Artif Life Robotics (2008) 12:161–166
DOI 10.1007/s10015-007-0460-x

ORIGINAL ARTICLE

Ayahiko Niimi · Hiroshi Shimada · Rika Goto
Masaaki Wada · Kei Ito · Osamu Konishi

Peer-to-peer sensor network system for a school temperature measurement system

Received and accepted: July 17, 2007

Abstract In this paper, we propose the technique of sensor data mining by the peer-to-peer (P2P) network. The mechanism that it is possible to share on the P2P network is considered by receiving information from the sensor by the P2P application. A searching request for a sensor unit and mining the sensor data occurs on the P2P application. We applied the proposed technique to a school environment measurement system. In this system, sensor units are arranged on campus and a user can measure a room's temperature and humidity. The temperature sensor and the humidity sensor are implemented in a microcomputer board that can connect to the Internet, and we define the microcomputer board as a sensor unit. We construct the P2P sensor network on which a PC accesses the sensor unit and the P2P application on its PC uploads on the P2P network. The P2P network can disclose sensor information after more advanced processing is given by thinking as a P2P application and not a sensor unit, but on the sensor unit and the PC.

Key words Sensor data mining system · P2P · JXTA · School temperature measurement system

A. Niimi (✉) · H. Shimada · R. Goto · K. Ito
Department of Media Architecture, Future University-Hakodate, 116-2 Kamedanakano-cho, Hakodate 041-8655, Japan
Tel. +81-138-34-6222; Fax +81-138-34-6301
e-mail: niimi@fun.ac.jp

M. Wada
Collaborative Research Center, Future University-Hakodate, Hakodate, Japan

O. Konishi
Department of Complex Systems, Future University-Hakodate, Hakodate, Japan

This work was presented in part at the 12th International Symposium on Artificial Life and Robotics, Oita, Japan, January 25–27, 2007

1 Introduction

We can now obtain various data easily by using a high-performance computer and the Internet. Data mining that extracts significant knowledge from a large amount of data has become popular. The technique for applying data mining to text information such as a Web page has developed recently, although data stored in databases was targeted in normal data mining. On the Internet, various time-series of data can be obtained. For instance, the image data of the weather satellite and the data of various sensors can be obtained. The feature of these data is continuous data in the time-series. The techniques which applied data mining from databases are used for time-series data, but some techniques were improved for the time-series data.

Digital measurements of the temperature and humidity, etc., become possible, and connecting the system that acquired the measured data to the network becomes possible. However, there are many measurement systems which are rich systems that use sensors on a PC, or which are cheap microcomputer systems that need to construct a special network for the sensor network. We propose the sensor network system using a microcomputer board that can connect to the Internet. This proposed system can acquire information from the sensor of the microcomputer group arranged on the network, and can view collected information on a Web browser.

In KES2006,[1] it was shown to be possible to construct easily a microcomputer's sensor network which was combined with microcomputer modules (microcube) and the database server and a Web application server. A system that measured the room temperature on a school campus was constructed. It has run for 4 months, and the effectiveness is verified.

Ecopic[2,3] research is similar to this research. Ecopic research has aimed to construct an ecopic of a weather-observing system that is easy for the user. Our proposed system aims to improve the extendibility by using a microcube that is a generality module.

There is much research about MOTE, which is the wireless sensor network platform, and middleware that treats the sensor network as a database has also been researched.[4-6] A query processing system called TinyDB[7] that runs on TinyOS,[8] which is a compact OS for wireless sensor equipment (MOTE), was proposed. A lot of sensor nodes are needed to construct the system, which covers the entire university by the wireless sensor network. When the system that covers the campus is constructed, it has a small number of sensor nodes, and using the wired network at the school becomes possible in the proposed system.

In this paper, we propose the technique of sensor data mining by the peer-to-peer (P2P) network. The mechanism that is possible to share on the P2P network is considered by receiving information from the sensor by the P2P application. A search request for a sensor unit and mining the sensor data occurs on the P2P application. The advantage of the P2P system is the scalability of the number of sensors. It becomes possible to correspond to the change in the number of sensors easily by constructing the sensor network on the P2P network.

Section 2 describes the sensor module using the microcube. Section 3 describes the composition of the sensor network as a server–client system. We describe the installation of the microcube, the server, and the client, and the technique of collecting and viewing data. Section 4 describes the P2P sensor data mining system. In Sect. 5, we describe construction of our proposed system, and discuss the problems of constructing a sensor network. Section 6 gives a conclusion and describes future work.

2 Sensor module

In this section, we describe the proposed sensor module.

2.1 Outline of the microcube

The microcube is a board computer and is composed of several stackable boards.[9,10] Figure 1 is a photo showing one of the combinations of a stacked microcube. The specifications of the CPU and extension boards are summarized in Table 1. It has a CPU board with a RENESAS H8 CPU and a TCP/IP Protocol stack. Stackable boards can vary, e.g., an Ethernet LAN board, a compact flash board, a PCMCIA board, a serial board (RS232C and RS422), and so on (some boards are shown in Figs. 2 and 3). Since the different combinations of stackable boards make a seamless connection with the sensors, users can structure an ad hoc sensor network very easily. To get sensor information through the Internet, HTTP is also employed so that the user can get data via a standard Web browser.

2.2 Instrumentation of the present system

The microcube used in the system to get information of the room's condition is composed of an H8/3069 CPU board, a LAN board, and a special sensor board. The special sensor board used is the board of the programming practice class at Future University-Hakodate (the sensor board is shown in Fig. 4). Future University-Hakodate has a practice programming class with a microcomputer and assembler language as "Media Architecture Practice II." The special

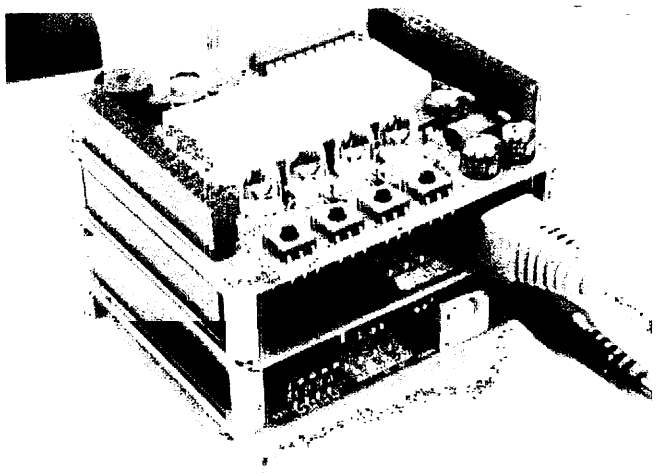

Fig. 1. Photograph of a stacked microcube

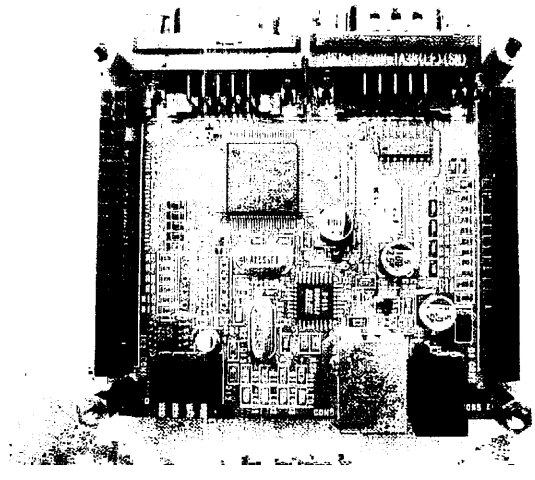

Fig. 2. CPU board

Table 1. Line-up of the CPU and extension boards of the microcube

Board name	Features
H8/3048BV	CPU board for battery operation
H8/3069	Same for general purposes (see Fig. 6)
H8s/2638	Same for controller area network (CAN)
LAN	Extension board for ethernet connection (see Fig. 6)
CF	Same for compact flash slot
IDE	Same for storage devices
ADIO	Same for analog/digital IO
COM4	Same for 4-port serial interface
RF	Same for wireless communication
PCMCIA	Same for PCMCIA slot

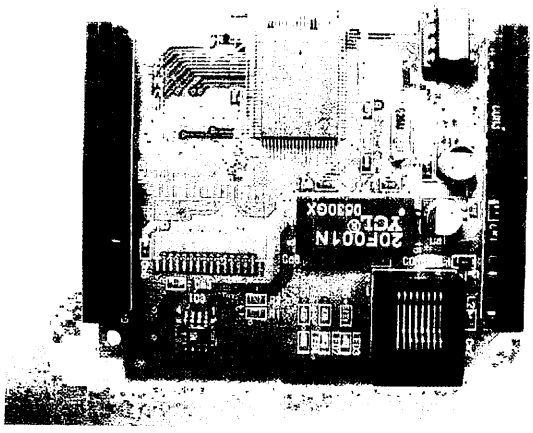

Fig. 3. LAN board

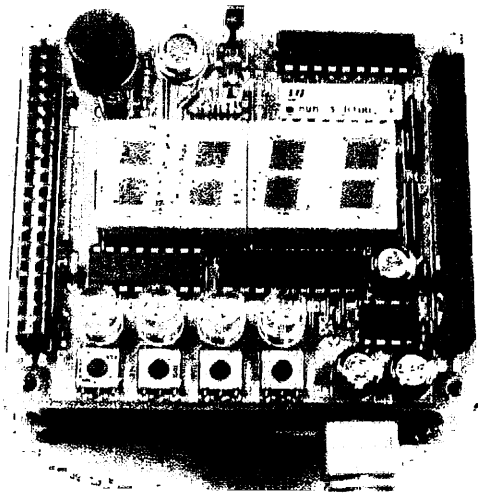

Fig. 4. Sensor board

board for the microcube was designed for its practice class. The push switch, the thermally sensitive resistor (temperature sensor), and the CdS sensor (optical sensor) were attached on this board as input. Moreover, four seven-segments LEDs and four twocolor LEDs were attached as output. Because an accurate temperature measurement using a thermally sensitive resistor is difficult, a digital sensor is added to this board for our experiment. Humidity can also be measured by this digital sensor. Only the temperature data is acquired in this experiment, although some sensors are attached on the board. The exchange and the addition of the sensor can easily be done by exchanging the sensor boards.

To confirm the measurement data easily, the measured temperature was displayed in a seven-segment LED. Moreover, data can be got by HTTP through the network. When only one sensor module runs, the user can display the present temperature when the user accesses it using a Web browser.

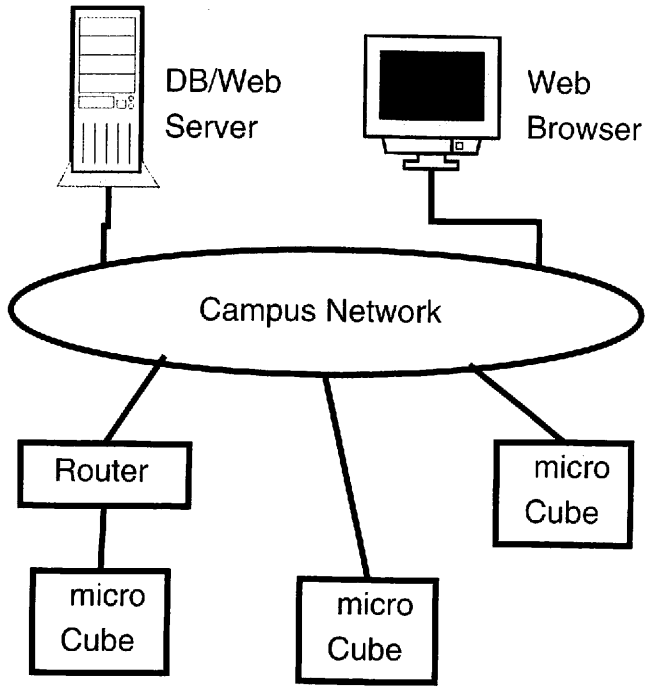

Fig. 5. Network configuration

3 Network configuration

The sensor network was constructed by using the microcomputer described in Sect. 2. Figure 5 shows the composition of the sensor network system constructed. First of all, we constructed the proposed sensor network system as a server–client system.

The software used is shown in Table 2. The data store is implemented by Perl, and the data display is implemented by JSP.

The following steps show the collection of data and the stored data display.

1. Data storage:
   - — the Perl script accesses the URL of the microcube;
   - — the microcube returns the measurement result by HTML format;
   - — the HTML is parsed, and the necessary data are preserved in the database.
2. Data browse:
   - — the URL of the server is opened from a Web browser;
   - — the JSP accesses the database;
   - — the necessary data are acquired from the database;
   - — the result is processed in a graph and displayed on a browser.

The microcube arranged in the school is connected with the campus network (LAN). The data from each sensor module are acquired with the server set up on the campus network at regular intervals, and are stored in the database. In this experiment, data are acquired from the sensor module every 10 min. The acquired data are processed with

Table 2. Software used in the web database server

System	Software
OS	Red Hat Linux release 9
HTTP	Apache 2.0.40
Database	PostgreSQL 7.3.2
Software codes	Tomcat 5.0.28 and Perl 5.8.0

the Web application server set up on the same server, and can be displayed from a Web browser of a PC on the campus network.

At first, the microcube is connected to the campus network by arranging it in the router because the router had not been exceeded in the LAN of the microcube. Afterwards, connecting the microcube to the campus network even if we modified the program and the router was not set up became possible, so that the router was not required.

4 P2P data mining system

In this paper, we propose the technique of sensor data mining by the peer-to-peer (P2P) network. The mechanism that makes it possible to share on the P2P network is considered by receiving information from the sensor by the P2P application. The searching request for a sensor unit and mining the sensor data goes on the P2P application. The advantage of the P2P system is the scalability of the number of sensors. It becomes possible to react to a change in the number of sensors easily by constructing the sensor network on the P2P network.

We consider the case where the proposed technique is applied to a school environment measurement system. In this system, sensor units are arranged on campus, and the user can measure a room's temperature and humidity. The temperature sensor and the humidity sensor are implemented in a microcomputer board that can be connected to the Internet, and we define the microcomputer board as a sensor unit. We construct the P2P sensor network on which a PC accesses the sensor unit and a P2P application onto its PC uploads onto the P2P network. The P2P network can disclose sensor information after more advanced processing by thinking as a P2P application not in the sensor unit, but on the sensor unit and the PC. Moreover, even if one sensor unit per peer is not allocated, it is also possible to arrange a peer that integrates some sensor units on the network. We constructed a P2P sensor data mining system used a microcube as a sensor unit and a JXTA as a P2P platform.

JXTA technology is a set of open protocols that enable any connected device on the network, ranging from cell phones and wireless PDAs to PCs and servers, to communicate and collaborate in a P2P manner.[11] JXTA peers create a virtual network where any peer can interact with other peers and resources directly, even when some of the peers and resources are behind firewalls and network address translations (NATs), or on different network transports.

The sensor data constructs a system that can also flexibly correspond to different kinds sensor data by using the XML form. The advantage of the proposal is that it is easy to respond to a change in the number of data sources. A change in the system is not too hard even when the composition of the sensor changes. Moreover, the data acquisition system from a sensor in a remote place can easily be constructed by constructing the system on the Internet.

We constructed a P2P sensor network using a P2P file-sharing application. We developed a P2P file-sharing application called "funny."

We developed a P2P file-sharing application for the University. We aimed at distributing and sharing a necessary file and material, without using the server as a system, that it was possible to use at a lecture. We constructed the network by using a pure-type P2P without using the server, and aimed at an accuracy more than the server type. To achieve this aim, we proposed these functions.

1. Construction of a pure-type P2P network only in the environment of the lecture room.
2. File-sharing by many teacher and students.
3. Comparison verification by a hash value to keep a file of any correspondence.
4. Load-balancing to improve speed all over the network.

We developed the application with these functions by using JXTA. We experimented to verify the system. We were able to learn from the result of the experiment.

First, we describe the certainty and the network band management. The certainty cannot be completely guaranteed on the P2P network, but this P2P network is used in a limited environment. We think that certainty can be guaranteed with one server or more (peer) in a limited environment. When we think of a closed environment, we think that the P2P-type system is better than the server-type system. Moreover, we designed the system to give security to the downloading of a file because it is assumed to be a priority that the file is distributed. Also, a peer with a high transfer speed learns so that it may communicate at a high speed. A peer with a low transmission rate learns so that it may communicate at a low speed.

The file transmission request is preferentially chosen in a peer with a high transfer speed. As a result, a smooth load balance in the system becomes possible.

5 Experimental results

The system that is explained in Sect. 3 was actually constructed. The system was constructed in December, 2005, and it is still running at November, 2006. Because a lot of modules were able to be reused, the time from construction to development was about 1 week.

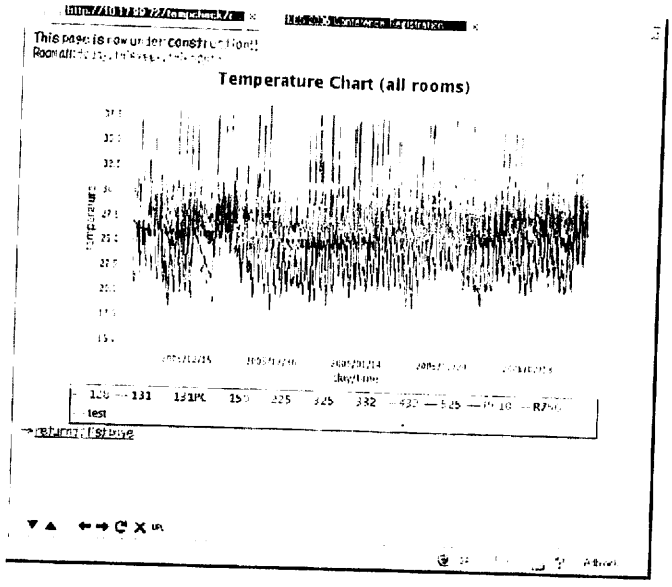

Fig. 6. All data on one chart

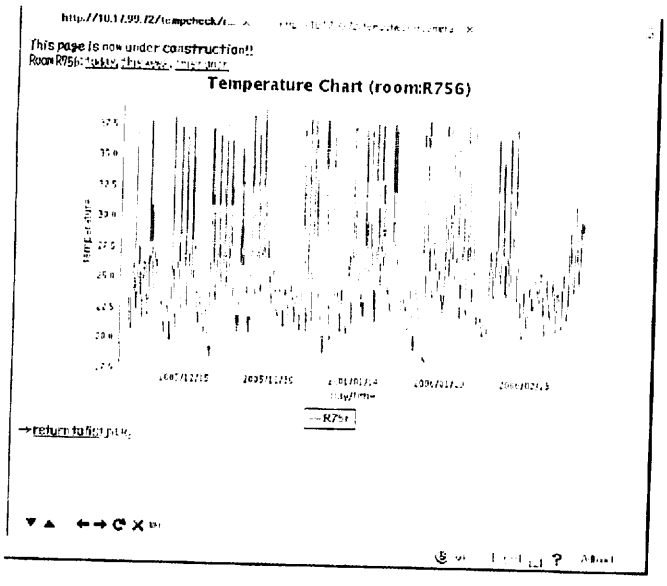

Fig. 7. Selected data on one chart

Some data display examples are shown in Figs. 6 and 7. The displayed data can be switched to all or part of room. The displayed range can be switched to a day, a week, a month, or permanently. Figure 6 shows all data in one chart, and Fig. 7 shows one item of data in one chart.

At first, the microcube was connected to the campus network by arranging it in the router because the router had not been exceeded in the LAN of the microcube. However, data might not be able to be acquired normally in some routers. Then connecting the microcube to the campus network, even if we modified the program and the router is not set up, became possible so that the router was exceeded.

It took time to solve the problem when data was not able to be acquired normally because the microcube was

```
<?xml version="1.0" encoding="Shift-JIS"?>
<?xml-stylesheet type="text/xsl" href="sensor.xsl"?>
<!DOCTYPE all SYSTEM "sensor.dtd">
<all>
  <data><sensor>thermometer</sensor><value>25.7</value></data>
  <data><sensor>hygrometer</sensor><value>22.4</value></data>
  <data><sensor>illuminometer</sensor><value>1009</value></data>
  <data><sensor>barometer</sensor><value>0880</value></data>
</all>
```

Fig. 8. XML output

connected to the campus network. Then the problem was considered in cooperation with Systems Engineer (SE) that resided in school. For the router problem, we constructed an environment, such as a dummy server with a PC–UNIX server passing the router setting, bypassing the router setting, and this resolved the problem while capturing the information that flowed in the network.

We constructed a P2P file-sharing system as a P2P sensor network by JXTA, which is called "funny." We added functions for JXTA, such as an MD5 file check and up/down speed autotuning. We did a file-sharing test on a PC using more than 50 peers. The file-sharing could be done to the teacher in the experiment by an actual lecture to students.

We construct a P2P sensor network on which a PC accesses the sensor unit and uploads data by P2P application. We modified the sensor unit module to be able to output XML format. One output example is shown in Fig. 8. A data-mining module is still being constructed. Because data began to be collected, the temperature data are scheduled to be analyzed in the future.

6 Conclusion

We proposed the technique of sensor data mining by a P2P for a sensor network system using a microcomputer board that can connect to the Internet. This proposed system can acquire information from the sensor of the microcomputer group arranged on the network, and can view collected information on a Web browser. It was shown to be possible to construct the microcomputer's sensor network, which is a combined microcomputer module (microcube), and the database server, and the Web application server. A system that measured the room temperature in a school campus was constructed. It has run for about 1 year, and the effectiveness was verified. We also proposed a P2P sensor data mining system. Because data began to collect, the temperature data are scheduled to be analyzed in the future. In the analysis of the data, it is thought that it will be possible to refer to the technique of the multiagent base,[12,13] and an analytical technique of the analysis of fixed point observation data.[14] We descussed the P2P sensor data mining system with microcomputers and JXTA.

An expanded system that acquires more different types of sensor information will be constructed, and then the data obtained are scheduled to be analyzed in the future. In addition, we want to attach the IR I/O module on the

microcomputer board, and to do research on ubiquitous computing of indoor environment controls.

References

1. Niimi A, Wada M, Ito K, et al. (2006) Construction of school temperature measurement system with sensor network. KES'2006, Proceedings, Part III, Lecture Notes in Artificial Intelligence 4253, Springer, pp 813–819
2. Toda M. Akita J, Kimura K, (2003) Construction of ubiquitous weather observation system. Proceedings of the 7th World Multiconference on Systemics, Cybernetics and Informatics (SCI2003), International Institute of Informatics and Systemics (IIIS), vol. I pp 192–197
3. Akita J, Toda M, Kimura K (2004) Handy meteorological observation system for hands-on study. Proceedings of the 8th World Multiconference on Systemics, Cybernetics and Informatics (SCI2004), International Institute of Informatics and Systemics (IIIS), vol X, pp 155–159
4. Madden S, Franklin M, Hellerstein J, et al. (2005) TinyDB: an acquisitional query processing system for sensor networks. ACM Trans Database Syst 30:122–173
5. Intanagonwiwat C, Govindan R, Estrin D, et al. (2002) Directed diffusion for wireless sensor networking. IEEE/ACM Trans Networking 11:2–16
6. Yao Y, Gehrke J (2002) The cougar approach to in-network query processing in sensor networks. ACMSIGMOD Record 31(3): 9–18
7. Madden S, Franklin M, Hellerstein J, et al. (2003) The design of an acquisitional query processor for sensor network. ACM SIGMOD International Conference on Management of Data, ACM, pp 491–502
8. Hill J, Szewczyk R, Woo A, et al. (2000) System architecture directions for networked sensors. Architectural Support for Programming Languages and Operating Systems, ACM SIGPLAN Notices, Volume 35, Issue 11, pp 93–104
9. Wada M, Hatanaka K, Kimura N, et al. (2004) Applying an information technology in fishing industry. I. Acquisition of a three-dimensional topography (in Japanese). J Jpn Inst Nav 112: 189–198
10. Hatanaka K, Wada M, Kotaki M (2005) Instrumentation for the measurement of shallow seabed topography by a fishing echo sounder. Oceans 2005, MTS/IEEE Conference Proceedings, Ocean Instrumentation I, MTS/IEEE, pp 1–6
11. JXTA Community Projects, http://www.jxta.org/
12. Niimi A, Konishi O (2003) Data mining for distributed databases with multiagents. KES'2003, Proceedings, Part II, Lecture Notes in Artificial Intelligence 2774, Springer, pp 1412–1418
13. Niimi A, Konishi O (2004) Extension of multiagent data mining for distributed databases. KES'2004, Proceedings, Part III, Lecture Notes in Artificial Intelligence 3215, Springer, pp 780–787
14. Toda M, Osanai A, Niimi, et al. (2005) Information access method to meteorological data for educational application. ED-MEDIA2005, Proceedings, Association for the Advancement of Computing in Education (AACE), pp 4404–4408