Remote Water Quality Warning System Using Water Fleas

Se-Hyun Park, Eung-Soo Kim, and Se-Hoon Park, *Member, KIMICS*

Abstract—Hardware for monitoring the water quality using water fleas is developed. Water flea is a frequently used biological sensor for monitoring the water quality. Water fleas quickly respond to the incoming toxic water by changing their activity when they are exposed. By measuring the activity of water fleas, the incoming toxic water is instantly detected. So far the measurement of activity of water fleas has been done with a system equipped with both a light source of LED and a light detector of photo transistor. Water flea itself is, however, sensitive to light resulting in incorrect response and the system has two inconvenient separate parts of the light source and the detector. This paper suggests a system using a CCD camera instead of a light source and a detector. The suggested system processes the image data from the CCD camera in real time without any delay. The developed system becomes a part of the remote water monitoring embedded system.

Index Terms—Water flea, Embedded Server, Socket, Remote Monitoring.

I. INTRODUCTION

Safety of water has been getting attention as the quality of life becomes an important issue. Determination of water quality requires various physical and chemical sensors. Biological sensors are able to replace the bulky and complicated physical and chemical sensors especially in toxicity test of water. Toxicity test by the biological sensors has advantages over the physical and chemical sensors[1][2][3]. The advantage includes the quick response, less maintenance, and easy implementation.

The biological sensors generally use microscopic organism, selected fish, and water flea, etc. It is well known that the microscopic organism shows very fast response to the incoming toxic material. The microscopic organism is, however, easily contaminated by other microscopic organisms. And the facts that this process is checked only by using the microscope and the contamination process is relatively fast can lead to the measurement error. Thus for microscopic organism, there must be additional preventive measures for the prevention of contamination. On the other hand, the biological sensor using fish shows a relatively slow response to the variation of water quality compared with the microscopic organism sensor even though it is easily checked with bare eyes. The fish sensor is, therefore, a complementary method of other biological sensors. The water flea is, however, not only easy to check with bare eyes but also easy to maintain. And the water flea sensor is applicable over a wide pH range and especially sensitive to the toxic material. With all these advantages, EPA in US recommends the water flea as biological test animal for toxic materials.

When the water flea is exposed to the incoming toxic material, there is a change of the amount of activity. Inflow of toxic material is checked by the change of activity of water fleas.

The conventional system for measurement of the activity of water flea is shown in Fig. 1 (a). The system consists of the light emitting part of LED and the light detecting part of photo transistor. The amount of light detected by photo transistor decreases proportionally with the increase of the amount of activity of water fleas. The measured result is filtered to display the figures proportional to the amount of activity of water flea. This configuration has an inconvenience of having water fleas between the light emitter and its detector. In this set-up, the position between the light emitter and detector is also to be precisely adjusted for the laser diode which is used to prevent the diffraction of light. In addition, as the water flea is sensitive to the light, the stress received by water flea from the light influences the activity of water flea. In the conventional system, it is also impossible to change the number of LED and photodiode for optimized measurement of water flea activity.

This paper suggests the implementation of real time image processing system for measurement of water flea activity using CCD camera as shown in Fig. 1 (b). This new implementation obviates the difficulties of the conventional system.

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Se-Hyun Park and Se-Hoon Park are with the Department of Electronic Engineering , Andong National University, Andong, 760-749, Korea (Tel: +82-54-820-5681, Fax: +82-54-820-5915, Email: separk@andong.ac.kr)

Eung-Soo Kim is with Department of IT Electronic Engineering , Daejeon University, Daejeon, 300-716, Korea (Tel: +82-42-280-2584, Email: eskim@dju.ac.kr)

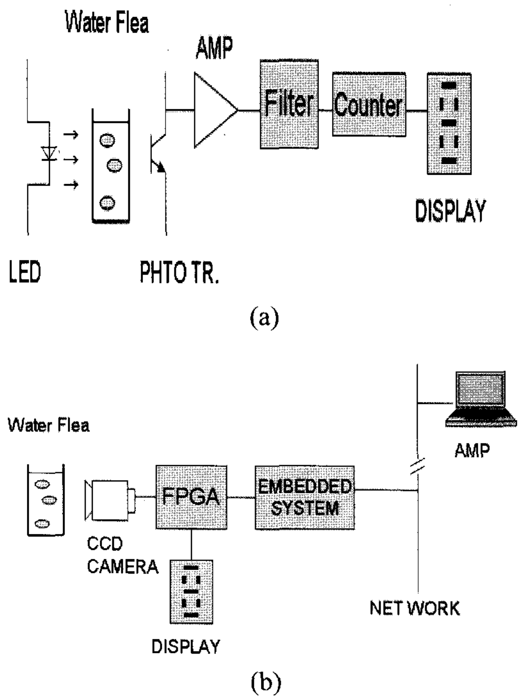

Fig. 1 (a) The conventional system to measure the activity of water flea. (b) The suggested system for real time measurement of water flea activity

The suggested system doesn't need the light source and its precision adjustment. The activity of water flea is measured in term of image enabling maximization of the sensor range.

The philosophy of the suggested system is to measure the water flea activity in real time with hardware without any help of software. The CCD image data is not saved in the memory and not processed by computer or DSP software for real time measurement. Even with typical CCD camera of NTSC image output can have the precision of 1/30 sec. Together with the suggested system, the remote water quality warning system is implemented with corporation of the embedded system technology.

II. DESIGN OF REAL TIME HARDWARE FOR THE MEASUREMENT OF WATER FLEA ACTIVITY

The CCD camera outputs sequentially digital data for each individual pixel of entire area of the screen. The unit area for the measurement of activity of a flea is defined by N x N pixels. And the whole screen area is filled with the unit areas in the lattice form. In this paper, the unit area which is called a cell corresponds to the area of two water fleas.

The row of cells is called a cell line. Fig 2 shows the cells in a cell line. The cell line corresponds to the horizontal scanning line. M x M pixel in a cell is the real image area of water flea.

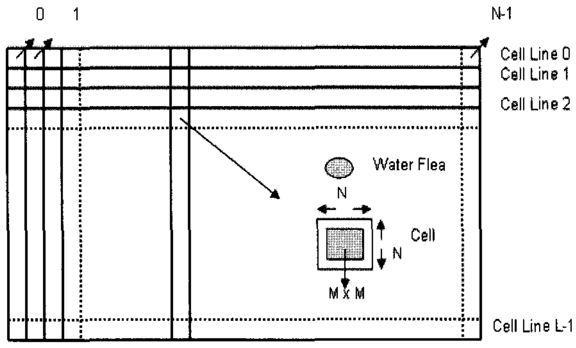

Fig. 2 Cell line and the structure of cell

The capture of the image of water flea is converted into two bit values of '1' and '0' through gray level. As the image of water flea is captured with the background of single color, the image is easily distinguished from the background color using only two levels.

Fig. 3 illustrates the window filter capturing the image of water flea. If the gray level is between the low limit and the high limit, it is defined as the image level of water flea. Other than that, it is defined as the background. The image of water flea is given '1' value and the image of background is given '0' value. The image gray level for the maximum brightness is defined as 0 and the darkness is defined as 255. The values of low and high limits are adjusted depending on the environment. The size of N and M is implemented as the counter and is variable.

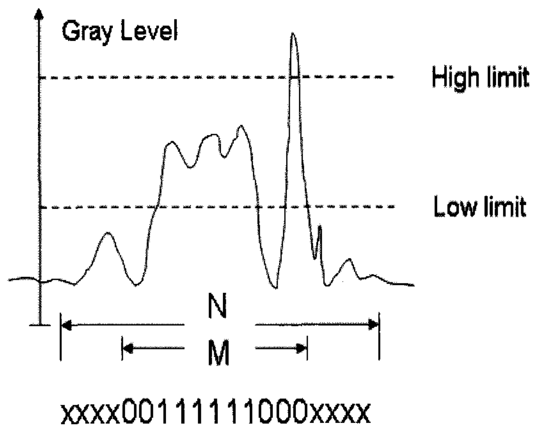

Fig. 3 The gray level and the bit conversion limits of high and low.

The number of '1' is counted in each cell to recognize the image of water flea. When the number of '1' is over a threshold value, the image in the cell is recognized as a water flea. The value of the threshold is related to both the size of M x M and the brightness of environment.

Fig. 4 is hardware to accumulate the number of counted '1'. As the cell line consists of N horizontal scanning lines, all of cells in the cell line should be scanned N times accumulating the counted number of '1'. One memory cell is required for each cell.

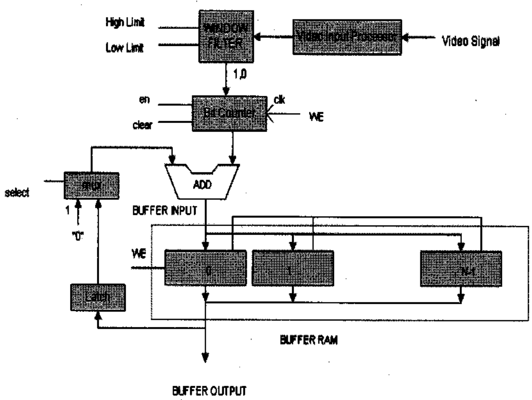

Fig. 4 Hardware structure of cells in the line.

ADD logic and Buffer Ram are used to accumulate the counted value of the present horizontal scanning line and prior cells. For each cell, the counter is initialized at the starting point of N x N. At M x M region the bit counter starts to count. And at the end point of N x N region, the value in Buffer Ram memory and the present counted values are added to be saved in Buffer Ram again. At the last scanning line, the value of Buffer Ram of each cell is checked whether it is more than the predetermined threshold value to recognize the water flea.

The hardware of Fig. 4 is reused for new cell line. MUX in Fig. 4 is used to initialize the Buffer Ram for next cell line. Fig. 5 is the block diagram of the hardware for recognition of water flea and measurement of its activity.

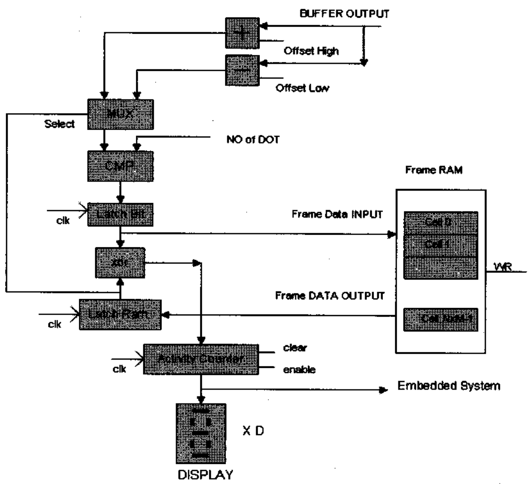

Fig. 5 The block diagram of hardware for measurement of water flea activity.

The BUFFER OUTPUT is the accumulated number of '1' of a specific cell in a cell line. After comparing the value of BUFFFER OUTPUT with a threshold value (the number of DOTs) at CMP, the existence of water flea is determined. The output of Latch Bit is '1' if there is water flea in the cell or '0' if no water flea in the cell.

The activity of water flea is checked by comparing the present state of the cell with its prior state. If the state of a cell changes from '1' to '0' or '0' to '1', there is activity of water fleas. Other than that, there is no activity of water flea. In Fig. 5 XOR is responsible for this operation.

To keep the state of prior state of a cell, the memory named Frame Ram in Fig. 5 is required. The Frame Ram has enough space to save the status of the cell, '1' or '0'. Each cell has one bit of memory.

After the present state of a cell is compared with the prior state of the cell, it is again saved in the Frame Ram. There is a case that the change of state in the cell can occur due to vibration not related to the activity of water flea or error of image itself. To prevent this false change of state, the BUFFER OUTPUT is not simply compared with the threshold value of the number of dots but has the hysteresis characteristic memorizing the prior state. This operation is taken care of by MUX, +, -, and CMP logic in Fig. 5. Table-1 explains the CMP logic with hysteresis characteristics.

The activity of water flea is measured by counting the output of XOR logic in unit time. The figure showing the activity of water flea can be displayed on LED or monitored remotely by the system implemented using the embedded system.

Table 1 The comparative logic with hysteresis characteristics

State of Cell (Latched Ram)	Two input of the comparative logic (Input of CMP)	
'0'	No_Of_DOT	Buffer_output + offset_high
'1'	No_Of_DOT	Buffer_output - offset_low

III. DESIGN OF REMOTE MONITORING EMBEDDED SYSTEM FOR WATER QUALITY WARNING USING WATER FLEA

A remote monitoring embedded system for water quality warning system is designed using water flea as a biological sensor. Remote monitoring of the water quality is essential for collection and analysis of the measured data and ultimately building of its data base for wide area application. Fig. 6 shows the block diagram of the designed remote water quality monitoring system. The designed system is not a client/server type requiring two separate softwares. Instead, the designed system makes the remote monitoring easy by accessing the embedded system through web browser using Java applet and Java socket.

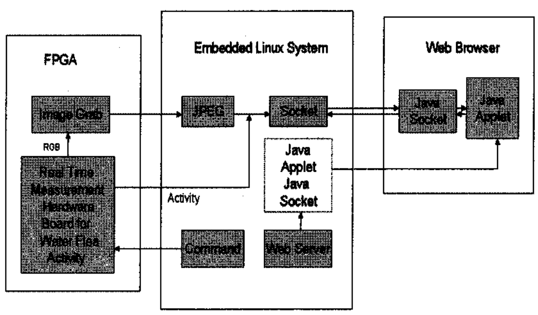

Fig. 6 The block diagram of the designed remote water quality monitoring system.

It is, generally, impossible to access the data in the server without using the serverlet. In this study, MPC860 is used as the embedded processor. It requires a great deal of efforts, time, and cost to build the serverlet with most of embedded processors including MPC860. In this system, however, a socket is used in Java applet to deal with remotely the data in the server simply using the applet. Using the socket, the parameters of the hardware measuring the real time activity of water flea (FPGA) are controlled and the real image of water flea is monitored [4].

In Fig. 6 the image of water flea is captured by Image Grab and compressed into JPEG type. The captured image together with the figures representing the activity of water flea is transmitted through the embedded socket and Java socket to the remote web browser. As a result, the figure representing the activity of water flea is real time data but the image of water flea is dependent on the speed of network.

Fig. 7 is a flow chart of software for the designed water quality warning system. In the embedded system, the server program drives the web server from the start of the system. And the initial parameters of the board of Fig. 6 are set up and the socket is generated. The system is ready for the client's access. When the clients access the system, the socket communication starts between the client and the server.

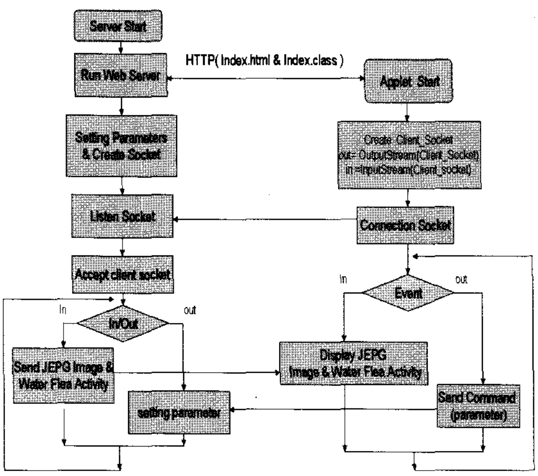

Fig. 7 The flow chart of software for the designed water quality warning system.

When the web server is accessed by a client through the web browser, the web server hands over the classes of Index.html and Index.java, which is the index.class, to the web browser. Here the Index.html and the Index.class are the web page and the applet respectively which are displayed on the web browser. The remote browser generates the web pages using Index.html and the client socket using Index.class. The Index.class generates the input/ output streaming for the client socket communication enabling the socket communication with the server.

In the server, the client socket communication transfers the figures representing the activity and JPEG image of water flea to client. Then the client displays the figures of activity and image of water flea on the web page.

The communication from the client to the server transfers values of various FPGA parameters such as N x N/M x M counter, Low Limit/High Limit, Offset High/Offset Low, Number of dots, and Clear/Enable, etc. And the server sets up the received information in FPGA.

IV. EXPERIMENTS AND RESULTS

Fig. 8 shows a screen of the client monitor of the remote monitoring system. In Fig. 8, a model of seven fleas for operation test is shown and N x N/M x M is not set up yet.

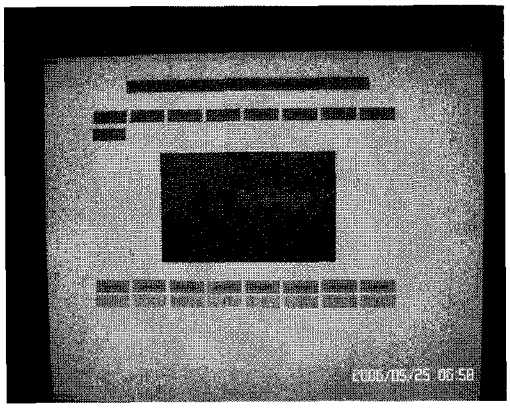

Fig. 8 The screen of the client monitor of the monitoring system using water flea.

Fig. 9 shows the monitor screen with N x N/M x M set-up where N=16 and M=8. When Low Limit=45, Offset High/Offset Low=6/6, and Number of dots=18, two water fleas are recognized in Label Ch 7. Here the High Limit is not given. When the model of water flea is in action, Ch 6 displays the activity figure. Figs. 10 and 11 show the screens of client monitor for set-up of N=16, M=4 and N=16, M=13 respectively.

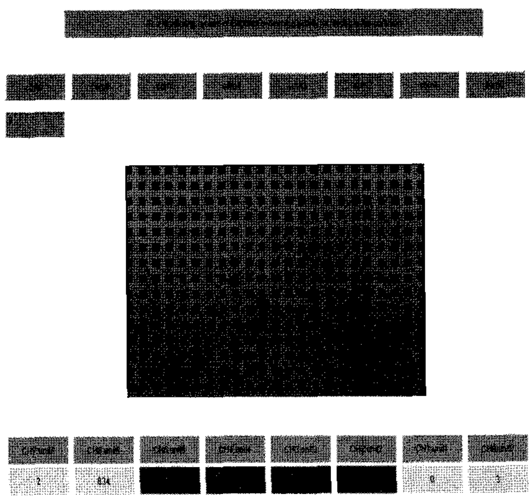

Fig. 9 The monitor screen with N x N/M x M set up where N=16 and M=8

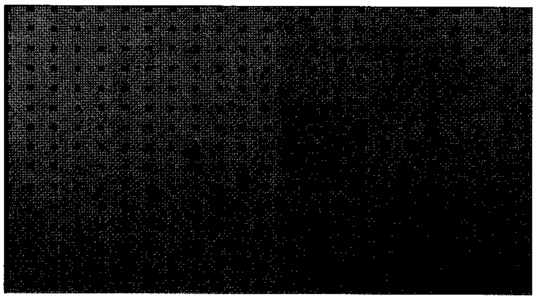

Fig. 10 The monitor screen with N x N/M x M set up where N=16 and M=4

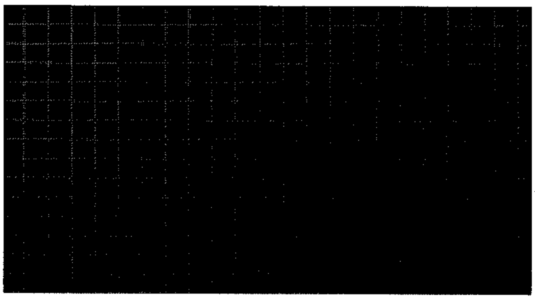

Fig. 11 The monitor screen with N x N/M x M set up where N=16 and M=13

Fig. 12 shows the gray level screen when the Low Limit is 45. The gray level is shown in white.

Fig. 12 The gray level screen when the Low Limit is 45.

V. CONCLUSIONS

A water quality monitoring system using water flea is developed. Hardware to measure the activity of water flea is designed and developed. The developed hardware is applied to the remote embedded system for water quality warning system.

The disadvantages of the conventional system to measure the activity of water flea such as two bulky parts of the emitter and the detector, measurement errors caused by water flea's sensitivity to light, and the fixed number of photo diodes are obviated by using CCD camera. The measured data is processed in real time using the hardware.

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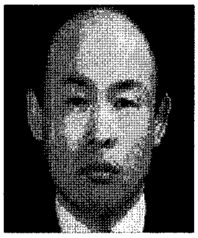
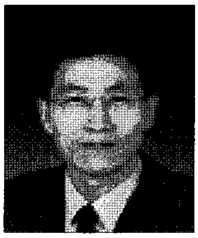
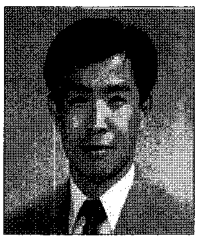


Se-Hyun Park
Received the B.S. and M.S. degrees in Electronic Enginee-ring from Kyung Pook National University, Korea in 1980 and 1982 respectively and Ph.D. in Electronic Engineering from Ajou University, Korea. in 1990. He is a professor at Electronic Engineering, Andong National University, Korea. His research interest is in the microprocessor, embedded system, and digital system.



Eung-Soo Kim
Received the B.S. and M.S. degrees in Electronic Engineering from Pusan National University, Korea in 1977 and 1979 respectively and Ph.D. from Tohoku University, Japan in 1993. From 1982 to 1994, he was a senior engineer at ETRI, Korea. He is a professor at IT Electronicengineering Daejeon University, Korea. His research interest is in the signal processing, HCL, BCL, embedded system and wearable computer.



Se-Hoon Park
Received the B.S. and M.S. degrees in Electronic Enginee-ring from Kyung Pook National University, Korea in 1980 and 1982 respectively and Ph.D. in Electrical Engineering from Arizona State University, USA in 1993. From 1983 to 1986, he was with Semiconductor Division of Hyundai Electronics. From 1993 to 1995, he was a senior engineer at ETRI, Korea. He is an associate professor at Electronic& Information Engineering, Andong National Univer-sity, Korea. His research interest is in the design of analog and digital communication systems.