IoT enabled Robots with QR Code based localization

Sandeep Babu
M.Tech(VLSI & ES) Scholar
Department of ECE
Model Engineering College,
APJ Abdul Kalam Technological University
Thiruvananthapuram, Kerala,India.
sandeepbabu.mec@gmail.com

Suja Markose
Assistant Professor
Department of Biomedical Engineering
Model Engineering College,
APJ Abdul Kalam Technological University
Thrikkakara,Kochi, Kerala,India
sujamarkose@mec.ac.in

***Abstract*— Robots are sophisticated form of IoT devices as they are smart devices that scrutinize sensor data from multiple sources and observe events to decide the best procedural actions to supervise and manoeuvre objects in the physical world. In this paper, localization of the robot is addressed by QR code Detection and path optimization is accomplished by Dijkstras algorithm. The robot can navigate automatically in its environment with sensors and shortest path is computed whenever heading measurements are updated with QR code landmark recognition. The proposed approach highly reduces computational burden and deployment complexity as it reflects the use of artificial intelligence to self-correct its course when required. An Encrypted communication channel is established over wireless local area network using SSHv2 protocol to transfer or receive sensor data(or commands) making it an IoT enabled Robot.**

Keywords*— *Path optimization, QR code, Indoor Localization, Internet of Things, Floor Mapping, Artificial Intelligence, Indoor Navigation

I. INTRODUCTION

A robot is a programmable machine designed to carry out tasks in the most efficient and economical way. They can be guided with inputs from different sensors to increase their reliability to perform a task with good competence. Robots that has to navigate precisely has to resolve its localization in the field. i.e its ability to calculate its position headers in the assigned reference frame at any given instant.

Quick Response Code, commonly known as QR code, is a two-dimensional barcode that is gaining popularity due to its high data storage capacity and fast readability by standard barcode readers. QR codes can be detected easily and with high accuracy by standard softwares available in the market and thus its use as visual landmarks is increasing every year in the automation industry.[4]-[6]

Navigational efficiency of a robot is enhanced by adopting shortest path from source to destination during its operation. In this paper, the shortest path to destination is pre-planned using Dijkstra's Algorithm which analyses all connected nodes from source serially to find the least distance between the nodes.[8] The algorithm stops when destination node is accounted for and shortest path is plotted across relevant nodes. The data from dead reckoning is a good solution to achieve high accuracy and trustworthy localization by using QR code visual landmarks as a means to self update its position headers. The correctness of resolving localization however depends upon the quality and reliability of the sensors used.[1].

The Internet of Things [IoT] is all about connecting devices, sensors, etc to an existing network infrastructure as a means to transfer and manipulate data from them remotely and sometimes even to control their functionality. Internet of Robotic Things [IoRT] is a relatively new concept of treating an intelligent device. i.e a Robot as an IoT device and manipulate the data from sensors and other peripherals connected to it treating them as pseudo IoT devices.[3]

In proposed approach, Robot is a IoT device who is connected to a common local server exchanging data regarding its localization, destination and path mapping. The robot updates its localization header whenever it crosses 2D barcode printed on every node (in floor) and self-correct its course to destination based on obstacles it may interfere in its path. This approach heavily reduces the need for heavy computation to increase localization accuracy and gives more freedom to robot to find its own path to destination based on its dynamic territory as shortest path from any node to destination node is always available from server to robot. This is the fundamental soul of Artificial Intelligence i.e. any device that strive to achieve its goals in an efficient manner by taking sound decisions by analyzing data from its environment.

978-1-5386-5744-7/18-$31.00©2018IEEE

II. BACKGROUND

A. Robotic System

Robotic systems are autonomous machines programmed to manage and complete tasks efficiently. The inclusion of robotics systems in the industry has brought monumental alterations in various socio-economical facets of human civilization[3].

IEEE Society of Robotics and Automations Technical Committee on Networked Robots has elucidated that the col- lection of robotic devices that are inter-connected via any communication network as networked robotic system [9]. Tele-operated robots can be classified under Networked robotics i.e human operators control robots remotely via communication network by sending commands, a multi robot system where task is performed by smart interchange of sensor data between robots in self cooperative fashion.

B. Quick Response (QR) code

Denso Wave Company invented Quick Response code (QR code) in 1994 as means to track vehicles in assembly line during its manufacture and attain high speed component scanning. Alphanumeric characters can be encoded in QR code to store data. [2].In Fig.1 , a QR code structure is shown and how data is encoded in it. Results from Table I help us choose QR code technology to solve localization as compared to other options.

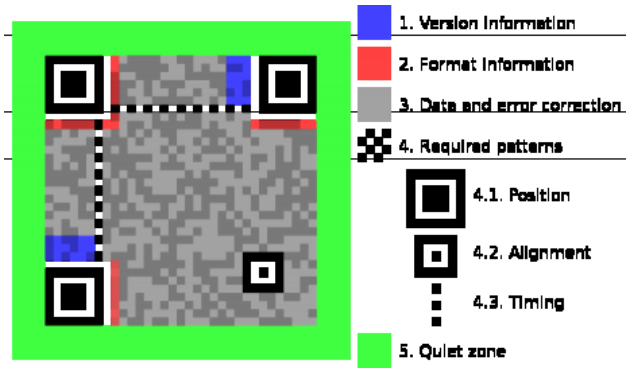

Fig.1. QR Code

TABLE I. COMPARISON OF DIFFERENT APPROACHES

Method	Infrastructure cost	Reliability	Maintenance Cost
QR Code	Low	High	Low
Bluetooth	High	Medium	Medium
GPS	High	Less	High
RFID	High	Medium	High

C. Dijkstra's Algorithm

Dijkstra's Algorithm is the most well planned successive algorithm on directional graphs with non negative weight to find shortest path between source and destination nodes. Shortest path problem that can be defined for both directed as well undirected graphs is resolved in graph theory by examining weights of integral edges between connected nodes and subsequently finding the shortest path.[8]

In Fig.2, Implementation of Dijkstra's algorithm to find the optimum path from 's' node to every other nodes is shown. The algorithm is normally used to find the shortest path between any given node to every other node in the network. In this paper, the algorithm is used to find the optimum path from source node to destination node by stopping the algorithm once calculations to obtain shortest path till destination node is completed.

D. Raspberry Pi Integration

In this experimental set up, Raspberry Pi (RPi) is adopted as the physical link between the Python script , sensors and actuators in the robot as well as with local server. Indeed, we wanted to exploit its main advantages of portability, low-cost, and variety of configurable interfaces, among which USB ports and a Wi-Fi module.

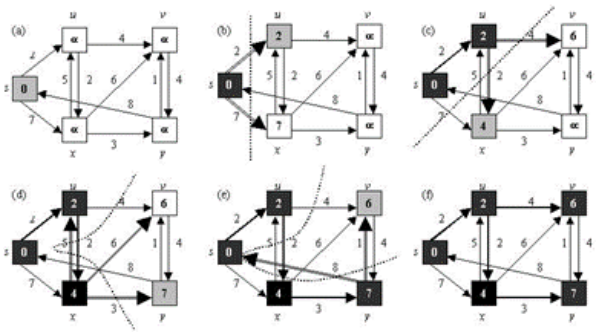

Fig.2.Dijkstra's algorithm

The merits of RPi such as its low cost, portability, Wi-Fi module, configurable interfaces such as USB ports is utilized appropriately.[7]

E. SSHv2 cryptographic network protocol

Secure Shell (SSH) is a cryptographic network protocol for operating network services securely over an unsecured network.[10]

SSH Features:

- A good configurable SSH server.
- To accomplish remote logins, secure file copying and remote command enactment across the communication channel.
- Provides easy access by SSH agent that cache keys.
- A lot of encryption algorithms and authentication procedures to choose from.

SSHv2 is an upgraded version with new attributes to provide a robust and more complete product. These attributes comprise encryption ciphers such as AES,3DES,etc as well as efficient MAC(Message Authentication Code) algorithms for integrity verification and provides support for public key

certificates. We use SSHv2 protocol for communication between robot and local server.

III. Design

Every Node in the environment is typically a floor tile with unique QR code printed. The data encoded will be its 'X' and 'Y' Co-ordinates stored as X-Y.

A. Extracting Coordinates from QR Code

Camera is positioned to captures images from the floor it travels. Frames are sampled continuously using the analog camera(pi-camera) to recognize QR code .As soon as a QR Code is detected in the frame, it is decoded and data retrieved is manipulated to extract the co- ordinates. The Flowchart of this process is shown in Fig.3

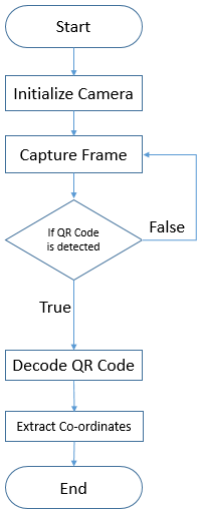

Fig.3.Flowchart for extracting Co-ordinates

B. Updating Co-ordinates to Local Server

After extracting co-ordinates from QR Code, the robot now needs to update its localization data in the server. The information is transferred using SSHv2 protocol. Robots and server are connected via wireless local area network (WLAN). Paramiko is a python implementation of SSHv2 protocol providing both client and server functionality. Fig. 4. is SSH Connection Protocol Message Exchange from Client(robot) to server.

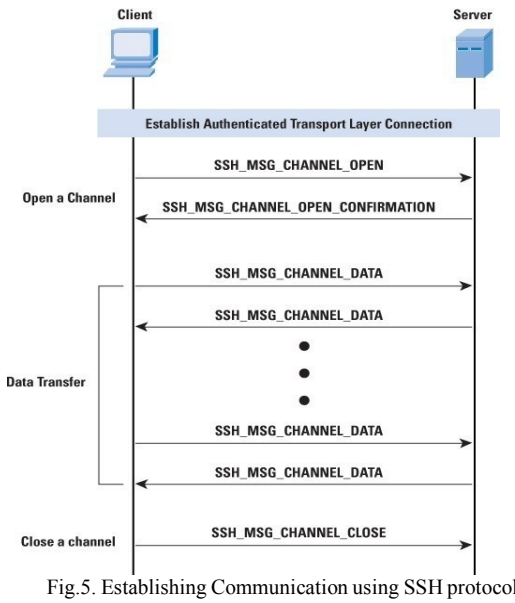

Fig.5. Establishing Communication using SSH protocol

Information necessary to access permission to write data to file in server is given through function call. Static IP is given to each device and it is the machine name required to start connection. User-name, Password, directory path, filename,& data to be sent are given as function parameters. An SSH connection is initiated and file is updated with new data.

C. Floor Mapping

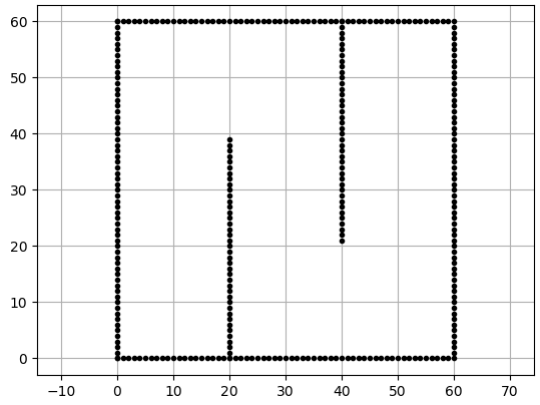

Fig.4. Mapping the Floor

The contours of the environment for mapping can be made by assigning the respective nodes(tiles)as blocked or assign it is an obstacle. This allows for plotting route to destination avoiding walls as well as obstacles in its path.

Robot can be tasked to physically explore the environment by trying to visit every qr coded tile and mark the tiles which robot was not able to visit due to obstacle in its path. This approach makes it easy to map any environment for the robot to work as long as QR code tiles are placed correctly.Fig.5 shows floor mapping by a robot which attempted to visit all nodes within the room.

D. Path Optimization

The server read the file updated by robot to know the robot's present location. Dijkstra Algorithm is utilized to calculate the optimum path to destination. This most appropriate path is written back to the robot by the server using the same SSHv2 Protocol. The server adopts round robin with interrupt method by continuously reading corresponding file written by each robot and solves their path optimization and then write back the optimum shortest path to each bot.

In Fig.6, Dijkstra's algorithm implementation is shown to find the optimum path to destination. The plotted path is highlighted in blue colour.

E. IoRT Factor

The various sensors connected in the robot such as proximity, temperature, pressure etc need not be IOT devices. The Robot will read the data from these sensors and update these data in a configuration file unique to that robot in the server. Any authentic user can access these config file stored in server and read the sensor values for required information over connected network. Similarly commands and settings of the robot as well as sensors can be edited in a similar config file. The Robot will continuously monitor this file to change its settings accordingly.

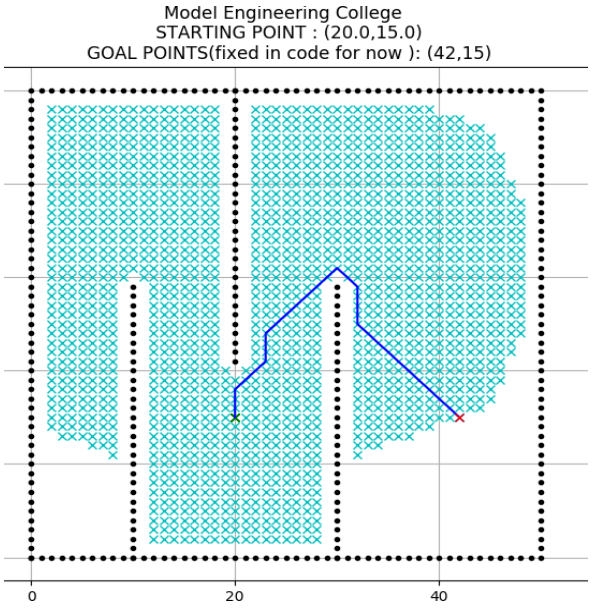

Fig.6. Shortest Path Mapping

Thus the robot effectively transforms all sensors in it to IoT sensors. Thus it can be considered as IoRT device.

F. Artificial Intelligence Factor

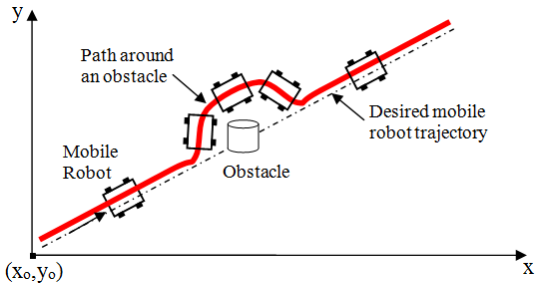

Fig.7. Path around an obstacle

The robot will have proximity sensors to protect itself from colliding with other robots as well as any human operator in its path. The robot will effectively change direction to avoid these dynamic obstacles or there is a chance it was pushed away from its path from external forces. Since it deviated from its assigned path, it will update its latest co-ordinates and shortest path to destination is reassigned and it moves in this newly assigned path.Fig.7 shows a robot dodge the obstacle and re-enter its assigned path

Thus the ability to interact with environment and take decisions to change its course to avoid collisions and finding new path to destination to fulfill its objective gives this robot an AI(Artificial Intelligence) element in its operation.

IV. Discussion & Results

The localization for the robot was solved with QR code technology and provided far more accuracy than GPS. Floor mapping was done by a robot initially. A secure encrypted communication channel was established between robot and server using SSH v2 protocol. The position headings decoded from QR code was sent to server and server returned shortest route to destination. The data from sensors on robot was made available to server effectively giving an IoT characteristic to sensors. The Robot avoided a random obstacle in its path and adopted best path to destination soon after.

In this approach, it was cost effective to implement as well as Complexity and time to implement is also less. Fixing QR code with unique co-ordinates in correct sequence initially required effort. The ability to correctly detect and decode QR code rely on the camera quality as well lighting assistance given to the camera. The camera quality limits the speed of the robot so as to get reasonable qr code detection.

A Trade off between performance throughput and computational load exist in this proposed method.

- Performance throughput may be slightly affected if dead reckoning data is not infused to improve localization accuracy.
- Computational load increases dramatically if dead reckoning data is invoked with accelerometer and gyro- meter sensors.

V. Conclusions

In this paper, path optimization using Dijkstra's Algorithm and localization using QR code for indoor robot navigation is described, & implemented in Raspberry Pi 3 Model

B. The artificial intelligence element and self dependency in resolving its path to allotted destination is visible in the proposed method. SSHv2 protocol is adopted for se- cure encrypted connection between Raspberry Pi(Client) and pc(server). This effectively makes it an IoRT device which can communicate and receive commands. Innovative research efforts are expected to enhance the use of the robots into much wider area for different needs in the near future.

VI. APPENDIX

Raspbian OS , a Debian based operating system, is used in the Raspberry Pi Board tasked with the control of the Robot. Ubuntu OS, a Linux distribution based on Debian architecture and an open source operating system for computers, isused in the server system.

ACKNOWLEDGMENT

The authors would like to thank Fund for Improvement of S&T Infrastructure of DST for providing some infrastructural support to carry out this project.

REFERENCES

[1] P. Nazemzadeh, D. Fontanelli, D. Macii and L. Palopoli, "Indoor Localization of Mobile Robots Through QR Code Detection and Dead Reckoning Data Fusion," in *IEEE/ASME Transactions on Mechatron- ics*, vol. 22, no. 6, pp. 2588-2599, Dec. 2017.

[2] L. Belussi and N. Hirata, "Fast QR Code Detection in Arbitrarily Acquired Images," *2011 24th SIBGRAPI Conference on Graphics, Patterns and Images*, Maceio, Alagoas, 2011, pp. 281-288.

[3] P. P. Ray, "Internet of Robotic Things: Concept, Technologies, and Challenges," in *IEEE Access*, vol. 4, pp. 9489-9500, 2016.

[4] C. Gionata, F. Francesco, F. Alessandro, I. Sabrina, and M. Andrea, An inertial and QR code landmarks-based navigation system for impaired wheelchair users, in *Ambient Assisted Living*, S. Longhi, P. Siciliano,

[5] M. Germani, and A. Monteri, Eds. Springer International Publishing, 2014, pp. 205214.

[6] A. Basiri, P. Amirian, and A. Winstanley, The use of quick response (QR) codes in landmark-based pedestrian navigation, *International Journal of Navigation and Observation*, vol. 2014, pp. 17, Apr. 2014.

[7] H. Zhang, C. Zhang, W. Yang, and C. Y. Chen, Localization and navigation using QR code for mobile robot in indoor environment, in *Proc. IEEE International Conference on Robotics and Biomimetics (ROBIO)*, Zhuhai, China,, Dec. 2015, pp. 25012506.

[8] B. Donato *et al.*, "Raspberry Pi driven flow-injection system for elec- trochemical continuous monitoring platforms," *2017 IEEE Biomedical Circuits and Systems Conference (BioCAS)*, Torino, Italy, 2017, pp. 1- 4.

[9] T. T. Alam, A. N. Chowdhury and M. Z. Rahman, "AN intelligent road traffic management system using NVIDIA GPU," *2016 19th International Conference on Computerand Information Technology (ICCIT)*, Dhaka, 2016, pp. 419-424.

[10] IEEE Society of Robotics and Automations Technical Committee on Networked Robots, available: http://www-users.cs.umn.edu/ isler/tc/

[11] Y. Tian, T. Matsuno and S. Ma, "Development of remote robot control system for snake-like robot based on SSH protocol and iOS system," *2016 IEEE International Conference on Robotics and Biomimetics (ROBIO)*, Qingdao, 2016, pp. 100-105.