Development of Control Software by All-software Simulation

Syuzo Tanaka
Takamichi Kono
Yuu Moriyama
Kengo Iino
Takeshi Fukazawa

Abstract

In recent years, the number of ECUs (Electronic Control Unit) has been on the increase, and ever more integrated and complex vehicle control systems are now installed in a vehicle, due to high functionalization and complication of vehicles. Moreover, for vehicle development, the move toward shortening the production lead-time and reducing the length of prototype production are noticeable. The most important issue today, therefore, is to develop new software for vehicle development with more efficiency, within a short period, while maintaining our product quality standard.

This paper reports our development of a new software development environment, "Virtual ECU", which will enable us to design the software to produce highly reliable ECUs without a prototype production. This system primarily consists of two parts: 1) HIL (Hardware In the Loop) Simulator CRA-MAS (ComputeR Aided Multi Analysis System), and 2) High-Performance Microcomputer Simulator, "CoMET/METeor".

1 Introduction

In recent years, the vehicle industry has been offering many technical advantages and highly advanced functions mostly by using electronic controls. For example, the fact that a recent model vehicle is equipped with more than 70 ECUs (Electronic Control Unit) shows the extent to which the demand of developing electronic control systems are on the rise, especially, in the area of control software. Moreover, since the public awareness of safety issues has been more noticeable year by year, it is essential that we develop highly reliable control systems with fault tolerance (trouble resistance). Under these circumstances, the quest to enhance our quality standard while reducing the necessary test period for checking operations is now urgent and more important than ever before.

Taking these circumstances into consideration, this paper reports our new development of a development environment, "Virtual ECU", which enables us to design software for highly reliable control system within a short period of time, by combining HIL (Hardware In the Loop) simulator, "CRA-MAS" (ComputeR Aided Multi Analysis System) and high performance Microcomputer simulator, "CoMET/METeor.

2 Current Situation of Vehicle Control System Development

In response to the year-by-year stronger and stricter demand for improvement of development efficiency and product quality, it is now more and more popular to develop vehicle control systems using simulation technology. There are two methods available when simulation technology is introduced for the development of vehicle control software. One method is to simulate the exterior of vehicles, while the other is to simulate the interior of vehicles (Microcomputer). In this paper, the information on both exterior simulation method and that of interior simulation will be described in detail. The information on the former is mentioned in Section 2.1 and that on the latter in Section 2.2.

2.1 Vehicle Control Software Development Using Vehicle Simulation

Generally speaking, any newly developed vehicle-control software must be verified its operation using actual vehicles with ECUs installed. However, in reality, parallel development, whose aim is to shorten the period for development, often makes it impossible for the engineers to receive suitable vehicles for verification. Even if actual vehicles are available for use to test a new product, the condition regarding introduction costs, maintenance costs, and necessary space for the facilities, are making it harder for companies to allow each engineer to use actual vehicles for testing their individual projects. Furthermore, more engineers nowadays find their experiments difficult to be examined using actual vehicles. Today, it cannot be decided so readily that the most suitable method for testing a new product is to install it in an actual vehicle. Some cases, such as the case to perform the limit test just before the engine breakdown, have already proved that the use of actual vehicles is not the best method for verification.

This situation brought us to pay attention to a method that offers verification by simulating the vehicle part. The adoption of simulation method enables us to experiment control software in much the same state as to test them under on-board conditions.

Moreover, the issue of introduction and maintenance costs, and the need for space saving will be solved, while allowing the allocation of one PC per developer simultaneously, if the highly advanced PC technology is introduced into simulation implementation. Furthermore, operations can be tested under various conditions when the simulation setup is changed, even beyond the extent that the verification in an actual vehicle does not offer.

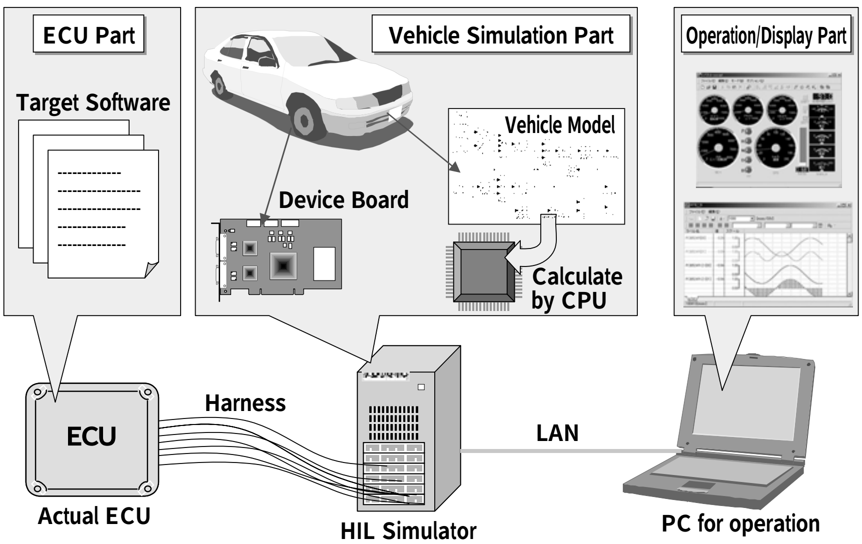

Fig.1 Conceptual Diagram of HIL Simulation

There are some methods available to simulate the vehicle part. The most popular method among them is one that receives electronic signals that were output from the ECU as shown in Figure 1, and process them arithmetically on the vehicle model part that operates on CPU, and convert the processing results into electric signals on the hardware (output board), and give feedback to the ECU. This method is called "HIL (Hardware In the Loop) simulation" due to the fact that hardware such as ECU, input/output board, and high-performance CPU, together, forms a feedback group.

As HIL simulation is mainly used for dynamic qualification with actual ECU, it is primarily used for the middle process and lower process, more specifically, in the "mounting" and "verification" process.

Fujitsu Ten, as an ECU manufacturer, had paid attention to HIL simulation system since the early stage of its introduction, and independently developed HIL Simulator, "CRAMAS". The simulator has been used for development and verification and has contributed greatly to improve the quality of our products and development efficiency. Furthermore, many companies, such as Toyota Motors Corp. and some other automotive service manufacturers have adopted it to develop vehicles with cutting-edge technology.

Fig.2 Exterior View of CRAMAS

2.2 Development of Control Software by Microcomputer Simulation

Apart from the methods that simulate the vehicle part with an actual-equipment equivalent ECU, the methods that simulate ECU itself have been examined and implemented. More specifically, the method that operates new control software in the environment simulating microcomputer and peripheral circuitry has been tested. Among them, the method that simulates both actual microcomputer and peripheral circuitry using software alone has attracted many people's attention.

This method, by enabling the whole system consisting of software, allows the engineers to perform simulation checkout using PC alone. This simultaneously leads to a release of the engineers' worries about troublesome hardware, while also bringing them two benefits- 1) the reduced costs both for introduction and maintenance, and 2) the space saving. Moreover, as both the microcomputers and the timer for peripheral circuitry are simulated, stopping and restarting simulation during operation are easier, while verification of source code level by stepwise execution is also possible. These features altogether make the method with microcomputers suitable for the upper process and the middle process, more specifically, the planning process and the logic-verification process of development.

CoMET/METeor, developed by VaST Systems Technology, is a development environment that enables us to simulate the environment including micro processing unit and peripheral LSI with high speed and high precision while allowing us for timing verification at the clock cycle level.

The use of CoMET/METeor offers four significant benefits as follows:

(1) The software for a newly developed product can be debugged before the completion of actual equipment.
(2) If the microprocessor for a newly developed product is simulated by software as a whole, that will enable the engineers to stop during a debug process as well as to debug it step by step.
(3) The reproduction rate of the debug environment is high, since its copy maintenance is easy.
(4) The reproducibility of the debug environment is 100%, unlike that of the debug environment using actual ECU.

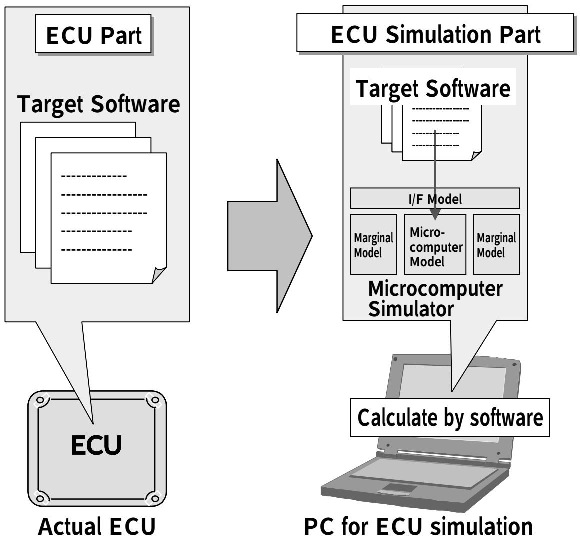

Fig.3 Conceptual Diagram of Microcomputer Simulator

3 Development of Control Software by All Soft Simulation

3.1 Ultimate Simulation Environment: "Virtual ECU"

The methods to simulate vehicles' exteriors have been developed as independent development technique, different from the methods to simulate vehicles' interiors. However, technological advancement in electronic control technique for vehicle development has been moving forward at the speed far quicker than our expectation, and technical advancement of CPU have not caught up with the speed of that of simulation performance. Furthermore, parallel developments by shortening of the development period and spiral developments that enables a repetitive examination of each process within a short period are now underway. Consequently, the following issues have had to be addressed urgently:

①To improve simulation capacity that is not dependent on CPU performance to a large extent

②To develop a new simulation environment that can cover development steps from the beginning to the end seamlessly.

The situation led us to develop a new control software development environment, "Virtual ECU", as a result of combining two parts: ①HIL simulator, "CRAMAS" portion, and ② microcomputer simulator, CoMET/METeor. The combination offers a new simulation environment that exercises both vehicle simulation technology and dynamic simulation technology accumulated by HIL simulator, and static simulation technology with more precision accumulated by microcomputers.

In other words, "Virtual ECU" is an ultimate possible simulation environment that can control "time" and "space" freely, as a consequence of releasing the users from the process that takes much of their time and physical involvement. The details of this newly-developed product, "Virtual ECU", will be described in the following section.

3.2 System Configuration of "Virtual ECU"

Figure 4 shows the system configuration of "Virtual ECU". As understood from the figure, it consists of the CoMET/METeor part and the CRAMAS part.

The CoMET/METeor part can further be divided into: microcomputer model portion, marginal model portion, and I/F (interface) model portion.

The microcomputer model portion simulates the operation of microprocessors, while the marginal model portion simulates the operation of peripheral circuitry, such as LSI, together with the operation of the ECUs in a vehicle. The virtual ECU operates the same OS (operation system) as that of the actual ECU operation. Thus, there is no need for the replacement of control software, while the execution at the binary level is practicable.

Accordingly, the operations of control software verified by Virtual ECU are assured. Moreover, since the compilers and debuggers used in the simulation environment are the same as those in the actual environment, the users of Virtual ECU can develop control software in the same way as they do in the actual environment. Furthermore, through the I/F model portion, CRAMAS can receive the same results in the simulation environment as it receives in the actual environment.

The CRAMAS portion is comprised of CRAMAS GUI portion, vehicle model portion, and device model portion. The vehicle model portion mainly implements physics processing, while it enables an interface with the virtual ECU portion that is actuated by CoMET/METeor by converting arithmetic values to equivalent electronic signals in the device model part.

The CRAMAS GUI portion implements the setup of simulation parameter in the vehicle model portion and the device model portion, as well as indication of simulation results. The specifications of CRAMAS GUI portion is completely the same as that of HIL CRAMAS, thus enables its users to develop control software in the same way as they develop control software by using HIL simulators.

Furthermore, as Virtual ECU can share the setting for vehicle model and simulation parameter in common with HIL simulator, it can be used in the whole development process seamlessly.

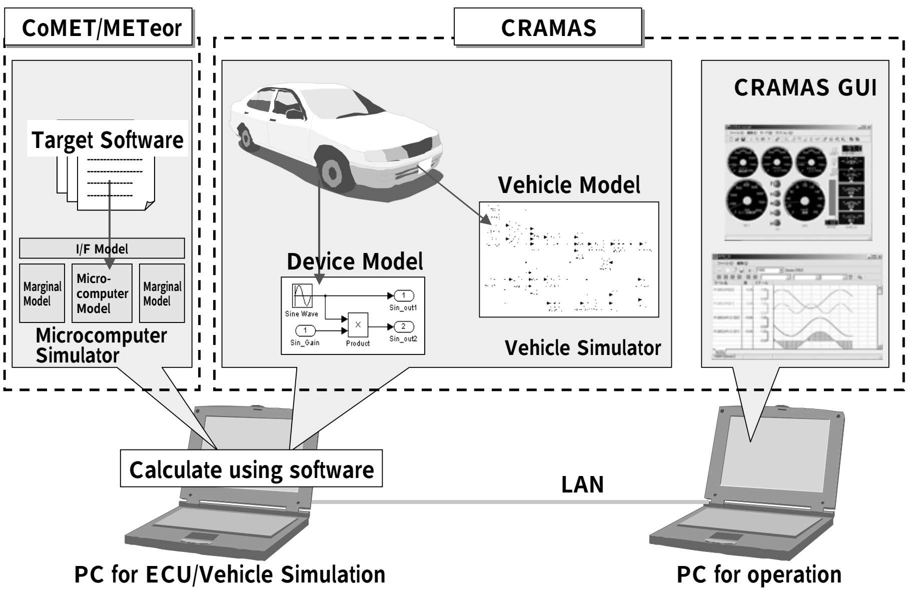

Fig.4 Configuration of Virtual ECU

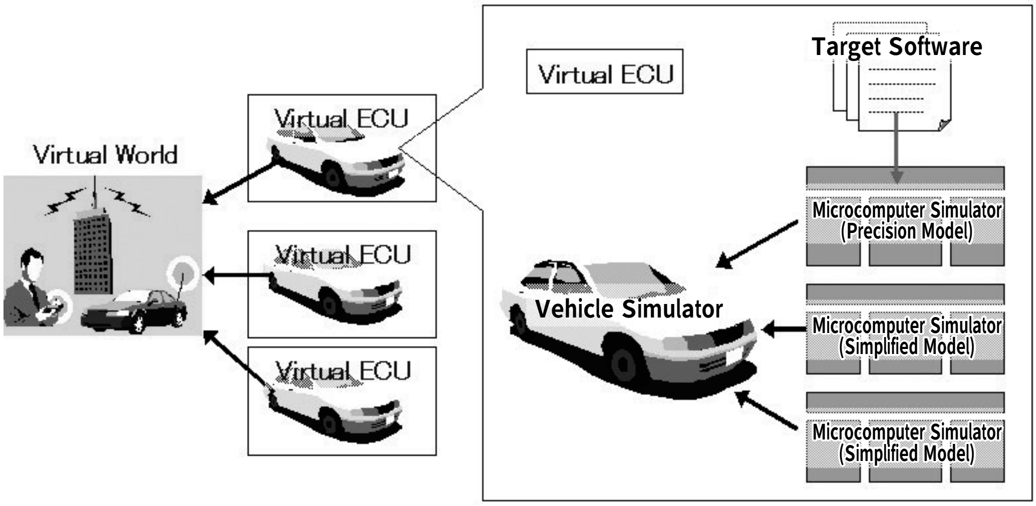

Fig.5 Application Example of Virtual ECU

A trigger in the CoMET/METeor side is responsible for executing the vehicle model portion and the device model portion. This enables the operation time in the overall Virtual ECU to be controlled by the timer in the CoMET/METeor side, which means the model execution and the timing of I/F in one portion are synchronized with the other.

Due to this characteristic, if a debugger suspends the control software, the vehicle model portion and device model portion will be suspended temporarily. When the control software is reactivated, the vehicle model part and device model part will also restart their operations.

Consequently, Virtual ECU enables seamless implementation of both static qualification and dynamic qualification, by the former using step execution and the latter using a feedback group.

3.3 Future of "Virtual ECU"

Virtual ECU is neither a simple medium to realize all-software simulation developments, nor a trivial tool that can be used from the upper process to the lower process.

Multiple combinations of Virtual ECUs have a possibility to improve conventional framework of development scale and development efficiency on a vast and overwhelming scale.

It all begins with simulating all the electronic control units in a vehicle. All the electric control units and the main vehicle part (the part other than ECUs) in a vehicle are to be restructured by "Virtual ECU". Then, all the ECUs that are to be replaced by "Virtual ECU" do not necessarily have to be precision models equivalent to actual ECUs. The control software that are the target for testing shall be adopted of precision models, while the rest of the portion may be of simplified ECU models. If the simplified ECU models are made into a library with replaceability, this will enable to structure a platform for verification by making all stand-alone control software in a vehicle, to be linked with the control software of the whole vehicle.

This virtual vehicle can be used for examining vehicle integration control systems that will move into high gear in the near future. Also, if multiple virtual vehicles can be operated at one time, then, the currently time-consuming process of inspections and reproduction of low-probability failure can be reduced by parallel work operation.

"Virtual ECU" can realize not only the environment of a vehicle, but also the environment surrounding a vehicle. For example, Virtual ECU enables the users to reproduce a virtual driver and let him drive in a virtual vehicle in a virtual town, all of which are reproduced on "Virtual ECU". This enables the engineers to perform a prior verification by control software with realization of various virtual situations that a vehicle might have. The virtual environment can be applicable to the verification of ITS technology such as communication between a vehicle and infrastructure (Road-Vehicle Communication), and communication between one vehicle and another (Vehicle-to-Vehicle).

4 A Business Model (Virtual ECU Club)

"Virtual ECU", with its combination of vehicle simulation and microcomputer simulation, is a next-generation development environment that possesses various features that were not possible in a conventional development environment.

However, the range that simulation checkout is adopted is now wider even to the whole vehicle, and the level of simulation applied is likewise- from electronic simulation of microcomputer to mechanical simulation of the vehicle part. This situation, together with the fact that today's vehicle development is more specialized and work-divided into small areas of processes, makes it impossible for any one company to develop a product and offer customer support independently without any assistance from other companies. The situation resulted in establishing a consortium called "Virtual ECU Club", led by a strong support of Toyota Tsusho Electronics Corp.

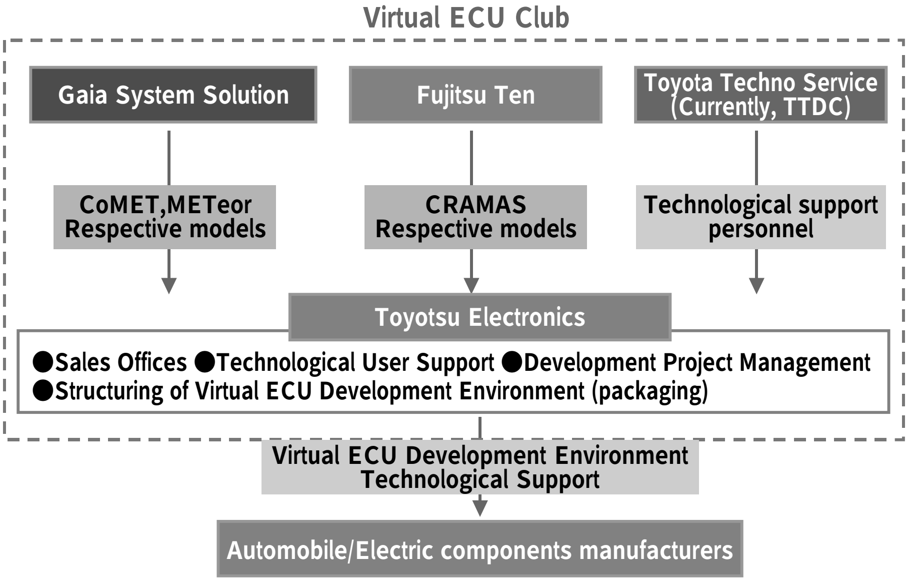

Fig.6 Image of Virtual ECU Club

The participants in this organization are: Fujitsu Ten Limited, Gaia System Solutions Inc., Toyota Techno Service Corp., and Toyota Tsusho Electronics Corp.

Virtual ECU Club, as Figure 6 shows, enables the car manufacturers and electric components manufacturers to design highly reliable ECU software without actual equipments, and offers the solution to the issues of shortening the design period and reducing the costs. With these issues solved, acceptance of order, production development, and customer support will be implemented without a hitch. Thus, it is expected that Virtual ECU will be adopted widely in the automotive industry, and further, in other industries.

5 Conclusion

As above, our new development environment for control software, "Virtual ECU", has been described in this paper.

The development of new control software using all-software simulation has become a reality by combining two different simulators: CRAMAS (HIL simulator) and CoMET/METeor (microcomputer simulator).

Hereafter, further studies on speeding up of the simulation process itself and new application methods for this system are needed.

We would like to take this opportunity to express our sincere thanks to those who were involved in the development of "Virtual ECU", as their support and guidance were indeed helpful.

Profiles of External Writers

Syuzo Tanaka

Established GAIA System Solutions Inc. in January 1996. Since then, has engaged in CoMET/METeor technical support and development of model and preinstalled software. Currently the Chief Technology Executive and Executive Director.

Takamichi Kono

Entered Toyota Tsusho Corporation in 1999 and was engaged in in-car electronics component sales. Assigned to work in Toyota Tsusho Electronics Corporation in 2004, since then has engaged in in-car preinstalled software related business and administrative work in the Limited Liability Intermediate Corporation JAS-PAR.

Profiles of Writers

Yuu Moriyama

Entered the company in 1998. Since then, has engaged in development of simulator (CRAMAS) used in control system development. Currently in the CRAMAS Engineering Department of CRAMAS Division, AE Group.

Kengo Iino

Entered the company in 2003. Since then, has engaged in development of simulator (CRAMAS) used in control system development. Currently in the CRAMAS Engineering Department of CRAMAS Division, AE Group.

Takeshi Fukazawa

Entered the company in 1980. Since then, has engaged in development of automobile electronics devices and development assistant tools. Currently the Manager of the CRAMAS Engineering Department of CRAMAS Division, AE Group.