CHAPTER-1

Introduction

Navigation is one of the most demanding capabilities required of a mobile robot. The four building blocks of navigation are:

Perception- the robot must interpret its sensors to extract meaningful data;

L*ocalization*- the robot must determine its position in the environment;

Cognition- the robot must decide how to act to achieve its goals; and

Motion-control- the robot must modulate its motor outputs to achieve the desired trajectory.

Of these four components, localization has been the focus of several research advances done in the past decade. Localization can be very easily and cost effectively achieved by using GPS, but given the poor accuracy of GPS in small spaces and that to in indoor conditions we had to come up with something different and something which can be easy to setup and cost effective as well.

Now a days, each and every smart phone has that capacity and capability to carry out extremely complex and compute intensive tasks. So we're using the smart phone camera sensor as the primary driver for - detecting the positions of the bot in 3D space, finding out the 2D coordinates of the bot and then transmitting those coordinates to the server or our PC where the distance between the bot and the destination is computed and transmitted to the bot.

Now the second and most important problem that needs to be addressed is actually identifying the bot in 3D space. This can be attained with the help of image processing, to differentiate and identify the bot in the environment and this process is made simpler by using ArUco markers and Python's OpenCV library for image processing.

After the initial setup is completed, the chassis of the bot is readied, the electronics are mounted and the ArUco markers are pasted on top of the bot so that the camera can distinctly identify the marker and instructions can be relayed to a particular bot using a message broker service like MQTT.

Review of Literature

Navigation systems have countless applications in real life. It is extensively used for finding an entity's location and for navigating from one position to the next. GPS is extremely useful for outdoor positioning and navigation application where accuracy does not matter that much, but for indoor navigation we cannot rely solely on GPS to give us an accurate location.

1.1 Fiducial marker-based detection (over other detection methods)

There are a lot of alternate solutions to this problem through which we can achieve our objective of indoor navigation system. Some of these solutions include - LiDAR sensors, IR sensor or vision-based positioning which utilizes one or more camera sensors. Although these are viable solutions, but they are too expensive to work with. So instead of using any extra hardware we can use our smart phone camera which would act as the eyes for our bot and keep track of its position in real time. Vision-based localization (VBL) takes advantage of visual landmarks and image processing to extract information. Camera based solution is an efficient and cost-effective option since we're using our smart phone camera which has the requisite hardware, making the Vision Based Localization approach a beneficial choice for designing indoor navigation system.

For indoor navigation system based on Vision Based Localization we need to have a marker-based detection, for which we have two available options – fiducial marker or natural marker. Now natural marker tracking can be little difficult and often tricky because it depends on the object's natural features which can be different under different lighting conditions or circumstances. That is why we're making use of ArUco marker which is basically a Fiducial marker constructed with the sole purpose of encoding/decoding information in the marker and tracking the marker **[2]**.

1.2 ArUco markers (over other fiducial markers)

ArUco marker is a square binary fiducial marker that is commonly used in AR applications in order to determine position. The aruco module is based on the ArUco library, a popular library for detection of square fiducial markers developed by Rafael Muñoz and Sergio Garrido **[4]**.

Advantages of using ArUco marker: -

a) The ArUco library used for marker detection is very fast and optimized which makes it is a good choice for video capturing.

b) The ArUco markers provide information in encoded format without adding any overhead with unnecessary complexity.

c) We are also able to find out the heading information without any extra computation. It returns the top right, top left, bottom right and bottom left corners just by scanning the marker, thus from this information we can very easily find out the head position of the bot and relay instructions accordingly.

d) ArUco markers are made of a 2D array of black and white variations of which only a few are used for id generation with the rest being available for error detection. So it is even great for detecting marker that are occluded due to external factors **[3]**.

1.3 ArUco-Scanner application (over IP webcam and other methods)

A lot of things need to be taken care of for the bot to move in the right direction. So, we need an overhead camera that can translate the position of marker/bot to the client/PC as corner coordinates, then we need to calculate the centre and head position of the particular marker, compute the distance between the marker and the destination, and then send the signal through a message broker to the bot.

While all of this is time consuming process, the IP webcam which we had initially planned to go ahead with had latency issues thus adding to the problem. The problem was, IP webcam app had limited functionality i.e. it would translate the live video feed frame by frame to the client/PC, after which all calculation i.e. corner detection, centre and head calculation, distance computation between the marker and destination is done at the client/PC. This leads to a time delay and thus makes the whole process laggy and not effective in real-time.

Instead we chose ArUco-Scanner because it reduces the load on the client. It makes use of the smart phone's processing power to identify the corner coordinates of the marker and calculate the centre. Finally instead of sending live video feed to the server, like IP webcam, it forwards just the corner and centre coordinates to the server. This greatly reduces the latency and it appears as if everything is happening at real-time.

Previous work done and challenges imposed:

Sl. No.	Author Name	Paper Name	Contribution	Challenges
1	Babinec, Andrej & Jurišica, Ladislav & Hubinský, Peter & Duchoň, František	Visual Localization of Mobile Robot Using Artificial Markers[5]	ArUco tags lowered the cost of implementation of visual localization	Distance between camera and markers play a major role and reduce effectiveness and accuracy of using smaller ArUco markers
2	Alves, Paulo & Costelha, Hugo & Neves	Localization and navigation of a mobile robot in an office-like environment[6]	Global localization and ROS enabled navigation showed promising results	Hardware implementation involved webcam mounted robots which increase development costs