Development of LED Display System of Earthquake Ground Motions

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SUMMARY:
An LED (light-emitting diode) display system to illustrate the propagation of earthquake ground motions is developed as a teaching material for disaster prevention. Time series of earthquake ground motions can be simultaneously demonstrated by illuminating the computer-controlled LEDs embedded in the relief map. On the map, LEDs are located at the observation stations of the K-NET, which is employed by NIED (National Research Institute for Earth Science and Disaster Prevention) and has more than 1,000 observatories deployed all over Japan. The records obtained by the seismographs are acquired at a control center in Tsukuba by telemetry and the data of ground motions have been released on the Internet. The downloaded data of ground motions are converted to commands and sent to the LED display device. Since 3-D spatial map is used, this system helps the instinctive understanding about the features of earthquake ground motions.

Keywords: earthquake ground motions, seismograph, LED, relief map, teaching material

1. INTRODUCTION

People's awareness of disaster prevention is increased after a huge earthquake. However, since it fades over time, regular education of disaster prevention is required. Especially, education from the age of young child is important. Researchers and Engineers often give lectures at schools and culture centers about disaster prevention. Though the contents of lectures range widely, one of the important topics is the propagation of earthquake ground motions. In Japan, where Earthquake Early Warning system which provides advance announcement of the estimated seismic intensities and expected arrival time of principal motion is in operation, the knowledge of earthquake ground motions is necessary to understand the principle and to utilize the system correctly.

When we educate about how fast the earthquake ground motions propagate and how different the strength of shaking is by location, we fell strong need to develop such the teaching material as to help the instinctive understanding. CG (Computer Graphics) is often used to express the propagation of earthquake ground motions by animated image. But, CG is not always sufficient in terms of reality to the children who often play computer games, because the images created by CG are always virtual reality to them

In this study, an LED (light-emitting diode) display system of earthquake ground motions is developed as a teaching material. Time series of earthquake ground motions can be simultaneously demonstrated by illuminating computer-controlled LEDs embedded in the relief map. On the map, LEDs are located at the observation stations of K-NET, which is employed by NIED (National Research Institute for Earth Science and Disaster Prevention) and has more than 1,000 observatories deployed all over Japan. The records obtained by the seismographs are acquired at a control center in Tsukuba by telemetry and the data of ground motions have been released on the Internet. The downloaded data of ground motions are converted to control commands and sent to the LED display device. Better educational effect and more realistic expression for the understanding of earthquake ground motions can be expected by using this system compared with by using CG. Moreover, it is helpful to understand the relation between the land features and the ground motions, since the three-dimensional spatial map is used.

2. OUTLINE OF DEVICE

Surface ground motions are largely affected by source mechanism, wave path of seismic wave and site characteristics. Even at the neighbouring sites which are less than hundred meters apart from each other, the strength of motions can differ. Thus the effect of site characteristics is especially important. The relief map is useful to help understanding of the land features. The relief map, the size of which is 920 mm high, 620mm wide and 180mm thick, is used taking portability into consideration. The map is made at a scale of 1 to 700,000 in the planar direction and 1 to 2.7 in the height direction. Kinki, Chugoku and Shikoku regions are on the map.

Full-color LEDs are embedded in the map at the corresponding locations to the observation stations of K-NET. Downloaded digital data from the web site are converted to the value of RGB and sent to the LED device through the control board by serial communication method. Each LED lights in the associated color with the strength in the ground motions at the site. Software is also developed to treat the downloaded enormous quantity of data collectively.

Using this system, the following expression is possible.
1) seismic intensity
2) peak acceleration
3) propagation of earthquake ground motions

3. HARDWARE

The configuration diagram of LED display system of earthquake ground motions is shown in Figure 1. 10 control boards with 8 sockets for MIL connector are used. LEDs are attached to the end of the

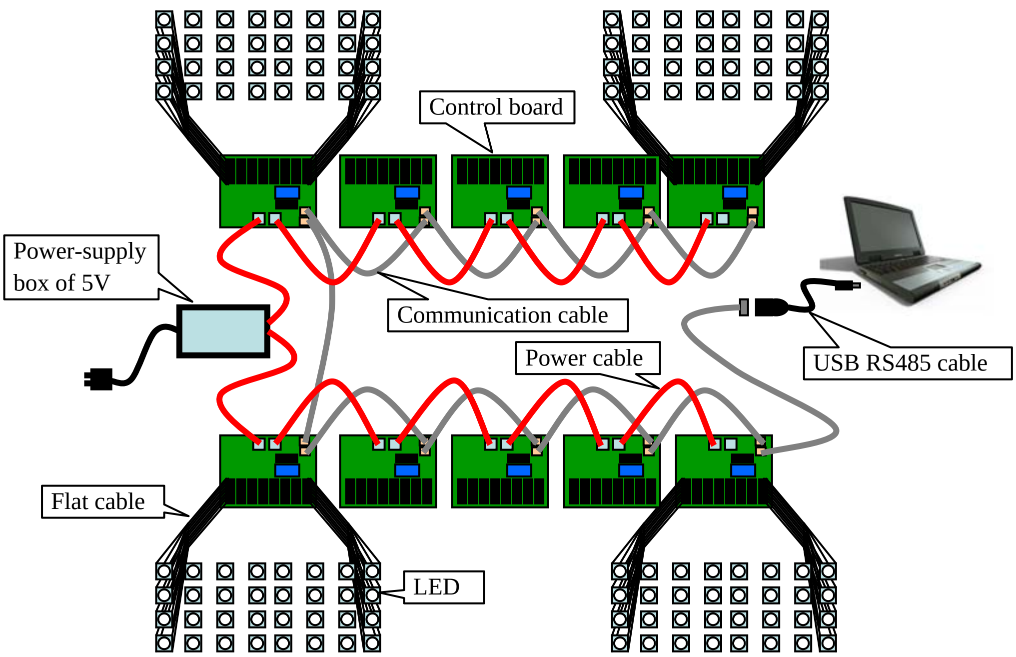

Figure 1. Configuration diagram of LED display system of seismic motions

flat cable, the other end of which is attached to the MIL connecter. The model of LED is OSTA71AD-A shown in Figure 2 which is traded by Akizuki Denshi Tsusho Co. Ltd., Japan. The data of the earthquake ground motions to light LEDs is sent from PC to the control boards through USB-RS485 cable, which is made in CONTEC Co. Ltd., Japan. Each control board is connected with the communication cable and supply cable. Power-supply box of 5 bolts is used. Figure 3 shows the basic color of LED. Arbitrary color is expressed by mixing the primary color of red, green and blue.

LEDs are embedded in the drilled holes on the relief map, the locations of which correspond to the observation stations of K-NET. Four cables are soldered to the terminal pins for red, green and blue colors and power source of LED, and they are insulated with sleeving as shown in Figure 4. 300 LEDs are embedded in the relief map.

Figure 2. Full color LED

Figure 3. Three primary colors of LED

Figure 4. LED connectd by cable and sleeve

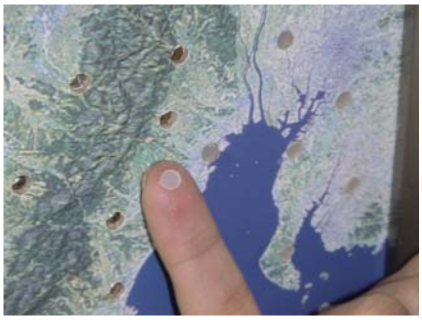

Figure 5. Translucent silicon rubber

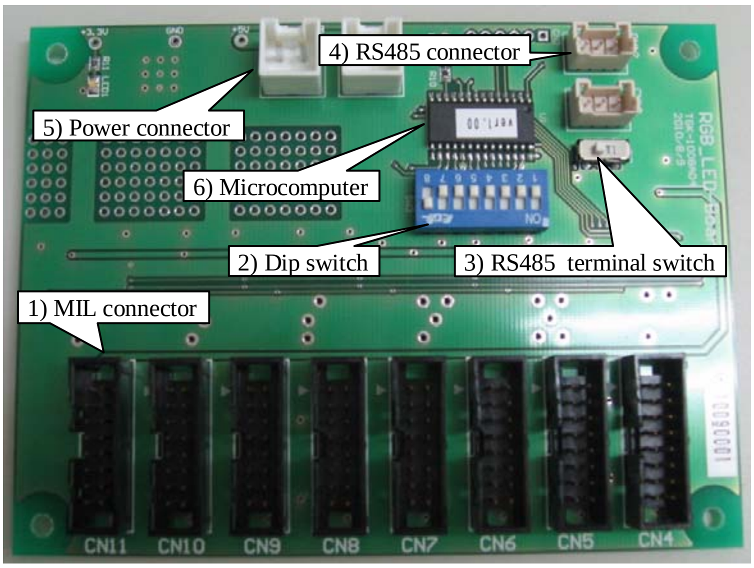

Figure 6. Control board

Table 1. Parts on control board and their functions

number	name	function
1)	MIL connector	socket of MIL connector to be connected to LED by flat cable
2)	Dip switch	switch to assign ID number to the control board
3)	RS485 terminal switch	switch to assign the terminal of control boards
4)	RS485 connector	socket of RS485 cable connector
5)	Power connector	socket of power cable connector
6)	Microcomputer	microcomputer (PIC24) to control LED driver

Figure 7. Front view of LED device

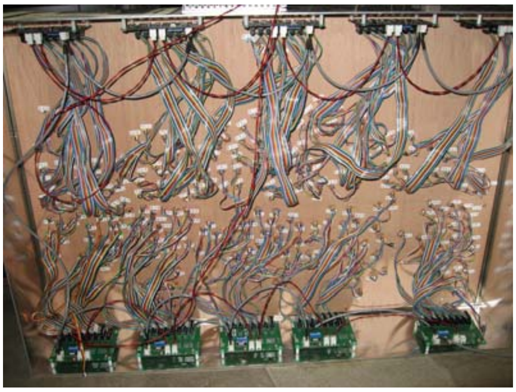

Figure 8. Back view of LED device

A full-color LED can produce any color by adjusting the strength of three light sources, namely red, green and blue color in it. However, it turned out that the color changed if looked at from different angles. Then, translucent silicon rubber, by which drilled holes are capped as shown in Figure 5, was found to be effective. It played a role in mixing the light sources moderately.

Figure 6 shows the control board in detail. The functions of the parts on the board are shown in Table 1. The drivers for RS485 and LED are attached on the other side of the control board. The front and back view of the completed device are shown in Figures 7 and 8, respectively.

4. SOFTWARE

4.1. Application for Creation of Data Set

Ground motions observed at the stations of K-NET can be downloaded from the web site of NIED. At each station, the acceleration data of 3 components, namely EW, NS and UD directions, are available in the different files. If the ground motions are observed at 300 stations in the area of the map, 900 files are to be managed to create the data set. Since the processing of such enormous amount of data takes time through the troublesome procedure, the program built with Microsoft Excel macro is used to treat them collectively. Figure 9 shows the sheet of Microsoft Excel macro. The fundamental data in the yellow-shaded cells such as the folder name in which the files of ground motions exist and the file name in which the processed data are to be written should be entered. The file name of LED table should be also entered in which the station code of K-NET and ID of LED is related. Then by clicking in order of the buttons of “Read Seismic Motions”, “Create Data Set” and “Create Control Data”, required data set is created. The sampling frequency of ground

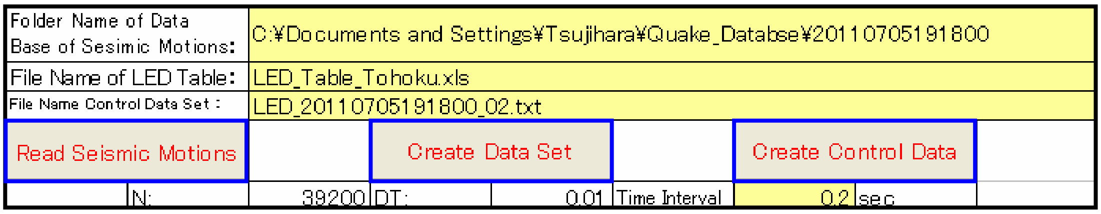

Figure 9. Excel sheet to treat enormous amount of data collectively and create required data set

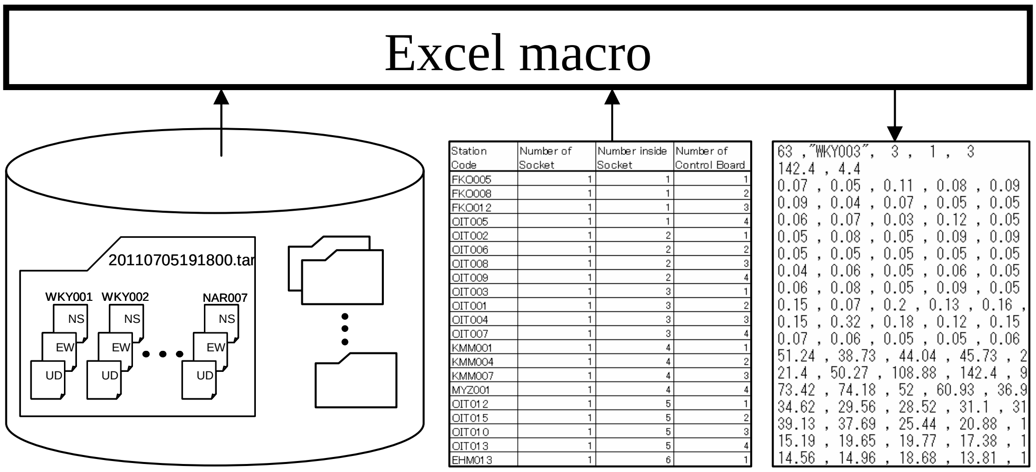

Figure 10. Relation between Excel macro and data files

acceleration in K-NET is 100 Hz. Changing the color of LED at the interval of 0.01 second is too quick to be recognized. The interval can be changed by assigning any second in the work sheet in Figure 9, though 0.2 second turned to be appropriate after several tests. Acceleration of the resultant value of 3 components is calculated and the time series is rebuilt as the series of maximum acceleration in the assigned each interval. Figure 10 shows the ration between Excel macro and data files.

4.2. Application for Control of LED Device

The main routine of this application is to read the data set which is created as shown in the previous section and to send the signal of seismic intensity, peak acceleration or time series of acceleration at the observation stations to the LED device. The lights of RGB in an LED can be changed in 16 levels, respectively, so that an LED can express as many as 4096 colors. Since the seismic intensity which is defied by Japan Meteorological Agency is in 9 levels, 9 colors of blue, light blue, green, greenish yellow, yellow, orange, purple, pink and red are selected. The signal corresponding to the color is sent from PC to the device by serial communication implemented in relation to RS485. RS485 is the improved version of RS232C, by which multiple receivers can be connected. The communication specification is shown in Table 2. The basic commands and their explanation are shown in Table 3 and 4, respectively. BCC (Block Check Character) is the control code to check communication error.

The data set of earthquake ground motions is changed into hexadecimal number which denotes the color of light, and is sent to the LED device with the control code. Figure 11 shows an example of the command to assign the color of LEDs. “F”, “0” and “0” in “F00” correspond to the intensity of the light red, green and blue, respective, for a LED. “F00”, “3F3”, “000” and “0F0” denote the colors red, greenish yellow, solid color and green, respectively. For the LEDs connected to a

Table 2. Communication specification

communication system	RS485
transmission policy	Half duplex double wire system
synchronization scheme	asynchronous method
transmission rate	500kbps
bit configuration	start bit : 1 bit data bit : 8 bits parity bit : none stop bit : 1 bit

Table 3. Configuration of command line

STX	command	board No.	data	ETX	BCC

Table 4. Explanation of basic command

Control code	Explanation
STX	control code to show the beginning of the command line
command	1 : start to send data 2 : update the display 3 : adjust brightness
board No.	Number of control board (1 to 10)
data	32 sets of three hexadecimal numbers to assign the colors to LEDs on the control boad
ETX	control code attached to the end of data
BCC	block check character

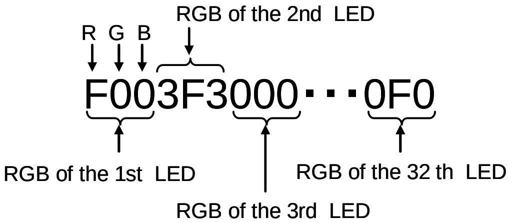

Figure 11. Part of data in the command line

control board, a single command-line string is sent, which consists of 32 sets of three hexadecimal numbers in between the control codes such as “STX” and “BCC”. In the same manner, command-line strings are sent for other LEDs connected to other 9 control boards. In the case to demonstrate the propagation of earthquake ground motions, the control code to update the colors is sent and then next command-line strings are sent at the assigned time interval.

The application for the communication in this system is programmed with Microsoft Visual Basic 6.0.

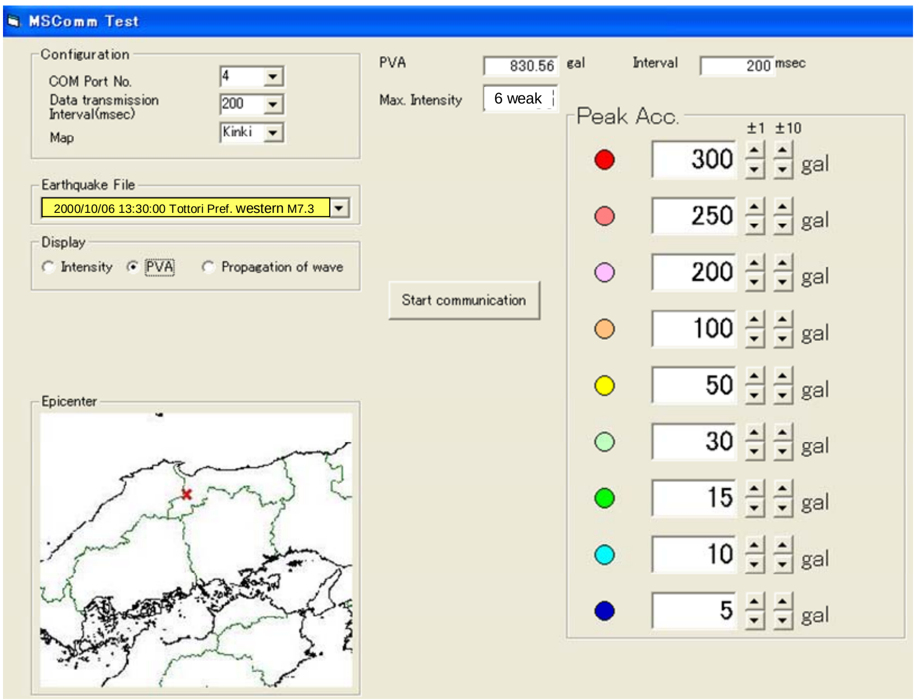

Figure 12. Graphic user interface of application

MSComm (Microsoft Communication) control, which is one of the custom controls prepared in MS Windows, is utilized to communicate with the COM (Communication) port. MSComm makes it easy to realize the serial communication on MS Windows.

The graphic user interface of the application is shown in Figure 12. Select the event of earthquake in the combo box, next seismic intensity, peak acceleration or propagation, and then click the start button. Then control commands are sent to the LED device. If peak acceleration or propagation is selected, threshold values in the color legend can be changed.

5. USE OF LED DISPLAY SYSTEM AND EDUCATION

The list of data set of the events is shown in Table 5. Though the records in any event download from the web site of K-NET can be applicable, those of which the epicentres exist in the area of the relief map are selected. Figure 13 shows the seismic intensity in some events. Some scenes of the time series of acceleration in the Tottori Prefecture Western earthquake in October 6 in 2000 are shown in Figure 14.

This LED Display System can be used for the education of the following contents.
1) There is the relation between the seismic intensity and the distance from the epicentre.
2) Primary wave comes before secondary wave.
3) Ground motions in the plain continue longer than in the mountain area.
4) Intermittent aftershocks follow the main quake around the seismic source.
5) What principle is Earthquake Early Warning system based on and how effective is it?

Table 5.Event catalog of earthquake

No.	yy/mm/dd	time	Epicenter		M	Depth (km)
			lat.	lon.		
1	1996/12/03	07:18:00	31.786	131.631	6.6	35
2	1997/06/25	18:50:00	34.453	131.665	6.1	12
3	1997/09/04	05:16:00	35.270	133.380	5.2	6
4	1998/04/22	20:32:00	35.170	136.564	5.4	10
5	1998/05/23	04:49:00	33.703	131.848	5.5	85
6	1999/08/21	05:33:00	34.053	135.464	5.4	70
7	2000/06/07	06:16:00	36.840	135.547	6.1	22
8	2000/10/06	13:30:00	35.278	133.345	7.3	11
9	2001/01/12	08:00:00	35.466	134.489	5.4	10
10	2001/03/24	15:28:00	34.123	132.705	6.4	51
11	2001/03/26	05:41:00	34.111	132.717	5.0	49
12	2001/04/25	23:40:00	32.788	132.351	5.6	42
13	2001/08/25	22:21:00	35.150	135.657	5.1	10
14	2002/09/16	10:10:00	35.370	133.739	5.3	10
15	2002/11/04	13:36:00	32.411	131.870	5.7	35
16	2004/01/06	14:50:00	34.215	136.714	5.4	37
17	2006/03/27	11:50:00	32.602	132.157	5.5	35
18	2006/06/12	05:01:00	33.133	131.407	6.2	146
19	2010/11/29	15:20:20	33.900	135.400	4.1	60
20	2011/02/21	15:46:00	33.900	135.400	4.9	50
21	2011/07/05	19:18:00	34.000	135.200	5.4	10

(a) 1998/05/23 4:49:00 quake

(b) 1999/08/21 5:33:00 quake

(c) 2000/10/06 13:30:00 quake

Figure 13. Seismic intensity

6. CONCLUSIONS

LED Display System of earthquake ground motions is developed as a teaching material for disaster prevention. The features and the educational effects are summarized as follows.

(a) after 1 second

(b) after 9 seconds

(c) after 18 seconds

(d) after 45 seconds

(e) after 95 seconds

(f) after 265 seconds

Figure 14. Some scenes of propagation of seismic motions in Tottori Prefecture Western earthquake 2000/10/06 13:30:00

1) Students can realize the land features of their home town in the comparison with the other area, since the 3-dimensional spatial map is used. It helps the better understanding of the relation between the land features and earthquake ground motions.
2) Such the topics that how fast earthquake ground motions propagate, how significantly the seismic intensity decreases as well as the aftershocks followed by a main quake, and the principle of Earthquake Early Warning System and its effect can be educated with this system.
3) The size of the device is 920mm x 620mm x 180mm, and it has the advantage in the portability.

4) The operation of the device is easy enough to be managed even by elementary students.

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