NOTE

HIL Simulator "CRAMAS" for ITS Application

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1 Introduction

These days, HIL (Hardware In the Loop) simulators are widely used as tools for developing automotive control systems effectively and for securing product quality. HIL simulators have been mainly used in the fields of powertrain and drive-train, such as engine control and transmission control. "CRAMAS (ComputeR Aided Multi-Analysis System)" which is the HIL simulator developed by FUJITSU TEN Limited, is used for ECU (Electronic Control Unit) development inside and outside the company. These days, it is also used in wide fields such as ITS (Intelligent Transport System) which uses millimeter-wave radars.

Therefore, the new functions are demanded for that simulator. By this report, we introduce the application examples of CRAMAS and new approach to the security / safety field.

2 What is CRAMAS

CRAMAS is a unique simulator developed by FUJITSU TEN, shown in **Fig. 1**. The most significant feature of CRAMAS is that it can simulate a target control system in real time. CRAMAS was originally developed as a simulator for testing ABS (Anti lock Brake System) in 1996.

A simulator mainly substitutes for a target real vehicle. And it is an effective tool for testing in various cases; a situation that a real vehicle cannot be prepared, a phenomenon that is hardly occurred with a real vehicle, and dangerous testing with a real vehicle. In accordance with the recent environment change and the demands for fuel efficiency, control systems are more complicated and expanded. Besides, development period is shortened due to shortening of product cycles, and we have to perform enormous tests in shorter period. Under these circumstances, the automatic test tools attract attention.

Fig.1 CRAMAS

2.1 Application example

These days, motor-powered vehicles such as electric cars and hybrid cars are in use. We have developed simulators to support the control system developments for these vehicles.

A conventional motor simulation has calculated electrical and mechanical models designed in MATLAB/Simulink by software processing. However, in some cases, it is difficult to ensure the accuracy required for testing a control unit because the software processing cannot cover all the electrical behaviors.

To solve this problem, we have developed an exclusive function board (motor board) that is capable of calculation in 1 microsecond cycle by hardware macro using FPGA (Field Programmable Gate Array) to implement the electrical behaviors with less-frequent changes. **Fig. 2** shows a configuration of HIL simulator with the motor board.

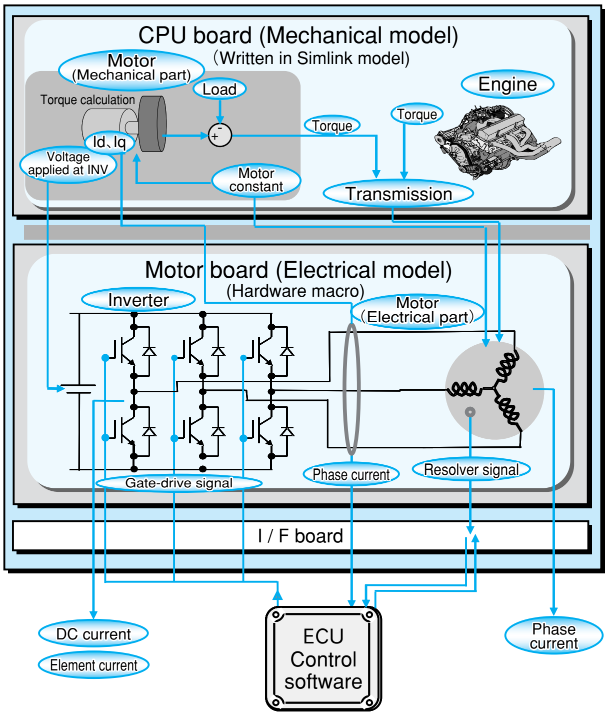

Fig.2 Motor Simulation

On the other hand, we are developing simulators for testing communication network such as CAN (Controller Area Network). The plural networks using various protocols are in a vehicle. The networked ECUs collaborate in controlling to connect and communicate between that networks, an ECU functioning as a gateway (hereinafter referred to as G/W) is required. Along with the enlarged network, multi channel types of G/W-ECUs are increasing. **(Fig. 3)**

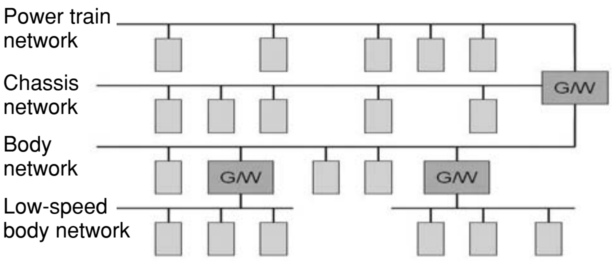

Fig.3 G/W-ECU

A G/W-ECU is tested in the following points; communication load and condition (sleep/wake-up) of each network, and behavior influenced by bus disconnection/short-circuit. As for a multi channel type of G/W-ECU, the number of combinations of these tests is larger. To carry out these tests effectively, we have developed the following functions.

①Adjustment function of bus load

②Time synchronization between communication behavior and I/O

③Communication-log viewer

④Function for automatic generation of test patterns and their sequential implementations

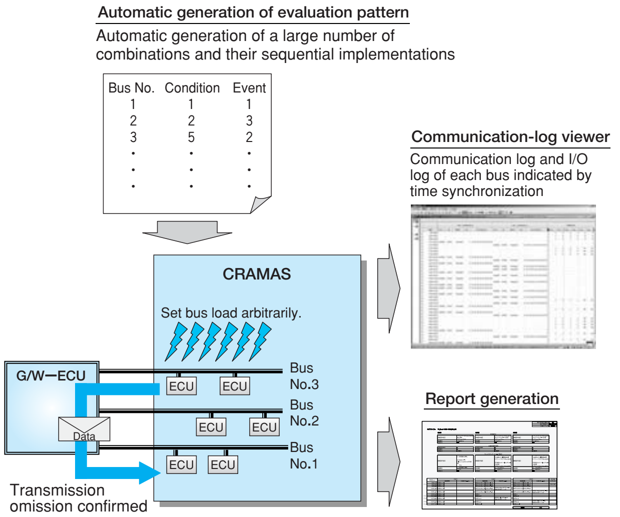

Fig.4 CRAMAS for G/W ECU

3 Application to Security / Safety System

3.1 Requirements for Equipment to Test Radar

We have developed control system development units and data collection analyzer mainly for vehicles. For example, simulations of power train are carried out for measuring analog signal outputs from respective sensors and RAM-value of ECUs to be tested, and for simulating communication data connected to the unit to be tested. Its sampling is carried out at a maximum speed of approx. 100 μs. However, for the development and the tests of an ITS, it is important to store large volumes of same-time event data at high speed, which relate to an own vehicle, a target vehicle, and monitoring situation around the vehicle.

Specially, regarding to the security / safety system, the millimeter-wave radars require the sampling speed of 1 MHz (1 μs) or more for measuring beat signals*(1), and at the same time, require the functions to carry out high-speed sampling and to store large volumes of data without any data gap, to measure GPS signals for testing positions of an own vehicle and a target vehicle accurately, and multi-channel camera signals for storing the situation around the vehicle. **(Fig. 5)**

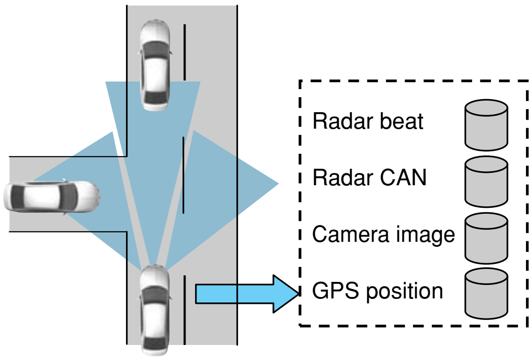

Fig.5 Measurement Data for Millimeter-Wave Radar

3.2 CORMO

We have developed a data measurement unit, "CORMO," to deal with these tasks. **(Fig. 6)**

CORMO carries out various measurements; analog/digital beat signals of radars at a maximum sampling speed of 5 MHz, camera image data, CAN communication data and RS232C communication data (GPS position). It transmits large volumes of data at high speed via PCIe (Peripheral Component Interconnect express) to PC, and stores them in a hard disk sequentially. After 1 microsecond-accuracy timestamps are added to these stored data, the whole measured data are playable by time synchronization.

Fig.6 CORMO

*(1) In FM-CW (Frequency Modulation Continuous Wave) method of millimeter-wave radars, the distance and the speed of a target are measured concurrently from beat signals. First, transmitted waves from radar reflect at a target and become received waves. Then, the beat signals are made by mixing of the transmitted waves and received waves at a receiver.

Table 1 CORMO Specifications

Measurement	CH	Sampling	Application
Analog measurement	8	Max 5MHz	Beat signal measurement
Digital I/O	24	Max 5MHz	Measurement timing signal
Camera image	4	30fps	Perimeter monitoring
CAN	4	—	Radar calculation, velocity, etc.
RS232C	2	—	Position measurement by GPS
LVDS	4	—	Communication with external device
LAN	1	—	Communication with PC
PCIe	1	—	Communication with PC, data storage

3.3 Application for Measurement

This section introduces an application for measurement and reproduction that we have developed along with CORMO. The application (**Fig. 7**) runs on Windows of a host PC via PCIe communication between the PC and CORMO for setting measurement conditions, operate measurement, storage and reproduction. The application has functions to show a birds-eye view of target states (distance, angle and relative velocity) recognized by radar, a tracking display connected with camera images, and graphs as well as unprocessed analog/digital signals and CAN data on monitoring screen. This application enables back-in-time data storage triggered by long-period driving measurement or changes in CAN signals.

It also has functions to show a FFT graph of beat signals, radar recognition values, a birds-eye view, target tracking on camera images, variable number behaviors and targets during algorithm calculation described below.

Fig.7 Monitoring Screen

3.4 Test Equipment for algorithm development

A millimeter-wave radar algorithm is the function to extract targets (vehicles/motorcycles ahead and oncoming vehicles/motorcycles) from all the detected targets included in beat signal components and to calculate their distances, horizontal angles and relative velocities to own vehicle. The algorithm has to be able to deal with the cases of lost targets and nonexistent targets (ghosts) caused by the influences of surroundings.

As an algorithm development method, in order to improve recognition, beat signals are measured at a test course or a field test site using prototype radar installed on a vehicle, and the measured beat signals are repeatedly reproduced and input into the algorithm designed in C language or MATLAB/Simulink on PC. However, it is impossible to execute a program conforming to interrupt sequence on PC. Besides, actuator drive and data communication to other ECUs according to PC calculation result lack real-time performances. Thus, this method is used only in the case of developing a radar.

So, we have developed "CORMO + Rtype" using Rapid Prototype ECU "Rtype" that we had developed for powertrain control development in 2002. Rtype is capable of similar processing as an actual ECU without making an ECU hardware prototype.

Fig.8 Application CORMO with Rtype

The cooperation of this Rtype and the previously-described CORMO enables an efficient development/test of ITS. Specifically, the data of the beat signals measured by CORMO are transmitted to Rtype via LVDS (Low Voltage Differential Signaling) communication, and a CPU (Pentium) installed on Rtype implements fast filter calculation (FFT), calculates the target recognition software capable of simulating an algorithm to be installed in radar, and outputs the target recognition results to CAN communication data or a host PC.

Besides, the cooperation enables the judgment easily whether the algorithm result is positive or not by transferring camera image data to Rtype and tracking the data with the recognition results calculated by Rtype. The cooperation also enables development/test of the whole system control not only the algorithm of radar. The whole system control can be conducted by installing control applications in Rtype, such as ACC (Adaptive Cruise Control) to control automatically vehicle velocities and distances from detected driving vehicles, and PCS (Pre-Crash Safety) system to reduce damages caused by collision with a leading vehicle, an obstacle, a pedestrian, etc.

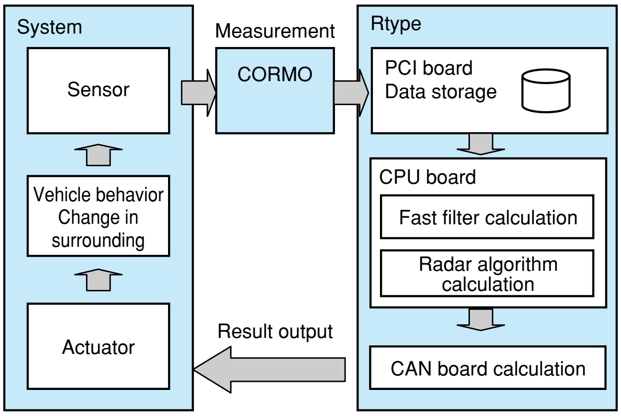

Fig.9 CORMO and Rtype Configuration Diagram

We plan to approach to build an environment for automatic test of radar sensor and ITS. The developed radar sensors and algorithms are tested by the method of comparing the target vehicles in the camera images taken during driving and the target vehicles recognized by radar, which takes thousands of man-hours.

To solve this problem, by the use of a high-precision GPS and the combination of CORMO and Rtype, the installed logic to judge radar acquisition in Rtype enables automatic tests. **(Fig. 10)**

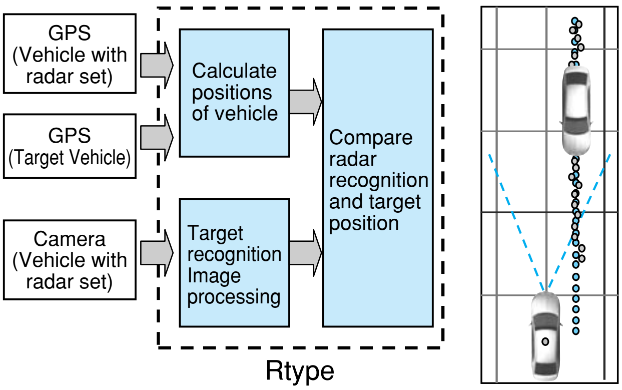

Fig.10 Automatic Test Outline

3.5 Conclusion

The tools for ITS development require variety of information of driving states and surrounding environment as well as radars, cameras and GPS. The information include various data concerning a vehicle cabin, vehicle surroundings, communication between vehicles, road conditions, satellite signals, communication with service center, etc.

This paper introduced CORMO with Rtype using millimeter-wave radar. We plan to pursue advanced toolchain CORMO as a comprehensive development tool, which is capable of prompt algorithm development including systems and measurements of mass data at high speed. Work restructuring and efficiency for development are required in growing fields of environmentally conscious technology, security / safety technology, communication technology, etc. We are focusing on utilizing and improving development environment represented by HIL simulators, etc. as well as our other ECU products.

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Profiles of Writers

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Entered the company in 1989. Since then, has engaged in manufacture of controllers for vehicle and in development of simulators for control system development (CRAMAS). Currently in the CRAMAS Department of Common Technology Division, ITS Engineering Group.

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