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Autonomous SLAM based Forklift Robot

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Abstract

This paper proposes and develops a sophisticated design of Autonomous Simultaneous Localization and Mapping (SLAM) based Forklift Robot. The main idea of this work is to design such an object lifting forklift robot which works in dynamic and unknown environment like warehouses to lift and shift the boxes from one place to another. Since the forklift robot is a SLAM base so it has the ability to empower the controller of the robot to take decisions related to the movement of the robot on its own without any human intervention and reach to the objects for detection and lifting. For object detection uses the machine learning approach called Optical Character Recognition (OCR) in which we use K-nearest principle to detect the user define object (box). Our design follows three basic steps: the forward motion planning which is the part of SLAM approach for navigation in forward direction and also generating a real time map. The second step is object detection in which robot match the alphanumeric code written on the box with the code defined by the user to detect and lift that box. The third step is reverse motion planning which follows the map was generated during the forward motion planning to get back its initial position with the box. This map is also display on the user's interface wirelessly.

Keywords: Forward Motion Planning, Optical Character Recognition, Object Detection, Reverse Motion Planning, Simultaneous Localization and Mapping

1. Introduction

In new era the speed of the advancement in technology is like a rocket and seems to be never ending till the world exists. This advancement completely changes and raises the living standards of the people and surrounded by the machines. The best example is robots which are involving in every field of life especially in Japan, America and some European countries. Now in Asian countries robots are penetrating rapidly in the fields like Electronic Industries, Defense Systems, Medical Industries, Mechanical Industries, Communication, Transportation and Education Systems etc which creates a deep impact on the people. In short robots are rapidly evolving from factory work horses to robot companions. In past most of research have been done that how the robot can be used in our daily life more effectively and more research is still going on. In[1] proposed a car transportation system iCARII (intelligent Cooperative Autonomous Robot Transporters - type II) by designed a control algorithm for a robot to transport a car to a desired position even if the motion errors occur. In[2] design a substrate handling system in which robot transport the substrate within the chamber. In[3,4] design a mobile robot or human symbiotic robot which helps the humans to browse books of a library from a remote location, provides an attendant care with high power, kitchen support with handiness to the aged person. In[6] presented an invention of refuse collection vehicle in which receptacle lifter assembly connected with the front end of the vehicle for lifting and dumping the contents of the receptacle into an intermediate refuse collection container. In[7] implemented a complete vision guided adaptive robotic welding system which is used to track and weld a wide variety of test and production parts of different range in size. In[8] designed a sliding mode controlled dual arm robotic system for the purpose of safe load handling, transportation and trajectory realization. This can also be employed in hazardous situations. In pro-

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posed a control method which is applied to the task in which human and robot lift an object cooperatively. For this purpose investigate the human arm by analyzing its exerted force and displacement. On the basis of analyzation develop a force controller to the arm of the robot. In[5,10] designed a mobile robot for detect moving objects by using a single camera mounted on the mobile robot in an outdoor environment, tracking multiple moving objects by developing a sample based variant of joint probabilistic data association filters to track features originating from individual objects. On the basis of above discussion we conclude that robots are using for many purposes with different shapes and algorithms. In this paper propose a design of autonomous object lifting forklift robot which can be use for different application but here it is especially use in warehouses to shift the boxes from one place to another. Navigation is required to move the forklift robot from one place to another. There are many ways to navigate the robot but here we design a SLAM base forklift robot because SLAM techniques are at the core of many successful robot systems. SLAM is a way to navigate the robot in which robot is able to take decision related to its movement in an unknown environment by build a map of that environment in real time and simultaneously work out its own location within the map. Therefore forklift robot is able to navigate in indoor environments on its own using the principle of grid SLAM. In addition to this, there are lots of issues related to the implementation of the SLAM and in past researches provided the solutions of those issues and there are lots of research is still going on related to the methods of implementing the approach of SLAM in different ways and with different techniques. In[11,15] consider simultaneous localization and mapping is a problem and described the probabilistic form of the SLAM problems. It also defined the essential methods to solving them by estimate robot location and map of the environment. In addition to this also summarized the key implementations and demonstrations of those methods and also examined the observability of the different versions of the SLAM problems. The use of SLAM with detection and tracking of moving objects is a problem therefore in[12,17] presented a method to integrate SLAM and Detection and Tracking Moving Objects (DATMO) to solve both problems simultaneously for both indoor and outdoor applications by deriving the Bayesian formula and provided a practical algorithm for performing DATMO from a moving platform equipped with range sensors. In[13] analyze the mapping and localization with the RFID technology to improve the localization of mobile robots and persons in their environment. The probabilistic measurement model for RFID readers allow to accurately localizing the RFID tags in the environment and these maps used to localize a robots and persons in their environment. In[14] developed an autonomous robot called Dynamaid for domestic service tasks and has three main functions are: robust navigation by four individually steerable different wheel pairs, mobile manipulation with two anthropomorphic arms that include a gripper and trunk for lifting and last function is intuitive communication with the users by using stereo cameras and movable head. In[16] discussed the advances in computational methods and the recursive Bayesian formulation of the SLAM problem in which estimate relative or absolute locations of landmarks, computational complexity, data association and environment representation. In[18] invention is related to methods and apparatus that use a visual sensor and dead reckoning sensors to process SLAM for robot navigation and this technique automatically generate and up-date a map. In[19] presented a novel algorithm which is visual SLAM based on vision and also provided low cost navigation in populated environments and no initial map is required. Grid slam based robots have been previously developed like robots utilizing probability grids in moving environment utilizing efficient ways of navigation[20]. In addition to this utilizes static environments but with some enhancements in sensors like laser distance acquisition and vision based navigation. In this paper the SLAM base forklift robot detects the particular object for lifting. In past researches different techniques were proposed for object detection and more new techniques are still developing in upcoming researches. The technique used for object detection depends on the system requirement. In[21] implemented an automatic number plate recognition system for vehicle by implementing OCR after extracted the number plate region by using the image segmentation and then compare it with the database. In[22] object detection is used to design an intelligent traffic control system in which traffic signal is controlled intelligently by determining the traffic density on the road. In[23] presented algorithm for detecting the text which is appeared in digital video by implementing a scale-space feature extractor that feeds an artificial neural processor to detect text blocks. In[24] described the machine learning approach for visual object detection in which detector computed the features and then by suing the learning algorithm which is AdaBoost used to select a small number of critical visual features from a larger set and then process it. In this paper using Optical Character Recognition (OCR) for object detection by using Knearest Principle on python software.

The paper is organized as follows: section 2 provides the introduction of the system model. Section 2.1, 2.2, 2.3 and 2.4 explain the subparts of the system model. Finally section 3 explains the analysis of the system model and section 4 concludes the paper.

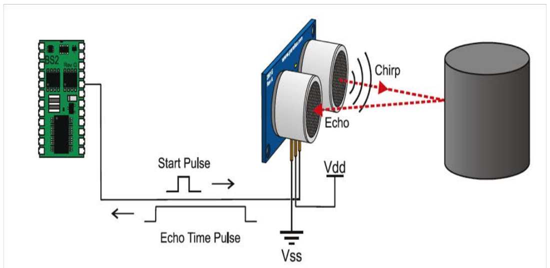

Figure 1. Block Diagram of the Proposed Model

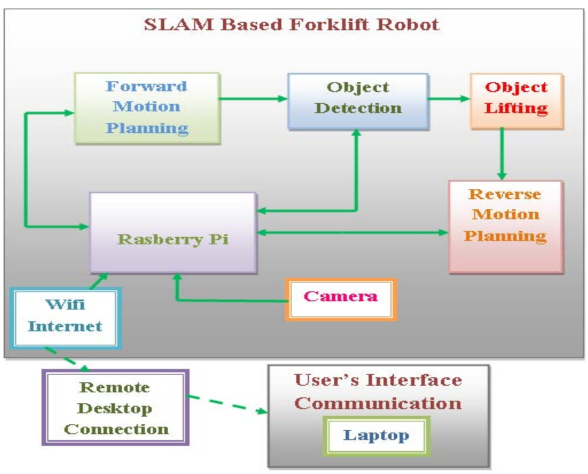

Figure 2. Working Principle of Ultrasonic. Sensor[25].

2. System Model

The System model, autonomous SLAM based forklift robot is divided into four main parts. The first part is the forward motion planning and map generation to move the forklift to the destination. The second part involves desired object detection by using machine learning approach. K-nearest principle use for optical character recognition to read and match the alphanumeric code written on the object with the user defined code in python software. The third part is the reverse motion planning to return the forklift to its initial position after lifting the object. Finally the forth part is creating the communication between user interface and the controlling device on the forklift to see the map and other information on the user interface. The overall block diagram of the proposed system is illustrated in Figure1. Despite having various options for motion planning, map creation and image processing, all these tasks have been performed on python. Our software utilizes a series of surrounding data which are acquired by using local distance sensors. Furthermore, various image processing codes are used to detect and read the desired object. The map generated (the path of motion) on a py-game window is also wirelessly communicated to our main computer.

2.1 Forward Motion Planning and Map Generation

Motion (path) planning (the path which is followed by robot) in an unknown and dynamic environment is very critical for any robot. Navigation is required to move the robot in such an environment like warehouses to detect and lift the object from one place to another. But it is not easy particularly when an external location reference such as Global Positioning System (GPS) is not available or where it is not possible to create and provide a map to the robot before starting the navigation due to unknown and dynamic environment. In this system uses Simultaneous Localization and Mapping (SLAM) approach to solve this problem. By using SLAM the forklift robot is able to navigate and also build the map of the unknown environment in real time and simultaneously work out its own location within the map. The first step is to plan or execute the forward motion of the robot and also record it in the form of map which is generated in the form of arrays for the reverse motion of the forklift robot. Most of the approaches being implemented for SLAM based robots to plan the forward motion like: One approach that can be applied is feedback mechanism in the form of PID (Proportional, Integrator and Differentiator) to neutralize any deviation in the motion of actuator (permanent magnet DC motor or window motors), another approach that could be applied is encoder systems to record motor movements to attain motion information. In this paper we have used an approach in which record all forward motion in the form of array based coordinates as shown by the Cyan and Pink based blocks in Figure 4. This eliminating the use of encoder and due to the motors is synchronized using the PWM (pulse width modulation) technique which reduces the need for a PID controller to neutralize any deviation in the motion of actuator.

For navigation in forward direction, plan the forward motion of the forklift to reach the object (box) by using the ultrasonic sensors. In forward motion planning initially the robot is placed in any random position statically or motionless. In order to move the forklift robot from its static position to reach the destination to detect and lift the desired object, first step is to calculate the front distance, left distance and right distance from the static position of the forklift robot to move either straight in forward direction or in left direction or in right direction respectively. To calculate the front, left and right distances use three ultrasonic sensors which acquire the environmental data in the form of distances. These three ultrasonic sensors mounted on a raspberry pi in a way that one sensor at 0^0 right, second at 90^0 front and third at 180^0 left to get accurate distances. Under static condition distance is acquired in a way that these ultrasonic sensors is activated when it receive trigger signal of 3.3v at its trigger pin from the raspberry pi. This generates an ultrasonic sound signal of 40 kHz which is beyond human audibility and strikes the solid surfaces which exist in their surroundings[25]. Thus, creating an echo sound from front, left and right directions which are received at the echo pins of the sensors. This generates different time intervals between sending and receiving sound signals for these directions which are calculated by the raspberry pi. Since the speed of sound is known and the time intervals are known so the front, left and right distances between the sensors and the solid surfaces are calculated by the raspberry pi sequentially. The mechanism of ultrasonic sensor is illustrated in fig2. After determining the front, left and right distances, the controller check whether the front distance is greater than 0.5 meter or not from the obstacle or solid body because this is the minimum distance required for moving straight in forward (positive y-axis) direction. If the front distance is less than 0.5 meter then the forklift robot will detect the box. In either case of after box detection or not take the decision either moves towards left (negative x-axis) direction or right (positive x-axis) direction. But if the front distance is greater than 0.5 meter then the forklift start to move straight in forward (positive y-axis) direction. After each step to move forward, there is a 500ms pause and it calculate the front, left and right distances and check the front distance again in the same manner. As the forklift robot move the front distance is reduces.

Once the front distance mitigates to lower than 0.5 meter our controller quantitatively analyzes the current left and right distances values which already calculated along with the front distance. If the right distance is greater than the left distance it will turn right and will turn left if the left distance is greater than the right distance. In forward motion planning the second step is to record the path which is followed by the forklift robot (the movement of the forklift robot) according to the forward motion plan in order to reach the destination to detect and lift the desired object. This is done by generating the real time map on the py-game window as the forklift robot move. For example, if robot takes first right or second right or first left or second left or move straight, the map is generating according to the movement of that robot. Fig4 shows a real time map generated during the forward motion planning which shows the path from its initial point to the final destination point in forward direction. To portray this motion in the form of a real time map the algorithm is developed on raspberry pi by using python which is illustrated in the fig3. According to the algorithm the map is generated in a two dimensional Euclidean domain to clearly shows the left direction and right direction movements of the robot because here the forklift robot may take more than one right or left. For example on the map the positive x-axis represents the right direction and the negative x-axis represent the left direction. If the robot take first right which on a positive x-axis then it take again second right which is also on the positive x-axis so it means there is no difference shows between the first right and the second right on the real time visual map. It seems like the horizontal line which shows the route is not change. Similarly happens if the robot take first left and then second left. The developed algorithm shown in fig3 also resolves these issues. In fig3 considered a one of the scenario of the forklift robot movement to explain the algorithm. In algorithm two variables *"a & b"* are uses and values of these variables depict the direction of the robot on the map and map is produce. The increment in the value of variable *"a"* by one and *"b"* is remain same if the robot move left and if the robot move right the increment in the value of variable *"b"* by one and *"a"* is remain same. For example initially $a=1$&$b=1$, and a forklift robot start to move straight forward in positive y-axis direction on the real time map, after straight movement if it takes first right the route is changed from positive y-axis to positive x-axis on the map on the py- game window and $a=1$&$b=2$. After first right if it take second right the route is changed from positive x-axis to negative y-axis on the map and $a=1$&$b=3$ (but after first right if it takes first left the route is changed from positive x-axis to positive

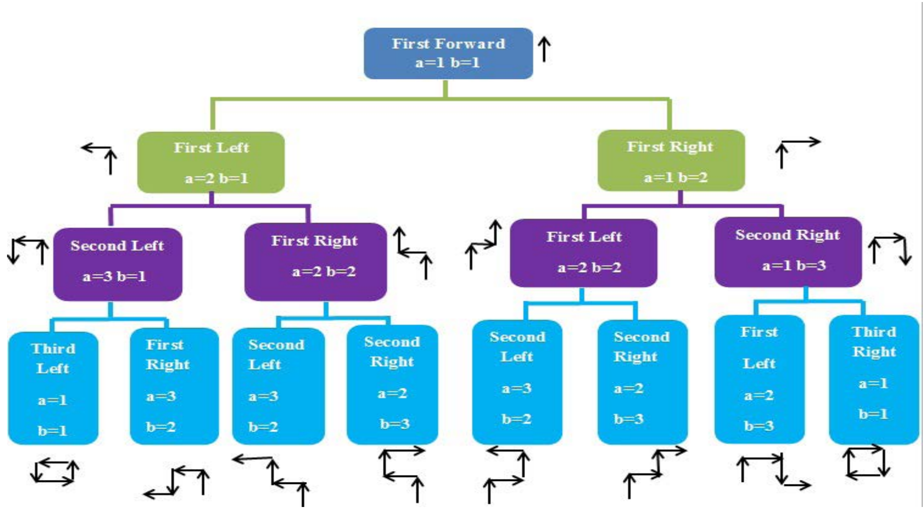

Figure 3. Algorithm for Real Time Map Generation.

y-axis and *a=2&b=2* and then for second left the route is changed from positive y-axis to negative x-axis and *a=3&b=2*). After second right if it takes third right the route is changed from negative y-axis to negative x-axis and *a=1&b=1***,** this is the same values of variables as is shown initially because it came back to the origin which means square is completed. But after second right if it takes first left the route is changed from negative y-axis to positive x-axis and *a=2&b=3*. Similarly after straight movement if it takes first left the route is changed from positive y-axis to negative x-axis and *a=2&b=1*. After first left if it take second left the route is changed from negative x-axis to negative y-axis on the map and *a=3&b=1* (but after first left if it takes first right the route is changed from negative x-axis to positive y-axis and *a=2&b=2* and then for second right the route is changed from positive y-axis to positive x-axis and *a=2&b=3*). After second left if it takes third left the route is changed from negative y-axis to positive x-axis and *a=1&b=1* which means square is completed. But after second left if it takes first right the route is changed from negative y-axis to negative x-axis and *a=3&b=2*. The fig4 shows that the visual route on the real time map is changes every time when the forklift robot changes its route or turn in any direction.

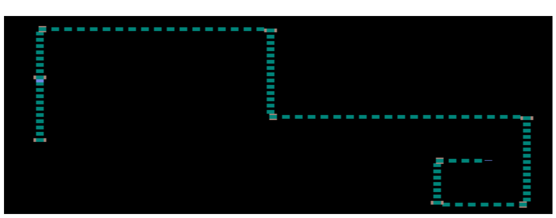

Figure 4. Real Time Map Generation on the py-game Window.

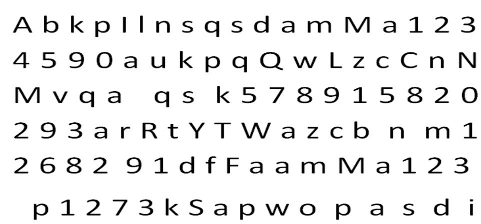

Figure 5. Database of 310 Samples.

2.2 Object Detection by using Optical Character Recognition

The second step is to detect that object which is lift by forklift robot. Here consider a box as an object. There are many boxes in a warehouse and each box has an alphanumeric code written on it. The alphanumeric code of the box which wants to lift is always defined by the user and compares it with the code written on that box in string form. Machine learning principle is use to read that code. There are various approaches can be use for a robust detection of the object like image comparison, color detection etc but for robust detection of the box by extracting or reading the alphanumeric code which is written on the front of the box, Optical Character Recognition (OCR) is used. In this paper OCR algorithm is implemented by using K-nearest Principle. This method is implemented on python software in which first train our system with the predefined database of different patterns of alphabets and numeric digits. Before implementing the K-nearest principle in OCR first we have to train our controller raspberry pi with the database of 310 samples of the capital and small alphabets (A-Z & a-z) and the numeric digits (0-9) which is predefined in the K-nearest principle to accurately read the alphanumeric code written on the box for the detection as shown in Figure 5. In this figure shows few samples of database. In complete database there are 10 (0-9) numeric digits, 26 capital letters and 26 small letters of alphabets and each has 5 samples with different styles, pattern and font. Therefore the total samples of the numeric digits 50, capital letters and small letters of alphabets are 130 each in this database. In order to detect the box first perform the learning process to train the rasberry pi by loading the file of database of 310 samples on the python file. As a result of training process, the set of 310 images of 310 samples are formed. In detection process after defined the alphanemeric code of the box which needs to be lift the second step is to capture the image of that box. Once the forklift robot's front distance is less than 0.5m from the obstacle or any solid object then it stop to move and capture an image by using a camera mounted on the robot to detect the box as shown in fig 6. If box is detected then forklift robot lift that box otherwise it will take the decision either move towards left (negative x-axis) direction or right (positive x-axis) direction as defined in forward motion planning. Figure 6 shows the image of that portion of the box where code is written. On this image perform histogram equalization which allows the overall adjustments of contrast in a gray scale image and eliminate or equalize the illumination effects of an image as shown in Figure 7. The Eq (i)&(ii) probability density & cumulative density functions respectively and Eq (iii) final output image shows this phenomenon[26].

$p_x(i) = n_i/MN$------------------------------------Eq (i)

$P_x(i) = \Sigma p_x(j)$------------------------------------Eq (ii)

$y(n) = (L-1)P_x(x(n))$----------------------------Eq (iii)

Figure 6. Original Image of the Box's Front Side.

Figure 7. Histogram Equalization Image of Figure 6.

After histogram equalization, it is necessary to sharpening the histogram image to properly read the code because histogram equalization produces blurring effect on the image especially blurred the code which is readable for the human but not for K-nearest principle. Figure[8] shows the phenomenon of sharpening the image[27] in which the histogram image pass through the high pass filter which only passes the portion of image which is change from low intensity to high intensity (white to black) which extract the area of the image where alphanumeric code is written. This image is multiply with the default value or system value of the intensity (λ) which defined the intensity level which used to sharp the alphanumeric code. This image is a mask of dark high intensity value of the histogram image which superimposes or adds this image with the original histogram image. As a result blurring effect is eliminated and it make much sharper image especially the area where code is written visible properly as shown in Figure 9. The sharpening of the image may result produces two noises called Gaussian Noise and Salt and Pepper Noise. In the presence of these noises the code is still not readable by the K-nearest principle. Therefore Gaussian noise smoothing is applied by using a low pass filter known as the Gaussian Blur filter to eliminate the Gaussian noise as shown in Figure 10 and Eq(iv[28] shows the phenomenon. But it also blurs the alphanumeric code and salt and pepper noise as well. We have applied a Gaussian Blur filter by using a 15x15 matrix kernel.

$$g(x,y) = \frac{1}{2\pi\sigma^2} \cdot e^{-\frac{x^2+y^2}{2\sigma^2}}$$ ---------------Eq (iv)

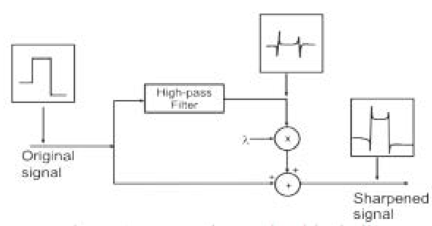

Figure 8. Image Sharpening Block Diagram[27]

Figure 9. Sharpening Image of Figure 7.

After Gaussian noise filtering, the image is converted into binary form and adaptive threshold is applied to make the code more visible. The adaptive threshold set the default threshold value for the pixels in a way that the value of the pixel below this threshold value consider as a black pixel and above this threshold value consider as a white pixel as shown in Figure 11. After this the characters of the alphanumeric code are readable but in this image salt and pepper noise is still exist and more visible as well due to the implementation of adaptive threshold. This noise is eliminating by using median filter which is shown in fig 12. Now the image in a form that the characters of the alphanumeric code can be read or detect easily by using the K-nearest Principle in OCR. Therefore the OCR is applied by using K-nearest Principle in which each character of

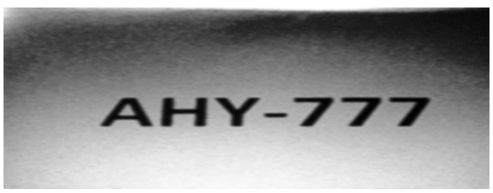

Figure 10. Eliminating Gaussian Noise.

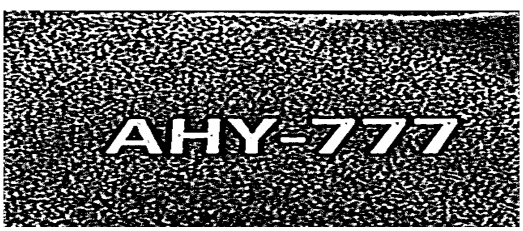

Figure 11. Adaptive Threshold Image without Median Filter.

the alphanumeric code of the image of Figure 12 is compared with the database of 310 samples. The system is pre trained with the database which has been done earlier so it can easily compare with the database and read the code more accurately and robust. K-nearest principle is implemented by converting the original image into new database file and then compares this new database with defined database horizontally. After read the code, that code shows on the screen which is shown in fig 13. After that this alphanumeric code is compare with the code which is defined by the user in string form. If it is match, it means this is the desired box which needs to be lift by the forklift robot which shows the box is detected. After correct detection of the box the forklift robot lift this detected box by using hydraulics and move back to its original position where the forklift robot started by using reverse motion planning.

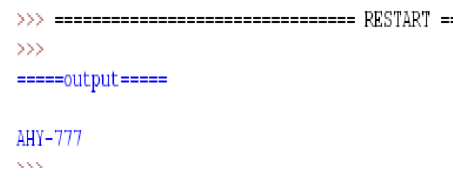

Figure 12. Adaptive Threshold Image with Median Filter.

Figure 13. Shows Resulting Desired Output.

2.3 Reverse Motion Planning

After lifting the detected box (object) by the forklift robot the third step is the forklift robot returns back to its starting position with the box where it started to move. This is done by using the reverse motion planning in which the robot follows the map which was generated during the forward motion planning. It means the way the forklift robot moved forward to reach to the destination to get the box, follow the same path by using that map but in reverse direction to get back to its starting position. Figure 4 shows the map which is constructed by the dots in a way that the displacement between the dots is 10 steps because the each step of the forklift robot is equal to 10 displacements. Each dot has a two dimensional co-ordinates to define the position of the dot on the map, so in the map to represent each dot generating a two dimensional array. The array defined the co-ordinates of starting point, all turning points and the destination (ending) point where the object is detected but there is no need to define the co-ordinates of intermediate points between starting point to turning point or one turning point to another turning point or turning point to the ending point. All points or dots in the map denoted in the form of pink and cyan dots on the py-game window shown in fig 4. The length of this array is varying depending on the number of turns. In order to forklift robot return back to its starting position, first calculate the distance or steps or displacement from its current position or point to the first turning position or point in reverse direction and second the direction where it moves either horizontally or vertically. Because there is a two dimensional array so possibly have only two directions to move either x-axis direction (horizontal) or y-axis direction (vertical). To calculate the displacements, firstly get the length of the array of the co-ordinates of the current point and the first destination point which means the first turning point from its current point which shows in the map. After get the coordinates of both points, subtract the current point coordinates with the first turning point coordinates as a result we get the magnitude of the difference vector. As we know that the displacement between the dots is 10 steps so divide this magnitude by 10 and as a result we get the number of steps required to reach the first turning point from its current point. The magnitude of the difference vector is always in either x co-ordinate or y co-ordinate. To find the direction observe the magnitude of the difference vector. If the magnitude of the difference vector is in **x** co-ordinate it means the robot move in reverse x-axis direction and if the magnitude is in **y** co-ordinate it means the robot move in reverse y-axis direction. For example the current point co-ordinates are (30, 100) and the first turning point co-ordinates are (30, 50) in reverse direction.

Then after subtraction the magnitude of difference vector is (0, 50). After divided by 10 the result is (0, 5) which means displacement is 5 and in **y** co-ordinate. Therefore 5 steps required by robot in the y-axis direction (vertically) to cover the distance from current point to the first turning point in reverse direction. Once the turning point is reached, from here before the calculation of magnitude difference vector need to decide whether it move left or right. To do this follow the same logic defined in the forward motion planning that is the left and right sensors measure the distance and if the right distance is greater than the left distance it will turn right and will turn left if the left distance is greater than the right distance. After that the same principle is implemented as done previously to move further in reverse direction that it again calculate the steps and find the direction to reach the second turning point from current turning point. This process is keep going until get the starting point. When the result of the subtraction between the co-ordinates of two points is below zero, the program is halted. Note that in reverse direction the current point is the point where the object is detected and lifted which means in reverse motion planning the destination point of forward motion planning become the starting point of the forklift robot. This approach enables the forklift to return to its original position no matter how complex the path of motion is.

2.4 User's Interface Communication

In this system, we can also see the real time map generation during the forward motion planning on user's interface like laptop computers. In order to view the map on the user's interface the communication link between the raspberry pi and the user's interface must be establish. This is done by creating an ad-hoc network between raspberry pi and the user's interface by using internet in which the IP address is assigned to the raspberry pi which is then accessed from laptop computers by using remote desktop connection.

3. Analysis of the System Model

This SLAM base forklift robot design is based on sensors which is different from the other existing encoder base designs in terms of cost, navigation and energy efficiencies. The presented model is designed for the smaller coverage area of the warehouses with dynamic environment. Due to this it can efficiently navigate by using the presented approach in both forward and reverse direction with navigation efficiency of 90% and cost effective. For the larger coverage area this model can also efficiently work with future enhancement will discuss in future work. The encoder base design are more navigate efficiently especially for larger coverage area but not cost effective for smaller coverage area. This presented system model is operated by using chargeable DC batteries and it is energy efficient for smaller coverage area with backup of 3hrs to 4hrs. But for larger coverage area need to be enhancement in future. The efficiency of object detection is 95% in high brightness areas and 80% in low brightness areas. This can be further improve in future.

4. Conclusion and Future Work

In this paper the autonomous SLAM based forklift robot is developed which work especially in warehouses to move the boxes or other objects. The main advantage of this forklift robot is that it is not dependent on any navigation system to move in unknown and dynamic environment because the robot is SLAM based so it can take the decision related to the navigation on its own by implementing the ultrasonic sensors and real time map generation. The other advantage of this SLAM based forklift robot is it can be used in hazardous situations and those difficult places where it is not possible by the human to work. The specialty of this work is the object detection which is implemented by machine learning approach that is OCR by using K-nearest principle in which the system is trained with 310 samples of alpha numeric digits so it can detect the objects by using code written on the box with different patterns or fonts. The proposed system does not require installation of any additional devices.

This work can be enhanced in future by implementing the different and better approaches of the SLAM like SLAM with RFID technology, computational method by Bayesian formula, by using encoder etc.. In future we can also improve and more robust the object detection which is implemented in this paper by increasing the database of 310 samples to thousands of samples and by also including the object detection on the basis of handwritten alphanumeric code. We can also enhance the object detection by implementing better methods of OCR like image segmentation, PCA (principle component analysis), correlation etc. On the basis of this work in future for larger coverage area we can design the autonomous SLAM base robot for warehouses with more long range sensors, with high speed, with more energy resources and with more robust object detection.

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