

## **A novel method for vehicular network system using static QR code for bituminous roads**

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**Abstract**

The simultaneous localization and mapping approach is used to predict a robot's location as there is a concern in predicting a robot's movement in lane environment. Simultaneous Localization and Mapping (SLAM) and Detection of Moving and Non-Moving Objects in Wireless Sensor Network (WSN) are the two main tasks involved in perception for detection of objects. The robot may generate a map of its surroundings while being localised at the same time through SLAM using sensor data. An analysis on Extended Kalman Filter- (EKF) and Unscented Kalman Filter (UKF) SLAM and EKF SLAM with WSN data augmentation for path prediction & correction for autonomous vehicle is presented. Improvised Active Edge Table (AET) algorithm based on above analysis is proposed. In this paper, the detection of obstacles is done through edge points. The experimented environment for route planning is the bituminous lane system road. Robot route planning is based on Quick Response (QR) data collected from WSN system and obstacle mounted QR system. The authors analysed the behaviour and movement of robot by comparing the route path by applying UKF and EKF SLAM algorithms. We conclude that while implementing UKF algorithm the probability for object collision with robot is 31%, whereas if EKF- SLAM with WSN algorithm is applied the probability for object collision is 25%.

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**Subject Classification:** 68M25.

**Keywords:** Simultaneous localization and mapping, Extended Kalman filter, Unscented Kalman filter, Active edge table, QR.

**1. Introduction**

There is a concern in predicting a robot's route planning through QR code in road lane environment. The simultaneous localization and mapping (SLAM) approach is used to predict a robot's location and its next move. Front- and back-end operations are categorized under SLAM algorithm as the position of a robot can be determined using sensors like lasers and cameras [1]. WSN involve a sensor nodes that collect data from the environment, by augmenting the data can be beneficial as it helps in improving the accuracy. The robot's location, acceleration, and orientation are all measured by the front end's SLAM sensors, which are also used to locate and observe landmarks. The GPS, IR, acoustic sensors, IMU, LiDAR, and RADAR are the most utilised SLAM sensors [2]. However, there aren't many computational power in sensors, especially in environments like those with powerful computers. As a result, several practical sensor suite combinations have been suggested for perceiving the surroundings. For estimating the condition of obstacles, LIDARS, Radars, and stereo cameras, have all been used as standalone sensors in the past. The authors in [3] [4] provide a non-linear regression-based data aggregation and multiparty data fusion approach that preserves sensor data confidentially. This

enables the sensor data that is acquired from the sensor nodes to be represented as non-linear regression functions. The UKF and EKF are the filtering techniques that are used for projectiles of a robot [2]. On the similar lines of research, the authors in [4] discusses about edge detection algorithm for movement of robot for indoor positioning only. But, path planning based on Quick Response (QR) with WSN data augmentation using Edge Fill algorithm is underexplored. SLAM and Detection of Moving and Non-Moving Objects in WSN network (DMNOWSN) are the two main tasks involved in perception for detection of objects. The robot may generate a map of its surroundings while being localised at the same time through SLAM using sensor data. For the control system to take each obstacle's behaviour into account, DMNOWSN needs the robotic vehicle to identify each obstacle inside the boundaries of the road and maintain track of it.

This must be ensured even in the event of sensor failure, asynchronous time sampling preventing sensor measurements, unusual weather conditions, occlusions, or any other situation where missing data might result in blackouts. The estimating method must ensure that information gap does not influence the motions planners to make erroneous decisions. Also, the existing work focuses on an integrated approach that gives state estimates based on augmentation of SLAM-EKF with WSN based lane system for robot and obstacles surrounded by it. Afterwards, SLAM based EKF employed in WSN (Active Edge Table) based sensory environment. Here, Edge Fill Algorithm is reversely applied to set sparse point cloud for obstacles detection. A multi-sensor architecture that includes SONAR [5] positioned within the robot along with IR's mounted on the top of the robot. According to DMNOWSN, the tracking process receives integrated

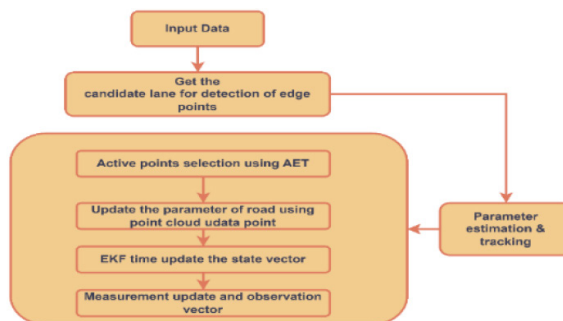


**Figure 1**

**Overview of proposed approach**

environmental information. Curvature coordinates allow the relative position and speed of each obstacle to be determined from the localization of the robotic vehicle along the track inside the local reference frame of the road using the information of the lane map. The autonomous vehicle prototype as illustrated in Figure 1 has been equipped with this integrated algorithm, which has been tested experimentally on the Bituminous Road.

#### Major contributions

- We deploy WSN in robotic movement for obstacle detection in Bituminous Lane system using embedded sensors and QR scanner.
- Development of Improvised AET algorithm which checks the information of objects through QR scanner.

## 2. Related Work

The extensive study of literature reveals that authors focus on SLAM algorithm which uses EKF, UKF for obstacle detection using the embedded sensors [6] [7] [8].

The idea of delivering estimates in curved coordinates by observing the fusion and behavioural reasoning of barriers within the road borders has been specifically investigated by authors in [9]. The transformation of coordinates from Cartesian to curvature can be advantageous in many areas of autonomous driving, including communication systems between various cars, as was suggested by authors [10]. GPS sensors with Real Time Kinematics correction techniques are becoming used in autonomous and intelligent cars when it comes to vehicle placement. The inertial navigation system may be built up affordably using these sensors' 6-DOF inertial units (IMU). A GPS receiver is integrated by the authors of [11] into the estimate procedure based on a kinematic vehicle model. They show how these sensors may increase estimate accuracy even for lateral velocity of the vehicle. This idea, when used to set parameters for autonomous driving, enables avoiding a difficult reverse engineering approach for tyre cornering stiffness and relaxation lengths, mass, and moment of inertia [12]. The installation of several GPS receivers on the same vehicle can also estimate the absolute heading angle. For a comparable estimating approach, authors in [5] examined the performances of the EKF and UKF algorithms. Results show that UKF ensures quick calculation times while delivering more accurate results. The submitted study, which uses the position of objects and their relative motion in relation to the

robot's movement are estimated using a nonlinear measurement model for path prediction and correction in cartesian coordinates in comparison to the state of the art. As a result, a UKF & EKF with WSN data augmentation has been used because it provides a compromise between precision, computational effort, and implementation simplicity.

### **3. WSN data augmentation in Path correction**

A crucial feature of WSN is localization, which is especially important in areas without precise GPS and inertial sensor equipment [13] [14] [15]. Here, WSN-based obstacle detection in a lane system is designed for autonomous mobile robot. Obstacle identification is the prerequisite of achieving path planning for robots. Wireless sensor nodes in this system are equipped with IR sensors and with wireless communication interfaces. The robot senses its surrounding obstacles that may affect its motion through the equipped environment sensing system consisting of various sensors. For sensing the environment, the robot is equipped with SONAR and IR sensors and can move in lane to communicate with WSN.

The lane system is furnished with IR sensors which are connected wirelessly through a system and transmits the information through Bluetooth/ Radio system network and perform data capturing for EKF SLAM. This system has potential uses in cases when robot is moving in a lane. The WSN control centre oversees overall coordination. Depending on the exploration approach employed, the control centre assigns each robot its role. A robot executes exploration of a known area after receiving information from the control centre.

### **4. Development of Improvised AET algorithm**

Each moving and non-moving objects is equipped with a QR code that can be used exchange vehicle identity and physical attribute information with WSN base station [4]. The principle of determining the position of obstacles in bituminous road is based on the value of proximity from robot and obstacles node. The verification procedure will be done at the initial level. Each object assigned a QR code at the time of the admission. The QR enabled WSN will process it and extract the essential information and distinct values. The information will send to the WSN database to perform analysis of the real time data for moving and non-moving objects. The inference of moving objects is more as compared to date of non-moving objects. The objects are equipped with single QR code after then

the improvised AET algorithm as shown in algorithm find the edges from the lane and move through the list of points on edge.

**Algorithm: Improved AET algorithm**

1. Represent  $l_{min}, l_{max}, m_{min}, m_{max}$  of  $(l, m)$  coordinates (for coloured pixels indicating object availability)
2. Initiate local environment (for movement of robot having QR scanner on it)  $E_{goal} = E_{initial}$
3. For all QR code scanned objects in map grid  $(G)$ , If moving object identified Then, collect the data at window level
  - a. For each scan line do: begin
4. Collect object parameters (like length, width, current speed) when enter in the lane window and transform it into the viewport:
  - a. Built object table at time of entering lane window where QR code is determining factor, Enabled lane window with QR code
  - b. Object coordinates  $L_{omax}, L_{omin}, M_{omax}, M_{omin}$  transforms to system coordinate viewport  $v_{max}, L_{vmin}, M_{vmax}, M_{vmin}$ .
5. QR-enabled robot collects moving objects data:  
Object motion detection (by comparing pixel values from previous camera frame to current one). Find altered areas in last frame and extract objects contours.
6. Estimate moving and fixed objects  
(Robot uses viewport and global active QR code table by accessing set of QR codes based on their speed)
7. Update a robot-observed item table by Lane system QR code exchange.  
Scan Bituminous Lane and set up the QR-code-based Active Edge Table (QRAET).
8. Traverse all intersection point sensors of edges with scan line
  - a. Here Line QRrec = record; Real QRl,QRdl;
  - b. Integer QRdm; end; Line recs=linerec list; Begin For all i: mmin to mmax do
    - i. If inside (window size,j,i)
    - ii. Get edges of the Bituminous Lane road and store in array [0..n]

- iii. Get QR code-based active edge list (QRAEL) and store it
  - iv. Integer QRm;
9. In QRWSN all the vital information gets updated using QRrobot.
- a. Set QRAEL:nil; For  $m = m_{\min}$  to  $m_{\max}$  do, Begin, Add all the edges in edges [m] to QRAEL;
  - b. If QRAEL != Nil, Then, Begin
  - c. Sort ael by increasing l
    - i. Fill pixels along m by scanning ael and filling alternate m segments;
    - ii. Delete from ael edges for which  $dm=0$ ; Update each l in ael by  $bm dl$
10. End

AET is used to analyse the path of robot in related a continuous space to discrete one. It uses information about active points that compose robot's navigation area where obstacles are found that prevent possible movement.

## 5. Experimental Environment

EKF SLAM with WSN is used to express all measurements that are made to enhance the data from SONAR and IR sensors [1] [5]. The multi-sensors augmented data fusion architecture provided in this study can be thought of as being centralised, for pre-processing of SONAR & IR data. Pre-processing of data from several sensors works as the input for a central module that performs object tracking and classification based on the entire collection of data. Surface mobile robots drive from one position to another on a Bituminous Road. Therefore, EKF-SLAM with WSN data augmentation will be implemented for path prediction and correction of an autonomous robot. The robot is equipped with front end sensors like SONAR IR and movement is done through D.C. motor. The sensors are mounted on the microcontroller board which works as a controller board of the robot. The Wifi module is deployed on a robot designed for experiments. Once the robot is positioned then it is moved in a lane through the Android and Bluetooth controller module on the road map, raw data from IR and SONAR sensors is analysed. Further it combined in EKF with augmented WSN to show the tracker potential impediments. State estimate is then carried out in coordinates with the lane. The algorithm has been proven by

a few test sessions run on the Bituminous Road lane. As we are focusing on coordinate space architecture, the research involved moving the robot on a wireless network of sensors and evaluating Euclidean distances when it went in a lane with moving and non moving obstacles. Calculating a Euclidean distance between a robot and moving obstacles in a lane and verifying that it won't collide with the lane edges are both necessary, to assess the viability of the employed EKF method. The objective of the path prediction is to produce the collision free path. The approach can be used for collision-avoidance path planning, in which metrics such as the dense data points in a Bituminous Road Lane for mapped surface can be minimized.

6. Data collection & Analysis of Experimental Results

In the process of data collection in this article, first, the QR code image of object is taken by the QR enabled scanner placed on robot. It gives various information like weight of object, dimensions of object, velocity or acceleration of moving object, distance of object with respect to robot. Sensors installed on the robot created as part of this research collect real-time data. The EKF with WSN approach is referenced as object detection and counter measure system. The global frame of reference is used to compute the state estimation of robot, followed by the local reference frame for the road. This is accomplished by utilising the mapped information, which links each centerline point to a description of the direction and lane of the road along the considered field of view (FoV).

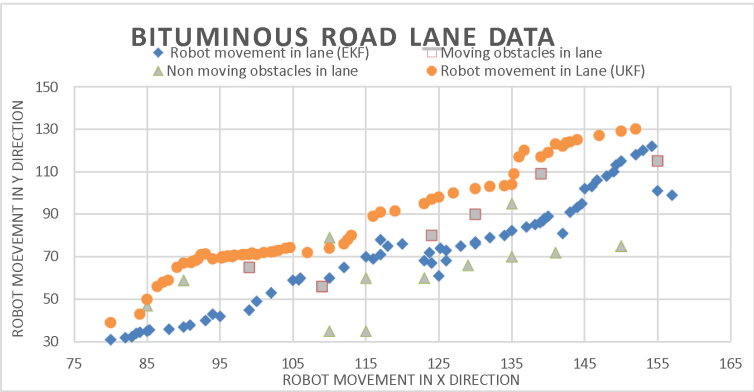


Figure 2  
Comparison among the robotic path using EKF and UKF algorithms.

Table 1 shows data of movement of a robot in bituminous road lane by applying EKF and UKF algorithm and calculates the Euclidean distances for the same. The authors analysed the behaviour and movement of robot, a comparison among the robotic path using EKF and UKF SLAM algorithms performed shown in Figure 2.

Identification of several QR code enabled objects with the help of QR enabled scanner on robot having the capability to read the information. It is evident from the results shown in Figure 2 that when robot move on bituminous road there are presence of moving and non moving objects.

**Table 1**  
**Movement of a robot in Bituminous Road Lane**

| Robot movement in lane (EKF- SLAM) |        | Robot movement in lane (UKF- SLAM) |        | distance between robot and object EKF- SLAM with WSN(cms) | distance between robot and moving object by applying UKF- SLAM (cms) |
|------------------------------------|--------|------------------------------------|--------|-----------------------------------------------------------|----------------------------------------------------------------------|
| X axis                             | Y axis | X axis                             | Y axis |                                                           |                                                                      |
| 80                                 | 31     | 80                                 | 39     | 0                                                         |                                                                      |
| 85                                 | 35     | 87.9                               | 59     | 1.118033989                                               | 1.220655562                                                          |
| 85.3                               | 35.7   | 89.1                               | 65     | 0.761577311                                               | 6.118823416                                                          |
| 88                                 | 36     | 90                                 | 67     | 2.716615541                                               | 2.19317122                                                           |
| 90                                 | 37     | 91                                 | 67.3   | 2.236067977                                               | 1.044030651                                                          |
| 95                                 | 42     | 92.4                               | 71     | 1.414213562                                               | 2.039607805                                                          |
| 100                                | 49     | 94                                 | 69     | 4.123105626                                               | 2.507987241                                                          |
| 105.8                              | 59.2   | 95.8                               | 70     | 0.824621125                                               | 0.5                                                                  |
| 110                                | 60     | 96.3                               | 70.4   | 4                                                         | 0.316227766                                                          |
| 115                                | 70     | 97                                 | 70.7   | 5.830951895                                               | 0.761577311                                                          |
| 125                                | 61     | 98.4                               | 71     | 18.78829423                                               | 0.412310563                                                          |
| 125.2                              | 74     | 107                                | 72     | 5.660388679                                               | 3.324154028                                                          |
| 130                                | 76     | 112.5                              | 78     | 2.236067977                                               | 2.061552813                                                          |
| 135                                | 82.3   | 117                                | 91     | 2.507987241                                               | 2.236067977                                                          |
| 137                                | 84     | 119                                | 91.5   | 2.62488095                                                | 2.061552813                                                          |
| 140                                | 89     | 130                                | 102    | 1.118033989                                               | 3.605551275                                                          |
| 145                                | 102    | 136                                | 117    | 7.011419257                                               | 8.030566605                                                          |
| 150                                | 115    | 142.5                              | 123.6  | 1.931320792                                               | 1.676305461                                                          |
| 155                                | 101    | 150                                | 129    | 21.01523257                                               | 3.605551275                                                          |

Total number of nearby objects (5) that can collide while moving the robot by using UKF algorithm are at locations: (85,47), (90,59), (99,65), (110,79) and (139,109) whereas when EKF SLAM with-

WSN data augmentation applied the number of nearby objects (4) that can be collide are at locations: (109,56), (123,60), (124,80) and (155,115). At robotic path (116,69) using EKF we have both moving and non-moving object. Hence, 31% objects get collide in case of UKF, for EKF-SLAM with WSN 25% objects get collide.

## 7. Conclusion

This paper focuses on movement of mobile robots to deploy WSN for object detection. The embedded sensors and QR scanner in robot allow monitoring of available objects and provide data to WSN. Therefore, the research work focuses on object detection and robot positioning technique. In simulation EKF-WSN exhibits more accuracy and robustness as compared to UKF as while applying EKF, previous state information can be obtained through active edges and next state information can be obtained through group of active process. While applying UKF, more number of sigma points are required so computation burden is more. In test area, while implementing UKF algorithm the probability for object collision with robot is 31%, but it gets reduced by 6% in case of EKF-WSN algorithm. Hence in terms of computing performance the proposed method is better than implementing the UKF. Further, EKF algorithm does not measure the speed of moving object for that machine learning technique can apply.

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