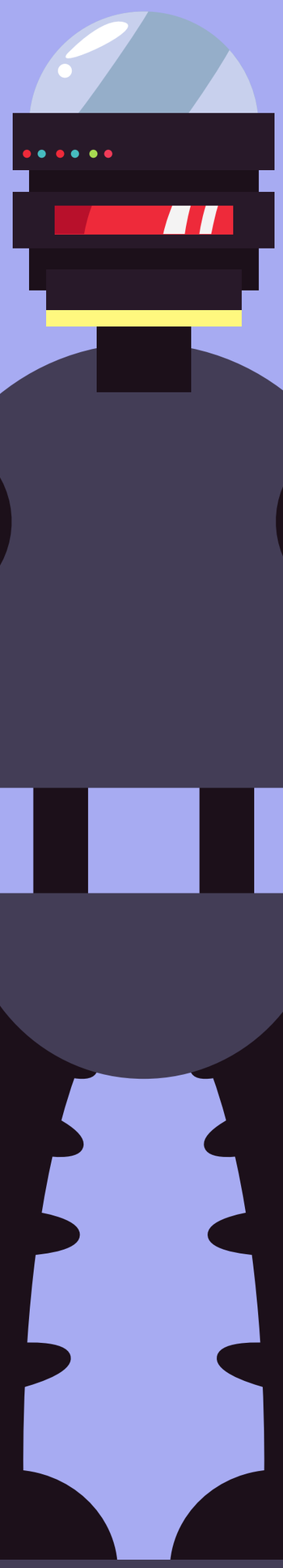
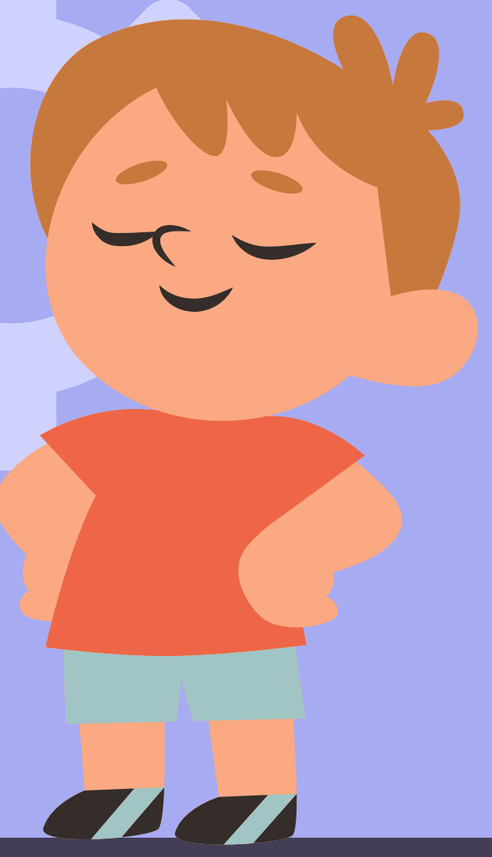
LAB RATS

THE ASSEMBLERS 101 HANDBOOK





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ABOUT THE PROJECT

Assemblers 101 is a part of Lab Rats, a social initiative that aims to increase access to robotics learning for underserved students across public schools in Delhi/NCR, India. The project has been conceptualized to stand as a bridge between the current gaps in STEM education for young adolescents; by creating hands-on opportunities for them to engage with robotics through a variety of mediums including structured workshops, guided competitions and a dedicated robotics lab in the near future.

This handbook has been written so it can serve as a friendly guide by breaking down key concepts in robotics in a way that is easy to understand and engaging. With graphics and real-world examples, Assemblers 101 introduces readers to the exciting world of robot design. Encouraging one to develop their own creations and be confident because sometimes, all it takes is a little push and support, to show you that you too, are capable of contributing to the world around and building something amazing.

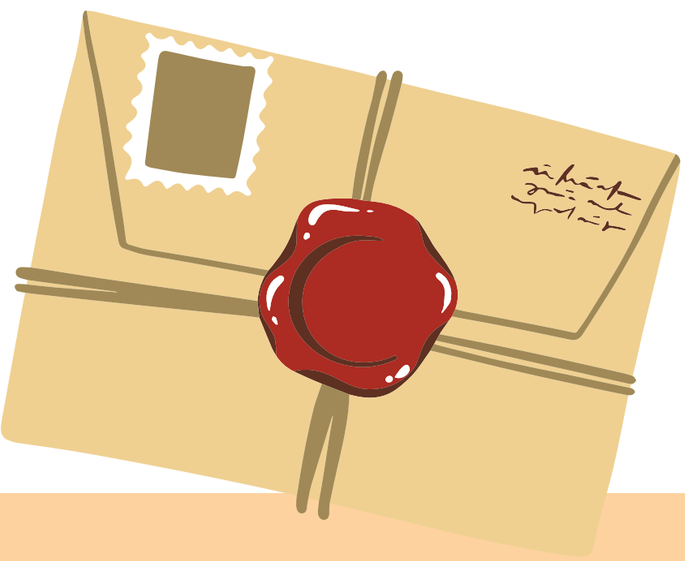
MESSAGE FROM THE AUTHOR

Hello everyone,
I first got interested in robotics when I built a small robot that changed colour and made a little buzzing sound. It of course wasn't perfect, but the process of working on it, understanding the building and coding of it all and seeing a final product of my efforts that actually worked made me feel extremely excited and proud. This made me want to learn more - how does code work? how do motors make parts move and how can machines do what we tell them to? It seemed complicated at first but as I learned and observed, I saw just how fun and enjoyable it can be; and how not everyone had the same chance like me to do so. Many of us still don't have specific robotics classes, guiding teachers or the tools we need to explore this area.

I believe that anyone like me, who is curious about machines and science, should get to try robotics. This is exactly why I decided to write this handbook. I hope it serves as a handy resource for all you readers, helping you understand the basics of robots and feel confident and inspired to make your own. Robotics isn't all hard, it can be interesting, and you can be a future robot-assembler too!

Happy Reading!

Prashast Kumar
Author, The Assemblers 101 Handbook



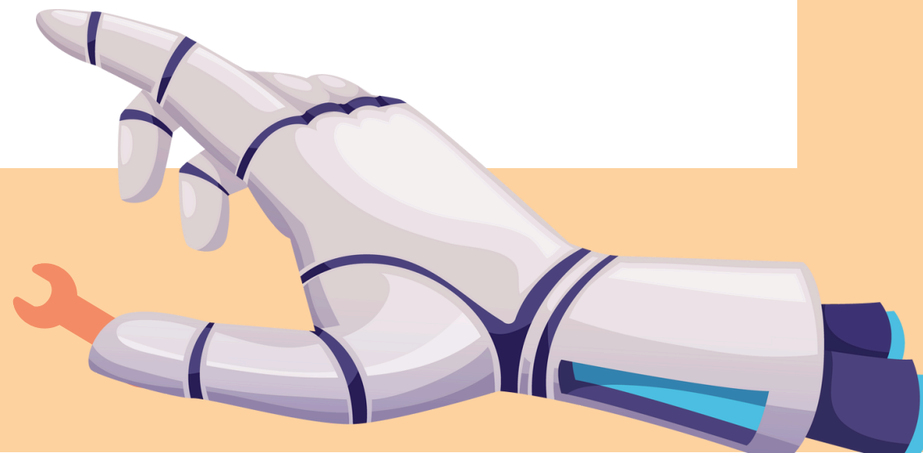
CHAPTER 1 - WHAT MAKES A ROBOT: PARTS, PURPOSE & POSSIBILITY

Imagine a machine capable of amazing feats like building cars, going to space, or even helping out around the house! A robot is a particular kind of extraordinary machine that is capable of performing tasks, sometimes independently. The process of designing and managing these robots is known as robotics.

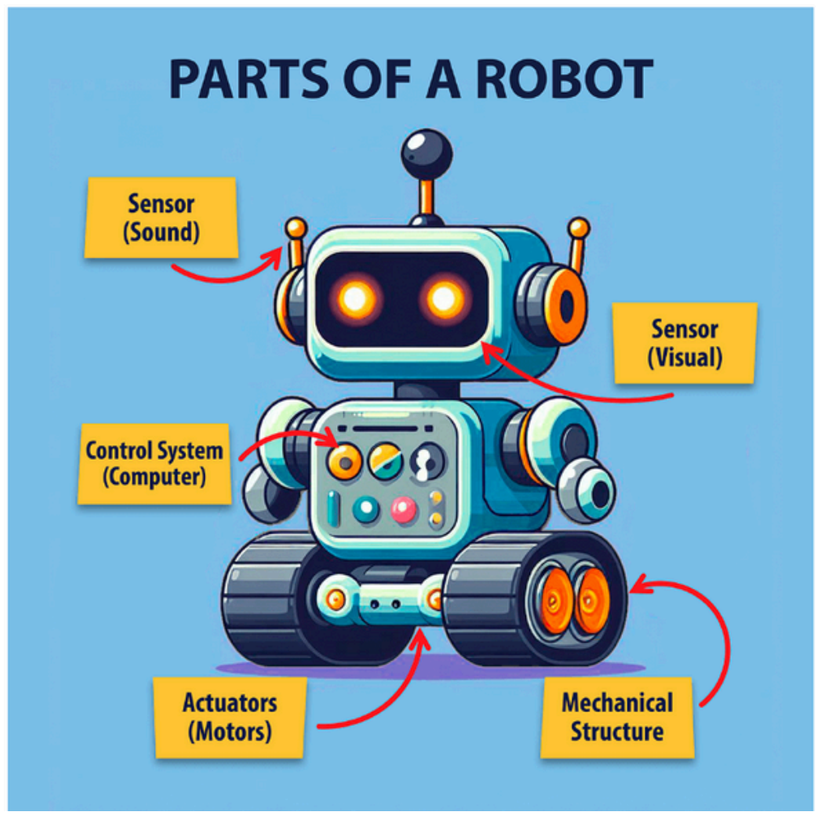
Before we dive in, let's explore some basic ideas that shape how robots work. Robotics combines mechanics, electronics, and computer science; it's all about making machines that can sense things, think, and act. These three ideas form the foundation of any robot so it can then detect what's around it, make decisions based on that information, and carry out an action. This is what separates robots from other machines that only work when a button is pressed. Robots can act on their own based on their design.

So, what makes a robot a robot? It's like building a three-piece puzzle

- The Brain (Controller): Every robot needs to have a brain that tells it what to do. This "brain" is usually a computer or small electronic circuit. It collects information, makes choices, and issues commands to the rest of the robot components. You might consider this piece of equipment as the ship captain!
- The Senses (Sensor): How does a robot perceive its environment? It uses "senses" referred to as sensors. They resemble a robot's eyes, ears, and sense of touch. Due to an array of sensors, robots are capable of viewing colors and shapes, hearing sounds, and even detecting if something is warm or cold. All these pieces of information assist the robot in knowing its environment.



- The Movers (Actuators): After the brain has made up its mind what to do, it needs to be able to move the robot or cause it to do something. And that is where the actuators are needed! Actuators are kind of like the muscles of a robot. They may be noisy bits that move things, arms that pick up things, or even motors that spin wheels. Actuators enable the robot to carry out its function.

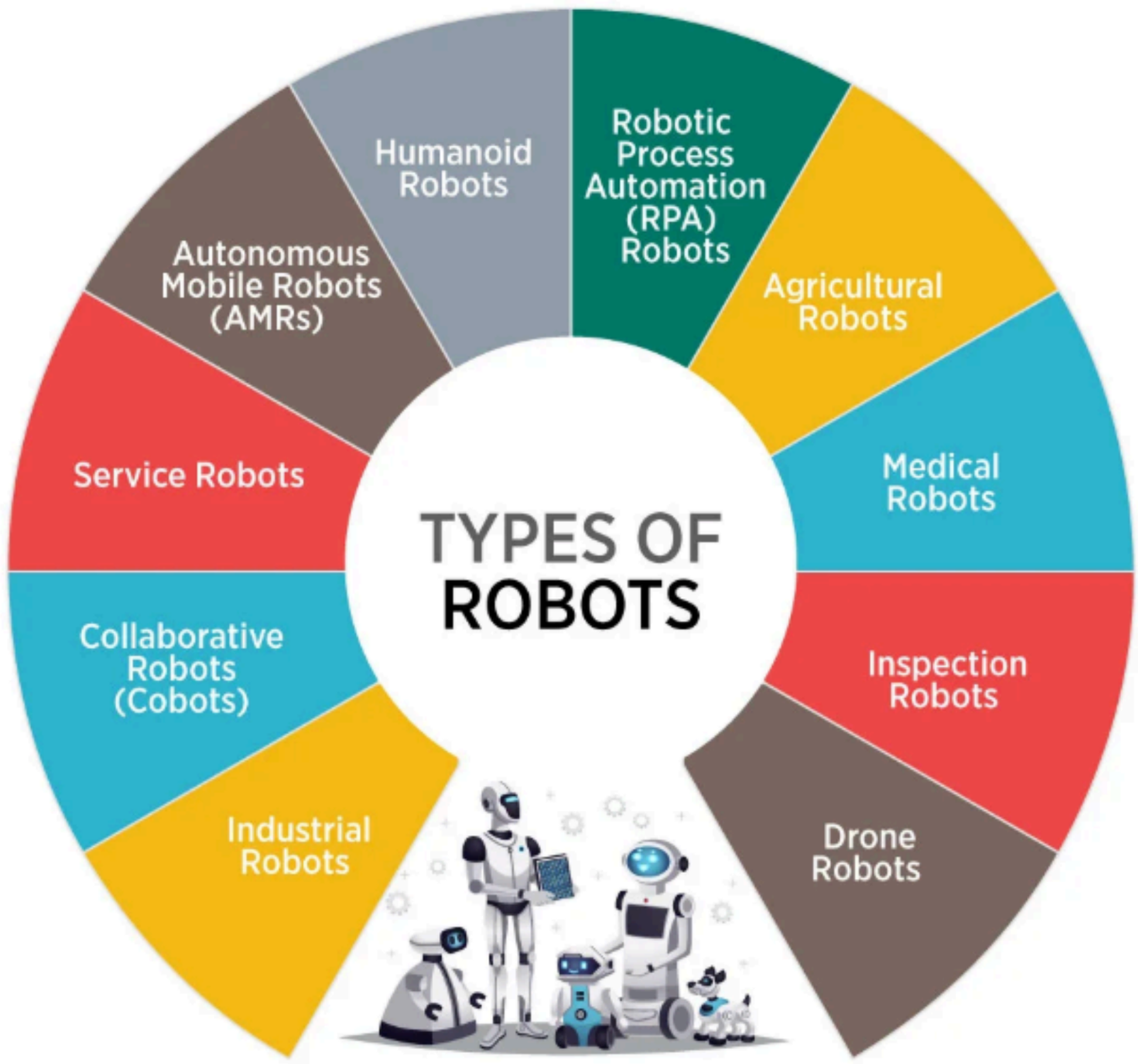


Together, the controller, sensors, and actuators are the three primary components that provide a robot with the capacity to feel, think, and do! In addition, did you realize that robots exist in many diverse forms?

While some are tiny and delicate, others are huge and powerful

- Industrial Robots: The rugged, hardworking robots used in factories are referred to as industrial robots. They are particularly good at repeating the same activity over and over, such as assembling car parts or transporting heavy crates. They assist in producing many of the products we use on a daily basis!
- Domestic Robots: They are robots that assist us at home. Consider having a robot cut your grass or a robot vacuum to clean your floors. They ease our lives.
- Robots in Healthcare: These assist nurses and doctors. Some are able to make surgeries safer and more precise. Others may assist with distributing medicine in hospitals or even helping individuals who have difficulty navigating. They are the equivalent of useful buddies in a hospital or clinical setting.

- Robots for Exploration: Some robots are even flown to far-off places where human travel is unsafe or too difficult like Mars, a planet to explore for example. The robots are used to clean up dangerous areas, travel to these planets and collect data for scientists, and even go deep into the ocean for research!



You'd be amazed at how many robots you already meet in your daily life! Apart from the examples we discussed, consider a car that assists you with parking, a vending machine that provides you with a snack or the tiny dispenser in washrooms that helps you dry your hands. A lot of these operate using robotic technology. Robots are not only for movies; they are real and becoming an increasingly larger part of our lives, simplifying many things, making them safer and more enjoyable! In the next chapter, you'll learn more about how these components work together to enable a robot to actually move and perform all its tasks!

CHAPTER 2 - MEET THE TOOLS: ELECTRONICS, MATERIALS & SAFETY

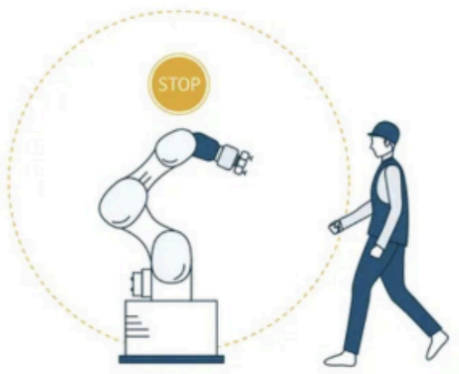
In Chapter 1, we learned that robots are fantastic machines with brains, senses, and movers. But what are all of these made up of? Just like constructing a house requires various materials such as wood, bricks, and glass, constructing a robot requires special materials as well! Consider what a robot must be able to do. Some robots may be heavy-duty, others light, and some flexible.

Here are some common materials that go into building different parts of a robot

- Metals (Like Steel and Aluminum): These are similar to the heavy bones of a robot!
    - Steel is really, really tough and strong, ideal for robots that need to lift heavy objects or operate in rough environments.
    - Aluminum is strong but much lighter than steel. This is excellent for robots that need to move quickly or fly, since being lightweight allows them to conserve energy.
- Plastics: (These are really flexible!):
    - Hard Plastics can be utilized as the outer cover of the robot to safeguard its internal components. They are also easy to mold in various designs.
    - Flexible plastics or rubber are utilized for components that have to bend, such as wires linking various robot components, or for soft grippers which hold delicate objects.
- Wires and Circuits: (These are essentially the robot's nervous and circulatory system):
    - Copper wires are perfect for conducting electricity, which is the way the brain of the robot communicates to its muscles.
    - Circuit boards are little cities where all the electronic components are wired in, so the robot can think and process things.

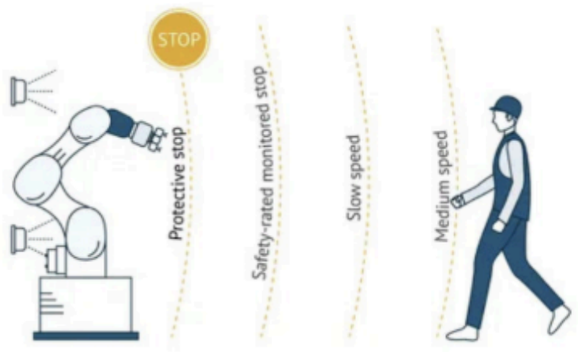
Now, when we interact with robots, particularly large ones, safety is extremely crucial! Think of a robot arm going super fast, we must ensure no harm comes to anyone. Following are some important points to keep in mind

- **Keep Your Distance:** Always be aware of where a robot is operating and maintain a safe distance. Robots are capable of quick and strong movement! Consider it like a train: you would not stand on the tracks, would you?
- **Safety Zones:** Factories and workshops usually have designated "safety zones" painted on the floor around robots. These are places where only authorized individuals are supposed to go, and in some cases, the robot even halts or stops working if someone unauthorized enters the zone.
- **Emergency Stop Buttons:** Robots usually have large, red "Emergency Stop" buttons. In case something goes wrong, pressing this button will have the robot come to an immediate standstill. It's like a robot's panic button!
- **Training:** Similar to learning how to ride a bike, you must have training in order to safely work around robots. It is important to understand how they operate and what to (and not to!) do under the supervision of someone with experience.

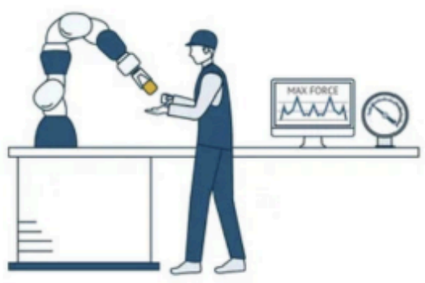


Safety-rated monitored stop

Hand guiding



Speed and separation monitoring



Force and torque limitation

You may be asking yourself, "If robots can be dangerous and unpredictable, why do we even use them?" That is a good question! Although we do have to be cautious around them, robots do make most workplaces safer and easier as well.

- Taking Over Hazardous Work: Robots have the ability to perform tasks that are too hazardous for humans, such as working with extremely hot materials, lifting extremely heavy loads, or working with harmful chemicals. In this way, fewer people get injured!
- Avoiding Repetitive Strain: Think about repeating the same motion with your arm thousands of times every day. Eventually, that hurts! Robots don't tire or get hurt by performing repetitive actions, and that protects human employees from getting strained and hurt. This is what we call - ergonomic benefit, which makes work healthier and more comfortable for humans.
- Compliance with Rules: Robots can be made to comply with safety rules and regulations very strictly. Unlike people, machines don’t get sidetracked, forget procedures, or make too many silly mistakes which assists businesses in complying with current standards, preventing accidents and keeping up with their productivity!

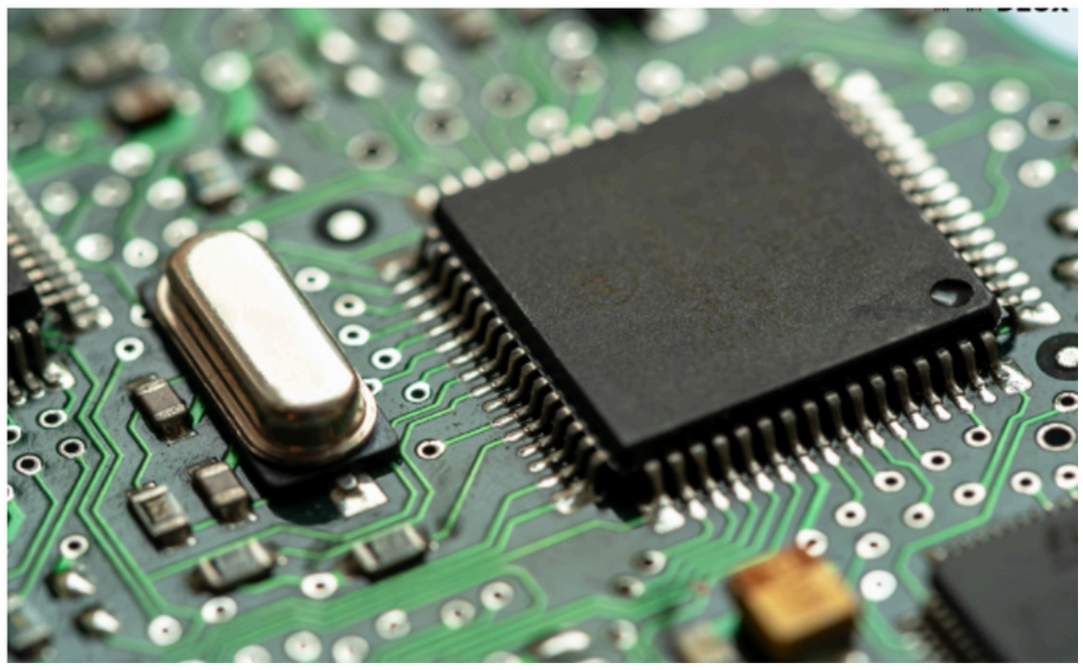
So, sure, we always have to be intelligent and cautious when around robots, but they are also amazing machines that serve to make our world, and our workplaces, so much safer for all of us.

CHAPTER 3 - WIRING THE BRAIN: CONNECTING HARDWARE COMPONENTS

Now that we've covered what a robot is and the materials that go into making it, let's come to one of the most important parts of a robot - the brain. Think of your robot like a human body. The microcontroller is its brain. As we know, it helps your robot think, decide, and react. But just like a brain needs nerves to send messages to the body, your robot's brain needs wires to connect to its sensors, motors, and other parts. In this chapter, we'll learn how to safely and correctly connect these wires so your robot can come to life.

What is a microcontroller?

A microcontroller is a tiny computer that makes your robot work. Your microcontroller will receive signals from sensors and send instructions to motors to move, stop, or respond to the environment.



Not all wires are the same! Selecting the right wire makes your robot work more efficiently and safely.

- **Stranded Wires:** Flexible and suitable for moving parts, such as robot arms, without affecting the structure of the bot.
- **Solid Wires:** Stiff and suitable for the non-moving parts.

Tip: Employ wires of various colors (such as power for red, ground for black) to prevent confusion when setting up and using or fixing the same.

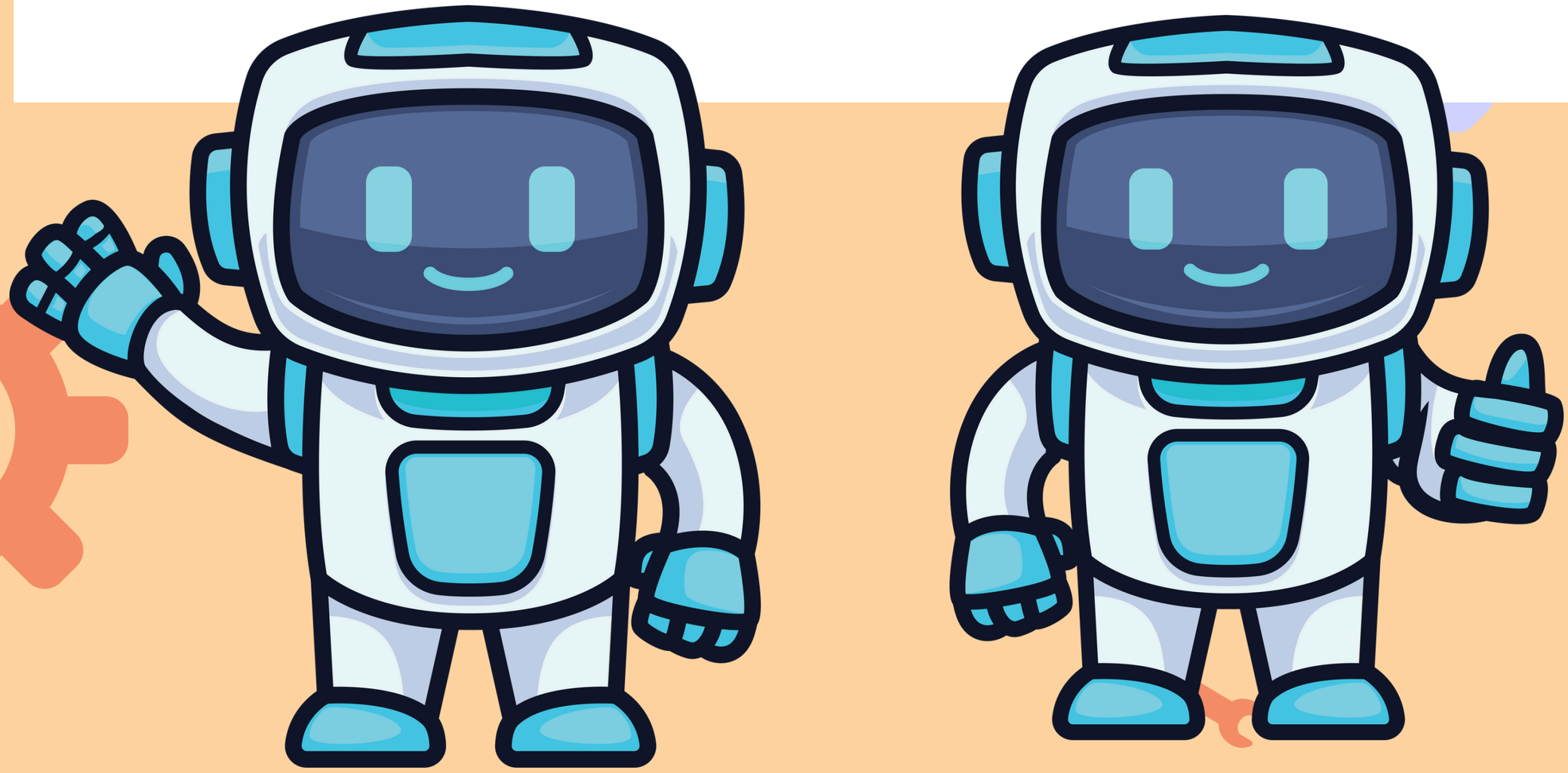
Steps to wire your robot's brain

- Plan Your Circuit: Draw a rough sketch of your circuit before plugging anything in.
- Strip the Wire Ends: Hold a wire stripper and remove approximately 1 cm of insulation from both ends.
- Connect to Pins: Microcontrollers use very small pins. Push or solder the stripped wire ends into the appropriate pins, depending on your diagram.
- Double-Check Connections: Ensure every wire is connected to the correct pin. An incorrect connection can prevent your robot from functioning.

Soldering Basics

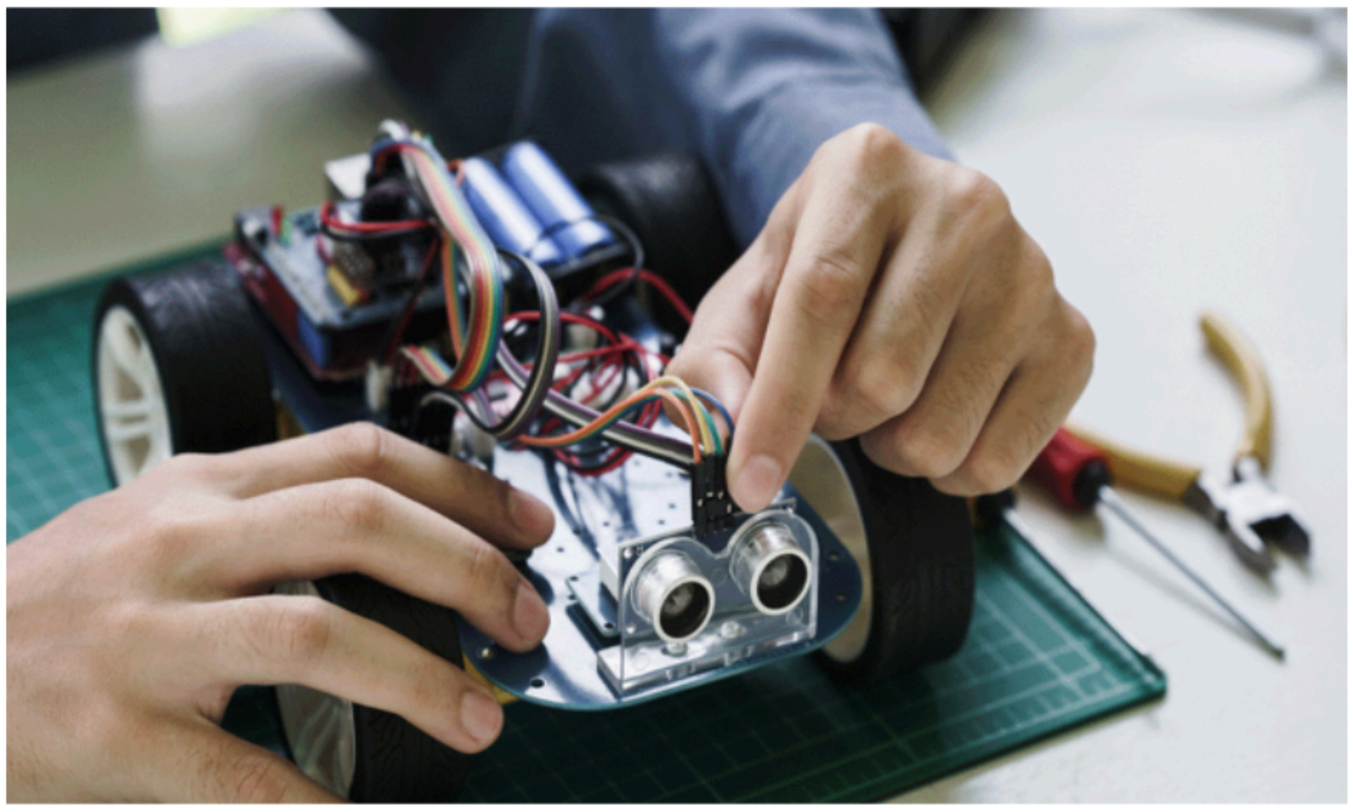
Occasionally, you have to solder wires in order to keep them properly connected. Soldering is where you heat a metal that melts and bonds wires together or to a circuit board. Always work in an open area. Never handle the tip of a soldering iron as it's extremely hot!

- Warm up the soldering iron.
- Slurp the iron tip onto the wire and connection point.
- Feed a small amount of solder onto the hot spot, but not directly onto the iron.
- Take the iron away and allow the solder to cool for a second or two.



Managing wires and keeping it neat

Loose wires can become tangled and damaged. Proper cable management makes your robot look tidy and function better. Bundle wires together with cable ties or tape. Separate power and signal wires when possible. Don't stretch wires tightly; leave some space.



Why good wiring matters

Your robot brain sends the message down through the wires. If your wires are incorrect or loose, your robot will not reply correctly. This is similar to a phone line; if the wire breaks, the message is not delivered. Clean, proper wiring guarantees your robot replies both fast and correctly. Selecting the proper wires, connecting them meticulously, and keeping them organized lays the foundation for an intelligent and responsive robot.

Let’s go over a quick recap - The microcontroller is your robot's brain. Use proper wires (stranded or solid) for the task by making sure you design, strip, connect, and verify your wiring multiple times. Go over some simple soldering to create secure connections and finally organize wires neatly for a long-lasting performance. In the next chapter, we’ll explore how to program the robot and coding basics with these microcontrollers!

CHAPTER 4 - PROGRAMMING THE BOT: CODING BASICS WITH MICROCONTROLLERS

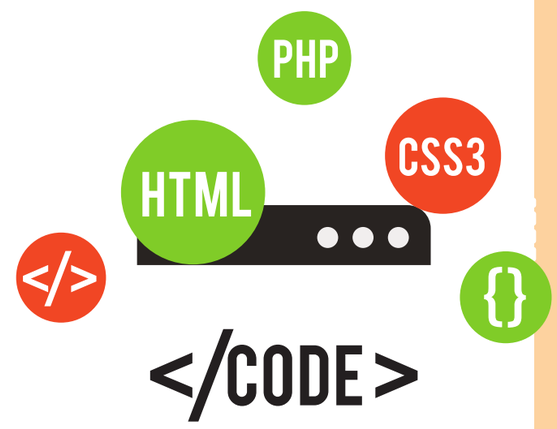
While building a robot is a wonderful process, the real magic lies in getting it to think. That's where 'programming' comes in. In this chapter, you will learn how to use code to give instructions to your robot's microcontroller so that once it's well-connected to the other parts using the wires we discussed, it can then when to move, and respond to its surroundings.

Meet your robot's brain: Arduino and friends

Your robot requires a tiny computer to execute commands. Arduino Uno is one of the most well-liked beginner-level microcontrollers. Some others are Raspberry Pi Pico and ESP32. Guess what? Microcontrollers do not require complicated code to operate. Even basic instructions, such as "if the sensor identifies something, activate the motor," can make your robot travel and react.

What is coding, really?

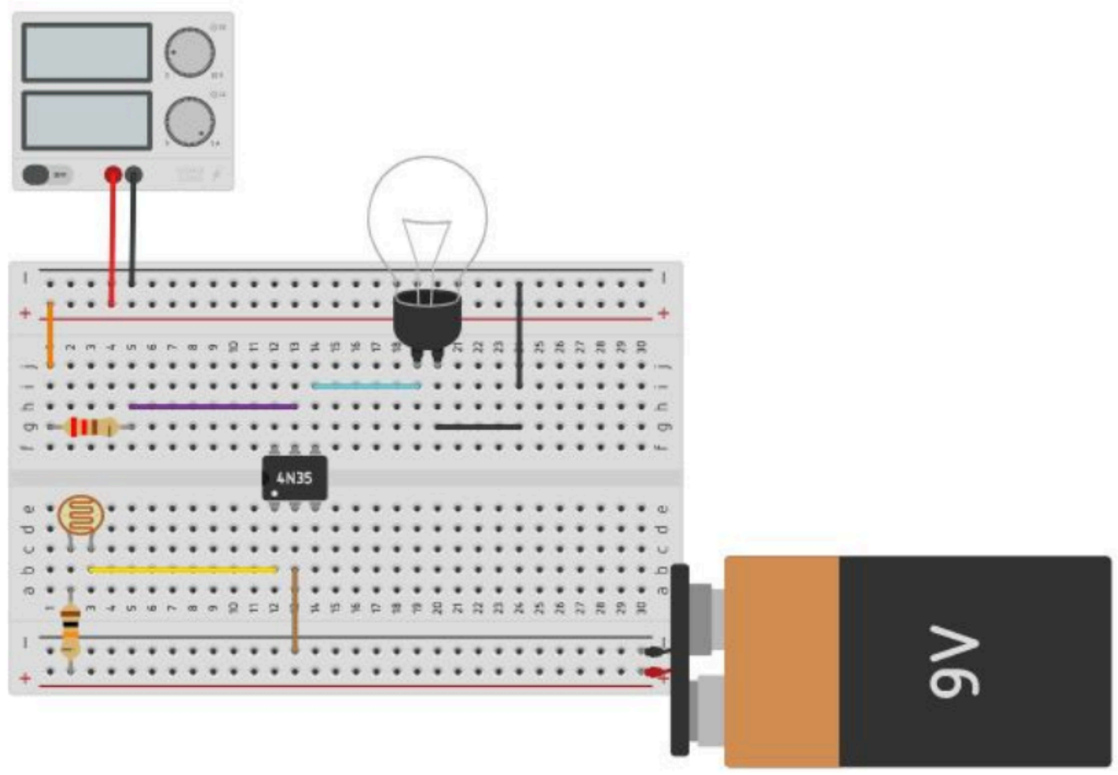
Coding is just a language you use to communicate tasks to your robot. You'll type these using a computer, which then sends them to your robot's brain. This tells your robot how to behave.



In robotics, coding helps your robot:

- Control movements smoothly (like moving forward)
- Make decisions (like when to stop or start)
- React to the environment using sensors (like turning around or moving sideways if an object appears ahead)

Think of coding as teaching your robot its daily routine, a to-do list if you will. Most microcontrollers use text-based programming languages like C/C++ or Python. But for beginners, platforms like TinkerCAD Circuits also offer something known as block-based coding, where you snap code blocks together like puzzle pieces!

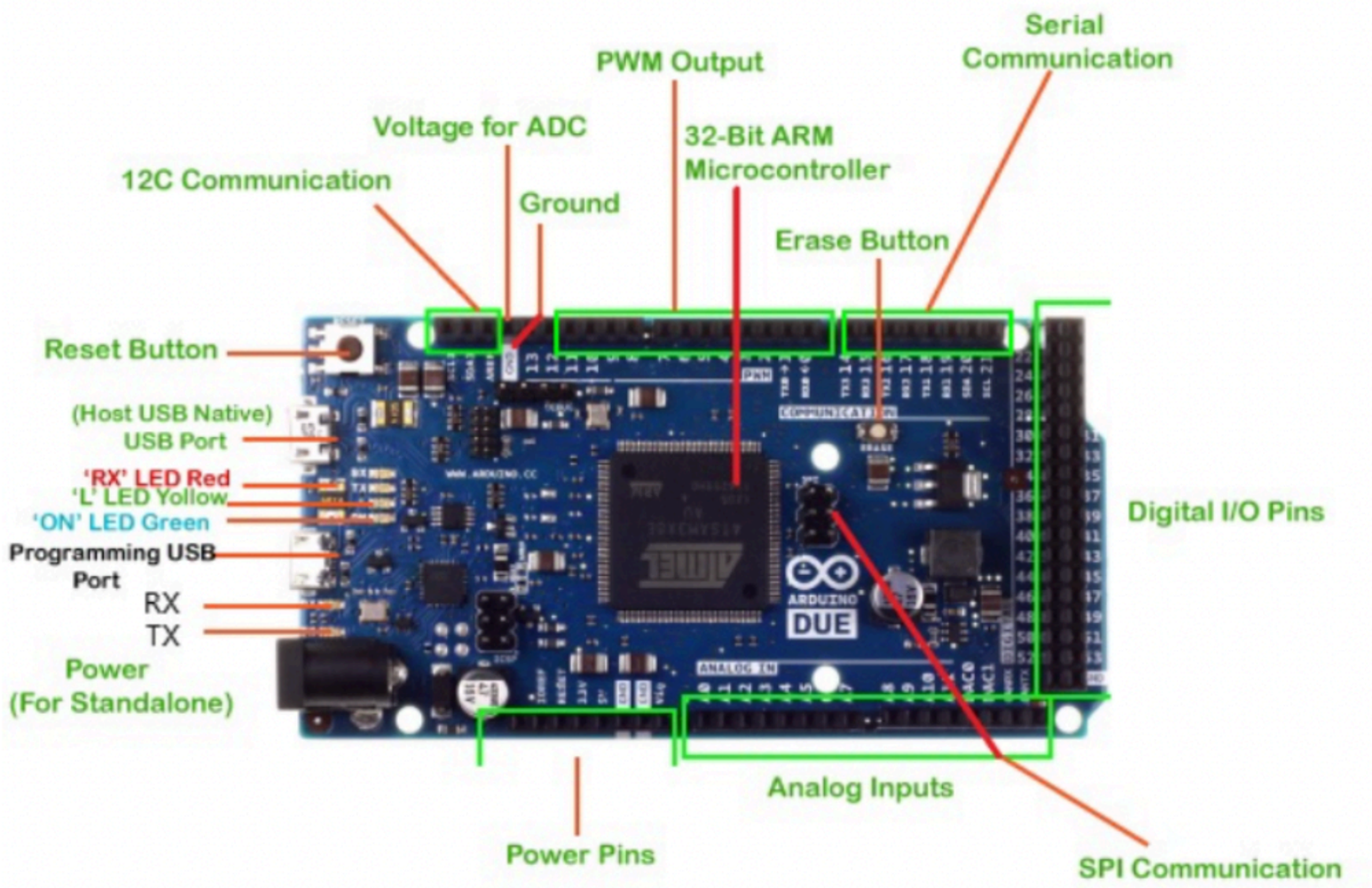


Example of a Tinker CAD Circuit for a Light Detector!

Your robot “feels” the world around it through input and “acts” through output. Microcontrollers like Arduino have small metal pins around their edges which connect to wires from sensors and motors.

- Input Pins: These receive signals from sensors. (Example: A distance sensor sends a message when something is nearby.
- Output Pins: These send signals to parts like motors or lights. (Example: Turn motor On.)

As a programmer, you’ll write code to say: “If input pin A gets a signal from a sensor, then send a signal through output pin B to make something move.” This logic is called an ‘if-then condition’, and is one of the most important building blocks in robot programming! Don’t worry if these terms feel new. As you practice, it will become easier!



Without programming, your robot is just metal and wires. Coding brings your robot to life, giving it the power to move automatically, sense obstacles and avoid them as well as follow commands like stop, start, or turn.

You can write your robot's instructions using special software like the Arduino IDE (Integrated Development Environment). This free tool lets you:

- Write code.
- Check for errors.
- Upload the code to your robot's brain.

There you have it, you're officially a robotics programmer now! By now, you've met your robot's brain (Arduino), learned what code is, and discovered how to connect what your robot senses to how it responds. Every good robot starts with a single line of code. In the next chapter, we'll understand how to test and improve your robot's movement because writing code is only the first step… getting it to work perfectly is where the fun really begins!

CHAPTER 5 - ROBOTICS FOR GOOD: INNOVATING WITH PURPOSE

Great job making it till here. Now, once robots are all built and set-up, the question that comes up is what do we do with them? In this chapter, we'll take a deeper look into some of the many ways robots help us, the trends that allow robots to participate in industries, with a special focus on healthcare, if you remember the brief introduction we covered in Chapter 1. Let's dive in!

Kitchens: Here, robots help by taking orders, serving food, cleaning up, and sometimes even preparing ingredients or cooking. There's a lot for robots to do in kitchens; Flippy is one example which helps fast-food joints prepare their foods!

Households: Chores like cleaning the floor, folding clothes, taking care of pets are all things that robots can do. The most famous example of this is the Roomba - a robot vacuum that automatically cleans houses.

Workplaces: Construction sites, archaeological sites and factories are all places where robots can be quite helpful. They can assemble parts (like those of a car), move building materials, and scout out locations in advance for safety; one such robot dog called Spot is popular for doing this!

Spot helping out with safety checks in Pompeii (a city with ancient Roman ruins)

Current trends in Robotics

- Collaborative Robots (Cobots): These cobots are built to interact with humans and help them with daily logistics. They are easy to use and safe to work with.
- Modular Robots: These have interchangeable parts (sort of like a transformer) that can adapt to different tasks. Examples include having wheels to move things around or arms for lifting items.
- Artificial Intelligence and Machine Learning (AI & ML): Nowadays with AI getting more and more popular, robots can automatically analyze patterns, make plans and predictions too; all on their own! Its processing can also be updated in real-time making them quicker and more immediate with their response to not specific but many situations!

But these trends aren't happening separately. Depending on the industry, robots today are designed keeping more than one of the above trends in mind. Manufacturing and logistics industries sometimes have robots with all three trends. On the other hand, while agriculture has AI-powered cobots; healthcare has modular cobots.

Gary: A look at robotics in healthcare

Gary is a robot designed to help healthcare professionals in a variety of tasks. From taking over mundane administrative tasks like filling out patient forms to interacting directly with patients to provide bedside assistance, there's a lot for Gary to do.

But Gary has found particular success in Geriatric care or that which is provided to the elderly.

In this picture, Gary is seen helping a patient named David. The bot was able to do so by conducting brain-training exercises, connecting him to his family via video calls, and reminding him to take his medication.

Generally too, robots in healthcare have been quite successful by creating positive impact in terms of inventory management, transporting lab samples, preparing meals and of course, improving the lives of those with disabilities through prosthetic limbs!

As you can see, robots aren't just cool gadgets; they're real-world helpers making life better. With the rise of cobots, modular designs, and AI, robots are becoming more adaptive, responsive, and even caring companions like Gary. In the next chapter, we'll explore the future of robotics a little more. After all, the future of robotics starts with you!

CHAPTER 6 - THE FUTURE OF ROBOTICS: SCALABILITY, ETHICS & INCLUSION

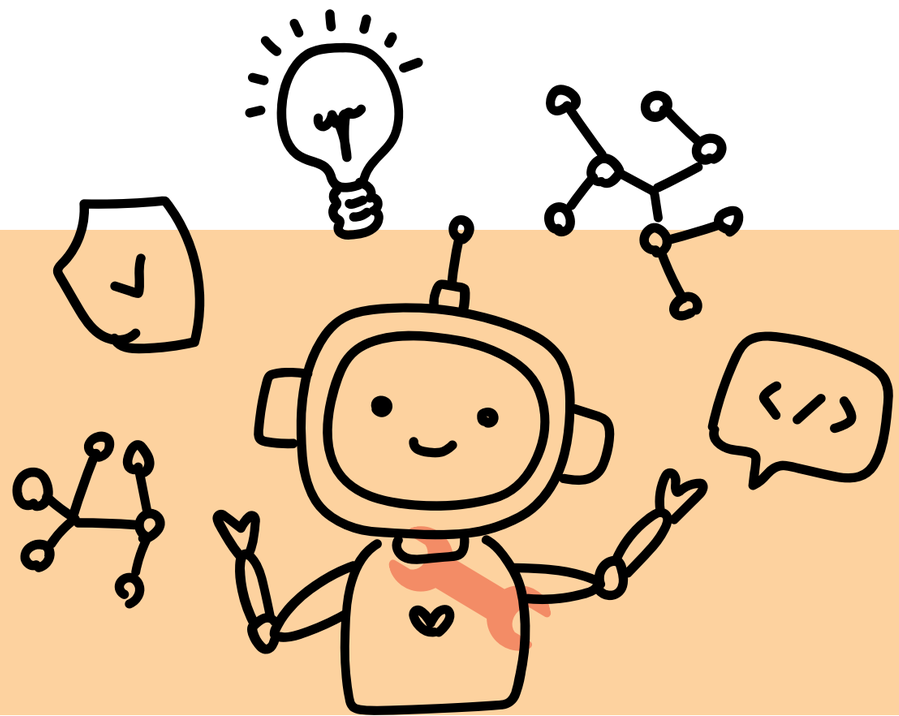
You've come a long way in understanding what makes a robot work. In the last chapter especially, we went over some present-day examples of how these are constantly advancing and helping us out in our daily lives. This final chapter is like a sneak-peek into the future - how robots powered by Artificial Intelligence are shaping the world and some ethical questions this brings so that everyone can be part of such an exciting future!

As you learned in Chapter 5, AI gives robots the ability to learn from their surroundings and make decisions in real-time. But in the near future, this won't just be a bonus feature, it'll be the main driver of how they work. AI is working on helping robots:

- See with Computer Vision (recognising objects, people, and places)
- Move with Automatic Navigation (exploring unknown spaces without crashing into things)
- Understand Us (Humans) with Natural Language Processing (responding to speech just like Siri or Alexa do!)

What this means is that robots are getting smarter, faster, and more capable of working like us, if not better. In fact, experts think that by 2030, up to 30% of jobs could be automated. Industries like manufacturing and customer service are already seeing this shift.

Given the positives, there are also some concerns when it comes to robots working in the service industry.



- **Privacy and Security:** Robots in service roles often collect data from voice commands to personal details. But who controls this data? And how do we keep it safe from hackers? These are questions we still need to work on.
- **Biases:** A robot is only as good as the data it is trained on. If the AI behind a robot learns from biased data, it might make unfair decisions like treating some people differently or using racist terms. This is why it is so important to design fair codes and algorithms for robots.
- **Accountability:** If a robot messes up, say it delivers the wrong medicine, who's to blame? The maker? The programmer? These questions don't have easy answers, and they're part of what makes AI ethics such an important field today.

What next?

The good news? Robotics is no longer limited to science labs at big universities. Around the world, initiatives are making robotics education more inclusive and accessible for young students like you! Be that through programs like FIRST Robotics, Girls Who Code, and even the project this book comes under - Lab Rats!

Why is this important?

- **Hands-On Learning:** Building robots teaches through doing which means no more boring lectures and better retention or remembering.
- **Critical Thinking:** Through robotics, students can learn how to break big problems into small, solvable pieces that address real-world issues.
- **Creativity:** Robots need smart, new ideas and that means out-of-the-box thinking, in line with problems today like environmental pollution and garbage management.
- **Teamwork:** Robotics projects are almost never solo efforts. You learn to build together and can make new friends along the way that not only help but also teach you new things.
- **An Introduction to STEM:** From mechanics to coding, robotics introduces students to the full range of STEM - Science, Technology, Engineering, and Math.

Even the ethical questions we went over can lead to meaningful classroom discussions that make you build robots while thinking deeply about why they are made and who they can help.

The future of robotics is bright; but it's also in your hands. Whether you want to design smarter robots, fix the ethical issues, or bring robotics to more students like you, there's a place for you in this journey.

Robots are no longer just machines. They're the companions, coworkers, and co-creators who and need the next generation of thinkers and makers.

Maybe.. that's you.

SOURCES

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THANK YOU!