Model-Based Development and Artificial Intelligence

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1. Introduction

It was about 15 years ago that I first heard the term “Model-Base Development (correctly Model-Based Development in English): MBD” from an engineer of an automobile manufacturer. I remember I said, “Why don’t you use “Model-Based” just as is said in English?” However, “Model-Base” is commonly used today for its easier pronunciation in Japanese. I am pleased that the term “Model” has become widespread not only in the academic community but also in industry. While the term “Model” has different meanings depending on the person who uses it, a model in this article refers to the essence of a complicated phenomenon represented by a formula. It becomes possible to simulate an actual system by obtaining a model. Furthermore, utilization of a model will open up a path to a standard design.

In the meantime, the third boom of “Artificial Intelligence (AI)”[(1)] has arrived as a result of a significant increase in people’s interest in AI represented by “machine learning” which utilizes so-called big data. In this article, I present the close relationship between model-based development and machine learning from the viewpoint of control theory[(2)], my own specialty.

2. Model-Based Development

A scheme wherein software cycles of which each process has an associated test is called a V-cycle model. Especially in the automobile industry, model-based development (MBD) has become widely used to reduce man-hours and development time by applying a model to the entire V-cycle. In the V-cycle model, development starts from design using a model, after which system design verification on a computer and prototype hardware verification are performed.

Then a mass production code is generated based on the model and the model is handed over to simulation in the system verification (see Fig. 1).

Models are used to improve performance and secure vehicle system quality in developing a vehicle which is a large system comprising some 30,000 parts. It is no longer possible to develop vehicles without a model under the present conditions where vehicles are complicated and have highly enhanced functions. In the automobile industry, MBD is often defined as "a method to create a model of a control target and control device using a CAE tool (MATLAB/Simulink for instance) and develop a control system based those models."

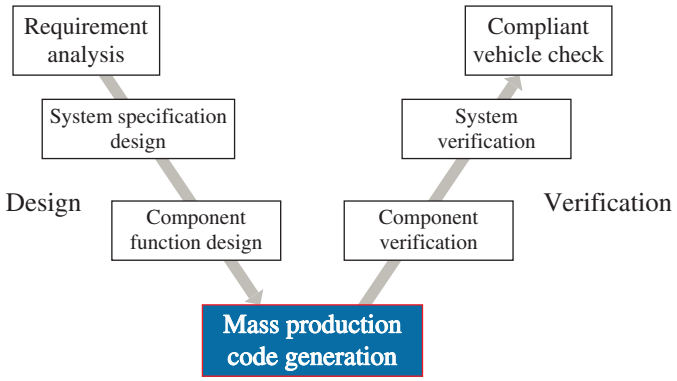

Fig. 1 V-cycle in MBD

3. Relationship between Model and AI

Fig. 2 shows a cycle to understand a phenomenon and design it as a target[3].

The cycle starts from inquisitiveness to desire to "understand" a phenomenon in nature. This is so-called science. "Data" provide a clue to the goal. For example, Kepler estimated motion of Mars relative to the Sun based on a large amount of observation data and discovered the three Kepler's laws. A true achievement of Kepler is that he pioneered a method to derive a mathematically supported physical model. That is, Kepler discovered physical laws from observation data and represented them as models (formulae).

Newton wrote "Principia (Mathematical Principles of Natural Philosophy)" (1687) to systematically organize the knowledge of physics investigated and quantified by Kepler and Galileo, as well as the knowledge acquired by nature philosophers of the same period using mathematical descriptions represented by calculus. Newton and Descartes are said to have given birth to modern science and the foundation from which they made their accomplishments was the approach to simplify and represent complicated phenomena by formulae. A typical example thereof is Newton's second law: (Mass × Acceleration (or the second derivatives of position) = Force). The differential equation can be considered as a model of dynamic system.

In this way, laws and principles are derived from a large amount of data, that is big data and a model is obtained by representing them by a formula. This process is called modeling. There have been only a few people called geniuses who could accomplish these endeavors since the period of

Newton. However, machine learning is attempted lately to use a machine to perform the process using big data and the technology is called artificial intelligence (AI). The left half of Fig. 2 shows what has been described above. Like this, models and AI are closely related through data.

Once a model is obtained, what is desired next is to use it. The first step of this is "analysis." Using a model enables one to investigate characteristics of the target to "predict" its behavior in the future. For example, if you can construct a precise weather forecasting model in a computer, you will be able to predict the future movement of a typhoon. Furthermore, you will desire to manipulate the target at will. This is the technological creative spirit called "design," or so-called "engineering." Then, "control" plays the central role. As described above, the right half of Fig. 2 shows MBD.

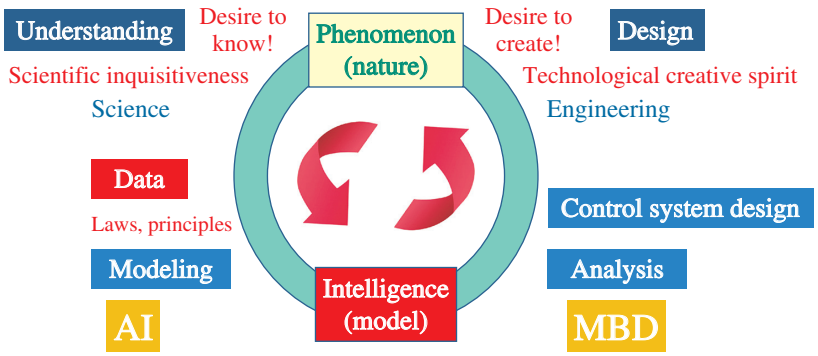

Fig. 2 From understanding of phenomenon to design

4. Concept of Model-Based Activities

As described in the previous section, it is very important to convert a complicated natural phenomenon into a model, a simplified mathematical expression, and unique modeling techniques have been developed in various fields.

When targeting a large scale/complicated system, development efficiency is enhanced through standardization by basing the development upon a common language "model." Furthermore, sharing a model makes it easier to make "coordination" between the persons in charge of development to contribute to improvement in quality of the development. Like this, it is expected that using a model enables an organization to break through the limits of each person's specialty.

For example, when developing vehicles, vehicles are composed of an engine, power train, brakes, an air conditioner, audio equipment and other various components. Especially electric vehicles comprise two major components, the drive power source, the "motor," and the energy source, the "battery."[4] The motor is subjects to physical laws including Fleming's law, Newton's law and Kirchhoff's law. The battery operates according to a complicated electrochemical reaction formula. That means there is a need for an interface to connect the different technology areas, physics and electrochemistry. A strong candidate for this is the "model." Physically modeling a motor enables one to obtain a model which represents the relationship between the input and the output of the motor (specifically a transfer function). The battery[5] is modeled by a method called system identification[6] from input and output

data, taking the current flowing into the battery as the input and the voltage between terminals of the battery as the output and, as with motor modeling, a model called the transfer function is obtained. By using these models, it becomes possible to handle the motor and battery in the same field. Once a model is obtained, it can be used to design a control system as well as to estimate physical quantity which cannot be measured using a Kalman filter[7].

5. Summary

A “Model” is a result of successful synthesis of knowledge. “Data” is the resource required to create a model. This article has described that, from the viewpoint of control theory, there is close relationship between the model-based development (MBD) and artificial intelligence (AI) represented by machine learning utilizing data and that they are not independent of each other. Especially when addressing a target represented by vehicles which are subject to physical laws, you must not forget to utilize not only data, but also its physical characteristics (dynamics).

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