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Software Safety Simulation and Failure Analysis of Adaptive Cruise Control System

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Abstract*— Over the last few years, embedded systems have been increasingly used in Safety-Critical applications where failure can have serious consequences. The design of these systems is a complex process, which is requiring the integration of common design methods both in hardware and software to fulfill functional and non-functional requirements for these safety critical applications. The embedded systems are used in different industrial sectors such as - transportation, automotive, biomedical, process control industries, nuclear and defence industries, implantable medical devices, antilock braking software used in high-end cars, smart vehicles etc. Adaptive Cruise Control System is an automotive sector. Driver Assistance System like Adaptive Cruise Control (A CC) can help to prevent accidents by reducing the workload on the driver. A radar system attached to the front of the vehicle is used to detect whether slower moving vehicles are in the ACC vehicle's path. If a slower moving vehicle is detected, the ACC system will slow the vehicle down and control the clearance, or time gap, between the ACC vehicle and the forward vehicle. If the system detects that the forward vehicle is no longer in the ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. In this paper, we have used two safety analysis methods. Those are Failure Mode and Effective Analysis (FMEA) and Fault Tree Analysis (FTA). By using these methods we have listed out the failures of the system and these listed failures have solved by using New Adaptive Cruise Control Algorithm. The Results of this Adaptive Cruise Control System has simulated using C# with Window Forms and MATLAB-Simulink.

Keywords: adaptive cruise control, safety analysis, speed control, FMEA, FTA.

I. INTRODUCTION

Embedded System is a combination of hardware and software. The performance, reliability and safety of whole system depend on quality of the software. Safety is a property of a system that it will not endanger human life or the envir onment [1]. A failure of a safety-critical system can lead to injuries and even loss of life it is extremely important to provide designers with safety assessment methods that help to minimize the risk of the occurrence of such disastrous events. There are two safety assessment methods mostly used in the safety analysis. One of the method is failure modeand effective analysis (FMEA) [2]. In FMEA, trained engineers or system designers team analyses the cause consequence relationships of component failures on system hazards. Second method is Fault tree analysis, serves as an effective method in reducing component level testing effort and also plans an effective integration and system testing.

There are many applications that have traditionally been considered safety critical but the scope of the definitionhas to be expanded as computer systems continue to be introduced into many areas that affect our lives.The future is likely to increase dramatically the number of computer systems that we consider to be safety critical [3]. The dropping cos t of hardware, the improvement in hardware quality, and other technological developments ensure that new applications will be sought in many domains. The cost of critical system failure is so high means trusted methods and techniques must be used for development. Adaptive cruise control (ACC) is an intelligent form of cruis e control that slows down and speeds up automatically to keep pace with the car in front of you. If a slower moving vehicle is detected, the ACC system will slow the vehicle down and control the clearance, or time gap, between the ACC vehicle and the forward vehicle . If the system detects that the forward vehicle is no longer in the ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. Adaptive Cruise Control is also called active cruise control, autonomous cruise control, intelligent cruise control, or radar cruise control. This is the case because distance is measured by a small radar unit behind the front grille or under the bumper. The Focus of this paper is to listout the failures of Adaptive Cruise Control (ACC)syste m using FMEA and FTA methods and listed failures are solved by using New Adaptive Cruise Control algorithm. The most critical failure parts are Radar and Speed Sensor. The Radar may fail due to the failure of electrical components, induced noise or clutter effect. The Speed Sensor may fail due to the failure of power supply to sensor system fail or crucial electrical components fail. The Results of this Adaptive Cruise Control System has simulated using C# with Window Forms and MATLAB Simulink.This paper is organized as follows: section 2 describes A daptive Cruise Control system without safety, section 3 describes simulation of Adaptive Cruise Control system using MATLAB, section 4 presents results and discussion and section 5 concludes the paper.

II. ADAPTIVE CRUISE CONTROL SYSTEM WITHOUT SAFETY

Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment. A radar system attached to the front of the vehicle is used todetec t whether slower moving vehicles are in the ACC vehicle's path [4]. If a slower moving vehicle is detected,the ACC s ystem will slow the vehicle down and control the clearance, or time gap, between the ACC vehicle and the forward ve hicle [5]. If the system detects that the forward vehicle is no longer in the ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. This operation allows the ACC vehicle to autonomously slow down and speed up with traffic without intervention from the driver [6]. The method by which the ACC vehicle's speed is controlled is via engine throttle control and limited brake operation [7].

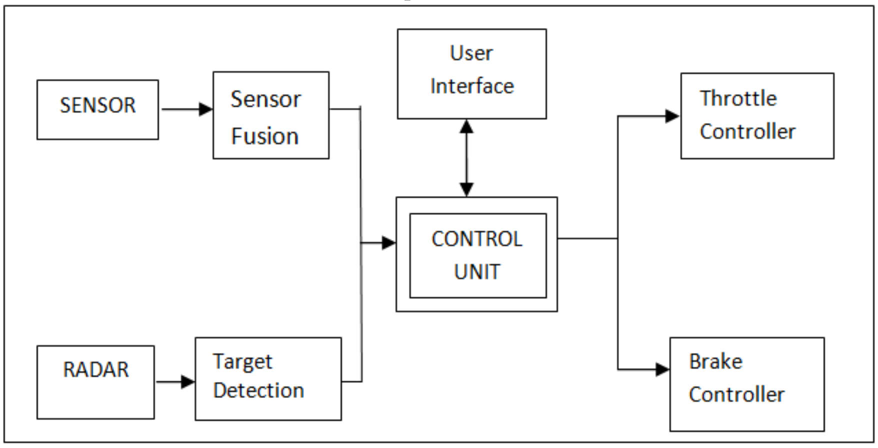

Figure 1: Architecture of Adaptive Cruise Control System

As shown in Figure 1, the crucial components of Adaptive Cruise Control system are:

Sensor: Wheel sensors are used to measure the speed of the host car and road-tire friction is also estimated. Sensors are also used to know the current position of throttle and brake.

Radar: Radar used in ACC system, must be able to detect targets of different sizes in front of the host vehicle. Radar sensor helps to identify the leading vehicles and track the most relevant vehicle [6]. It provides information such as relative velocity and distance to the Control Unit which controls the distance and velocity of the host car.

User Interface: This unit takes care of the communication to and from driver. Driver should be aware of the environment and action being taken by the ACC system. There is a strong need for systematic handling of the output to the driver from different subsystems in the car, in order to guarantee that the driver gets the relevant information at the right time through the right communication medium. Authors list driver needs and support functions in this user interface system.

Throttle: An actual adjustment of speed is done by brake and throttle actuators. They are electronically controlled components driven by the commands from Control Unit. They are controlled with low level controllers for requested acceleration by high-level controller. As Throttle cannot be operated beyond certain range, system makes use of Brake actuator beyond that range.

Control Unit: maintains up-to-date information about the environment, and determines the corresponding control commands. The strategy is determined by evaluating the cruise set speed, host vehicle speed, relative velocity, distance of leading vehicle and other factors such as human intervention, road curvature, etc [8].

III. SIMULATION OF ADAPTIVE CRUISE CONTROL SYSTEM USING MATLAB

The modeling has done by using Simulink model in C# with window forms and MATLAB. The MATLAB provides library editor for designing the input and output screens. The manual working of Adaptive Cruise Control system was simulated in window forms and MATLAB-Simulink. The manual working steps ware discussed in the algorithm and flow chart and also safety part when there is a need to bypass the signal from one sensor to another sensor was simulated in MATLAB-Simulink. This safety part of bypassing has shown in Figure 2.

A. New Adaptive Cruise Control Algorithm

START
Step1: Start the Engine
Step2: Operate the vehicle manually using the acceleration and brake pedal.
Step3: Check whether ACC is turned on.
Step4: If the ACC is turned off go to step2.
Step5: Check whether any object detection is fails or not.

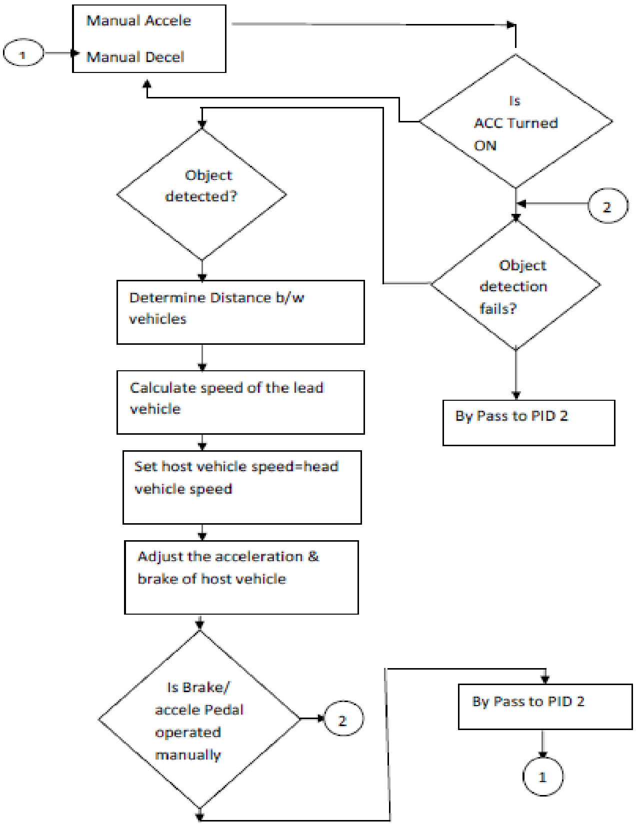

Figure 2: Flow Chart of New Adaptive Cruise Control

Step6: If object detection fails bypass the procedure to PID Controller. As shown in Figure 2.
Step7: Otherwise checks object detection fails or not.
Step8: If no object is detected that the host vehicle speed=set speed.
Step9: After the object is detected calculate the distance using the time difference technique.
Step10: Get the host vehicle speed.
Step11: Set host vehicle speed=Lead vehicle speed.
Step12: Adjust the acceleration and brake pedals in order to achieve the safe speed required.
Step13: If user manually presses the acceleration or brake pedal, then deactivate the ACC.
Step14: Display user that ACC is deactivated.
Step15: Repeat process continuously.

B. *Circuit Components*

1) Input values to the ACC system: pressure, throttle and distance (in b/w 1 to 100 meters) range values are shown in Figure 3, The Throttle value used in this paper is a constant value and distance must not be zero. The pressure is force per unit area that is applied to the pedal. Here we have given the input values to the ACC system, depending upon the input values speed will changes.

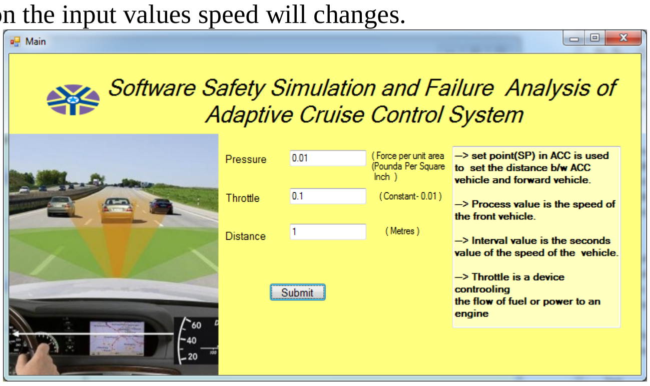

Figure 3: Input values to the Adaptive Cruise Control System

2) Adaptive Cruise Control circuit: The control enters into ACC when there is an obstacle present in front of host vehicle. Here we are going to calculate the amount of acceleration and brake required by using two external parameters as distance and speed. These input parameters have sent to controller and controller checks the distance of the lead and ACC vehicles and also it checks the throttle value. It is shown in Figure 4.

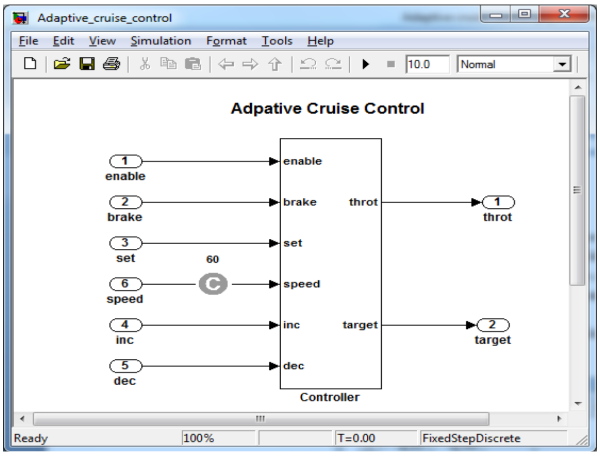

Figure 4: Adaptive Cruise Control (ACC) circuit

3) Speed Calculator: The speed calculator block calculates the speed of the lead vehicle based on the distance between the cars. It is shown in Figure 5. Here there is a need of PID controller to calculate the error value. If error value is more means distance is very near between the vehicles, the ACC system will automatically slow down the speed of the ACC vehicle.

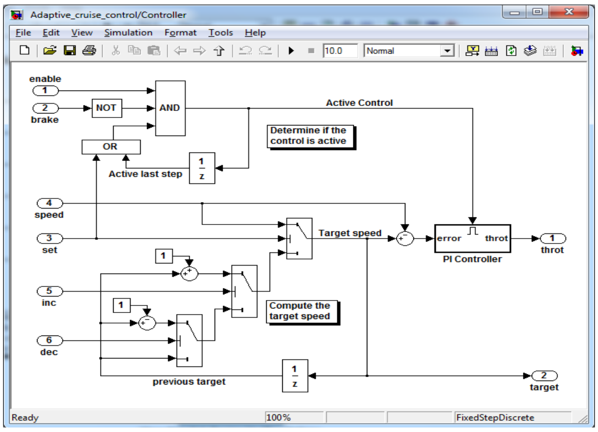

Figure 5: Speed Calculator

4) Bypassing signals from one sensor to another sensor: The Adaptive Cruise Control works by taking inputs from the surrounding vehicles and calculates speed and distance and control the vehicle. If there is failure of one sensor then the entire system may fail. So there is a need of another sensor. Figure 6 shows the bypassing of the resulted signals from one sensor to another sensor.

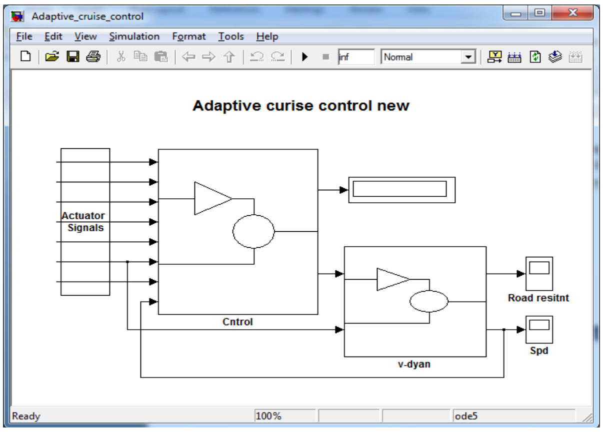

Figure 6: Bypassing of signals to another sensor

IV. RESULTS AND DISCUSSION

Figure 7 shows the map of distance between the lead vehicle and ACC vehicle. It also shows the interval value between both the vehicles. The blue color curve shows the speed of front vehicle and red color shows the speed of the ACC vehicle. Here error value means the distance between front and ACC vehicle. If error value is negative the distance between the cars are very near. If error value is above zero then there is a more distance between the vehicles. At first distance between the vehicles must be one meter. The set point is used to set the distance between the vehicles for applying the adaption of speed control.

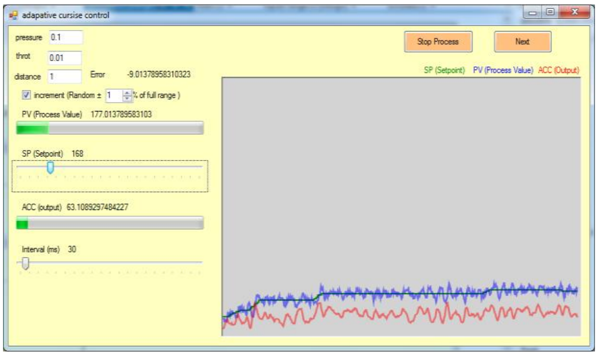

Figure 7: Simulation of Adaptive Cruise Control System using Window Form

Figure 8 shows actual and expected speed of both vehicles. If distance between both vehicles are equal means with in the range of setpoint value it shows same graph. Other wise it will give different graph values. Depending upon the speed and distance values the graph changes.

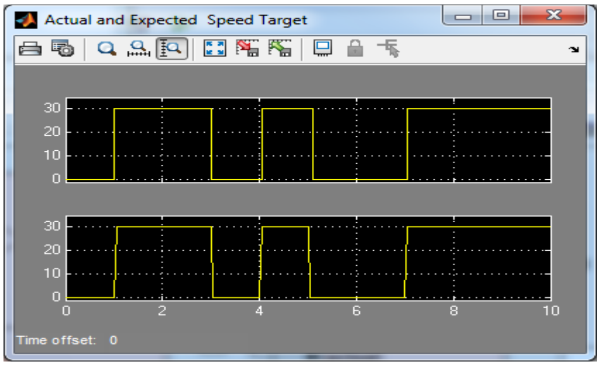

Figure 8: Actual and Expected speed of the Adaptive Cruise Control System

Figure 9 shows the scope of speed and road resistant. Depending upon the road conditions the speed may changes. If the road condition is good the vehicle goes in normal way. If the condition of the road is not good the speed may down. From the figure, it shows the variation of speed when there is a change in road condition.

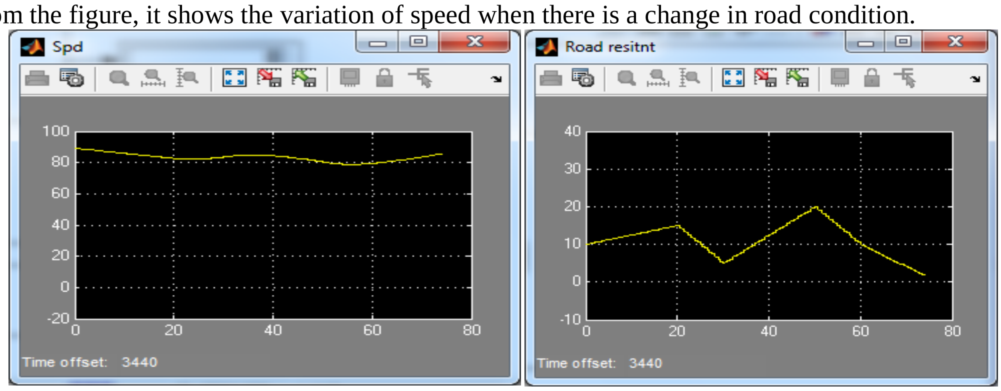

Figure 9: Scope of Speed and Road Resistant

Limitations

One of the limitations of this project is considering an input values which consists of Pressure value, throttle value and distance value which were given out of the range. In this case incorrect simulated output will be shown and also there are two important input values used in this paper those are set point value and increment value. Without adjusting of these inputs they will be a chance of getting uncorrected output. In this the efficiency of output will be generated by giving the input values within the range otherwise inefficient output will be generated.

V. CONCLUSION

Adaptive Cruise Control system was developed for the purposes of driving safety and comfort. It reduces the number of brake and switch operations that are required of the driver. As a result, the system reduces the driving burden so that the driver can drive in comfort. The effects and causes of these ACC parts were identified by using Failure Mode Effective Analysis (FMEA) and root causes of these failures were analyzed by using Fault Tree Analysis (FTA). The combined results of FMEA and FTA provide input for analysis of temporal or causal justification for prioritization of verification or validation test systematic approach from system down to subsystem. These results were giving to PID Controller, depending upon the calculation of error value, the distance has maintained between the host and front vehicle.

By using these methods we list out the failures of the system and these listed failures have solved by using New Adaptive Cruise Control Algorithm. The Results of this New Adaptive Cruise Control System has simulated using C# with Window Forms and MATLAB-Simulink. Here we experimented with only some specific input values not for all input values. There are, however, a few cases that may cause incorrect outputs occurs at the beginning of the System.We will experiment with a different input values in future work such that throttle value may be changes and also pressure value. Here we only focused on speed calculations and distance calculation with respect to time. But there are some other failures like radar failures due to radar clutter failure, noise failure and electrical component failures and weather conditions (snow, fog, rain etc).

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