Participatory Radiation Information Monitoring with SNS after Fukushima

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ABSTRACT

We developed a series of inexpensive but accurate mobile radiation detectors, which we named Pocket Geiger (POKEGA), to address the urgent desire of ordinary people to measure and share radiation levels in their milieus and to discuss the results of the Nuclear Disaster in Fukushima, Japan. This action research reports on a new style of pragmatic model of radiation monitoring, which employs the features of Participatory Design and Participatory Sensing and adopts modern communication platforms such as crowd-funding, open source development, and Facebook. This paper proposes an interaction model between the project management body, and other inclusive corroborators, e.g., ordinary users and experts, and focuses on three development phases of the project: start-up phase, evaluation phase, and operation phase. This paper also considers a reliability assurance model on disaster information sharing between the citizen layer and the official layer by data sharing and discussion activities in the POKEGA community.

Keywords

Facebook, Nuclear Disaster, Open Source Hardware, Social Inclusion

INTRODUCTION

The number of environmental hazards producing wide-ranging contamination, such as the Bhopal disaster, the Chernobyl disaster, the Fukushima Daiichi nuclear disaster and PM2.5 air pollution, seem boundless. In such hazards, local residents should know the exact risk of pollution to avoid over-confidence (i.e., excess of trust) or over-diffidence (i.e., deficiency of trust). Castelfranchi and Falcone (2010) proposed that trust is epistemically rational when it is based on well-motivated evidence and on good inferences, and when credibility is correctly based on external and internal reliable sources. To propagate appropriate risk communication based on rational trust, a social system design is needed to support local residents' decisions by swiftly providing them risk information regarding an appropriate action, such as staying at home or evacuating, through *discussions* with the disaster expert team (Tanaka and Itoh; 2003).

Especially in the Fukushima Daiichi nuclear disaster situation, people wanted to *measure* and *share* radiation levels in their milieus since radiation readings differed, even in limited areas, depending on natural environmental conditions such as weather, vertical intervals, or vegetation. Simultaneously, they also wanted their community to acquire knowledge of quantitative risk, radiation protection, or appropriate methods of radiation measurement through *discussions* with experts such as researchers, engineers or medical doctors.

APPROACH

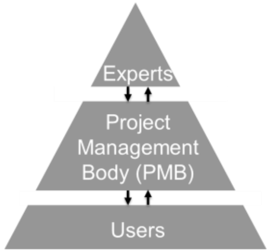
We developed a series of inexpensive but accurate mobile radiation detectors connecting to smartphones. We named the detectors, shown in Figure 1, Pocket Geiger (POKEGA). The detectors address the pressing desire of ordinary people to *measure* and *share* radiation levels in their milieus since the Fukushima Daiichi nuclear disaster. The detectors use GPS and the networking capabilities of the smartphone for logging data, data *sharing* and *discussions* in a Facebook group.

To reduce costs while maintaining accuracy and flexibility, we used the combination of a photodiode detector connected to a smartphone via a microphone cable. It is already known that a PIN photodiode can detect various nuclear radiations at its depletion layer (Dearnaley and Northrop, 1966). However, our project marks the first time a photodiode of this type has been combined with a general smartphone in a practical manner. The detector circuit design is optimized for simplicity and low cost, whereas the smartphone software application is tasked with handling the complex processing. The technical details of POKEGA are shown by Ishigaki et al. (2013). In addition, to establish a production base and to enable the nuclear disaster to contribute to job security in the area affected by the Great East Japan Earthquake, we collaborated with a skilled OEM factory located in that area.

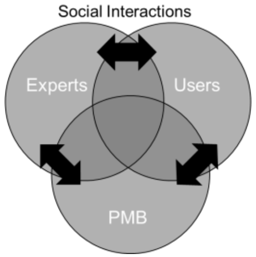
Figure 1 Pocket Geiger Device and software

We designed the POKEGA based on general-purpose semiconductors under an open-source license and rapidly launched the development project on a website, which we named Radiation-Watch.org, to gather volunteer collaborators from all over the world. We also used the crowdfunding site called Kickstarter.com for quicker and more cooperative development compared with traditional methods such as business financing or research funds.

Figure 2 shows two interaction models between stakeholders in system development. Figure 2A shows the development model in a traditional commercial system. In such a hierarchal organization, the *Project Management Body (PMB)*, such as manufacturers, system integrators, fab-less companies, or planning agencies, organizes *Experts* such as engineers and professionals based on a contract of employment or a research agreement. *Users* cannot contact the *Experts* directly. In contrast, Figure 2B shows an interaction model between the stakeholders – *PMB*, *Experts*, and *Users* – created in the POKEGA community. We named this model Participatory Development Model (PDM). In PDM, it is expected that the stakeholders voluntarily join the community, and they autonomously collaborate with each other through open discussion via social media. As a result, they contribute to improving radiation literacy in the community.



A. Hierarchal model



B. Participatory Development Model (PDM)

Figure 2 Development models

We derived the basic idea of PDM from Participatory Design, which is a known method to involve users in development by active participation of developers into a user community for consensus building. The method was originally used in a project for the Norwegian Iron and Metal Workers Union (NJMF) in 1971 in order to reconstruct the work environment and organization structure. In this project, researchers actively involved laborers in the development phase (Bjerknes and Bratteteig, 1995; Bødker et al., 2000).

We facilitated Facebook groups to *share* measured data quickly and *discuss* radiation protection directly with *Users*, *PMB* and *Experts*, based on the measured data by the POKEGAs. Burke et al. proposed the basic concept of Participatory Sensing by smartphone devices to form interactive community that enable public and professional users to gather, analyze and share local knowledge assuming realistic, social applications such as urban planning, public health, cultural identity and creative expression, and natural resource management (Burke et al.; 2006).

This action research reports on a new style of pragmatic model of radiation monitoring in nuclear disaster situation, from the aspects of Participatory Design and Participatory Sensing, adopting modern communication platforms such as crowd-funding, open source development and SNS. This paper also proposes interaction model between *Users*, *PMB* and *Experts*

in the community on three development phases of the project; start-up phase, evaluation phase and operation phase.

START-UP PHASE

We chose the crowdfunding site Kickstarter.com to raise money for our initial project expenses. Figure 3 shows the investment trend of our project. A number of popular Internet news sites, including Gizmodo and Makezine, featured the project at the beginning of July 2011. In the time since then, the project page has been shared via various social media thousands of times, and the investment trend has risen rapidly. As of this writing, the project is supported by 167 backers from 23 countries. We received many positive messages from backers, especially from Japanese backers, and also received business offers, particularly from US backers. Furthermore, we received unexpected offers of help from professional researchers in the form of technical advice, calibration testing, and field experiments, as shown in the following subsections. These achievements demonstrate that crowdfunding has been quite effective not only for financing but also for publicity and attracting experts sympathetic to the goals of the project.

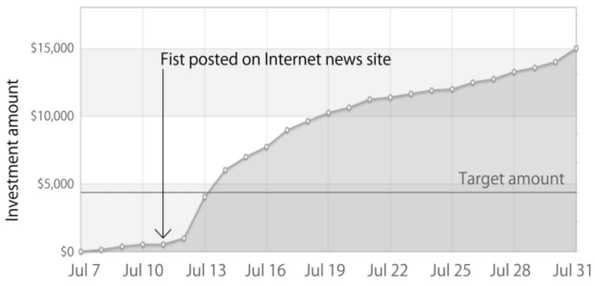


Figure 3 Project investment trends

EVALUATION PHASE

Two Dutch researchers at the Department of Defense in the Netherlands separately and voluntarily offered to calibrate the POKEGA device in their special facilities. Their examination was very useful to us because it revealed that the Cs^{137} measurement range for a POKEGA-equipped smartphone was approximately 0.05 to 10 mSv/h, as shown in Figure 4 (Kuipers et al., 2011), which covers most radiation levels measured in Japan. According to an interview article in a Dutch Newspaper (Van De Weijer; 2013), they found the project on Kickstarter and decided to support it since they deemed it worthwhile.

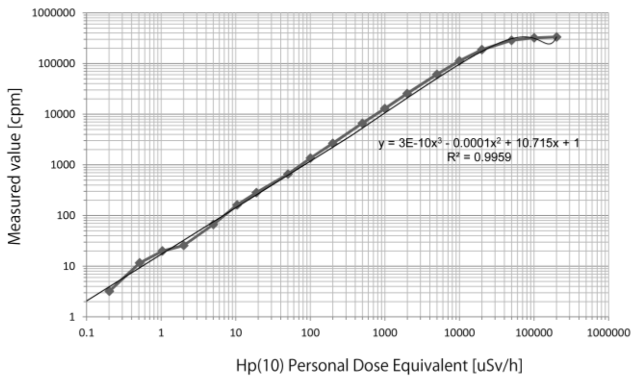


Figure 4 Measurement range for Cs^{137} (Kuipers et al., 2011)

A Japanese researcher of soil physics at the University of Tokyo also offered to examine the performance in an outdoor environment in an evacuation area in

Fukushima. With colleagues, he constructed field monitoring systems including POKEGAs in three different areas of vegetation: a garden area, a forest area, and a non-deforested area in October 2011 (Mizoguchi et al., 2012).

From the results of experiments in such a distressed environment, we found realistic problems of false detections having two error modes. One error mode was caused especially on sunny days, because the infrared beam of sunshine sometimes penetrated the shade tape inside the POKEGA case. Another error mode happened especially on warm days, because thermal noise generated a false signal in the photodiode sensor at a temperature of approximately 40 ºC or higher. As countermeasures for these problems, we improved the performance of the shade tape and reconfigured the parameters of the circuit to set higher thresholds for the radiation signal to prevent false detection.

OPERATION PHASE

Approximately 12,000 POKEGA units were shipped in the six months following the start of the project, and a total of 50,000 units have been distributed as of this writing. In total, 2,500 subscribers joined the Facebook community, where they could report measurement results and discuss radiation protection or technical improvements. Figure 5 shows the classification of 1,549 threads posted by users on the POKEGA Facebook group between July 2011 and July 2012. The following sections show details of the topics.

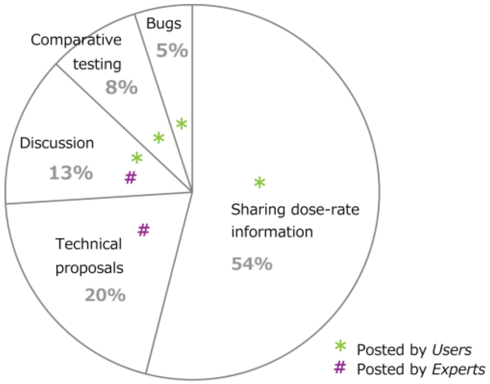


Figure 5 Posted topics on the POKEGA Facebook group

The topics posted by *Users* are marked '*' in Figure 5: *Sharing Dose-Rate Information* (54%) is overrepresented in the posted topics shown in Figure 5. The topic refers to data sharing of radiation levels measured by POKEGA users, especially around their daily milieus, such as a children's park, the user's own home or garden, a school, or farmland. Most of the posts included photos. For example, Figure 6A shows contaminated soil covered by a blue-colored sheet in a children's park and a poster advised children to leave the area since the background level in the area was 0.49 uSv/h, while the normal level in Tokyo was around 0.05 uSv/h. Figure 6B was taken in a prohibited area around the frontline base called J-Village when the poster recommended users to return to home until administrative approval was given. The radiation levels were from 0.45 to 1.90 uSv/h. Through data sharing, people learned the radiation levels in various locations, including in places where they do not typically go.

Comparative Testing (8%) is the fourth major topic in Figure 5 and it refers to technical reports of the testing to compare readings between POKEGA and other calibrated dosimeters. The tests were executed mostly by ordinary people. For example, Figure 6C shows comparative tests with an official monitoring station constructed by the Japanese Government few months after the nuclear accident. Because POKEGA showed almost the same readings as other detectors in most cases, the detector obtained the users' trust. In contrast, some people commented that they changed their mind about the trusting instruments constructed by the government because they did not trust the government before the testing.

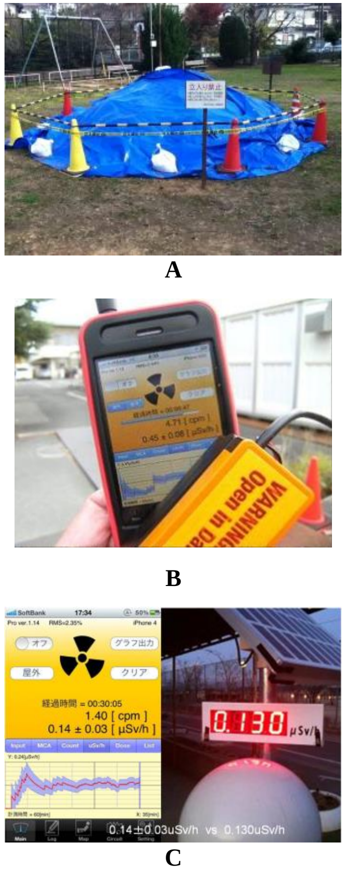
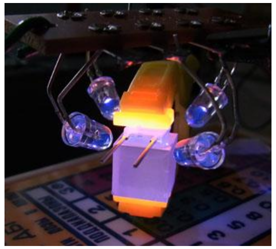


Figure 6 Posted Photos taken by POKEGA Users



A. POKEGA with attached crystal

B. Wireless connection

Figure 7 Technical proposals

Bugs (5%) refers to error reports. All of those were fixed by on-line software update and no hardware recall was needed, since most functions of POKEGA were implemented by smartphone software.

The topics posted by *Experts* are marked '#' in Figure 5: *Technical Proposals* (20%) is the second major topic in Figure 5. We released six types of POKEGA series by improving various technical specifications such as sensor efficiency, internal power generation, noise reduction, visualization features, and support of various mobile devices. Most of these improvements were inspired by the technical proposals on the SNS from voluntary engineers and radiation professionals. For examples, an engineer suggested an improvement of POKEGA efficiency by attaching a scintillator crystal on its photodiode sensor, as shown in Figure 7A. Another engineer presented an embedded application of POKEGA to create small monitoring posts with wireless connections, as shown in Figure 7B.

Figure 8 Example of a discussion by the POKEGA Facebook community

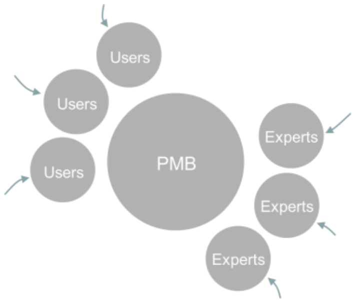
Users and *Experts* provided rich *Discussions* (13%), which is the third major topic in Figure 5. Subscribers of the SNS group autonomously helped each other based on their knowledge and expertise. For example, Figure 8 shows an interaction between users and radiation professionals that originated from a question from a business traveler. The traveler found that the natural background was slightly high (0.13 uSV/h) in Okayama prefecture, although the area is over 600 km away from Fukushima prefecture, and other user posted almost the same reading in Fukushima. Consequently, a radiation specialist noted that the average, natural background in Okayama prefecture had been around 0.126 uSv/h because of a geological property existing before and after the nuclear disaster. In this case, three POKEGA users, including the radiation specialist, quickly and adequately answered the question within four days after the first post.

PARTICIPATORY DEVELOPMENT MODEL

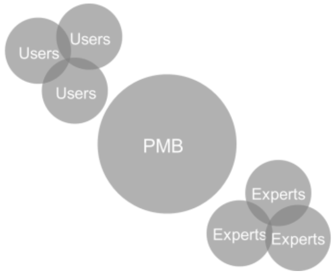
Figure 9 shows the dynamics of the PDM through three phases: start-up, evaluation, and operation. In the start-up phase, shown in Figure 9A, *Users* and *Experts* separately contributed to project development because they individually backed the Kickstarter campaign and helped its publicity distribution by re-tweeting or sharing the site on SNSs. Some professionals personally offered voluntary examinations. In the evaluation phase, as shown in Figure 9B, the stakeholders started bottom-up collaborations in their respective groups; *Users* started sharing radiation levels in their milieus with each other, and *Experts* reported comparative testing results and started communicating technical information based on the open-source style. Finally, in the operation phase, as shown in Figure 9C, the stakeholders started mutual collaborations across the groups to which they belonged.

Experts provided fruitful information for ordinary *Users* through *Discussions* in the Facebook group and most users expressed words of appreciation for them. Such direct radiation risk communication was quite helpful for the *Users* and also could satisfy the *Experts'* need for self-actualization as experts, which is not permitted in the hierarchal role model.

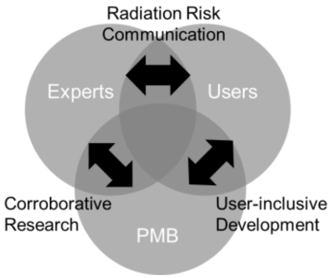
Experts also actively contributed to POKEGA development by providing rich technical advice for the *PMB* from laboratory experiments or by technological suggestions of circuit design and smartphone software. As a result of such corroborative research, POKEGA has evolved throughout six types of devices.



A. Start-up phase



B. Evaluation phase



C. Operation phase

Figure 9 Interaction models of development phases

For example, the latest types, compared with the first type, are ten times more efficient for detecting gamma radiation.

Users also actively reported comparative testing results or bugs and *Experts* followed up the posts. Such user-inclusive development style contributed to quick, user-centered development of POKEGA.

In the action research, PDM enabled quick development of the world's first, smartphone-connected radiation detector and constructed an inclusive community for radiation protection formed by voluntary *Experts* and ordinary *Users*. We think POKEGA will be widely useful in environment monitoring and risk communication for various hazards such as PM2.5 air pollution, soil and water contamination, or earthquake detection and analysis.

PARTICIPATORY DISASTER INFORMATION SHARING MODEL

Turoff et al. (2010) designated the effectiveness of unofficial, user-generated information, e.g., "back-channel information" or "wisdom of crowds", in crisis communication as generated by ordinary people through social media. At the same time, they also indicated the risks of misinformation or over-confidence (or over-diffidence) and the difficulty of information sharing with an official body.

To seek solutions for these problems, we model the dynamics of data sharing and reliability assurance for environmental information based on the action research of POKEGA, as shown in Figure 10. The model has four quadrants of closed access and open access, as well as the Official Layer and the Citizen Layer. In the Official Layer, a decision-making process is needed to disclose data and generally the process takes a long time. Soon after the Fukushima accident, the Japanese government knew detailed simulation results from a computer-based decision support system for a nuclear plant accident, named SPEEDI (System for Prediction of Environmental Emergency Dose Information), which was developed for nuclear disaster management (Imai, 1985). However, the government did not disclose the dispersal data with the Japanese public or researchers for two months, although they showed some documents to the public two weeks after the accident because they were exposed to harsh criticism (Onishi and Fackler, 2011). Ono (2013) indicated that the risk assessors' hesitation might be due to the deficit of skill of when to use/disclose simulation results or the deficit of skill to explain error or uncertainty.

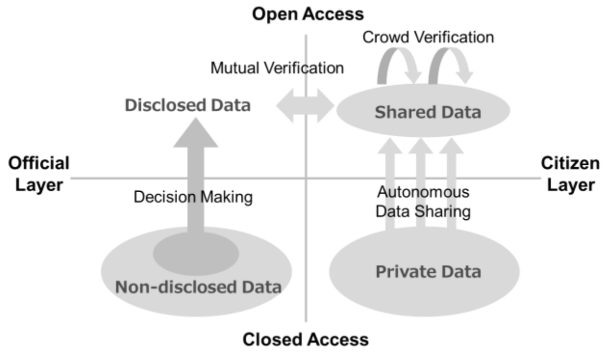


Figure 10 Reliability assurance model

In contrast, POKEGA allows ordinary people to measure environment data quickly in *Private Data*. In the meantime, a large amount of *Private Data* was passed to *Shared Data* by autonomous data-sharing by users through social media. *Users* also self-validated the *Shared Data* of each other by using POKEGA and other instruments at various places, which we call "Crowd Verification". Some people placed a comparative test of POKEGA with the *Disclosed Data* shown on official monitoring stations constructed by the Japanese Government, which we call "Mutual Verification". The verification process widely ensures POKEGA's absolute performance, reliability, and trust for users. On the other hand, after the verification, some users accepted that the *Disclosed Data* from the Japanese Government were true.

We assume that the Crowd Verification process plays an important role in quick and wide-ranging monitoring in crisis management and the Mutual Verification process is also effective to ensure reliability of instruments and reduce distrust of citizens by cooperation and discussions between citizen and professionals through social media. Both verification methods are considered to have great potential for future applications such as environment monitoring or product safety.

REFERENCES

1. Bjerknes, G. and Bratteteig, T (1995): User Participation and Democracy: A Discussion of Scandinavian Research on System Development, *Scandinavian Journal of Information Systems*, 7(1), pp.73–98.
2. Bødker, S., Ehn, P., Sjögren, D. and Sundblad, Y. (2000): Co-operative Design -- perspectives on 20 years with 'the Scandinavian IT Design Model', *Proc. of Nordi CHI 2000*, October, Stockholm, Sweden.
3. Burke, J.A.; Estrin, D., Hansen, M., Parker, A., Ramanathan, N., Reddy, S., Srivastava, M. B. (2006): Participatory Sensing, *Proc. of the International Workshop on World-Sensor-Web (WSW'2006)*, ACM, October 31, Boulder, U.S.A.
4. Dearnaley, G. and Northrop, D.C. (1966): Semiconductor Counters for Nuclear Radiations, Second Edition, New York, *John Wiley & Sons, Ltd*.
5. Falcone, R. and Castelfranchi, C. (2001): Trust and Deception in Virtual Societies, 'Chapter 3: Social Trust: A Cognitive Approach', Dordrecht , *Springer Netherlands*, pp. 55-90.
6. Imai, K. (1985): SPEEDI: a computer code system for the real-time prediction of radiation dose to the public due to an accidental release, *Japan Atomic Energy Research Institute (JAERI) Report*, No.1297, Vol.17, Issue 21.
7. Ishigaki, Y., Matsumoto, Y., Ichimiya, R., Tanaka, K. (2013): Development of Mobile Radiation Monitoring System Utilizing Smartphone and Its Field Tests in Fukushima, *IEEE SENSORS*, Vol. 13, Issue 10, pp. 3520 -3526.
8. Kuipers, T., Wout, C. V. and Bader, F. (2011): iPhone als stralingsdetector, *Dutch Journal of Radiation Protection*, Issue 2, pp. 32-34 (in Dutch).
9. Mizoguchi, M., Ito, T. and Kobayashi, D. (2012): Environmental Monitoring of Village Contaminated by Radionuclides, *Proc. AFITA/WCCA 2012*, Taipei, Taiwan, Seminar(19)-03, 138.
10. Onishi, N. and Fackler, M. (2011): Japan Held Nuclear Data, Leaving Evacuees in Peril, New York, *The New York Times*, Published: August 8, 2011.
11. Ono, K. (2013): Issues emerged after the 3.11 Earthquake in Japan focusing on risk governance deficits in radioactive materials: Deficits on risk assessment, '(booklet) Emerging Issues Learned from the 3.11 Disaster as Multiple Events of Earthquake, Tsunami and Fukushima Nuclear Accident', *The Society for Risk Analysis Japan*, pp.42-43.
12. Tanaka, K. and Itoh, M. (2003): Communication and Information Inducing Suitable Danger-avoidance Actions from Disaster, *Disaster Information*, No.1, pp.61-69 (in Japanese).
13. Turoff, M., Van de Walle, B. and Hiltz, S. R. (2010): Information Systems for Emergency Management, 'Section 16: Emergency Response Information Systems: Past, Present, and Future', pp.369-388, London and New York, *Routledge*.
14. Van de Weijer, B. (2013): Een onderzoeker in ieders broekzak Smartphones inhet regenwoud, Netherland, *Volkskrant*, 2013-07-13 (in Dutch).