USING REAL-TIME RESPONSE MULTI-AGENT BASED SYSTEMS IN VEHICLE SAFETY

Anivesh Reddy Minipuri

University of Windsor

ABSTRACT:

Now-a-days vehicle accidents have unfortunately become very common. Many people die as a result of car accidents. 110 people die every day in North America due to accidents. Several techniques have been introduced to improve vehicle safety. To make the vehicles safer real time response in-vehicle intelligence techniques were implemented by using Multi-Agent Based Systems (MABS). One of the major problems is that these techniques have a high cost and requires a lot of time to implement. Various researchers have tried to enhance vehicle safety by using MABS which are easy to implement and are cost effective.

KEY WORDS: multi-agent based system, vehicle safety.

Contents

1. INTRODUCTION

Much research enhancing vehicle safety on the road is essential in order to avoid accidents. Accidents have become a major health hazard throughout the world. If we improve vehicle safety on the road we can reduce automobile collisions and can reduce number of deaths that are caused due to accidents. This survey is about the use of real time multi-agent based systems in order to improve automobile safety

For conducting this survey Google Scholar and ACM digital library were used for finding published papers. The various keywords that were used are multi-agent based system, safety, vehicle etc. Author names were also used to search relevant papers.

Papers that were published in conference proceedings are Burmeister et al. [1997] Gietelink et al [2004], Gietelink et al [2004], Lemmen et al. [2005], Yang sibo et al. [2008] Kakkasgeri and Manvi [2009] and Jin et al. [2012]. Papers that were published in journals are Gietelink et al [2006], Hannan et al [2008] and Xiaowei [2011].

From the ten selected papers it is observed that most of authors focused on reducing the collision of vehicles on the road. One of the papers discusses about how the multi-agent based system is used in traffic and transportation. However all the techniques that are introduced by the author are very costly and time consuming. There should be a technique which has low cost and which is more reliable.

This survey consists of different approaches, concluding comments and annotations of ten selected papers. Three different approaches are discussed. The first section deals with the use of multi-agent based system (MABS) in traffic control and traffic management and the second section deals with the application of MABS in avoiding collisions. The third section consists of application of MABS in wireless communication among intelligent vehicles. Finally there is a concluding part followed by annotations.

2. MULTI-AGENT BASED SYSTEMS IN VEHICLES

Many different approaches have been taken into consideration to improve vehicle safety. This survey focuses on those approaches that enhances vehicle safety by using Multi-agent based system (MABS). It is observed that all approaches are categorized into three sections. One of them deals with use of MABS in traffic control and traffic management another approach deals with usage of MABS in avoiding collisions and the last one deals with application of MABS in wireless communication among vehicles.

2.1 MABS in Controlling Traffic and Transportation

Burmeister et al [1997] address the use of real time multi-agent system in the management of traffic flow. The authors state that the control of traffic and transportaion is a very tough task to handle. The authors also state that better management of traffic flow enhances vehicle safety .

The authors do not refer to any of my selected paper as their related work.

The authors state that the use of agent-oreinted techniques reduces the handling of complex traffic in an effective way and ensures vehicle safety. The authors propose a new architecture called the BDI architecture. It is a meta-level control mechanisim for practical reasoning. The authors also inroduce the COSY architecture. This architecture consists of five top-level modules they are actuators, sensors, motivation, communication, and congnition. The BDI architecture is underlying principle in the COSY architecture.

The authors state that by using the COSY architecture they made some state changes over the agents that are interacting with other agents. They monitored the agent behaviour by using the COSY architecture and different stage changes in each agent was noticed. They also state that different protocols were used in crash scenario analysis.

The authors state that by using their COSY architecture individual behaviour of each agent is observed. The authors also state that the protocols worked well and the simulation component in the proposed COSY architecture sucessfully simultes the motivation, sensors, actuators communication and environment by models for each application which provides fair results in terms of behaviour of agents.

The authors claim that their new agentoriented techniques provides a new approach to software devolopment. They also state that AOT's (agent oriented techniques) reduces the complexity in system design by making available abstraction that lend themselves to a more natural way of modelling system. AOT's techniques makes traffic and transportation more efficient and improves safety.

This paper is cited by Xiawei [2012]

Year	Author	Title of paper	Major contribution
1997	Burmeister et al.	Application of multi-agent systems in traffic and transportation	Describes the use of multi-agent systems in traffic and transportation and new architecture called BDI architecture was introduced to handle the complex traffic and makes the traffic management systems more effective.

2.2 MABS in Collision Avoidance

Vehicle collisions on the road are the major factor for accidents. Research papers that are presented in this section deal with avoiding collisions on the road. Different approaches are used to avoid collisions.

2.2.1 Pre-crash systems: Gietelink et al [2004] introduce pre-crash systems to reduce the impact of collision when there is an unavoidable collision. This approach is based on real time response MABS. The authors state that sometimes unavoidable collisions may occur even if the vehicle is assissted with advanced driver systems. In that case pre-crash systems are used in order to reduce the impact of collisions.

The authors refer to previous work by Schutter [2003].

The authors state that Schutter[2003] discusses the usage of VEHIL concept in intelligent vehicles and gives detailed information of how the hardware in-the loop (VEHIL) concept deployed in pre-crash systems and that simplifies the creation of pre crash systems incorporated with simulation and agent communication. The authors state that limitations of this model is it does not integrate software tools and the hardware loop.

The authors state that in order to have an efficient methodology new tools are designed to evaluate the perfrmance and reliability of pre-crash systems. The new software tool Pre crash senario analyzer (PRE-SCAN) is introduced to intelligent vehicles and it is integrated with hardware in the loop (VEHIL). The PRE-SCAN and VEHIL both are based on real-time multi agent simulation.

For evaluation of their proposed system the authors experimented with the pre-crash systems in the vehicles.The pre-crash system is equipped in one vehicle and tested on the road and makes a note that how well the vehicle responds to actual road situations in a reliable and fast manner which limits the collision factor.

According to the authors the pre-crash systems equipped vehicle drives on the road and suddenly the other vehicle creates obstacles and if there is no sufficient time for the vehicle to avoid a collision at that point of time the pre-crash systems in a vehicle activates with the help of virtual sensors in PRE-SCAN and avoids the collision to the maximum extent. The virtual sensors in PRE-SCAN are modelled in such a way that online interaction with virtual world is permitted.

The authors claim that using the concept of PRE-SCAN and VEHIL helps in devolopment and ensures more safety in intelligent vehicles. They state that the new software tool PRE-SCAN and VEHIL overcomes the limitation of VEHIL implemented in the paper Schutter [2003]. Safety is the key feature of VEHIL as the actual collision is prevented and no test drivers are expose to risk. This ensures vehicle safety.

This paper is cited by Gietelink et al [2004], Lemmen et al [2005], Gietelink et al [2006], Hannan et al [2008], Worell et al [2010]

2.2.2 Devolopment of pre-crash systems: Lemmen et al [2005] discuss the development of pre-crash systems in order to reduce vehicle collisions. The authors state that in order to make the vehicle more safe there is a need to integrate both active and passive safety restraints. The authors also state that an intelligent vehicle has to respond to every situation in dangerous traffic and able to activate the safety devices before a collision occurs. This makes the vehicle more safe.
The authors refer to previous work by Gietelink et al [2004].

The authors state that Gietelink et al [2004] introduced a pre-crash safety system which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that the pre-crash systems are effective only when there is one direction collision and relative motion of vehicles are not taken into account in pre-crash systems. The authors state that there should be a method that works effectively if there is a collision in any direction to make the vehicle more safe.

The authors state that an evaluation of pre-crash systems is done using the vehicle hardware-in-loop (VEHIL) test facility. The VEHIL laboratory enables testing of intelligent vehicles in hardware loop environment where the relative motion between the host and target vehicle is reproduced. The authors state that a radar system is modeled with the pre-scan simulation which enables the simulation of environment sensors in a virtual environment.

The authors state that a study was performed to define test scenarios for the evaluation of the system. The devolopment process is illustrated with some results. The tests were performed by considering the vehicle collision in all directions, front collision, side on collision, pedestrain or obstacle impact etc. The authors also state that pre-crash systems is modeled with pre-scan simulation tool to evaluate the pre-crash systems in a virtual environment. The authors state that a total of 74 pre crash systems were executed and verified.

The authors state that with time-to-time collision threshould at 500ms the driver can be fully retracted from their forward position to an optimal crash position. The authors also state that after the fine tunning of the system, the system passed all the tests and activates the safety measures in vehicles (airbags) only when it is required to do so and well in time.

The authors claim that the repeatability and accuracy of VEHIL test setup has been improved and braking systems are accurate. They also state that the system has passed all the tests like activating

seat belts, braking system etc. The authors claim that by introducing the radar sensor model the reliability and repeatability of pre-crash systems has achieved in an effective manner.

There are no specific references to this paper by other papers in the bibilography

2.2.3 Advanced Driver Assistance Systems (ADAS): Gietelink et al [2006] discuss the development of advance driver assistance systems in vehicles which are used in reducing the collision of vehicles. The author state that improving the vehicle safety is the best way to avoid accidents. Exsisting methods such as advance driver assistance systems need to be more reliable in terms of validation phase in intelligent vehicles. This makes the vehicle more safe by avoiding collisions.

The authors refer to previous work by Gietelink et al [2004].

Gietelink et al [2004] introduced a pre-crash safety systems which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that Gietelink et al [2004] has not taken the front collision warning system in to account and the pre-crash systems are very costly and hard to implement.

The authors state that vehicle collision is the main factor that effects vehicle safety. In order to limit vehicle collision new methods are to be implemented which are cheaper and more reliable. The authors also state that by reducing the vehicle collision we can ensure vehicle safety.The authors propose a new method for the design and evaluation of advanced driver assisstance systems (ADA'S). Hardware in loop (VEHIL) simulations in vehicle devolops the process and the validation phase of intelligent vehicles is carried out in more specific manner. The authors also present a method for forward collision warning of a vehicle. It is a collision warning system which is activated before a collision is expected. A warning is issued to the driver when a threshold of maximum acceleration is excedeed and thus avoids the front on collision.

For evaluation of their proposed new design a full scale ADAS equipped vehicle was set up in a hardware loop environment where a chasis dynometer is used to emaluate the road interacs to represent the other traffic. In this controlled environment the performance dependability of an advanced driver assisstance systems was tested with great accuracy. The working principle of forward collision warning (FCW) was also demonstrated .

The authors state that the Adaptive Crusine Control (ACC) system is an added value in VEHIL in identifing the requirement and capabilities for safety critical traffic scenarios. The front warning collision system is activated shortly before a collision occurs and sends the information well in time and in a fast manner.

The authors claim that they present a new VEHIL concept for testing ADAS where real intelligent vehicles are operated in VEHIL environment. They claim that the test results for ACC and FCW is demonstrated and VEHIL is an added value in several phases of devolopment process. They also claims that the ACC and FCW are demonstrated in closed loop environment which reduces the collision a vehicle and ensures vehicle safety.

There are no specific references to this paper by other papers in the bibilography

2.2.4 Testing Advanced Driver Assistance Systems in Fault Management: Gietelink et al [2004] discuss the testing of advance driver assistance systems in vehicles which are used in reduction of vehicle collisions and ensuring vehicle safety. The authors state that the vehicle collision is the main factor that effects the vehicle safety. In order to limit the vehicle collision new methods are to be implemented which are cheaper and more reliable. The author also state that by reducing the vehicle collision we can ensure vehicle safety.

The authors refer to previous work by Gietelink et al [2004]

The authors state that Gietelink et al [2004] has introduced a pre-crash safety systems which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that the pre-crash systems provides safety to vehicles by reducing the impact of collision but it doest not completely avoids the collision. The author state that using of ADAS makes the vehicle more safe and reliable.

The authors state that in order to limit the vehicle collision new methods are to be implemented which are cheaper and more reliable. For this purpose they have devoloped a vehicle hardware in loop (VEHIL) facility. They also state that this VEHIL relies on multi-agent real time simulation environment in which the vehicles the infrastructure and their interactions are simulated. The authors also presents the basic schema of fault management system design is implemented in order to validate ADA'S.

The authors state that they have conducted experiments by integrating the ADA'S system in a vehicle and relative motion of which with other vehicles are tested. The authors state that the probablistic approach is used in fault management of Adavanced Driver Assisstance systems. The author also sate that they have tested vehicle in extreme scenarios and analyzed how the vehicle responds to real time situation.

The authors state that the fault management techniques of advanced driver assisstance systems able to work efficently in real time response situation. They also state that the ADA'S is working efficiently and responding to situations in extreme conditions like collision warning, obstacle detection etc.

The authors claim that VEHIL is an addedd value in several phases of ADA'S. VEHIL also enables a better transition between other validation tools which improves the efficiency of ADA'S and its devolopment process in time and cost effective. The author also claims that their proposed suitable test program for validation of ADA'S provides safety and more reliability.

There are no specific references to this paper by other papers in the bibilography

2.2.5 Embedded ISS: Hannan et al [2008] addresses about the usage of embedded ISS in vehicles which is used to detect the front crash collision. Avoiding the front crash collisions enhances vehicle safety. The authors state that crash detection is the main problem of ensuring vehicle safety. The authors also state that vehicle crashes occurs at various speeds and modes. For that purpose there is

a need to have a crash detecting method which is able to detect the crash at any point of time and which makes the vehicle safer by avoiding collisions.

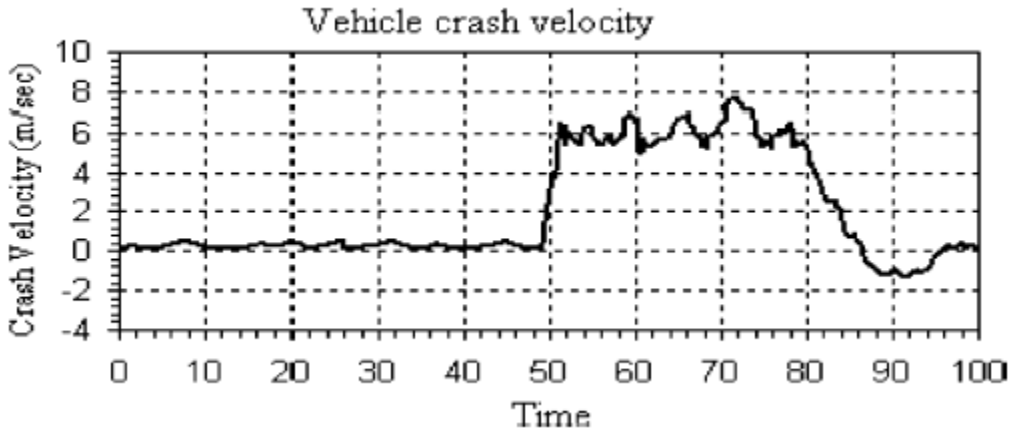
The authors refer to previous work by Gietelink et al [2004]

The authors state that Gietelink et al [2004] has introduced a pre-crash safety systems which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that the pre-crash systems (PCS) test is very critical and it is a trial and error method and it is difficult to analyze. The authors also state that the pre-crash system is time consuming and it is costly and it should be more reliable.

The authors state that detecting front crash collision of vehicles in advance and well in time is necessary in order to avoid accidents on the road. The authors also state that by limiting the front crash collision on the road ensures vehicle safety on the road.The authors states that in order to improve the crash detection procedure a crash simulator and sensing algorithm is inroduced. This sensing algorithm is embedded with ISS (intelligent safety systems). The author state that the embedded ISS gives a signal when the impact from the crash is detected. The crash generating device collects the simulated crash data using a peripheral component interconnect data acquistion card (DAQ) and charecterizes the crash being detected. The PCI DAQ consists of both hardware and software which serves as embedded ISS.

The authors state that they have implemented and analysed their proposed sensing algorithm. In order to illustrate the performace of sensing algorithm some of the results obtained from embedded systems are demonstrated. The authors also state that they implemented an embedded ISS that uses generated crash data measured by MEMS accelerometer with crash sensing algorithm that detects and monitors the vehicle crash.

The authors state that in their experiment the crash is detected only when the crash generating device hits the bumper at a velocity greater than 22.5 km/hr. They also state that as velocity of vehicle increases the reaction force also increases which in turn increases crash severity.



(Figure 5 pageno-7 from Hannan et al [2008])

The authors claim that with the devolopment of ISS a crashworthiness has been performed at low cost and it is reliable. They also state that the embedded ISS system has been devoloped in order to

ensure the front crash detection is properly adressed and it provides crash data information for the application of automative safety restraints.

There are no specific references to this paper by other papers in the bibilography

2.2.6 Reactive Multi-Agent System: Yang et al [2008] discusses about the application of reactive multi-agent based system which helps in reducing the collisions and ensures vehicle safety.The authors state that vehicle collision avoidance is promising safety approach with innovative capabilities such as obstacle detection, vehicle collision avoidance control strategy. The author also state that vehicle collision avoidance control strategy must be able to adapt all different obstacles that may occur unexpectedly. This reduces the vehicle collision problem and makes the vehicle safe.

The author do not refer to any of my selected paper as their related work.

The authors state that In order to limit the accidents on road vehicle-collision avoidance techniques have to be improved in a fast and reliable manner by generating the real time response.The authors introduce a new multi-agent system for vehicle collision avoidance. This new multi-agent system is composed of four basic components they are environment, agents, interactions and organisation of decisioin agents. Each agent is specified with its roles. The authors also state that they transformed the vehicle and it's real world in to environment in which they face the agents.

For evaluation of their proposed new multi-agent model the authors conducted an experiment by taking some attributes for the obstacle agent. The physical inspiration is used to validate some of charecteristics of multi-agent model. The connecting components can automatically connect to sensors installed on vehicle by TCP/IP in order to acquire some information like size, speed, mass of obstacles are present infront of vehicle.

The authors state that their reactive multi-agent system automatically calculates the speed vector and position vector of vehicle in each time according to its initial position and initial speed of the vehicle. They also state that they can find vehicle collision avoidance trajectory to control the speed and orientation of vehicle.

The authors claim that their new reactive multi-agent model is able to limit the vehicle collision by calculating the trajectories of vehicle based on decision process of reactive multi-agent system. They also state that their new multi-agent system has charecteristics such as adaptability, flexibility, and reliability.

There are no specific references to this paper by other papers in the bibilography

2.2.7 Summary

Year	Author	Title of paper	Major contribution
2004	Gietelink et al	Pre-crash system validation with PRE-SCAN and VEHIL	Pre-crash systems were introduced to reduce the impact of collision when there is unavoidable collision.

2004	Gietelink et al	Testing advanced driver assisstance systems in Fault Management.	Pre-crash systems are analyzed in closed environment and checks the performance of adavance driver assisstance systems (ADAS).
2005	Lemmen et al	Devolopment of pre-crash systems using vehil test facility	Devoloped existing pre-crash systems and radar systems are modeled to caluculate relative motion between host and target vehicle.
2006	Gietelink et al	Devolopment of adavanced driver assisstance systems with vehicle hardware-in-the-loop simulations	Devoloped an adavance driver assisstance systems that gives warning when there is a collision
2008	Yang et al	Application of reactive multi-agent system to vehicle collision avoidance	Devoloped a new reactive multi-agent based system that limits collision avoidance of vehicles by calculating trajectories of vehicles
2008	Hannan et al	Devolopment of an embedded vehicle safety system for front crash detection	Devoloped an embedded vehicle safety system to avoid front crash detection by using crash simulator and sensing algorithm.

2.3 MABS Wireless Communication among Intelligent Vehicles

Enabling wireless communication among intelligent vehicles helps in reducing collisions. We will see some of application of MABS wireless communication system among intelligent vehicles in detail.

2.3.1 Critical Information Gathering in Vehicular-ad hoc Network (Vanet's): Kakkasageri et al [2009] discuss the use of the push-pull algorithm which is a multi-agent based system approach. By gathering the critical information among the vehicles we can improve the vehicle safety on the road.The authors state that the gathering of critical information in terms of vehicle safety such as navigation, co-operative collision avoidance, lane changing, speed limit, accident, obstacle is very difficult among the vehicles in Vanets (vehicle Ad Hoc Network). The gathering of this critical information plays a significant role in safety-related applications.

The author do not refer to any of my selected paper as their related work.

The authors propose a new new algorithm called the push-pull algorithm. This algorithm is also refered as a push-pull agency since it takes the appropriate decision on push or pull event. This agency works on the principle of a black board architecture. It consistes of several components such as Manager Agent (MA) and push-pull classification on agent and many more. This algorithm helps in gathering critical information and their probabilities of information are computed in a dynamic

manner. The push-pull algorithm is based on multi-agent based system. It is a combination of heavy weight and light weight static mobile agents.

For evaluation of their proposed algorithm the authors conducted an experiment on four different vehicles. All the four vehicles are present in the Vanet. In this experiment vehicle v1 sends critical information to another vehicle v2. By using the push-pull algorithm they show how the information is transmitted to all other vehicles (v3 and v4) in the Vanet.

The authors states that the experiment which they conducted proves that critical information from one vehicle is gathered and sent efficently to all the vehicles present in Vanets which helps in avoiding collisions.

The authors claim that their new multi-agent based push-pull algorithm reduces the congestion in the network, band width usage with minimum delay time and also that critical information is shared through all the vehicles in Vanet in a more efficient manner.

There are no specific references to this paper by other papers in the bibilography

2.3.2 Hybrid Agent Model: Xiaowei [2011] dicusses the application of wireless communications and multi-agent systems in intelligent transportation systems which helps in improving the vehicle safety on the road.The author state that improving the vehicle safety is only way to avoid accidents. The author also state that enabling wireless communication among vehicles helps in improving vehicle safety

The author does not refer to any of my selected paper as their related work.

The author state that using wireless communication and a multi-agent based system in intelligent transport systems helps in traffic control and traffic guidance which generates real time response and ensures an improvement in vehicle safety.The author state that the consultive mechanism of both traffic control and traffic guidance can collabarate with multi-objective optimization and yields good results. The author propose a new architecture called the hybrid agent model. It mainly concentrates on giving its own guidance to vehicles and response to a real time situation. The hybrid agent consists of two systems namely delibrative system and reactive subsystem agent. It is a heirarchial system based on the above two systems.

The author state that the new architecture called hybrid moedel is introduced in the inelligent vehicle and tests how well the vehicle is responding to the real time situations and tests the ability of the architecture that communicates with other agents. This new hybrid model has a capability of making the decision support system more reliable and effective.

The author states that the new hybrid agent model that is used in inelligent vehicles is not complete and can be devoloped furthur by reducing its structural complexity. This hybrid agent model can react on its own and gives real time response target. The author state that the new hybrid model can efficently communicate with other other agents

The author claims that the new architecture has a capability to give the gudiance on its own and it has an ability to communicate with the other agent. It has a charecteristic feature of real time response and decision making which reduces traffic accidents and ensures vehicle safety.

There are no specific references to this paper by other papers in the bibilography

2.3.3 Advanced Traffic Management Systems: Jin et al [2012] discuss the interaction between the connected vehicles using a multi-agent based approach which ensures the improvement of vehicle safety. The authors state that accidents are become very common sight these days. The author also state that the only way to avoid accidents is to improve vehicle safety.

The authors do not refer to any of my selected papers as their related work.

The authors state that transportation is responsible for traffic congestion. In order to reduce traffic congestion and to improve road safety and smooth traffic flow new techniques are to be implemented in an effective way ensures vehicle safety. The authors propose a new advanced traffic management system for connecting vehicles using a multi-agent based approach. They state that multi-agent based approach has a potential to solve complex real world problems. This MABS approach improve interaction efficiency using the capabilities of connected vehicles. The author also state that the vehicle agent of one vehicle communicates with other vehicle agent and avoids collisions and optimizes the driving strategies. The authors also mention that by using connected vehicle technologies this multi-agent system avoids unnecessary acceleration/deceleration when compared to present standered traffic signals.

The authors state that a virtual advanced traffic management system for connected vehicles using multi-agent based approach was created in SUMO (simulation of urban mobility) and performance of this system was evaluated and analyzed under different conditions. The authors also state that they compared the results with those from conventional traffic signal in terms of average travel time fuel consumption etc.

The authors state that the advanced traffic management approach significantly outperforms the conventional traffic signal control in terms of average travel time under different conditions. The adavanced traffic management approach uses roadway occupancies more effectively when compared to the traditional signal control method.

The authors claim that their new advanced traffic management system makes traffic flow smoothly and increases the interaction between vehicles. The authors also state that interaction between the vehicle agents is improved by which we can avoid collision of vehicles on road and ensures vehicle safety.

There are no specific references to this paper by other papers in the bibilography

2.3.4 Summary

Year	Author	Title of paper	Major Contribution
2009	Kakkasgeri and Manvi	Push-pull based critical information gathering in VANETs:Multi agent system based approach	Enabled the wireless communication between the vehicles and able to gather and sent the critical information from one vehicle to other vehicles present in VANET.

2011	Xiaowei	The application of wireless communications and Multi-agent system in intelligent transport systems	New hybrid agent model was proposed which has a capability to give the guidance on its own and it has an ability to communicate with other agents.
2012	Jin et al	Advanced interaction manage ment for connected vehicles using multi-agent systems based approach	New advanced traffic management system was introduced that makes the traffic flow smmothly and increases the interaction between the vehicles by which we can ensure vehicle safety.

Citations

PAPER	CITED BY
Gietelink et al 2004	Gietelink et al 2004, Lemmen et al 2005, Gietelink et al 2006, Hannan et al 2008, Worell et al 2010.
Burmeister et al 1997	Xiawei 2012.

3.CONCLUDING COMMENTS

This survey mainly focuses on the problem of how to improve vehicle safety using a MABS approach. Several research attempts have been made to have an efficent system that avoids accidents and that system should be easy to implement and cost effective.

It is observed that Gietelink and his team are working more significantly in this area. Gietelink et al [2004] introduced pre-crash systems. These pre-crash systems can be incorporated in intelligent vehicles and activate safety devices to reduce crash severity. But this method is difficult to analyze. Later Lemmen et al [2005] devoloped pre-crash systems which calculate the relative motion between the host and target vehicle.

Several attempts have been made to avoid collisions on the road. Yang sibo et al [2008] introduced re-active multi-agent system that can avoid collisions and in 2008 Hannan et al [2008] developed an embedded ISS for front crash detection. The advance driver assistance systems (ADAS) were developed by Gietelink [2006] to avoid collisions on the road.

Next Kakkasgeri and Manvi [2009] introduced MABS wireless communication among the intelligent vehicles. Communication among the vehicles helps in improving the vehicle safety. Later Xiaowei [2011] and Jin et al [2012] has improved the application of wireless communication in vehicles.

It is intresting that most of my ten selected papers refers to Gietelink et al [2004]. As mentioned earlier Gietelink and his team are working more significantly in this area. Most of the applications that present now are very costly and difficuilt to implement. However, there is a need to improve the present safety applications in order make the vehicles more safe.

In future the PRE-SCAN libraries are continuosly updated with new senarios, sensor models, vehicle models and there is a need to optimize configuration parameters of multi-agent model in order to adapt different kind of obstacles. The use of MABS in VANET's provides flexibility adapatability which helps in improving communication among intelligent vehicles and provides good services with in next generation of VANETs environment.

MABS is a hot problem in artificial intelligence re-search and it is important branch in Distributed Artificial Intelligence (DAI). The goal of MABS is to construct large and complex systems (software and hardware systems) to a small systems that communicates and co-ordinates with each other and provides easy management system.

4) ACKNOWLEDGEMENT

I have the honour to acknowledge the knowledge and support I received from Dr.Richard Frost throughout this survey. I convey my deep regards to my supervisor Dr. Ziad Kobti for encouraging me and helping me unconditioanally. I would also like to thank my friends for providing me immense strength and support in completeing this survey.

5) ANNOTATIONS:

5.1 Burmeister et al 1997

Citation:

BURMEISTER, B., HADDADI, A., AND MATYLIS, G. 1997. Application of multi-agent systems in traffic and transportation. *IEE Proceedings - Software Engineering 144*, 1, 51.

Problem: The authors state that the control of traffic and transportaion is very tough task to handle. The authors also state that better manage of traffic flow enhances vehicle safety .

Previous work: The authors do not refer to any of my selected paper as their related work.

Shortcomings of previous work: No shortcommings of previous work were mentioned by the authors.

New Idea/Algorithm/Architecture: The authors state that the use of agent-oreinted techniques reduces the handling of complex traffic in an effective way and ensures vehicle safety.The authors propose a new architecture called the BDI architecture. It is a meta-level control mechanisim for

practical reasoning. The authors also inroduce the COSY architecture. This architecture consists of five top-level modules they are actuators, sensors, motivation, communication, congnition . The BDI architecture is underlying principle in the COSY architecture.

*Experiments conducted:*The authors state that by using the COSY architecture they made some state changes over the agents that are interacting with other agents. They monitored the agent behaviour by using the COSY architecture and different stage changes in each agent was noticed. They also state that different protocols were used in crash scenario analysis.

Results: The authors states that by using their COSY architecture individual behaviour of each agent is observed. The authors also state that the protocols worked well and the simulation component in proposed COSY architecture sucessfully simultes the motivation, sensors, actuators communication and environment by models for each application which provides fair results in terms of behaviour of agents.

Claims: The authors claim that their new agent oriented techniques provides a new approach to software devolopment. They also state that AOT's (agent oriented techniques) reduces the complexity in system design by making available abstraction that lend themselves to a more natural way of modelling system. AOT's techniques makes traffic and transportation more efficient and improves safety.

Citation by others: Xiawei [2012]

5.2 Gietelink et al 2004

Citation:

GIETELINK, O.J., LABIBES, K., VERBURG, D.J., AND OOSTENDORP, A. F. 2004. Pre-crash system validation with PRESCAN and VEHIL. *IEEE Intelligent Vehicles Symposium, 2004*, 913–918.

*Problem:*The authors state that sometimes unavoidable collisions may occur even if the vehicle is assissted with advance driver systems. In that case pre-crash systems are used in order to reduce the impact of collisions.The authors state that reducing the collisions of vehicles on the road enhances the vehicle safety.

*Previous work:*The authors refer to previous work by Schutter [2003].

*Shortcomings of previous work:*Schutter [2003] discusses the usage of VEHIL concept in intelligent vehicles and gives detailed information of how the hardware in-the loop (VEHIL) concept deployed in pre-crash systems and that simplifies the creation of pre crash systems incorporated with simulation and agent communication. The authors state that limitations of this model is that it does not integrate software tools and the hardware loop.

*New Idea/Algorithm/Architecture:*The authors states that in order to have an efficient methodology the new tools are designed to evaluate the perfrmance and reliability of pre-crash systems. The new software tool Pre crash senario analyzer (PRE-SCAN) is introduced to intelligent vehicles and it is integrated with hardware in the loop (VEHIL). The PRE-SCAN and VEHIL both are based on real-time multi agent simulation.

*Experiments conducted:*The authors state that they experimented with the pre-crash systems in the vehicles.The pre-crash system is equipped in one vehicle and tests on the road and makes a note that how well the vehicle responds to actual road situations in a reliable and fast manner which limits the collision factor.

Results: According to authors the pre-crash systems equipped vehicle drives on the road and suddenly the other vehicle create obstacles and if there is no sufficient time for the vehicle to avoid a collision at that point of time the pre-crash systems in a vehicle activates with the help of virtual sensors in PRE-SCAN and avoids the collision to maximum extent. The virtual sensors in PRE-SCAN are modelled in such a way that online interaction with virtual world is permitted.

*Claims:*The authors claim that the using the concept of PRE-SCAN and VEHIL helps in devolopment and ensures more safety in intelligent vehicles. They state that the new software tool PRE-SCAN and VEHIL overcomes the limitation of VEHIL implemented in the paper Schutter [2003]. Safety is the key feature of VEHIL as the actual collision is prevented and no test drivers are expose to risk. This ensures vehicle safety.

Citations by others: Gietelink et al [2004], Lemmen et al [2005], Gietelink et al [2006], Hannan et al [2008] Worell et al [2010].

5.3 Gietelink et al 2004

Citation:

GIETELINK, O., PLOEG, J., DE SCHUTTER, B., AND VERHAEGEN, M. 2004. Testing advanced driver assistance systems for fault management with vehil test facility. *In Proceedings of the 7th International Symposium on Advanced Vehicle Control (2004*),579-584.

*Problem:*The authors state that the vehicle collision is the main factor that effects the vehicle safety. In order to limit the vehicle collision new methods are to be implemented which are cheaper and more reliable. The author also state that by reducing the vehicle collision we can ensure vehicle safety.

Previous work: The authors refer to previous work by Gietelink et al [2004]

Shortcomings of previous work: The author state that Gietelink et al [2004] has introduced a pre-crash safety systems which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that the pre-crash systems provides safety to vehicles by reducing the impact of collision but it doest not completely avoids the collision. The author state that using of ADAS makes the vehicle more safe and reliable.

New Idea/Algorithm/Architecture: The authors state that In order to limit the vehicle collision new methods are to be implemented which are cheaper and more reliable.The authors propose a new method for the design and evaluation of advanced driver assisstance systems(ADAS). For this purpose they have devoloped a vehicle hardware in loop (VEHIL) facility. They also state that this VEHIL relies on multi-agent real time simulation environment in which the vehicles the infrastructure and their interactions are simulated. The authors also presents the basic schema of fault management system design is implemented in order to validate ADAS.

*Experiments conducted:*The author state that they have conducted experiments by integrating the ADAS system in a vehicle and relative motion of which with other vehicles are tested. The author state that the probablistic approach is used in fault management of Adavanced driver assisstance systems. The author also sate that they have tested vehicle in extreme scenarios and analyzed how the vehicle responds to real time situation.

*Results:*The authors states that the fault management techniques of advanced driver assisstance systems able to work efficently in real time response situation. They also state that the ADAS is working efficiently and responding to situations in extreme conditions like collision warning, obstacle detection etc.

*Claims:*The authors claim that VEHIL is an addedd value in several phases of ADAS. VEHIL also enables a better transition between other validation tools which improves the efficiency of ADAs and its devolopment process in time and cost effective. The author also claims that their proposed suitable test program for validation of ADAS provides safety and more reliability.

5.4 Gietelink et al 2006

Citation:

GIETELINK, O., PLOEG, J., DE SCHUTTER, B., AND VERHAEGEN, M. 2006. Development of advanced driver assistance systems with vehicle hardware-in-the-loop simulations. *Vehicle System Dynamics 44*, 7, 569–590.

Problem: The author state that improving the vehicle safety is the best way to avoid accidents. Exsisting methods such as advance driver assisstance systems needs to be more reliable in terms of validation phase in intelligent vehicles. This makes the vehicle more safe by avoiding collisions.

Previous work: The authors refer to previous work by Gietelink et al [2004]

Shortcomings of previous work: Gietelink et al [2004] has introduced a pre-crash safety systems which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that the Gietelink et al [2004] has not taken the front collision warning system in to account and the pre-crash systems are very cost and hard to implement.

New Idea/Algorithm/Architecture The authors state that the vehicle collision is the main factor that effects the vehicle safety. In order to limit the vehicle collision new methods are to be implemented which are cheaper and more reliable. The author also state that by reducing the vehicle collision we can ensure vehicle safety.The authors propose a new method for the design and evaluation of advanced driver assisstance systems (ADA'S). The hardware in loop (VEHIL) simulations in vehicle devolops the process and the validation phase of intelligent vehicles is carried out in more specific manner. The authors also present a method for forward collision warning of vehicle. It is a collision warning system which is activated before a collision is expected. A warning is issued to driver when a threshold of maximum acceleration is excedeed and thus avoids the front on collision.

*Experiments conducted:*For evaluation of their proposed new design a full scale ADA'S equipped vehicle is set up in a hardware loop environment where a chasis dynometer is used to emaluate the road interaction and robot vehicles to represent the other traffic. In this controlled environment the performance dependability of an advanced driver assisstance systems was tested with great accuracy and reliability. The working principle of forward collision warning (FCW) was demonstrated with some test results.

*Results:*The authors states that the Adaptive crusine control (ACC) system is an added value in VEHIL in identifing the requirement and capabilities for safety critical traffic scenarios. The front warning collision system is activated shortly before a collision occurs and sends the information well in time and fast manner.

*Claims:*The authors claim that they present a new VEHIL concept for testing ADA'S where real intelligent vehicles are operated in VEHIL environment. They claim that the test results for ACC and FCW is demonstrated and VEHIL is an added value in several phases of devolopment process. They also claims that the ACC and FCW are demonstrated in closed loop environment which reduces the collision a vehicle and ensures vehicle safety.

5.5 Hannan.MA et al 2008

Citation:

HANNAN, M. A., HUSSAIN, A., MOHAMED, A., AND SAMAD, S. A. 2008. Development of an embedded vehicle safety system for frontal crash detection. *International Journal of Crashworthiness 13*, 5, 579–587.

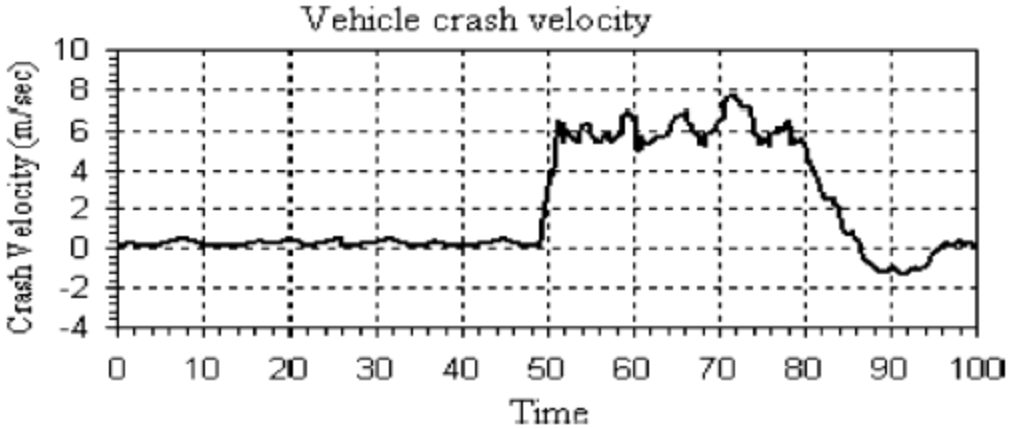
Problem: The authors state that crash detection is the main problem of ensuring vehicle safety. The authors also state that vehicle crashes occurs at various speeds and modes. For that purpose there is a need to have a crash detecting method which is able to detect the crash at any point of time and which makes the vehicle safer by avoiding collisions.
*Previous work:*The authors refer to previous work by Gietelink et al [2004]

Shortcomings of previous work: Gietelink et al [2004] has introduced a pre-crash safety systems which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that the pre-crash systems (PCS) test is very critical and it is a trial and error method and it is difficult to analyze. The authors also state that the pre-crash systems is time consuming and it is costly and it should be more reliable.

New Idea/Algorithm/Architecture: The authors state that detecting front crash collision of vehicles in advance and well in time is necessary in order to avoid accidents on the road. The authors also state that by limiting the front crash collision on the road ensures vehicle safety on the road.The authors states that in order to improve the crash detection procedure a crash simulator and sensing algorithm is inroduced. This sensing algorithm is embedded with ISS (intelligent safety systems). The author state that the embedded ISS gives a signal when the impact from the crash is detected. The crash generating device collects the simulated crash data using a peripheral component interconnect data acquistion card (DAQ) and charecterizes the crash being detected. The PCI DAQ consists of both hardware and software which serves as embedded ISS.

*Experiments conducted:*The authors state that they have implemented and analysed their proposed sensing algorithm. In order to illustrate the performace of sensing algorithm some of results obtained from embedded systems are demonstrated. The authors also state that they implemented an embedded ISS that uses generated crash data measured by MEMS accelerometer with crash sensing algorithm that detects and monitors the vehicle crash.

*Results:*The authors state that in their experiment the crash is detected only when the crash generating device hits the bumper at a velocity greater than 22.5 km/hr. They also state that as velocity of vehicle increases the reaction force also increases which in turn increases crash severity.



*Claims:*The authors claim that with the devolopment of ISS a crashworthiness has been performed at low cost and it is reliable. They also state that the embedded ISS system has been devoloped in order to ensure the front crash detection is properly adressed and it provides crash data information for the application of automative safety restraints.

5.6 Jin et al 2012

Citation:

JIN, Q., WU, G., BORIBOONSOMSIN, K., AND BARTH, M. 2012. Advanced intersection management for connected vehicles using a multi-agent systems approach. *2012 IEEE Intelligent Vehicles Symposium*, 932–937.

*Problem:*The authors state that accidents are become very common sight these days. The author also state that the only way to avoid accidents is to improve vehicle safety.

*Previous work:*The authors do not refer to any of my selected papers as their related work.

*Shortcomings of previous work:*No shortcommings of previous work were mentioned by the authors.

New Idea/Algorithm/Architecture: The authors state that the transportation is responsible for traffic congestion. In order to reduce the traffic congestion and to improve road safety and smooth traffic flow new techniques are to be implemented in an effective way ensures vehicle safety.The authors propose a new advanced traffic management system for connecting vehicles using a multi-agent based approach. They state that multi-agent based approach has a potential to solve complex real world problems. This MAS approach improve interaction efficiency using the capabilities of connected vehicles. The author also state that the vehicle agent of one vehicle communicates with other vehicle agent and avoids collisions and optimizes the driving strategies. The authors also mention that by

using connected vehicle technologies this multi-agent system avoids unnecessary acceleration/deceleration when compared to present standered traffic signals.

*Experiments conducted:*The authors state that a virtual advanced traffic management system for connected vehicles using multi-agent based approach was created in SUMO (simulation of urban mobility) and performance of this system was evaluated and analyzed under different conditions. The authors also state that they compared the results with those from conventional traffic signal in terms of average travel time fuel consumption etc.

*Results:*The authors states that the advanced traffic management approach has significantly outperforms the conventional traffic signal control in terms of average travel time under different conditions. The adavanced traffic management approach uses roadway occupancies more effectively when compared to traditional signal control method.

*Claims:*The authors claim that their new advanced traffic management system makes traffic flow smoothly and increases the interaction between vehicles. The authors also state that interaction between the vehicle agents is improved by which we can avoid collision of vehicles on road and ensures vehicle safety.

5.7 Kakkasgeri and Manvi 2009

Citation:

KAKKASAGERI, M.S. AND MANVI, S.S. 2009. Push-pull based critical information gathering in VANETs: Multi agent system based approach. *2009 IEEE International Conference on Vehicular Electronics and Safety (ICVES)*, 1–6.

*Problem:*The authors state that the gathering of critical information in terms of vehicle safety such as navigation, co-operative collision avoidance, lane changing, speed limit, accident, obstacle is very difficult among the vehicles in Vanets (vehicle Ad Hoc Network). The gathering of this critical information plays a significant role in safety-related applications.

*Previous work:*The author do not refer to any of my selected paper as their related work.

*Shortcomings of previous work:*No shortcommings of previous work were mentioned by the authors.

New Idea/Algorithm/Architecture: The authors propose a new new algorithm called the push-pull algorithm. This algorithm also refered as push-pull agency since it takes the appropriate decision on push or pull event. This agency works on principle of black board architecture. It consistes of seceral components such as Manager Agent (MA) and push-pull classification on agent and many more. This algorithm helps in gathering the critical information and their probabilities of information are

computed in a dynamic manner. The push-pull algorithm is based on multi-agent based system. It is a combination of heavy weight and light weight static mobile agents.

*Experiments conducted:*For evaluation of their proposed algorithm the authors conducted an experiment on four different vehicles. All the four vehicles are present in Vanet. In this experiment vehicle v1 sends critical information to another vehicle v2. By using the push-pull algorithm they show how the information is transmitted to all other vehicles (v3 and v4) in Vanet.

*Results:*The authors states that the experiment which they conducted proves that the critical information from one vehicle is gathered and sent efficently to all the vehicles present in Vanets which helps in avoiding the collisions.

*Claims:*The authors claim that their new multi-agent based push-pull algorithm reduces the congestion in the network, band width usage with minimum delay time and also that critical information is shared through all the vehicles in Vanet in a more efficient manner.

5.8 Lemmen et al 2005

Citation:

LEMMEN,P., GIETELINK, O., SHAH, M., PARENTEAU C., KOSIAK, W.,and CASHLER, B. Development of a pre-crash system using the vehil test facility. *In 19th International Technical Conference on the Enhance Safety of Vehicles (2005),* no. 05-0322.

Problem: The authors state that in order make the vehicle more safe there is a need to integrate both active and passive safety restraints. The authors also state that an intelligent vehicle has to respond to every situation in dangerous traffic and able to activate the safety devices before a collision occurs. This makes the vehicle more safe.

Previous work: The authors refer to previous work by Gietelink et al [2004].

Shortcomings of previous work: The authors state that Gietelink et al [2004] introduced a pre-crash safety system which activates the safety devices to reduce the crash severity by implementing active safety measures before a collision occurs. The authors state that the pre-crash systems are effective only when there is one direction collision and relative motion of vehicles are not taken into account in pre-crash system. The author state that there should be a method that works effectively if there is a collision in any direction to make the vehicle more safe.

*New Idea/Algorithm/Architecture:*The authors state that an evaluation of pre-crash system is done using the vehicle hardware-in-loop (VEHIL) test facility. The VEHIL labaratory enables testing of intelligent vehicles in hardware loop environment where the relative motion between the host and

target vehicle is reproduced. The authors state that a radar system is modeled with the pre-scan simulation which enables the simulation of environment sensors in a virtual environment.

*Experiments conducted:*The authors state that a study was performed to define test scenarios for the evaluation of the system. The devolopment process is illustrated with some results. The tests were performed by considering the vehicle collision in all directions, front collision, side on collision, pedestrain or obstacle impact etc. The authors also state that pre-crash systems is modeled with pre-scan simulation tool to evaluate the pre-crash systems in virtual environment. The authors state that a total of 74 pre crash systems were executed and verified.

*Results:*The authors states that with time-to-time collision threshould at 500ms the driver can be fully retracted from its forward position to an optimal crash position. The author also state that after the fine tunning of the system, the system has passed all the tests and activates the safety measures in vehicles (airbags) only when it is required to do so and well in time.

*Claims:*The authors claim that the repeatability and accuracy of VEHIL test setup has been improved and braking systems are accurate. They also state that the system has passed all the tests like activating seat belts, braking system etc. The authors claim that by introducing the radar sensor model the reliability and repeatability of pre-crash systems has achieved in an effective manner.

5.9 Xiaowei 2011.

Citation:

XIAOWEI, W. 2011. The Application of Wireless Communications and Multi-agent System in Intelligent Transportation Systems. *Information and Management Engineering*, 2011, 391–397.

*Problem:*The author state that improving the vehicle safety is only way to avoid accidents. The author also state that enabling wireless communication among vehicles helps in improving vehicle safety

*Previous work:*The author does not refer to any of my selected paper as their related work.

*Shortcomings of previous work:*No shortcommings of previous work were mentioned by author.

New Idea/Algorithm/Architecture: The author state that using wireless communication and a multi-agent based system in intelligent transport systems helps in traffic control and traffic guidance which generates real time response and ensures an improvement in vehicle safety.The author state that the consultive mechanism of both traffic control and traffic guidance can collabarate with multi-objective optimization and yields good results. The author propose a new architecture called the hybrid agent model. It mainly concentrates on giving its own guidance to vehicles and response to a real time situation. The hybrid agent consists of two systems namely delibrative system and reactive subsystem agent. It is a heirarchial system based on the above two systems.

Experiments conducted: The author state that the new architecture called hybrid moedel is introduced in the inelligent vehicle and tests how well the vehicle is responding to the real time situations and tests the ability of the architecture that communicates with other agents. This new hybrid model has a capability of making the decision support system more reliable and effective.

*Results:*The author states that the new hybrid agent model that is used in inelligent vehicles is not complete and can be devoloped furthur by reducing its structural complexity. This hybrid agent model can react on its own and gives real time response target. The author state that the new hybrid model can efficently communicate with other other agents

*Claims:*The author claims that the new architecture has a capability to give the gudiance on its own and it has an ability to communicate with the other agent. It has a charecteristic feature of real time response and decision making which reduces traffic accidents and ensures vehicle safety.

5.10 Yang sibo et al 2008

Citation:

YANG, S., GECHTER, F., AND KOUKAM, A. 2008. Application of Reactive Multi-agent System to Vehicle Collision Avoidance. *2008 20th IEEE International Conference on Tools with Artificial Intelligence*, 197–204.

Problem: The authors state that vehicle collision avoidance is promising safety approach with innovative capabilities such as obstacle detection, vehicle collision avoidance control strategy. The author also state that vehicle collision avoidance control strategy must be able to adapt all different obstacles that may occur unexpectedly. This reduces the vehicle collision problem and makes the vehicle safe.

*Previous work:*The author do not refer to any of my selected paper as their related work.

*Shortcomings of previous work:*No shortcommings of previous work were mentioned by the authors.

New Idea/Algorithm/Architecture: The author state that In order to limit the accidents on road vehicle-collision avoidance techniques have to be improved in a fast and reliable manner by generating the real time response.The authors introduce a new multi-agent system for vehicle collision avoidance. This new multi-agent system is composed of four basic components they are environment, agents, interactions and organisation of decesioin agents. Each agents are specified with their roles. The authors state that they transformed the vehicle and it’s real world in to environment in which they face the agents.

*Experiments conducted:*For evaluation of their proposed new multi-agent model the authors conducted an experiment by taking some attributes for obstacle agent. The physical inspiration is used to validate some of charecteristics of multi-agent model. The connecting components can automatically connect to sensors installed on vehicle by TCP/IP in order to acquire some information like size, speed, mass of obstacles are present infront of vehicle.

*Results:*The authors state that their reactive multi-agent system automatically calculates the speed vector and position vector of vehicle in each time accoirding to its initial position and initial speed of the vehicle. They also state that they can able to find vehicle collision avoidance trajectory to control the speed and orientation of vehicle.

*Claims:*The authors claim that their new reactive multi-agent model is able to limit the vehicle collision by calculating the trajectories of vehicle based on decision process of reactive multi-agent system. They also state that their new multi-agent system has charecteristics such as adaptability, flexibility, and reliability.

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