On-site experiment of seismic monitoring network by utilization inside sensors of mobile terminal

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1. INTRODUCTION

Mobile terminal devices have small, lightweight, and cheap acceleration sensors so-called MEMS(Micro Electro Mechanical Systems) with wireless communication adaptors inside. By using MEMS sensors densely for monitoring earthquake, we would know detailed distribution information of shaking intensity. By sharing those information through the cloud computing system, we could raise public awareness for disaster prevention. "i-Jishin" is one of examples, which is an experimental earthquake observation system developed using inside sensor of iPhone/iPad/iPod touch.

2. DEVELOPMENT

“i-Jishin” was released as application for iPhone/iPad/iPod touch in August 2010. Anyone who have these terminals can install “i-Jishin” and record shakings. Signals recorded by these terminals are sampled with frequency of 100Hz and given time stamp every 0.01sec synchronized with UTC by using external NTP server.(Fig.1,Table.1) Wave data are recorded as CSV file in the memory inside these terminals up to 30 files, and if wireless LAN connection is alive, they are uploaded to the virtual server installed in the cloud computing environment. (Fig.2)
If we search the recorded data, to access “geonavi” web site (http://www.geonavi.com/), we can download wave data and seismic intensity. (Fig.3) And we can also analyze data on the web browser.(Fig.4)

Fig.1 Screenshot of “i-jishin”(corresponding to multilingual)

Fig.2 Key map of “i-jishin” and “geonavi”

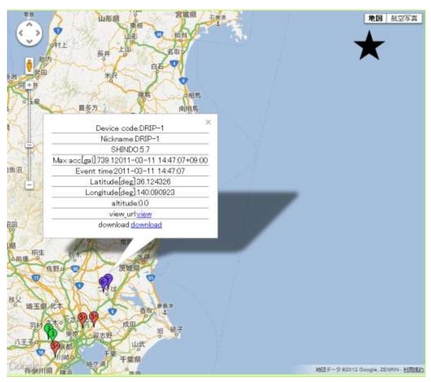

Fig.3 Screenshot of “geonavi ”

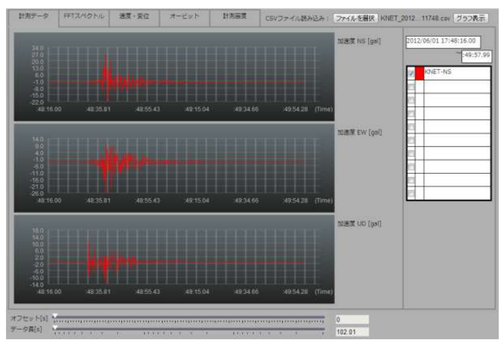

Fig.4 Wave viewer of “geonavi”

Table.1 Specification of “i-jishin” as a seismometer

Items	Values
Sampling frequency	100Hz
Channels	3
Resolution	12bit (1.6gal)
Noise level	10gal(p-p)
Gauging range	±2,000gal
Time Correction	NTP(10msec)
Connection	Wi-Fi / 3G
Triggering	EEW / setting value
Memory	5min × 30 files

3. PERFORMANCE TESTS

・We installed “i-jishin” on the base and observed in parallel with K-NET02, the standard seismometer used for strong motion observation in Japan(Photo.1) , then we have concluded that the consistency would be perfectly for JMA seismic intensities large than 3(Fig.5), and contaminated by noises for less than 2(Fig.6).
・We have made a vibration test on the shaking table and examined in parallel with other standard seismic intensity meter (Photo.2) ,and compared them from a viewpoint of frequency domain(Fig.7).
・We set up 12 machines of iPod-touches on the 3-D Full-Scale Earthquake Testing Facility ,nicknamed “E-Defense” (Photo.3) ,and observed 10 different kind of seismic waves. The response spectrum showed nonlinear characteristics depending on vibration levels and layers in which case they were shook at strong motion such as JMA Kobe.
Recorded data has some differences depending on a location setting. So, when we set ”i-jishin” we must fix on the floor or wall tightly, so that not to conflict with surroundings.

Photo.1 Earthquake observation test

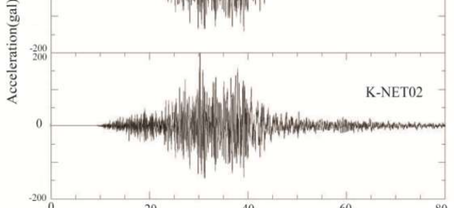

Fig.5 Comparison of the waveform

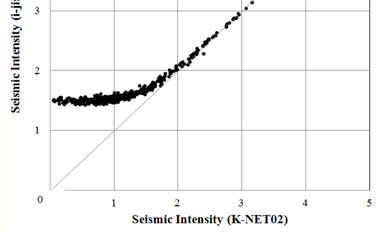

Fig.6 Relationship between the Seismic Intensity recorded at earthquake observation test

Photo.2 Vibration tests

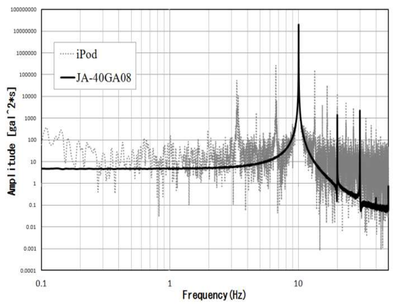

Fig. 7 Comparison of the spectrum recorded at vibration tests

Photo.3 Performance tests on E-Defense

4. ON-SITE EXPERIMENT

・We installed 10 terminals on two different floors in 5 low-rise RC buildings, and started monitoring since January 2012(Photo.4, Table.2). After installation, we were able to get a large number of earthquake records corresponding up to JMA intensity 4(Fig.8). By analyzing these data, one building showed significantly high velocity response values(Fig.9). It was consistent with the fact that this building was significantly damaged in the non-structural component after the Tohoku-Pacific Ocean Earthquake. After that, the microtremor observation using JU-310(Hakusan Corp.) also found the largest amplification compared to others in this building regarding the H / V spectral ratio.
・We installed “i-Jishin” on more than 30 different buildings which have different structure types and network environments around the city of Nagaoka, Niigata Prefecture and Fujisawa, Kanagawa Prefecture since January 2012(Fig.10). In that case, the staff of NPO installed terminals to the houses of volunteer that well understood about the effect of sensing. However, many problems were still found such as, diversities of networking environment, uneasily understandable benefits of installation, requirement to ensure the stability of the measurement, and needs of human resources for maintenance.
To solve these problems, we have to develop a more reliable and accurate systems or easily understandable systems for public. Besides we are going to enhance the cooperation with "i-Bidou" which is the system of the cloud type microtremor observation (Senna et al 2012). We are planning to keep developing of the system to visualize the hazard information of regional soil and building conditions, and keep performing experiments of the sensor network system so that everyone can measure and share information of the buildings.

Photo.4 (1)-(5)Appearance of buildings (6)Installation of “i-jishin” (7) ,(8)Damages of K building after the Tohoku-Pacific Ocean Earthquake

Table.2 Characteristics of the building

Contracted name of the building	Structure	Floors	Building date	Building Standards Act
H	RC	3	1975	old
F	RC	3	1981	old
S	RC	2	1995	new
D	RC	2	1999	new
K	RC	3	2003	new

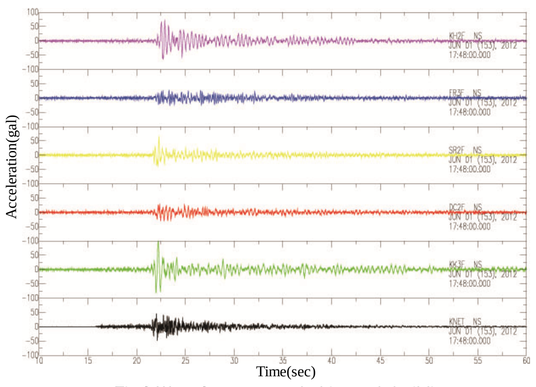

Fig.8 Waveforms recorded in each buildings

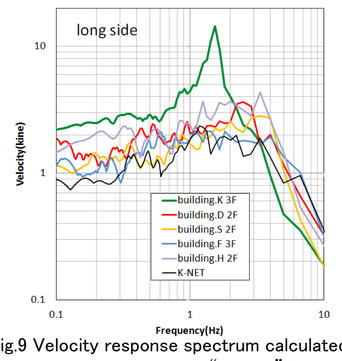

Fig.9 Velocity response spectrum calculated with waveforms recorded by “i-jishin” terminals

Fig.10 On-site experiment in Fujisawa and Nagaoka