A REVIEW PAPER ON CYBER PHYSICAL SYSTEM

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ABSTRACT

This work is about the development of improved engineering models for CPSs. Historically, predictable models have been very helpful, especially in the industrial and information revolutions. The single-threaded imperative programmes are deterministic models that have already shown to be effective. The cybersynchronous physical systems use models in such a manner that non-deterministic behaviour occurs. In both cases, project A and project B demonstrate that it is conceivable and practicable to create deterministic CPS models with accurate physical realisations. This initial effort, which was called PRET, was a proof of concept demonstrating that real-time digital logic timing accuracy could be successfully accessed at the software level of abstraction. The second project is Ptides (which uses a predictable model for distributed cyber-physical systems), which demonstrates that faithful realisations of deterministic models for distributed cyber-physical systems exist. These projects offer evidence that it is feasible and practicable to use a deterministic CPS model.

KEYWORDS: Cyber Physical System, Engineering, Model.

INTRODUCTION

A cyber-physical system (CPS) is a collection of computers and physical systems that are orchestrated. Embedded computers monitor and regulate physical processes through feedback loops in which physical processes influence calculations and vice versa. Automotive systems, manufacturing, medical devices, military systems, assisted living, traffic control and safety, process control, power generation and distribution, energy conservation, HVAC (heating, ventilation, and air conditioning), aircraft, instrumentation, water management systems, trains, physical security (access control and monitoring), asset management, and disaster recovery are all applications of CPS (telepresence, telemedicine).

As an intellectual exercise, CPS is about the junction of the physical and the virtual, not their unification. It blends mechanical, environmental, civil, electrical, biomedical, chemical, aeronautical, and industrial engineering models and procedures with computer science models and procedures. This article claims that since these models and procedures are incompatible, CPS forms a new engineering field that requires its own models and procedures.

Around 2006, Helen Gill of the National Science Foundation in the United States created the phrase "cyber-physical systems." Although the name "cyberspace" is credited to William Gibson, who introduced it in the book Neuromancer, the word CPS has longer and deeper origins. It is more correct to see the phrases "cyberspace" and "cyber-physical systems" as deriving from the same root, "cybernetics," invented by Norbert Wiener, an American mathematician who had a significant effect on the development of control systems theory. During World War II, Wiener invented technology for automated anti-aircraft gun targeting and fire. Although he did not employ digital computers in his mechanisms, the ideas behind them are comparable to those utilised in modern computer-based feedback control systems. Because his control logic was basically a calculation, albeit one using analogue circuits and mechanical components, cybernetics is the synthesis of physical processes, computation, and communication. Wiener's phrase is taken from the Greek v (kybernetes), which means helmsman, governor, pilot, or rudder. The analogy is appropriate for control systems.

The word CPS is sometimes used interchangeably with the phrase "cybersecurity," which refers to the confidentiality, integrity, and availability of data and has no fundamental relation to physical processes. Thus, the word "cybersecurity" refers to the protection of cyberspace and is only tangentially related to cybernetics. While CPS undoubtedly entails several difficult security and privacy considerations, they are far from the only ones.

CPS is inextricably linked to the phrases Internet of Things (IoT), Industry 4.0, the Industrial Internet, Machine-to-Machine (M2M), the Internet of Everything, TSensors (trillion sensors), and fog (like the cloud, but closer to the ground). All of them represent a vision for a technology that intimately integrates our physical and digital worlds. To our mind, the term "CPS" is more fundamental and long-lasting than any of these, as it does not directly refer to either implementation approaches (e.g., "Internet" in IoT) or specific applications (e.g., "Industry" in Industry 4.0). It instead focuses on the basic philosophical difficulty of bridging the cyber and physical worlds' engineering traditions. A "cyber-physical systems theory" is comparable to "linear systems theory."

VARIED MODELS

Three main notions are involved in modelling: the entity being modelled, the model, and the modelling paradigm. For instance, a Newtonian model of a mass and a spring (the modelled object) is composed of an ordinary differential equation (ODE) (the model). The modelling paradigm is calculus and differential equations mathematics. A mechanical engineer could use a Newtonian model to construct or analyse a mechanical system.

A very different example is a C-language computer software (the model) that simulates the behaviour of an electrical machine (a computer) that converts binary data stored in electrical memory. The modelling paradigm in this case is imperative programming theory from computer science.

Engineers often mistake the model with the modelled object. Electrical engineers, for example, may refer to an ODE as "the system" and state, for example, that "the system is stable." However, such a statement is not true regarding a physical system. It is a remark regarding a physical system's model. Any conclusive assertion about a system (stability, determinism, timeliness, dependability, and safety) is, arguably, a statement about a model, not about the entity represented. This concept is referred to as the "Kopetz principle" in honour of Hermann Kopetz, from whom I learnt it. Solomon Wolf Golomb famously observed, "you will never hit oil by drilling through the map," emphasising the need of not confounding the model with the item being represented.

This does not, however, impair the utility of a map in any way. A model is a representation of the item being modelled. A model may be used for a variety of reasons. In general, the objective of a model in science is to provide insight into and prediction of the entity being modelled. However, models are often used in engineering to create systems that do not yet exist. The model acts as a specification in this scenario. It is now the responsibility of the physical system to emulate the model, not the other way around. For example, a C programme specifies the design, and the silicon and wires of the physical embodiment are supposed to emulate the program's behaviour.

DETERMINISTIC MODEL

Determinism is a very beneficial quality that models may possess. Given the model's inputs, a deterministic model has precisely one behaviour. Such a characteristic is useful because it may explicitly specify the "right" behaviour of the modelled object when the same inputs are used. A model of this kind may be used to construct tests that assess, for example, if an engineering physical system is sufficiently true to the model to be considered "right" and hence ready to ship. A probabilistic model is less effective for this purpose, since there may be several "right" actions.

While this concept of determinism seems straightforward, there are several nuances. Consider a C programme. What constitutes the inputs? They may be bit patterns in files or memory that existed previous to the commencement of the program's execution; or they might be data delivered during the program's execution. In the latter situation, the order in which those inputs are presented may influence the program's behaviour. Is that time included in our definition of "the inputs?" If this is the case, even a basic single-threaded imperative programme may be a nondeterministic description of the computer's behaviour. Such issues must be resolved inside the modelling paradigm before we can reasonably inquire about the model's determinism.

A modelling paradigm may be deterministic, which means that it is limited to deterministic models. Restricting models to this paradigm has the benefit of making them deterministic by definition.

CONCLUSION

This article discusses how to improve the engineering of cyber-physical systems via the use of more accurate models. I have underlined the need of distinguishing models from the item being modelled, an all-too-common mistake among engineers. I have argued that deterministic models have historically been incredibly beneficial, even serving as the bedrock of the industrial, digital, and information technology revolutions. Differential equations, synchronous digital logic, single-threaded imperative programming, and instruction set architectures are all examples of important deterministic models. However, cyber-physical systems mix these concepts in such a manner that their determinism is lost. I then outline two initiatives that demonstrate the feasibility and practicality of deterministic CPS models with accurate physical realisations. PRET is the first project, demonstrating that the timing accuracy of synchronous digital logic can be successfully realised at the software abstraction level. Ptides is the second project, which demonstrates that deterministic models for distributed cyber-physical systems may be faithfully realised in practise. Ptides makes use of network clock synchronisation, which I anticipate will become more prevalent in the future. These are only existence proofs, and there is little question that further work is required before engineers begin using deterministic models for CPS on a frequent basis.

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