Development and emulation of automatic accident avoiding system in a real time scenario using SLAM technique.

Muhammad Ibrahim Khalil
Department of Mechatronics and Control Engineering
University of Engineering and Technology, G.T. Rd,
Lahore 54890, Pakistan.
iffi_uet@yahoo.com

Dr. Ummul Baneen
Department of Mechatronics and Control Engineering
University of Engineering and Technology, G.T. Rd,
Lahore 54890, Pakistan.
ubaneen@gmail.com

***Abstract*— Road safety is a major concern in most countries and the attention is turning towards active safety system. This research paper focuses on developing an automatic accident avoiding safety system which can help to prevent road side crash and accidents. Our proposed system has a capability to do work with the implementation of Simultaneous Localization and Map building (SLAM). This project makes use of that information to efficiently recognize the landmarks in the way which can help in minimizing the risk of collision and developing a solution of no risk factor. An Arduino based project is proposed in this paper that will work as obstacle avoiding system as well as it will do implementation of SLAM using ultrasonic sensors. Moreover, an algorithm, based on MATLAB, is developed that has the potential to achieve the desired performance.**

Keywords*— Simultaneous Localization and Map building (SLAM)

I. Introduction

In this world of nourished technology, the people of the world are still suffering from road fatalities. An astonishing numbers of accidents are recorded in developed countries and these numbers increase dramatically day by day in under developing countries. In last few years, the attention is turning towards active safety system that is not only developed to reduce the consequences of accidents but also to reduce the number of driver errors and thereby the number of accidents. In 2013, 1.4 million deaths are recorded in road injuries, up from 1.1 million deaths in 1990.[1] Also, according to Swedish and European authorities, approximately 13000 lives are lost in Europe yearly in traffic accidents involving Heavy Goods Vehicles. 40 percent of these fatalities are unprotected road users, 6 percent are truck drivers, and 54 percent are drivers and passengers of cars. [2] In Africa, the death rate is the highest (24.1 per 100,000 inhabitants); the lowest rate is to be found in Europe (10.3). [3]

Vehicle Technologies have a very important role in recent years. These technologies have a major concern with breaking systems and sensor detection. Especially, with truck-related accidents are made up a relatively large part of all road fatalities. Hence, there should be an automatic accident avoiding system for vehicle which operates the vehicle autonomously. For this reason, our developed system is able to not only decrease the accidents, but also lead the reduction of road fatalities.

On the other hand, map localization is the utmost need for any autonomous robot. Simultaneous Localization and Map Building (SLAM) has been most common research topic over fifteen years. Typically SLAM consists of the process of building a map of the environment. At the same time, this map helps to determine the location of the vehicle. So, we can say that, a vehicle start with an unknown environment and uncertain location and build a map while maintaining localization error.

It is a technique used by robot and autonomous vehicle to build up a map within an unknown environment (without a priori knowledge), or to update a map within a known environment (with a priori knowledge from a given map), while at the same time keeping track of their current location.

One of the most difficult problems of localization algorithms is not feature extraction, but feature validation and data association. The basic navigation loop is based on dead reckoning sensors that predict the vehicle high frequency maneuvers and low frequency absolute sensors that bound the positioning errors. For every land navigation application, we must have reasonable trajectory of the vehicle.

II. Related Work

A number of researchers had done a work on applying estimation-theoretic methods to mapping and localization problems. This research leads to invention of simultaneous localization and map building method. The structure of the SLAM problem, the convergence result and the coining of the acronym `SLAM' was first presented in a mobile robotics survey paper presented at the 1995 International Symposium on Robotics Research. [4] It is well known that with the different type of GPS implementations, we can obtain position fixes with errors of the order of 2cm to l00m. [5] Range and bearing lasers have become one of the most common sensors for localization and map building applications due to their accuracy and low cost.

In the last twenty years, a notable work has done in the construction of local terrain maps. A remarkable work at CMU and JPL on grids is the example of it. [6] These methods provide general terrain models for navigation and path planning. However, now a days, these methods demands the knowledge of platform location.

III. Autonomous Vehicle Algorithm Approach

The accident avoiding technologies have a major concern with braking systems and sensor detection. In this point of view, many automatic accidents avoiding system for the passenger safety had entered the market to mitigate the consequences of an accident and to reduce the number of fatalities among car occupants. There are different luxury cars which are using different system based on radar sensors, laser sensors, IR sensors, and utlrasonic sensors. The radar sensor can detect the vehicle ahead up to 200m in the same lane and it can also calculate the distance and speed between obstacle and vehicle. [7] In risky situations, the radar sensor also proposes different kind of actions that can be taken into account in order to avoid any possibility of accident. The drawback lies in the activity of such system like Adaptive Cruise Control system which switches off at low speed and it comes as a surprise when the vehicle approaches a traffic jam or a red traffic light.

To avoid or mitigate the near end collision of the commercial heavy vehicles, the automatic accident avoiding system's algorithm is developed based on the prior work which has done until now. If incase driver fails to apply an enough pressure on the brake, it provides an adequate pressure to the pedal of brake to avoid collision.

To evaluate the overall safety of the system, Jan Lundgren at al. suggests the Time Exposed TTC and Time Integrated TTC values. [8] The automatic accident avoiding control algorithm consists of two parts: obstacle detection part and main controller part.

In the obstacle detection part, front obstacle information was measured and collected for the main controller's decision. The main controller for this system is composed of the two control stage: upper and lower level controller. By using the collected obstacle information, the upper level controller of the main controller decides the control mode. Next, the lower level controller determines warning level and braking level to maintain the longitudinal safety. When the control algorithm calculates the desired deceleration, brake generates brake pressure to maintain the controller's decision.

By using these two level threshold values of each parameter, control mode can be defined as 4 Phase: Safe Region, Warning Region, Braking Region and Collision Mitigation Region. In case of the Braking Region and Collision Mitigation Region, it is important to decide whether a collision with an observed object is avoidable or not. When the driving state is in a Warning Region, the first level warning starts running. If the driving state is in the Braking Region or Collision Mitigation Region, the second level warning is operated. According to the warning level, the warning is composed of two kinds of alarm: alarm sound only and alarm sound with tightening a seat-belt. In case of the

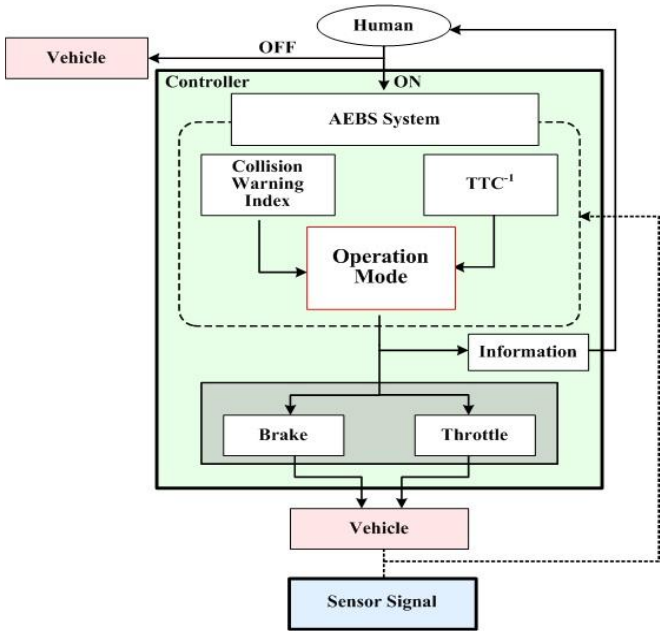


Fig.1 Control Algorithm for Automated Accident System [9]

Braking Region, lower level controller gives first level brake operation. When the lower-level controller decides the Collision Mitigation Region, the second level brake starts operating.

By using the collected obstacle information and the control mode of the algorithm, warning index and TTC-1 parameters are considered. From the definition of theses parameters, if the vehicles longitudinal safety comes to dangerous situation, TTC-1 will increase but warning index will decrease. Therefore, vehicles longitudinal safety level can be defined in the warning index and TTC-1 phase. To divide the control model, threshold value for each parameter is set two levels: Safety threshold and Warning threshold. The Safety threshold means the value at which driver start feeling fear for driving situation. When the parameter comes near to the Warning threshold value, it means that driver should be start braking to avoid the rear-end collision.

Hence, to ensure real road safety improvements, an automatic accident avoidance system for vehicle helps in reducing the road side accidents and hence the road fatalities. The goal of this research is the development of the automatic accident avoidance system's algorithm for the Commercial Vehicle and relevant assessment methods of system by the objective safety index in the dangerous driving situation which can be occurred rear-end collision.

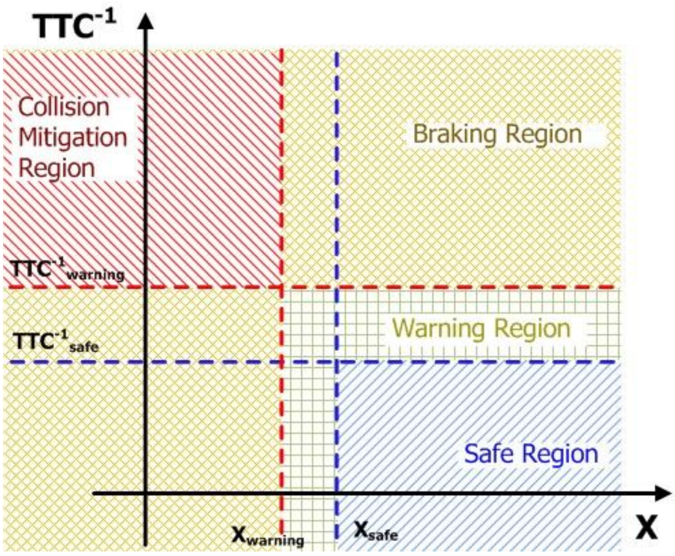


Fig.2 Main Control System for Automated Accident [10]

IV. Sensor

A few years ago, Schroter et al. presented his work with SLAM using sonar sensor and showed some problem with large maps. [11] Pandey et al. also worked on the SLAM by using sonar sensor but he focused on more feature of the grid map. [12]

We can describe Sonar more precisely by labelling it Sound Navigation and Ranging sensor. The ultrasonic sensor is helpful to avoid obstacles while the robot navigates. The other feature of this sensor is to recognize its environments as well as the distance and robot location.

It is basically a transducer, on which a transmitter and a receiver has attached. A signal is transmitted or emitted through the sensor. This signal goes into the air and collide with the object in its way. After colliding it with the object, it reflects back to the receiver. The sensor measures the time difference between transmitted signal and received signal. By doing this, we get information about the environment, a measurement of the distance and position of the other object. It is most popular and have low cost.

V. Modelling Aspect

In order to do experiments on the above mentioned phenomenon, we have made a simple kinematic model. Most of the parameters such as the radius of the wheel, steering control angle α and the slip angle can be taken into account by this model. In the global coordinates, the kinematic model can be represented as shown in figure.3. On the front side of the moel, an ultrasonic sensor is attached. This sensor sense the obstacle at a distance up to 32 meters. The landmarks is represented as $B_{(\ i=1\ldots n,)}$ relative to the vehicle coordinates (x_L, y_L).

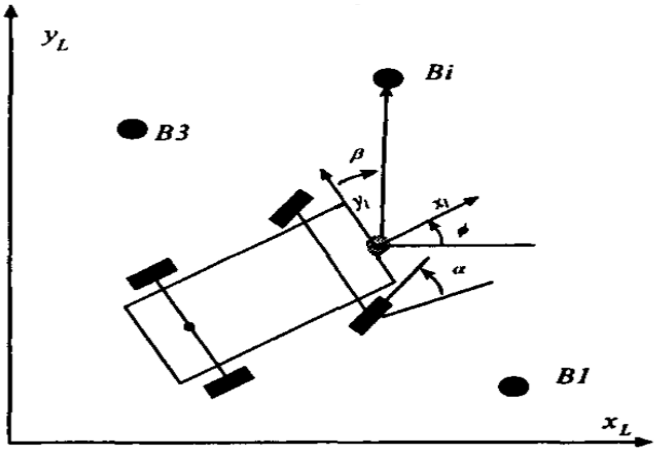


fig.3 Vehicle Coordinate System

Taking into account the requirements of the vehicle by means of a control velocity $V_{C.}$ The trajectory of the vehicle can be predicted by the following formula;

$$\begin{pmatrix} \dot{x}_c \\ \dot{y}_c \\ \dot{\emptyset}_c \end{pmatrix} = \begin{pmatrix} V_c \cos\emptyset \\ V_c \sin\emptyset \\ \frac{V_c}{L}\tan\alpha \end{pmatrix}$$

The translation of vehicle from one point to another point can be calculated as:

$$P_L = P_C + a.T$$

While the transformation matrix is;

$$T_\emptyset = (\cos\emptyset, \sin\emptyset)$$

The parameters of length can be represented as;

$$x_L = x_C + a.\cos\emptyset$$

$$y_L = y_C + a.\sin\emptyset$$

The overall state of the of the vehicle can be represented as;

$$\begin{pmatrix} \dot{x}_L \\ \dot{y}_L \\ \dot{\emptyset}_c \end{pmatrix} = \begin{pmatrix} V_c\cos\emptyset - a.\sin\emptyset\,(\frac{V_c}{L}\tan\alpha) \\ V_c\sin\emptyset + \frac{V_c}{L}(a.\cos\emptyset)\tan\alpha \\ \frac{V_c}{L}\tan\alpha \end{pmatrix}$$

In global coordinates, the discrete model of the vehicle turn into as following;

$$\begin{pmatrix} x(k) \\ y(k) \\ \emptyset(k) \end{pmatrix} = \begin{pmatrix} x(k-1) + V_c(k-1).\cos(\emptyset(k-1)) - \frac{V_c}{L}(k-1).a\sin(\emptyset(k-1))\ \tan(\alpha(k-1)) \\ y(k-1) + V_c(k-1).\sin(\emptyset(k-1)) + \frac{V_c}{L}(k-1).a\cos(\emptyset(k-1))\ \tan(\alpha(k-1)) \\ \frac{V_c(k-1)}{L}\tan(\alpha(k-1)) \end{pmatrix}$$

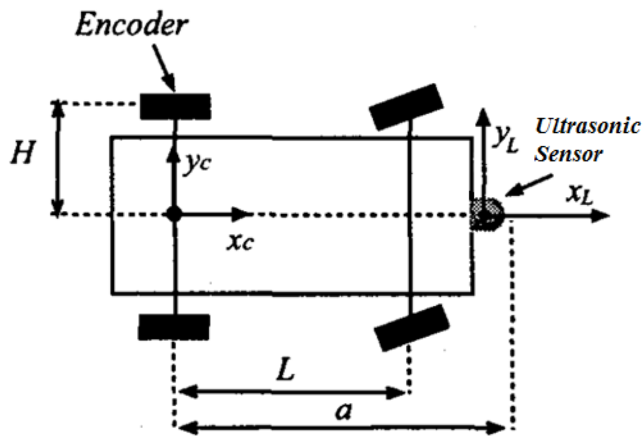


fig. 4 Kinematics Parameters

To relate the observation state with the estimated state, the equation can be manipulated as;

$$\begin{pmatrix} Z_r^i \\ Z_\beta^i \end{pmatrix} = \begin{pmatrix} \sqrt{(X_L - X_i)^2 + (y_L - y_i)^2} \\ atan\left(\frac{(y_L - y_i)}{(X_L - X_i)}\right) - Ø \end{pmatrix}$$

Here z represents the observation values while [x, y, Ø] represents the states values.

VI. SLAM Algorithm using Ultrasonic Sensor

Building map is one of the most important tasks for the autonomous mobile vehicle. As a mobile vehicle moves through an unknown environment, the estimates of these landmarks are correlated with each other because of the common error in estimated vehicle location. This work shows a consensus that there must a higher degree of correlation between estimation of location of landmarks in the map and that indeed these correlations would grow with the successive observation. It not only needs sensors to track the environment but also it may have decision for the model selection based on the sensor's observations. Many implementations use the segment or the line as the main kind of feature, and some of them use corners or edges modeled as points. There may be pure grid and pure feature based approaches. The feature-based SLAM problem can be cast into a state-estimation problem by including the feature parameters among the state variables. The navigation algorithm works as information. This algorithm is more attractive because Kalman filter works on external information from different sources and at different time. The conventional way of driving path estimation is based only on on-board sensor and Kalman filter using vehicle dynamics. The simultaneous localization and map building (SLAM) have more complexity till now. The algorithm complexity can be reduced in order to N2, N being the landmarks in the map. For long duration mission, number of landmarks increases and the map will not be updated. This problem occurs due to the full map is correlated. The correlation is observed by the sensor mounted on the mobile vehicle. This correlation needs to be maintained during full duration of mission. That's why further work is done on the implementation of simultaneous localization and map building (SLAM).

The improving capability of SLAM is purposed in this paper by ultrasonic sensors. The ultrasonic sensor based algorithm has a feature to extract a robust point and line feature. The picture of the front side ultrasonic sensor is given below. Same as the front side, a left and at a right side of the vehicle, there are ultrasonic sensor for obstacle avoidance and as well as to get a fine SLAM mapping.

The vehicle navigates through an unknown position and measure the environments landmarks with respect to its position. The states can be measured as;

$$X = \begin{pmatrix} x_v \\ x_L \end{pmatrix}$$

$$x_v = (x, y, Ø) \epsilon R^3$$

$$x_L = (x_1, y_1, \dots, x_n, y_n) \epsilon R^N$$

Where x_v denotes the vehicle states and x_L denotes the actual landmarks. The new states in the dynamic model of the system becomes;

$$x_V(K+1) = f(x_V(K))$$

$$x_L(K+1) = x_L(K)$$

Here, we can see that, as the landmarks are static so x_L is invariant. Therefor, the Jacobian matrix turns into the following equation;

$$\frac{\partial F}{\partial X} = \begin{pmatrix} \frac{\partial f}{\partial xv} & Ø \\ Ø^T & I \end{pmatrix} = \begin{pmatrix} J_1 & Ø \\ Ø^T & I \end{pmatrix}$$

$$J_1 \epsilon R^{3x3}, Ø \epsilon R^{3x3}, I \epsilon R^{NxN}$$

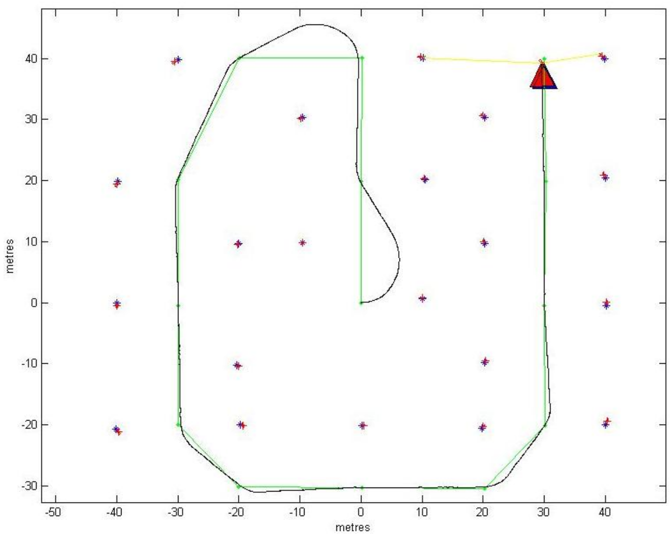
For the landmarks relative to position of the vehicle and its orientation, the Jacobian matrix can be evaluates as;

$$\frac{\partial h}{\partial X} = \begin{pmatrix} \frac{\partial h_r}{\partial X} \\ \frac{\partial h_\alpha}{\partial X} \end{pmatrix} = \begin{pmatrix} \sqrt{(X_L - X_i)^2 + (y_L - y_i)^2} \\ atan\left(\frac{(y_L - y_i)}{(X_L - X_i)}\right) - Ø \end{pmatrix}$$

To track the vehicle position and building a map for the navigation, these equations might be used.

VII. Results

The vehicle we have designed gives us real time mapping output. As we are using three ultrasonic sensors, these three sensors provide information about the obstacle on the way and show those obstacles as landmarks.



It is MATLAB based output. The map of the terrain is subjected to the path of the terrain.

VIII. Conclusion

This mobile robot has features to avoid obstacle/collision and navigate autonomously in unknown environment and map the path of the robot simultaneously using low-cost ultrasonic sensor.
The methodology adopted has capability to use multiple sensors for mobile robot and make it as an autonomous robot. The framework is real time and portable for any environment.

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Dr. Ummul Baneen received her BSc in Mechanical Engineering from University of Engineering and Technologoy (UET),Lahore, Pakistan in 2003 and M.Sc in Mechatronics Engineering from the same institution in 2006. She got a Phd degree in Structural Health Monitoring from University of New South Wales, Sydney Australia in 2013. Her research interests include: Structural health monitoring, Modal analysis, Damage detection by using Environmental excitation, Expansion of damage detection algorithm to 2D and 3D structures.

M. Ibrahim Khalil received his BSc in Electronics Engineering from NFC IET (BZU) Multan, Pakistan in 2011. He is currently doing MSc Mechatronics and Control Engineering from UET Lahore, Pakistan. His research interests include: Advanced Robotics, Mobile Robot System, Control System, and Electronic Devices & Circuit.