Making Smart Rainwater House

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ABSTRACT

A smart rainwater house (SRH) is build for individual residence. Resident of this SRH is Toshiyuki Moriyama which is one of author for the experiment of smart rainwater tanks. Urbanization including development of residential area made a flash flood more frequently, and peak of discharge from urbanized watershed be faster and increase the amount of peak discharge. The tanks can save the rainwater and monitored via sensor network to visualize the amount of rainwater storage and possible to control the pump to waste rainwater before the heavy rainfall by prediction of weather using SOM with pattern recognition of meteorological field.

1 INTRODUCTION

1.1 Background

1.1.1 Rainwater

Many of the flooding disasters that have occurred in Kyushu, Japan, have been associated with fatalities. In 1999, extensive flooding occurred in the Hii River catchment of Fukuoka City, Japan, after heavy rains with

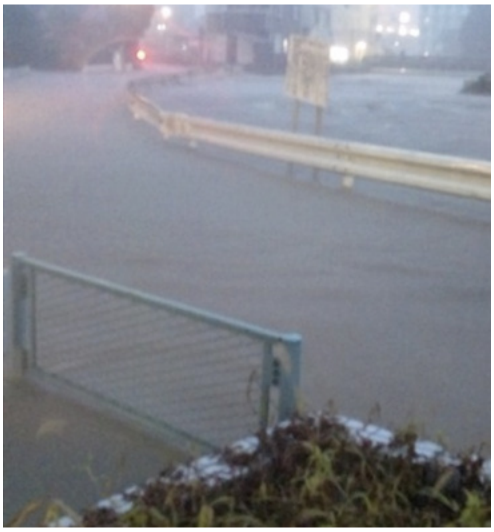

Fig.1 Flood occured in 24th Jul. 2009. Photo by Labo. of Prof. Watanabe

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an intensity of 100 mm/hr. After the disaster, the Hii River Citizen's Conference on Water Control (HiiCC) was convened in order to discuss ways in which flooding could be prevented/decrease in the Hii River Basin.

HiiCC proposes flood control with store on basin to the local government of Fukuoka city and Fukuoka prefecture, that is, storing the rainwater everywhere in the basin, rather than relying on river refurbishment or large-scale rainwater storage facilities. HiiCC are also promote the technology development for that purpose (Yamashita et. al.,2016).

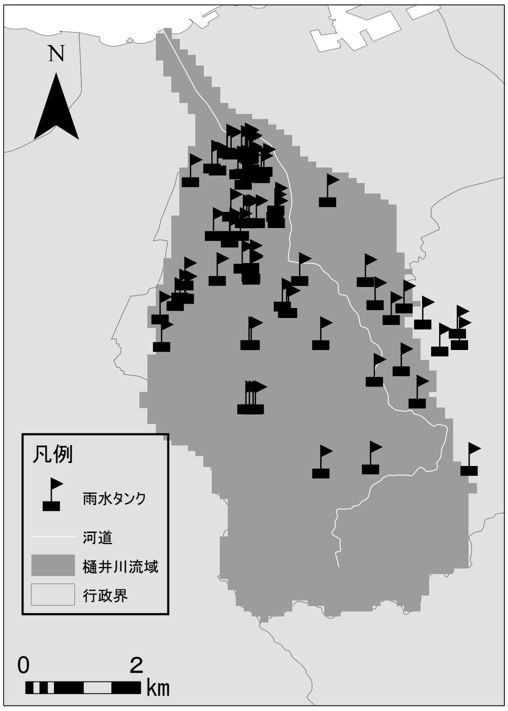

Fig.2 Distribution of small rainwater tanks in Hii River Basin. Location data is served by Labo. of Prof. Watanabe

1) Installation of 106 200 L rainwater tanks in the Hii River Basin.

Proposals also include rainwater saving on site using rainwater tanks. HiiCC and NPO have already lent and installed 106 rainwater tanks in the Hii River Basin (Fig. 2). However, despite this installation being for disaster prevention, it was found that only 29% of residents manually pre-release before the heavy rainfall. Therefore, when heavy rain is predicted, it is considered necessary to automatically drain stored rainwater in advance (Moriyama et. al., 2013) .

2) Rainwater Harvesting House for Personal


Fig.3 Prof. Watanabe's Rainwater House

Watanabe, a member of HiiCC constructed large-scale rainwater tanks for a personal residence shown in Figure 3. One 20 tons tank was installed under the house, and another 27 tons tank was installed under the parking area. Watanabe and his family use the rain water for flushing the toilet, bathing and washing. Water quality tests revealed that the water is well suited for these uses, except immediately after constructing the house. The amount of rainwater in the tanks is considered sufficient for four family members for one year, and Watanabe intends to test this in 2013 or after (Watanabe et. al. (2012) .

3) Rainwater Harvesting House of the apartment complex

With the guidance of Shimetani, head of the HiiCC, Daiken Co. Ltd. installed and distributed the apartment complex "Ogiura Garden Suburb" with 110 tons tank in Itoshima City in 2012 shown in Fig.4. The rainwater is used for gardening and for flushing toilets. We install a sensor network for water level of the rainwater tank, quantities of outlet and rainfall rate in 2013. It is possible to check these terms via web site shown in Fig.5. The collection data system is requesting a data from internet gatway to sensor node (Misumi et. al., 2013; Moriyama et.al., 2013). But it is sometimes delayed when the wireless connection using XBee Series 1 is disconneced. The time is recorded at gateway, the value for rainfall rate and water quantity sensor is not accurate when wireless network was interrupted.

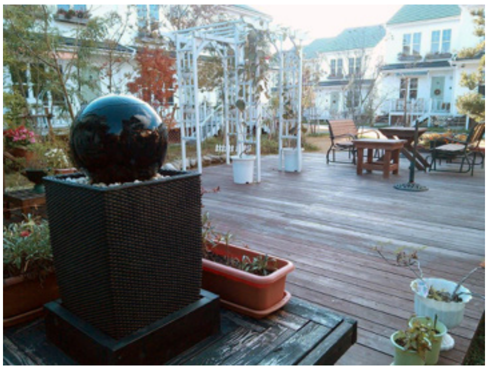

Fig.4 Garden in the Oginoura Gaeden Suburb. 110tons rain water tank is installed under the deck

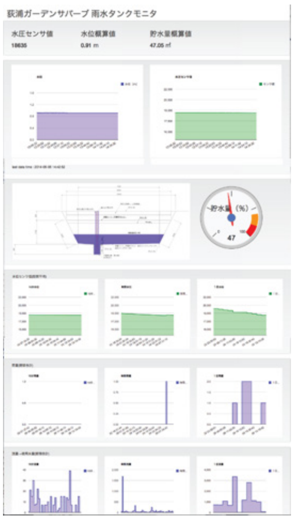

Fig.5 Web Display (Moriyama et.al.2014)

The sensor node newly adopted Seeeduino Stalker v 3.0 (Stalker, Fig.6) equipped with Real Time Clock (RTC) (Moriyama,2016b). Stalker is started regularly by RTC, and data is transmitted to Raspberry Pi 2 Model B (RasPi 2) shown in Fig.7 via a wireless sensor network using XBee Series 1 (2.4 GHz), and RasPi 2 is connected via 3G/LTE network based on celluar phone. It stores the data in Dynamo DB on Amazon AWS and (Moriyama et.al., 2016b) shown in Fig.8. Time series values are made

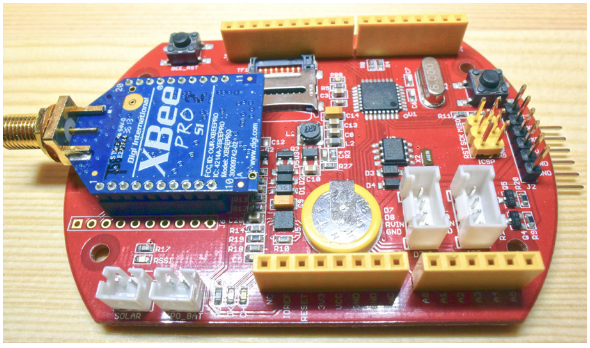

Fig.6 Seeeduino Staker V3.0 with XBee

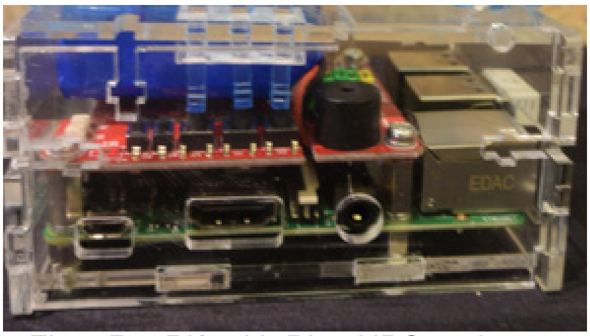

Fig.7 RasPi2 with Pico UPS and case

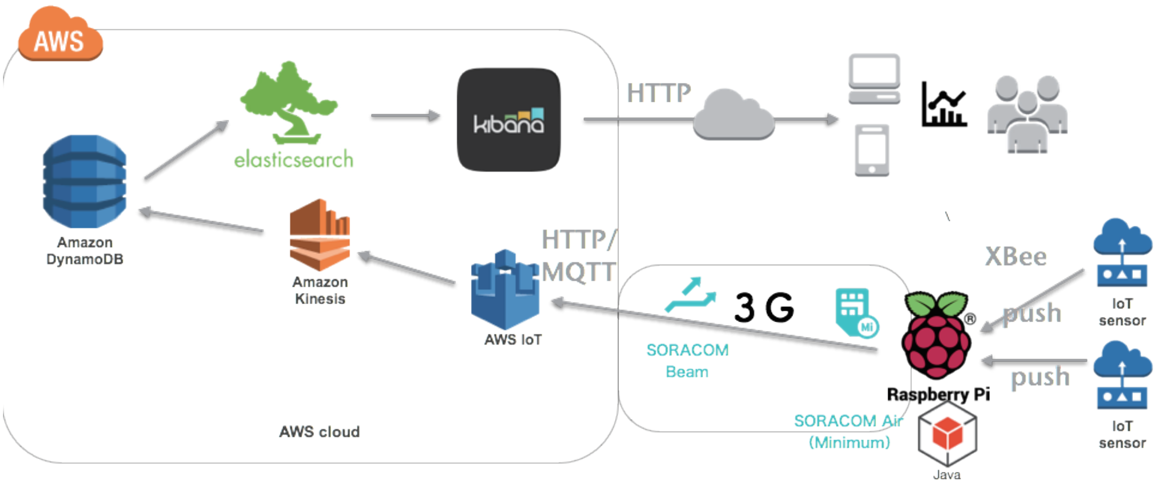

Fig.8 Block Diagram of visualization of Rainwater

visible by Elastic Search and Kibana on AWS. The display can be viewed not only on a PC but also on a smartphone.

We also use this 110 tons tank for the gauge of rainfall rate, but this tank is gravel filled type and the water level sensor used pressure mesurement method. When heavy rainfall is occured, it is observed that a spike of the pressure. It is needed other way to use for gravell filled rainwater tanks for raingauge (Moriyama et.al, 2015).

4) Development of furniture-type rainwater tanks

To facilitate adoption of the system by residents in the catchment, rainwater tanks that doubled as furniture were developed. The capacity of these outdoor or indoor tanks is approximately 1000 L. The tanks are constructed using timber from forest thinning and are shown in Fig. 9 and 10 (Moriyama et.al, 2013).


Fig.9 Building a Furniture type Rainwater Tank


Fig.10 Installed a furniture type Rainwater tank

5) Retention ponds that function as sports grounds

A permeable retention-type sports ground was installed at Fukuoka University in the Hii River Basin shown in Fig.11. The field has a surface area of 10,274 m^2 and it certified by

FIFA as Two Star-class football ground shown in Fig.11. The retention pond delays runoff and contributes to groundwater recharge. It also improves the thermal environment of the city by evaporation after the rainfall and, as an additional benefit, the field can be used immediately after the rainfall and on hot days (Moriyama et.al, 2015).

Fig.11 Reserving Type Playground

6) Maintenance of an agriculture reservoir

With a capacity of approximately 90,000 t, the Genzou Ike agricultural reservoir is the largest reservoir in the Hii River Basin shown in Fig.12. Approximately one forth of this capacity is required to cut the peak of 40% od discharging in this basin. Water from the reservoir is only used to irrigate a small paddy field; all of the other paddy fields have been developed. Unfortunately, several administrative problems currently prevent using the reservoir for disaster risk reduction. HiiCC members and the authorities responsible for managing the reservoir have entered into discussions about this problem. As a first step, HiiCC members will help with drying the pond . Drying pond was traditional event that involved local community, but it was stopped about 20 years. Drying pond improves water quality as the mud on the bottom is exposed to air and oxygenated. The last time the pond was dried was in October 2011 shown in Fig.13.

Fig.12 Genzou Ike Reservoir for Agriculture on Google Map

Fig.13 Drying Genzou Ike Reservoir

7) Signs indicating the depth of flood waters

Signs showing the depth of floodwaters

Fig.14 Posting Sinage for Depth of Inundation at Torikai Area, Hii River Hii River Basion

in areas that are frequently inundated are important for residents and tourists. Placement of the signs is undertaken in consultation with local residents. The signs were placed on 29th March 2013 with Prof. Sampei Yamashtia, a designer/student from Kyushu Sangyo University, and key community members, including Ms. Kumiko Kakudo. Fig.14 and 15 shows a sign in the Torikai area in the Hii River Basin (Moriyama et.al, 2015) .

Fig.15 Details of Sinage for Depth of Inundation at Torikai Area, Hii River Hii River Basion

8) Painting rainwater tanks

To encourage citizens to adopt rainwater tanks and to promote our concept, tanks were painted by the art club of a junior high school (Minagawa et al., 2012) shown in Fig.16. After the rainwater tanks were painted, they were installed in the Jonan Junior High School.

Fig.16 Painted tanks and art club of the Jonan Junior High School students(Moriyama et.al, 2015:Fig.10)

9) Development of Social system that corresponds to the basin water storage

After the 2016, HiiCC is dividing in two sector. One is the Rainwater Society Study Group, which is a research department, and the other is Mizubering Hiigawa promoting the better relationship with residents on the Hii River basin. The Rainwater Society Study Group has received research grants from RISTEX of JST, Japan since 2015 (Shimatani, 2016).

1.1.2 Eco House

In general, the eco house is considered to be the Zero Energy House (ZEH) recently. However, considering ecology from a broader perspective, it is necessary to consider not only energy, but also life cycle access (LCA) and long-term availability. ZEH ignores the energy consumption at the time of building and dismantling, because promoters of ZEH disregards it as about 10%, but 10% is considerably large, and it is not desirable from the viewpoint of LCA. Recently there is a problem of gypsum board which costs about 3 times as much as the product for disposal. Hydrogen sulfide is generated when filling the gypsum board, but until recently processing equipment has not spread. Furthermore, in Japan, high insulation and high airtightness has advanced from the viewpoint of energy reduction, and 24-hour ventilation is mandated to discharge harmful gas such as formaldehyde generated from commonly used chemical products. This is a contradiction.

1.1.3 Disaster Prevention

The house is also necessary to prepare for disasters (disaster prevention). Since large earthquakes have occurred in Japan in recent years, further earthquake resistance has become a problem. Generally, it is thought that it is better to strengthen the structure. From the viewpoint of shortage of skilled technicians and cost reduction, there are increasing methods of strengthening laminated wood with metal bonded materials, but the former has been pointed out as durability of adhesive, the latter has external force more than designed, there is a danger of collapsing momentarily.

Also, shortly after the Kumamoto earthquake (Fig.17) that occurred in April 2016, despite the fact that the Kumamoto district was rich in groundwater, water pipes were damaged, so the hill was shut off for several weeks and the water supply car was used. It is fresh to remember, because Kumamoto-city, which uses groundwater, was forced to cut off water because of the cloudy groundwater by earthquake.


Fig.17 Damaged Buildings and Revee in Kumamoto Earthquake.

1.2 OBJECT

In order to solve the above problems using above technologies, Moriyama who is one of the authors of this paper tried to help solving these problems by actually constructing a SRH that combines the capabilities of eco house and disaster prevention house.

2. METHOD

2.1 Rainwater Tank

Using the rainwater tank not only for rainwater harvesting but also for flood control, the volume of 100 to 300 liters which is generally commercially available is insufficient. Urban heavy rainfall exceeding 100 mm/h has occurred several times per year in Japan, and in some cases it will be 120 mm/h or more.

In Hii River in Fukuoka city, existing rivers and sewers correspond only up to 79 mm/h. Local government of Fukuoka city has built 40,000 tons of rainwater storage facilities depending on the location, but the cost is as high as 600,000 Yen / ton, and the sewerage that gathers rainwater to storage will overflow first. The cost of repairing this sewer system is quite expensive.

Therefore, in order to correspond to the remaining about 20 to 40 mm/h at each site, it is necessary to have a rainwater tank with a capacity of about 2 to 4 tons/100 m^2 on site.

Fig.18 Beam and Pillar of SRH

2.2 Structure of SRH

The SRH is tried to satisfy the conditions of the disaster-prevention house and the eco house in a well-balanced manner.

Fig.19 crosspieces and wedges through the Pillar

As a disaster-prevention house, it is used a large dried cross section beam of cedar and at least about 4.5-inch (12 cm) pillar at the minimum shown in Fig.18, it is used a wood plug to connect beams and pillars without using metal bonded materials, and it will be bear as long as possible during large deformation when earthquake occurred . That is, it was structured not to collapse instantaneously. Also, at the time of breakage, braces have a possibility of pushing up the beam. So it is not using braces and using crosspieces and wedges shown in Fig.19. In the wall, the moisture absorbing property and secured by softly absorbing the energy during the earthquake with the earth wall shown in Fig.20.

Fig.20 Making Earth Wall

And without the insulation material, securing the heat retention property, and plastering on it without the chemical substance shown in Fig.21. Here, it was important to decide that pure wood material, earth wall and plasters are materials that can be recycled and it is suitable for LCA. However, in this configuration, the strength becomes insufficient with simple wall quantity calculation method. But if you hope to clear this problem, to use the limit strength calculation method in Fukuoka prefecture, Japan will be judged in Tokyo. It will take a lot of time and cost, so a multilayer volcanic vitreous board is used to reinforce the wall.

As an eco-house, it is installed a 10 KW of solar panel on the roof and sold all the power using Feed-in Tariff. Regarding heating, a wood burning stove is installed, and biomass is used as energy shown in Fig.22.

The rainwater tank has installed a 5.6 tons plastic tank under the parking space shown in Fig.23. The saved rainwater is used for toilets, washing and bathing. In the case of a rainwater tank where about 6 tons capacity per 200m ^{2} area is not so large for flood control.

Fig.21 Plaster on Earth Wall

Fig.22 Wood Burning Stove

Fig.23 5.6 tons rainwater tank

It is necessary to drain the tank water before heavy rain occurred. Therefore, the authors already developed a method of predicting rainfall by forecasting weather patterns using a self-organizing map (SOM) which is a kind of pattern recognition in advance (Nishiyama et.al.,2007;Nishiyama et.al,2013). It is possible to predict rainfall 7 hours ahead in a range of 100 to 200 square km^2 with a certain degree of accuracy shown in Fig. 24 (Moriyama et. al., 2016a).

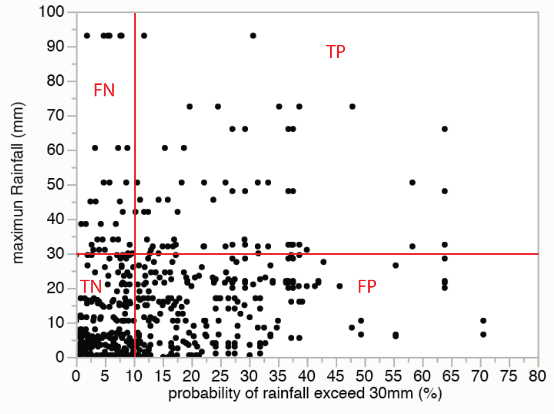

Fig.24 Diagnosis of exceeded 30mm/hour VS observed maximum rainfall rate in North Kyushu District (Moriyama et.al., 2016a:).

TP prediction: exceed 30mm, result: exceeded

FP prediction: exceed 30mm, result: not exceeded

FN prediction: not exceed 30mm, result: exceeded

TN prediction: not exceed 30mm, result: exceeded

4. Results

A year and a half have been passed since establishing a SRH, it is still used rainwater for washing, bathing and the toilet even now. At first, It was smelling of sulfur, but it got no smell when used for about two month.

The wood stove utilizing biomass is the second season now. The first year it was mostly burned dried hardwoods. In the second year, wood of coniferous trees such as cedar and cypress get from sawmills are used. However, if the furnace temperature is low, the coniferous trees make soot which come out and sparks fly through the chimney. For that reason, I got the logging of hardwood trees, It is cutted vertically and dried for one year. The dried one is burn the fuel mixed with coniferous trees in a stove.

Since monitoring of the water level of the rainwater tank is currently not worked well. At this stage, the sensor node is unstable, so this system does not work well. The sensor node wakes up from sleep every 10 minutes by a timer interrupt using RTC and send measured value from the sensor to the gateway. But it stops awakening or stops operation irregularly. If data can be sent to the Cloud in a stable, fluctuations of the water level of the rainwater tank will be made visible through the web as shown in Fig.25 with Elastic Search and Kibana on the AWS.

The cost of this rainwater tank is about 20,000 Yen / ton. Because it costs money to embed in the basement. Although this is cheaper than the rainwater storage facility in Fukuoka city, it is still high to disseminate the rainwater tank to residents for flood control purposes.

Fig.25 Example of water level of SRH with Elastic Search and Kibana on AWS

5. Future work

5.1 IoT network for water monitering

Currenty, we used a 2.4GHz ISM band of Personal Area Network(PAN) and 3G/LTE network. Former is crowded and latter needs to pay some cost to celluar phone company. But it is not needed much bandwidth for sensor nodes and these wireless communication method needs much power consumption.

Recently, LPWA has been spreading. This is a communication method that attempts to cover a wider range than WiFi etc. and suppressing the power consumption, instead of reducing the communication speed and narrowing the bandwidth. There are standards such as LoRaWAN and Sigfox, and it is thought that it will spread widely in the future. In this research, It will be conduct a verification experiment of LoRaWAN. LoRaWAN and Sigfox are utilizing ISM band 920 MHz. These frequency band around 920 MHz is easy to bend even at building corners, and it is generally said a platinum band because it is hard to attenuate even in plants.

Within one year at the time of the manuscript writing, we plan to set up more eight smart rainwater tanks for visualization in the basin of Hii River.

5.2 Forecasting the water level of the river

Furthermore, it is planning to predict floods in the basin based on rainfall data from 10 smart rainwater tanks in total, rainfall data from precipitation radar and water level data from the Hiii river. Five water level observation stations will be installed in the basin. The sensor node acquires data from the ultrasonic water level sensor installed in the river and sends it to the cloud. Perform this prediction calculation on the smartphone. This is based on the flood forecasting method developed (Hirano at el, 1986) and it worked without problem even with the slow PC at that time, so it will work well with the current smartphone (Moriyama et.al., 2009).

5.3 Cost down for the rainwater tank

In order to further disseminate the rainwater tank to citizens, it is important to reduce the cost. For example, it is necessary to install rainwater tank under the wood deck, without embedding underground. Or we will try the overflowed rainwater from the tank, to serve the garden without increasing the capacity of rainwater tank itself.

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