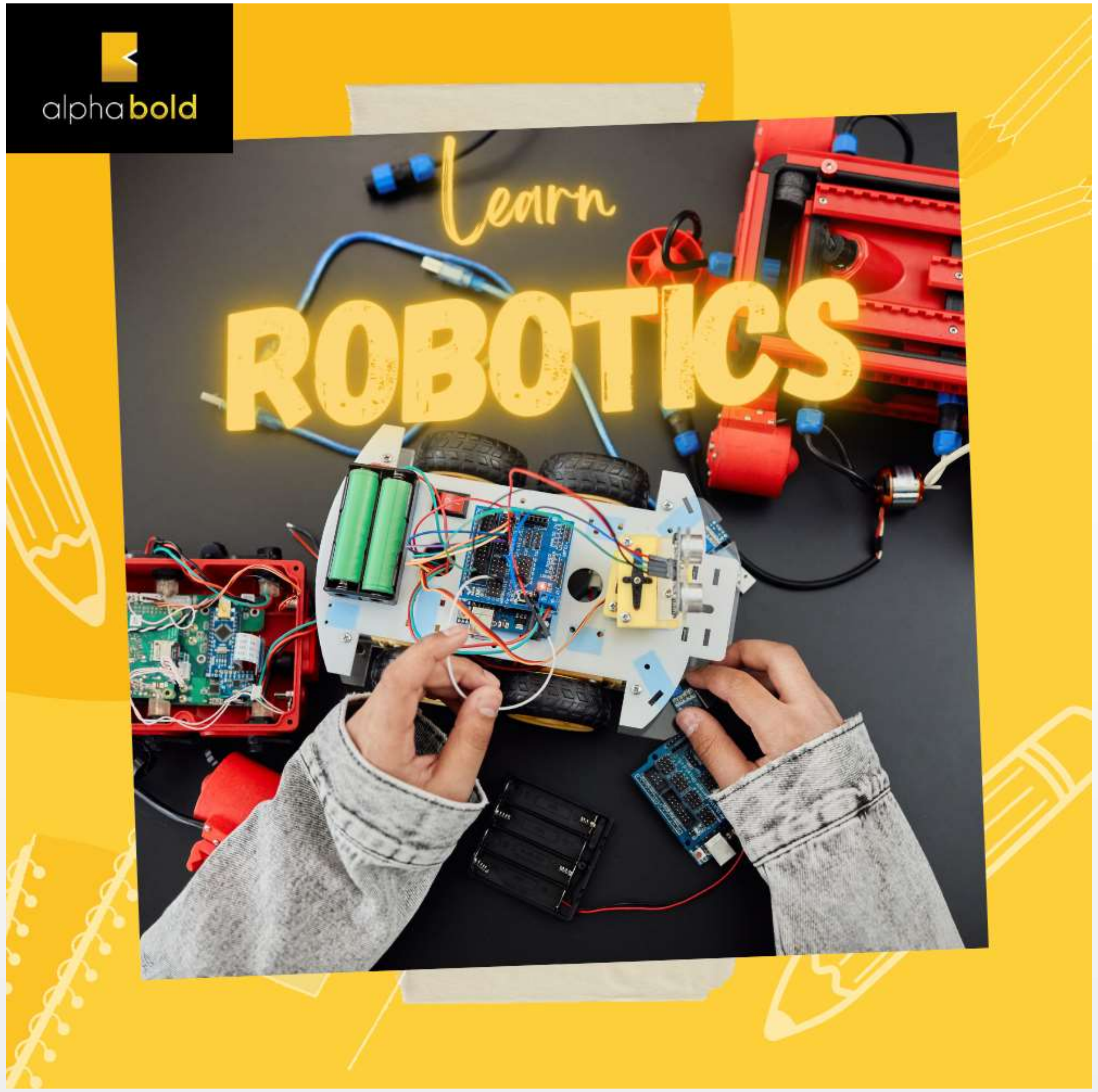
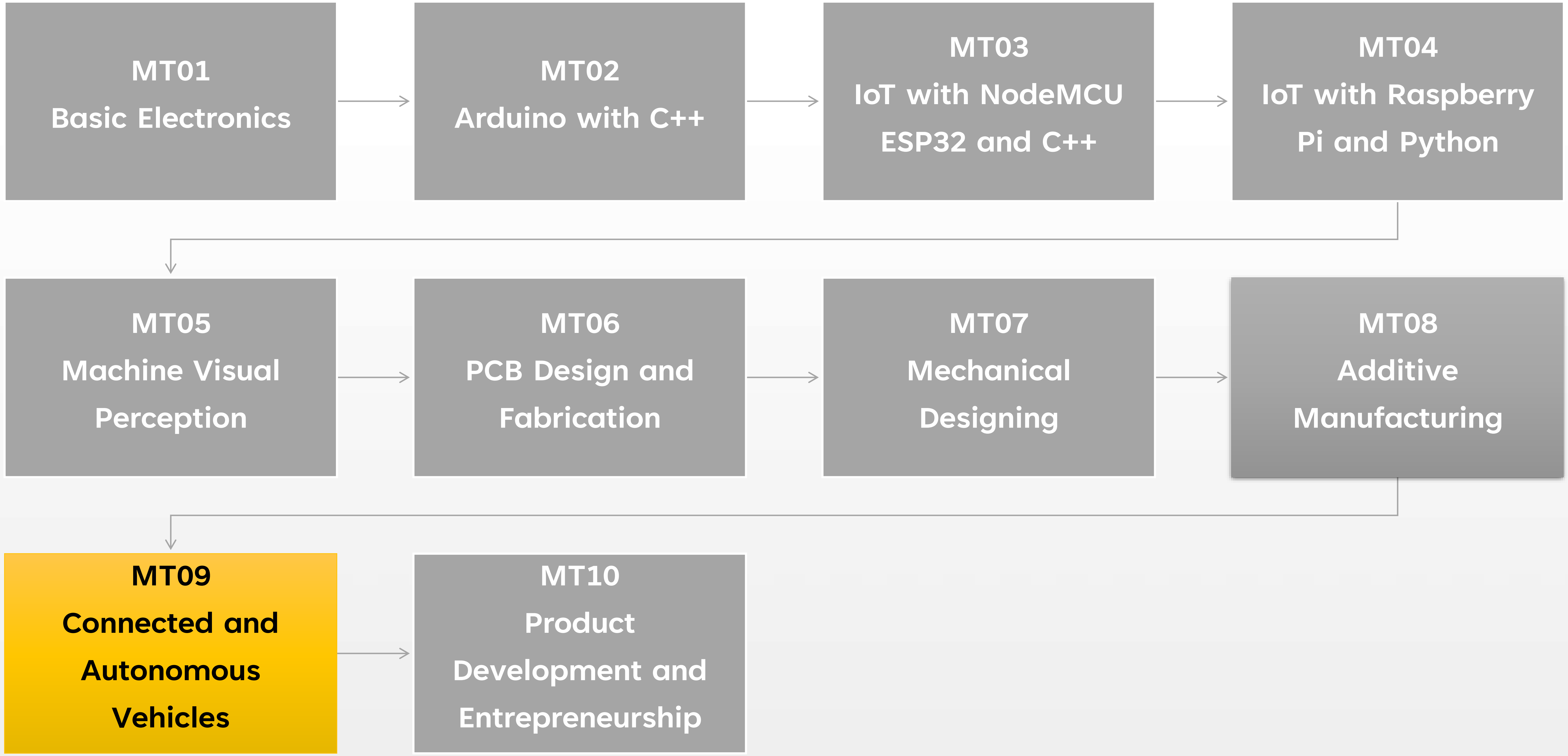
Connected and Autonomous Vehicles

Autonomous Vehicles in ROS



Learning Pathway: Robotics

MT



MT01
Basic Electronics

MT02
Arduino with C++

MT03
IoT with NodeMCU
ESP32 and C++

MT04
IoT with Raspberry
Pi and Python

MT05
Machine Visual
Perception

MT06
PCB Design and
Fabrication

MT07
Mechanical
Designing

MT08
Additive
Manufacturing

MT09
Connected and
Autonomous
Vehicles

MT10
Product
Development and
Entrepreneurship

Course Unit Details

Overview

Welcome to the "Autonomous Car" course, an advanced program designed to delve into the realms of Computer Vision and Artificial Intelligence within the framework of the Robot Operating System (ROS). This course unit equips you with the foundational knowledge and skills necessary for understanding and working with Connected and Autonomous Vehicles (CAVs). You'll explore the core principles behind autonomous cars, delve into the Robot Operating System (ROS) - a critical software framework for robotics - and gain hands-on experience implementing functionalities for autonomous navigation.

Aims

- Introduce the concept of autonomous vehicles and their potential impact on transportation.
- Equip you with a strong understanding of the Robot Operating System (ROS) for robotic development.
- Develop essential programming skills for building communication pathways within ROS networks.
- Explore key technologies for autonomous navigation such as Laser Scan Matching and Simultaneous Localization and Mapping (SLAM).
- Provide hands-on experience in implementing basic autonomous behaviors through real-world projects.

Learning Outcomes

- Upon successful completion of this course unit, you will be able to:
  - Explain the fundamental concepts of autonomous vehicles and their significance in modern transportation.
  - Describe the core functionalities and applications of the Robot Operating System (ROS).
  - Navigate the ROS filesystem and manage software components effectively.
  - Utilize Publisher and Subscriber functionalities within the rospy API to facilitate communication in ROS networks.
  - Implement complex functionalities using Services and Launch files within the ROS framework.
  - Explain how rospy manages time synchronization and utilize Bag files for data recording and playback.
  - Apply Laser Scan Matching techniques to enhance odometry accuracy for autonomous navigation.
  - Grasp advanced concepts and applications of Laser Scan Matching for robust odometry performance.
  - Set up a robotic system for functioning and implement tele-operation for remote control.
  - Design and implement a wall-following behavior using reactive methods in ROS.
  - Master the concept of ROS Transformations and Frames for accurate coordinate handling within robotic systems.
  - Explain the principles of Simultaneous Localization and Mapping (SLAM) and its role in autonomous navigation.
  - Implement a Pure Pursuit Controller for autonomous path following and engage in research projects related to Connected and Autonomous Vehicles.

Syllabus

Lectures

1. Introduction to Autonomous Cars
2. Introduction to ROS
3. ROS Filesystem
4. rospy API Part-1: Publisher/Subscriber
5. rospy API Part-2 : Services and Launch
6. rospy API: Time + Bag files
7. Laser Scan Matching for Odometry
8. Scan Matching - Part 2
9. Setup and Tele-Operation
10. Reactive Methods - Part 1: Wall Following
11. ROS Transformations and Frames
12. Simultaneous Localization and Mapping - SLAM
13. Follow the Gap
14. Project: Pure Pursuit Controller and Research

Labs

- Installing Ubuntu - Tutorial
- Installing ROS - Tutorial
- Lab Handout 1: Understanding ROS using Turtlesim
- Lab Handout 2: ROS Filesystem, Packages, and Publishing/Subscribing
- Lab Handout 3: ROS Services and Launch
- Lab Handout 4: ROS Simulator
- Lab Handout 5: ROS Simulator Part 2
- Lab Handout 6: ROS Transformations and Frames
- Lab Handout 7: Online Simulator

Detailed Course Outline

1. Introduction to Autonomous Cars: Explore the fundamentals of autonomous vehicles, their significance in modern transportation, and the underlying technologies driving their development.
2. Introduction to ROS: Gain a solid understanding of the Robot Operating System (ROS), a powerful middleware framework widely used in robotics research and development.
3. ROS Filesystem: Learn about the ROS filesystem, its organization, and how it facilitates the management of software components in a robotic system.
4. rospy API Part-1: Publisher/Subscriber: Dive into the rospy API, focusing on the Publisher and Subscriber components for effective communication within a ROS network.
5. rospy API Part-2: Services and Launch: Extend your knowledge of the rospy API by exploring Services and Launch files, essential for implementing complex functionalities in ROS.
6. rospy API: Time + Bag Files: Understand how rospy manages time and utilizes Bag files for recording and replaying data in ROS.
7. Laser Scan Matching for Odometry: Delve into the technique of Laser Scan Matching to enhance odometry, a critical aspect of autonomous navigation.
8. Scan Matching - Part 2: Further explore advanced concepts and applications of Laser Scan Matching for improved accuracy in robotic odometry.
9. Setup and Tele-Operation: Learn the process of setting up a robotic system and implementing tele-operation for manual control.
10. Reactive Methods - Part 1: Wall Following: Explore reactive methods in robotics, starting with the implementation of a wall-following behavior.
11. ROS Transformations and Frames: Master the concept of ROS Transformations and Frames, crucial for handling coordinate transformations in robotic systems.
12. Simultaneous Localization and Mapping - SLAM: Gain insights into Simultaneous Localization and Mapping, a key technology enabling robots to understand and navigate unknown environments.
13. Follow the Gap: Learn about the "Follow the Gap" algorithm, a navigation strategy that enables robots to follow open spaces.
14. Project: Pure Pursuit Controller and Research: Apply your acquired knowledge to develop a Pure Pursuit Controller and engage in research projects to deepen your understanding of autonomous car systems.

Requirements

Desired

Prerequisite Courses

- MT01 to MT08

Background Knowledge

- Familiarity with robotics concepts such as integrating microcontrollers with sensors and motors
- Understanding of programming concepts such as function calls, conditional statements, loops and recursion

Prior Programming Skills

- Intermediate Python (Preferably)
- Intermediate C++

Software and Packages Required

- OS: Ubuntu/ Raspberry Pi OS
- Middleware: ROS
- Latest Python Release
- Library: Open CV

Hardware Required

- Electronic Components:
  - Microcontroller: Raspberry Pi
  - Necessary Sensors and Motors
- Computing device with internet connectivity

Recommended

ROS Programming

Machine Learning

Basic Physics (Newtonian Mechanics)

Calculus and linear algebra

- Single variable calculus and differential equations
- Matrix operations – transformations and rotations

Basic Statistics and probability

- Probability distribution
- Sampling, Mean, variance

Unix / Linux command line/ shell basics

- File commands: ls, cd, pwd, mkdir, rm, cp, mv, touch, cdhmod, tar
- Process management: ps, top, kill pid
- SSH user@host.., grep, locate, echo
- Installation:./ configure, make, make install
- Ports

Thank you for learning with alpha bold

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