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DEVELOPMENT AND CURRENT STATUS OF KURAMA-II*

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Abstract

KURAMA-II, a successor of a carborne gamma-ray survey system named KURAMA (Kyoto University RAdiation MApping system), has been developed and applied to various activities related to the nuclear accident at TEPCO Fukushima Daiichi Nuclear Power Plant in 2011. KURAMA-II has established its position as an effective method for the radiation monitoring method in environment. The development of KURAMA-II is still on the way to extend its application areas such as the trial to port the system to a single-board computer or the development of a new cloud service. In this paper, the current status of KURAMA-II on its developments and applications along with some results from its applications are introduced.

INTRODUCTION

The magnitude-9 earthquake in eastern Japan and the following massive tsunami caused a serious nuclear disaster for the Fukushima Daiichi nuclear power plant. Serious contamination by radioactive isotopes was caused in Fukushima and surrounding prefectures, but the existing radiation-monitoring schemes were incompetent for this situation due to damage and chaos caused by the earthquake.

KURAMA [1] was developed to overcome difficulties in radiation surveys and to establish air dose-rate maps during and after the incident. The design of KURAMA was intended to enable a large number of in-vehicle apparatuses to be prepared within a short period of time by using consumer products. The in-vehicle part of KURAMA consists of a conventional radiation survey meter, a laptop PC, a USB-type GPS dongle, and a 3G pocket wi-fi router. The data-sharing scheme based on Dropbox, a cloud technology, has enabled high flexibility and scalability in the configuration of data-processing hubs or monitoring cars. KURAMA succeeded in the simultaneous radiation monitoring extended over a wide area such as Fukushima prefecture and the eastern Japan, in contrast to other conventional carborne survey systems lacking of scalability.

As the situation became stabilized, the main interest in measurements moved to the long-term (several tens of years) monitoring of radiation from radioactive materials remaining in the environment. KURAMA-II [2] was developed for such purpose by introducing the concept of continuous monitoring from vehicles moving around residential areas, such as local buses and postal motorcycles. The ruggedness, stability, autonomous operation and compactness were well taken into consideration in its design, and an additional measurement capability of pulse-height information along with location data was also introduced. KURAMA-II has been successfully introduced to the continuous monitoring in residential areas and other monitoring activities.

In this paper, the outline and the current status of KURAMA-II along with some results from its applications are introduced.

KURAMA-II

System Outline

The system outline of KURAMA-II is shown in Fig. 1. The in-vehicle part is based on CompactRIO to obtain sufficient ruggedness, stability, compactness and autonomous operation feature. The radiation-detection part of KURAMA-II is the C12137 series by Hamamatsu Photonics [3], a CsI(Tl) detector series characterized by its compactness, high efficiency, direct ADC output and USB bus power operation. The size of CsI(Tl) scintillator varies depending on the usage, typically 3.4 cc for conventional carborne surveys. The ambient air dose rate, $H^*(10)$, is calculated from the pulse height spectrum obtained for each measurement point by using G(E) function method [4–6]. Since the energy dependence of detector efficiency is properly compensated by the G(E) function, more reliable results are expected in the case of environmental radiation that is dominated by γ-rays scattered by air, soil, or buildings etc. All components of the in-vehicle part are placed in a small tool box (34.5 cm × 17.5 cm × 19.5 cm) made of wood covered with thin aluminum sheet for the better handling.

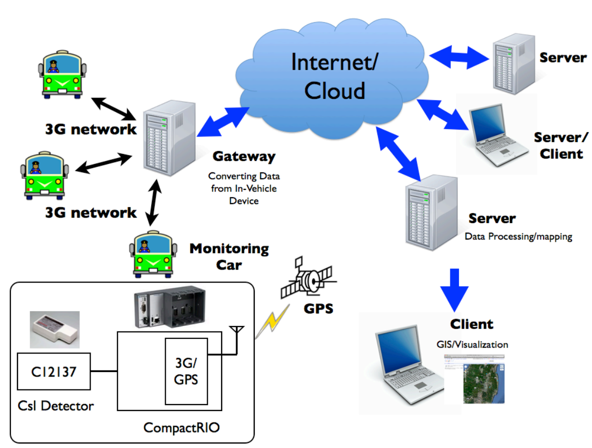

Figure 1: The system outline of KURAMA-II.

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Data Communication in KURAMA-II

The file transfer protocol used in KURAMA-II has been designed to send data without any loss under the poor coverage of the mobile network expected in emergency situations, as well as to comply to the standard protocols that are widely used in today's networks, such as Web Services.

In this protocol, two timestamped files, a text file for the air dose rates and a 32-bit binary file for the pulse-height spectra are separately produced for every three measurement points as data files. Generated data files are transferred to a remote "gateway server" by the POST method. All communications between in-vehicle units and a remote "gateway server" are based on RESTful API. Unsent files are archived inside an in-vehicle unit as a single zip file and wait for the next available network connection.

Once data files are received by the "gateway server", two text files on Dropbox, one is for the air dose rate and the other is for the pulse height spectra, are updated. These updated files are shared with remote servers via Dropbox, as was done in KURAMA.

A New Cloud Service for KURAMA-II

Now we are moving to a new cloud data storage service based on ownCloud [7] especially for KURAMA-II, allowing the full control of the cloud system to the users for the immediate recovery and easier operation of the system under emergency situations. The scheme used for the new cloud service is shown in Fig. 2. Two virtual servers, a RESTful API server with the database for received data and a cloud server for ownCloud, are implemented on a FreeBSD physical server. All the data sent from in-vehicle units are stored in a database on an API virtual server as well as data files on a cloud virtual server. The uploaded data is shared with remote servers via ownCloud. Other methods like WebDAV or SFTP may be used for the communications with other existing data sharing scheme.

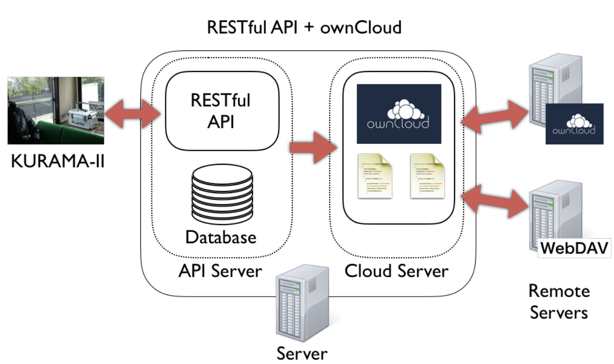

Figure 2: The outline of a new cloud service for KURAMA-II.

This new cloud service shows high reliability and flexibility for the use with several in-vehicle units on local buses and several units for walk survey in Fukushima prefecture, but the file synchronization with remote servers is slow due to the lack of delta synchronization in ownCloud. We expect improved file synchronization speed with the next release of ownCloud that is expected to implement delta synchronization [8].

APPLICATIONS OF KURAMA-II

Air Dose Rate Estimation in Residential Areas in Fukushima

A huge amount of data have been compiled for the air dose rate in eastern Japan by extending and continuing radiation monitoring activities by KURAMA-II [9, 10], and the characteristics of air dose rate in residential areas in eastern Japan has been studied. Saito and Andoh compared results from carborne surveys with those from walk surveys by KURAMA-II in residential areas (Fig. 3) and from the measurements in undisturbed flat fields [11, 12]. The air dose rates measured by walk surveys in residential areas are always between those from the car-borne surveys and the undisturbed field measurements (Fig. 4). Additionally, the measured air dose rates decrease more rapidly than expected from the physical decay, indicating the acceleration of decrease caused by various human activities.

Figure 3: Walk survey by KURAMA-II [12].

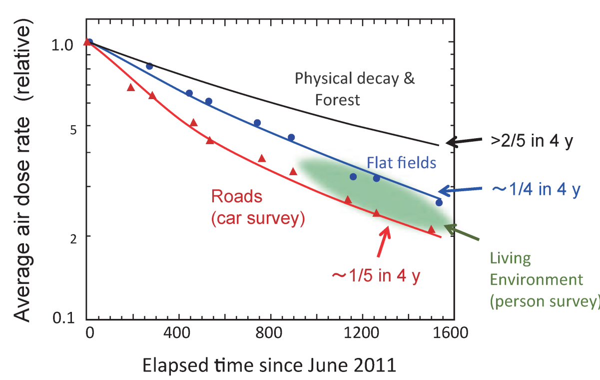

Figure 4: Temporal change of the average air dose rate for different conditions [11]. Air dose rates measured by walk survey are always between those measured by carborne survey and those by the undisturbed field measurements.

Recovery of Farmlands near Fukushima Daiichi Nuclear Power Plant

A differential measurement technique has been developed for the evaluation of soil contamination [13, 14] based on

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a high flexibility in hardware configuration of KURAMA-II. In this technique, the contribution from surroundings measured by a nondirectional detector is subtracted from the intensity measured by a detector collimated towards the ground surface to obtain only the contribution from the radioactivity on the ground.

For the practical application of this technique, a three-year project starting from the fiscal year of 2018 has been approved by Ministry of Agriculture, Forestry and Fisheries, Japan, to build a "robot" for the recovery of contaminated farmlands (Fig. 5). This "robot" will be a faming tractor equipped with KURAMA-II for radioactivity, an optical spectrum sensing system to measure the fertility and chemical property of soil, and the high precision guidance system for the operation of tractor in farmlands. All the data will be shared over the Cloud system developed for KURAMA-II and simultaneous visualization of radioactivities and fertility of farmlands will be performed on the smart phones and tablet-type devices to help farmers to recover their farmlands.

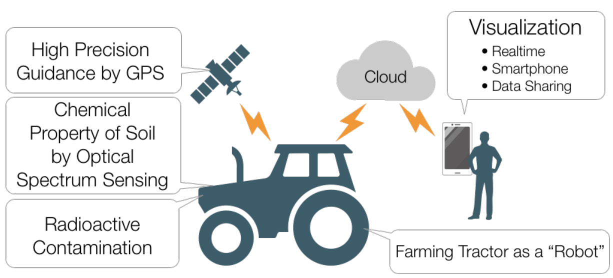

Figure 5: A conceptual scheme of a "robot" for the recovery of farmlands.

Development of a Single-board KURAMA-II

KURAMA-II is now porting to a single-board computer, to extend its applications to extreme conditions including the disposable usage for the immediate measurement in areas extremely contaminated by radioactivity. In such case, many single-board KURAMA-IIs will be deployed from unmanned aerial vehicles to the target area and continue measurements while their power last.

Spresense from Sony [15] is chosen as the platform of KURAMA-II because of its integrated GPS, audio processing capability applicable to pulse height analysis, and a powerful multi-core micro controller. C12137 is used as a detector in the beginning for feasibility studies, and a CsI(Tl) detector and a shaping amplifier will be implemented and the audio input will be used for the pulse height analysis.

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