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REVIEW ON LIMP HOME MODE IMPLEMENTATIONS

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ABSTRACT
Modern transport systems have come a long way in terms of user comfort and performance. A lot of vehicles nowadays offer a great user experience with its combination of efficient design and optimized technology. As the systems have increased in complexity, it is paramount that a user is aware of errors in the same. Fail-safe systems such as limp home mode are novel ideas to improve the overall comfort of the vehicle. These systems provide real time information about the nature of the error which has occurred to the user in a simple manner. The limp home mode also offers minimum operational capacity to the vehicle so that the user is not stranded without help in a particular area. The vehicle can then be driven to the nearest service station for technical support. This study is a review on the various patents available for limp home mode in a vehicle system.

Keywords: Transport systems, Comfort, Performance, Fail-safe, Limp home.

INTRODUCTION
Modern vehicles, commercial vehicles in particular, have grown more complex in nature over the years and integrate a huge number of sub-systems which help in the hassle free operation of the vehicle. As complexity increases, it is natural that the faults associated with them increase too and pose a challenge to overcome. A robust system which can detect the faults on-board and alert the user is of paramount importance in this age. These systems generally consist of a lot of electronics. Controller Area Network (CAN) based communication systems represent one of the most widely used vehicle bus standards designed for microcontroller communication in the absence of a host computer. It is one of the five protocols used in the On-board Diagnostics (OBD)- II standard. It was first developed in 1983 at Robert Bosch GmbH. The latest version of the CAN specification was introduced in 1991 [1]. These robust systems have paved the way for manufacturers to include fail safe measures in their products. A well-known fail safe implementation is the limp home mode. Each manufacturer has its own take on these systems and their exact functioning is a well-guarded secret. This paper is a basic study about the various patents dealing with limp home systems in order to understand the need for future research.

ON-BOARD FAULT DIAGNOSIS IN AN AMT SYSTEM
Modern vehicles are equipped with a variety of on-board electronic systems. Fault diagnoses of these systems improve the reliability and safety of the vehicles. Such diagnosis can be divided into two methods namely the physical redundancy methods and the analytical redundancy methods [2]. The analytical redundancy models are based on the mathematical models of the associated systems. All vehicle systems are non-linear in nature and hence cannot be equated to a linear system and this is one of the biggest drawbacks of the analytical redundancy models. The on-board vehicle systems cannot tolerate too much computing too [3]. During normal operation, some of the components may be coupled while others may be uncoupled at any given instant of time. Therefore, it is beneficial to employ local structure and local time models for fault

diagnosis in an AMT system. Fig. 1 shows a basic AMT control system [4].

A typical AMT is composed of a dry clutch, gearbox and a control system. The control system comprises of speed sensors, throttle opening sensors, shifting actuators, throttle actuators and the Electronic Control Unit (ECU). As stated earlier, automotive systems are non-linear in nature.

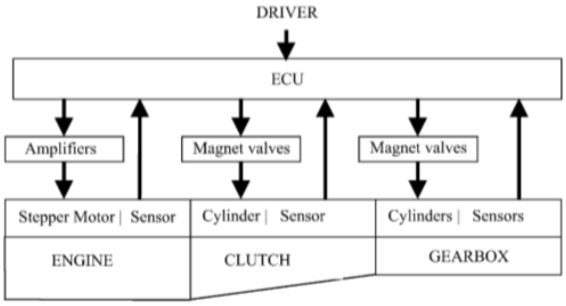

Figure 1: AMT control system
Source: Guihe Qin, Anlin Ge, Huansong Li, "On-Board Fault Diagnosis of Automated Manual Transmission Control System,"

However, when the input values vary only within a small range, they can be equated to a linear model. It should however be noted that this is still an approximation. In the non-load condition of the engine, it can be considered as a system with the rotation speed being the output and the throttle speed being the input. The model used is a Single-Input-Single-Output Controlled Auto-Regressive Moving Average (SISO CARMA) model. In order to obtain such a model of the engine system, a random input time sequence of throttle opening is used and the corresponding engine rotation speeds are recorded [4]. While shifting, the throttle should be drawn back, the clutch should be disengaged and the gear positions should be changed. When the clutch is disengaged, the engine is said to enter an idle phase. The parameters measured should be in line with the predictions of the model. After the shifting has been done, the ECU of the vehicle will compare the measured and model parameters. If there are no errors in the engine speed sensor and the throttle opening sensor, the model can be considered to be stable.

Similar models for clutch actuation and gearbox were developed. All the models are local models and hence do not require high computational power [4]. The fault diagnosis occurs as long as the shifting occurs. It includes the following steps.

- Calculation of residual function from the measured and estimated data
- Testing the failure of the residues
- Diagnosing faults according to the tested results and the isolating relation
- Processing of the faults if they had occurred

Various sub-routines have been embedded in the AMT controller. A test board was used to test the fault diagnosis functions. The system could detect most of the faults accurately while some of them required a deeper understanding. In some cases, the set fault and the fault detected were not the same. This was due to the reason that a set fault can lead to multiple abnormalities. The system reflects the first fault which was detected and hence the difference in the set faults and the faults detected. However, this still is a comprehensive model to detect the faults during the shifting process without any addition of new hardware.

Though the study provides a successful method for on-board fault diagnosis in a vehicle system, it has a few shortcomings. Foremost of that is the fact that the study deals with limited number of errors. These do not encompass all possible errors in a system and further research is needed for the same. Another shortcoming is that the model proposed does not represent the correct error in some cases. Though a minor issue, it can still be misleading to the user and may elicit a dangerous response to the on-board problem.

RESEARCH ON LIMP HOME MODE

Falck et al. have worked on a transmission control system with limp-home function [5]. A normal control system of a vehicle consists of a vehicle powershift transmission. The transmission system, in turn, includes a set of electrical connectors. These connectors permit power to be transmitted to microprocessor controlled valve drivers for the transmission clutch control valves in normal mode. However, in a limp-home mode, these connectors are swapped to permit power to be transmitted directly to the transmission clutch control valves. Both these modes are equipped with a start-in-gear circuit including a pair of relays and switches coupled to the shift lever. This prevents the vehicle from starting with a gear engaged. In addition to this, the proposed system has a limp-home relay and a clutch disengaged switch. This prevents gear engagement until the operator has depressed and/or released the clutch pedal. The clutch pedal can be operated to modulate and control gear engagement. Most commercially available limp-home systems override the start-in-gear protection which is highly undesirable. The objective of the study is to develop a system which permits modulated gear engagement and not to override the start-in-gear functionality during limp-home operation.

Stratton et al. have proposed a method and apparatus for a limp home mode [6]. The study deals specifically with earth moving machines. The method proposed includes the detection of failure of the implement control system, enabling a limp home mode in response to the failure and controlling the implementation of the limp home mode. A flowchart depicting the same is shown in Fig. 2 [6].

The work implements of an earth moving machine such as a tractor are controlled by hydraulic circuits. An operator interface with joysticks, displays and keypads are provided to enable an operator to control the work implements. Faults are bound to happen in these systems and the machine should be functional enough to be driven to a nearby service station. The proposed method tries to tackle this problem. A series of control blocks are used to detect the failures. A failure in one of the control block may refer to problems with the joystick used for blade control in the earth moving machine. This may leave the blade in a position wherein the machine itself cannot be driven because of it. Hence, a limp home mode is useful here. The joystick under concern is first disabled in order to ensure there are no unintended or sudden movements. The control unit will ignore any data from the joystick and will deliver fault message to the operator. Similarly, if a solenoid failure occurs in a particular circuit, that particular solenoid is shut off while all the other solenoids remain functional. . Other control blocks may be used to enable a limp home mode.

The limp home mode is enabled when a failure has occurred in the implement system thereby hindering the use and control of the work implement. This is an attempt to overcome the effects of the failure. The mode may be enabled by an on-board or off-board operator. It can also be enabled by an automated program. The automated program will be initiated when a failure in the work implement system has been detected. The system informs the operator about the failure and the operator can choose whether to enable the limp home mode or not. Other control blocks may be used to precisely control the work implement during the limp home mode if necessary. The command signals are often short in duration as longer commands can damage the implement in case of a failure [6].

Gierer et al. have proposed a limp home device for a vehicle with automatic transmission [7]. The proposed system is a device which allows emergency operation of an automatic transmission motor vehicle and monitors pre-determined operating parameters. It also encompasses a diagnostic device to detect the faults, a control device to activate an alternate function in case of a failure and an output device to present the faults to the operator. The control device also provides the operator to operate the system during emergency and the degree of operation is determined by the degree of the fault. The device offering emergency operation represents a fail-safe system. If a fault is detected within a pre-determined range, for example in transmission, the system initiates the control system appropriate to the fault and activates the devices operating in conjunction with the system. The detected fault is assigned a certain priority based on its importance. Depending on the fault, the operator will be notified about the possible operation time of the vehicle. In order to effectively communicate the emergency to the operator, the notifications show the gradual reduction in operation time or distance and the reduction in number of gears available. The CAN bus can also be coupled with the telematics system in order to remotely communicate the failure.

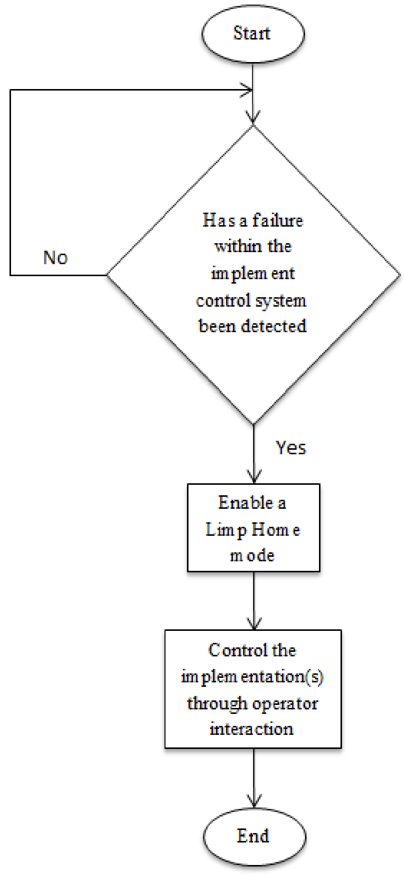

Figure 2: Proposed limp home mode actuation flowchart
Source: Stratton et al., United States Patent Number: US 6,253,136 B1

Patel et al. have proposed a limp home mode for an electric vehicle [8]. The proposed study includes the determination of resolver failure in the electric vehicle. If the resolver has failed, the electric motor of the vehicle uses sensorless rotor position and rotor speed signals for its operation. Electric motor systems in electric and hybrid vehicles use a resolver coupled with the electric motor. This is to generate signals corresponding to the position and speed of the rotor of the electric motor. However, when the resolver fails, the position and speed of the rotor cannot be identified. A limp home mode for such a system includes a sensorless speed and position estimator and a signal selector. The sensorless speed and position estimator generates rotor position and rotor speed signals. The signal selector is coupled to both the resolver and the sensorless speed and position estimator in order to receive signals from both as and when required. The signal selector can thus detect any failure in the resolver.

Kim et al. have proposed a limp home drive method and system for a hybrid vehicle [9]. The method proposes prohibiting the operation of an overdrive brake that is included in the transmission of a hybrid vehicle. A normal gasoline vehicle uses a mechanical oil pump which is connected to the engine. The pump is powered by a motor using a high voltage battery in an electric vehicle. The pump delivers oil to drive the transmission system. A pump controller controls the oil pump and consists of a relay which connects or disconnects the power supply to the pump. The pump controller can receive information from the Transmission Control Unit (TCU) through CAN communication. If there is a problem, the CAN communication is disrupted thereby preventing the pump from delivering oil to the transmission. The study proposes a system wherein a mechanical oil pump is used to drive the transmission during the limp home mode. This will aid the functioning of the transmission when the normal electric oil pump included in the vehicle fails.

Coldren et al. have proposed a limp home capable dual fuel engine [10]. The dual fuel engine under consideration uses natural gas and liquid diesel as fuel. During operation under low load mode, some of the engine cylinders use a high ratio of diesel and gas and the remaining cylinders are unfuelled. During operation under high load mode, all the engine cylinders use a low ratio of diesel and gas. The proposed system uses only diesel in all engine cylinders during limp home mode operation.

The above mentioned studies represent some of the most advanced research done in the field of fail-safe systems in vehicles and do not encompass all available technologies.

CONCLUSION

Most of the known researches in fail-safe systems concentrate on the limp-home mode for engine failures. A lot of simultaneous research is also being done to determine the various ways in which CAN communication can be used in these fail-safe systems. This study is an attempt to review some of the research done in the field and does not represent the whole picture. Considering that, it can be concluded that this field has a large untapped potential in terms of needed research and provides an exciting opportunity to improvise the existing research for our own benefit.

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