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Context-Aware Driver Assistance System

Wael Alghamdi[a], Elhadi Shakshuki[a],Tarek R.Sheltami[b]

[a]*Jodery School of Computer Science, Acadia University, 27 University Avenue, Wolfville,NS, B4P1N6, Canada*
[b]*Department of Computer Engineering, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia*

Abstract

In the last few years, significant improvements have been made in the area of vehicular communication systems. In fact, vehicle-to-vehicle communication and vehicle-to-infrastructure are considered a key concept for keeping roads safe. An efficient implementation of these systems is necessary to ensure the safety and to reduce the car collision rates. This paper proposes a Context-Aware Driver Assistance System that links drivers with the physical environment surrounding them. This is achieved by developing a vehicular warning system that assists drivers to avoid collisions and improve their response times. The proposed system architecture consists of a set of components to process the user's request, and provide responses and advices when needed. These components include communication, knowledge exchange, knowledge update, and context-history. Also, it includes other processes such as context-history manipulation, hazard detection, and hazard detection control. Over all, the main goal of the system is to reduce the number of car accidents and improve driver's decisions. To demonstrate the feasibility of the proposed system, it is developed and demonstrated on NXT Robots environment.

Keywords, Context-aware; V2V; Hazard Detection; Context History Minapulation;Lego Mindstorms NXT Robots;

1. Introduction

Nowadays, there are over 1.27 million car accidents all over the world [1]. To most people in society, the automobile industry provides recognizable value in regards to improvements in safety and efficiency. Accidents are considered one of the most detrimental aspects of the usage of automobiles. Ordinarily, these accidents stem from driver errors such as speeding and aggressive driving. In fact, more than 90% of the accidents happened because of driver errors while the costs of the total accidents are shocking (see table 1) [2].

* Corresponding author. Tel.: +1 902 698 8080; fax: +0-000-000-0000 .
E-mail address: 102431a@acadiau.ca.

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Table 1. Accidents Statistics Summary, USA

Fatal Accidents	38.2 Thousand accidents	43.4 Thousand vehicles
Injuries Accidents	1.82 Million accidents	3.29 Million vehicles
Property Accidents	4.30 Million accidents	7.51 Million vehicles
Total Accidents	6.16 Million accidents	10.86 Million vehicles
Autos	33 Thousand deaths	2.5 Million injuries
Pedestrian	5.85 Thousand deaths	118 Thousand injuries
Total Numbers	43.4 Thousand deaths	2.7 Million injuries

Most of these accidents happen due to drivers' behavior and poor infrastructure. We, as a society, need to find a solution such as building an intelligent system to help reduce accidents by linking the drivers' awareness to the infrastructure and to the surrounding area whenever possible. The proposed system should be able to make drivers pay more attention and allow them to communicate with other entities of the environments such as vehicles and drivers. This makes it possible for the system to acquire more information about the environment and becomes possible to enhance the vehicular safety. Consequently, the system is able to alert drivers before an accident could happen for instance speeding over the speed limit, or handling drivers' errors, for example pressing the brakes late or early.

We strongly believe that our approach should be able to detect hazards to avoid collisions. Also, it should react autonomously and provide advices to the driver in a visual and audible form. Several researchers [3,4,5,6] have proposed driver assistance system to help drivers to avoid car accidents. Having a system that combine all Advanced Driver Assistance System (ADAS) functions together, such as blind spot detection and traffic sign recognition, may guarantee on improving driver's behavior and reduce their errors. The main objective of the proposed system is to provide an alert system to drivers as well as informing them about upcoming hazard situations.

1.1. Related work

Advanced driver assistance systems are considered as an appropriate solution, while the use of sensors is a necessity [3,5,6]. Researchers have attempted to reduce the amount of accidents using different approaches. There are several attempts by many researchers to address the problem of reducing accidents by providing help to drivers [3,4,5,6,7]. Some of these attempts have focused on a single service such as providing parking assistance, because providing several services is expensive due to the cost of sensor and cameras. For example, researchers in [3] have noticed that having advanced driver assistance system equipped with several functions would be extremely useful for drivers to avoid car accidents. They proposed an integrated driver assistance system that utilizes image sensors. In their proposed system, several functions are employed such as adaptive cruise control, blind spot detection, and night vision system. Using image sensors is very important to provide the driver with the required information and warn him/her whenever is necessarily. They described the most important information which needs to be collected about the area around such as other vehicle's speed, direction, distance, size and type. This information is important to run those functions. Also, having all functions working together in one coherent system is useful for drivers [3,4]. Although they proposed excellent system which handles a great collection of functions, the proposed system is based on utilizing five cameras only.

Nowadays, many car companies consider and keep this type of systems in their minds when designing and producing new cars with extraordinary options. The main problem with those cars is that they become too expensive. For example, Honda company [5] proposed a new approach in 2008 to make their new cars safer for drivers. They installed five cameras in each side of the car. They called it Multi-View Camera System. The collected data from all cameras are displayed to the driver using LCD panel.

Rakotonirainy, A. [6] believes that there is a complex interaction between the driver, vehicle, and the environment. He suggested that several types of sensors are needed in order to make the interaction valuable. One of his challenges is how to simplify the driving task to reduce the amount of errors. His approach does bring different types of information using different types of sensors to the system. He attempted to improve the driver's behaviour that eventually means minimizing the umber of errors [6]. Driving tasks need an immediate and appropriate decision. His proposed system focuses on the interaction between the driver, the environment, and the vehicle in order to observe and understand the driving situations using Bayesian network. The main drawback of this system is that the Bayesian network evaluates future behaviour only. We believe that the best way is to combine advanced driver assistance functions in one system to produce the best performance.

2. Context-Aware Driver Assistance System

The architecture of the proposed system is designed to help drivers to avoid accidents. Figure 1 shows the main components that constitute the proposed architecture, including the user interface which helps the driver to enter his/her own information such as name, age and receive responses/warnings from the system. Context-History (CH) is the database of the system that stores all previous data collected from sensors in the form of scenarios with the associated actions taken in previous scenario.

Context-History Manipulation (CHM) component main function is to analyze and compare the current situation of the driving status with the existing scenarios previously saved in CH. Hazard Detection (HD) component consists of a set of functions such as Adaptive Cruise Control and Lane Keeping Assistance. Hazard Detection Control (HDC) component is responsible to formulate the appropriate message and alert the driver with the current situation. Knowledge Exchange (KE) component main responsibility is handling all communicated messages between vehicles i.e. vehicle-to-vehicle (V2V) communication, while the Knowledge Update (KU) component is responsible for updating the system's knowledge. Finally, sensors are the main sources for collecting the desired information from the surrounding area. The components of the architecture are described in more detail in the following subsections.

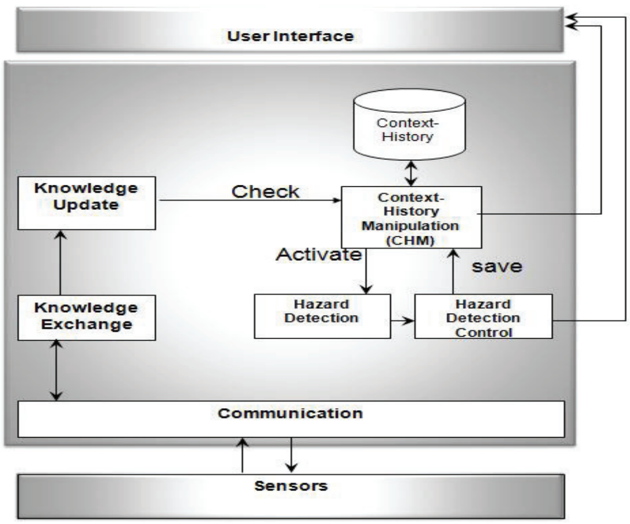

Fig. 1. System Architecture

2.1 Communication

Context-Aware Driver Assistance System is extremely valuable that allows drivers communicate with the outside world and make them aware of their driving actions. These systems are responsible for collecting the desired information and assist drivers in their driving harpist and decision-making [3,4]. All required information about objects in the road, other vehicles, and distance between the vehicle and other objects are collected through different types of sensors. Furthermore, some sensors are located inside the car with the functions to monitor the current state, for example, seat belt, and the sensors located outside the car to guide, for example, the driver to the right lane. The interaction between the outside sensors and the inside one is extremely important to achieve the goal of the system [3,6]. In this system, we consider using sensors such as ultrasonic sensors and colour sensors.

The communication component of the system is responsible for sending, receiving, and interpreting messages received from sensors from the outside the car to inside and vise versa. The communication can be established between this system and other systems from the same type, the system and sensors, and the system and the driver. The communication between the proposed system and the driver is established through graphical user interfaces. An example of a user interface is shown in Figure 2.

Fig. 2. Graphical User Interface

Through this interface, the driver is allowed to enter his name, age and date of the trip through buttons located on the left hand side panel. There are two buttons on the right hand side panel namely Depart and park. The driver can use depart button to depart from a parking lot and use the park button to request a parking assistance. The drivers are also able to adjust the volume and the brightness of the screen using the sliding buttons on the system controls panel. The communication between the system and the sensors are described by finite state representations. Figure 3 shows the process when the system sends a query requesting the sensors for information about the other objects, vehicles, and distances to objects in the surrounding area. The system formulates the request to sensors and sends it out in the format of <sensor type, information>, for example, the sensor type is ultrasonic and the information is distance. When the system receives the response back, it is analyzed by CHM component to identify the sensor's type. Then, the CHM component evaluates the response utilizing the information in CH. If data is found, then the actions exist. If data not found, then activate the HD and HDC to retrieve the appropriate actions for completing the process.

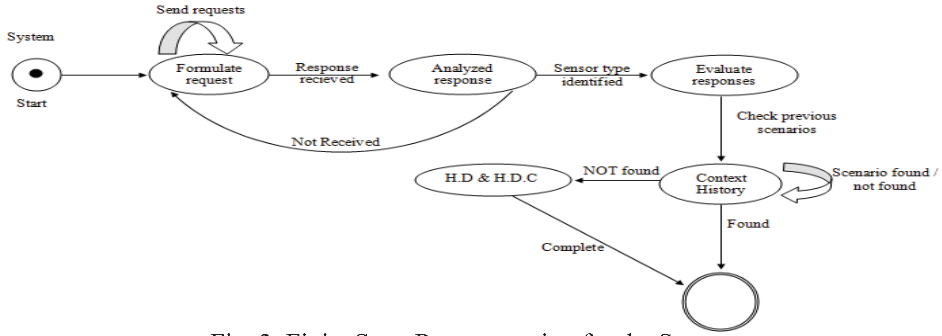

Fig. 3. Finite State Representation for the System

On the other hand, Figure 4 shows how the sensors receive the system's request through the communication component. As soon as a sensor of any type receives the request, formulates the response and sends it back to communication component of the system.

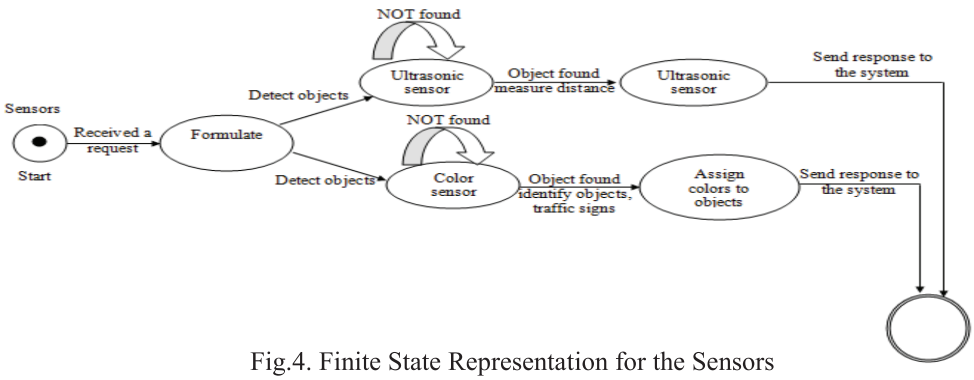

Fig.4. Finite State Representation for the Sensors

2.2 Knowledge Exchange and Knowledge update

Knowledge exchange component is responsible for message exchange between vehicles within the proximity of the used sensors, which is called vehicle-to-vehicle communication [7]. Knowledge exchange provides the system with up-to-date knowledge through exchanging information and building the complete knowledge for the driver. The communication between vehicles in our experiments is established by Bluetooth connection.

For example, car X established a Bluetooth connection with car Y. When car X became a closer to an intersection where car Y is coming to the same interaction from different road, car X sends a message in the form <speed, remain time to the intersection> informing car Y about how far currently it is from the intersection based on the data received from the ultrasonic sensor for which knowledge update component updates the current status of the environment. This exchanging of messages will continue on a predefined time frame until the connection is released. The connection is released based on the remained distance between the cars and the intersection. Conversely, the exchange of messages is terminated when the distance between car X and car Y increases to a certain limit that we consider no longer is dangerous.

2.3 Context History Manipulation (CHM)

One of the main components of the proposed architecture is the Context History Manipulation (CHM). The design of the functions of this component is similar to that presented in [7,8], with the main task to analyze and compare the current situation of the driving status with the existing scenarios previously saved in Context-History (CH). If there is a similar scenario stored in CH, then the driver is notified by sending a message that contains the action. Otherwise, the CHM passes the data to the Hazard Detection (HD) component and Hazard Detection Control (HDC) at the same time to save the actions after it processes the scenario in the this format <sensor type, information, action> . The goal of the database and CHM is to add speeding feature in the future by saving the system processing time. If it matches previous scenarios, there is no need to activate the hazard detection and hazard detection control components. It may be useful for people who are commuting to work every day at the same time and to the same place. This implies that those systems should be faster than usual; because, there is no need to activate HD and HDC to produce an action which eventually saves the system's processing time. The context-history manipulation component decides whether the current set of inputs, for example particular sensor detects a certain object in the same distance, about the environment matches previous recorded scenarios, or it should activate the HD and HDC components to determine the course of action to take and convey it to the driver through the graphical user interface. The course of action is determined by looking up the hazard detected in a precompiled table of responses. Due to page limit, we only describe an algorithm for Adaptive Cruise Control (ACC) function with the process of CH and CHM.

```
*A Radar sensor transmits a short pulse of radio signal
Measure the time t = t_received − t_sent
// t is the time required for the signal to hit an object which the
signal takes for the reflection to return
constant v = 300,000 km/sec // v is the velocity of light
If reflection signal detected Then
       an object is ahead
       Calculate distance d = v × t
       d = d/2
//only need half distance that represent the signal being reflected back
CADAS Communication component sends d to CHM
//Send d to Context-History Manipulation process
   If ( d = d`) Then    //CHM checks the database for previous value d`
            Reduce car's speed by 10km/h;
   Else
            Activate HD Component;//No similar scenario found
                  If d = > 2.5 m Then
                        no action provided;
   //It is assumed 2,5 m distance as a safe based on Canadian regulation
                  Else  the action A is "reduce speed"
            Activate HDC Component;
                  Select a proper sentence, picture, warning sound for
                  the action;
                  Save d, A, sentence, picture, and warning sound in CH
                  through CHM;
                  Issue an alert;
           Display the action to the driver in audible and visual forms;
```

Fig.5. The Algorithm for Adaptive Cruise Control

2.4 Hazard Detection

Hazard Detection is the core component of the proposed system architecture. It consists of a set of functions listed below and responsible for detecting hazard situations using sensors attached inside and outside the vehicle. The design approach of this component is similar to approach discussed in [9]; in addition to that we introduced a new function entitled Intersection Coordination. These functions are extremely beneficial for drivers because they work on improving the driver's behavior and provide the right suggestions to different situations [10]. The following list discusses all functions of the HD component.

- *Adaptive Cruise Control function:* To maintain the vehicle speed and issue warnings when necessary.
- *Blind Spot Detection function:* To detect blind spots of both sides of the vehicle, and issue warnings if it is dangerous to change lanes.
- *Environment Reconstruction function:* To display the area around on display panel and issue warnings when the system malfunctions, using real time video and GPS.
- *Forward collision Avoidance function:* To provide the distance of objects or vehicles in front of the vehicle and issue warnings, while it adapts the required speed depends on how far an object or a vehicle is from the vehicle.
- *Intelligent speed adaption function:* To read and monitor speed-limit signs, and issue warnings when the speed of the car exceeds by 10 km/h.
- *Lane Departure warning function:* To read marks on the roads and predict vehicle's departure path, and also issue warnings if there is an object blocking the vehicle path.
- *Night vision function:* To display the surrounding view during night and highlight objects on the display panel; issue warnings if the system malfunctions. It is a function that is more useful to seniors [11].
- *Parking Assistance function:* To calculate all distances from the surrounding objects and issue warnings whenever there is a threat of collision.
- *Traffic sign warning function:* To read traffic signs and to ensure appropriate driver's actions, and issue warnings if the signs are disregarded.
- *Lane keeping assistance function:* To help the driver stay on the right lane. Honda develops this function on 2009.
- *Intersection coordination function:* To establish communication with other vehicles If there is an intersection ahead and to decide who should go first.

2.5 Hazard Detection Control

This component is responsible for organizing the functions' results from the Hazard Detection (HD) component. If it receives a positive response from any function indicating that there is impending danger, then a warning message is issued; otherwise, the system continues normal processing of receiving data. Each result received from the HD is matched with a particular sentence and specific warning sound. The sentences are short and understandable by the driver. For example, if there is a car in the blind spot, the following message is displayed "avoid lane changing" or "unsafe lane changing"; however, if it is safe to change the lane then no action is provided by the system. Indeed, this component controls the results and displays messages to the driver in an organized manner. Then, the action that is represented in an audio and visual forms are passed to the user interface for display purposes; meanwhile the same data is sent to the context history manipulation component for future use.

3. The Simulation

To demonstrate the visibility of the proposed system, we performed a simulation of an environment that involves Lego Mindstorms NXT Kit [12]. In an attempt to enhance and complement a greater research work, this paper concentrates on the design and the simulation of a subset of the proposed functions. A few modules of CADAS functionalities are demonstrated on NXT robots [13] environment, with the capability of recognizing the status of the surrounding environment around the robots and achieving their goals while carefully examining and reacting to valid changes in that environment. The simulations covers the analysis and the implementation of the following three modules: 1) following a black line (road) which represents "Lane keeping assistance", 2) coordinating an intersection which represents the "Intersection coordination", if several robots come to an intersection they should decide who goes first and when to prevent collisions, and 3) adapting the required speed with respect to the obstacles in front of the robot which referred to it by "Forward Collision Avoidance". The robots have a limited number of components [14], sensors and motors with actuators. The functional components of each robot that are used for this simulation are:

- Touch sensor: it reacts on pushing the front button installed at the front of the robot only, which means that the robot collided.
- Light sensor: it identifies the reflected light intensity that ranges from high to low or from white to black.
- Ultrasonic sensor: it generates high frequency sound waves and evaluates the ECHO massage which is received back by the sensor to measure a distance.
- Three motors: they are used to rotate the wheels and make the robot moving.
- One controller: it is the processor of the robot where we can download programs.
- Colour sensor: it triggers six different colours and identifies them.

Figure 4 shows a simple environment, which consists of three NXT robots equipped with all the aforementioned components and functions. In this environment, a black tape is used for roads. For the Lane keeping assistance, each robot uses its light sensor to generate light and read the reflection from the map. This is how it identifies the reflected light intensity whether it is high or low, meaning the spot is white or black (or grey for middle values). The idea was that the robot would have to be placed somewhere next to the road from the beginning and then it would find it by slowly turning in one direction, moving forward a tiny bit and check if it is still on track, turning left and right again with increasing magnitude if it does not. Cycle in this loop unless some preset condition is met.

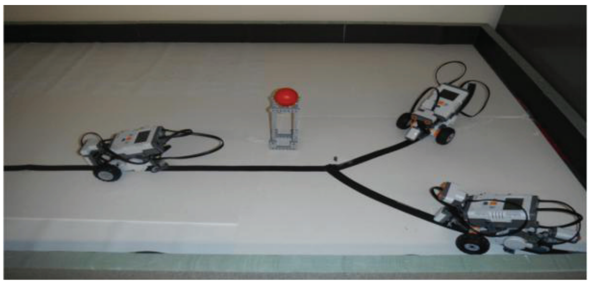

Fig. 6. The Environment

Intersection Coordination is the most advanced function of the three. It has to establish a Bluetooth connection and communicate with others to decide who will pass the intersection first and who will pass second, etc. Although there are several strategies that are exist such as First Come First Served or in presented [15], we equipped all robots with a simple strategy for the sake of simplicity and demonstration purposes. When there is an intersection, the robot with higher precedence has the priority to go first. They still have to exchange requests and clearances to resolve the conflict, but one will always have a higher priority. Intersection coordination starts with establishing a Bluetooth connection between two robots, having a master and slave roles, where the master is responsible for initiating the connection and keeping it up throughout the demonstration. After that both robots start moving towards an intersection on the map. Assuming the time between arrivals is negligible, the first robot should wait for the other robot and then negotiate by sending Requests-To-Go (RTG) and Clearance-To-Go (CTG) messages. The master however will discard all requests until it gets a clearance for itself, starts moving and then having forwarded far enough to avoid collisions, it sends a CTG to the slave. This way, the safety and order are ensured. Since no image recognition is available, the intersection is determined by using a stop-sign object right behind it so that a robot can use its ultrasonic sensor to measure a certain distance as a stop sign.

Forward Collision Avoidance [16] function is responsible for avoiding a front collision while driving the vehicle with the maximum speed allowed. For this function, two flags were set: one for critical distance at which the robot must break immediately and one for legal distance at which the robot must maintain the speed until it gets closer to the first flag or it gets further away and thus can increase its speed.

The speed is adjusted automatically based on predefined time and whenever the distance to the objects changes. If the distance is greater than the legal distance imposed by the government traffic law, then the speed can be increased. If it is legal but not critical then the speed must be the same or lower than before. At the end, when the distance is critical, say less than 10 meters then the car breaks until the obstacle is removed or distance increased.

One of the experiments performed is to demonstrate the Forward Collision Avoidance. In this experiment, we used two NXT robots driving down a simulated road one after the other. The leading robot is constantly monitoring the environment ahead, using the ultrasonic sensor and looking for any obstacles that may require a reduction in speed. The second NXT robot that follows the first robot is maintaining the legal distance. If the first robot encounters an obstacle and slows down, the second robot observes that the distance has diminished for which it started to slow down to maintain the legal distance. If the distance is critical or less, then the second robot will fully breaks, until the distance increases. This modelled the functionality of Forward Collision Avoidance in both robots.

4. Conclusion

This paper presented CADAS systems architecture that helps driver to avoid collisions. The main components are discussed and explained in details. Some of the basic features of the system are developed and demonstrated on NXT robots environment. The communication between the robots is established through Bluetooth. In the future, we plan to demonstrate more functions such as pedestrian detection system and parking assistance system. We also plan to enhance the communication techniques and develop negotiation strategies so that the system would be able to reach quick agreements to resolve any conflicts.

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