CURRENT STATUS OF A CARBORNE SURVEY SYSTEM, KURAMA

M. Tanigaki*, R. Okumura, K. Takamiya, N. Sato, H. Yoshino, H. Yoshinaga, Y. Kobayashi
Research Reactor Institute, Kyoto University, Kumatori, Osaka 590-0494, Japan

Abstract

A carborne survey system named as KURAMA (Kyoto University RAdiation MApping system) has been developed as a response to the nuclear accident at TEPCO Fukushima Daiichi Nuclear Power Plant in 2011. Now the system evolved into a CompactRIO-based KURAMA-II, and serves various types of applications. More than a hundred of KURAMA-II are deployed for the periodical drawing of the radiation map in the eastern Japan by Japanese government. A continuous radiation monitoring by KURAMA-II on city buses started in Fukushima prefecture as the collaboration project among Kyoto University, Fukushima prefectural government, and JAEA. Extended applications such as precise radiation mappings in farmlands and parks are also on the way. The present status and future prospects of KURAMA and KURAMA-II are introduced.

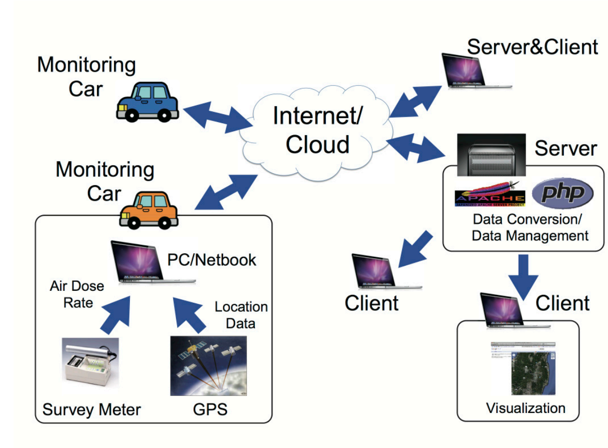

Figure 1: KURAMA system. Monitoring cars and servers are connected over the Internet by cloud technology.

INTRODUCTION

The magnitude-9 earthquake in the eastern Japan and the following massive tsunami caused the serious nuclear disaster of Fukushima Daiichi nuclear power plant, which Japan had never experienced before. Huge amounts of radioactive isotopes were released in Fukushima and the surrounding prefectures.

In such nuclear disasters, air dose rate maps are quite important to help take measures to deal with the incident, such as assessing the radiological dose to the public, making plans for minimizing exposure to the public, or establishing procedures for environmental reclamation. The carborne γ-ray survey technique is known to be one of the effective methods to make air dose-rate maps [1]. In this technique, a continuous radiation measurement with location data throughout the subject area is performed by one or more monitoring cars equipped with radiation detectors. Unfortunately, the existing monitoring system didn't work well in the incident. Such monitoring cars tend to be multifunctional, thus too expensive to own multiple monitoring cars in a prefecture. Fukushima was the case, and to their worse, the only monitoring car and the data center were contaminated by radioactive materials released by the hydrogen explosions of the nuclear power plant.

KURAMA [2] was developed to overcome such difficulties in radiation surveys and for establishing air dose-rate maps during the present incident. KURAMA was designed based on consumer products, enabling a lot of in-vehicle apparatus to be prepared within a short period. KURAMA realizes high flexibility in the configuration of data-processing hubs or monitoring cars with the help of cloud technology. Based on the success of KURAMA, KURAMA-II, a more improved version of KURAMA, has been developed and deployed for various applications. In the present paper, an outline of KURAMA/KURAMA-II and their applications are presented.

KURAMA

KURAMA is a γ-ray survey system with GPS and up-to-date network technologies developed for a primary use of carborne surveys. A typical configuration of KURAMA is shown in Fig. 1.

An in-vehicle unit of KURAMA consists of a conventional NaI scintillation survey meter with an appropriate energy compensation, an interface box for the analog voltage output of the detector to a USB port of PC, a GPS unit, a laptop PC, and a mobile wi-fi router (Fig. 2). Its simple and compact configuration allows users to set up a in-vehicle unit in a common automobile. The software of in-vehicle part is developed with LabVIEW. The radiation data collected every three seconds is tagged by its respective location data obtained by the Global Positioning System (GPS) and stored in a csv file. The csv files updated by respective monitoring cars are simultaneously shared with remote servers by Dropbox over a 3G network. With this feature, the system obtains much more flexibility in the configuration and operation than other conventional carborne systems. The radiation data is displayed in real time on Google Earth in client PCs after the dynamic generation of KML files in servers (Fig. 3).

KURAMA has served for monitoring activities in

* e-mail:tanigaki@rri.kyoto-u.ac.jp

ISBN 978-3-95450-139-7

Figure 2: The in-vehicle part is compactly composed of mostly commercial components. 1) GPS unit, 2) 3G mobile wi-fi router, 3) MAKUNOUCHI, 4) NaI survey meter, 5) PC.

Figure 3: The data is simultaneously plotted on Google Earth. The color of each dot represents the air dose rate at respective point.

Fukushima and surrounding prefectures employed by Fukushima prefectural government and the Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT). The team of Fukushima prefectural government makes precise radiation maps of major cities in Fukushima prefecture mainly for the "Hot Spot" search [3], while MEXT periodically performs carborne surveys in the eastern Japan including Tokyo metropolitan area (Fig. 4) [4].

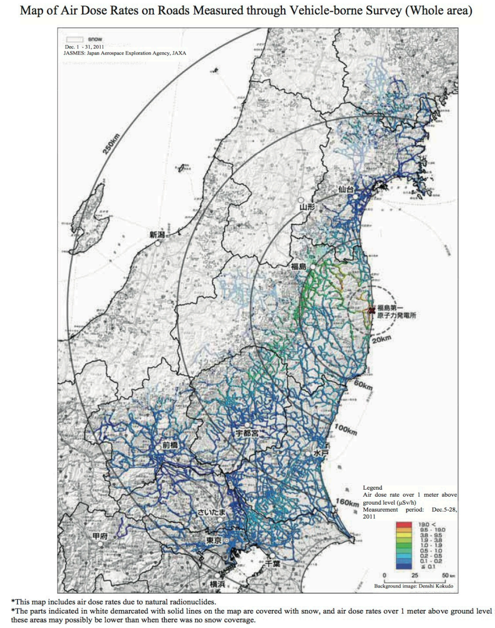

Figure 4: The air dose rate mapped by KURAMA in Dec. 2011 [4]. MEXT performed the first and second carborne surveys of the East-Japan by KURAMA in June and December 2011, respectively.

KURAMA-II

Long term (several tens years) and detailed monitoring of radiations are required in the living areas that were exposed to the radioactive materials, but a huge amount of resources and efforts are required for realizing this kind of surveillance. Such monitoring can be realized efficiently if vehicles that are moving periodically in living areas, such as buses, delivery vans or motorcycles for mail delivery, have compact and full-automated KURAMAs onboard. KURAMA-II is designed for such purpose.

KURAMA-II stands on the architecture of KURAMA, but the in-vehicle part is totally re-designed. The platform is based on CompactRIO series of National Instruments to obtain better toughness, stability and compactness. The radiation detection part is replaced from the conventional NaI survey meter to a Hamamatsu C12137 detector [5], a CsI detector characterized as its compactness, high efficiency, direct ADC output and USB bus power operation. The direct ADC output enables to obtain γ-ray energy spectra during the operation.

The software for KURAMA-II is basically the same code as that of original KURAMA. Additional developments are employed in several components such as device control softwares for newly introduced C12137 detector and 3G Gxxx module from SEA for telecommunications and GPS, the start up and initialize sequences for autonomous operation, and the file transfer protocol.

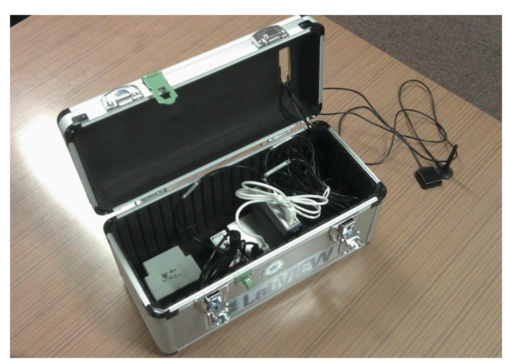

Figure 5: The in-vehicle unit of KURAMA-II. A CsI detector and a CompactRIO are compactly placed in a tool box with the size of 34.5 cm $\times$ 17.5 cm $\times$ 19.5 cm.

ISBN 978-3-95450-139-7

Figure 6: KURAMA-II under the field test on a city bus.

As for the file transfer protocol, a simple file transfer protocol based on RESTful was developed since Dropbox doesn't support VxWorks, the operating system of CompactRIO. In this protocol, a chunk of data as a timestamped file in csv format is produced for every three measuring points. The size of a chunk is about 400 bytes typically. Then every chunk is transferred to a remote "gateway server" by POST method. The gateway server combines received chunks to the data file, which is shared by remote servers using Dropbox as did in original KURAMA, and returns the name list of chunks which are successfully combined to the data files. The chunks in CompactRIO will not be deleted unless those names are confirmed in the returned list from the gateway server. Unsent chunks are archived at every one hundred of them as a single zip file and these are sent as soon as the network connection is recovered.

CURRENT STATUS OF KURAMA

Recent applications are mainly performed with KURAMA-II because of its autonomous operation and ease of handling. As soon as the development of KURAMA-II finished in December 2011, a field test on a city bus started around Fukushima city in collaboration with Fukushima Kotsu Co. Ltd., one of the largest bus operator in Fukushima prefecture (Fig. 6). City buses are suitable for continuous monitoring purpose because of their fixed routes in the center of living area, and their routine operations.

Following the success of the first field test in the area of Fukushima city, the coverage area has been expanded to other major cities in Fukushima, i.e., Koriyama, Iwaki, and Aizuwakamatsu, in the end of December 2012. No severe troubles were found since the expansion of the coverage in December 2012. The result of this field test has been released to the public through the web sites (Fig. 7) [6].

Various analyses are on the way to reveal the trends of air dose rate, the movement of radioactive materials, and the confirmations of decontamination effects in the coverage area, thanks to the advantages of city buses, i.e., fixed routes and daily operations. For example, the change of air dose rate was examined for every 100 m $\times$ 100 m grid cell defined as the standard mesh for statistical purposes by

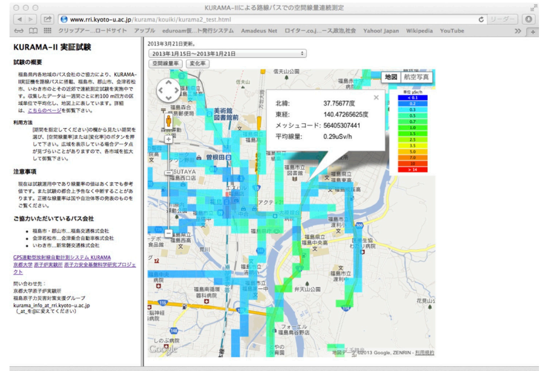

Figure 7: The website for the results of the field test with city buses released from Kyoto University. The results are released to public on weekly basis [6].

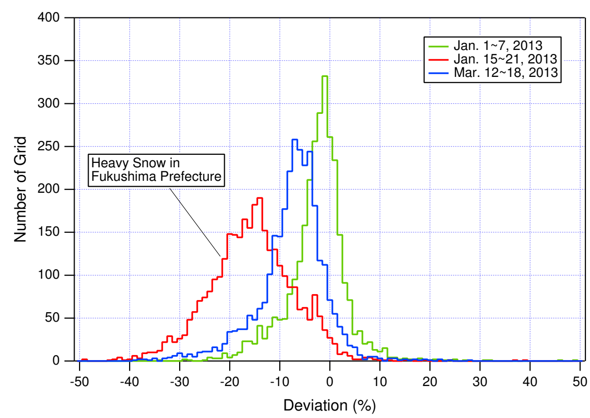

Figure 8: The deviation of air dose rate from the reference period (from Dec. 20 to 31, 2012) in Fukushima monitored by KURAMA-II on city buses. Heavy snow greatly reduced the air dose rate by shielding the radiation.

Ministry of Internal Affairs and Communications from January 2013 to March 2013. In this analysis, the data within every grid cell were averaged for every week, and compared with those in the reference period (from Dec. 20 to 31, 2012). As shown in Fig. 8, the air dose rate is drastically reduced by snow and more than 5 % reduction of air dose rate in average is observed even after the snow effect is disappeared. There are a few grids which become higher than the reference period, indicating the possible concentration of the radioactive materials such as contaminated soils.

This monitoring scheme using city buses will soon move to the phase of official operation by Fukushima prefectural government with the collaboration of Kyoto University and JAEA in fall 2013. In this operation, thirty more KURAMA-II will be deployed to the city buses to improve the coverage.

MEXT has introduced KURAMA-II for the periodic carborne surveys in the eastern Japan since March 2012 (Fig. 9) [7]. Around one hundred KURAMA-II are deployed

ISBN 978-3-95450-139-7

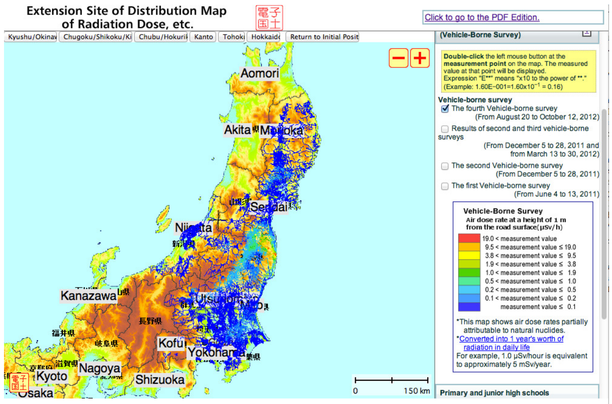

Figure 9: The periodic carborne surveys in the eastern Japan has been performed by MEXT and Nuclear Regulations Authority. The results are available from the interactive web site [8].

Figure 10: KURAMA-II on a motorcycle. A CsI detector and other components are separately placed in polycarbonate boxes. The height of the detector is adjusted to 1 m above the ground, to meet the standard for the air dose measurement in this accident.

to the local municipalities in eastern Japan in each survey, and the staff members in each municipality just attach KURAMA-II into a certain place of sedan cars, and drive around their municipalities. The results of these periodic surveys are released to public through the web site [8].

The hardware based on CompactRIO can be applied for the usages in harsh environments and small places. Using this advantage, the packaging of KURAMA-II are arranged for the surveys by motorcycles or on foot for the monitoring, and deployed for the measurements in the regions where conventional cars can not enter, such as rice fields, forests, parks (Fig. 10, 11).

ACKNOWLEDGMENTS

Authors are grateful to Dr. Mizuno, Mr. Abe, Mr. Koyama and staff members of the KURAMA operation team at the Fukushima prefectural government for the continuous support to field tests of KURAMA in Fukushima.

Figure 11: KURAMA-II for the measurement on foot. In this case, a differential GPS (DGPS) unit is used to achieve high accuracy (around 1 m) of positioning sufficient for walking survey.

The development of KURAMA-II is adopted by "Japan recovery grant program" from National Instruments Japan. Authors are indebted to Mr. and Mrs. Takahashi and the staff members at Matsushimaya Inn, Fukushima, for their heartwarming hospitality during the activities in Fukushima regardless of their severe circumstances due to the earthquake and the following nuclear accident.

REFERENCES

[1] "Guidelines for Radioelement Mapping Using Gamma Ray Spectrometry Data", IAEA-TECDOC-1363, International Atomic Energy Agency, 2003, p. 40.

[2] M. Tanigaki and R. Okumura and K. Takamiya and N. Sato and H. Yoshino and H. Yamana, Nucl. Instr. Meth. A **726** (2013) 162-168.

[3] `http://www.pref.fukushima.jp/j/soukoukekka.htm` (in Japanese).

[4] Press Release, "Results of Continuous Measurement of Air Dose Rates through a Vehicle-borne Survey by MEXT (as of December 2011)", March 21, 2012, MEXT, `http://radioactivity.mext.go.jp/en/contents/5000/4688/view.html`

[5] `http://www.hamamatsu.com/resources/pdf/ssd/c12137_series_kacc1196e01.pdf`

[6] From Kyoto University: `http://www.rri.kyoto-u.ac.jp/kurama/kouiki/kurama2_test.html`(in Japanese); From JAEA: `http://info-fukushima.jaea.go.jp/joho/car_survey/top.html` (in Japanese).

[7] Press Release, "Results of Continuous Measurement of Air Dose Rates through a Vehicle-borne Survey by MEXT (as of March 2012)", September 12, 2012, MEXT, `http://radioactivity.mext.go.jp/en/contents/6000/5637/view.html`

[8] `http://ramap.jmc.or.jp/map/eng/`

ISBN 978-3-95450-139-7