

# Role of Mechanical Engineer in Robotics and Automation

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**Abstract**— Robotics and automation play an essential role in the development of any industry. There is no doubt that the present era is about robotics and automation. Various activities have been replaced with the help of robotics and automation to make human life easy. New skills and experience are needed to design and develop such advanced robotics and automation systems. Robotics and automation systems combine the design, construction, operation, and application of robots coupled with computer-based control systems, sensory feedback, and information processing. The design and development of Robotics and automation systems put the fundamental principles of mechanical engineering, such as mechanics of machines, machine design and drawing, heat and mass transfer, production and manufacturing, computer-aided design and analysis, fluid engineering, material science, computational fluid dynamics, vibration, mechanical measurements, hydraulics, and pneumatics, programming software and many more. Many researchers are working in robotics and automation in the domain of mechanical engineering. However, the role of mechanical engineering is not highlighted in any of the recent articles. In the presented paper, we aimed to study various aspects of the role of Mechanical Engineers in robotics and automation development. We systematically represented the study in order to get a straightforward understanding of the importance of mechanical engineers. The paper highlights the role and includes a detailed discussion of the future of mechanical engineering, followed by various conclusions of the study.

**Keywords**— Mechanical engineer, Robotics, Automation, Engineering, Skills

## I. INTRODUCTION

There is no doubt that the present era is about robotics and automation. It is the key technology in making the industrial revolution, i.e., Industry 4.0 and Industry 5.0. Robotics and automation are an integral part of Mechatronics. Still, the terms robotics and automation are more popular than Mechatronics. Robotics and automation combine the design, construction, operation, and application of robots coupled with computer-based control systems, sensory feedback, and information processing. A robotic and autonomous system design combines mechanical engineering, manufacturing engineering,

electrical/electronic engineering, and computer engineering. For example, in manufacturing the industrial robot, mechanical engineers design the robot's structure, joint mechanisms, bearings, heat transfer characteristics, selection of material, etc. Electrical engineers take care of the control electronics and power amplifiers, while computer engineers design the robot's computing hardware and program it. Robotics & Automation engineering involves design, development, and up-gradation in terms of automating products, systems, and processes in every walk of human life. It has several advantages, such as cost-effectiveness, improved quality assurance, increased productivity, working in a hazardous environment, etc., and disadvantages as it requires skilled staff, the initial cost needs to be lowered, and potential job losses.

Although robotics and automation are multidisciplinary fields, mechanical engineering still plays an essential role in making it realistic and applicable. Mechanical engineering is an essential foundation for the expected growth in robotics and automation. Mechanical engineering provides the fundamental knowledge of the mechanics of machines, machine design and drawing, heat and mass transfer, production and manufacturing, computer-aided design and analysis, fluid engineering, material science, computational fluid dynamics, vibration, mechanical measurements, hydraulics, and pneumatics, programming software and many more for design and development of robots and autonomous system. Mechanical engineering has mainly supported and contributed to the modern development of the smart world. The development of robotics and automation is a very interesting research and working area nowadays. And the role played by mechanical engineering is significant. However, almost no papers highlight the role of mechanical engineering in developing robotics and automation systems. There is a need to identify new areas and highlight the contribution of mechanical engineering in their development. With this work, we aim to highlight the exact role of mechanical engineering in the development of robotics and automation systems. We systematically represented the study in order to get a straightforward understanding of the importance of mechanical

engineers. Section 1 of the paper gives a detailed introduction to the topic. In contrast, the paper highlights the role in the multiple phases of the design and development of robotics and automation systems in section 2. It includes a detailed discussion of the future of mechanical engineering in section 3, followed by various conclusions of the study in section 4.

## II. ROLE OF MECHANICAL ENGINEER IN ROBOTICS AND AUTOMATION

The mechanical engineer is among the most qualified to become a robotics and automation engineer. The roles and responsibilities in the field of robotics and automation can be easily understood by systematically representing various processes of the design, development, and after-sale activities of new robotics or automation systems in the multiple phases, such as

### A. Problem's identification phase

When finding a solution, we must know about the problem briefly. Various factors need to be considered and checked for the original cause or need. The problem identification phase plays a significant role in designing and developing any new system. This phase works on analyzing the particular problem and defining it to the point. This phase also highlights the needs of the project. In this first step, engineers are very clear on what they must achieve at the end of the project. Let us understand this phase with the following reference.

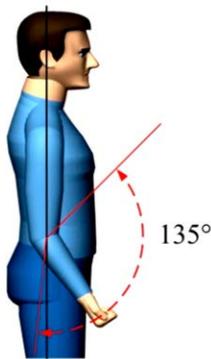


Fig 1: Upper limb paralysis [1]

There are various problems in this world. One of the significant paralysis problems is identified by Pang et al. [1]. Patients with upper limb paralysis have difficulty with their daily activities. The primary reason for paralysis they found was a stroke. They also identified the various causes of it, such as poor lifestyle, environmental factors, and others. Further, they also found the use of robotics; rehabilitation robots can help patients overcome shortcomings. There are many tasks that can be replaced with Reviewing papers helps a lot in studying the background of any new project. Monebbi [6] has reviewed all the terms related to human-robot interaction in the healthcare sector. He has majorly reviewed the contribution of rehabilitation robotics to solving various medical needs, such as those of the ageing population and neuromuscular and musculoskeletal disorders. They have also highlighted the machine learning approach,

various sensing technologies, and many more. Further, during the COVID-19, the use of robotics was beneficial. Zhao et al. [7] have reviewed various applications of robotics, artificial intelligence, and digital technologies in the development of smart healthcare systems. Such technologies were used to maintain social distancing, avoid person-to-person contact, track, etc. They have presented a study from almost 163 articles and reports. Furthermore, it has highlighted all the aspects of technologies used in such difficult times.

robotics technology. One of the tasks of painting the house and buildings is identified by Aris et al. [2]. They found the need for the development of robotics technology in the field of the construction industry. They identified the problem in current house painting methods, such as working in an upright position, which is very difficult for the workers. The manufacturing industry was always ahead in implementing various new robotics and automation systems.



Fig 2: Weed control problem [5]

Many workers are used in the packaging section to perform multiple tasks. However, Devala et al. [3] found a loss of cycle time in material handling in the packaging section. The significant loss was in the wrong object detections and picking them up. They noted the need for more efficient workers in these sections in order to reduce the cycle time. Further, with the development of robots in all industries, Rangapur et al. [4] found the need to develop robots for surveillance operations to help soldiers reach unknown places and continue watching the particular area. Further, they also identified the limitations of available robots. With this, they aimed to design and develop efficient and effective robotics systems for surveillance operations. In the agricultural sector, weed management is time-consuming and hard work to perform. Aravind et al. [5] have identified the use of unwanted chemicals in healthy crops other than weeds. They found the need for a system that can smartly identify and control weeds in the field.

### B. Research and Discussions phase

After analyzing and defining the problem statements, engineers look forward to studying various technical teams related to the problem statement in depth. This phase mainly involves activities like collecting data for the reference study and the easy development of the new system. This phase helps to collect a good amount of data on the finding from the available research work on all the related terms. This phase may also involve ground studies. Ground research helps to understand real-time challenges. Further, this phase gives a clear idea, or

methodology, of the design and development of the new system to the engineer's team. Many discussions are taken in this phase to understand and plan the project. A clear discussion helps clear all doubts and narrow the process. The following are a few references from researchers who performed this phase.

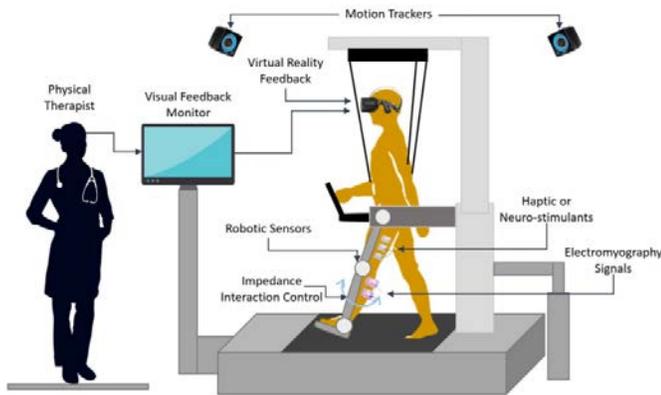


Fig 3: Study of Human-robot interaction [6]



Fig 4: Various types of healthcare robots used in Covid-19 [7]

Researchers have been working on developing the intelligent industry, also known as the time of the Industrial Revolution 4.0. Bahrin et al. [8] have worked on the industrial aspects of implementing robotics and automation. They aim to highlight advanced robotics and automation systems to achieve Industry 4.0. Further, Urhal et al. [9] have studied additive manufacturing with the help of robotics technology. 3D printing is very popular nowadays, but it has a disadvantage due to some limitations of the size it can print. To overcome this, many researchers have worked on designing and developing robots to do the job. In this paper, the authors have discussed the concepts of robotic-assisted additive manufacturing. They have also discussed various modern methods.

The development of Military robots is an emerging area of research. Multiple problems in this field need to be addressed. Szabolcsi [10] has highlighted the application of robotics in the military field and the development of the controller for UAVs. He has also presented the methodology, which can be used for reference studies in the future. Space exploration is the most exciting field of all time. Gao et al. [11] have worked on reviewing top-level science innovation with the help of robotics technology. They have presented basic concepts, historical context, and the evolution of robotics in the field of space exploration. They also highlighted many research gaps in this paper. The number of space robots studied and presented in this paper is a reference for the development of space robotics. The multiple problems in agriculture have led robotics technology

to get involved. Fountas et al. [12] have presented agricultural robots for efficiently working in farm activities. They have given a systematic review of literature on the various agricultural robots. They found that there are more studies on harvesting and weeding operations and less on disease detection and seeding robots

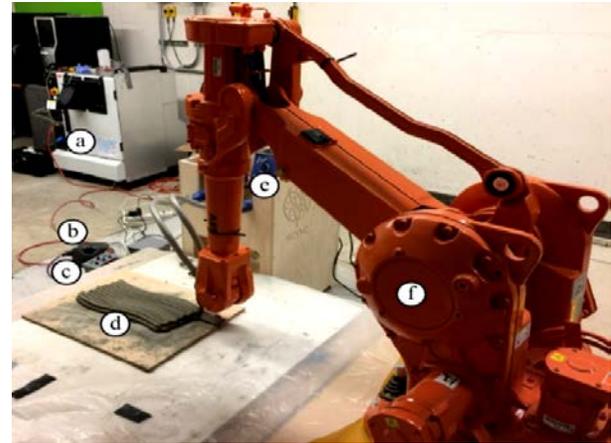


Fig 5: Additive manufacturing robot [9]

. Design phase

Until now, engineers have been working on how their system will overcome the problem and with the needed study of related terms. Now, in this phase, the time is to convert imagination to some form. With all the studies, multiple conceptual models of systems are designed. Every part is designed separately and then assembled to form a system. Various mechanical properties are kept in mind while designing. Then, multiple design analyses and calculations are performed. After designing conceptual models of the system, one is selected on the basis of its advantages over the other. In this phase, the engineer takes care of each and every aspect of the design for its long and safe life, such as its dimensions, materials to use, weight, and many more. Further, various electronic circuits are also being designed as per the requirements. The circuit diagrams are drawn for reference. The layouts of the circuit board are drawn with the help of layout software, which is also called printed circuit board (PCB) design. Almost every robotics and automation system undergo a design phase. The design aspects and properties change as per the requirements.

The representation of an idea is essential in any project. In the healthcare system, there are many factors that need to be considered when designing robots. Pang et al. [1] have worked on designing rehabilitation robots and have presented a 3D model of the same, as shown in the figure. With multiple designs and calculations, the final model is presented in this paper. The design and assembly of various mechanisms are always challenges. Devala et al. [3] show the PCB design for the sorting robot. The design phase has many advantages to reduce such challenges, such as Benhabib et al. [13] on mechanical robot design for industrial applications. This robot is capable of achieving optimal geometry for any specific task. They gave each part's design drawings and a complete robot drawing.

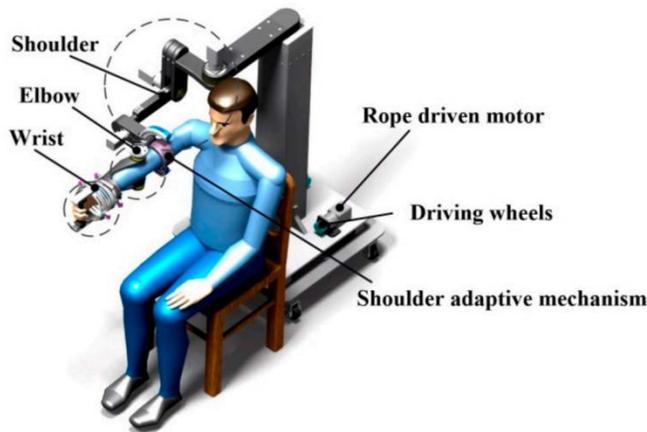


Fig 6: Ideation of project [1]

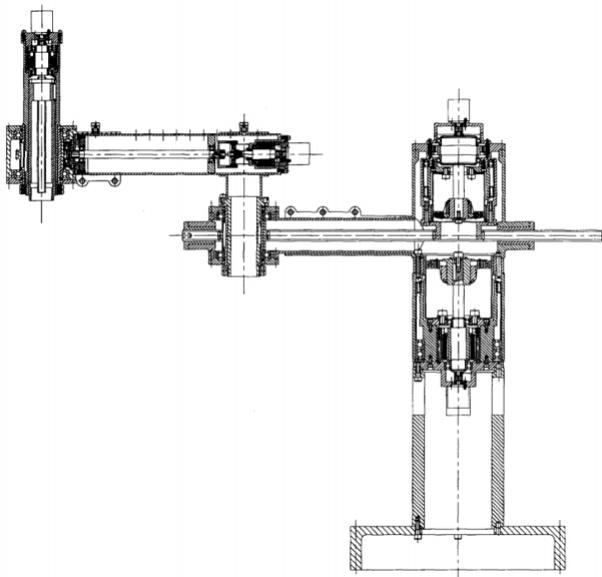


Fig 7: 2D CAD diagram [13]

The design of a spherical spy robot for surveillance is presented by Rangapur et al. [4]. They designed the model with the help of CATIA and performed multiple FEA analyses. The robot's outer shell is about 18 cm in radius and is made of acroleic material. Some other parts are designed individually and then assembled, as shown in Figure 11. Agriculture has many challenges, as does the designing of robotics systems. Quaglia et al. [14] have presented the design of UGV, powered by solar energy for precision agriculture, named Agri. q. It has multiple degrees of freedom, and it has robotic arms and power with computer vision. They have also shown various design parameters in this paper.

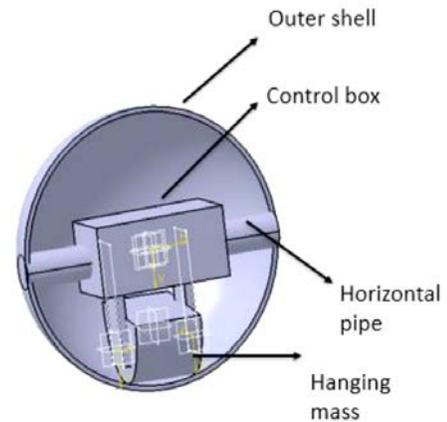


Fig 8: Robot CAD model intersection view [4]

C. Calculation phase

In order to design and develop a stable and perfect system, the calculations phase comes into the picture. Multiple calculations such as design, mechanical, power electronics, and many more are needed to perform, from the design phase to the maintenance phase. Engineers work very carefully in order to avoid future problems and errors. They try to keep everything simple and up to the requirements only. Engineers are very focused as they know that mistakes in this phase can cause a lot of damage to the project. During this phase, they are very sure of the system's performance.

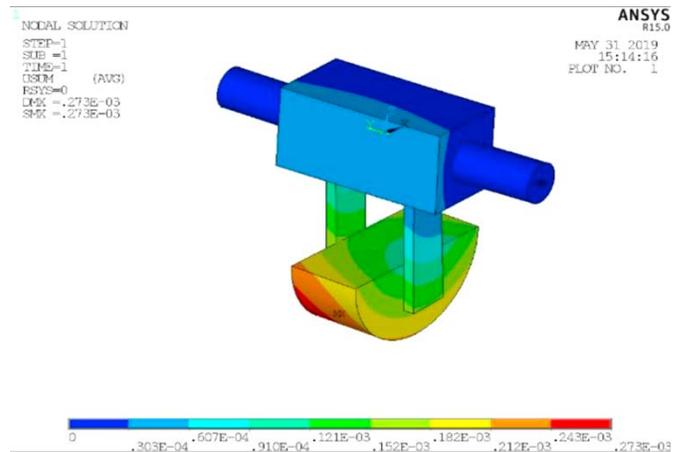


Fig 9: Ansys analysis [4]

Modelling and analysis are performed to verify the mechanical properties of any new product. Gargade et al. [15] have presented modelling and analysis of pipe inspection robots. They designed all the robot components with the help of Solid Works and performed stress analysis in Ansys 13 software, followed by manual calculations. They performed calculations for the selection of the motor, the Design of the Motor Shaft, and the Design of the pulley and belt. The robot must follow a particular way to perform any action. Martinec et al. [16] have presented methods for calculating the trajectory of the end-effector of an industrial robot. Various rotational and translation matrices are involved in this calculation. Any

system needs specific energy to perform particular tasks. Mohammed et al. [17] have worked on minimizing the energy consumption of robot arm movement. They have developed a module using MATLAB. They calculate the forces and torque applied to each robot's link and joint and then calculate energy consumption. The optimization of energy takes place. Further, Wei et al. [18] present the calculation for an underwater robot. The calculation of underwater kinetic resistance is performed.

#### D. Hardware and components gathering phase

With a clear idea of the requirements and having the needed specifications of various hardware and components, the task is to gather all the needed things, such as raw materials, electric components, mechanical tools, etc. This phase requires a deep study of the market in order to get the supply easier and less costly. Multiple quotations are calculated, and one with maximum advantage is selected. The proper care is taken while choosing the hardware and components to avoid any mismatch in the requirements.

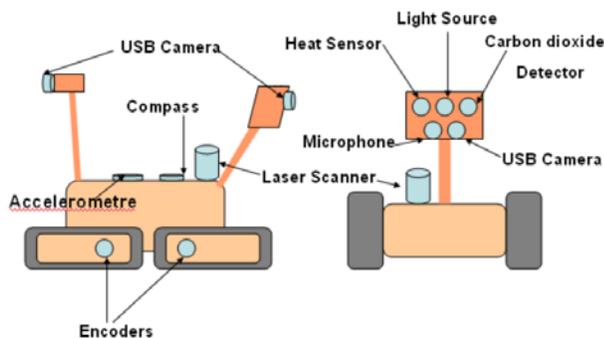


Fig 10: Hardware components of the rough-terrain robot [19]

Devalla et al. [3] have used multiple electronic components such as ATMEGA 16, MAX 232, L23D, DB9, USB to serial cables, and motors. All the components were outsourced. Similarly, Suthakorn et al. [19] have collected all the After fabricating the needed parts, it is time to build the needed electronic circuits for the systems. In this phase, with reference to the circuit diagram and PCB layouts, all the electronic components are arranged and soldered or wired together to complete the electronic system of the new model. The primary electronic parts are microcontrollers, sensors, and actuators. The power calculations performed in the calculation phase are used to balance the power requirements of the systems in this phase.

components needed to design and develop a rough-terrain robot. They have used servo motors, DC motors, Microcontrollers, encoders, and many more. Material selection plays an essential role in the performance of the robotic system. The material selection process for the wall-claiming robot is presented by Akhtaruzzaman et al. [20]. They selected aluminium to construct the body and legs of the robot. Further, they have also outsourced solenoid valves, tube connectors, and DC motors.

#### E. Manufacturing phase

As the name says, it is time to get the digital product or system into reality, a physical model. Once engineers gather all the needed hardware and components, they start with the manufacturing phase. In this phase, the CAD drawings are taken for reference for various measurements of a particular part. This phase involves many activities such as marking, jig fixture making, cutting, grinding, welding, buffing, drilling, colouring, and many more. Each part of the system is manufactured in this phase. After performing all the processes, the final check is performed in order to avoid any errors.

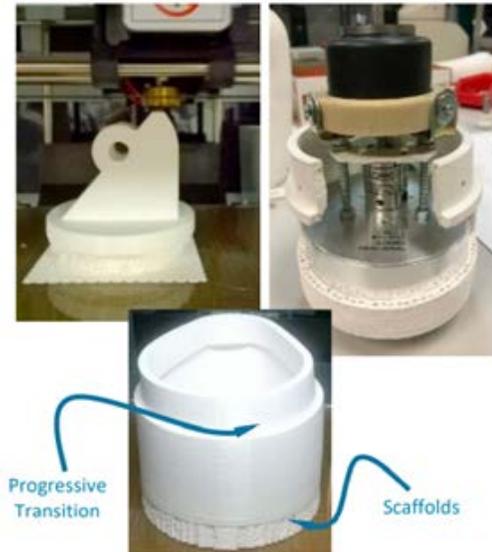


Fig 11: 3D printing of robot parts [21]

Gutierrez et al. [21] have manufactured a prototype of the lightweight robot arm using modern technology of 3D printing. They aim to manufacture robot arms at a low cost and fully working. Each individual path was manufactured one by one. The Maya social robot was designed and fabricated by Ranjkar et al. [22]. The multiple sketches were referred to fabricate the robot. The structure was 3D printed and was covered by a printed cover. Then the outer layer was covered with cloth. Quaglia et al. [14] have worked on designing and developing agriculture robots. In this paper, they have also presented the Agri.q02 prototype. It has many essential mechanical components. The body is manufactured of aluminum, and other elements are of steel.

Devalla et al. [3] have worked on making hardware of Eye for shorting bot. The multiple electronic components are placed as per the PCB layout. Similarly, Kumar et al. [23] have built the PCB circuit by referring to the initial logic layout circuit. Further, Samuel et al. [24] have presented their work on the robot for surveillance. They have used many outsourcing components. They have presented the block diagram of the built circuit

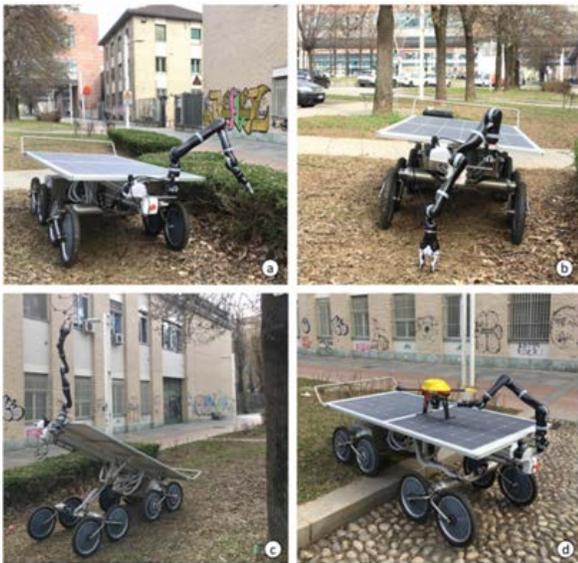


Fig 12: Agricultural robot designing and development [14]

**F. Building electronics circuits phase**

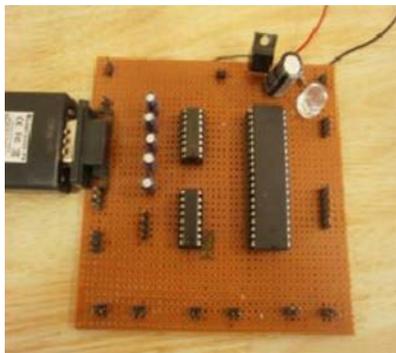


Fig 13: Electronic circuit [3]

**G. Programming phase**

Here comes the crucial phase of designing and developing automation or robotics systems. Without programming, the developed systems are useless. Here, the controller is programmed to perform particular tasks. Here, engineers use various logic to program specific tasks. With the knowledge of various programming languages, one is ready to code. Here, programmers with hardware knowledge are very efficient in the development of the program. After multiple modifications and eliminating errors, the program gets ready to implement on the physical model. Akhtaruzzaman et al. [20] have given an algorithm for wall-climbing robot programming. The flow chart in this paper explains various activities that the robot's controller will perform. After completing the specific tasks, the robot is programmed to come back to its initial position.

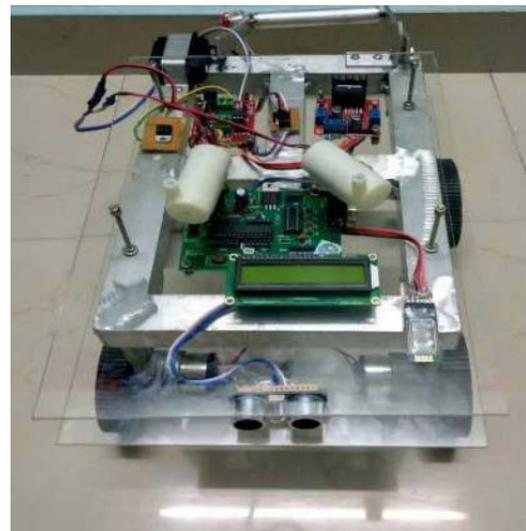


Fig 14: Electronic circuit connection [23]

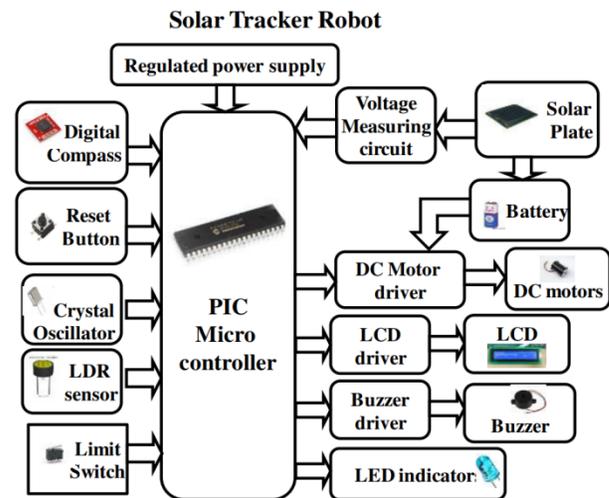


Fig 15: Basic block diagram [24]

**H. Programming phase**

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**I. Assembling, testing, and calibrating phase**

We have seen how engineers woke up to various aspects of designing and programming. Now it is time to assemble all the design, manufactured, electric, mechanical components, and

hardware to form a coupler system. After successful assembly, various performance tests are performed. In this phase, they look for minor errors and problems. Here, the majority of errors are due to the miscalibration of electrical components. After determining the errors, calibration tests are performed, and all the electric components are calibrated as required. Furthermore, the final check is performed in last, and the system's performance is checked and verified. Now, the systems are ready to go out in the market. Gutierrez et al. [21], after manufacturing various paths of a robot arm using 3D printing, assembling of all the paths is undertaken, followed by various performance tests.



Fig 16: 3D printed parts assembling [21]

### III. DISCUSSION

The world is getting multi-tasking, and each and every field is now dependent on each other. Robotics and automation are imaging fields of time and include multiple fields of science, technology, and management. The contribution of mechanical engineering in any field is significant, but no review paper has significantly mentioned it. In this paper, we have highlighted the contribution of mechanical engineers in the design and development of robotics and automation systems into 09 different phases of design and development such as the problem identification phase, research and discussions phase, design phase, calculation phase, hardware and components gathering phase, manufacturing phase, building electronics circuits phase, programming phase, assembling phase, testing, and calibrating phase. We have explained each of the phases in this paper and highlighted the contribution of mechanical engineering. We have also cited some research papers highlighting particular phases.

In our research, we utilized insights from nearly 24 research papers. It's evident that numerous researchers are actively engaged in the robotics and automation domain within mechanical engineering. Despite this, recent articles have failed to adequately emphasize the pivotal role of mechanical engineering in this field. In the presented paper, we aimed to explore various dimensions of mechanical engineers' contributions to robotics and automation development. We systematically organized our findings to provide a clear understanding of their importance. We discovered that

mechanical engineering is integral to every phase of robotics and automation system design and development. For enhanced comprehension, we meticulously outlined the specific contributions of mechanical engineers in each phase. Further, there were some phases, such as marketing, implementation, and maintenance, in which mechanical engineers contributed the most. As designers and developers, they have deep knowledge and are found to outperform the others. But surprisingly, the existing literature lacks recognition of this aspect. Notably, we couldn't find any research paper that adequately addressed this critical facet. Hence, future research will focus mainly on discussing it in depth about it.

### IV. CONCLUSION

Systematically represented the study in order to get a straightforward understanding of the importance of mechanical engineers. Mechanical engineers are integral to the design and development of robotics and automation systems across various phases. In this paper, we have highlighted the contribution of mechanical engineers in the design and development of robotics and automation systems in nine different phases of design and development, such as problem identification, research and discussions, design, calculation, hardware, and components gathering, manufacturing, building electronic circuits, programming, assembling, testing, and calibrating phase. It also emphasizes the need for recognition in research literature. Further, the future of robotics and automation relies heavily on the expertise and innovation of mechanical engineers.

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