Automotive R&D at Hitachi Overseas Laboratories

George Saikalis, Ph.D.
Shigeru Oho, Ph.D.
Takuya Shiraishi
Masahiko Amano, Ph.D.

OVERVIEW: The overseas Hitachi automotive research laboratories located in the USA (Automotive Products Research Laboratory: APL), and Europe (Automotive Research and Development Laboratory: ADL), are locally supporting Hitachi automotive business. The type of regional support takes on many different facets: contributing to product development by providing simulation models to carmaker' advancing mechatronics simulation technologies to better serve customers' future needs and customizing navigation technology for the local market applications. Collaboration with automotive customers is essential to promote mutual relationships. To this end, local R&D is needed to advance technology and adapt Hitachi devices to USA or European engines and platforms. Research vehicles have been developed using new products from Hitachi ITS and successfully tested on US highways. Furthermore, support of local Hitachi group companies is vital for technical synergy, along with joint work with industry consortiums such as AUTOMOTIVE OPEN SYSTEM ARCHITECTURE (AUTOSAR) and leading academic institutions. For Hitachi group companies' support, APL is operating a materials laboratory to further assist and enhance local Hitachi group engineering.

INTRODUCTION

HITACHI pursues global presence not only in business but also in R&D (research and development). To be a global automotive supplier, Hitachi carries on R&D operations in three key markets: Japan, North America, and Europe (see Fig. 1). In 1989, Hitachi opened its first overseas laboratory, the Automotive Products Research Laboratory (APL) in Michigan, USA. Since

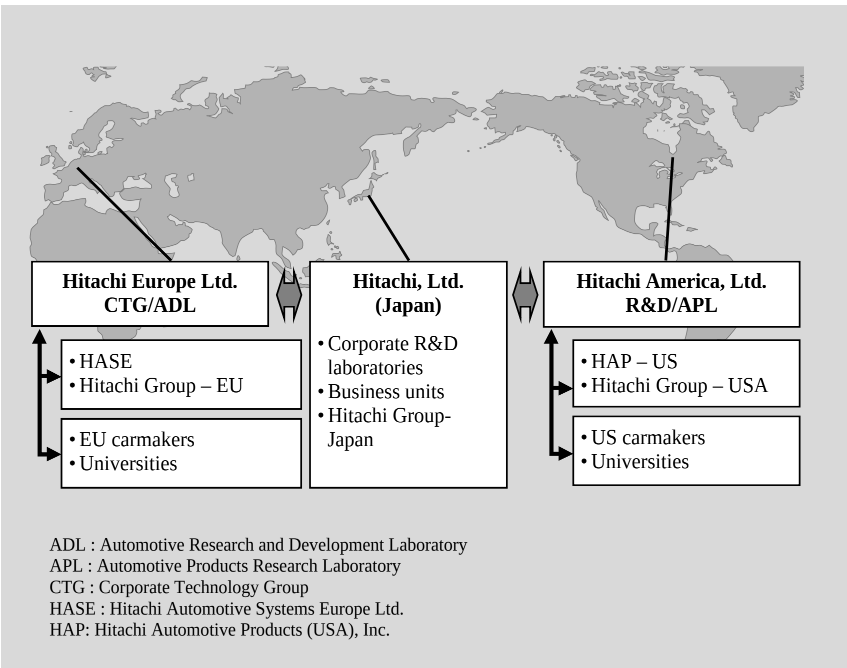

Fig. 1—Hitachi's Global Automotive R&D Network.
Hitachi carries out R&D operations in three key markets: Japan, North America and Europe. The overseas laboratories' most important mission is to directly contribute to Hitachi business.

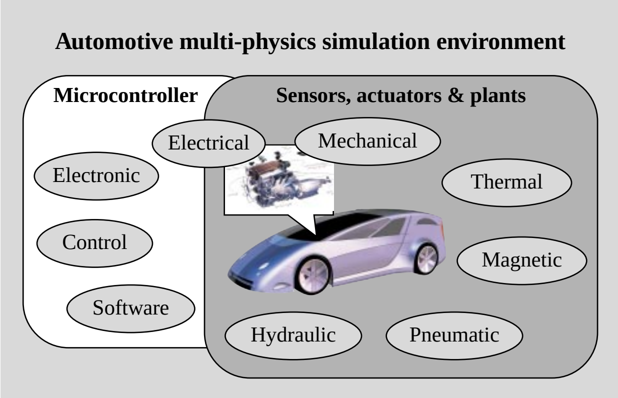

Fig. 2—Scope of Automotive Model-based Design.
Automotive systems are very complex and integrate a wide variety of engineering domains. Simulation model-based development allows a more efficient approach to solve complex mechatronics problems.

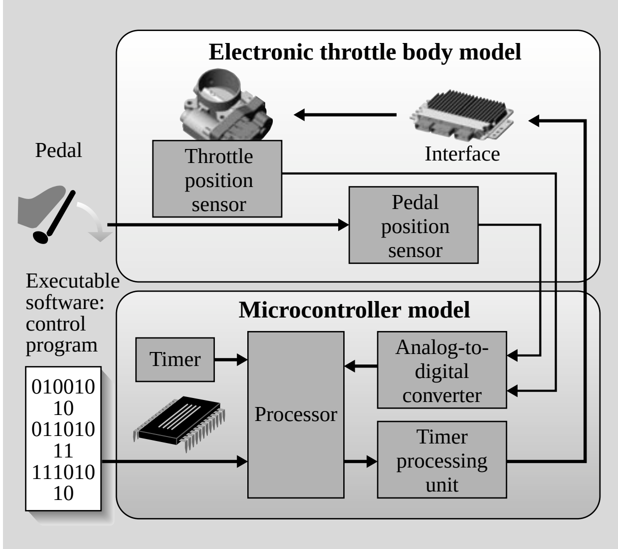

Fig. 3—Mechatronics Hardware-software Co-simulation for Automotive Subsystem.
Model-based simulation includes all the elements of a mechatronics system: microcontrollers, control software, electronic circuits, position sensors, motors, gears, springs, etc. This allows hardware/software system to be evaluated for superior quality and higher reliability.

its foundation, APL is located in Hitachi Automotive Products (USA), Inc. (HAP-US), which has its sales unit and a technical center in the Detroit area. As its name implies, APL concentrates on automotive technologies for the North American market and cooperates with HAP and Hitachi group companies. APL's most important mission is to directly contribute to Hitachi business by participating in product development and by providing technology solutions to resolve numerous engineering issues. Taking the regional advantage of "Motown Detroit," APL also communicates and often collaborates with Hitachi's customers, universities, and industry communities on advanced automotive technologies. The research projects at APL encompass a wide range of engineering domains, from automotive engine control to hybrid powertrain, from car navigation and ITSs (intelligent transportation systems) to materials and process engineering.

To expand overseas R&D further, Hitachi established a new automotive laboratory, the Automotive Research and Development Laboratory (ADL) in Europe in 2005. ADL has two operating sites; one at Hitachi Automotive Systems Europe GmbH. (HASE) in Munich, Germany, and the other in Paris, France. Like APL, ADL was conceived to strengthen the engineering capabilities of Hitachi in Europe and also to meet the growing technological demands of HASE and Hitachi group companies locally. In addition, ADL's mission was also to be able interact with regional customers and communities. Immediately after its launch, ADL started working on advanced product development of car navigation to expedite market penetration in Europe. It also began collaborating with industry consortiums and research organizations on embedded control software technologies, in which Europe has a regional advantage. ADL is preparing to establish R&D capabilities on engine powertrain technologies to better support local Hitachi business.

MODEL-BASED DEVELOPMENT AND SIMULATION

The demands for more complex system development and the ever-challenging tough requirements for hardware and software improvements have increased the need for model-based design and engineering. Model-based development allows a more efficient approach to solve mechatronics problems (see Fig. 2). Simulation models are graphical, hierarchical, executable sub-systems, block diagram representations of the physical system, and also algorithm behavior.

Simulation is the method that provides the possibility to build "what-if" scenarios and analyze the results. APL has been contributing to product development by providing customers with simulation models of both components and systems. The customers run simulation analysis before they finalize product design. The driving force is to improve quality with methodology such as DFSS (design for six-sigma). This was done for many components including the Hitachi electronic throttle body project with a North American customer(1).

Another APL undertaking is the advancement of mechatronics simulation technologies to better support customers' future needs. APL is investigating a model-based design that provides engineers with a very powerful approach to examine microcontroller architecture and functions before device manufacturing, and serves as a means to evaluate the behavior of a whole control system(2). The hardware-software co-simulation can include such mechatronic components as microcontrollers, electronic circuits, position sensors, motors, gears, springs, metal blades, etc. (see Fig. 3). The control software is executed as it is on the "virtual" embedded control system without any modification.

This mechatronics simulation approach inherently provides a platform for robust controller development. It enables design engineers to perform "what-if" scenarios for control system products without needing actual hardware, and help them expedite product development and validation cycles.

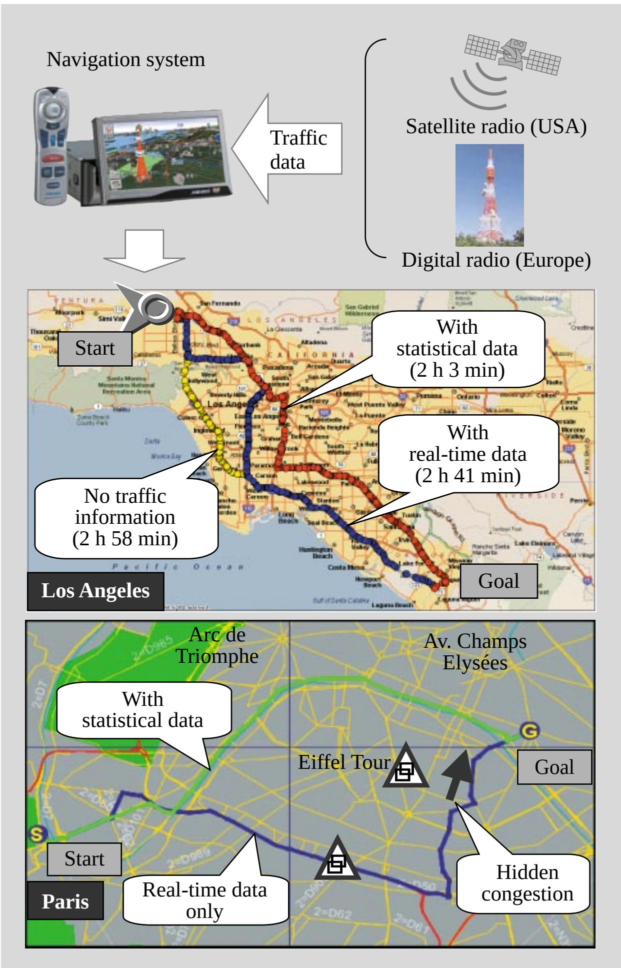

Fig. 4—Improving Route Guidance in Los Angeles, California, USA (upper) and in Paris, France (lower).
The traveling time may be reduced by the use of real-time traffic data and statistical analysis as shown in the automated route guidance results for Los Angeles. The statistical data analysis may also help avoid traffic jams as predicted for the route in Paris.

GLOBAL DESIGN AND LOCAL ADAPTATION OF CAR NAVIGATION SYSTEMS

Xanavi Informatics Corporation, a Hitachi affiliate, provides automotive navigation and multimedia systems for many automotive manufacturers in different continents. Market demands, government regulations and communication infrastructures differ in each market. Global design of the car navigation system architecture and local adaptation of product features to a specific market are very important and crucial in successful market penetration.

Route guidance, for instance, is one of the most important features of a car navigation system. Hitachi has been developing technologies to advance the route guidance feature; upgrading it from static route calculation to dynamic route guidance by utilizing real-time traffic information and predicting traffic congestions by analyzing traffic information statistics.

These technologies have already been in practical use in Japan since 2004, and are currently being adapted to other market requirements. Key core technologies such as data classification and route calculation algorithms can be used globally, but some key features need to be customized to each local market. For example, traffic data delivery schemes are different area by area. In Japan beacons are widely used, but in the USA only satellite radio can cover the whole continent. On the other hand, European systems adopt digital radio services.

At APL, real-time traffic information broadcast from satellites radios has been fully integrated into car navigation products for North America. ADL has developed a prototype of dynamic route guidance system with statistical traffic data for the use in Paris. The raw traffic data was supplied by a French traffic information provider. It was converted into Hitachi's proprietary data format, sorted out based on conditions such as weekends and vacation seasons, and utilized for route guidance. The results of trial runs of the prototype system look promising and show a great deal of improvement in the accuracy of real-time traffic prediction as compared to conventional static guidance systems (see Fig. 4).

PRODUCT DEVELOPMENT WITH BUSINESS DIVISIONS

APL has been involved in many projects related to business units. Projects such as digital-knock implementation have been accomplished in collaboration with HAP and projects related to the ITS, and intelligent vehicles have been achieved with Hitachi Automotive Systems Group of Hitachi, Ltd.

There are many benefits for APL to handle this type of development such as:

(1) Close communication—face to face—with local automotive manufacturers

(2) Technical exchange between Hitachi corporate research laboratories and business divisions

(3) Application of latest technologies available in the local market

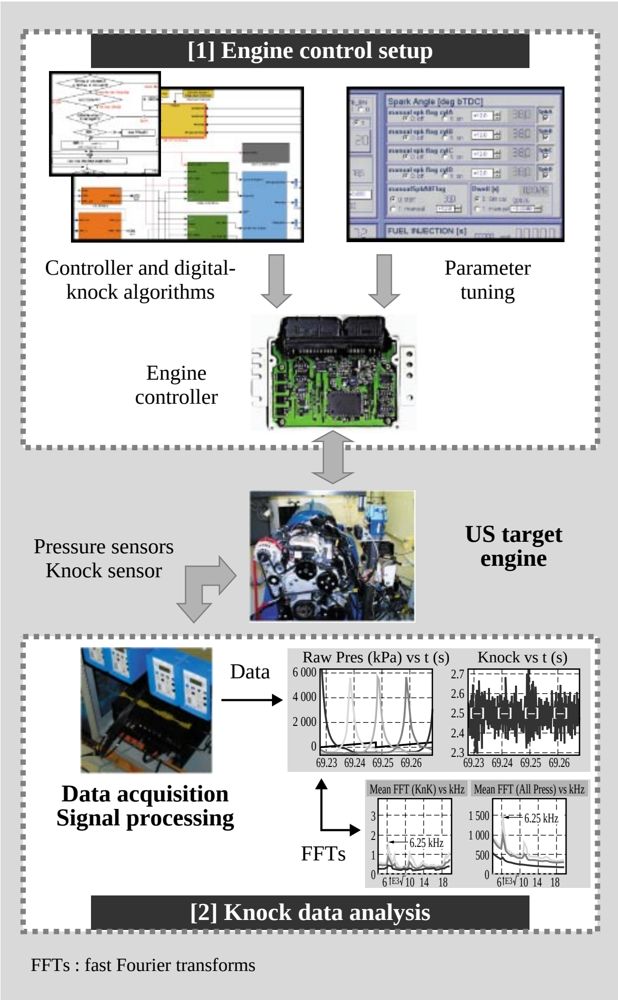

Fig. 5—Test and Knock Analysis Performed Jointly with US Carmaker.
Digital-knock relies on a piezoelectric sensor to capture the knock sound. Signal processing is done using an FFT algorithm. Close customer collaboration is the key in the final tuning of the algorithm on an actual engine.

Digital-knock Development for US Target Engine

Knocking of an automotive engine is a phenomenon that occurs when a portion of the air-fuel mixture spontaneously combusts ahead of flame propagation. This causes very high local pressures, which propagates in the combustion chamber and can potentially damage the engine. To suppress the engine knocking, the ignition timing must be optimally adjusted.

Hitachi needs to have the capabilities to better collaborate with customers. Digital-knock is a good example of customer collaboration, as it requires operation with actual engines to determine optimal design. To manage engine knocking, Hitachi has developed the digital-knock technique, an FFT (fast Fourier transform)-based signal processing algorithm for knock sound analysis.

APL investigated the digital-knock algorithm while working closely with a North American automotive manufacturer. One of the difficulties was to apply the algorithm with a non-ideal sensor location because of physical constraints. Knocking data was analyzed jointly with the customer to optimize the detection scheme (see Fig. 5).

Close collaboration with the local carmaker promoted exchange of technical ideas which eventually led to the fine tuning and implementation of the algorithm in production type application. To advance the technology further, APL works closely with universities to prepare for next-generation products[3].

ITS Research Vehicle

As another project illustrating our contributions to business units, APL has been working with Hitachi Automotive Systems to promote Hitachi ITS technology in North America. The goals of the research are to explore technologies to make automobiles safer and to adapt Hitachi's new electronic systems to US highways.

For that purpose, APL has developed an ITS research vehicle to test new types of sensors such as an image-processing camera, a monolithic 77-GHz milliwave radar, and a biometric ID (identification) system. The vision-based system consists of a camera,

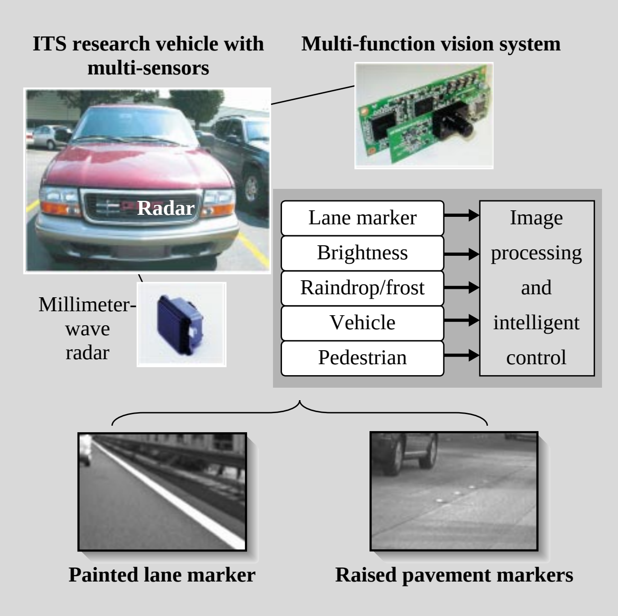

Fig. 6—Outline of ITS Research Vehicle for the US Market.
The multi-function vision system controls the outside lighting, the wipers, the defroster and warns the driver when the vehicle drifts from its intended lane; the millimeterwave radar measures the distance with preceding vehicles for the ACC (adaptive cruise control) and for collision avoidance.

a high performance processor along with a dedicated video chip (see Fig. 6). This system allows the following multi-function operations:

(1) Lane departure warning system when the vehicle drifts away from its intended lane
(2) Lighting control when lighting conditions change
(3) Adaptive headlights dimming when oncoming or preceding vehicle lights are detected
(4) Wiper control when raindrops are detected on the outside of the windshield
(5) Defroster control when condensation occurs on the inside of the windshield

Evaluating the performance of the vehicle within the US infrastructure is very important, since the technology has to operate reliably under many conditions. One such condition is the ability to detect raised pavement markers such as Bott's dots. The State of California is one of many users of Bott's dots instead of painted lane marker in the USA. Local testing and evaluation is therefore required to validate operation of the design with these markers and other environmental condition including day and night operation.

Hitachi's ITS technology has been promoted to many US based carmakers. The carmakers borrowed APL's research vehicle to evaluate Hitachi's system on their test tracks.

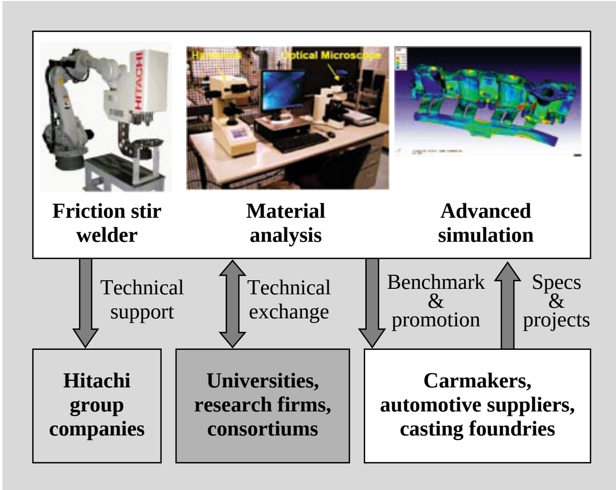

Fig. 7—APL Materials Lab Capabilities and Missions.
The Materials Lab has FSW (friction stir welding) machines, material analysis equipment, and CAE (computer aided engineering) tools. It is charted to serve Hitachi group companies in the North America and to collaborate with outside organizations.

COLLABORATION WITH REGIONAL COMMUNITIES

Advancing Material and Process Engineering in the USA

As Hitachi grows its overseas production, local capabilities of material analysis and process engineering are becoming indispensable. To meet the demand for material technologies, the Materials Lab was established as a new facility at APL. It is chartered to serve the Hitachi group companies in North America and also to collaborate with regional customers, industries and academia (see Fig. 7). The interaction with external parties encourages the development of mutually beneficial networks, and helps Hitachi better understand local market demands.

One of the technologies available at the Materials Lab is FSW (friction stir welding). FSW is a solid state joining technique for metals. A rotating cylindrical tool is plunged into the work pieces to be joined causing frictional heat which bonds the material together. The welding of the material is facilitated by severe plastic deformation in the solid state involving dynamic recrystallization of the base material. FSW has several advantages including low thermal distortion, no melting of base metal, no filler material required, etc. FSW can be also applied to spot welds. There is an increasing demand for FSW in the automotive industry as it is useful for producing lighter vehicles. APL is one of the leading advocators of the automotive FSW applications[4]. Collaboration with US companies is ongoing to apply light metals such as aluminum and magnesium to automotive doors, hoods, and body panels.

APL also has the capabilities of material and reliability analyses. The testing equipment allows analysis of material strength along with material surface properties. Furthermore, APL is providing development capabilities for casting simulation via tools such as ADSTEFAN (Hitachi's commercial simulation product). ADSTEFAN allows US companies to optimize their casting process and design, thereby improving product quality.

Advancing Embedded Software Engineering in Europe

As electronic control prevails in automobiles, automotive E/E (electric/electronic) systems become more complex and its embedded control software grows to an unmanageable size. Longer lead-time and increased cost of E/E system development are serious issues for both the carmakers and the suppliers. Thus, advancing embedded software engineering is a crucial subject in automotive industry today.

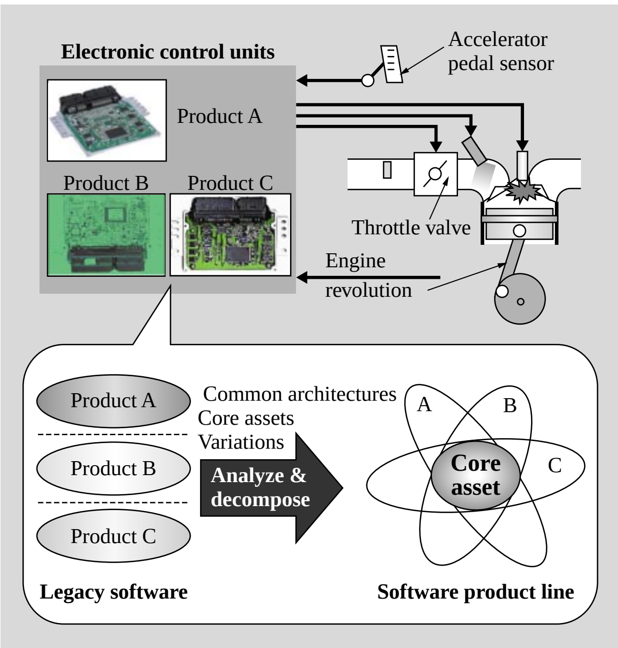

Fig. 8—Outline of Software Product Line Technique.
The software product line technique helps software engineers identify common architectures of legacy software, extract useful software components from it, and systematically reuse the extracted components when they develop a similar product.

Europe plays a leading role in advancing control software technologies, with its regional advantage of well-developed automotive and aerospace industries. European companies, universities and research organizations are contributing to improving automotive embedded software development processes. For automotive software standardization, AUTOSAR (Automotive Open System Architecture), an industry consortium, was organized in 2003 by carmakers and suppliers in Europe and is carrying worldwide activities. Its main goal is to establish a de-facto open standard for automotive E/E system architecture. Hitachi is a premium member of AUTOSAR since 2004.

ADL actively participates in the European software technology development and wishes to contribute to establishing an automotive software standard. At AUTOSAR consortium meetings, ADL researchers make proposals for software specifications, run analyses and discuss the draft standard. With this local presence in Europe, they try to be well informed of progress of standardization and to keep abreast of the latest technologies.

ADL is also cooperating with Fraunhofer Institute, a German national research organization, in software engineering. The SPL (software product line) technique is being applied to automotive software in order to improve its reusability. Conventionally, control software is individually tailored for each controller product. In SPL approach, a set of legacy control software is analyzed upfront and common architectures are extracted. The software modules are then decomposed into program components of "core assets" and "variations" (see Fig. 8). Control engineers look into the available stocks of these software components and reuse them as much as possible when a new product is developed. ADL developed a method to analyze commonality of legacy control software and applied the method to engine management systems[5]. Initial investigation showed good possibility of practical use, and SPL applications to commercial systems are being planned.

CONCLUSIONS

APL in the USA and ADL in Europe are the sister laboratories of Hitachi's corporate R&D for automotive technologies. They are both strategically located in two key continents, and provide local R&D capabilities for Hitachi's global automotive business.

The close access to technology resources in each region makes APL and ADL advantageous in communicating and collaborating with customers, consortiums, universities and trade associations. They are also playing more and more important roles fostering synergetic cooperation among automotive business units and R&D laboratories in the Hitachi group companies. As Hitachi expands its global customer base and its automotive operation around the world, the overseas automotive R&D need to keep abreast of emerging technologies and to grow further.

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ABOUT THE AUTHORS

George Saikalis, Ph.D.

Joined Hitachi America, Ltd. in 1990, and now works at the Automotive Products Research Laboratory. He is currently engaged in the embedded system and model based system modeling. Dr. Saikalis is a member of The Society of Automotive Engineers (SAE), the Institute of Electrical and Electronics Engineers, Inc. (IEEE).

Shigeru Oho, Ph.D.

Joined Hitachi, Ltd. in 1980, and now works at the System LSI Research Department, the Central Research Laboratory. He is currently engaged in the research on automotive semiconductor applications. Dr. Oho is a member of IEEE and SAE.

Takuya Shiraishi

Joined Hitachi, Ltd. in 1993, and now works at the Automotive Products Research Laboratory, Hitachi America Ltd. He is currently engaged in the engine system for automotive. Mr. Shiraishi is a member of The Japan Society of Mechanical Engineers (JSME), Society of Automotive Engineers of Japan (JSAE) and SAE.

Masahiko Amano, Ph.D.

Joined Hitachi, Ltd. in 1985, and now works at the Automotive R&D Laboratory, Hitachi Europe GmbH. He is currently engaged in the research on automotive control and electric/electronic platform. Dr. Amano is a member of The Institute of Electrical Engineers of Japan (IEEJ), IEEE, JSAE, and SAE.