氏　　名	JIANG,Geyang		
学位（専攻分野）	博士（工学）		
学位記番号	総研大甲第898号		
学位授与の日付	平成１７年９月３０日		
学位授与の要件	高エネルギー加速器科学研究科　加速器科学専攻 学位規則第６条第１項該当		
学位論文題目	Development of Embedded EPICS and its Application to Accelerator control system		
論文審査委員	主　査	教授	浦川　順治
		教授	春日　俊夫
		教授	川端　節彌
		教授	黒川　眞一
		教授	藤井　啓文
		教授	加藤　直彦（高エネルギー加速器研究機構）
		助教授	山本　昇（高エネルギー加速器研究機構）
		助教授	金谷　範一（茨城大学）

論文内容の要旨

Development of Embedded EPICS and its Application to Accelerator Control Systems

This thesis is on investigation and implementation of Embedded EPICS Controllers by the use of μITRON (Micro Industrial TRON) to overcome many disadvantages caused by the advent of Ethernet-based controllers in the EPICS device control layer.

At present almost all accelerator control systems are using of Distributed Control Systems (DCS) architecture on the basis of so called the standard model. In the standard model, the control system consists of three layers: the presentation layer, the device control layer, and the interface layer.

Another trend of accelerator control systems at present is to use a free toolkit for its middle-ware. Among a few toolkits, EPICS (Experimental Physics and Industrial Control System) is the most widely used. EPICS was first developed in 1991 and its open, free and full DCS-based features have made it to be adopted in many control systems of scientific facilities, such as accelerators, telescopes, and large high-energy experiments.

EPICS is designed on the basis of the standard model. The first two layers, namely, the presentation layer and the device control layer, are divided functionally, but connected with each other through a high-speed network such as FDDI. The presentation layer, which is called Operator Interface (OPI) layer in the EPICS terminology, is typically composed of several workstations and X-terminals that are used as operator consoles. The device control layer consists of VME Input/Output Controllers (IOC) and/or other kinds of computers to accomplish the data processing and control logic. The interface layer is composed of I/O modules on IOC or other field bus modules that interface devices.

Recent rapid development of Ethernet has made it de fact international standard of the network in accelerator control systems. More and more device controllers with Ethernet interface have been widely used, such as PLCs (Programmable Logic Controller), to replace old field-bus type interface device controllers. These Ethernet-based device controllers are equipped with more CPU power and memory capacity, and have become intelligent enough to process the control logic that was originally accomplished by IOCs.

Now due to the advent of Ethernet-based device controllers, the standard EPICS 3-Layer model becomes redundant and show some disadvantages:

- Lacking of real-time response: IOCs communicates with intelligent device controllers through Ethernet, while, Ethernet, as defined in IEEE 802.3, is unsuitable for strict real-time industrial applications because its

communication is non-deterministic.

- Ineffective use of hardware: in EPICS, when we use intelligent device controllers, a complicated device driver called "asynchronous driver" is put on IOCs to drive intelligent device controllers. Expensive VME machine are only used as "protocol transformer" that translates the manufacture's proprietary protocol to EPICS CA (Channel Access) protocol.
- Duplication of programs: We have put runtime database on IOCs and also similar programs at intelligent device controllers such as Ladder on PLCs.

One way to avoid these disadvantages and maximally use the benefit of using intelligent device controllers is to implement integrating control software (IOC core program named as iocCore in EPICS) on these intelligent device controllers, thus making existed intelligent device controllers to work as separated IOCs. We call this type of controllers Embedded EPICS Controllers.

From EPICS base 3.14.x, iocCore supports can run not only on vxWorks but also recent versions of RTEMS, Solaris, Linux, HPUX, Darwin and Windows, and there have been some implementations of Embedded EPICS Controllers running on vxWorks and Linux. But they all have some shortages. For example, Embedded EPICS Controller running on Linux does not have any good real-time response, and Embedded EPICS Controller running on vxWorks lacks BSP (Board Support Package) support from hardware manufacturers.

Many intelligent device controllers available on the market in Japan use μITRON, a kind of Japanese domestic real-time kernel. The advantage of μITRON is that it has BSP. We have investigated the use of μITRON as a kernel on Ethernet-based device controllers and also implemented Embedded EPICS Controllers on μITRON.

After implementing Embedded EPICS Controllers running on μITRON, the redundant device control layer can be omitted. EPICS architecture can be recovered back to the standard 3-Layer model and the disadvantages mentioned before can be eliminated. Also running iocCore on μITRON allows us to apply Embedded EPICS concept to smaller devices that could not be supported by previous solution.

This thesis also discusses the technical details of implementation Embedded EPICS on μITRON and the performance of the Embedded EPICS Controllers. The result shows that Embedded EPICS Controllers can be well used for real applications in accelerator control systems.

論文の審査結果の要旨

EPICS(Experimental Physics and Industrial Control System)は加速器の制御に用いられるミドルウエアであり、加速器制御における標準モデルである、３階層構造に基づいて作られている。３階層とは、OPI (Operator Interface)、IOC (I/O controller)、およびOPIとIOCを結ぶネットワークである。IOCの下には、インテリジェンスを持たない比較的単純な機器は接続されることが想定されている。

近年、Ethernetに直接接続できる、高いインテリジェンスを持ったPLCなどの装置が急速に普及してきた。もし、EPICSにおいて、これらのPLCなどをIOCのもとに接続すると、EPICSは、４層構造となり、IOCとPLCにおいて、インテリジェンスの重複が発生することになる。また、これにより、多くの場合、リアルタイム性が損なわれてしまう。

Jiang Geyang氏の研究は、最近のEPICSに発生したこのような欠陥を、PLC中にIOCの機能を持たせることにより、IOCを無くし、EPICSを本来の標準的な３層構造に戻し、システムを簡略化するとともに、リアルタイム性を回復することを主題としている。Jiang氏は、このようなPLCに組み込まれたIOC機能をを組込型EPICS Controller(Embedded EPICS Controller)と呼ぶ。

Jinag氏は、PLCに用いられるOSの候補として、日本が独自に開発し、かつ工業用に多用されている、μ-ITRONを用いることにし、まず、μ-ITRONがこの目的に適するものであるかについて、十分な調査を行った後、実際にPLC上にEmbedded EPICS Controllerを作成することにより、μ-ITRONに基づいたEmbedded EPICS Controllerが実現可能であることを示した。

Jiang氏は、さらに、μ-ITRONに基づいた彼が制作したEmbedded EPICS Controllerを用い、リアルタイム性の計測を行い、このシステムが十分なリアルタイム性を持つことを示し、今後、実際の制御へ大きな応用性を持つことを明らかにした。審査委員会は全員一致で、Jiang氏の仕事は、独創性に富み、EPICSの発展に貢献するものであり、また、加速器制御への大きな応用性を持つ価値ある研究であり、学位論文に値するという結論に達した。