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Modern Vehicles Technology –Advanced Emergency Braking System

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Abstract - Advanced Emergency Braking System (AEBS) is a software implemented on the hardware of the commercial vehicles to avoid road accidents. This new technique would bless the lives of many people that occurs due to the road accidents. The AEBS is basically a system which detects the possibility of collision with any obstacle, alerts the driver and in case no action is taken, it decelerates the vehicle. Its algorithm is used to send the warning signals to alert the driver when the probability of collision with the obstacle ahead is high in order to reduce the impact speed. In case of a truck, the collision is avoided with the help of the components of AEBS such as Wave Radar Sensor and CCD Camera.

Keywords: Road Safety, Traffic accidents, Accident avoidance, Sensor system

I. INTRODUCTION

The AEBS is the modern braking technology equipped in a vehicle along with the Adaptive Cruise Control (ACC) which basically measures and maintains the driver preset moving forward to the vehicle ahead by the automatic modulation of the engine control, and if required, automatically applies brakes up to a deceleration of 0.3g (where 'g' is the acceleration due to gravity and its value is 9.8 m/s^2). If no vehicle is ahead, the vehicle is set at a particular speed due to ACC. For the safety of road is a major issue nowadays, the safety systems have been developed keeping in mind the augmentation in the number of accidents. Three categories of safety systems used to avoid accidents are:

Collision Avoidance in which a potential collision is detected by the sensors and the immediate action is taken, taking control away from the driver. The vehicle can be brought to a standstill before the collision by applying emergency braking.

Collision Mitigation Braking Systems in which sensors detect a potential collision but no immediate action is taken to avoid it. Once it is detected that the collision is unavoidable, the emergency braking is automatically applied to reduce the collision speed and severe injuries.

Forward Collision Warning in which sensors detect a potential collision and the action is taken to warn the driver [1].

In order to determine how much safety impact of the AEBS is, a safety index is needed which results in simulation and analysis leading to the enhancement of the vehicle's safety in the dangerous driving situation which can lead to the destructive accidents. The goal of the research is developing the AEBS algorithm for the commercial vehicle and the methods of evaluation of the AEBS by the safety index.

The control algorithm of AEBS comprises of two parts. First, is the Obstacle Detection Part and second is the Main Controller Part. The Obstacle Detection Part measures and collects the front obstacle information for the main controller's decision. The two stages for the main controller are upper and lower level controller. The collected obstacle information is used for deciding the control mode by the upper level controller and the warning and braking level by the lower level controller to maintain the safety. When the deceleration is calculated by the control algorithm, the brake pressure is generated by the braking part.

To formulate the safety level, Longitudinal Safety Index is derived by a warning index and an inverse Time-To- Collision (TTC^{-1}). Also, the Total-Warning-Time (TWT) and Total Longitudinal Safety Value (TLV) are defined.

II. SAFETY INDEXES FOR DEVELOPMENT OF THE AEBS ALGORITHM

Several authors have derived safety indexes for the evaluation of vehicle's safety systems. The parameters in Adaptive Cruise Control (ACC) system and Collision Warning/Collision Avoidance Systems are:

1. TTC (Time-To-Collision, defined as the time left to a collision)

$$TTC^{-1} = \frac{v_{rel}}{p_{dist}} \quad (1)$$

where v_{rel} is the relative velocity between the subject vehicle and the preceding vehicle and p_{dist} is the longitudinal vehicle spacing for the subject's driving direction.

2. Warning index

The Warning index represents that the physical collision in the current driving situation is in danger and it is formulated as:

$$x = \frac{p_{dist} - d_{br}}{d_w - d_{br}} \quad (2)$$

where d_{br} and d_w are the braking-critical and the warning-critical distances. If p_{dist} exceeds d_{br} and d_w, then the warning index is greater than unity and indicates that the current driving situation is in a safe region. If p_{dist} is below d_{br}, then the warning index is negative and the current driving situation can be dangerous.

$$d_{br} = v_{rel} \times t_d \quad (3)$$

where t_d is the time which is calculated by the radar system controller. Now d_{br} can be calculated using relative velocity and the time calculated by the radar controller.

III. TECHNICAL PERFORMANCE OF AEBS

3.1. Systems in Production Vehicles

The following refers to the characteristics of systems that were identified as being in current production vehicles. Information obtained describing the technical performance of the main components of current production collision mitigation emergency braking systems may be summarized as:

a) Sensor System

Sensor range ahead of vehicle (m): long range 100 to 200, short range 30

Horizontal field of view (°): 16, 9, ±3, 80 (short range sensor).

Vertical field of view (°): 4, ±1.5.

Sensor Scanning Rate (Hz): 10 to 25.

b) Analysis/Processing System

Collision Scenarios identified: Front to rear shunt accidents on straight roads, potentially front to rear shunt collisions on curves depending on geometry.

Obstacles recognized: All moving vehicles, including large motorcycles travelling centrally in lane, excluding two wheeled vehicles (cycles) moving in edge of lane, stationary vehicles, pedestrians not recognized.

Operative velocity range (km/h): either >10, >15, 10 to 180, or <70, if approaching stationary obstacle (depending on system).

Relative velocity between vehicle/obstacle for activation (km/h): >10 or >15.

Collision risk judgement algorithm update frequency (Hz): approximately 50.

c) Autonomous Braking

Passenger car:

Deceleration (g): 0.2 to 0.4, >0.5 >0.6, >0.8g or maximum achievable (full ABS braking) depending on surface conditions.

Brake System Reaction Time (s): 0.2, 0.2 to 0.3, 0.12 to 0.20 with pre-filled circuits.

Heavy vehicle deceleration (g): maximum achievable (full ABS braking) depending on surface conditions,

d) System deactivated when

Sensor view is blinded during periods of heavy precipitation (heavy rain, snow etc).

The sensor head is impaired because of debris build-up (dirt, snow etc).

When a system fault is detected.

e) System ineffective when

There is a sudden encounter such as a vehicle cutting immediately in front or an emerging at a junction.

Sudden acceleration is applied and the vehicle ahead is coming too close.

The distance between vehicles is extremely short.

The overlap with obstacle ahead is short.

It can be seen that the circumstances these systems are expected to be effective is quite limited. Effectively, the systems will only function fully in front to rear collisions where both vehicles are

travelling within the same lane on reasonably straight roads in good weather conditions.
Some systems are capable of functioning effectively in a wider range of collision circumstances, including head on and front to side collisions on straight roads and curves and pedestrian collisions. This was achieved using a range of different sensors (radar, camera image technology, infra-red, far infrared, laser etc)
AEBS alone would have limited abilities in collisions and junctions because of restricted line of sight and more complex situations. So that is why, vehicle to vehicle communications are added to develop the functions in this collision type.

IV. OUR PROPOSED ALGORITHM

The AEBS alorithm is developed to avoid or mitigate a real end collision of the commercial vehicle. As brought out above, the AEBS algorithm is a two step process : obstacle detection part and the main controller part [3]. The complete AEBS algorithm is shown in Fig.1 below.

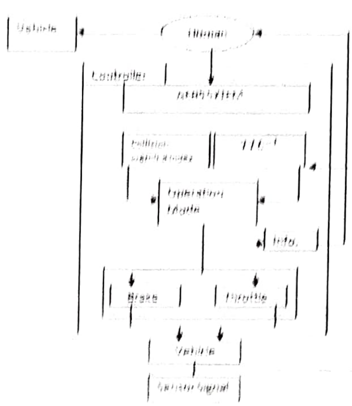

Fig 1. AEBS Algorithm Flowchart

4.1 Obstacle Detection

In the Obstacle Detection part, front obstacle information was measured and collected for the main controller's decision. Vision sensor can provide the classification of objects. However, range and speed measurements are less accurate. On the other hand, radar sensor has a high accuracy in measuring of range and speed. Therefore, these two types of sensors are used to detect the front obstacle information [2]

4.2 Main Controller

The Main Controller of AEBS algorithm consists of two control stages: upper and lower level controller.

4.2.1 Upper level controller

By using the collected obstacle information, the upper level controller of the main controller decides the control mode. To decide the control mode of the AEBS algorithm, warning index and time to collision inverse parameters are considered. In case of the warning index beyond the threshold value and the inverse Time To Collision (TTC^{-1}) below a threshold value, it indicates that the current driving situation is in a safety region. Otherwise, the current driving situation can be dangerous. Therefore, vehicles' safety level can be defined in the warning index as shown in Fig 2.

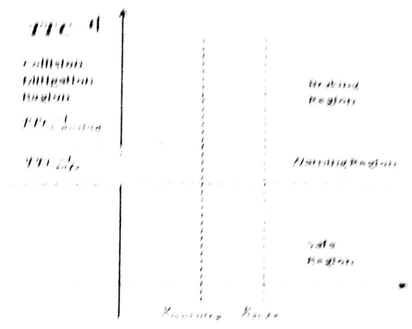

Fig 2. Safety Mode in the warning index

To divide the control model, threshold value for each parameter is set two levels: 'Safety Threshold' and 'Warning hreshold'. The Safety Threshold means the value of which driver starts feeling fear for driving situation. When the parameter near the Warning Threshold value, it means that the driver should start braking to avoid rear-end collision. By using these two levels, Threshold value of these parameters, control mode can be defined in four phases: 'Safety Region', 'Warning Region', 'Braking Region' and 'Collision Mitigation Region'. In case of the 'Braking Region' and 'Collision Mitigation Region', it is important that the assurance assessing approach whether a collision with an observed object is avoidable or not.

4.2.2 Lower Level Controller

Upper level controller decides the control mode, the lower level controller determines the warning level and the braking level to maintain the safety.

i) Warning Phase

If the vehicle isn't in the 'Safe Region', lower-level controller gives the warning signal to the driver. The warning level is classified in two levels. When the driving state is in 'Warning Region', the first level of warning starts running. If the driving state is in 'Braking Region' or 'Collision Mitigation Region', the second level warning is operated.

2. Braking Phase:

If the vehicle is in 'Braking Region' or 'Collision Mitigation Region', inspite of the driver does not give a braking instruction, autonomous braking is necessary until the vehicle's control mode returns to 'Safety Region'. The braking system is shown in Fig.3.

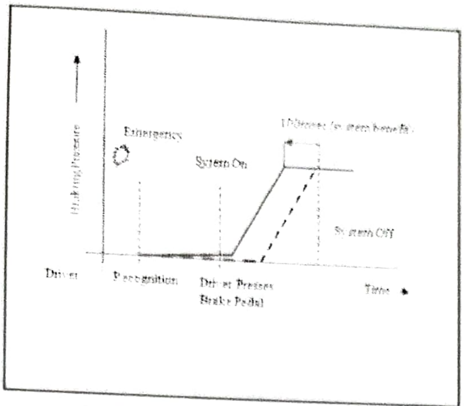

Fig 3. Brake system reaction

Also when the driver gives a brake instruction/action, the driver's braking intention should influence to the AEBS braking level. Therefore, the braking level of the AEBS algorithm are based on the control mode and braking instruction.

In case of 'Braking Region', the lower-level controller gives first level brake operation. When the lower level controller decides the collision mitigation region, the second level brake starts operating. Only if collision mitigation mode is decided and driver's braking instruction is in operation, the full braking action is triggered.

V. PHASES OF COLLISION MITIGATION IN AEBS

There are four phases in the collision mitigation systems. These phases are Normal Driving Phase, Preparation Phase, Braking Phase and Post-Collision Braking Phase as shown in [4].

The vehicle first enters the Normal Driving Phase in which the vehicle is normally moving ahead with a particular speed without any emergency situation and hence there is no need of the AEBS operation to happen in this phase.

Next is the Preparation Phase. In this phase, there are two cases after coming out of the normal driving phase, i.e. collision likely and collision unavoidable. Before the collision likely phase, the Time To Collision (TTC) is calculated. After the collision likely phase, the collision warning is sent to the driver and the system and they get prepared for reacting to the emergency situation and thus the vehicle enters the safety margin situation.

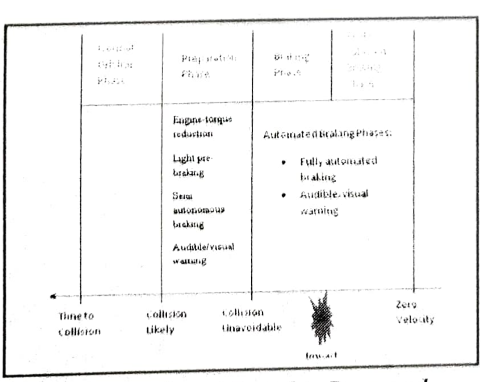

Fig 4. Collision Mitigation Phases

At the end, when it appears that the collision is unavoidable, the vehicle enters the automated braking phase, i.e. the fully automated phase and the audible/visual warning. And once the impact occurs, the vehicle is finally at standstill with the zero velocity.

VI. CONCLUSIONS

In this paper, the AEBS algorithm for the commercial vehicles is proposed. The proposed AEBS algorithm consists of obstacle detection part and the main controller part. In the obstacle detection part, front obstacle information is measured by the vision sensor and the radar sensor. The main controller of the AEBS algorithm is composed of two control stages, upper and lower level controller. The upper level controller decides the control mode based on collected obstacle information and the lower level controller determines warning level and braking level to avoid the collision.

Finally, closed loop simulation is conducted to demonstrate the proposed algorithm by using vehicle model and sensor model. From the simulation result and analysis, it is shown that proposed AEBS algorithm can enhance the commercial vehicles' safety in the dangerous driving situation which can occur in rear-end collision.

Also, AEBS, in production, mitigate two vehicle shunt accidents as well as some collisions with fixed objects and motorcycles with the help of ACC (Adaptive Cruise Control) and forward collision warning systems. Substantial difficulties have been encountered in trying to define the benefits of AEBS in terms of casualty reduction. It is not possible to establish detailed and accurate estimates of the costs of system because of commercial sensitivity. AEBS is highly likely to be a very effective measure in saving the innocent lives.

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