

ภาคผนวก ก

รายชื่อบทความที่ได้รับการเผยแพร่ระหว่างการศึกษา

รายชื่อบทความที่ได้รับเผยแพร่ระหว่างศึกษา

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AUTONOMOUS MOBILE ROBOTS FOR MATERIAL HANDLING IN AN INDUSTRIAL PLANT

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Abstract

Industrial mobile robots are one of the most common handling equipment in the manufacturing. It is a way of increasing production efficiency while significantly reducing operating cost and facilitating because of the inflexibility of the Automated Guided Vehicle (AGV) with regard to modifying the robot's route. Because the AGV commonly use magnetic tape embedded under concrete to create a path for the robot. When to change the route or added the production line, need to destroy the area to reengineering causing an increase in spending. Therefore, Autonomous mobile robots respond to the problem involved with Simultaneous Localization and Mapping (SLAM) techniques, it can be used to located and create Maps. And AMR moves according to maps and localization, it cause the main features is the flexibility to change routes. In this research will present to a various system and usability of AMR for material handing in an industry.

Keywords: Industrial mobile robot, Automated guided vehicle, Autonomous mobile robot, SLAM

1. Background/ Objectives and Goals

Automated guided vehicles are becoming one of the most common smart handling tools in the manufacturing industry. Nowadays, Industrial plants prefer to use Automatic guided vehicles (AGV) to transport materials from warehouses to target points to wait for the production process, the AGV has been designed to be more efficient in the industry. [3,6,7] AGV working principle uses magnetic sensors to detect magnetic tapes under the concrete floor. Use computer principles to control the AGV to follow the route created, which can be customized according to work requirements. Some AGVs use QR codes instead of Magnetic tape [1]

It is impossible to deny that one of the main points of the AGV is routing. Sticking magnetic tape or QR codes on the ground provides a fixed route. It is difficult to change the route if you want to change routes or add routes, you must destroy the ground to dislodge the system. There will be a supplement in each case. It is hard to Computer programming and time-consuming to edit. When the AGV is used for a long period of time, the magnetic tapes or QR codes degrade. AGV performance declines and faults may result.

The main problem with implementing AGV is its inflexibility. If an industrial plant wants to change or add a production line, it will need to repair the whole system. This increases the cost; therefore, the Autonomous Mobile Robot responds to the problem involved. The main characteristic is the flexibility to change the route. The aim of the research is to present the application of AMR in industrial plants.

2. Methods

2.1. System architecture

Fig. 1 illustrates the shape of robots that our team created together with the company. It has the following Important Components: There are Navigation Sensors installed in front and back of robots. There are safety sensors installed both in the front and back of the robots. Our model has a Monitor used for control and Monitoring. There is a charger. Installed surround Safety bumper. Fig. 1 shows the component of the robot.

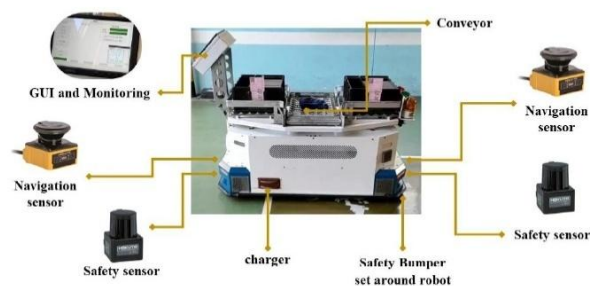


Fig. 1: Component of robot

Fig. 2 shows robot architecture consists of High level and Low levels. Low levels are used to connect the sensor and actuator to data transmission with each other such as sending orientation from the IMU command filter, feedback transmission of an encoder, and sending commands on motor control. The High-level sections contain a user interface where the algorithm resources are required to be processed. The queue

for the robot is set up via GUI and WEB Master and then the queue is then handled in the route planner process. First, we check the robot state observer for other operations. The next step is the robot's Pose checker, which checks the robot for being in a position and orientation. Then the process is Dijkstra's Route Planning. Is an algorithm used to determine the path of the robot to get the short path. Finally, Path collinearity remover steps remove points in the same line. Then select the mode of operation, AMR mode or AGV mode sends a command to navigation software.

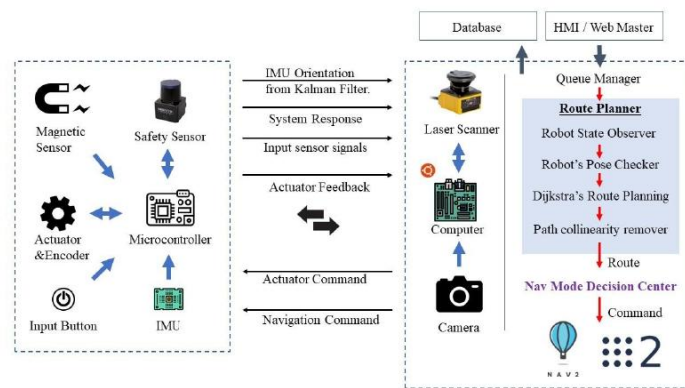


Fig. 2: Robot system architecture

2.2. Hardware

The IMU is a multi-sensor device detecting acceleration, angular velocity, angle as well as magnetic field. The small outline makes it perfectly suitable for industrial retrofit applications such as condition monitoring and predictive maintenance. A sensor measures 3-axis angle, angular velocity, acceleration, and magnetic field. Its strength lies in the algorithm which can calculate three-axis angles accurately.

LIDAR sensor is a laser-powered distance sensing device with high accuracy in measuring distance and can operate in low light or reflected light. A LIDAR sensor emits a laser beam at an object and measures its distance by measuring the time it takes for the light to return after reflecting on the sensor. LIDAR sensors are often used in research, robotics, and autonomous vehicles. High-precision and highly efficient instruments are used in various science and technology applications. LIDAR utilizes a range that rotates clockwise, enabling 360° full-scan detection of the surrounding environment and producing a map of the area. The sample rate of LiDAR directly decides whether the robot can map quickly and accurately. LIDAR improves the internal optical design and algorithm system to make the sample rate up to 8000 times/second. Computers are important devices used for calculating large amounts of

complex mathematical data. The researcher used a computer with a CORE I5 CPU.

A microcontroller is an electronic device that consists of a processor with memory and signal amplifiers used to control and process data in various electronic systems. Microcontrollers are used to control motion. Sensor Data Collection and data transmission. The researcher uses an ARM Cortex M7 32-bit 600 MHz. It is appropriate in terms of resources and processing speed.

The servo motor is a device that converts electrical energy into mechanical energy for use in the propulsion of the robot. It is precise and can control the rotation with high precision. There is an electronic control system inside the motor to control the position and rotation speed of the motor to be precise. The researcher used a 400-watt servo motor with a rated speed of 3000 rpm.

A safety sensor is a device used to detect the status or movement of objects or people to prevent danger or accidents. For the robot, it uses a 2D scanner for measuring the distance between the sensor and its surroundings. Faster response, 66 mms, and can be connected to a control system to trigger an alarm or stop it automatically. to prevent the danger that may occur in various situations.

A bumper is a device that helps in matters of safety. The behavior of the bumper is like a switch. When an object collides with the bumper, it sends an electrical signal to the robot to automatically alert or stop working. The bumper is the last safety device that will work. because it prevents the robot from colliding with the object. HMI and Web servers are part of receiving commands for the operation of the robot and monitoring its operation. Including information about the robot for users to know.

2.3. Odometry

Is the process of calculating the position or direction of a mobile robot. Using sensors connected on the Robot body to measure rotational motion. Use the data obtained to calculate the position of the Robot relative to the initial position. Odometry works well in highly dynamic environments but in an environment of constant change, the data is not as accurate as it should be. Therefore, SLAM (Simultaneous Localization and Mapping) is required to increase the accuracy of the position of the robot or vehicle.

2.4. Mapping

Simultaneous Localization and Mapping (SLAM) is the process of locating the robot's position and creating a map. It uses measurement data from the Lidar sensor to use its surroundings to estimate a map of the robot's environment and movement. Collect data own movement from Odometry and collects environment feature such as angles or block. Based on detection by the Lidar sensor. The SLAM process requires mechanisms such as Extend Kalman Filter (EKF) to update the data and estimate the degree of uncertainty of the robot's position and data in the environment. This process continues while the robot moves to obtain information about the environment and can be used to create a map in the end. It works in conjunction with the cartographer algorithm, which is used to create 2D maps by extracting and removing important features. The Cartographer algorithm uses feature points detection and tracking to extract functionality.[4]

2.5. Localization

Robot localization is the process of determining where a mobile robot is located with respect to its environment. Localization is one of the most fundamental competencies required by an autonomous robot as the knowledge of the robot's own location is an essential precursor to making decisions about future actions. In Robotics research, Adaptive Monte Carlo Algorithm is commonly used to create a map and direct the robot to the desired location based on information from the LIDAR Sensor to calculate the probability that the robot will be in that position. The algorithm employs random sampling to estimate the potential position of the robot and uses this value to determine the direction of the mobile robot at each period. In order to implement AMCL on mobile robots, to provide and comprehensive sensor data must be prepared as required. and continuously update the robot model to improve the AMCL statistical model over time. The statistical model uses data from sensors to estimate the probabilities of the robot's current position. This model will be continuously updated as new information is received.[2]

2.6. Navigation

Navigation in mobile robot is a process that enables the robot to move efficiently to the desired destination. The ROS2 Navigation Stack is an important module for mobile robot management. It consists of several modules which work together to enable the robot to move efficiently and safely in its environment. In addition, ROS2 Navigation Stack is a versatile tool that can be customized by adding or removing modules used in the Navigation Stack as the case may be.[5]

2.7. Route Planning

Route Planning is the process of planning a route suitable for moving from the starting position to the destination position. It uses information such as a Regions Maps, Destination, Environmental information and other variables to plan a route that can move safely and efficiently within a given environment. This Route planner uses the A* algorithm to help with route planning in order to find the shortest way from the starting point to the destination.

2.8. Command System

The part of command system. At first, the user selects a task for the robot and adds that task to the queue. Confirm the queue and enter the correct password. The task is sent to the robot then the robot functions depending on the order it receives. While running, the status and task are shown on the monitoring menu when the robot has finished the task, it deleted completed tasks from the queue. Next step is to store task information to the database and completed tasks are shown in the history menu. (Fig. 3)

2.9. Safety System

The safety system is robotic collision sensors. There are two safety features, a safety sensor and bumper switch. Safety sensors are connected to the front and back of the robot. The first case, the robot moves forward with the front safety sensors if it activated the robot stopped moving. The second case, the robot turns when one of the security sensors is activated and the robots stops moving. The third case, the robot turns back if the back safety sensor is activated the robot stopped moving. Another important case is the safety sensor is not working. The robot collides with an object and the bumper switch activated then the robot will stop working as well. (Fig. 4)

2.10. Data storage system

Is a storage device used for storage of various data. The objective is to store the information in a secure form and can access information quickly and efficiently. Use Cloud Storage to store data online. The collected data for example, all robot tasks, recording the number, date, time and information on the task.

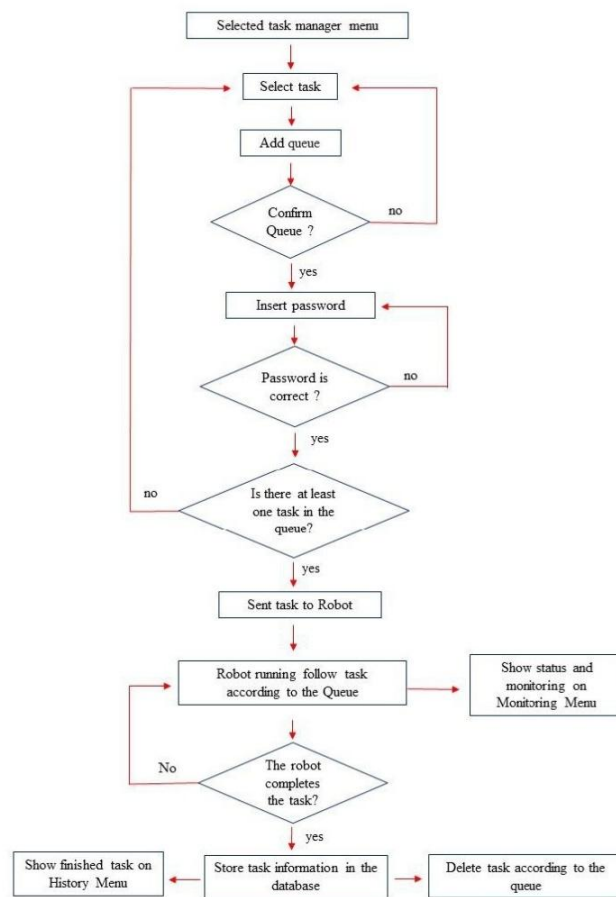


Fig. 3: flowchart of command system

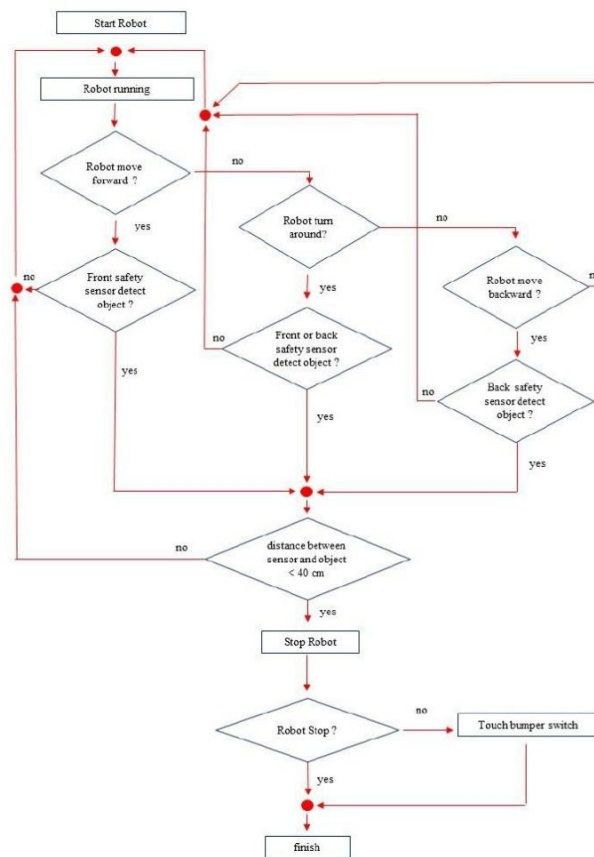


Fig. 4: flowchart of safety system

3. Results

3.1 Mapping

Data collection for creating maps uses a robot remote control method. By entering teleportation mode, then activate the cartographer to enter map creation mode. And then control the robot to move to every area we are interested in completely. In this research, the area we have mapped is an area in an industrial plant. The scanned area was 70x25 m. (Fig. 5)

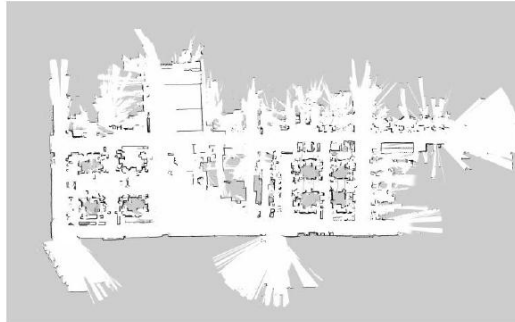


Fig. 5: The map for the testing

3.2 Navigation

For navigation testing, the robot was tested in a real factory environment. The temperature is 32 degrees Celsius. Almost area is indoor condition but there are some factory gates between the route and the robot's LiDAR must face the sunlight from outside. The sunlight did not affect the navigation of the robot due to the sunlight resistance of LiDAR. When the orders are submitted, the route management or route planning system will send the overall route in the robot's lane to the navigation stack of robot. From testing, the robot can track the path of navigation and can keep itself within predetermined lane. Fig. 6 illustrates the predetermined route of navigation system and Fig 7 illustrates the example of robot during operation. During operation, the green siren was power on the buzzer will have been activated.

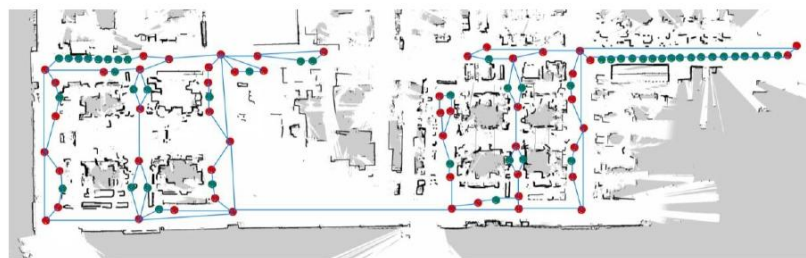
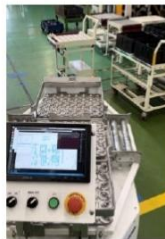


Fig .6: Route of navigation system



Fig .7: Robot during operation

In order to dock to the destination, the robot is necessary to stop at the entry point and rearrange the orientation before docking and change the operation mode to docking mode. Fig 8(a) illustrates the example of robot at the entry point and Fig 8(b) illustrates that how the robot docked at the station. From utilizing the automated guided vehicle style in docking, the gap between robot chassis and the station roller can be less than 3 centimeters and the tolerance in longitudinal direction is less than 2 centimeters.



(a)



(b)

Fig. 8: (a) The robot at the entry point of station (b) The robot after docking.

3.3 GUI and Web master

Fig. 9(a) shows the GUI screen on the robot. It consists of two parts. The first part, the touch screen is used to add tasks in the robot queue and can be added the multiple tasks. After a task is selected, press confirm queue and switch to auto. Then press run button, the robot works as a function of the task in the queue. The second part, the switch part has a switch to turn on and off the robot. Robotic operation mode selection button has two modes: manual and auto. There is a run button to start working.

From Fig. 9(b) shows the web master as a website that is able to access the robot from anywhere with a specific URL. When we login, we can order the robot's queue via

this web master. Then the queue will to the robot's screen. And then wait for confirmation that the robot will keep moving.



(a)



(b)

Fig. 9: (a) the GUI on the HMI of robot (b) the GUI of web master on web browser

3.4 Safety

Testing the safety of the robot we tested it in a real environment. A total of 15 tests were conducted, divided into tests according to the characteristics of the robot's motion, that is the robot moves, turns, and backs up. The results are 100 safety percentages. Table1 shows the recording of the experiment.

Table1. Result of safety sensor testing

Motion	Test	Front safety sensor	Back safety sensor	Result
Forward	1	✓	-	Robot stops
	2	✓	-	Robot stops
	3	✓	-	Robot stops
	4	✓	-	Robot stops
	5	✓	-	Robot stops
Turn around	1	✓	✓	Robot stops
	2	✓	✓	Robot stops
	3	✓	✓	Robot stops
	4	✓	✓	Robot stops
	5	✓	✓	Robot stops
Backward	1	-	✓	Robot stops
	2	-	✓	Robot stops
	3	-	✓	Robot stops
	4	-	✓	Robot stops
	5	-	✓	Robot stops
safety percentage				100%

4. Conclusion

In this research, the main components of AMR are used for transporting materials into Industrial plant. The main purpose of AMR is to transport materials from warehouses to the various production lines of industrial plants. The results can be divided into several sections. Regarding the collection of maps using the teleoperation mode by keep the size of the map 70x25m. The AMR can be located and navigate to different points on the map. Moreover, it can receive commands from the user, both the GUI on the robot and web master, which can be run from anywhere via a URL. The AMR motion safety system has been tested in a number of cases. And ability to prevent an accident by collisions around 100 percent. At the end of each task, the data can be stored in database to analyze the efficiency or number of tasks performed each day. The AMR developed by the researcher is actually used in industrial plants. In the future, researchers will develop a more effective AMR that will work in multiple environments.

5. Acknowledgement

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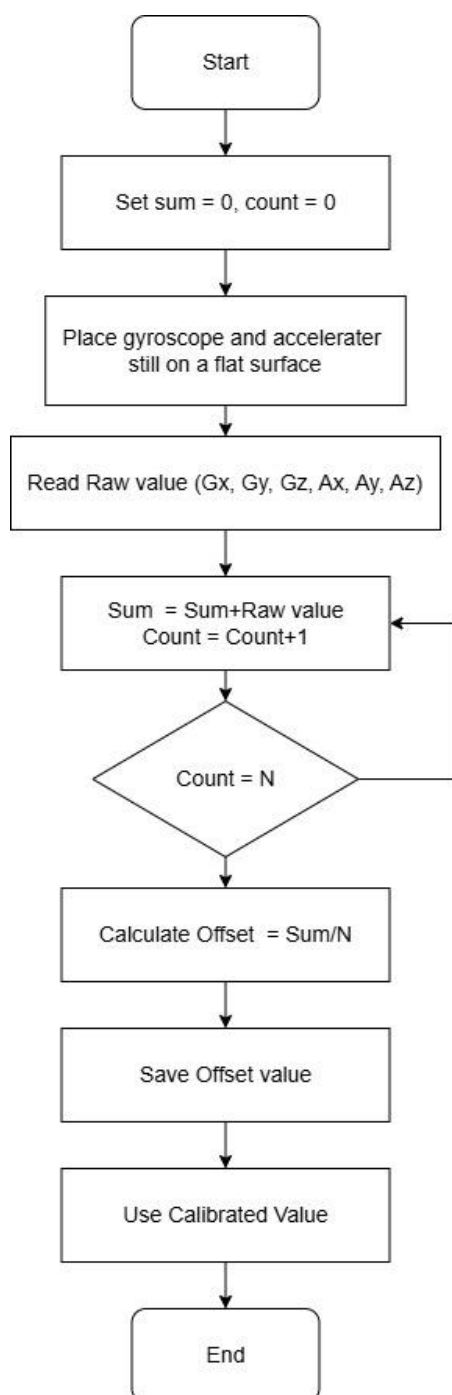
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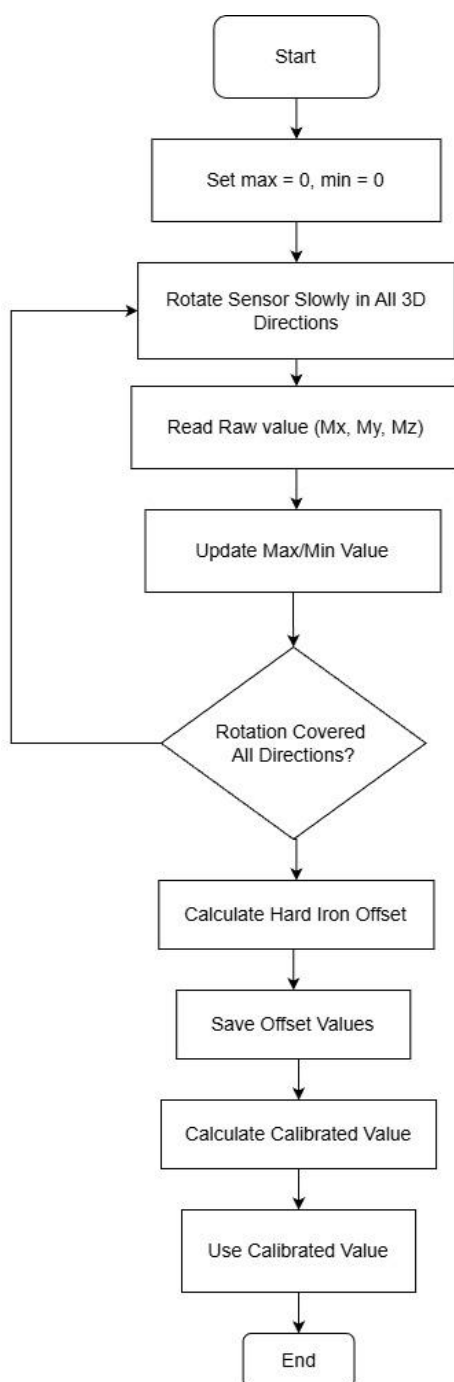
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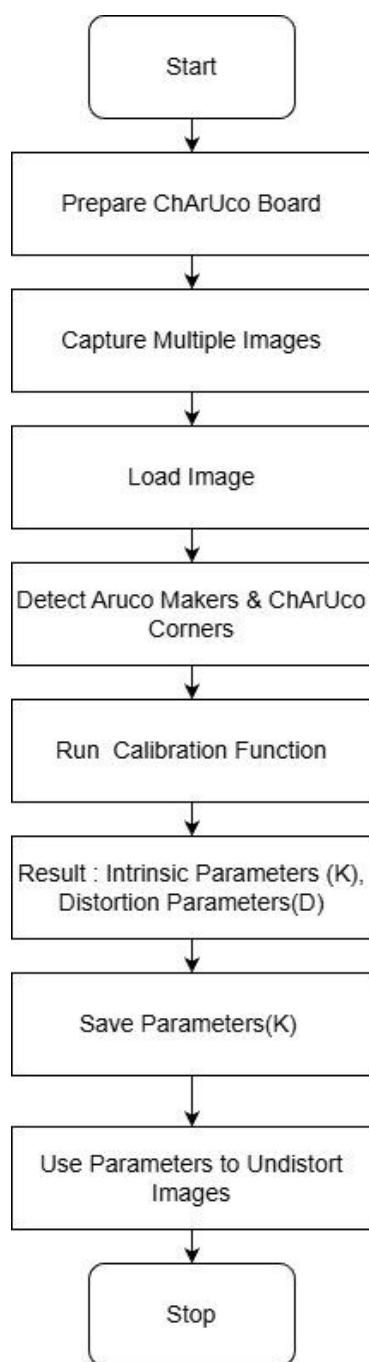
แผนผังการเตรียมข้อมูลเซนเซอร์ต่าง ๆ



รูปที่ ข.1 แผนผังการเตรียมข้อมูลไจโรสโคปและแอคเซเลอโรมิเตอร์



รูปที่ ข.2 แผนผังการเตรียมข้อมูลแมกนีโตมิเตอร์



รูปที่ ข.3 แผนผังการเตรียมข้อมูลภาพจากกล้อง