A Driving Assistance System for Navigation in Urban Environments

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Abstract. Mobile robot navigation in urban environments is a very complex task. As no single sensor is capable to deal with these situations by itself, sensor fusion techniques are required to allow safe navigation in this type of environment. This paper proposes an approach to combine different sensors in order to assist a driver in a cooperative manner. An adaptive attention zone in front of the vehicle is defined and the driver is notified about obstacles presence, identifying dangerous situations. Experiments using a commercial vehicle loaded with GPS and a LIDAR sensor have been performed in real environments in order to evaluate proposed approach.

Keywords: Mobile Robot Navigation, Urban Environment, Driver Assistance, Sensor Fusion, Vehicles Safety Systems.

1 Introduction

Mobile robotics is a multidisciplinary research area that aims to develop machines capable to use sensors to perceive the environment, make decisions, and move autonomously to complete assigned tasks. Although most research work in this field deals with autonomous systems, there are several other applications for the perception and decision making algorithms used in robotics.

Autonomous vehicles development has been receiving considerable attention by robotics community in the last five years. Initiatives like DARPA Grand Challenge [1], DARPA Urban Challenge [2] and ELROB [3] have been concentrating efforts of several universities and research institutes to push the state of the art in outdoor navigation algorithms. Although autonomous cars are not yet available commercially, several techniques developed by robotics researchers can already be applied in day by day problems.

Car accidents are one of the major causes of death in the world. Traffic accidents are already the major cause of death of young people in U.S. According NHTSA (US National Center for Statistics and Analysis) [4]. In United States (2002) occurred 6.3 million cars crashes, 2.9 million people got hurt and 42,600 people died. In Brazil the number car crashes are up to 1.5 million with 35 thousands deaths per years. In large cities, like São Paulo, statistics demonstrate that more peoples die by urban traffic crashes than by attacks or natural causes [5].

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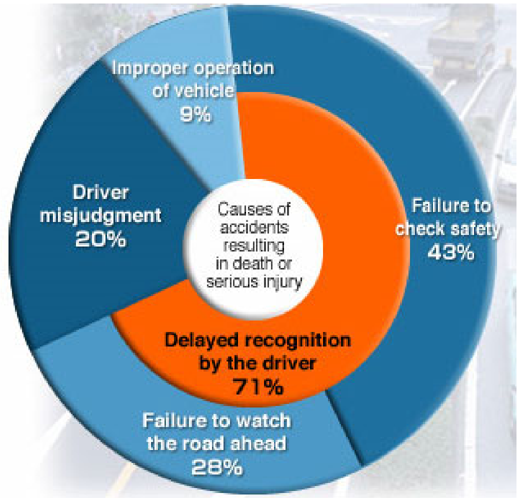

Fig. 1. Causes of accidents resulting in deaths or serious injury [6]

Based on [6], 71% of the car crashes that result in death or severe injury happen due to delayed recognition of the scene by the driver, 43% are due to failure to check safety, and 28% failure to watch the road ahead (Fig 1). Many road accidents could be avoided if the driver were notified of a dangerous situation. In many cases, this task can be performed by sensors that provide information about the environment and a computational system capable of interpreting the sensor data.

Another important application to driving assistance systems is making driving easier to elderly and handicapped people. As the overall population becomes older, the number of older people driving in the streets has increased. A research carry of Johns Hopkins [7] evaluated vision, cognition, and health alterations among 1200 drivers with age into 67 and 87 years. Around 1.5% of them gave up to drive by themselves and more 3.4% reduced intentionally their time at the steering well motivated by visual capacity reduction. In these cases, a system capable of notifying the driver of a possible collision can substantially reduce the risk of a car accident.

Automotive industry has put a considerable effort in the development of new systems to improve safety; however most of these systems do not perform in a proactive manner. Recently, Volvo developed the LKS (Lane Keeping Support), which generates an alarm in case of drowsiness or fatigue of the driver and when a unexpected route changes is detected. This system also assists in a maneuvering by signaling the presence of other vehicles in blind spots. ImapCar [8] is also a commercial systems capable of detecting the presence of people, obstacles and other cars ahead of the vehicle, as well as identifying a traffic lane crossing like. In this case, a video camera is used to acquire information about the surroundings. As the camera cannot estimate the distance to the obstacles, the precision of obstacle detection is very limited.

The techniques developed in the DARPA challenges and EUROB are very efficient for autonomous navigation in urban environments. On the other hand the cost of such systems is well above 1 million dollars, which is prohibitive for most commercial applications. It is also necessary very accurate GPS information of the traffic lanes, crossroads and other details of the environment to use these techniques appropriately. Other simpler approaches have also been developed like [9], which consists of a low cost detection and obstacle avoidance based on ultra sound sensor system. However only very close obstacles (5 or 6 meters away) are detected.

This work proposes an approach to a driver assistance system based on GPS and LIDAR sensors. The GPS provides global position of the vehicle (allowing for trajectory anticipation), while the LIDAR can accurately detect the presence of obstacles ahead of the vehicle. An adaptive attention zone in front of the vehicle is defined and the driver is notified about presence of obstacles, identifying dangerous situations.

2 DAS Hardware and Software Implementation

The proposed Driving Assistance System (DAS) is composed by a commercial vehicle (Fig. 2) equipped with an integrated hardware and software system capable of detecting and warning the driver about frontal obstacles. The hardware is composed of three different types of sensors (LIDAR, GPS and Compass), a CPU (embedded PC), and a software system. This set work together to sensing the environment, logging and fusion data, generating obstacles detection and to emit collision warnings.

Fig. 2. Vehicle used in experiments equipped with a frontal Sick LMS 200 Laser sensor and with a compass and GPS system

2.1 Sensors Used

A SICK LMS291 [10] is a LIDAR (Light Detection and Ranging device) sensor used to detect obstacles. It has been set with a maximum range of 80m, covering 180 degrees at 37,5Hz. Using an infrared laser beam, this sensor type can detect obstacles accurately even in the complete darkness, compensating some human vision limitations. The LIDAR sensor has been mounted in front bumper of the vehicle where it is capable to detect obstacles ahead of the car. We also had tested other configurations using the sensor on the top of the vehicle, pitching it down to detect bumps and depressions. However, this is beyond the scope of this paper.

A Garmin GPS 18x-5Hz [11] was also part of the experimental setup. Although the GPS provides latitude, longitude, altitude, heading and velocity, the accuracy of this information depends largely of the number of satellites available and proximity between them (Dilution of Precision). Usually, the horizontal error in the position estimation ranges from 3 to 10m in a clear sky situation. In order to increase the heading precision from GPS receiver, a TNTC Revolution [12] digital compass has been used.

2.2 System Implementation

The implemented system uses the data acquired by the LIDAR sensor and fusing with GPS and Compass data to establish a differentiated attention zone, as demonstrated in Fig. 3. One important particularity of this system is the fact that GPS data have been previously collected in the very same path we are expecting to follow using the vehicle.

Initially the distances from the vehicle to any obstacles in a range of 180 degrees with a radius of 80 meters are measured, resulting into a vector of 361 distance measurements readings (0^{o} to 180^{o} with step of 0.5^{o}). Then, the GPS position and compass orientation is obtained in order to determine the vehicle positioning related to a previously defined path.

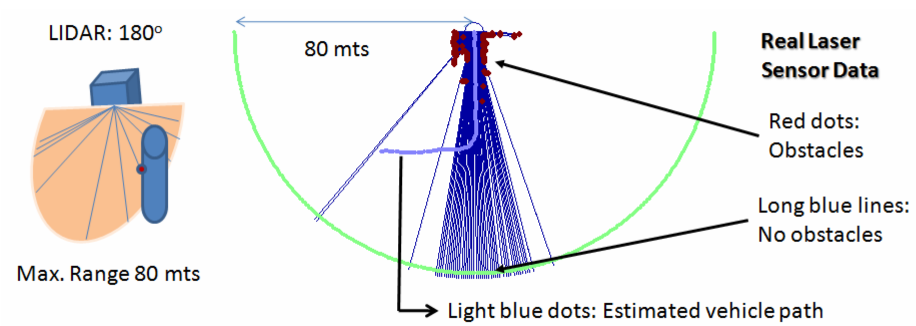

Fig. 3. LIDAR sensor data and obstacle detection

This data set allows us to estimate the vehicle path (as indicated in Fig. 3) and to focus the attention on potential obstacles present in this path. Note that several obstacles are detected by the laser sensor but many of them are not in the vehicle route. Due to this approach we are able to reduce significantly the number of false alarms of dangerous obstacles in the vehicle trajectory.

2.3 Obstacles Detection

The obstacle detection can occur in three ways: i) *Global Detection*: detect all the obstacles that are around the vehicle in the LIDAR sensorial range; ii) *Fixed Rectangular Region*: detect only the obstacles that are in the frontal area of the vehicle; iii) *Adaptive Region*: use an intelligent algorithm to detect only the obstacles that are in the frontal area of the vehicle and also inside the adaptive region obtained by data fusion and analysis of vehicle path.

Global Detection

As presented in Fig. 4(B), any obstacles that are in the laser sensorial range are detected and considered as potential harmful objects. Once the laser has an 180^{o} wide scanning (see Figs. 3 and 4(A)), all the obstacles in a radius of 80 meters inside the ahead scanned area are detected. This approach is not practical since we detect several obstacles that do not represent a significant menace to the car neither to the driver, as for example, trees and lampposts that are side by side with the vehicle (not in the vehicle trajectory).

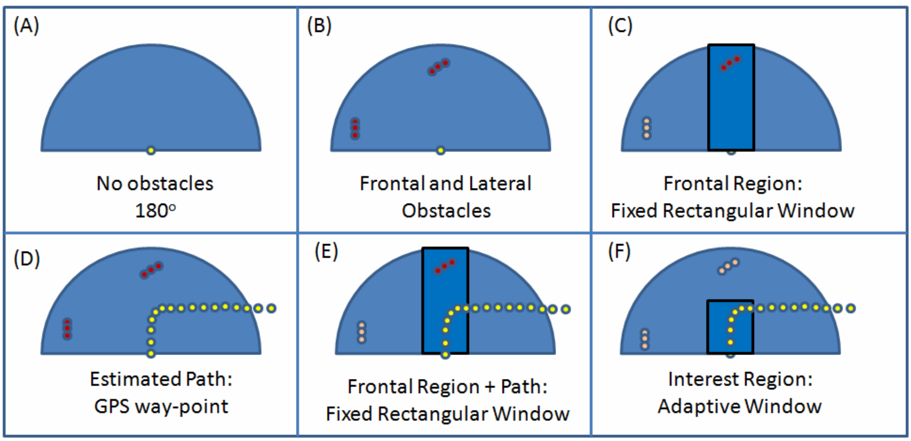

Fig. 4. Obstacles detection using sensor fusion, fixed and adaptive windows: (a) LIDAR visible region; (b) LIDAR detection of obstacles; (c) LIDAR only based fixed rectangular window for frontal obstacle detection; (d) LIDAR and GPS fusion: GPS estimated path (way-points); (e) False alarm caused by obstacles which are out of the estimated vehicle trajectory; (f): Sensor Fusion: adaptive window used to avoid false alarms.

Fixed Rectangular Region

As presented in Fig. 4(C), it is possible to define a rectangular bounding box in front of the vehicle. Only the obstacles that are inside of this rectangular window are considered as possible harmful obstacles. The user can set it up the dimensions of this fixed rectangular area in front of the vehicle, as for example, defining a rectangular

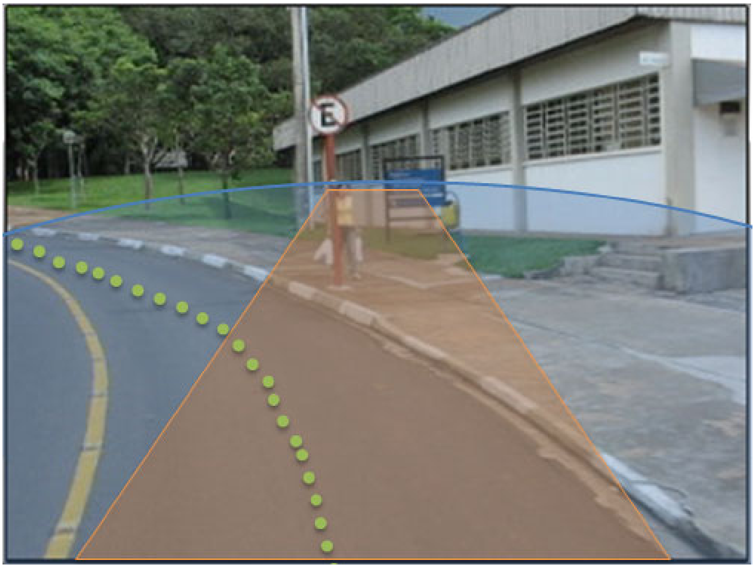

Fig. 5. Obstacles detection using a fixed rectangular region

area of 20m x 3m (Length x Width) which is used to limit the inspected sensorial area searching for possible obstacles. This approach reduces significantly the total number of detected obstacles.

The problem of adopting a fixed rectangular bounding box in front of the vehicle is the fact that usually the driver has a predefined path to be followed, and there are several other obstacles surrounding the vehicle, which are not blocking or harming the specified trajectory. For example, as presented in Fig. 4(D) and in a real situation during experiments (Fig. 5), when the vehicle turns, all the obstacles that are in front of the vehicle, after passing the turning point, should not be considered (e.g. trees, people crossing the street, buildings etc.). As it can be observed in Fig. 4(E), depending upon the vehicle trajectory, several obstacles can produce false alarms when present in front of the vehicle, even if these obstacles do not represent any danger related to the vehicle trajectory.

Adaptive Region

Our proposal is to intelligently integrate the GPS and Compass data that describes the vehicle estimated path within the LIDAR sensor data that are showing the obstacles present in the environment. The sensor fusion allows a better adjust of bounding box used to identify potential obstacles in the vehicle path. The Figure 4(F) presents an example of the rectangular bounding box resizing when the vehicle was preparing to turn right. Note that some obstacles are in front of the vehicle, but they are in a region out of the vehicle path. So, after the intelligent adjust of attention zone, they are not considered as possible harmful obstacles, resulting in a reduction in the number of false alarms.

2.4 Intelligent Attentional Algorithm: Adaptive Region Selection

The proposed algorithm is presented bellow (see Algorithm 1):

Algorithm 1. Adaptive Region Selection

Adaptive Region Algorithm	Inputs:	LIDAR Data: Vector [] – Angle/Distance measurement points; GPS Position: Latitude Longitude and Compass Heading
	Outputs:	GPS Way-Points: Vector [] - Lat., Long., Heading Obstacles: Vector [] – Angle/Distance measurement points

1. Find the closest GPS way-point (P*i*) related to the present GPS position (P*t*)
2. Considering '*N*' GPS way-points starting at Pi (from P*i* to Pi_{+N})
   2.1 Transform the absolute coordinates of P*i+j* (Lat., Long, Head.) to relative coordinates measuring distances and orientations relative to the frame of the LIDAR sensor.
   2.2 Plot the LIDAR range obtaining an half-circle (180^o x 80m radius)
   2.3 Plot each LIDAR Data according to Angle/Distance measured
   2.4 Plot the transformed GPS points P*i+j* inside the LIDAR range area
3. Considering the vehicle width W, create a rectangular bounding box, defining the maximum limits of each laser beam (max. distance)
   3.1 Find the last point *k* of the GPS points P*i+j* that remains inside the rectangle borders defined by the vehicle width W (left/right borders)
   3.2 Using the GPS point P*k,* obtain the maximum distance of this point related to the origin of the frame of the LIDAR sensor. Use this distance D*k* to adapt the length of the adaptive region selection
   3.3 Plot the rectangle defined by the vehicle width W and length D*k* inside the LIDAR range area
   3.4 Select all LIDAR data points that remain inside this rectangle and copy them to the Obstacles Vector (Output)

3 Experimental Results

The experiments have been carried out at the University campus. The path chosen for data collection corresponds to a very diverse circuit with 840 meters of campus internal streets (Fig 6). The passage comprised by points A and B is a straight street, with width equivalent to two cars and two-way orientation. In the left side there is an area reserved for upright vehicles parking, and in the right side, a walkway and a large building that occupies the entire block.

Between points B and C there is an open area with trees and some information signs. The segment between C and D is composed of crossing routes and also some tracks for pedestrian crossing. Section D and E is mostly a straight way with grass on both sides, while the last (E and F) is wide open. At the F point, there is an 180deg turn in front of the campus entrance.

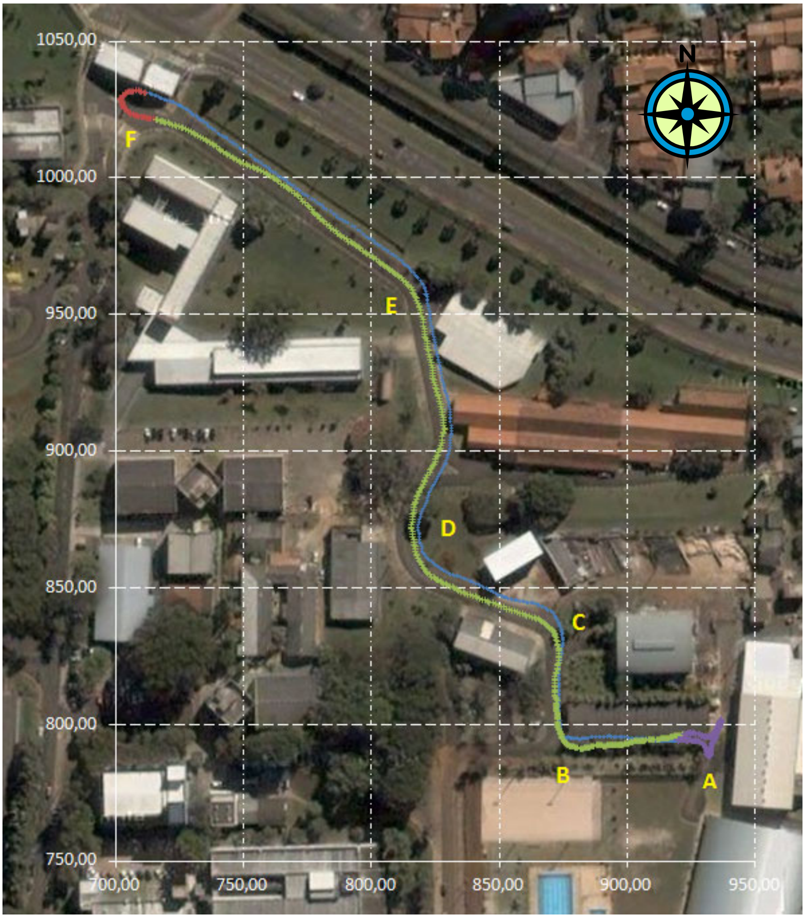

Fig. 6. Area used for the experimental tests

The Table 1 describes the experimental results obtained to route comprised by AEA segment:

Table 1. Experimental Results

DATASET 1	*Global Detection (GD)*	*Fixed Rect. Region (FRR)*	*Adaptive Region (AR)*
Total Data Points detected inside the attention area	5861	604	82
Total of Warnings for different obstacles	>> 100	27	2

Considering the tabled results, we can observe that the proposed method can drastically reduce the number of false alarms. Using the adaptive region we are able to reduce from hundreds of possible harming obstacles to only 2 alarms of dangerous obstacles. When observing the *Global Detection* results (no fusion, all sensorial range), we get a large number of alarms and elements detected, as expected. The *Fixed Region Rectangle* Fig. 7 (left) where had no fusion, fixed rectangular bounding box of 3 meters width and 20 meters length, resulted in 604 collision data points, and estimated occurrence of 27 different alarms for unique obstacle count. The proposed approach of using *Adaptive Region* using a sensor fusion Fig. 7 (right), reduced the alarms to only one situation when 2 different obstacles were detected. Observing the video captured from the experiment, these two obstacles are really dangerous elements that are very close to the vehicle path, and the warning emitted in this situation probably will be well accepted by the driver.

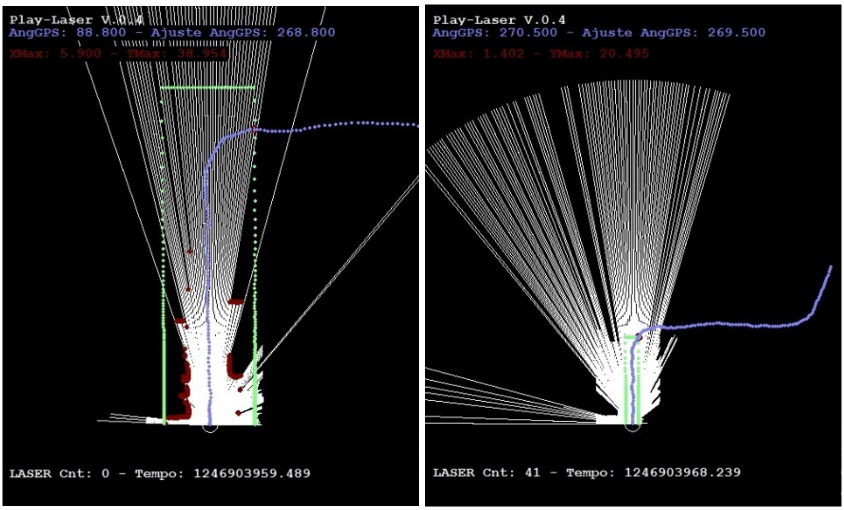

Fig. 7. Screenshots of DAS System taken during experiments

4 Conclusion

This work presented an approach to combine GPS and laser scanner data in order to focus the attention to significant possible collision data points that are in the vehicle estimated path. Through sensor fusion an intelligent algorithm can adjust the perception area and differentiate potential harmful objects of real dangerous obstacles. The proposed approach allowed a significantly reduction in the number of false alarms of possible collisions, as demonstrated in our practical experiments based on real data acquired using a vehicle equipped with LIDAR, GPS and Compass sensors.

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