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An Educational MBL Platform Development with Remote Access Functionality

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원격 제어 교육용 MBL 플랫폼 개발에 관한 연구

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Abstract The Microprocessor Based Laboratory Systems(MBL) with the remote access functional could put basic science experimental facilities together by providing a modern platform that the students can utilize simultaneously to learn basic physics, chemistry and biology. Our educator target platform combines a highly integrated 8-bit embedded Atmega128 processor and real time embedded OS (operating system), allowing plenty of headroom for follow-on basic science projects for students. The proposed MBL-NUTOS (Microprocessor Based Laboratory-NUT/OS) employed in the lab are available with internet base simulation capabilities, on public servers and students personal PCs, enabling the students to study at home and increasing the opportunity of accessing for the science laboratory facility.

Key words : remote control, embedded system, TCP/IP protocol, RTOS, educational platform

요 약 본 논문에서는 물리, 화학, 생물 등 실험 교과목에 대하여 학생들이 가정 및 여러 장소에서 원격 접근 기능을 가지는 마이크로프로세서 기반 실험 장치(Microprocessor Based Laboratory Systems, MBL)의 소프트웨어 및 하드웨어 플랫폼 구조 설계에 관하여 연구 하였다. 본 시스템에서는 학교 실험실에서 수행되는 실험교과목에 대한 다양한 주변 환경 및 실험방법에 대하여 지원 가능하도록 원격접근기능을 TCP/IP 프로토콜로 구현한 NUTOS를 실시간 운영체제를 사용하였다. 본 논문에서 제안한 MBL-NUTOS(Microprocessor Based Laboratory-NUT/OS)는 실시간 인터넷 접속이 가능하며 서버 또는 클라이언트로 활용 가능하도록 설계 되었으며 실험을 통하여 본 플랫폼의 유용성을 입증하였다. 본 MBL 하드웨어 플랫폼에서는 기존의 마이크로프로세서 기반 실험 장치가 가지고 있지 않은 네트워크 접근 기능이 구현 되었으며 또한 실시간으로 실험 상황을 인터넷으로 억세스 할 수 있는 장점을 가지고 있다. 더욱이, 저비용 고집적도를 가지게 설계되어 일선 학교에서 용이 하게 사용 할 수 있도록 하였으며, 학교 실험실에서 수행되는 실험이 미래 유비쿼터스 교육환경에 적용 가능하도록 하여 첨단 과학에 대한 학생들의 인지를 넓히는 주요 매개체로서 그 교육 효과를 높이도록 하였다.

1. Introduction

Many basic science education programs stay on abstract environments based on theories and limited experiments. As a result, opportunities to access the practical concepts utilizing laboratory facilities are limited. However, as microprocessor based systems become ever more widespread, the ability to view experimental facilities as an integrated whole is a crucial part of science education.[1]. At the Kongju National University, we have developed Microprocessor Based Laboratory Systems based on NUT/OS utilizing MBL-NUTOS[2]. The major feature of MBL-NUTOS is the integration of a modern 8-bit microprocessor platform with TCP/IP based internet access devices, allowing simultaneous design of basic science experimental facility components in a real-world environment.

The objectives for the MBL-NUTOS are summarized below:

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- To learn the basic science experimental facility aspects integrated with basic science principles based on the internet remote systems.
- To learn the operating principles and get used with hands the basic science experimental facilities such as physics, chemistry, biology, mathematics, and geology.
- To gain practical experience in applied science design projects.
- To be exposed to the science experimental tools and techniques utilizing remote access ability. And
- This paper outlines the motivation behind the MBL-NUTOS, describes the lab infrastructure and lab sequence, and concludes with a look at possible future directions.

2. Goals

In the typical process of teaching and learning the basic science subjects, we feel that it will be good for the students to work with a general-purpose microcontroller-based laboratory system with remote access capability. Experimental facilities are highly useful keys for better understanding of the problems in the science and for the verification of the theories. We have developed an MBL system for the students, which the lab facilities can be accessed from anywhere even in home and anytime. Therefore, we designed an embedded system platform (MBL-NUTOS) containing an embedded system board based on ATmega128 microprocessor, the real time NUTOS, and a set of science experimental modules.

The main CPU of the MBL-NUTOS is the ATmega128, which can be called heart of the proposed system. The reason behind choosing ATmega128 is an 8-bit microcontroller having high-performance and low power consumption. Furthermore, it has advanced RISC architecture, very high code density, and faster execution up to 16MIPS. Moreover, it has large flash Rom of 128KB as well as 4KB EEPROM and 4KB internal SRAM. Compared to the other 32-bit microprocessors, it is a cost effective, and the board based on Atmega128 is easier to design and less cost to manufacture[3]. These excellent features make it perfect for our proposed MBL applications.

MBL is not enough for studying and education. When it comes to the software, two things have to be done. The first thing is porting the NUTOS to MBL. The next stage is developing the MBL sensor Blocks. The NUTOS is a tiny real time operating system, which had been written to implement a TCP/IP stack, and the TCP/IP part has been named Nut/Net. It has many good features such as portable, ROMable, scalable, preemptive, real-time multitasking and royalty free for educational use as well as supplying source code which makes it useful as the MBL software [4-6]. The MBLBB (Microprocessor Based Laboratory Building Blocks as a set of science experimental modules, NUTOS, and a MBL platform (NUTOS Embedded Systems Hardware Board) all are included to give the name MBL-NUTOS[7]. Integrating the NUTOS and the ATmage128, we have implemented the MBL-NUTOS.

3. MBL-NUTOS Infrastructure

This chapter describes the creation of small network appliances, which helps us to access the system remotely. For the requirement of the remote access, a network appliance must be built having internet connection facility, and being "network friendly" in student's home network, in short it should support standard protocols. This deduces the burden of the MBL with an internet protocol and RTOS that called as MBL-NUTOS. To create MBL-NUTOS platform neutral, the standard TCP/IP network protocols were used[8-10].

For communication purpose with the student of a home PC, standard web server protocols are used that make it easy to test each end of the network independently. The system can be pictured as the home PC of the student is the web server and the MBL-NUTOS is the web client. Our specific server implementation runs on a Windows XP machine and utilizes Perl scripts running as a common gateway interface (CGI) under Internet Information Server (IIS). Since the flat-file architecture is chosen for storage, little work needs to be done to port that software to other environments. As a result of these choices, the client software running on MBL-NUTOS does not care about what the student on the server use as long as the server's network interface is the same.

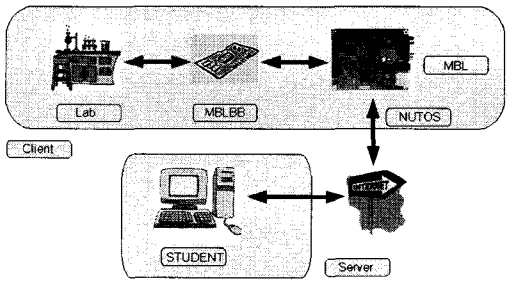

Figure 1. A schematic of MBL-NUTOS system configuration

The hardware is based on a reference design that is popular among many embedded developers, being fit for this particular application and providing hardware support for each requirement. To minimize the effort a custom TCP/IP INTERNET ACCESS -based expansion board is added to an existing processor development platform. The employed platform uses the Atmega 128 microcontroller and an external internet interface. The Atmega CPU provides more than enough power and I/O for this project. Furthermore, it does this with low power consumption, which was mentioned initially. The initial implementation is simple as shown in figure 1. In the figure 1 the configuration of The MBL -NUTOS system can be seen which is composed of MBLBB (Microprocessor Based Laboratory Building Blocks as a set of science experimental module), NUTOS and a MBL platform (NUTOS Embedded Systems Hardware Board).

3.1 Software Design

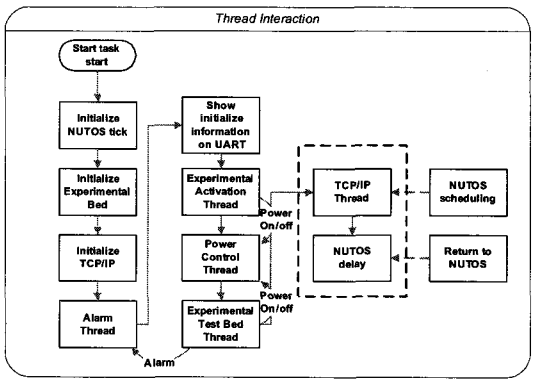

Figure 2. The MBL-NUTOS and the host PC thread interactions

There are a number of interactions available between MBL-NUTOS and the host PC (student's home PC), which are shown in the diagram in figure 2. When the system is packaged and installed, the MBL-NUTOS mounts on the experimental test bed and it is ready to use. The MBL-NUTOS software consists of the five main processes, which are also shown in figure 2. When MBL-NUTOS is powered on, it first starts up a few device drivers. In the next step, the platform initializes the connected hardware with the internet adapter. Afterwards, when the internet device has been properly registered, it then tries to startup sequences to bring the other threads online.

Experimental Activation Thread In this status, the reading for experimental facility is carried. After this startup, when the experimental facilities are on the active states, it performs two jobs that include allowance of signals to the Power Control Thread so it stays power on state and connections of the signals to the experimental facilities through the TCP/IP transaction thread.

TCP/IP Transaction Thread This thread manages the transactions through TCP/IP to the home PC (student PC, web server). At power up, it requests the entire list of experimental facilities from the home PC, and caches them locally. Then, when a web transaction is initiated from the experimental activation thread, it can query the local cache. If it finds a match, it signals the home PC. Furthermore, if the experimental facility is not known by the home PC, it can signal the PC not to throw away this item until the student PC database has been updated. If for some reason it cannot successfully contact the home PC, the experimental facility in the outbound queue are cached. It keeps trying periodically until the connection is made.

Alarm Thread As the name implies, this one is responsible for signaling to the teachers and students if the experimental test bed is in the host PC database or not. The different beep sounds indicate that the non-availability of desired experiment in the host PC database.

Experiment Test Bed Thread This thread monitors the state of an experimental sensor that knows when the experimental platform is on the ready state. When the platform is ready, it signals the status to change the power control thread. When the experimental platform is on the deactivation state, it signals the power to be turned on.

Similarly, when the experimental platform comes back into the ready status, it signals the power to be turned off.

Power Control Thread This thread accepts the direct requests to turn power on and off as well as manages a timeout. With each power maintenance signal, a timer is reset to keep the experimental platform on. In absence of power maintenance signals, the timer is expired and this thread turns the power off, even if the experimental platform is not the ready state.

3.2 Hardware Design

The Ethernut 2.1 board manufactured by Egnite Software GmbH is employed to implement the hardware platform of MBL-NUTOS. The board is well suited for application development in the network-based sensors, the remote monitoring equipment, the alarm service providing the remote diagnose and service, the industrial ethernet applications in home. Moreover, it meets nearly all requirements of MBL-NUTOS, and does so in a small size and low power consumption.

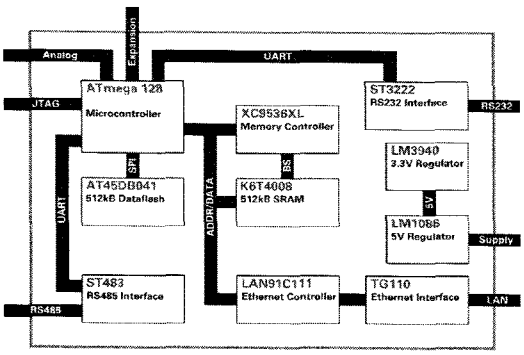

Figure 3. MBL-NUTOS configuration with Ethernut 2.1 platform[2]

As shown in figure 3, the Ethernut features the Ethernut 2.1[11], a tiny (80 x 100 mm) board combining Atmel's Atmega128 RISC microcontroller with SMSC's LAN91C111 Ethernet controller. The main features are the ATmega 128 RISC microcontroller with up to 16 MIPS throughput, the full duplex IEEE 802.3 compliant 10/100 Mbps Ethernet controller with onboard, the 128 kByte in-system programmable Flash ROM and 512kByte serial flash memory, 22 programmable digital I/O lines, and 8-channel, 10-bit analog/digital converter. Operation of the system depends on the NU/OS and application software running on the MBL-NUTOS. Moreover, the experimental platform data are saved on the 128 kByte in-system programmable Flash ROM and the 512kByte serial flash memory as a character file. The experimental platform data in this file are the 8 bit binary numbers ranging between 0 and 255, reflecting the 8-bit resolution of the MBL's on-board analog to digital converter. This file also includes the experimental platform comments about the laboratory location, experimental platform and the test bed information, the experimental time, the experimental date, and so on. This text file is readily imported into the editor software for analysis. For example, most applications will require that the file's experimental platform data can be converted to the basic science standardized units such as temperature, stage height, pressure, etc. by application of a calibration function.

4. Experiment

In addition to familiarizing students with the MBL-NUTOS environment, it is required that the labs provide time to present necessary background material in lecture. The MBL-NUTOS labs build on each other to the point where students have carried the experiment for the system with internet and without internet. The sequence is capped with a simple mini project that allows the students to explore or expand on facets of the system that are covered in the experiment facilities. So far, a temperature measurement experiment has been carried that can be connected to the MBL-NUTOS to create a recording thermometer. In this experiment, the MBLBB (Microprocessor Based Laboratory Building Blocks as a set of science experimental module) are employed on a thermistor. The MBLBB sensor circuit is powered by a separate 9 V battery regulated by a 7805A voltage regulator to provide a constant 5 V power supply. A regulated supply eliminates voltage drift that could result from decreasing battery output over the deployment period. The sensor and circuitry cost under $10 to construct. The sensor was deployed between the inner and storm window of our lab for approximately five days to monitor daily cycles in air temperature. The daily cycle in temperature detected by the MBL platform is temporally consistent with observed daily and longer-term changes in outside air temperature. The MBL-NUTOS and a student's PC have monitored the all data

through the internet. At this stage, we have investigated the basic operation of MBL-NUTOS and the role the home PC. As time progresses, we plan to incorporate the more successful and exciting mini-projects from previous experiments into updated standard labs in next semesters. So, we will look at the transactions from two perspectives. Firstly, if MBL-NUTOS is imagined as the server, then the home PC will be the client to query MBL-NUTOS periodically. We would investigate the performance about this approach. Since the home PC is used for many things including game playing, the performance should be investigated under this environment. The MBL-NUTOS must take care a lot of data from the experimental facilities. When the students log in to the home PC, they can run a program to pull the list from MBL-NUTOS, thereby emptying its cache. This model doesn't help very much with that requirement for signaling the students. Secondly, we would consider the other way. If MBL-NUTOS is a client, then when it has something new for the home PC as server, it will establish the connection, and push the experimental results to the home PC in real-time. If this home PC is online most of the time running a server application, then MBL-NUTOS can push the experimental results immediately and the need for a large MBL-NUTOS cache goes down. Based on this model, the PC must be reasonably accessed and must run some type of server program, regardless of who's logged in. 2.

To evaluate the teaching performance on the proposed MBL we have investigated the project interests of 18 students. Out of the about 27%(index1 in figure 4) of the students(all of them coming from Middle School) enjoy building different software applications for NUTOS MBL. Another 27% of the students (index2 in figure 4) like playing the proposed MBL whereas 33% of the students(index 3 in figure 4) like TCP/IP access software labs for allowing internet access. The rest 11% of the students(index 4 in figure 4) dislike TCP/IP functionality due to lack of graphic interface of pc. We have also investigated the students learning outcomes on the one physics course: Winter 2006 in the computer course for Kongju National University Gift Program. The students who have experiences on the coures have 15% higher grades in the semester compared with other students without NUTOS experiments. It came from the MBL-NUTOS teaching performance improvement since we have learned from previous experiences. The 10 students have highest average score, which may be due to their high interest physics foundations during their studies. We have also used team works to carry out those labs (each team has 2 to 3 students) and We found that the students can share experiences and submit better results.

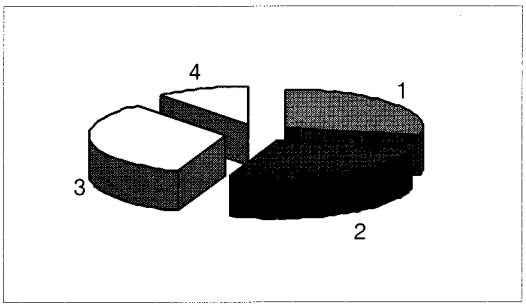

Figure 4. Students project choice

5. Conclusion

By combining a highly integrated 8-bit embedded processor with high-density TCP/IP INTERNET ACCESS, we have investigated the MBL-NUTOS as a flexible, powerful lab platform with plenty of headroom for MBL. This TCP/IP INTERNET ACCESS allows the students to carry the experiment from remote places. The objectives for the MBL-NUTOS are that the students will experience the basic science experimental facility aspects with integrated basic science principles based on the internet remote systems and learn the operating principles. Moreover they will be familiar with basic science experimental facilities such as physics, chemistry, biology, mathematics, and geology as well as obtain practical experience in applied science design projects and being exposed to the science experimental tools and techniques utilizing remote access ability.

This paper presents, outlines the motivation behind the MBL-NUTOS and describes the lab infrastructure with hardware and software. For further instance the lab sequence is shown as a case to implement the MBL-NUTOS and concludes with a look at possible future direction as follows:

- To expand the range of hardware devices that can be interfaced.
- To allow more students play their home PC into the

MBL-NUTOS to evaluate the system performance.

- To provide further opportunities to the interested students by offering additional experimental courses using the same or similar lab equipment.
- To develop more laboratory examples by expanding the range of experimental facilities that can be interfaced into MBL-NUTOS.

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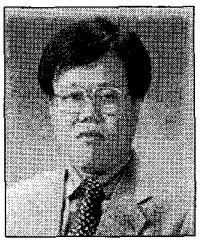

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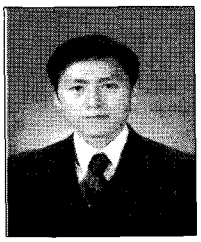

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