

CHAPTER 2 – LITERATURE REVIEW

Autonomous mobile robots (AMR) and autonomous guided vehicles (AGV) are two types of mobile robots (AGV). The autonomy function of these robots is said to be the difference between AMR and AGV. An AGV navigates in a pre-defined area on a predefined route using physical directions. AGVs have long been used in manufacturing, but they have recently been replaced by AMR. AGVs are well-suited to manual activities like line follower robots, and they are often engineered and manufactured for specialized tasks. Since AGVs cannot make decisions and lack a decision system based on artificial intelligence, the role that they would execute must be meticulously prepared and all information must be defined to them by the programmer. AGVs operate according to pre-programmed programs and protocols, making quick transition difficult. AGVs may not be the right fit for a business model that reacts to patterns or is otherwise agile. As previously said, the key drawback of AGVs is their inability to execute rapidly shifting functions. An AMR can maneuver in an unpredictably changing environment. AMRs will sense the environment's conditions, build a model of the environment, and place themselves within the model. As a result of this action, AMR is able to create a navigation strategy and refine it using a special planning algorithm. In a nutshell, an AMR has no predetermined navigation strategy. An AMR may also use sensor data to build a chart of the area and then locate itself on the map. Simultaneous localization and visualization is the term for this (SLAM) (Köseoglu et al., 2017). SLAM allows the programmer to build a highly responsive navigation strategy that can be dynamically revamped and changed. A variety of environmental sensors are needed for an autonomous mobile robot to complete its mission. These sensors are either built into the robot or used as an external sensor that is placed in the environment. The number of various types of sensors installed on the mobile robot to perform complex tasks like estimation and localization makes the overall system's architecture extremely difficult. Locomotion, perception, and navigation are the foundations of mobile robotics.

2.1. Autonomous Mobile Robot Systems

Because of the amount of RDEs available and the release of new systems, as well as the complexity of robotics as a science, a complete accounting and detailed comparison of all RDEs is simply impractical within the limits of a survey document. A collection of qualifying restrictions is used to restrict the range to a particular subset of representative RDEs, making the assignment more manageable. The IEEE International Conference on Robotics and Automation (ICRA) proceedings are split into three categories:

Single robot: SLAM, Planning/Navigation, Learning, Hierarchical Behavior, and Education.

Human-Robot Interaction: task Allocation, Learning, and Assistive Robotics.

Multi-robot tasks: Sensing, exploration, mapping, localization, planning, coordination, formation, and task all allocation

2.2. Body Structure Material

Autonomous mobile robot consists of several material parts in its body structure. The structure consists of a frame as the basic foundation for an autonomous mobile robot, a base for each electric part and sensor part, and an outer cover as the outer layer to make it look compact.

2.2.1. Frame Material

There are various materials that can be compared to form a frame for autonomous mobile robot.

2.2.1.1. Steel Hollow

Steel hollow sections are frequently used in welded frames, columns, and beams, and they offer a variety of advantages in a variety of construction and mechanical applications. RHS (rectangular hollow sections), SHS (square hollow sections), and CHS (circular hollow sections) are the three primary varieties of steel hollow sections (structural steel tube) (circular hollow sections). Each hollow piece has its unique characteristics that are employed for a certain purpose.

For mechanical, structural, and building purposes, rectangular hollow sections (RHS) are a preferred choice.



Figure 2. 1 Steel Hollow

Steel hollow is used as the material for the frame because of the nature of the hollow which is strong enough as a foundation because the hollow has supporting sides, so that the distribution of the load will be better. And the burden is not too heavy.

The hollow itself is made out of steel alloy. This material been chosen because of its easy availability. And it is quite easy to manufacture, this way it will make it easier during the manufacturing process later.

The steel hollow used has the dimensions of 30x30mm square tube because it will so much easier to adjust if it has a square tube size, and later it is easy to add additional parts to attach.

2.2.2. Base and Cover Material

There are various materials that can be compared to form a base and cover for autonomous mobile robot;

2.2.2.1. Acrylic

Acrylic has a variety of benefits, such as; Acrylic is 30 times more potent than glass. This may sound shocking but acrylic sheets printed are actually thirty times as powerful as regular glass. This is because acrylic sheet is a plastic shape, and is much more flexible. It doesn't split quickly, less likely to break in the process. During processing, ordinary glass has a very high chance of breaking but acrylic sheets are safe. Plexiglass or transparent acrylic has nearly limitless processing options. These sheets can be sawed, milled, drilled, etched, glued, polished and bended (with heat).

In addition, acrylic is 2 times lighter than glass. Plexiglass or Acrylic sheet is twice as light as regular glass. Acrylic sheets are also cheaper, for those looking to save money, acrylic sheets are

2.2.2.2 Steel Plate

Steel has a wide range of compositions. Steels have a lower carbon content and lower levels of impurities like phosphorus and sulfur than cast irons. The ranges shown in the composition chart above are common for basic steel components. Boron, Chromium, Cobalt, Columbium (Niobium), Copper, Molybdenum, Nickel, Nitrogen, Selenium, Tantalum, Titanium, Tungsten, and Vanadium are among the alloying elements used to improve steel's corrosion, high temperature, and mechanical qualities. Steels have a variety of qualities, which are detailed below. In general, qualities like density, thermal conductivity, and electrical resistivity are unaffected by composition or heat treatment, but

tensile strength, elongation, and hardness are substantially influenced by composition and heat treatment.

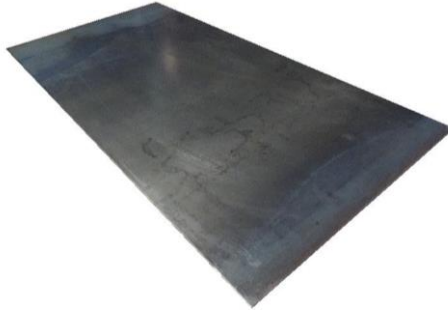


Figure 2. 2 Steel Plate

Steel has a wide range of compositions. Steels have a lower carbon content and lower levels of impurities like phosphorus and sulfur than cast irons.

Just like hollow steel, the materials used are also alloy steel. It is easy to fabricate as cut, welded, grinded to fit the required design.

2.3. Locking System

In robotics, locking mechanisms are commonly used to secure springs and joints, as well as to reconfigure robots. Autonomous mobile robot would later need a system for this job assignment to help it sustain its transportation so that it is not separated from the mobile robot when doing the job. A locking mechanism is a device that allows and prevents relative motion between two parts by switching between allowing and preventing relative motion. The specifications for a locking mechanism vary depending on the application.

The characteristics of an ideal locking mechanism:

Adjustable locking directions: The system can lock in one of three directions: zero, one, or two.

1. Unlocking when under load: The locking mechanism should be able to unlock even though it is under load.
 2. Low energy consumption: The computer does not consume energy when it is activated or unlocking.
 3. Lockable in any position: The unit can be locked in an infinite number of positions.
 4. Compact: The unit should be compact in comparison to its intended use.
 5. Lightweight: The unit should be light in comparison to its intended use.
 6. Short switching time: The system turns on and off in a split second.
 7. Low cost: The system should be low cost in comparison to its operation.
- High locking
8. Force: The device should have an infinite locking torque.

Some locking systems can also be used as controllable brakes, which means that the locking torque can be adjusted and the brake slips when the external torque exceeds the locking torque. Any technological difficulties must be solved in order to create such robots. Based on three locking principles (Plooi et al., 2015), the locking systems are divided into three key classes;

Mechanical locking's: The locking or unlocking of a mechanical part is determined by its location. Wedges and pawls are examples of such components. This location can be calculated by an actuator or it can be influenced by factors such as the position of a joint or the velocity direction. In the section titled "Locking Systems Based on Mechanical Locking," these locking devices are addressed.

Friction-based locking: decides whether the joint is locked or unlocked by engaging or disengaging two friction surfaces. This engagement may be determined by an actuator or based on factors such as joint location or velocity direction.

Singularity locking: occurs when a mechanism's transfer ratio approaches infinity. The locking mechanism has an infinitely strong locking force and an infinitely small unlocking force in this singular position.

		Locking Principle		
		Mechanical	Friction	Singularity
Activation	Active	Latches Ratchets Dog Clutches Hydraulic Locks	Electromagnetic (EM) Overrunning Self-Amplifying Capstans Piezoelectric Bistable Statically Balanced Thermic	Four-Bar Linkages
	Passive	Latches Ratchets Cam Based	Overrunning Nonbackdrivable	Nonlinear Transfer Ratio

Figure 2. 3 The main categories locking devices

2.3.1 Stepper Motor

Stepper motors are used in a variety of small devices that require high torque or fast speeds. The motor's physical architecture often enables precise monitoring of the motor's location without the use of closed-loop feedback techniques (Siripala & Sekercioglu, 2013). Stepper motors have made their way into a variety of control systems. In applications such as robotic arms and precision assembly controls, stepper motors have proven to be effective in factories and assembly environments. Stepper motors can be found in printers, hard drives, toys, automobiles, and a variety of other applications and goods. The versatility with which these motors can be powered, as well as their compatibility with digital systems, contribute to their widespread popularity. Stepper motors are particularly well-suited to drive systems that involve discrete, repeatable movements at moderate to low frequencies. In applications such as robotic arms and precision assembly controls, stepper motors have proven to be effective in factories and assembly environments. Figure 2.2, illustrates a

device with a microcontroller, stepper motor, and feedback as an example block diagram. While feedback is not always needed with stepper motors, it can still be given for precision purposes.

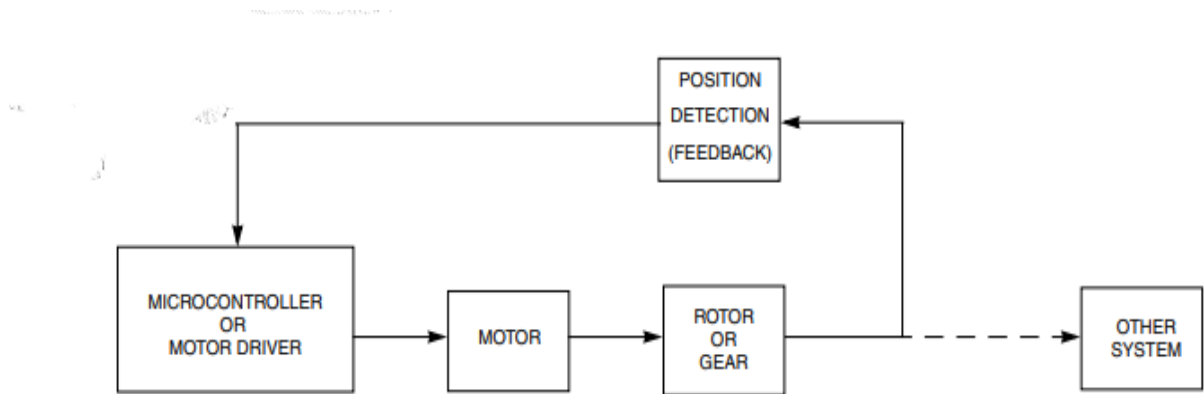


Figure 2. 4 Example System with an MCU, Stepper Motor, and Feedback

There are several different types of stepper motors, but the majority of them can be divided into two groups:

Permanent-magnet (PM) stepper motor: This type of motor rotates by using the forces generated by electrical current between a permanent magnet and an electromagnet. This motor has an interesting feature in that it has some magnetic resistance to turning even when it is not driven.

Variable-reluctance (VR) stepper motor: Unlike the PM stepper motor, the VR stepper motor has no permanent magnet and relies solely on electromagnetic forces to rotate. When the motor is not powered, there is no magnetic resistance to turning it.

Stepper Motor Basics A stepper motor is an electric motor whose main characteristic is that its shaft rotates by making moves, i.e., by going by a set number of degrees. This function is obtained thanks to the motor's internal structure, which helps you to know the shaft's exact angular location by simply counting how much would have been done without a sensor. This feature makes it ideal for a wide variety of applications, too.

Stepper Motor Operating Principles All stepper motors have a stationary part (the stator) and a moving

part (the rotor) as all electric motors have. There are teeth on the stator on which coils are mounted, while the rotor is either a permanent magnet or a core of variable reluctance iron. The basic operating theory of the stepper motor is as follows: By energizing one or more of the stator stages, the current flowing in the coil produces a magnetic field and the rotor aligns with this field. The rotor can be rotated by a particular amount to achieve the desired final position by delivering various phases in series. Stepper engine types and design the performance of a stepper engine both in terms of resolution (or phase size), speed, and torque is affected by the nature of the design, which can also affect how the engine can be operated at the same time. As a matter of fact, not all stepper motors have the same internal structure (or construction), as different configurations for rotors and stators exist.

Rotor

There are essentially three types of rotors used for a stepper motor; Permanent magnet rotor: The rotor is a permanent magnet that aligns with the magnetic field of the stator circuit produced. This approach ensures a strong torque and also a torque of detentions. That means the engine can resist a change of location, even if not very strongly, regardless of whether a coil is being energized. The downside of this approach is that it has a lower speed and a lower resolution than the other forms.

Rotor variable reluctance: The rotor is made of an iron core and has a particular shape that allows it to interact with the magnetic field. It is simpler to obtain a higher speed and resolution with this approach, but the torque it produces is also lower and has no detent torque.

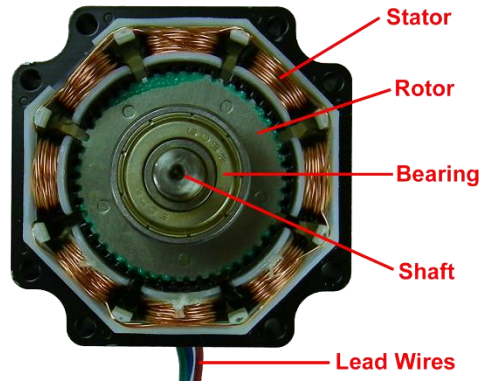


Figure 2. 5 Stepper Rotor Stator

Stator

The stator is the component of the engine responsible for generating the magnetic field the rotor will be aligning with. The stator circuit's key characteristics include its number of phases and pole pairs, and the orientation of the cable. The number of phases is the number of individual coils, while the number of pole pairs shows how each phase occupies the principal pairs of teeth. The most widely used two-phase stepper motors, while three-phase and five-phase motors are less common Stepper Motors Advantages and Drawbacks Compared to other types of motors, now that we understand the operating concepts of stepper motors, it is useful to sum up their pros and cons. The Stepper has many advantages. The stepper motors do not need a sensor to detect the motor location due to their internal structure. Since the motor moves by doing "steps," by simply counting these steps, at a given time you can get the motor position. The stepper motor control is, moreover, very simple. The motor requires a driver, but for proper functioning it does not require complicated calculations or tuning. The control effort is usually lower as compared to other engines. You can achieve high location accuracy with micro stepping, up to about 0.007° . Stepper motors at low speeds offer good torque, are ideal for holding position and have long service life. Stepper motor has a few disadvantages; If the load torque is too high, they will skip a move. This impacts the control negatively, because there is no way to know the motor's actual location. Micro stepping makes stepper motors much more likely to encounter this problem. And while even these motors drain maximum current, which makes

efficiency worse and can cause overheating. Stepper engines have low torque, and at high speeds become pretty noisy. Last but not least, stepper motors have low power density and poor torque to inertia ratio.

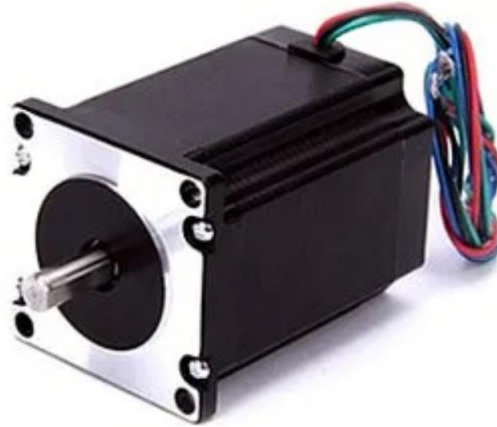


Figure 2. 6 Stepper Motor

To sum up, stepper motors are good when you need an inexpensive, easy-to-control solution and when high speeds do not require efficiency and high torque. [Click here](#) to learn more about how to choose the right type of engine for your project, and the differences between stepper, brushed, and brushless engines.

2.3.2 Stepper Motor Driver

A stepper motor is a digital electromechanical system in which each electrical pulse input rotates the rotor by a defined angle known as the step angle, thus the name. Stepper motors are widely utilized in industry for a variety of purposes ((IEEE Staff & IEEE Staff, n.d.)). Robotics is one of the fields in which the usage of stepper motors is critical. For precision, robotic applications need precise motions. Because it moves in distinct stages, a stepper motor is well suited for robotic applications.



Figure 2. 7 Driver Steppe Motor

In each step, it travels by a defined angle called the step angle. Because of its excellent durability, low cost, great torque at low speeds, and easy design, stepper motors are used in commercial and industrial applications. A stepper motor's movement is controlled by its driving system. A modular drive system will provide precise control of a stepper motor's movement, allowing it to be utilized in robotic applications.

2.3.3 Steel Shaft

A shaft is a spinning machine element with a circular cross-section that is used to convey power from one part to another, or from a power-producing machine to a power-absorbing machine. Shafts are an essential component of machinery. They support rotating components such as gears and pulleys and are supported by bearings in the stiff machine casing. The shafts' job is to transfer power from one spinning element to another that is supported or linked to it. As a result, they are susceptible to torque from power transfer as well as bending moments from responses on the parts they support. The shafts, which likewise support rotating parts but do not transfer power, are not to be confused with shafts. Shafts are always circular in cross-section, and they can be solid or hollow. Straight, cranked, flexible, or articulated shafts are the different types of shafts. Straight shafts are the most prevalent type of power transmission shaft.

2.4 BLDC Motor

Brushless Direct Current (BLDC) motors are one of the fastest-growing motor types. Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment, and Instrumentation are among industries that employ BLDC motors. BLDC motors do not employ brushes for commutation; instead, they are electronically commutated, as the name indicates. In comparison to brushed DC and induction motors, BLDC motors provide a number of benefits such as; improved speed-to-torque characteristics, higher speed ranges, high dynamic responsiveness, high economy, long operational life, and noiseless operation. Furthermore, the torque provided per unit of motor size is greater, making it helpful in situations where space and weight are crucial.(AN885, n.d.). BLDC motors are used in almost every industry category. BLDC motors are used in a variety of industries, including automotive, appliance, industrial controls, automation, and aviation. BLDC motor control into three categories based on these factors:

- **Continual load:** These are the kinds of applications where having a variable speed is more critical than maintaining a set speed's precision. Furthermore, the rates of acceleration and deceleration do not change dynamically. The load is directly linked to the motor shaft in these applications. Fans, pumps, and blowers are examples of these sorts of applications. These applications need low-cost controllers that are essentially open-loop.
- **Differential loads:** These are the applications in which the motor's load fluctuates throughout a speed range. High-speed control precision and good dynamic reactions may be required for these applications. Washers, dryers, and compressors are examples of household appliances. Fuel pump control, electronic steering control, engine control, and electric vehicle control are all instances of this in the automobile industry. There are a variety of applications in aerospace, such as centrifuges, pumps, robotic arm controls, gyroscope controls, and so on. These applications may make use of speed feedback devices and operate in either a semi-closed loop or a completely closed loop. These applications make use of complex control techniques, which makes the controller more difficult to operate. This also raises the overall cost of the system.

Applications for positioning: This category includes the majority of industrial and automation applications. This category includes applications with some form of power transmission, such as mechanical gears, timing belts, or a basic belt-driven system. The dynamic reactivity of speed and torque is critical in these applications. These applications may also experience frequent rotational direction reversals. An acceleration phase, a constant speed phase, and a deceleration and positioning phase are all part of a normal cycle. During all of these phases, the load on the motor may change, making the controller complex. The majority of these systems work in a closed loop. Three control loops might be active at the same time: Torque Control Loop, Speed Control Loop, and Position Control Loop. The real speed of the motor is measured using optical encoders or synchronous resolvers. The same sensors are sometimes utilized to provide relative location data. Separate position sensors can be utilized to get absolute locations if necessary. CNC (Computer Numeric Controlled) machines are an excellent example. This category includes process controls, equipment controls, and conveyer controls, among others.

2.5 BLDC Motor Controller

Brushless DC motor speed control is an important part of many industrial processes, and several control schemes have been developed to improve the speed control execution of Brushless DC motor drives. The BLDC motor's operating principle is similar to that of a regular DC motor, but its construction is different. The stator of a BLDC motor is identical to that of an induction motor, and the rotating section includes a permanent magnet, with brushes replaced by an electronically commutated system; hence, the BLDC motor is classified as a self-spinning synchronous motor. The BLDC motor's dynamic equivalent circuit is utilized to comprehend and study the motor's transient behavior (IEEE Staff, 2018).

2.6 Microcontroller

A microcontroller is a single-chip microprocessor designed particularly for control purposes in embedded computers. These devices are inexpensive and simple to use in digital control applications. The circuits required for computer control applications are incorporated into most microcontrollers. A/D converters, for example, may be included in a microcontroller so that external signals may be sampled. They also contain parallel input–output ports for reading and writing digital data to and from the microprocessor. Some devices include built-in D/A converters, and the converter's output can be utilized to control the plant through an actuator (e.g. an amplifier). A timer and interrupt logic may be integrated into microcontrollers. Microcontroller can be program to precisely implement the control algorithm by using the timer or interrupt features. A high-level language makes it easier to write programs. As digital controllers, PIC microcontrollers are employed. The high-level C programming language is used to program the microcontrollers (Ibrahim, 2006).