Automatic Guided Vehicle

Course Project | ME 714: Computer Integrated Manufacturing (CIM)
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AGVs: Introduction

AGVs (Automated Guided Vehicles) have gained popularity in the manufacturing industry in the past few decades. They have also been extensively used in the research sector. The main reason behind the popularity of AGVs is the precision with which they can do a particular task, the repeatability which they offer, and the fact that they can reduce the need for human interference, which in turn reduces the chances of other errors, which can be introduced during a process. Additionally, due to using AGVs in a particular process, the labour costs are reduced by an important factor. [1]

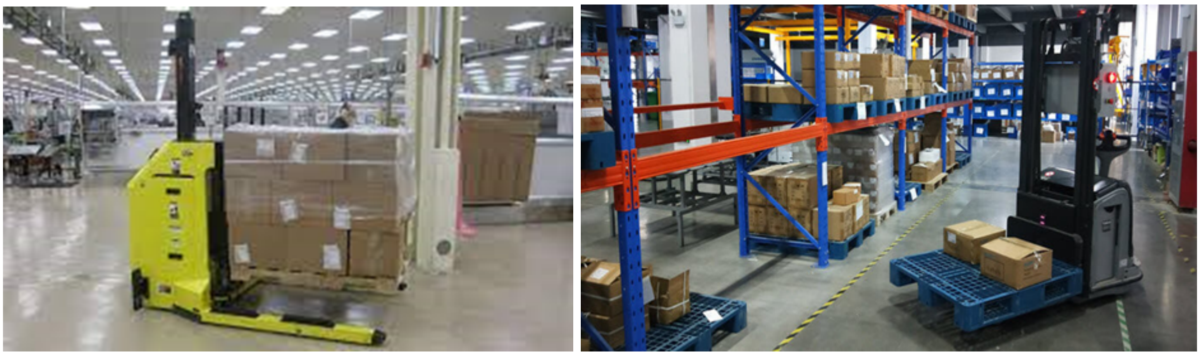

Fig 1. Different types of AGVs used in the industry

AGVs: Industry Applications

Raw material handling: Raw materials such as paper, steel, rubber, metal, and plastic are often transported by AGVs, this involves delivering products directly to production lines. This ensures a steady and reliable supply of raw materials to the production lines and minimize the required human intervention.

Intermediate goods handling: AGVs are also used to transport intermediate goods from one point to the other on the production line to ensure fast and efficient production of goods when different processes are carried out at various stations.

Fig 2. AGV carrying objects to different parts of the production line

Hazardous material handling: When we need to handle hazardous materials, for example, while transporting an intermediate product to a different part of the production line or disposing of waste material after the production of the product, an example of this can be seen in the production line Uranium enriching plants. During the enrichment of Uranium, the ore is processed through various steps. The product after each phase is then carried to a different part of the production line. Each intermediate product in this production line is radioactive, and hence we need to avoid human handling of these. Thus, AGVs are extensively used for material handling and intermediate good handling of the Uranium products, intermediate products, and by-products. Another example of this application is AGVs used to carry explosives.

Fig 3. AGV used for carrying explosives

Heavy object handling: Weighty objects or products need to be carried from one point to another. Doing this manually would be a very inefficient task. Hence AGVs with robotic arms can move heavy objects from one end to another.

Fig 4. AGV carrying heavy train part

Finished product handling: After the entire production is completed, the final goods need to be packed and transported to the correct stations from where they would be either shipped to their respective destinations or stored. This phase requires very gentle material handling as the products are prone to damage, so AGVs are used to increase the safety of the final products.

Fig 5. AGV carrying final products

Health & Pharma industry: The health and pharma industry has seen a boom in the use of AGVs to meet demands of quality and hygiene. They are used to transport meals, sterile supplies, waste bins, linen, etc.

Fig 6. Representation of uses of AGVs in the medical sector

Types of navigation techniques used in AGVs

Wired: In this method, a slot is cut along the path's entire length and a wire is laid inside the slot. This wire transmits a radio signal with the help of which the AGV follows a specific path. (See Fig 7)

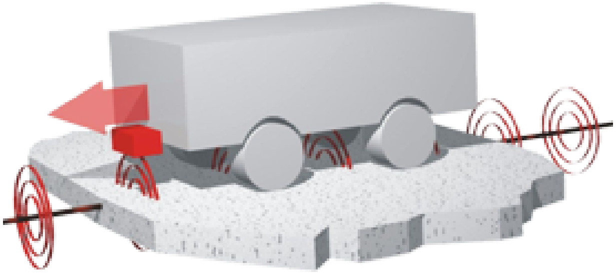

Fig 7. Wired type of AGV

Fig 8. Magnetic type AGV

Guiding tape: There are two principles used in guide tapes: Magnetic tapes and Coloured tapes. In both these types, appropriate sensors are used to detect the path. A magnetic bar can also be embedded in the floor, which works the same way as tapes but remains unpowered. (See Fig 8)

Laser target: This type of navigation can be achieved by using reflective tapes at various locations. The AGV has a laser transmitter and a receiver. From the received signal, we can get information regarding the angle and the distance from the reflectors. This information is then used to guide the AGV. (See Fig 9)

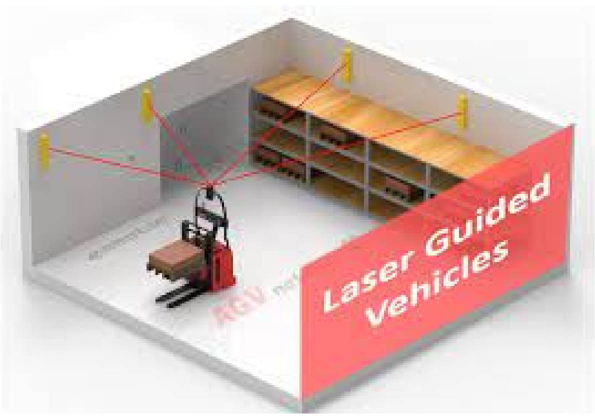

Fig 9. Working of a laser target AGV

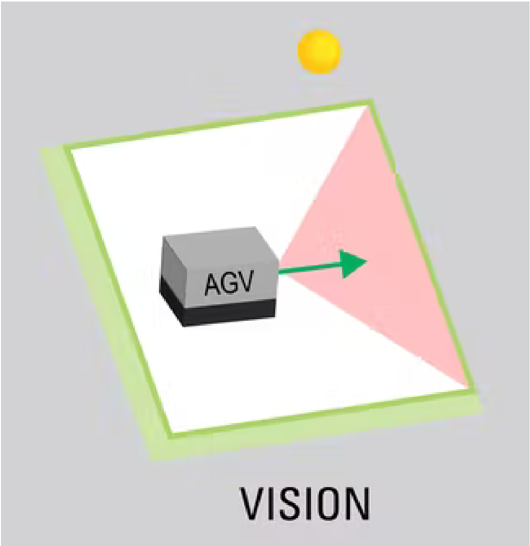

Fig 10. Working of a vision control AGV

Inertial (Gyroscope-based): Internal gyroscopes can be used to detect the change in direction and give necessary inputs to the AGV. The gyroscopes are highly accurate, and hence we can achieve very high precision and control.

Vision control: The vision control method uses recorded video of features along the route and later uses this recording to determine and control the path it has to follow. (See Fig 10)

Line follower AGVs: Guiding tapes

After the literature survey, we decided to use a line follower type AGV for our prototype. A line follower AGV basically uses some type of tape attached to the ground for its navigation.
The major types of line follower methods are as follows:
1) Magnetic tapes
2) Coloured tapes
A major advantage of these two methods is that if needed the tapes can be removed and relocated, thus the path can be easily modified.

In magnetic tapes, the tapes acquire magnetic properties when current is passed through them and appropriate sensors are attached to the bottom of the AGV, which detect the signals and direct the AGV accordingly.

In the coloured tapes, sensors can detect different RGB values and the AGV follows a particular path accordingly. This method is very inexpensive as the coloured types are cheap, although the tapes can get damaged pretty quickly and may need replacing. [1]

Problem Statement & overview

The problem statement that we have worked with is as follows:
An AGV has to transport three objects, all different in colour from a point to three different destinations. So, the AGV will first detect the type of object and then using the line follower method deliver the objects to their respective locations. For detecting the type of object we use OV7670, a camera which can detect the different colours. After that the destination is chosen and using the IR sensors and the tapes on the ground, the object is delivered to the given location.

CAD Model of the AGV

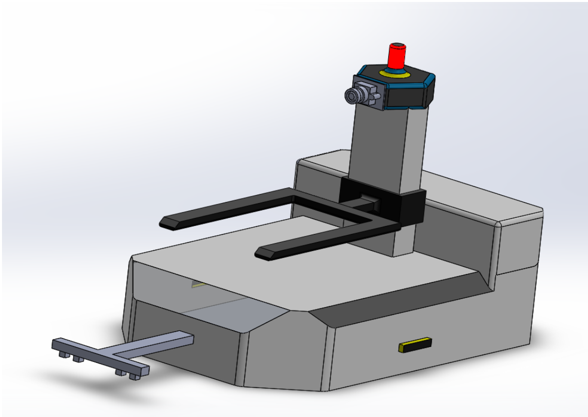

Fig 11. CAD Model of AGV

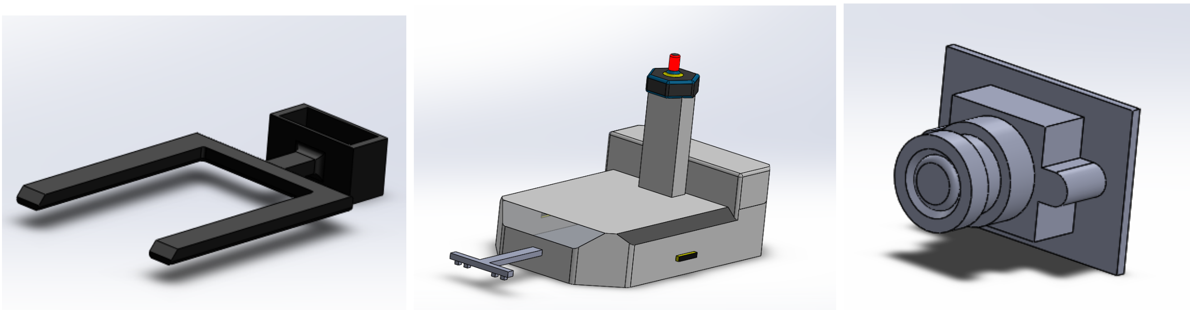

Fig 12. Parts of the AGV

The first figure shows the fully assembled CAD model of the AGV, the individual parts have appropriately mated to each other in SolidWorks.

In the next figures, we can see individual components of the AGV, which are the robotic arm, the main vehicle with the IR sensors attached in the front and the OV7670 camera.

The robotic arm is used to lift the objects once they are identified and used to carry and deliver them to their appropriate destinations. The main vehicle has the task to look into the movement of the entire assembly and the IR sensors attached are used to detect the tape laid on the ground. The OV7670 camera can identify different colours using RGB pixels and hence is used to identify the different objects based on their colours.

Flowchart & working of the AGV

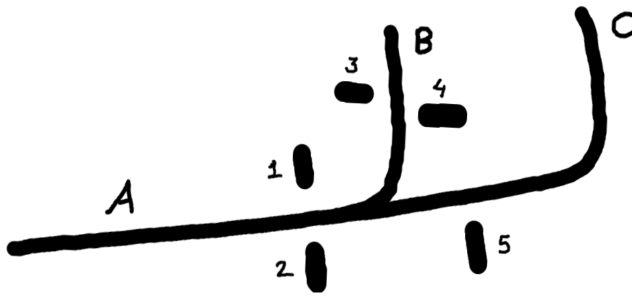

Fig 13. Configuration of different paths

The above figure highlights the five different checkpoints that are next to the black line. The AGV receives commands from the masters over the wireless network in the form of a Byte. That byte is then converted into a number that the AGV uses to interpret the master's command. The possible commands from the masters are as followed:

- 0: stop all motion
- 1: go from A to B
- 2: go form A to C
- 3: go from B to A
- 4: go from C to A

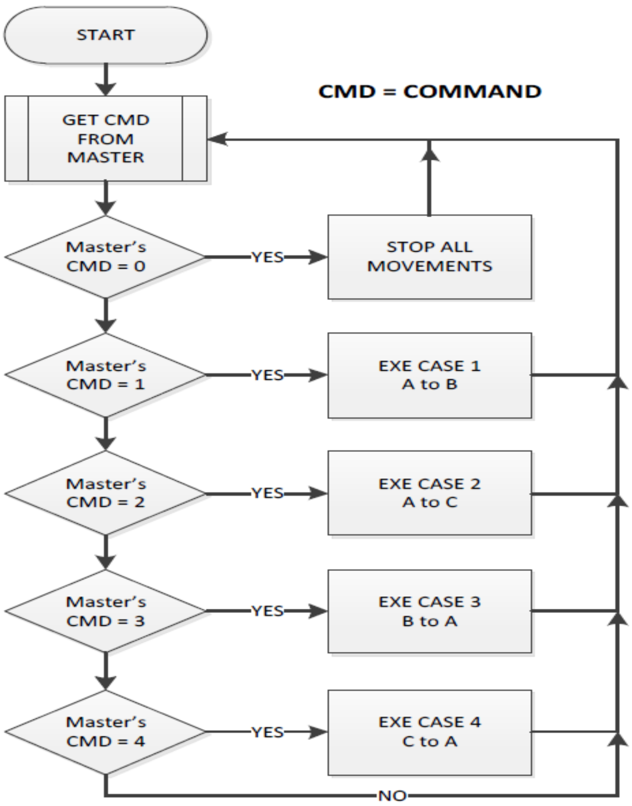

Fig 14. Flowchart for path selection

Depending on the object master gives the command and the AGV needs to follow a particular path. The above diagram represents the execution flowchart. It executes the particular block and leads the AGV to the final destination. Each block is programmed separately. Logic flowcharts for the first & the third cases are given below:

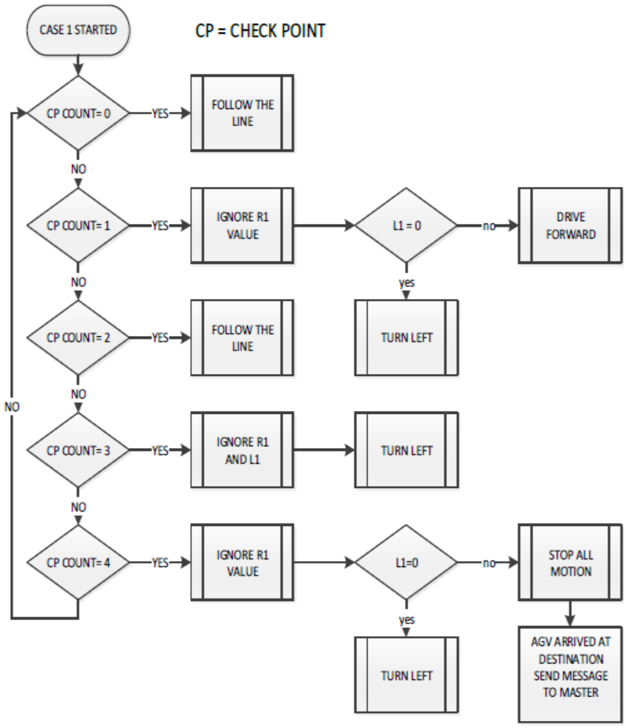

Fig 15. Flowchart for case 1 (from A to B)

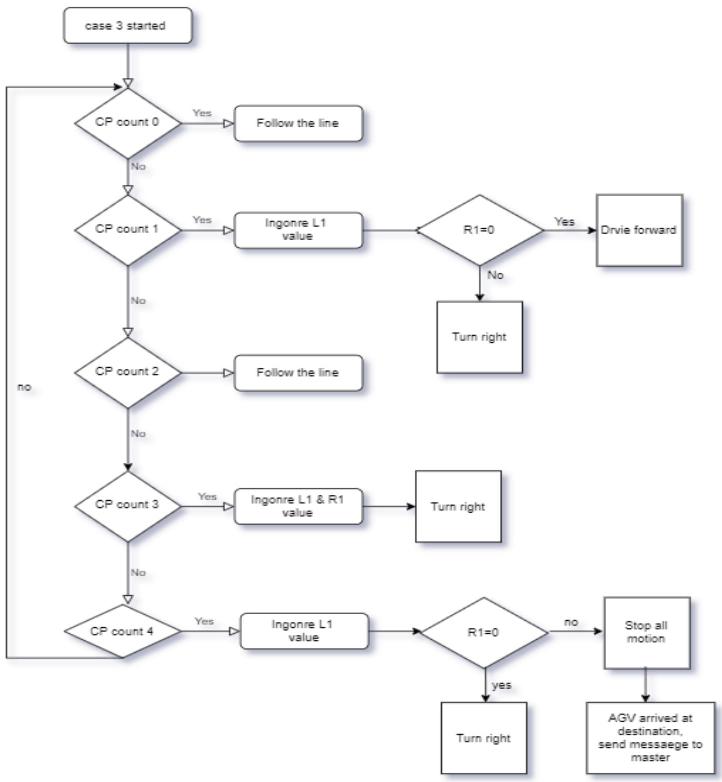

Fig 16. Flowchart for case 3 (from B to A)

Once the master gives the command for a particular case, the program runs that corresponding flowchart and leads the AGV to the desired destination.

At each destination point of the line (A, B, and C), there is a T shape that the AGV uses to know that it has reached its destination. When the AGV reads the T at any of these points (A, B, and C), it rotates to the left and repositions itself onto the line. This happens every time when the checkpoint count reaches a value of 3 and 4 in cases 1, 2, and 4. For case 3, it does for the values of 4 and 5. Every time that the AGV arrives at its destination and finishes repositioning itself on the line, it stops all motions, sends a message to the master, and waits for further commands to be executed. [5]

IR (Infrared) Sensor

Sensors are required to detect the position of the line to be followed with respect to the AGVs' position. The most widely used sensors for the line follower AGVs are photosensors. They are based on the basic concept that "white surfaces reflect a high amount of incident light whereas a black surface absorbs most of the incident light". IR sensors are preferably used to avoid interference with visible light.
A sensor circuit contains a transmitter and a detector. A photodetector is used to detect the intensity of light reflected back to the detector. A corresponding voltage is generated based on the intensity of reflected light.
The analog signal is converted to a digital signal by an ADC and compared with a threshold value to generate a logic '1' or '0' which is used by the controller.

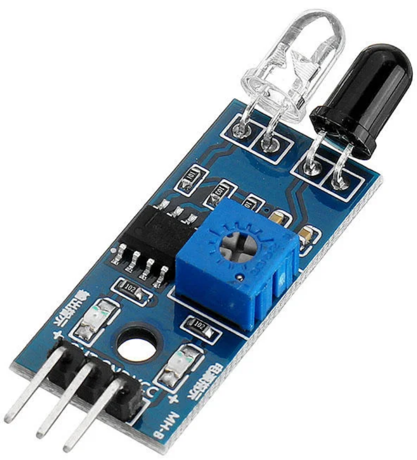

Fig 17. IR Sensor

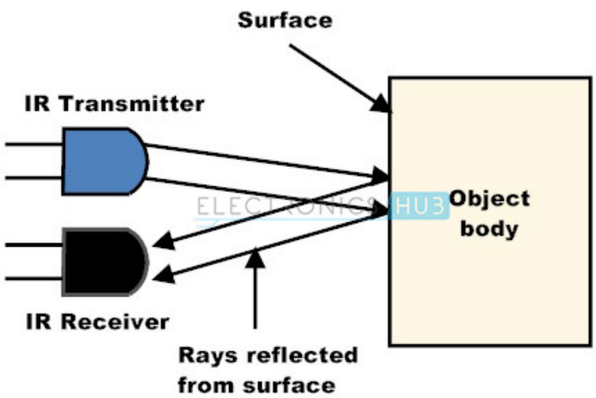

Fig 18. Working of IR Sensors

The working of a line follower AGV is as follows:
Line follower AGVs use IR transmitters and receivers also called photodiodes, used for sending and receiving light. When infrared light falls on a white surface, it is reflected back and detected by photodiodes which generate the corresponding amount of voltage. When IR light falls on a black surface, light is absorbed and very few rays are reflected back, thus the photodiode does not generate voltage more than the threshold value.
Here in this Arduino line follower AGV when the sensor senses a white surface then Arduino gets 1, ie, HIGH as input and when senses a black line Arduino gets 0, ie, LOW as input. [4]

PID Controller

The main algorithm behind making the Line Follower Bot is the PID Algorithm, which is described in detail below:

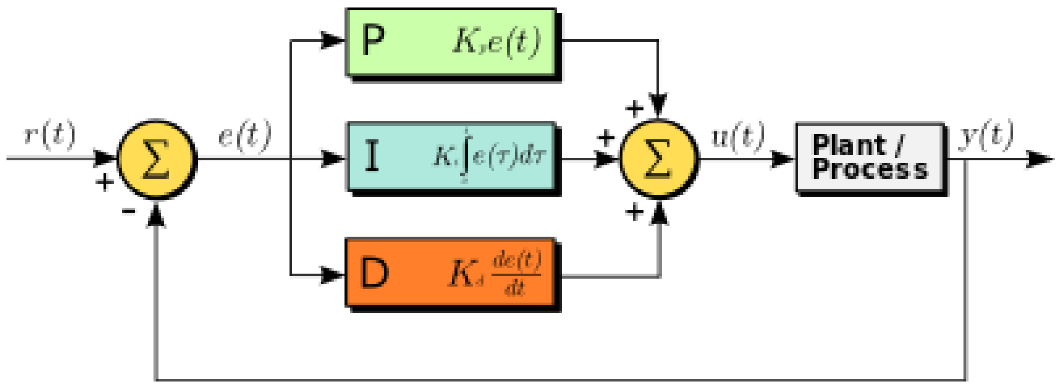

Fig 19. PID controller

- ➔ A Proportional–Integral–Derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback. So, PID is a closed loop controller

- ➔ error value e(t) as the difference between a desired setpoint {SP = r(t)} and a measured process variable {PV=y(t)} {e(t)=r(t)-y(t)}.

- ➔ This controller applies a correction based on proportional, integral, and derivative terms. The controller attempts to minimize the error over time by adjustment of a control variable u(t).

- ➔ Term 'P' is proportional to the current value of the SP − PV error. Taking into account the gain factor "K," if the mistake is high and positive, the control output will be similarly large and positive. Because proportional control requires an error to generate the proportional response, using it alone will almost always result in an error between the setpoint and the actual process value. Unless there is an error, the controller cannot alter the system.

- ➔ The term ‘I’ is calculated by taking prior values of the $SP-PV$ error and integrating them through time. If there remains a residual $SP-PV$ error after proportional control, for example, the integral term aims to eradicate the residual error by adding a control effect based on the error's history cumulative value. The integral term will stop growing once the error is removed. As the mistake lowers, the proportional effect will diminish, but this will be offset by the growing integral effect.

- ➔ Based on the current rate of change, Term ‘D’ is the best projection of the $SP-PV$ error's future trend. It's also known as "anticipatory control," because it works by exerting a control influence on the rate of error change to reduce the effect of the SP PV error. The higher the controlling or damping impact, the faster the change. [3]

Control loop

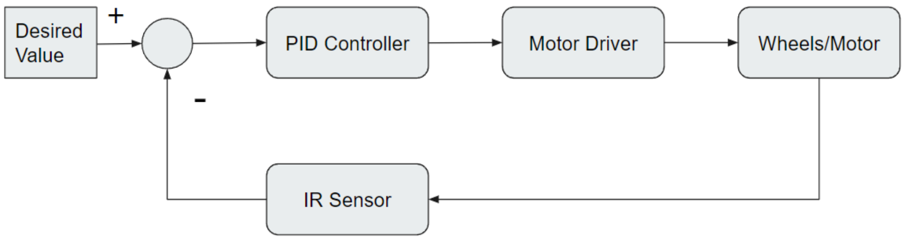

Fig 20. Line follower control loop

We want our line follower AGV to follow the black line, so the output from the IR sensor is required to be 0. We subtract the current reading value of the IR sensor from this desired value to generate an error function e(t) and pass it on to the PID controller. Then the controlled output signal is used as an input by the actuator which is a Motor Driver in this case. According to the controlled signal, the motor driver will deliver the appropriate voltage to the motor attached to the wheels and try to reduce the error to 0.

PID Tuning

Loop tuning is used to get the ideal control function by balancing these effects. The tuning constants, denoted by the letter "K," must be calculated for each control application since they are dependent on the response characteristics of the entire loop outside of the controller. The behaviour of the measuring sensor, the ultimate control element (such as a control valve), any control signal delays, and the process itself are all factors to consider. Approximate constant values can usually be input without knowing the type of application, but they are usually modified, or tuned, in practice by "bumping" the process by changing the setpoint and observing the system response. [2]

Parameter	Rise time	Overshoot	Settling time	Steady-state error	Stability
K_p	Decrease	Increase	Small change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Eliminate	Degrade
K_d	Minor change	Decrease	Decrease	No effect in theory	Improve if K_d small

Fig 21. PID constant tuning

Demonstration Videos

Prototype Video: Line Follower.mp4
Simulation Video: Simulation.mp4

Simulation Code and CAD Model (Use LDAP)

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References

[1] Automated guided vehicle - Wikipedia
[2] PID Controllers in Control Systems | Electrical4U
[3] PID controller - Wikipedia
[4] Line Follower Robot - Arduino Project Hub
[5] Navigation system for an automatic guided vehicle