Learning Roomba: Student’s Guide
Module 2 Robot Configurations

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1 What is a Robot Configuration?

How does a robot move through the environment? Where can it travel? These are the questions that the Configuration of a robot tries to answer. A tank moves differently than a car; the tank has the ability to turn in place while a car does not. A car can also travel on some roads that tractor trailers cannot fit. Why is this? Cars, tanks, and tractor-trailers all have different Configurations. The Configuration explains what happens when a drive motor is actuated. The Configuration also explains why some robots can fit in some areas while another that is about the same size cannot. A Configuration includes the physical shape of the robot as well as a model of how the robot can move in the environment.

For ground robots, movement is usually described in terms of how it rotates and how it translates. Rotation describes how the robot turns. Translation describes how it moves forward or backward.

Some Configurations are holonomic while others are non-holonomic. A holonomic robot can move in any direction while a non-holonomic robot is constrained to only certain types of movement. For example, if a car is trying to parallel park, it cannot move next to the parking spot and then shift sideways into the spot. Instead, it needs to do a complicated procedure of movements to get into the spot. Therefore, a car is non-holonomic.

2 Why is it important?

In many cases, we can just try experimenting with a robot to find out how it behaves. If you have an opportunity to build the robot though, it is important to know the limitations of a system that you are building prior to simply trying it out. Whenever possible, it is better to instantly understand a system by knowing the principles rather than by slowly building an understanding through trial and error. By understanding Robot Configurations, you can know how most robots work just by looking at them.

3 Several types of Configurations

There are many different types of Configurations. The ones listed here are just some examples and are focused on wheeled, ground robots. New robots are constantly being designed with unique Configurations, but these are the most common in small robots. Each Configuration has advantages and disadvantages.

3.1 Wheeled Differential Drive

A differential drive robot (Figure 1) consists of two powered wheels that are independently driven. The two wheels are in-line with each other and are usually located at the center of the robot. It rotates around the point that is the same
distance from each of the wheels. If the wheels are placed at the center of the robot, the robot can rotate in place without translating at all. Usually the robot has one or two casters to help stabilize the robot. A caster is a non-powered wheel that can swivel in any direction. A differential drive robot is the simplest robot platform and can go anywhere that the robot can fit.

Figure 1: An example differential drive robot

The shape of the robot also matters. Differential drive robots are typically round to maximize where it can go. Consider Figure 2. There are two differential drive robots pictured: a round robot (a) and a square robot (c). Both are given the same command to rotate 90 degrees to the left. However, the square robot is unable to perform the action, because it collides with the wall. The square robot has the same layout of wheels, but it is unable to go to the same locations as the round differential drive robot. Therefore, many differential drive robots are round in shape.

3.2 Wheeled Ackerman Steer

An Ackerman steer robot (Figure 3) is like a car. It is a four-wheeled vehicle with two rear fixed-rotation wheels and two front wheels that turn. The front wheels do not turn at the same rotation though. Instead, there is some imaginary point off the side of the robot that a line drawn perpendicular (90 degrees) to all the wheels will intersect. This point becomes the Center of Rotation or COR. If a robot is driven forward forever, the path the robot takes will be a circle around this COR point. The rear wheels are usually powered.

An Ackerman steer robot has a disadvantage of being mechanically more complicated, and the types of motion are significantly more complicated as well. Just like a car, an Ackerman steer robot is non-holonomic and cannot move
Figure 2: The shape of a differential drive robot matters. A round robot (a) is commanded to rotate -90 degrees. It succeeds in (b). A square robot (c) is given the same command. However, the square robot collides with the wall when it tries to rotate (d). Therefore, it is not able to perform the same rotation.

Figure 3: An Ackerman Steer Robot
instantly sideways. It has to perform a series of motions to achieve that motion. If the area is clear, it is usually not a problem, but if the environment is cluttered, the motions can become difficult. The advantage is that the robot is typically more stable and separates the drive functionality from the rotation.

3.3 Wheeled Tricycle Drive

A tricycle drive robot (Figure 4) is similar to the Ackerman steer robot, except that there is only one front wheel that turns. It is mechanically simpler, but has the same motion limitations as an Ackerman steer robot. Furthermore, it is less stable because of the sole front wheel.

![Figure 4: A Tricycle Drive Robot](image)

3.4 Wheeled Synchro Drive

A synchro drive robot is quite complicated. It consists of at least three wheels that all drive together and rotate together. There is one motor that rotates the wheels and another that drives the wheels. Figure 5 shows the top-view of an uncompleted synchro drive robot and Figure 6 shows the bottom-view without wheels attached. The advantage of a synchro drive robot is that you can have separate motors for driving and turning and yet still be able to travel in any direction without rotating the top base. The top can always be facing the same direction. This is, however, also a disadvantage in many cases since the top cannot turn.

3.5 Skid Steer

Skid steer robots (Figure 7) are similar to tanks. They can either have several wheels on each side that do not turn or have tank treads. The robot turns by making the wheels on one side of the robot go forward while the other wheels go backward. This allows the robot to move or less turn in place. The problem is that doing so requires some the wheels to skid or slide sideways which results in poor odometry (we will discuss this more in future Modules). The advantage is that skid steer robots can usually handle uneven terrain better than any of the other Configurations discussed so far.
Figure 5: Top View of a Synchro Drive Robot

Figure 6: Bottom View of a Synchro Drive Robot (Without wheels)
3.6 Roller Wheeled

Roller wheeled robots (Figure 8) consist of three wheels around the circumference of the robot. A line drawn perpendicular (90 degrees) to each wheel travels through the center of the robot. None of the wheels steer, but each wheel has rollers around the wheel. The rollers are non-powered that rotate perpendicular to the wheel itself. Figure 9 shows a roller wheel. The advantage is that the robot can rotate or translate freely. A differential drive robot can move in any direction, but it first has to rotate to the correct angle. A roller wheeled robot does not have that limitation. By adjusting the speeds of each wheel, the robot can immediately move in the desired direction. Or, it can also rotate in place and then translate forward. The disadvantage is that tracking position through odometry is difficult.

3.7 Legged Robots

Robots do not have to have wheels. Many configurations include a number of legs (Figure 10). Legged robots are complicated, but they can travel over a large amount of terrain that a wheeled robot would have difficulty with. For example, a wheeled robot usually is unable to climb stairs, but a legged robot may be able to overcome this hurdle.
Figure 8: A Roller Wheeled Robot

Figure 9: A Roller Wheel
3.8 Fixed-Wing Aerial

Up to this point, the configurations were all limited to ground robots. There are many robots that do not have that constraint. One example is a fixed-wing aerial robot (Figure 11) which is also more commonly called a plane. We will not discuss here how a fixed-wing aircraft moves through the environment, but it is important to understand that robots take many different forms and the Configuration is what describes how the robot moves and where it can go.

3.9 Rotorcraft Aerial

Another robot Configuration that also flies is the rotorcraft aerial robot (Figure 12), which is similar to a helicopter. Similar to the fixed-wing aerial robots, a rotorcraft aerial robot is not constrained to the ground. However, unlike the
fixed-wing aerial robots, a rotorcraft aerial robot is able to take off vertically.
The different Configurations lead to different functional abilities.

4 Roomba Configuration

The Roomba is a robot. So, what Configuration does it have? How can you tell? Begin by looking at the wheel placement. How are the wheels powered? Are they steered? Are they controlled independently? The Roomba has two wheels that are independently powered and non-steered. They are arranged at approximately the center of the robot on opposite sides of each other. Do these answers sound like any of the Configurations discussed so far? What physical
shape is the robot?

The Roomba is a round, differential drive robot that is a couple inches tall. This tells us a few things. It can travel anywhere on the ground that the robot will physically fit and can get to. It can move in any direction, but it first needs to turn to that direction. It is a simple Configuration and all the motion can be controlled by driving the two wheel motors. The ground clearance is rather low which means that it cannot handle off-road terrain very well.

Just knowing the Configuration tells us all this. It also tells us how to control the Robot to make it move in the desired way. How we do this will be discussed in future Modules.

5 Homework

This Module presented just a few of the different Configurations that a robot can have. Think about a few other Configurations that robots have or could have. What are the advantages/disadvantages to those Configurations? Also, try to find some examples of robots and describe their Configurations.