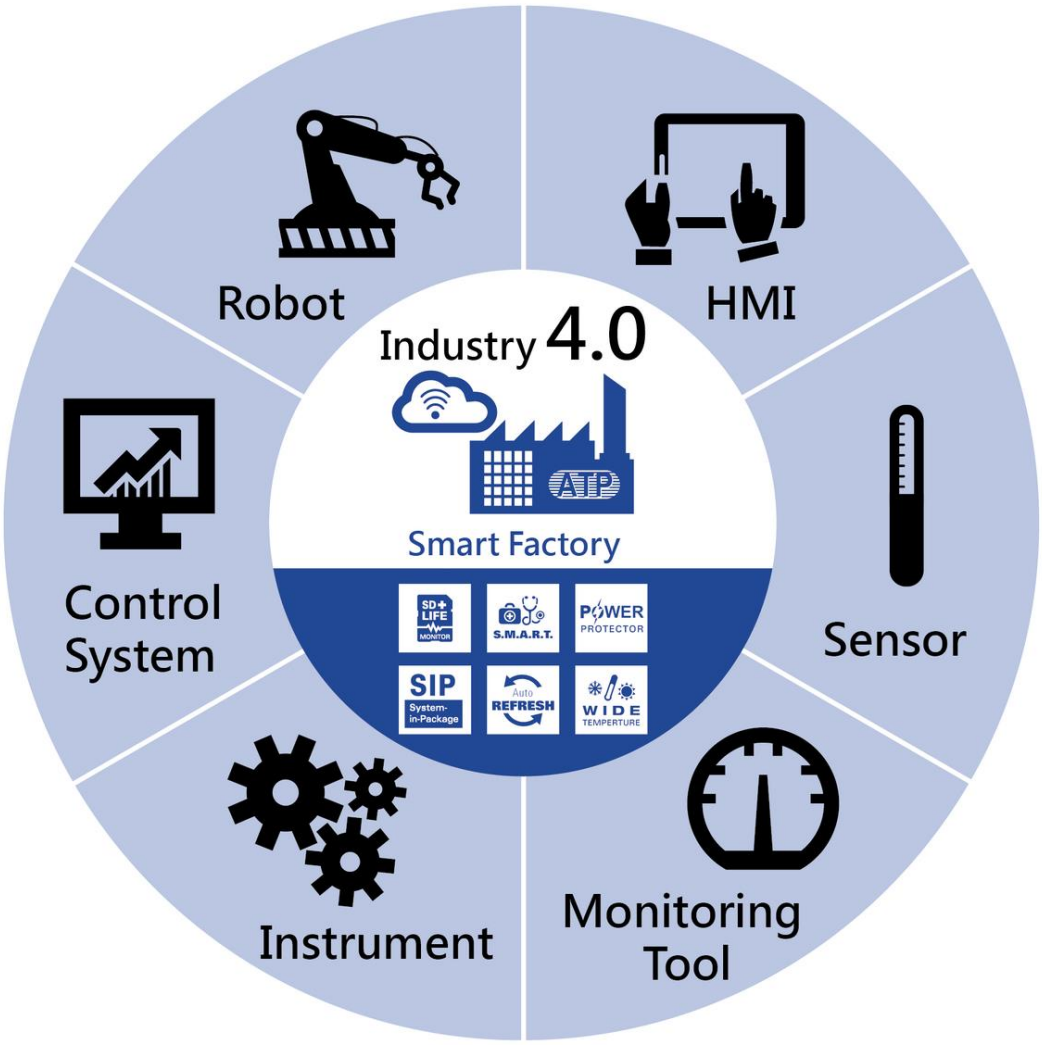

Figure 12. Concept of Industry 4.0 in Picture[12]

In this concept there are stations which play a major role in the Industry concept 4.0. The stations are SQL server, Robot Arm, Stack, Vehicle for transporting within the factory. The main function of the stack is to store the objects that are needed as per the requirement of the customer's order which will be sent from the server database. The Stack will hold the necessary and limited number of quantity of the objects that needs to be given to the vehicle. Vehicle helps in the transporting of the object from one point in the factory to the other, helping in co-ordination with Robot Arm. The materials for the

stack is given from the inventory or the main storage, when the materials are empty in the Stack or the required materials is not there in the stack.

The function of the Robot Arm in this concept, is that it acts as a manipulator, which helps in picking and placing of the object from a storage to the vehicle. The major role of the arm lies in co-ordinatinated operation with the vehicle, the vehicle asks for the specific part or the object as per the need of the customer, the Arm has to identify the specific need of the vehicle to pick and place the object inside the vehicle. For eg. When the vehicle is in need of the blue object, the arm has to pick up the blue and not red instead of blue, it is the same case with the Stack. Stack has to give the object red, if the need of the vehicle is red. In the case, if red is empty in stack, the vehicle moves to Robot arm for the red. The Stack gets the object from the inventory as it becomes empty.

The moving of the vehicle is in a specified track throughout the industry, which helps the motion to be in pathway according to the placing of the other machines like the Stack and Robot Arm.

The main problem in this setup arises, when the repair occurs in the Stack or the robot arm or the vehicle, which are the main parts. In this case, if error or repair occurs the information is directly sent to the Server base, where the information is stored and the past records are verified and the reason for repair is revealed. With this help of the information from the server, the repairmen are able to solve the problem or the repair that occurs in the machine. The Information is sent after solving the problem to the Server.

5.1 Internet of things(IOT)

Internet of things are a platform for the tranfer of information and also for effective communication between objects in the concept of Indutry 4.0. The term Internet of things refers to the usage of the connected devices and systems being used intelligently to collect the data that is stored in the actuators of the machines and other

working parts[13]. Internet of Things helps us to unleash the lastest method of technology which is expected to be spread vast over the upcoming years. This will lead to the new concept of the Life where the quality of life, productivity of the enterprises and more opportunity will be unlocked which would be called as Connected life[13].

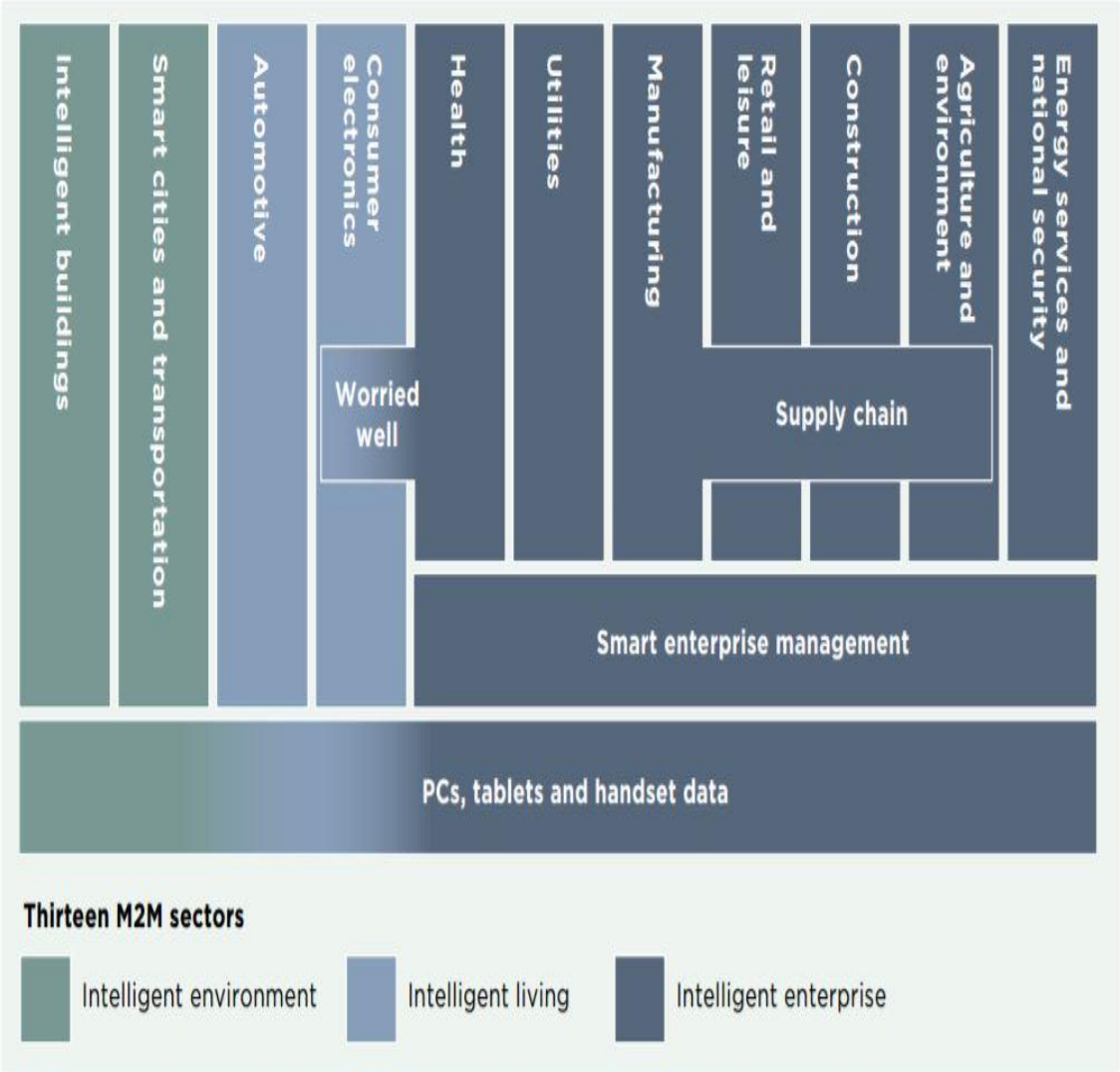

Figure 13. Industrial Sectors - Implementing Internet of Things[13]

The above shown figure shows the various industrial sectors that make use of the new concept of Internet of Things, through which the development and advancements are being brought up into various fields, which helps the people to raise the standard of living in a easy way[13].

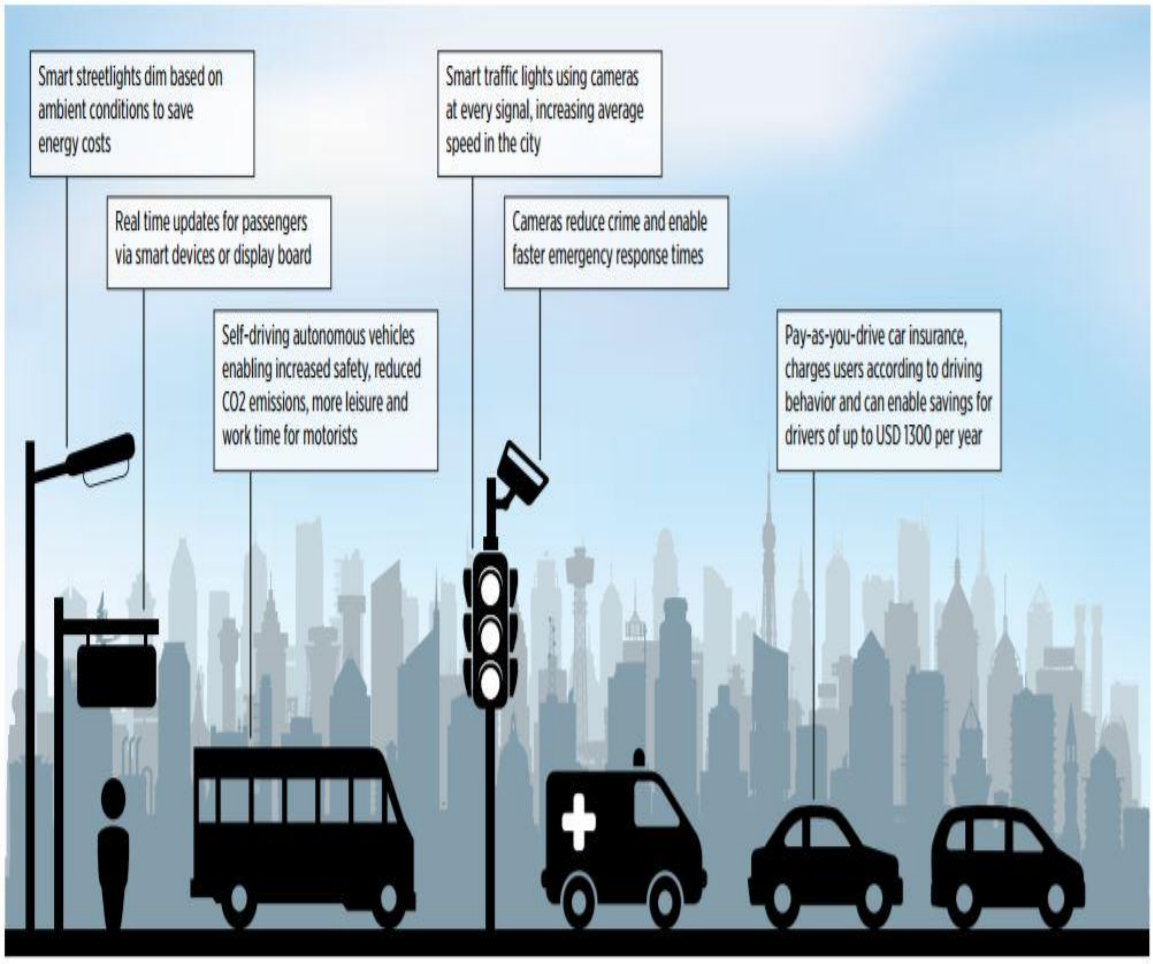

Figure 14. Internet of Things - Used in Smartcity Applications[13]

In the above shown Figure 14, the Internet of things is being implemented in the concept called as smartcity, where the nature's energy resources can be saved in a great quantity, helping for the future generation[13].

It helps in the various fields such as:

- Development of Smart Grids - Electricity that is being used effectively in combination with the Electronics[13].
- Data Analytics - Helping to achieve better business technologies[13].
- Autonomous vehicles - This helps in developing innovations, through an intelligent platform[13].
- Traffic management[13].
- Security[13].

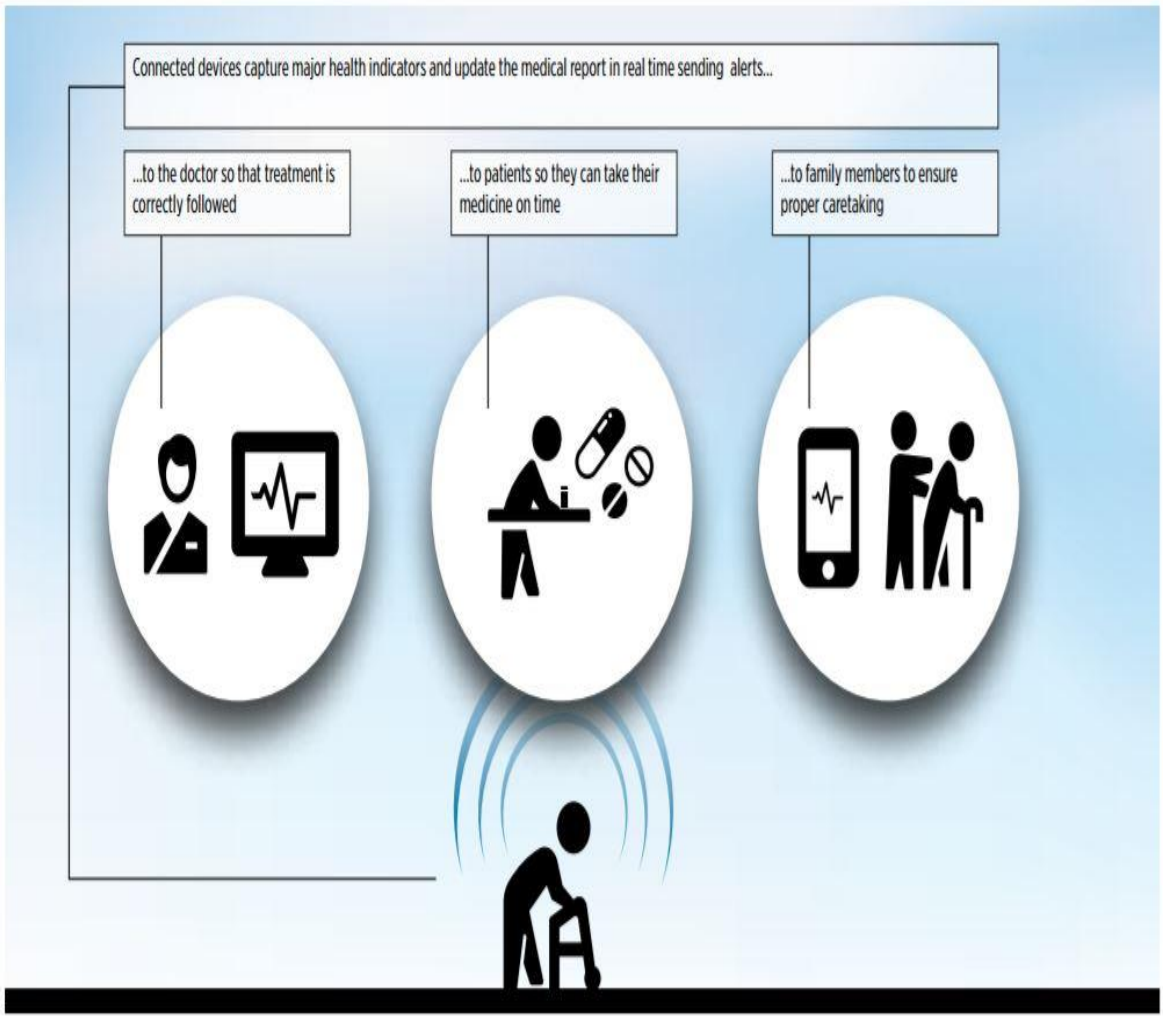

Figure 15. Internet of Things - Used in Health Industry[13]

By implementing the Internet of Things in the field of Health Indutry, the demand of the healtcare indutry can be reduced to a great extent[13]. Through the way of implementing the smart devices, many of the major chronic devices can be cured and by the method of making it global the access can be made for any kind of service needed by any hospital[13].

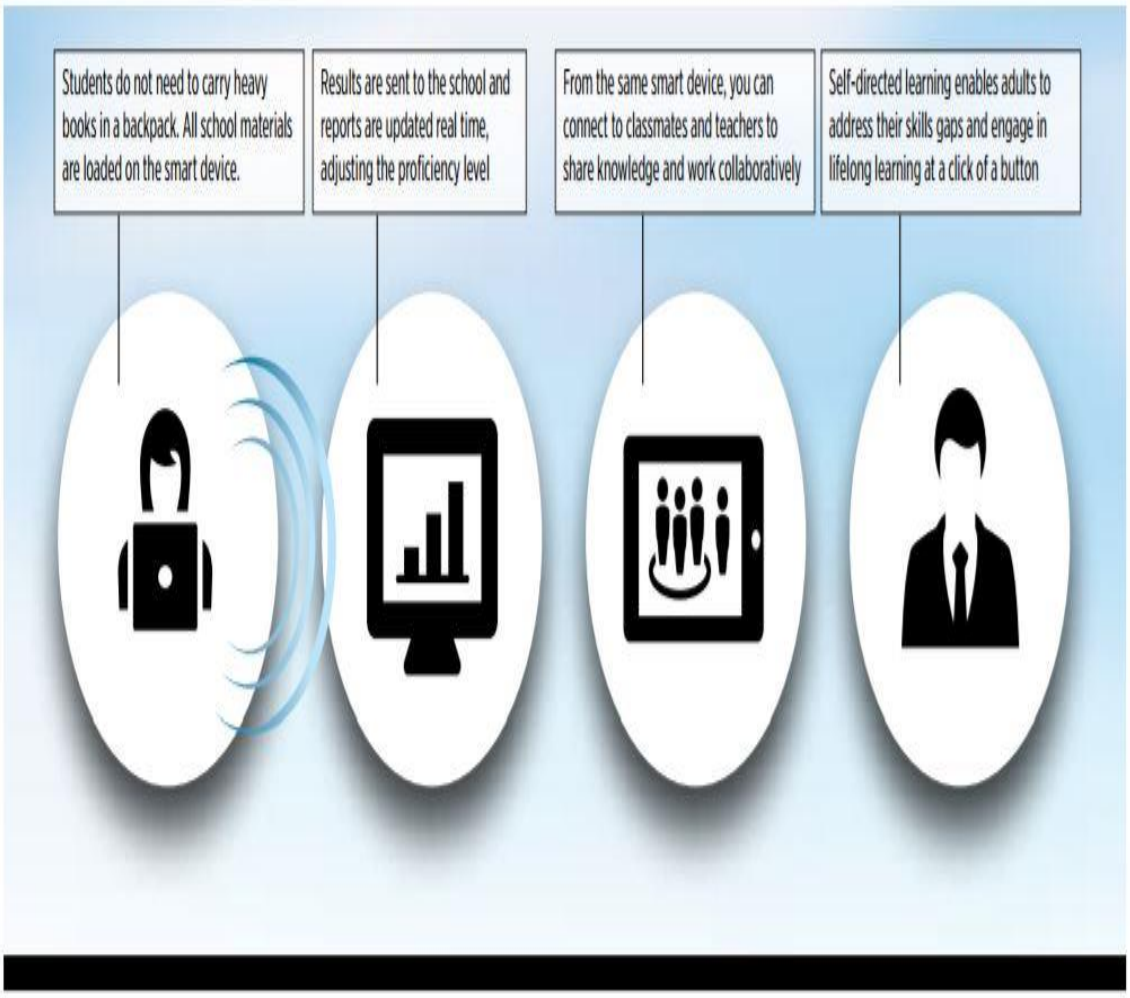

Figure 16. Internet of Things - Implemented in Education[13]

The method of implementing the Internet of Things in the education system, is the greatest advancement that can be achieved by IOT[13]. By this implementation, the efficiency of the system can be improved in a vast manner, by linking of the virtual and physical classrooms together in a single platform[13]. Mobile education can also be supported by the implementation of Internet of Things in a great way[13].

In the field of industry, IOT plays a effiecient role where the main platform called Time is being saved in every aspect[13]. The long distance business meetings have been made very easy by this implementation of Internet of things, video conferences, business meetings with clients are made at ease[13]. The time delay between the ordering and delivery has been reduced, cutomizing of the product has been made easy[13].

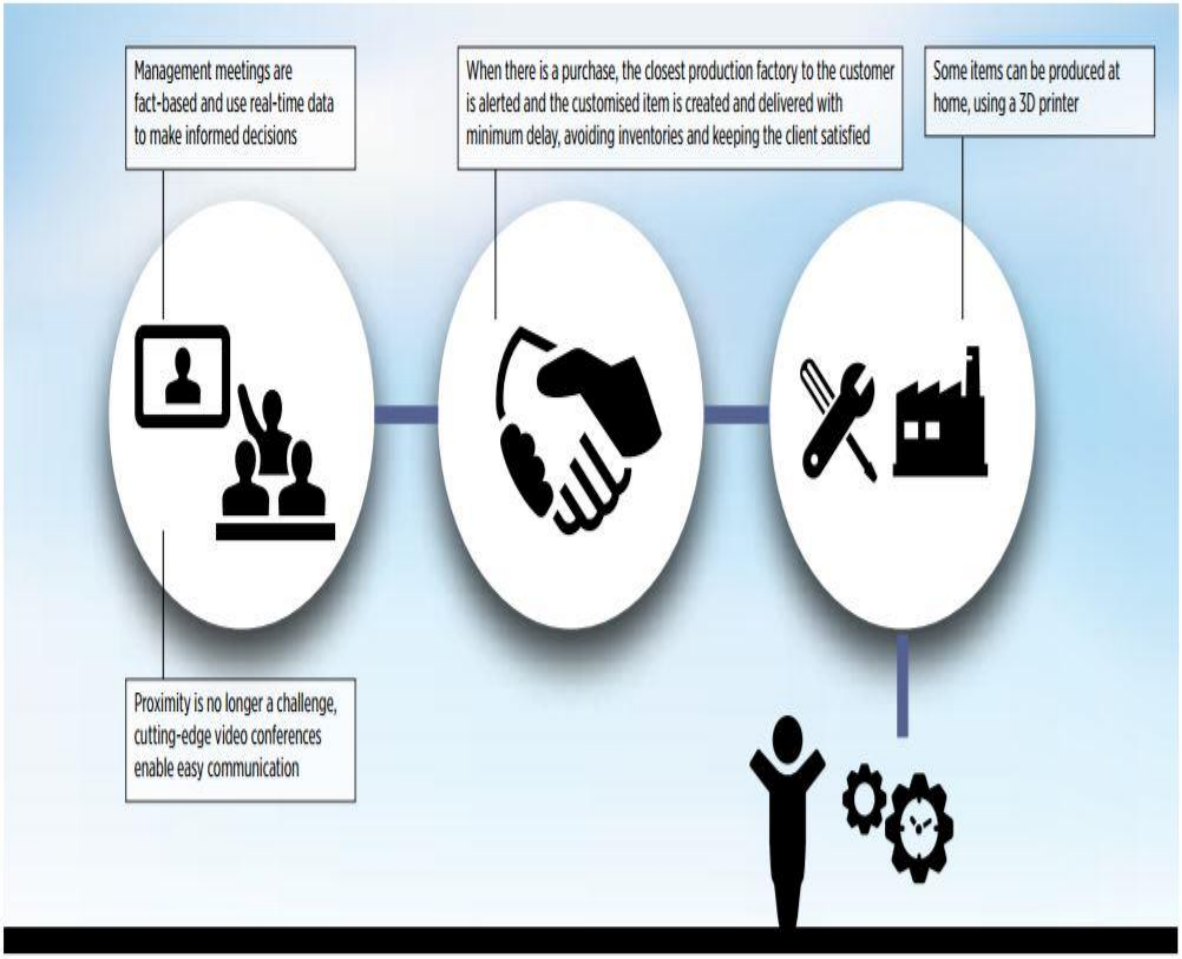

Figure 17. Internet of Things - Implemented in Productivity[13]

The Developments in Productivity by Internet of Things:

- Developments in 3D printing[13].
- Better usage of Sensors[13].
- Improved decision making[13].
- Improved Production efficeincy[13].
- Retail Personalisation[13].
- Quality food production[13].

On the wole Internet of things, helps in delivering the change in step for Individuals, by providing the Quality of Life and Enterprises productivity[13].

5.2 The Robot Arm - Basic Scheme and Assembly

Figure 18. Robot Arm

The robot arm is capable of handling objects and things around in the surrounding environment, by the programming given through the Arduino board to the robot. The robotic arm features in pick and place, which is a major part of the Industry concept 4.0.

5.2.1 Specifications of the Robot arm

Processor used - Arduino Mega2560

Servo motors - 6

Material - Metal

Arm length - 390mm

Height - 460mm

Base Diameter - 210mm

Power supply - 9 - 14V

5.2.2 Schematic parts repesentation used in the assembly of the Robot Arm

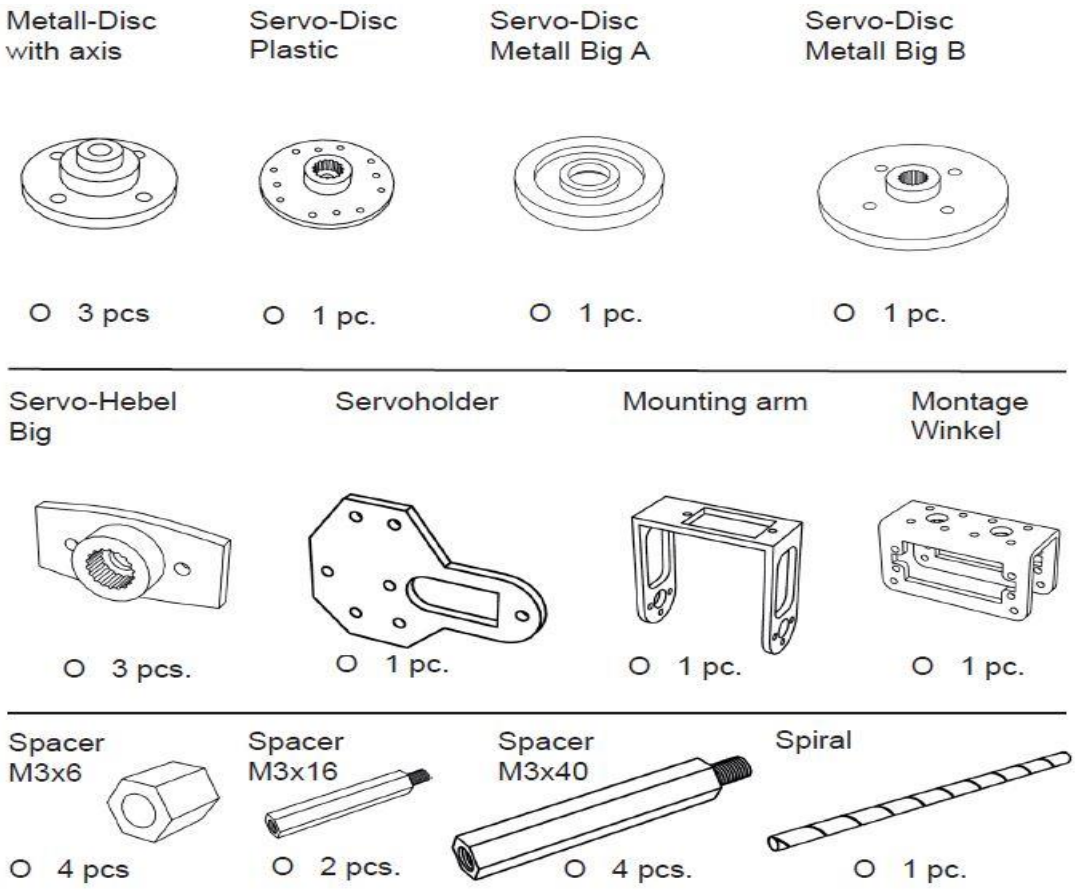

Figure 19. Parts used in the Assembly of Arm.

The above shown parts in the Figure 19 are the basic components used for the assembly of the Robotic Arm.

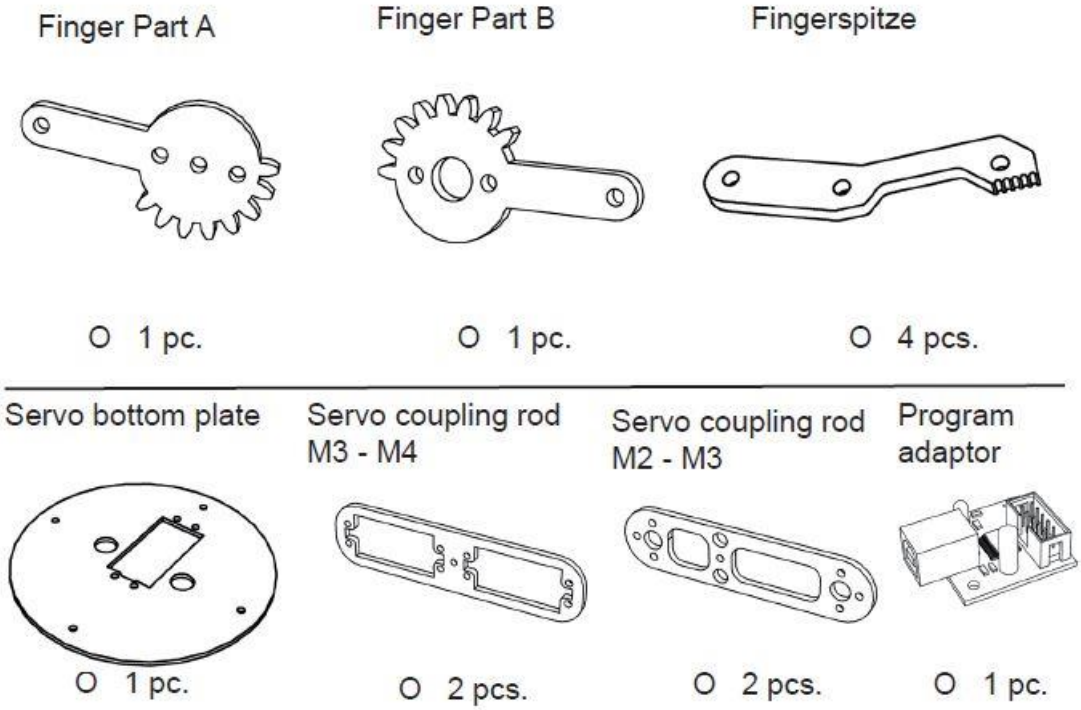

Figure 20. Parts used in Assembly of Gripper.

In the above mentioned Figure 20 the parts used for the assembly of the gripper are shown in detail with the list of parts used.

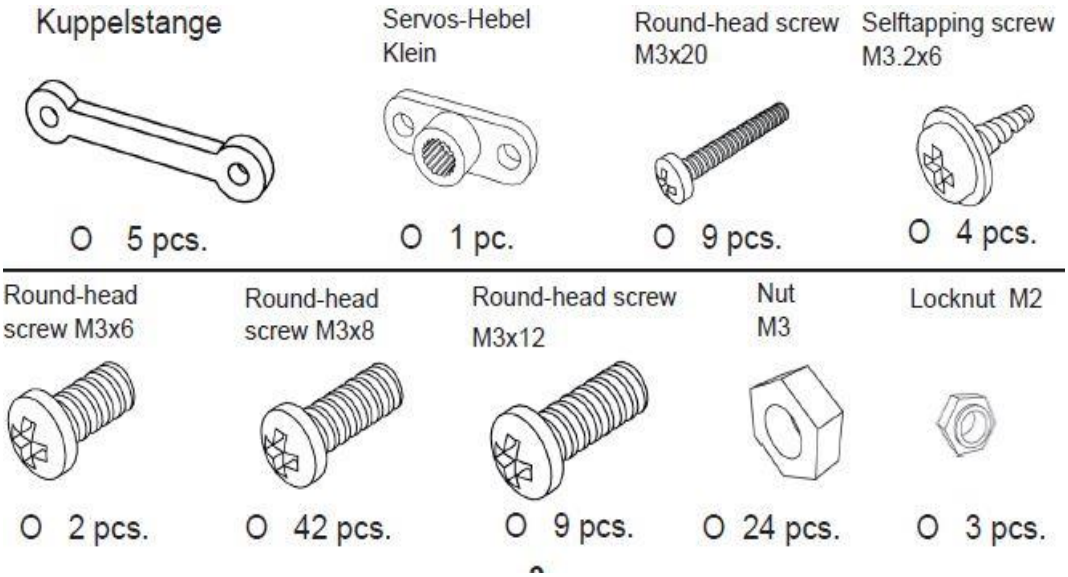

Figure 21. Screws - Used in the Assembly.

5.2.3 Main Step Assembly of the Robot - Pictorial Representation

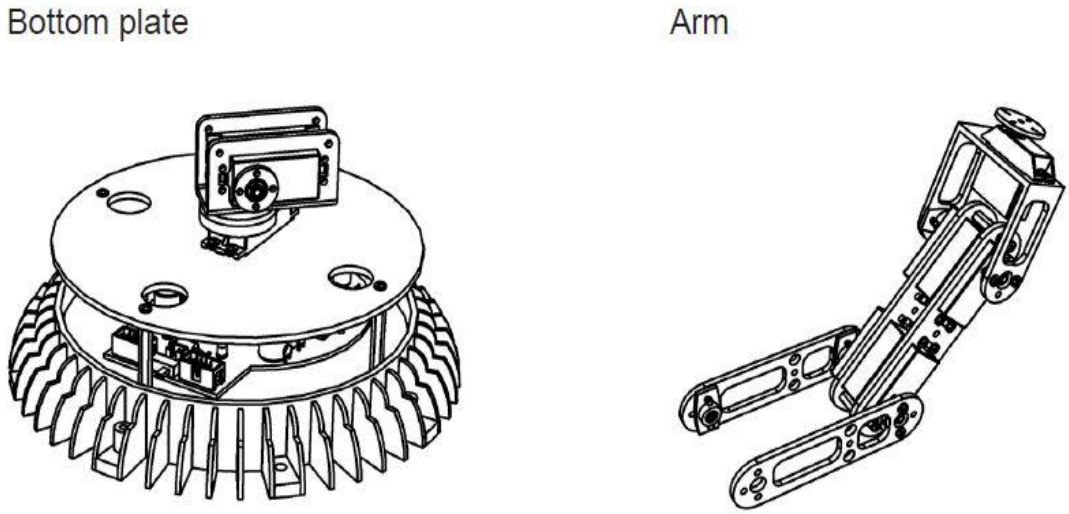

Figure 22. Assembly of the Baseplate(left) and Assembly of the Arm(Right)

The base plate consists of the Servomotor, support assembly for the arm and holes for the fixation of the arm on the surface using mountable screws. The arm helps to support of the other servos which help in the motion.

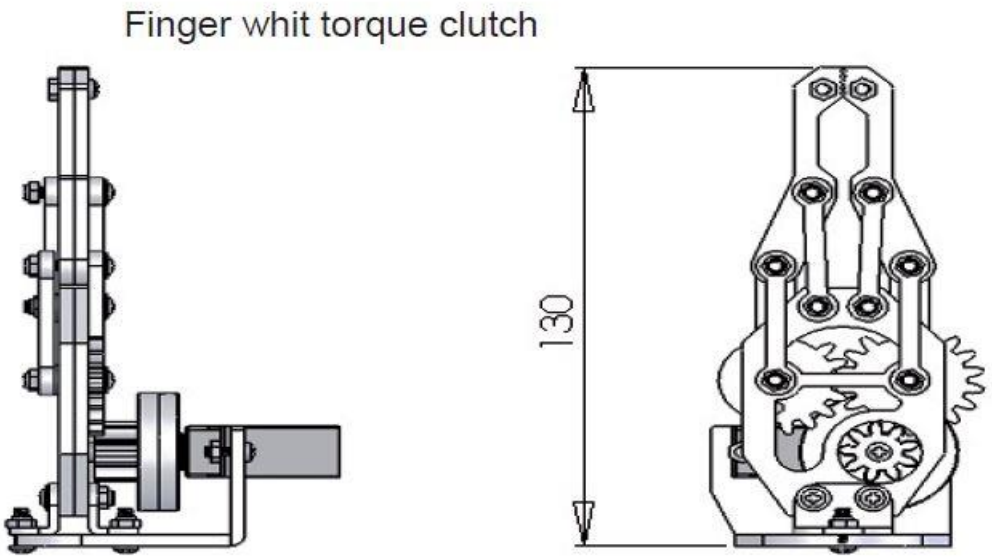

Figure 23. Front view and Side view of the Grippers assembly

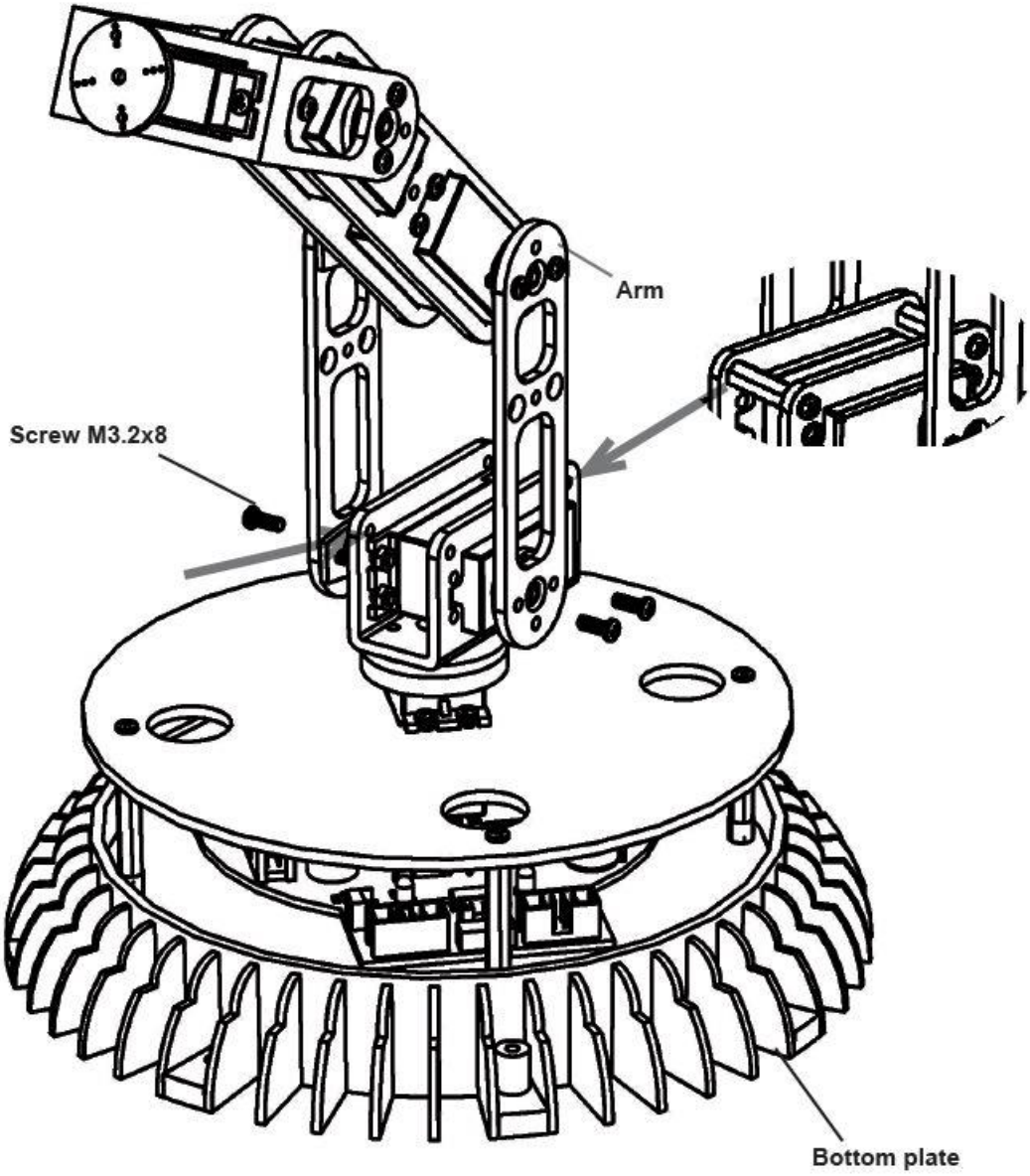

Figure 24. Construction of the Servo Arm

The above mentioned figure 24 shows the construction of the Robot arm with the base plate and the servos fixed to it. The fixation of the servos are placed even inbetween the arm parts to act as joins in each point of the servo fixation. The fixing of the base servo is done inside the base plate by creating the gap as per the size of the servo.

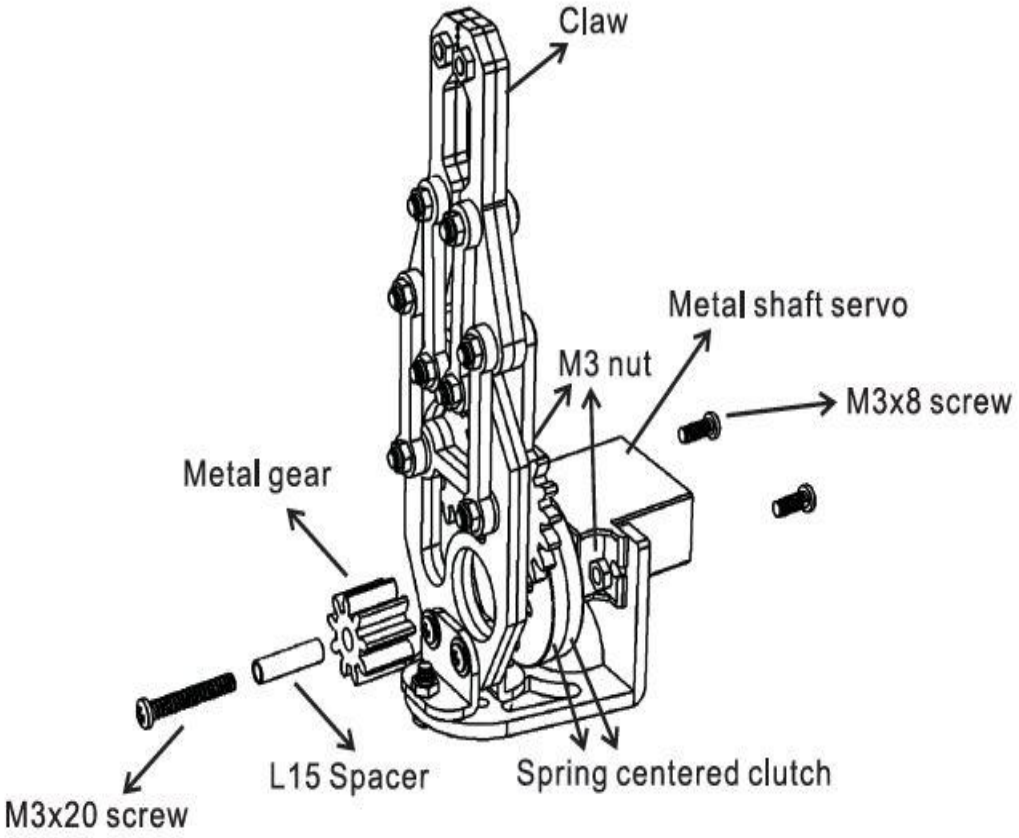

Figure 25. Gripper assembly and the Allignment of the parts

In the Figure 25, the assembly of the gripper by using the claws at the end is done. The gear arrangement of the robot arm is also done by using the set of screws and the gears for the better precision and accuracy of material handling during the operation of the arm. The power for the arm is supplied through the Servos, which are placed at the joints.

The entire process of the robot arm is supported by the grippers which helps in picking of the object from one place and placing at the other. The grippers are supported by the gear assembly helping for better grip with the object to be carried, which is a part of the Industry Concept 4.0.

The electrical equations of the potential drivers in the robot can be explained by using the Ohms law and the Kirchoff's law.

Based on the Ohm's law, the electric current passing in a circuit through a conductor from one terminal to the other is directly proportional to the potential difference across the two terminal points and is inversly proportional to the resistance of the conductor between the two terminal points[14]. The conditions are, in the case of real devices when the current and voltage exceeds cetain amount of time, there occurs a potential difference and it is called as the voltage drop[14]. In our task the electric current that is being passed in a circuit is being amplified by the pull up resistor attached to the breadboard and also conducted from one terminal to the other. The current being passed from one point to other is always proportional to the current difference between the two terminals.

It is denoted as , **I = V/R**

where I is the current in the terminal, V is the potential difference between the terminals, and R is the constant called as resistance. By applying this to our situation when the current supplied to the servos through the circuit exceeds a certain value, the potential drop occurs causing the function of the robot arm to be stopped.

In the other case, Kirchhoff's voltage Law appiles to our task in any loop connected with the robot and the arduino through the bread board, it is also called as the principal of conservation of energy[15]. It is given as, in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drope within the same loop[15]. The algebraic sum of all the voltages within the loop is zero[15]. In our task the sum of all the voltages in the loop connected with the robot is always zero. The image below illustrates the sum of the voltages in a single loop connected with the robot. VA, VB, VC, VD are the four points in the loop where the resistors are connected in series with the robot in a loop. Therefore the sum of the voltages entering the loop and leaving the loop are always zero.

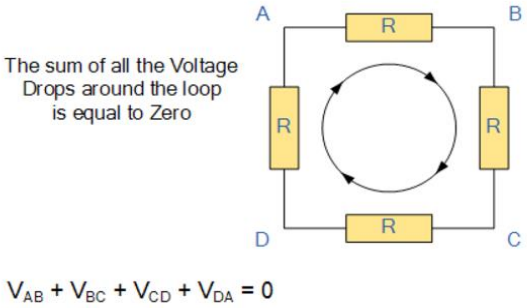

Figure 26. Voltage Law - In a Loop of the robot[16]

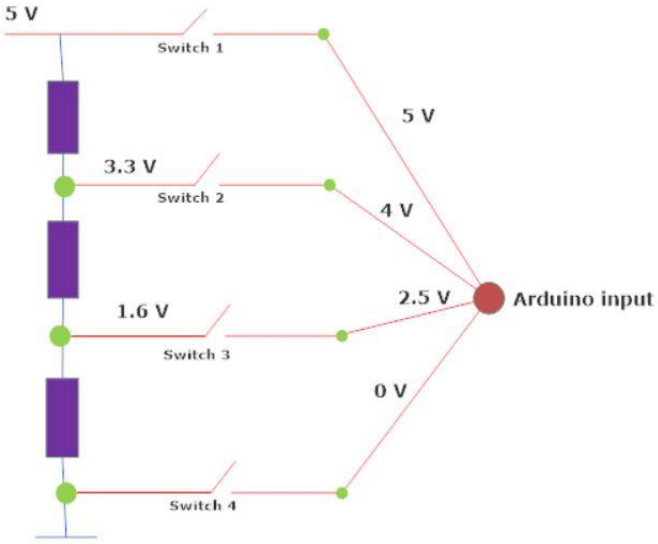

Figure 27. Without Pull up Resistor

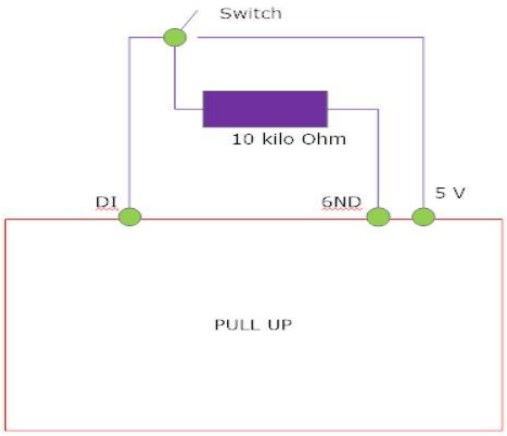

Figure 28. With Pull up Resistor

5.3 Schematic Representation of the circuit

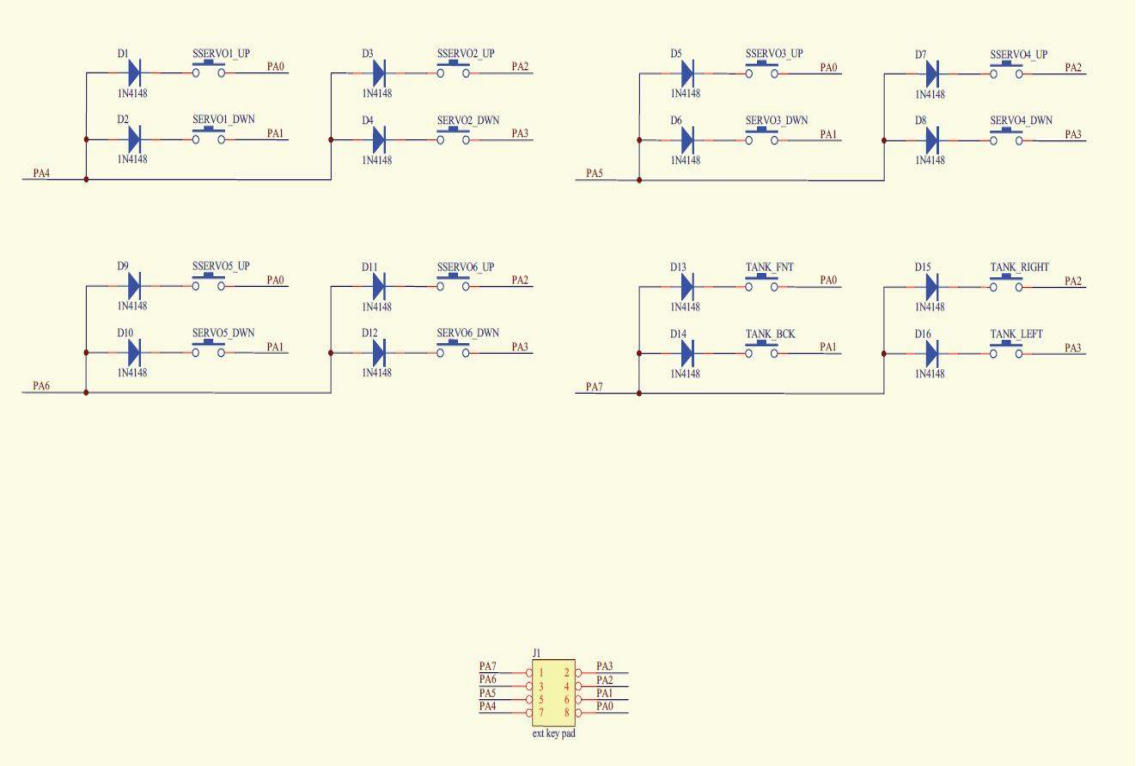

Figure 29. Schematic representation of the Keyboard Circuit[17]

The circuit for the Keyboard, shows the schematic representation of the buttons connected in three sets, by which the operation takes place when a key is pushed. In the first set of buttons, the connections are made with the Arduino Mega2560 in the pins 2,3,4,5 by which the Servo motors get activated and the movement of the Robot Arm takes place. In the same way for the second set of keys, connections are made with the Arduino Mega2560 in the pins 6,7,8,9 by which different servo motor gets activated and the movement of the Robotic arm takes place. This happens the same way even for the third set of keys.

The Initial or the starting operation lies with the fourth set of keys. The initial start up takes place by pushing the left key on the fourth set, which is being explained in the upcoming program by using a pictorial representation. The pushing of the initial start button leads to the start of the sequence of operations that the arm has to perform.

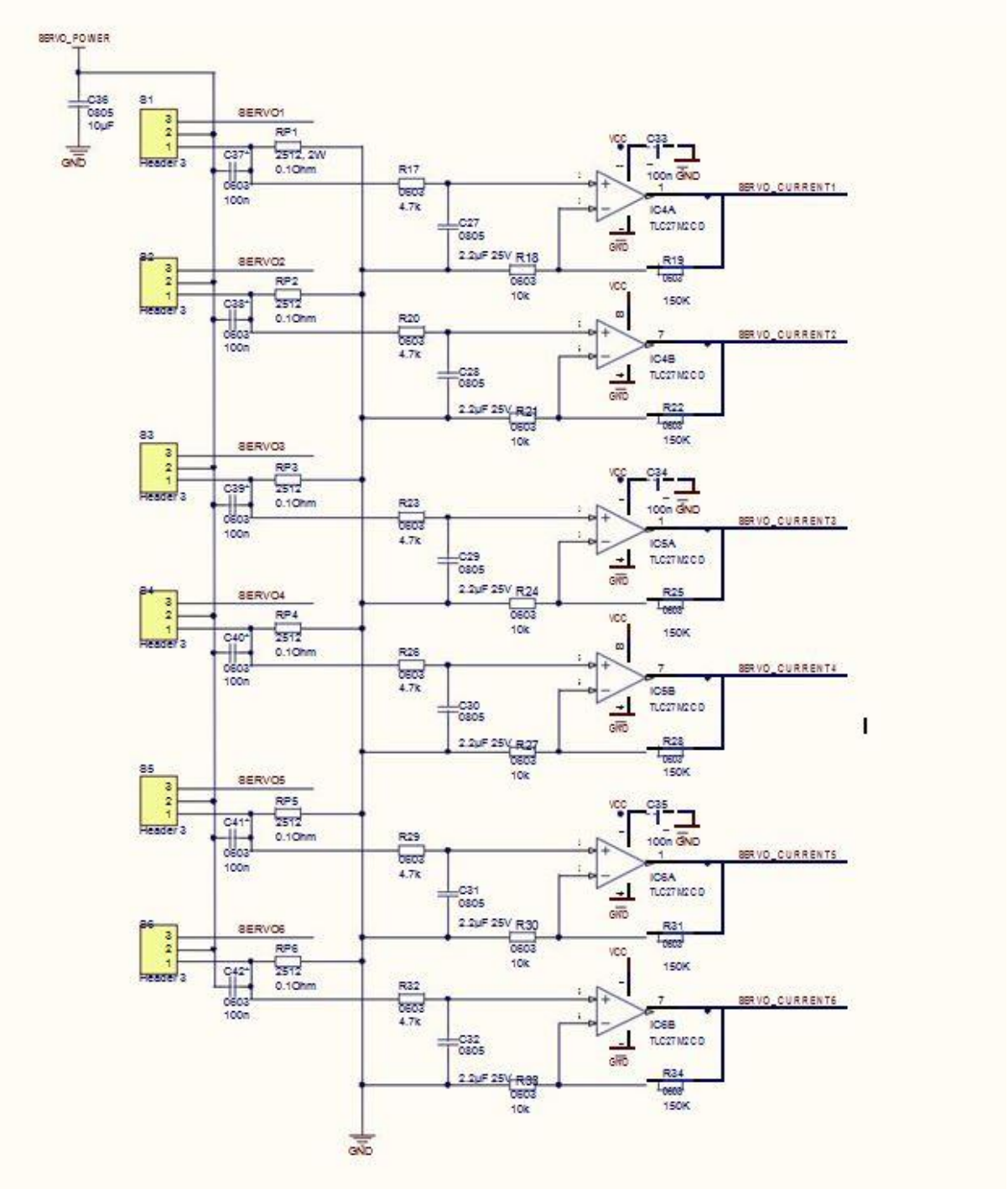

Figure 30. Schematic representation of the Amplifier and Servos[17]

In this scheme, the need of the amplifier is to step up or increase the current that is being supplied to the servos, with this increase in the voltage the servos are able to work effectively, to catch or release the subject based upon the needs of the operation to be done. The resistors, optical diodes are all connected in series on the breadboard.

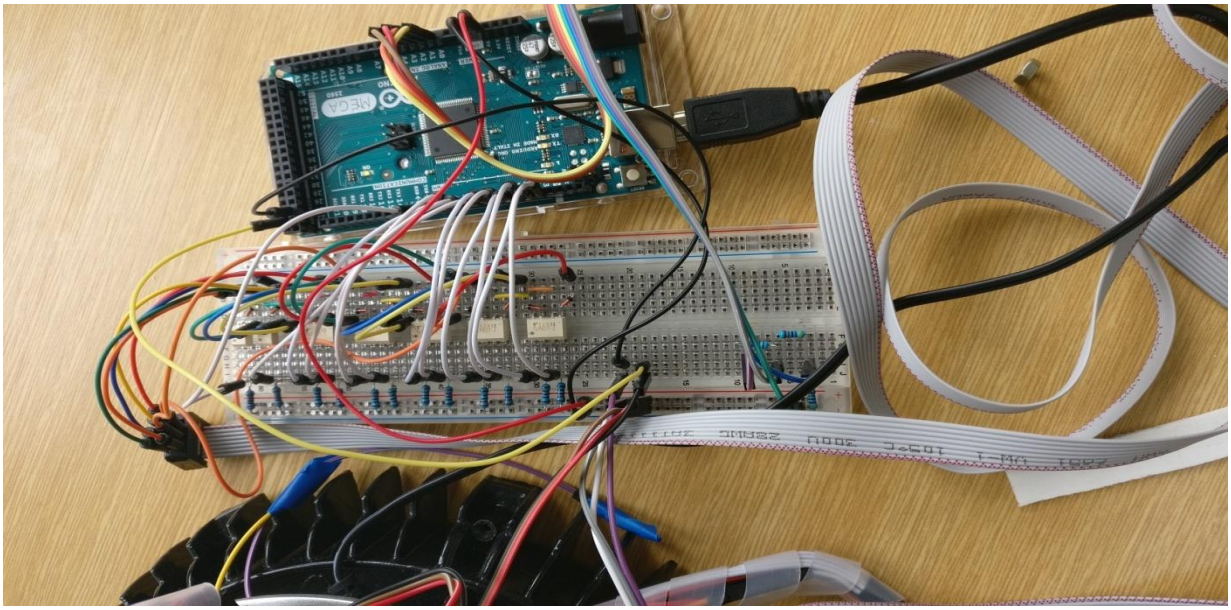

Figure 31. Pictorial Representation of the Breadboard with connections

In this Figure 28. it gives us the details of all the connections that are made with the breadboard and the Arduino. The Arduino is given the power supply from the USB port and the connections are made by using the connecting pins, resistors and the capacitors of 1 ohm and 2 ohm. The program given below explains the assembly.

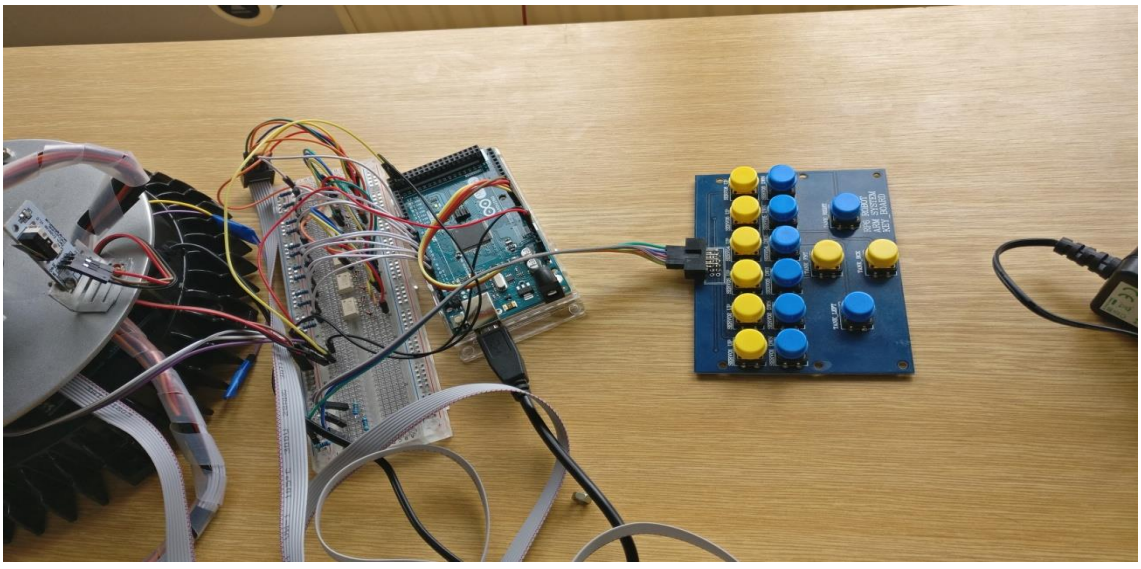

Figure 32. Pictorial Representation of the breadboard with the Arduino and Keypad

5.4 Scheme of the Program codes used for the Sequence of Operations

```
int levelA0 = 0;   // variables for voltage on analog pins
int levelA1 = 0;
int levelA2 = 0;
int levelA3 = 0;

int keyA0 = 0;     // variables for number of pressed pin
int keyA1 = 0;
int keyA2 = 0;
int keyA3 = 0;

int buttonLstate = 0 ;   // variables for reading states of buttons (L and R end-switches)
int buttonRstate = 0 ;

void setup() {
  pinMode(A0, INPUT_PULLUP);  // definitions of analog inputs
  pinMode(A1, INPUT_PULLUP);
  pinMode(A2, INPUT_PULLUP);
  pinMode(A3, INPUT_PULLUP);
  pinMode(13, OUTPUT);        // definitions of pins 2-13 as outputs
  pinMode(12, OUTPUT);
  pinMode(11, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(9, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(7, OUTPUT);
  pinMode(6, OUTPUT);
  pinMode(5, OUTPUT);
  pinMode(4, OUTPUT);
  pinMode(3, OUTPUT);
  pinMode(2, OUTPUT);

  Serial.begin(9600);         // initialization of serial monitor
}

int readButtons(int pin){  // returns the button number pressed, or zero for none pressed (IT IS A FUNCTION)
  int b,c = 0;
  c=analogRead(pin);                  // get the analog value
  if (c>1000){ b=0;}                  // buttons have not been pressed
    else if (c>320 && c<600) { b=1; }   // button 1 pressed
    else if (c>250 && c<319) { b=2; }   // button 2 pressed
    else if (c>150 && c<249) { b=3; }   // button 3 pressed
    else if (c>0 && c<149)   { b=4; }   // button 4 pressed
  return b;
}
```

Figure 33. Program Code - Part1

In the first part of the code, the intialising of the variables takes place.
The initialising of the variables for voltage on the analog pins, number of pins pressed and the variables for the reading state of buttons that has to be from Left to Right are done. The description of each pin, which acts as the output and which acts as the Input pullup are defined in this part. This part of the program defines also the digital set of Inputs. Finally the main state of the code begins with the if condition for the keys in the keypad.

```
void loop() {
  buttonLstate = digitalRead(22);
  buttonRstate = digitalRead(24);

  levelA0 = analogRead(A0);    // this reads analog inputs
  levelA1 = analogRead(A1);
  levelA2 = analogRead(A2);
  levelA3 = analogRead(A3);

  keyA0 = readButtons(0);      // this calls function readButtons - detection of button in each group
  keyA1 = readButtons(1);
  keyA2 = readButtons(2);
  keyA3 = readButtons(3);

  if (keyA0 == 0)         // No button in group A0 pressed
     {
     digitalWrite(2,LOW);
     digitalWrite(3,LOW);
     digitalWrite(4,LOW);
     digitalWrite(5,LOW);
     }
  if (keyA0 == 1)         // SERVO 1 DOWN is pressed
     {
     digitalWrite(2,HIGH);
     }
  if (keyA0 == 2)         // SERVO 1 UP is pressed
     {
     digitalWrite(3,HIGH);
     }
  if (keyA0 == 3)         // SERVO 2 UP is pressed
     {
     digitalWrite(4,HIGH);
     }
  if (keyA0 == 4)         // SERVO 2 DOWN is pressed
     {
     digitalWrite(5,HIGH);
     }

  if (keyA1 == 0)         // No button in group A1 pressed
     {
     digitalWrite(6,LOW);
     digitalWrite(7,LOW);
     digitalWrite(8,LOW);
     digitalWrite(9,LOW);
     }
```

Figure 34. Program Code - Part2

This part of the program code, gives a clear idea how the pressing of the keys are reciprocated in the function of the robot. The reading of the buttons from ecah group is detected, by the signals. The key state Low refers that the key is not active and the key state High refers that the key is active or the signal is being passed from the key to the robot through the Arduino. The pressing of keys in each state helps to supply power to the servos and the servos are activated. The List of Servos that is connected and also the function performed by them with each key can be identified by pressing of the keys.

```
 if (keyA1 == 1)          // SERVO 3 DOWN is pressed
    {
    digitalWrite(6,HIGH);
    }
 if (keyA1 == 2)          // SERVO 3 UP is pressed
    {
    digitalWrite(7,HIGH);
    }
 if (keyA1 == 3)          // SERVO 4 UP is pressed
    {
    digitalWrite(8,HIGH);
    }
 if (keyA1 == 4)          // SERVO 4 DOWN is pressed
    {
    digitalWrite(9,HIGH);
    }

if (keyA2 == 0)          // No button in group A2 pressed
    {
    digitalWrite(10,LOW);
    digitalWrite(11,LOW);
    digitalWrite(12,LOW);
    digitalWrite(13,LOW);
    }
 if (keyA2 == 1)          // SERVO 5 DOWN is pressed
    {
    digitalWrite(10,HIGH);
    }
 if (keyA2 == 2)          // SERVO 5 UP is pressed
    {
    digitalWrite(11,HIGH);
    }
 if (keyA2 == 3)          // SERVO 6 UP is pressed
    {
    digitalWrite(12,HIGH);
    }
 if (keyA2 == 4)          // SERVO 6 DOWN is pressed
    {
    digitalWrite(13,HIGH);
    }

 if (keyA3 == 0)          // No button in group A3 pressed
    {
                    // do something if cursor is unpressed
    }
```

Figure 35. Program Code - Part3

This part of the programme, helps to identify the working of servos in sequence as mentioned above. If loop plays major part in this coding, where the condition is based upon the pressing of the keys or buttons in the keyboard. Each condition with the code High refers that the servo is active. In this sequence when the Key A2 is not in action the power to the servo is not supplied, but in the case when the key A2 is pressed the servo motor 5 is activated and goes down, with the pin 10 being connected with the breadboard. In the same case when the KeyA2, connected with the pin 11 is pressed, the Servo 6 is activated and it goes up according to the sequence of operations. It happens in sequence for the Up and Down of the Servo Motor, by the pressing of the altenative buttons as per the sequence of the program.

```
if (keyA3 == 1)         // CURSOR DOWN is pressed
   {
  // insert sequence to catch the subject
   }
if (keyA3 == 2)         // CURSOR UP is pressed
   {
    // insert sequence to release subject for example
   }
if (keyA3 == 3)         // CURSOR RIGHT is pressed
   {

   }
if (keyA3 == 4)         // CURSOR LEFT is pressed
   {
     digitalWrite(13,HIGH);                                  // go anticlk to end position
     while(buttonLstate == 1) { buttonLstate = digitalRead(22);}
     digitalWrite(13,LOW);

     digitalWrite(3,HIGH);                                   // open the gripper
     delay(4000);
     digitalWrite(3,LOW);

     digitalWrite(8,HIGH);                                   // armA down
     delay(3000);
     digitalWrite(8,LOW);


     digitalWrite(7,HIGH);                                   // armB down
     delay(3000);
     digitalWrite(7,LOW);


     digitalWrite(2,HIGH);                                  // partly close the gripper - catch the subject
     delay(2000);
     digitalWrite(2,LOW);

     digitalWrite(6,HIGH);                                   // armB up
     delay(3000);
     digitalWrite(6,LOW);

     digitalWrite(9,HIGH);                                   // armA up
     delay(3000);
     digitalWrite(9,LOW);
```

Figure 36. Program Code - Part4

The sequence of the robot, from the initial position to the picking of the object to placing it at a different place takes place in this sequence of operations, mentioned above. The pins connected are 13,3,8,7,2,6 and 9 are linked with the operations like the opening and closing partly of the gripper, moving of the arm up to a particular position and also moving the arm down to a particular position, where the object needs to be dropped down or picked up as per the operation to be carried out. The power to the motor is given through the pins by the Arduino and the Servos function according to the sequence.

```
digitalWrite(6,HIGH);                    // armB up
delay(3000);
digitalWrite(6,LOW);

digitalWrite(9,HIGH);                    // armA up
delay(3000);
digitalWrite(9,LOW);

digitalWrite(10,HIGH);
delay(3000);
digitalWrite(10,LOW);

digitalWrite(12,HIGH);
delay(3000);
digitalWrite(12,LOW);

digitalWrite(7,HIGH);
delay(3000);
digitalWrite(7,LOW);

digitalWrite(8,HIGH);
delay(3000);
digitalWrite(8,LOW);

digitalWrite(11,HIGH);
delay(3000);
digitalWrite(11,LOW);

digitalWrite(3,HIGH);
delay(3000);
digitalWrite(3,LOW);
```

Figure 37. Program Code - Part5

The final part of the coding, deals with the sequence of the robot, in catching the subject from one place and placing the subject at a different place. The codes 'didgitalWrite(number, HIGH)' denotes the power given to each servo, the number denotes from which pin the power is supplied to the servomotor. The value 'HIGH' denotes that the servo is switched on. The 'delay(number)' denotes the time in seconds until which that particular servo motor needs to be switched on. The program runs in sequence as per the code.

The robot arm is started from the initial position. This initial position is also called as the starting position of the robot arm, from which the operation is started everytime as per the program codes. Initial Position of the arm is shown below in the figure. 38. The robot reaches to the subject by activation of the various servos in perfect time interval and catches the subject by the gripper and takes back to the vehicle or to the place mentioned as per the operation that is to be done in the entire sequence of concept of Industry 4.0.

5.5 Final Assembly of the Robot Arm with Arduino board

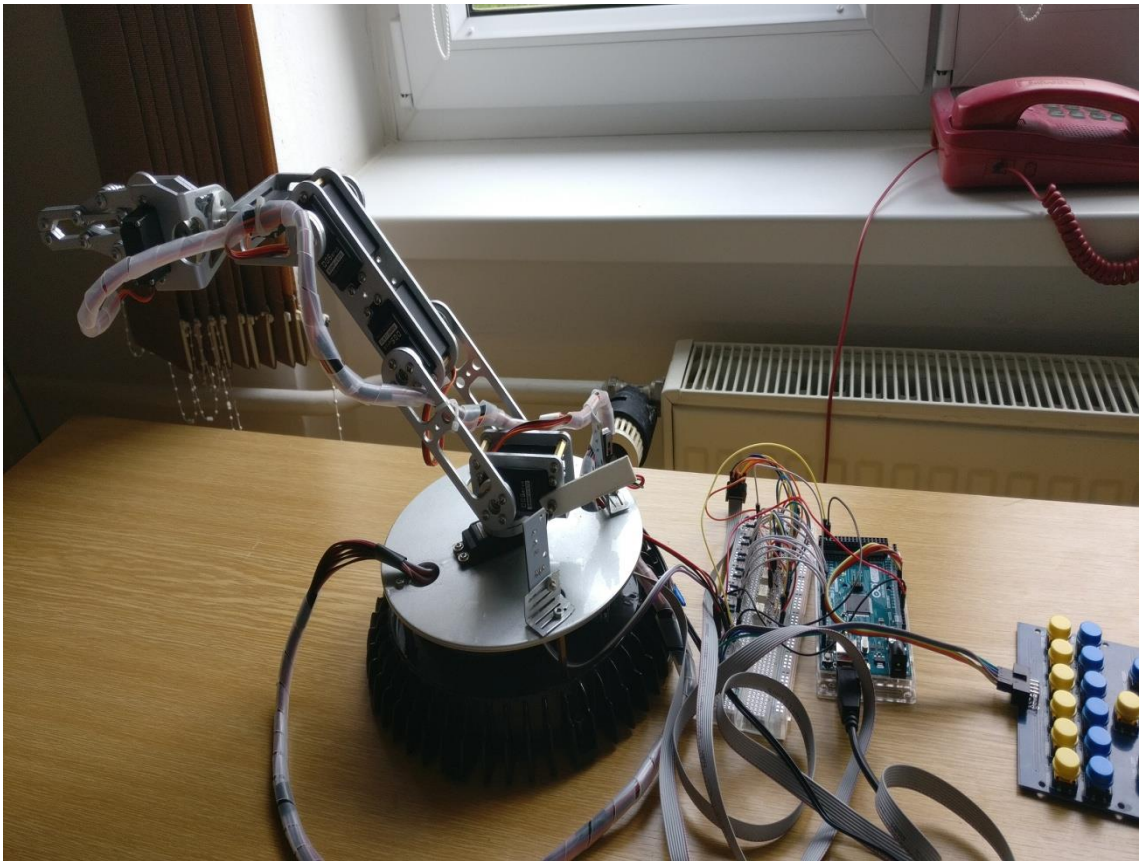

Figure 38. Initial Position of Robot Arm with Arduino

The Final assembly of the robot arm has the two main construction, which plays the main role in the operation of the arm from the base to the reaching position of the object. The first motion of the robot arm is time constrained and it moves from the inital position to the potion where the object needs to be taken and placed in the vehicle. This constructional movement of the Robot arm helps in the moving of the object from one place to the other, by using the end effector or the gripper, which goes to the object and the gripper closes partly helping for the catching of the object, then the arm is moved to position where the object needs to be placed in a specific location. The movement is made possible by the usage of the sequence of codes in a row from the program. It is called as the time constrained motion because at each position there is a time delay of about 1 second to 4 seconds which varies depending on the motion and function of the arm.

The second movement is motion constrained, which is done by the end switches which helps to restrict the rotational movement of the base of the robot arm with a specific limit. The rotation movement of the base is needed for reaching different end positions. The basic setup is in such a way that, the end switches are placed at different ends of the base of the robot arm and when the robot rotates to reach a position from one end the attachment made with the robot touches the switch and the movement of the robot is restricted until the end where the contact with the switch takes place and the robot stops its movement. When one end of the switch is pressed then the motion of the robot is stopped and the other set of sequence gets activated, which makes the robot to move to the other end and perform the desired operation. In the same way when the robot reaches the other end and contact with the next switch is made, the second motion is stopped where the place of contact with the switch takes place. These are the two main motions, one is time constrained motion and other is the movement constrained motion by end switches.

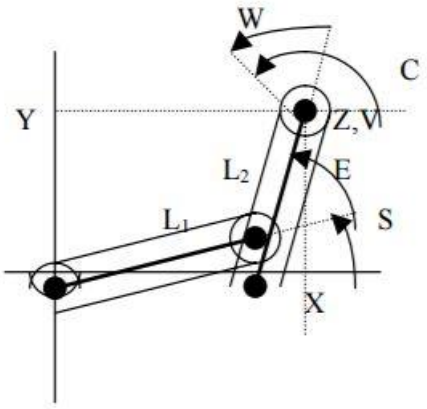

Figure 39. Example of Kinematic Equation in the Robot[18]

The kinematic equation for the each join of the robot acts similar to the figure represented above. The equations are represented as,

$$X = L_1*\text{Cos}(S) + L_2*\text{Cos}(S+E)$$

$$Y = L_1*\text{Sin}(S) + L_2*\text{Sin}(S+E)$$

The kinematics of the robot can be explained in every joint by using the equations, mentioned above along the X-Axis and the Y-Axis.

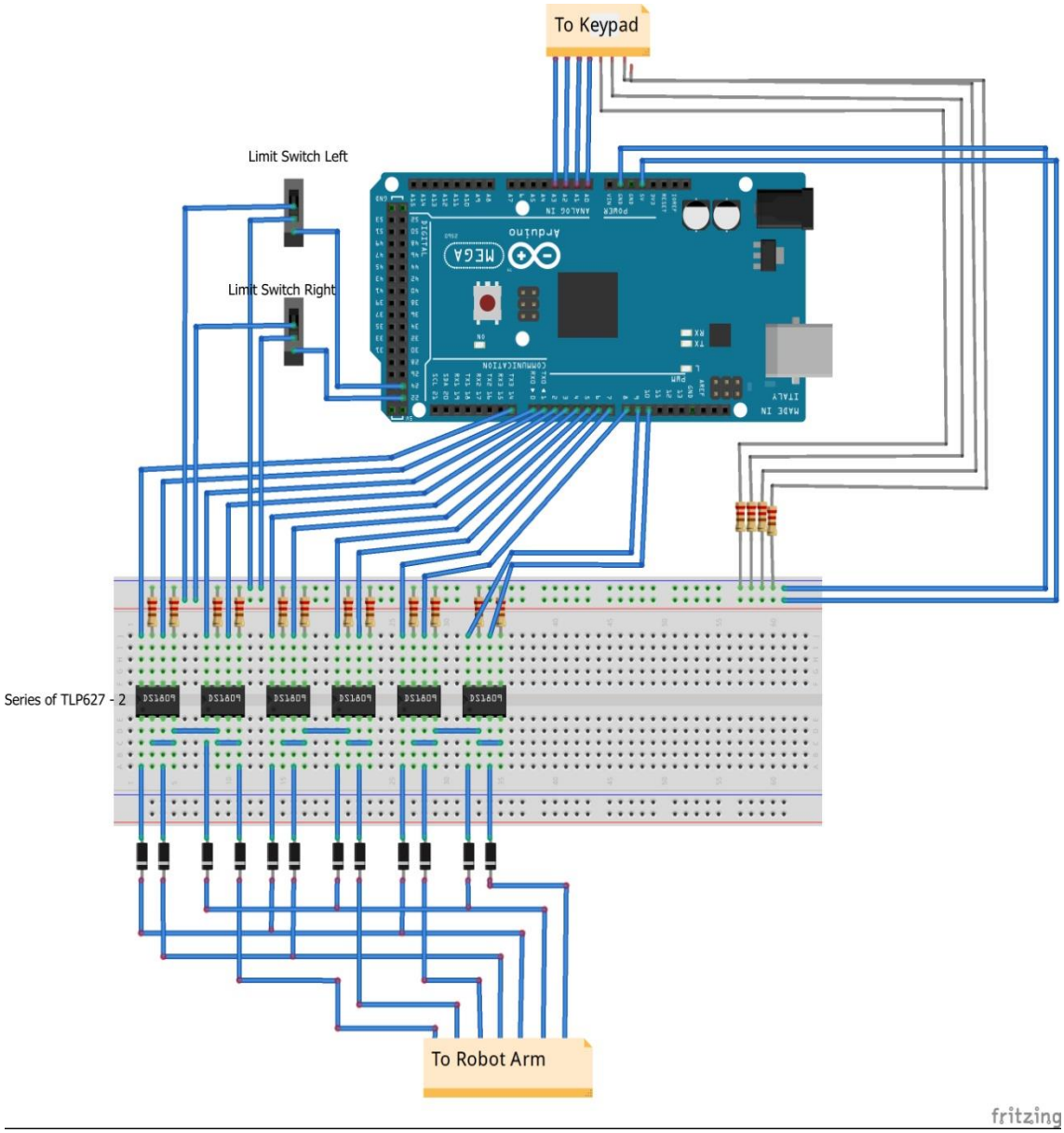

Figure 40. The schematic Representation of the circuit

This schematic representation shown above gives us the pictorial representation of how the circuit is being connected to the Robot Arm and the Keypad. The connection between the two is given by the Arduino and the breadboard. Breadboard acts as the common connector for the ports that has to be connected in common. The pull up resistor is used to provide the increase in the voltage as needed by the board for the operation. The Optical diodes acts as the connector bridges for the resistors from the arduino board and the robot.

There are other two ways of controlling the servo drives, one is by the electrical motors connected along with the gear, in this method the position of the arm can be entered by using of the analog output or by modulating the pulse width, which is also called as the PWM. The example program below will illustrate the function of calling the servo through the analop pins.

The other method of the controlling the servo drives is by the using of the library with function, serial communication. This serial communication can also be called as the discontinous form of signals being transmitted at intervals.

```
//control servo motor with serial monitering window

#include <Servo.h>

Servo arm1;  // create servo object to control a servo


int pos = 0;    // variable to store the servo position
int servodata;

void setup() {
  Serial.begin(9600);
  Serial.println("Ready");
  Serial.println("select speed 1 for 15ms  delay");
  Serial.println("select speed 2 for 25ms delay");
  Serial.println("select speed 3 for 5ms delay");
    arm1.attach(9);
}
```

Figure 41. **Example program for controlling servo speed by serial communication**

In this example program the initial process is the creation of the servo object where the movement is to take place. The next step is to initialize a variable to store the position of the servo, next step is the servo data assignment where the data is stored. The Serial.begin(9600) sets the data rate in bits per second for serial data transmission. This is used for the communication with the computer. In the next step Serial.Println, the data is printed to the serial port as human readable format. The other points specify the speed of movement with delay.

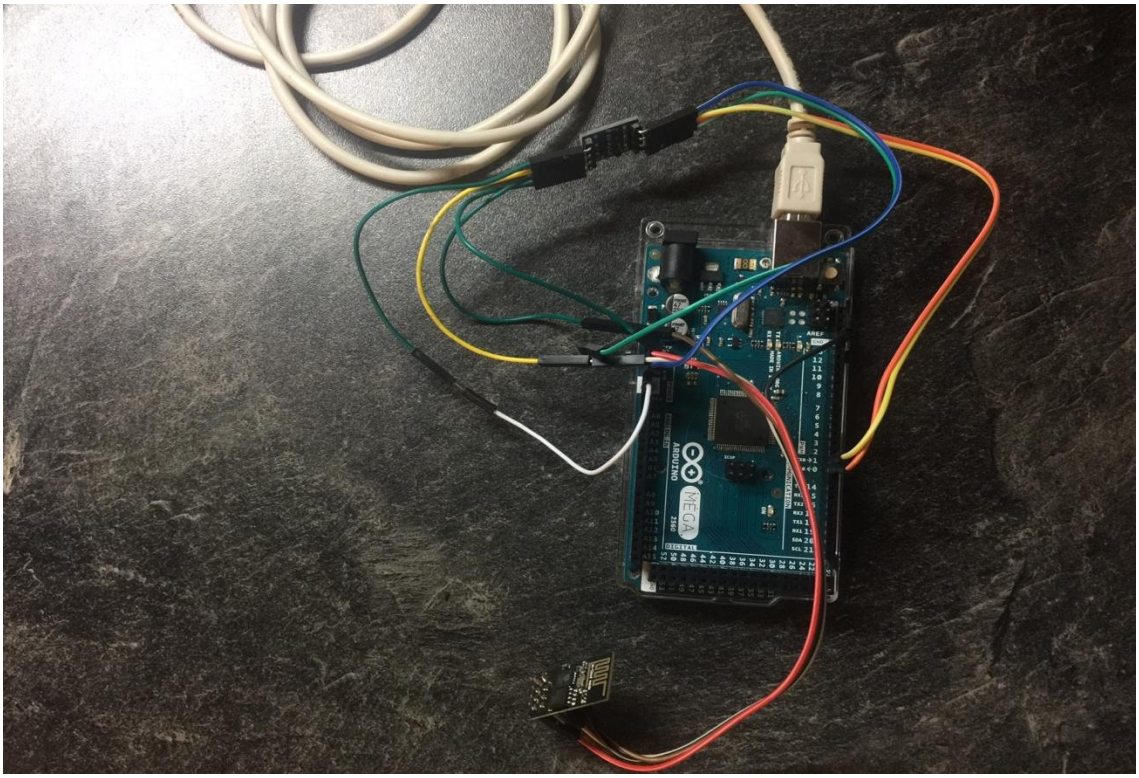

Figure 42. The Arduino Board connected with the Wifi Module

The above figure.42 shows the image of the Arduino connected with the wifi module, which acts as the mode of communication for the robot with the other parts of the smart factory, for easy working and transporting the subjects within the factory.

In the figure 43. which shows the schematic representation of the connection of the Arduino and the wifi module. The wifi module acts the source of the communication for one machine and the other machine. In our thesis, the communication of the robot arm with the other machines in the digital factory is carried out by placing a wifi module in the board connected at the ports Tx and Rx. The Tx and Rx refers to the transmission end and the receiving end in a single arduino board, the wifi module is connected with the Tx and Rx. The transmission end is used for the sending of the data to the other machines in the working environment, and the data sent by Tx is received by the Rx in the other end of the other machine, this is the main concept of the wifi module. In the same way the data that is being sent from the other machine through Tx is being received by the Rx of our robot arm and finally this helps in the effective communication between the machines in the working environment.

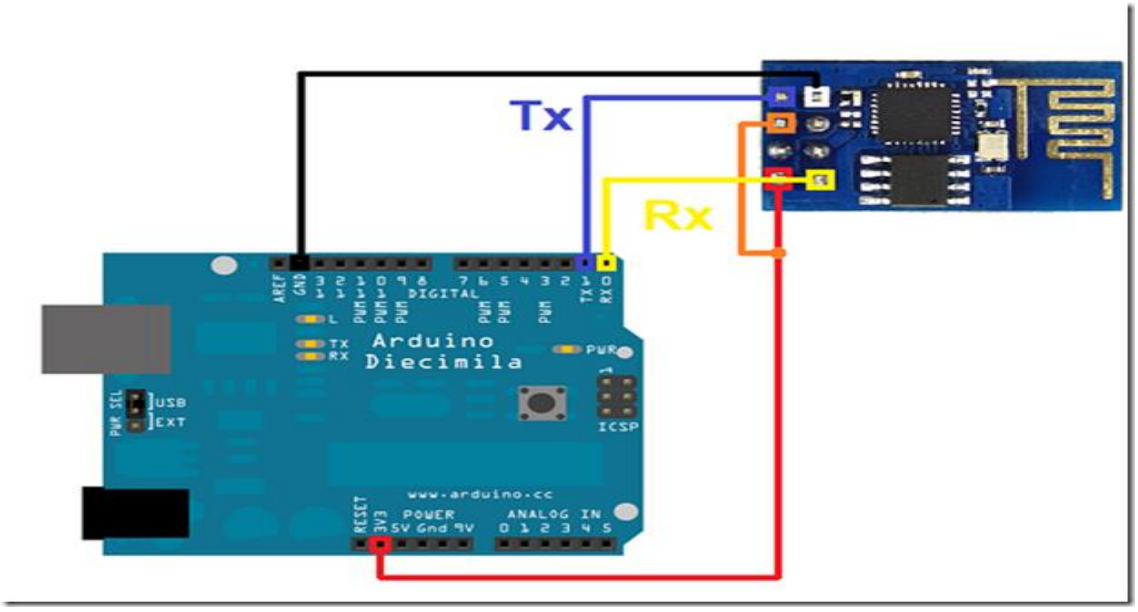

Figure 43. Schematic Representation of Arduino with Wifi Module

Figure 44. Automaton diagram - To reach initial position

Figure 45. Automaton Diagram - Movement with time 2 seconds

In the Automaton Diagram :

- S1 - No Movement.
- S2 - Anticlockwise movement of the robot arm.
- S3 - Robot Arm 1 Down.
- S4 - Robot Arm 2 Down.

- S5 - Stoping of the Robot Arm with the subject in the gripper.
- S6 - Robot Arm Up
- S7 - Robot Arm Up
- S8 - Clockwise Movement of the robot arm.
- S9 - Robot Arm 1 Down.
- S10 - Robot Arm 2 Down.
- S11 - Release Gripper.
- S12 - Robot Arm 2 Up.
- S13 - Robot Arm 1 Up.

The Automaton diagrams Figure 44. and Figure 45. represent the inital movement of the robot arm and the movement of the robot arm with the time gap of 2 seconds respectively. In Figure 46, the diagram represents the entire sequence of the operation of the robot arm.

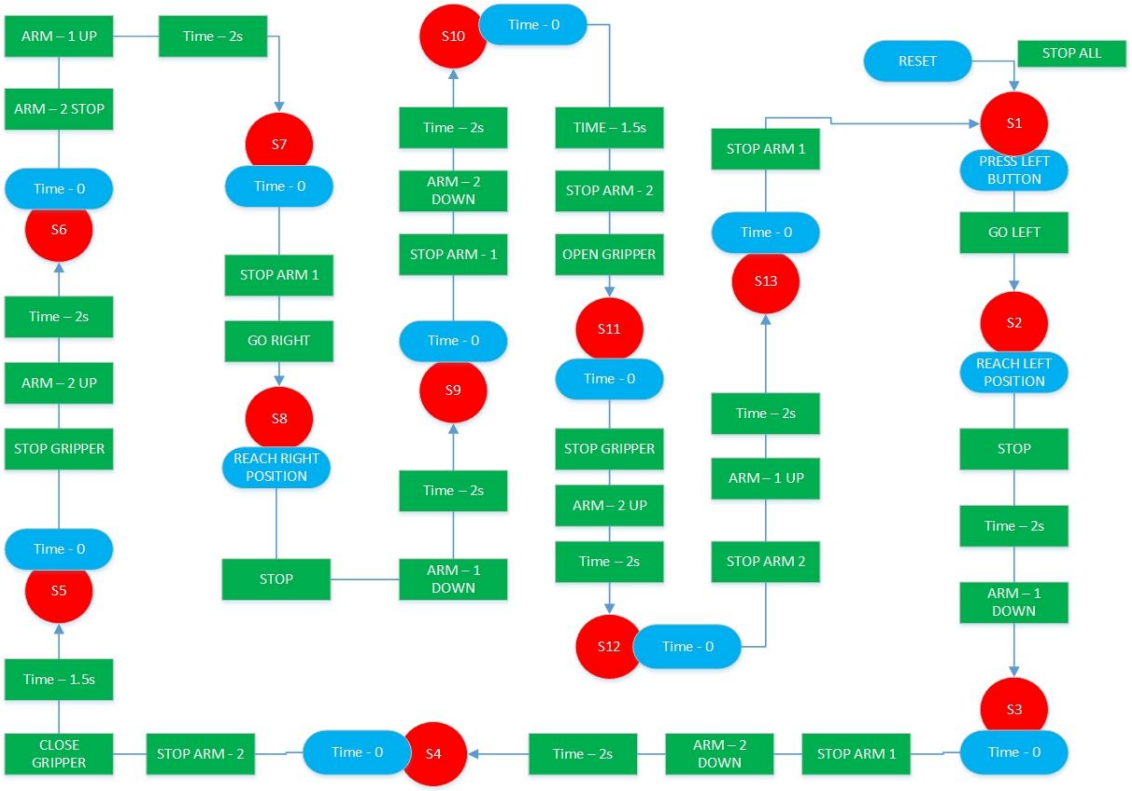

Figure 46. Automaton Diagram - Entire sequence of the operation

Automaton refers to the algorithm of the process, which are closely related to the actions that are being executed in the program. State transition machines is the other

name given to the automatons. The main frame or idea of a automaton is that every automaton acts as a unique state and does the transition by reading the previous input. In this process, the Automaton begins with the reset or in general with the start state. The examination of the text provided takes place at every state. Each time a transition takes place on a input, next input is processed by neglecting the previous one. When a the automaton is designated to a final state, the inputs that has been given until the final state has to accepted. This process is continued until there is no input and the rejection from the previous input is stopped. This automaton diagram, gives the clear view of the working of the robot in the sequence as per the coding giving in the program. The Automaton starts with the press of the left button in the keypad and the entire operation takes place till the end state. Once it reaches the end, the automaton is reseted and again the process is continued from the first by the pressing of the left key.

6 Developments through Automation

THE ANCIENT WAY	THE AUTOMATED WAY
The storage of data was in the form of papers in the files and other physical formats.	Storage has been made easy by the storage in the form of soft copy in Hard drives, External storage devices and cloud storage.
Usage of human power in the gas stations, problem of human absence causes a bad situation.	Card readers and sensors have enabled automated gas pumps, helping people to lead a tension free life.
Dish washing, which was time consuming and had to do before.	Dishwasher, device which operates with no human intervention.
Assembly in automobile sector was done by human working.	Automated assembly units have been emerged helping in faster operation.
In health industry, the surgical operations were being done by human, which had a possibility of causing a problem in the case of minute surgeries.	Automated and tiny devices of automation have been developed to perform the operations in accuracy and precision.

The testing of the climatic changes in the Arctic region and nearby to volcanic mountains was done by humans, risking their life.	Automated and Motorized robotic cameras have been developed to reach such dangerous regions and capture the changes, preventing loss of human life.
Communication transmitted by delivery boys and post offices.	E-mails, faxes, sharing of data through computer networks.

Table 2. Comparison between Old and Automated way[19]

The most trending and the most needed part of the automation is the usage of less power consumption machinery that are being developed and used in the present world. Designers play a major role in bringing these machinery, by building the machines with design and dimensions that allows for the best retrofits. The machinery with high efficeincy motors and with economic power consumption are being achieved through automation.

7 Advantages of using Industry Concept 4.0

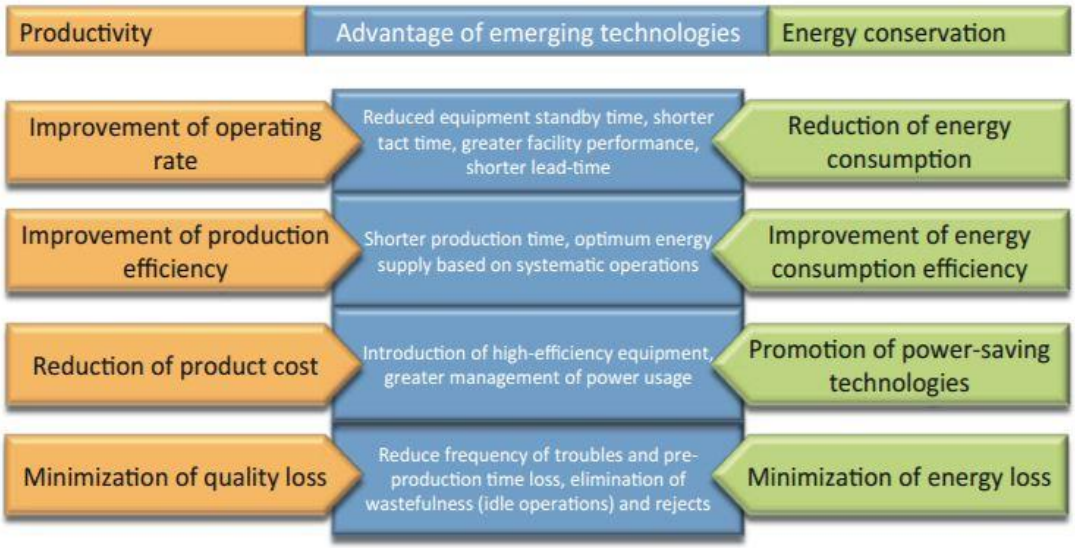

Figure 47. Advantages of Emerging Technologies[20]

The Figure 47 shows the advantages of emerging technologies in the basis of the productivity and energy conservation.

The major advantages or the developments by using the industry concept 4.0 are:

- *Cloud Technology or Cloud Storage* - Industry 4.0 deserves a powerful platform for the purpose of Storing, Sorting and Retrieving large amouts of data and reporting[21]. Having good source of data storage, can be a added advantage to perform the operations realtime[21]. The integration of the Cloud is not only an advantage but also an essential thing in the Industry concept 4.0.
- *Welcoming Internet of Things* - Industry 4.0 being a revolutionary step towards smart factories is being integrated by the platform called as Internet of Things[21]. Since Industry 4.0 supports a large part of making original equipment manufacturers, IOT becomes a core driver in creating companies demands[21].
- *Improved Customization* - Customization is one of the main aspect of the industries, which is needed by various customers according to their needs and changes. Customization has been made easy by the concept of Industry 4.0, which helps the customers to design or modify the product. This ability to provide the vast needs in customization helps the companies to be more responsive to restrain their producion programme[21].
- *Communication made easier* - Industry 4.0's main concept behind is to bridge the communication gap that is being in existence. By bringing the customers and the suppliers closer, it helps to make an effective planning of the production[21]. The coordination and communication of Intelligent planning platform are being made better and easy so that the production loss and loss of time can be prevented[21].

Industry 4.0 will always play a role in developing the integrated engineering throughout the production and also in the the life of customers. It has always been a support tool to ensure that the innovation is never limited within the traditional area of product innovation.

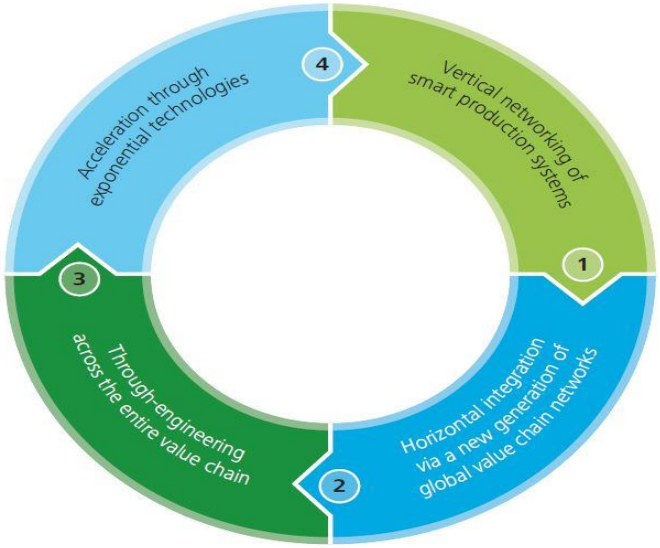

Figure 48. Advantages of Industry Concept 4.0[22]

8 Conclusion

The two main conclusions can be made from this dissertation, one can be positive and one can be a negative. The negative side of this study is that it can create negative impact on the working employees, who thinks that the automation will lead to the loss of jobs for the future generation and also in the present. These set of employees are the ones who are not willing to adapt themselves to the new set of trainings, tasks and requalification. The other side of the conclusion states about the young and the positive generation of employees who think and work towards the next level of change that is brought into the industrial sector in the form of automation. It is easy for them to adapt and train themselves for better working solutions towards the improving technology. Automation can be referred to many words like sustainability, high capability to adapt for the changes, more flexible and better problem solving situations. The industrial stability is provided by Automation, which helps us to achieve production without losses in time and quality.

On the whole concluding about the work done in this thesis, the assembly of the robot is made as per the figures provided in the above description. The hardware of the robot is being used as the drive to the servos, the control unit is made seperately and it is used to control the robot. The robot is equipped with the sensors at the ends, which help

in defining the end position of the robot arm and also to avoid the collision with the other objects. The model design diagram for catching and removing of the object was made. The manual operation is also possible by using the keyboard that is being designed for operating the servos motors connected in the robot arm. This manipulator or the robot arm is a part of the digital factory or the smart factory where automation acts as the backbone of the concept from which all the operations are being carried out. The operation of the robot arm can be made by the two ways, one way is the control through the electrical motor with gear, in this case the position is entered with the arduino or with the pulse width module and the other way is by the using of library functions with function of serial communication. The robot arm is always connected with the other machines in the factory and the communication takes place between the robot arm and the other machines by the wifi module. The robot arm will always be a essential part in the digital factory and future developments can be made to the arm, by adding technological advancements.

In this idea of automation, Industry concept 4.0, provides a clear state of progress in the development. Industry concept 4.0 is being implemented as the current trending technology in all industrial sectors and it has been an enormous success showing stable growth in the industries. This thesis deals with a part of the concept of industry 4.0 helping for moving of the subjects in the working environment from one position to a vehicle or to another position.

The innovative process of this thesis requires a broad vision in decision making and implementing, with these two visions this thesis can be prolonged into a long term strategic goals to overcome and qualify all the competitive changes and advantages. In the mainframe called, industry 4.0 the changes are dynamic with the value of time, time is the main factor which helps in the development. Technology such as automation and other things will help to improve the job standards rather than removing them from the employees. These technologies will encourage and motivate elements and anticipate goals among individuals. A technology will always help a human mind to tackle the problems and the challenging situations faced with great focus and higher value.

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