System Interface of an Integrated ISS for Vehicle Application

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Abstract. This paper deals with the system interface of the integrated intelligent safety system that involves the vehicle applications of airbag deployment decision system (ADDS) and tire pressure monitoring system (TPMS). Lab Window/CVI in C interface program is developed for prototype implementation. The prototype implementation is the interconnection between the hardware objects of the intelligent safety devices such as load cell, Logitech web-camera, Cross-bow accelerometer, TPM module and receiver module, data acquisition card, CPU card and touch screen. Integration of several safety subsystems decision such as the image processing module, weight sensing module and the crash detection module are fused for intelligent ADDS. The integrated safety system also monitors the tire pressure and temperature and analyze the TPMS data for tire condition classification. The system interface developed the integrated system prototype performance that is evaluated through several test runs. Their result proven the embedded intelligent safety system is unique, robust and intelligent for vehicle safety application.

1 Introduction

The term “intelligent safety” does not literally mean that intelligence resides inside the vehicle. The “intelligence” implies here as an active essential part of the vehicle that contribute to safety, security and driving comfort. Intelligent safety system provides operation to ensure the safety and comfort level of the occupant in the vehicle [1]. However, due to occupant expectation of high level of control and safety, a large number of individual safety systems are needed [2]. This increased concern for safety issues has resulted to design accurate integrated intelligent safety system that involves features technologies, characteristic of safety issues and providing solutions by monitoring, detecting, classifying, impending crash or unsafe driving conditions, warning the driver, improving his or her ability to control the vehicle and prevent the accident [3].

Many individual researches have been focused on the safety issues such as occupant detection, classification and position, vehicle crash detection and its severity analysis, TPMS etc. For example, occupant detection and characterization are the fundamental importance [4] to improve the safety and comfort features of the

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occupants. However, it is a difficult task, despite the success of some of these systems, the occupant detection such as human, non-human object and its classification still pose a number of challenges with respect to real time implementation and operation [5].

The vehicle crash detection is very helpful for preventative safety, preventing accidents and collision for minimizing human injury when an accident occurs [6]. However, in past it has been a rather seldom discussed on research and theoretical analysis of crash in the field of traditional engineering [7]. It is therefore NHTSA and other safety concern made rule that vehicle crash detection and analysis are mandatory for safety issue [8].

Similarly, the safety issue on TPMS is a significant factor in the driving experience and vehicle performance [9]. Accordingly, the NHTSA made a legislation known as the TREAD act in which after 31 October 2006, all vehicles in United States should have the option of TPMS [10].

The system interface for the prototype implementation of intelligent safety system is the most important. It is therefore, this paper pursue the interface program that are used for the development of an innovative integrated intelligent safety system to identify major hazards and assess the associated risks in an acceptable way in various environments where such traditional tools cannot be effectively or efficiently applied. The safety device provides data to the intelligent safety system that is useful for the development of ADDS and TPMS. The objective of this paper are met by integrating and developing the advance solution of the innovative safety issues likewise occupant detection, classification and position, vehicle crash detection and its severity analysis, TPMS and other detrimental issues.

2 System Integration

There are a number of limitations with the conventional architecture of the vehicles intelligent safety systems. The safety measures are challenging and increasing awareness of the automotive companies, due to customer expectation of high level of control and safety. However, because of the wide variety of individual safety system, it needs a large library of programs and much expensive individual platforms. This wide variety of safety is continuous increasing the complexity that would lead to a physical maximum and interdependence between the systems. So as to extract the most of the individual demands, the platform need to be integrated, addressed a robust algorithm and calibration process to optimized and validate the vehicle integrated safety system. The principle motivation behind the system integration is to reduce individual systems safety device management cost in the performance domain. The integrated intelligent safety system aims to provide heterogeneous workload management concepts and functions to the safety issues and validate them based on performance diagnosis of collected monitoring data in a developed platform.

The intelligent vehicle safety platform identifies the hardware and software execution environment of a system. The hardware platform identifies a set of hardware objects associated with processors. The system interface provides a high level of interface between software objects running on different processors that control the hardware. The proposed integrated safety system deals with the safety and comfort issues in the modern vehicle such as TPMS, occupant detection, detection and position and vehicle crash detection. This integrated safety system gathers data through a set of sensors, collected the data through acquisition processes and eventually reacts through a CPU and finally, safety issues are monitored in a LCD display unit.

3 Method and Algorithm

We have developed the algorithms for ADDS and TPMS. In ADDS, we have developed the individual algorithms for occupant detection, classification and position based on weight sensing and image process as well as for vehicle crash detection. In weight sensing, in order to classify, the weight measurement data are used with logic combination. We consider that less than 10 kg as a non-human object, while the child setting is ‘10 kg<child<35’ and the adult setting is 35kg<adult<100kg. For example, when an adult occupant is on the seat, the adult logic is true, and child and non-human object logics are false, which the dynamic output classifies as adult and displays its decision on the monitor. In position detection, we have calculated the centroidal distance Fx and Fy are as follows.

$$Fx = x\frac{(-F1 + F2 - F3 + F4)}{(F1 + F2 + F3 + F4)} \quad (1)$$

$$Fy = y\frac{(F1 + F2 - F3 - F4)}{(F1 + F2 + F3 + F4)} \quad (2)$$

where F1, F2, F3 and F4 are weight forces of the four sensors, while x and y are the distances from the centre to the sensor in x and y directions, respectively. These calculations of Fx and Fy provide the appropriate position of the occupant.

In image processing, the algorithmic approach for detection and classification of occupant, non-human object and non-object as shown in Fig. 1. The proposed system is functioned with the combination of fast neural network (FNN) and classical neural network (CNN), in which the FNN is trying to extract any positive detection including false detection. Post-processing strategies are applied to converts normalized outputs and for adjusting intensity histogram equalization or lighting correction function are also applied to solve false detection. The output of FNN is then feed to CNN to verify which region is indeed the system detection. This proposed combined network is quite robust on detecting accuracy and computation efficiency rather than single network, which is unable to fully eliminate false detection problem.

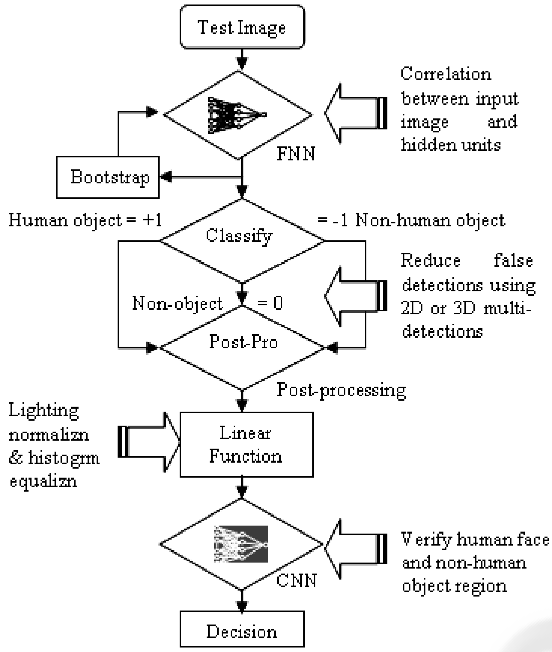

Fig. 1. Neural network algorithm for the occupancy detection.

This variable, Δv(t) is an essential parameter for crash detection that can be found in the algorithms development. The change in vehicle velocity, Δv(t) is obtained by computing the integration of the acceleration signal [hannan elsevier] as shown in below.

$$\Delta v(t) = \int a(t)dt = -A\omega^2 \int \cos(\omega t + \delta) \quad (3)$$

Selecting a threshold value of the vehicle velocity, V_{th}, is therefore required to facilitate the decision making of whether or not an effective crash has occurred. Such threshold V_{th} value can easily be determined from the lowest speed of an effective crash defined by NHTSA i.e. 22.54 km/h. In order to detect crash, the developed algorithmic steps are as follows,

i) If $\Delta v(t) \geq V_{th}$, then output ='1'; DECISION: Effective crash is detected.

ii) If $\Delta v(t) < V_{th}$, then output ='0'; DECISION: Effective crash is not detected.

An increase in vehicle speed during crash increases the crash severity factor. The change of velocity, Δv(t), over a period of time, T, at the detection state can be computed since the integral over the noise component is approximately zero. The circuit for computing Δv(t) can be designed using systolic architecture to achieve the real-time speed. The output of the detection state is fed into a data acquisition card for system development.

In TPMS methodology, there are two ways to acquire data from the sensor likewise, using a successive approximation algorithm or by a threshold check. A successive approximation provides an accurate conversion of the sampled temperature or pressure reading into an 8-bit value. In the threshold check, the DAR is preloaded with a threshold value during standby/reset mode to detect whether the pressure or temperature has crossed a particular level. The receiver module is capable of receiving both OOK and FSK through UHF receiver that communicates with the CPU by a SPI. The UHF receiver detects and demodulate the signal through Manchester-encoded bit stream, sending out the important data to the CPU that is monitor in the display unit. The TPM and receiver module is loaded with a simple software program to effective the functionality of the hardware. The assemble code for TPM tire module is written using the "WIN IDE" integrated development environment and programmed into RF2 through the programmer board that transmitted data to the receiver module. Receiver module communicates with the UHF receiver using the Turbo C Borland C compiler run under DOS. A function "TPMReceiverModule" created in the main interface program is called in UKM.dll to monitor pressure and temperature that is extracted from TPM receiver through SPI connection to CPU.

4 Prototype Structure

The hardware prototype is a vital representation of final design of integrated safety system. It is also the basic tool to find deep bugs in the hardware. This is why; it has a crucial step in the whole hardware structure design of embedded system.

This system implementation is developed through the physical interconnections between hardware objects using standard hardware design technique. The whole developed system structure consists of the following hardware objects such as sensors as tire pressure monitoring modules, load cell weight sensor, Logitech web-camera (WC) and Cross-bow accelerometer (AC) crash sensor, data acquisition card for analog to digital conversion, CPU card, touch screen for deploying result and ATX switch mode power supply (SMPS) as shown in Fig. 2.

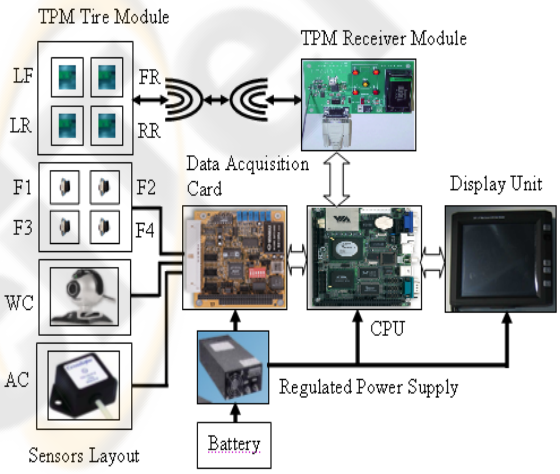

Fig. 2. Hardware structure of integrated prototype system.

5 System Interface

In this interface program, data are acquired from the weight sensor inside the passenger seat and crash accelerometer sensor fixed on the vehicle bumper through AXIOMTEK AX10410A acquisition card. This weight and crash sensor provides analog signal that received by CH0 to CH6 of the A/D converter of DAQ card from the 4 weight sensors and a 3 axis of crash sensor. A web-camera is connected to the CPU through USB. The program firstly determined whether the seat is empty, human or non-human something is on it according to the logic combination of measured weight sense and image on the seat. Then classify the occupant size based on weight measurement data with logic combination. For example, when an adult occupant is on the seat, the adult logic is true, and child and non-human object logics are false, which the dynamic output classifies as adult and displays its decision on the monitor. The interface system also determined the centriodal position of the occupant to find whether the occupant is in good position or not. Occupant detection, classification and position along with vehicle crash detection decision provides decision to the ADDS. TPM receiver module is connected to the CPU through SPI that extracted pressure and temperature for monitoring and provide warning system to the display unit. Details interfacing connection among the external sensors and power supply to the data acquisition card and CPU are shown in Table 1 and Table 2.

Table 1. Connection the external sensor to the DAQ and CPU.

DAQ and CPU	Sensor Type	Wire Color
Channel 0	Weight Sensor	Blue (Left Bottom)
Channel 1	Weight Sensor	Violet (Left Top)
Channel 2	Weight Sensor	Orange (Right Top)
Channel 3	Weight Sensor	White(Right Bottom)
Channel 4	Crash Sensor	Violet (X-axis)
Channel 5	Crash Sensor	Yellow (Y-axis)
Channel 6	Crash Sensor	Black (Z-axis)
USB	Web-Camera	USB Port
SPI	TPM Receiver Module	Serial Port

Table 2. Power connector on the power supply and CPU card.

Wire Colour	Wire Type
Yellow	12 volt
Red	5 volt
Black	Ground

The displays are shown on a touch screen. The touch screen has three different connectors likewise USB, VGA and 12 volt regulated power supply.

Table 3. Touch screen display unit connectors.

Connector on the Touch Screen	**Connection to the Other End**
USB connector	Connected to the USB connector on the CPU card.
VGA connector	Connected to the VGA connector on the CPU card.
Power connector, Red wire – 12 Volt Black wire – Ground	Red wire goes to the Yellow connector on the SMPS and the Black wire goes to the black connector on the SMPS.

6 Interface Program

The system interface between the software and hardware is developed based on Lab Window/CVI in C programming language. The Low level driver called "c:\cvinterface\UKM.dll" is written as a Win32 DLL file where the functions inside the DLL are called by the Lab Window/CVI C program. In this DLL file, the function called "Func1" processes the analog signal received by CH0 to CH6 of the A/D converter of DAQ card from the 4 weight sensors and 3 axis of crash sensor. The function "HumanDetection" provides the decision based on weight sensing whether the occupant is adult, child or empty. The function "ImageProcess" is called inside the UKM.dll to perform the face detection. This function returns a 1 if the image captured by the web-cam is detected as "human" else if it detects a "Non Human" the function returns a 0.

This 1 and 0 is fused with the logic combination of weight sensor to detect occupant as adult, child, non-human object or empty. The function "CrashSensor" is responsible for whether crash is generated or not. The function for position detection "PositionDetection" calculates the centroidal distance of x and y axis from the UKM.dll that display is the GUI and provides the decision for occupant position. Finally, the function "ABagParm" provides the airbag deployment decision upon fusing logic combination of occupant classification, position and vehicle crash detection decision. The function "TPMReceiverModule" also called in UKM.dll to monitor pressure and temperature that is extracted from TPM receiver through SPI connection to CPU. The Fig. 3 shows the details program flowchart diagram of the UKM.dll.

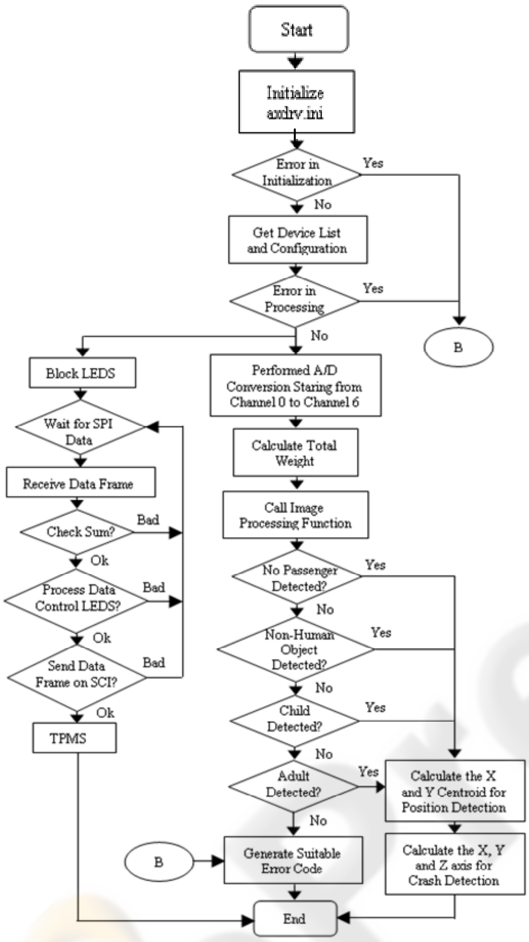

Fig. 3. Interface program flowchart of the integrated system.

7 Experimental Results and Discussion

The experimental results and graphical user interface on the touch screen graphs representing real-time field applications of the integrated intelligent safety system. The results contain for network interface processing, image and signal processing for occupant detection, classification and position, vehicle crash detection and its severity analysis towards ADDS and the performance monitoring of TPMS. Usually the real-time constraints vary up to 1 minute. However, in our prototyped hardware, the execution vectors of whole system are derived from the experimental measurements within 50 ms. The results in decision and graph on the GUI, the resource library is assumed that contain CPU, data acquisition card, sensors and their interface between sensor and CPU. Details of experiment results and its analytical discussions are given below.

7.1 Results and Discussion

Occupant detection, classification and position is confirm based on the logic fusion of image and signal processing data. In image processing, the intelligent safety system is used two-data sets of images in the experiments to test the detection performance of human face and non-human object, which are distinct from the training sets. The first sets consist of 253 test images, whose have a wide variety of complex background in the various environment and scale changes for the object of interest along with some occlusion and variations in lighting. 25 human face image of interest is taken for a total of 253 test image. The second data sets contain 112 test images that have been collected from 7 non-human object of interest is taken. The systems undergo the bootstrapping cycle with ending up 4500 to 9500 zero samples, to evaluate the performance of true detection of the test images and the rate of false detection from the image of natural scenes that do not contain human face or non-human object.

Table 4 shows the performance of human face detection results of various methods on the test set 1 and compare with other systems in term of the number of detect faces, miss faces, false detection and computation time. The successful rate of the proposed method is 97.6 %, with 6 false alarms. It should be noted that the number of false alarms is quite small in compared to methods Yacoub et al. [11] and Fasel et al. [12] which is 347 false alarms. This may show the capability of the combination of two networks to highly separate human face from non-object examples. The higher performance of Rowley et al. 1998 [13] is likely due to the size of training data. We used a 7344 human face images and 8000 non-object examples, while Rowley et al. 1998 trained with 16000 face images and 9000 non-faces images. However, the technique is less efficient than our techniques in term of the false detection and response time. On the other hands, Yacoub et al. [11] shows a very fast time processing but have a drawback of higher false alarms.

Table 4. Detection Rate of Set 1 on Different Methods.

Method	Human Detect (%)	Miss Human (%)	No. False Detec	Proces s Time
FNN+CN N	97.63%	2.37%	6	2.3s
Rowley et al.	97.86%	2.14%	13	0.013M
Yacoub et al.	84.31%	15.69%	347	0.7s
Fasel et al.	96.8%	3.2%	278	3.1s

Similarly, Table 5 shows the summarized results of non-human object on the test set 2 and compare with other systems. We found that non-human object detection rate is 96.42%, which mean 108 out of 112 numbers of non-human objects are detected. The false detection rate is 3.58%, which is lower that Agarwal et al. [14] and others methods [15]. However, the average process time is almost same with others method providing additional calculation on CNN. Based on the results shown in Tables 4 and

5, we can concluded that both human face and non-human object detection system make acceptable tradeoffs between the number of false detection and detection rate.

Table 5. Detection rates of set 2 on different methods.

Method	N-Human Object Detect	Miss N-uman Object	No. False Det.	Process Time
FNN+CNN	96.42%	3.58%	4	2.9s
Agarwal et al.	94%	6%	30	3.6s
Mahmud & Hebert	82%	18%	187	4.0s
Viola & Jones	95%	5%	71	0.7s

Once the image processing part completed, the “ImageProcess” function provides 1 for human and 0 for non-human object. This 1 and 0 is fused with the weight sense of the sensor situated inside the vehicle seat to provide accurate occupant detection and classification for the integrated intelligent safety system. To illustrate the performance, some exemplary results obtained from the prototype system are demonstrated for instances such as, when the seat is occupied or empty. If occupied, the occupant is classified as an adult, child or non-human object. Usually, human in the seat provides its weight with positional variation. However, non-human object like grocery bag is static and provides its weight without positional variation. It also demonstrates that the position of the occupant can be determined for consideration of safety issues in airbag application or for measuring the comfort level.

Figure 4 shows the centroidal position of y_centroid vs. x_centroid of the vehicle front passenger seat of size 50x50 cm that indicates various position of the occupant such as standard, good and bad with marking blue, green and violet lines, respectively. Figure 4 (a) shows that occupant in the seat is good position with relax mode aligning to the back of the seat. Figure 4 (b) shows that the occupant is in bad position i.e. the occupant is aligned very much right to the seat. On the other hand, Figure 4 (c) indicates that occupant is in bad position and very close proximity to the airbag. In that case, our safety device will not provide decision for airbag deployment. Similarly, Figure 4 (d) also indicates that the occupant is in extreme left of the of the vehicle seat.

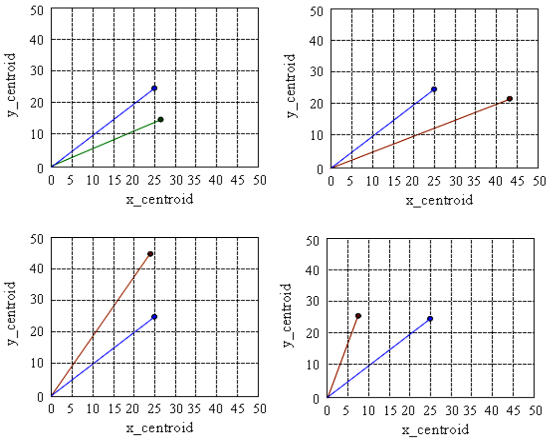

Fig. 4. Occupant centroidal position calculation.

Next, we have implemented the experiments of the frontal static crash using crash generating device and with the interface program. The experimental result of the crash reaction force being applied to generate crash is shown in Fig. 5. We have tried to obtain the reaction force during the repeated crash conduction at a time 51 sec to 80 sec. Figure 11 shows, during repeated crash, it gains a huge force of ~ 1000 N/m to ~ 5800 N/m and definitely the crash velocity immediately before the crash is greater than the 22.54 km/h. The reaction force depends on the crash velocity of the system. It is stated that as velocity increases the reaction force also increases, which in turn increases the crash severity. This is a situation that put the occupant at a higher risk.

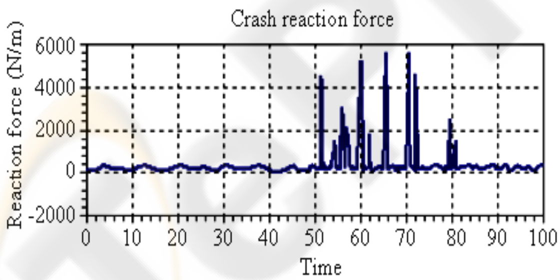

Fig. 5. Vehicle crash reaction forces.

For analysis of tire data, the 'Goodness of Fit' statistical analysis for the model is tested with all the variables. Figure 6 shows the 'Goodness of Fit' of the principle component analysis with polynomial fitting. The fitting result of parametric model of SSE is 0.1358 with 95% confidence bounds, which is close to 0 and indicates that the data fits well. The value of the multiple correlations R^2 coefficient is 0.8452, whilst the adjusted R^2 value is 0.8267. Both reveal about 85% and 83% match in the outcome which indicates a good fit. In addition, the RMSE value of 0.161, which is close to 0, also implies that the data fits well. In Fig. 6 (b), residuals of the polynomial fit appear to be randomly scattered around zero, which again indicates the model perfectly fits the data under the study. In short, we have statistically proven that TPMS can play an important role to enhance tire safety, performance and maintain reliable operation in combine with vehicle intelligent safety system.

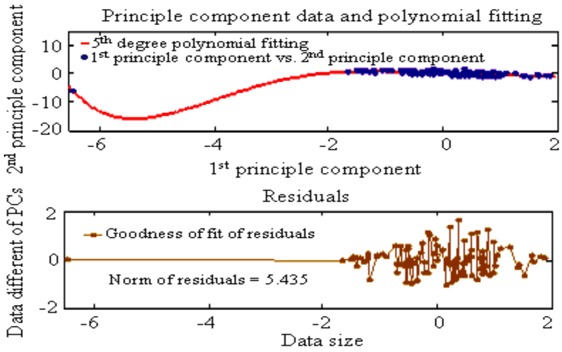

Fig. 6. Principle component analysis and goodness fit.

The Fig. 7 shows the display unit of experimental results and decision monitoring operation of the implemented integrated intelligent safety system towards ADDS and TPMS. The ADDS is involved on occupant detection, classification and position, vehicle crash detection and its severity analysis. The safety feature functions are activated by pressing start button.

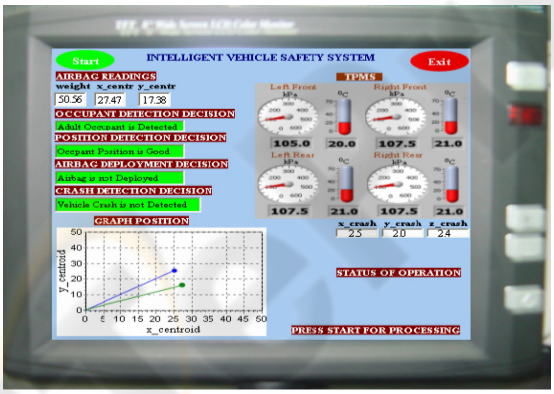

Fig. 7. Display of integrated intelligent safety system.

The display unit successfully achieved the decision application of safety features. Several safety issues related decision performances are fused using logic combination. In Fig. 7, its shows that when the system detect adult occupant and keeping good position, the airbag will not be deploy, provided there is no crash detected by the system. All the decisions in the display unit are shows as green mark. Accordingly, the icons of occupant total weight, centroidal position, axis wise crash data and position graph are displayed. For TPMS, the display unit also shows that all four tire acquiring the real-time temperature and pressure data, respectively. Therefore, the integrated prototype provides the optimum and their fused decision on various safety issues that is very useful related to the safety issues for vehicle driving assistance system.

Similarly, when adult occupant is detected and keeping good position, airbag is deployed only whenever the vehicle crash is detected.

However, if the occupant position is bad i.e. occupant is very close to the airbag unit, the airbag would not deploy though the vehicle crash is detected. This is because of the huge reaction force would hit the occupant due to close proximity between occupant and airbag unit. This is a situation that put the occupant at a higher risk.

8 Conclusions

In this paper, the system interface of the integrated prototype implementation of vehicle intelligent safety system has been presented. Lab Window/CVI in C interface program is used for the real-time intelligent safety systems prototype implementation. The safety system such as TPMS, occupant detection, classification and position, vehicle crash detection and its severity analysis are integrated. The prototype is made by developing the algorithms and methodologies of the hardware platform and system interface program. The application of the embedded intelligent safety system has resulted in successful real-time working device, which will provides the validation of the performance diagnosis of the safety system. The contribution of the interface system of this prototype are performance characterization, problem determination and real-time work load data monitoring of a distributed safety issues and provides safety warning, whose are applicable in successfully operation.

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