ENVRI[plus] DELIVERABLE

D14.4
GUIDELINES FOR DEVELOPING CITIZEN SENSOR OBSERVATORIES AND EDUCATION PLATFORMS

WORK PACKAGE 14 – CITIZEN OBSERVATORIES AND PARTICIPATIVE SCIENCE

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ABSTRACT

With the explosion of the internet, many citizen seismology projects have been carried out in the last 15-20 years. Many of which have been funded by the European Commission which included a '*Science with and for the Society*' theme within the H2020 framework program. In seismology, most of these fall into the subcategory of citizen observer/sensor networks, where citizens either help deploy sensors, and/or gather observation data of catastrophic events such as earthquakes.

During their development, most of these projects easily found their public because people found these initiatives entertaining and pioneering. They were led by enthusiastic and active people (researchers, engineers, teachers, developers …) and the development of efficient and ergonomic tools ensured their success. Moreover, many of these initiatives have benefited from media coverage and received funding to organise workshops dedicated to the public and/or to schools. However, at the end of the day, many of these projects are either stopped or are slowly dying. The two main causes are the lack of continuous and stable funding and the difficulty of retaining the participants in the long term.

Most studies of the guidelines and best practices in citizen science come to the conclusions that, in citizen science, participant retention is a key element. The success of a citizen science project is not a technical issue. Most authors insist that one needs a clear and feasible engagement strategy and must keep in mind that there must be a mutual benefit between citizens and scientists. Volunteers should receive regular feedback from the scientists. They need to be convinced that their participation is useful and to know how their data is used. Participants' motivations and their evolution over time must be understood and taken into account. The lack of motivation will result in a poor participant retention which, in the end compromises the success of the project.

Building on our experience in citizen seismology with QCN[1], Raspberryshake[2] and the LastQuake App[3], presented in this report, we propose additional recommendations on the necessity to identify pre-existing communities in relation to the project's topic. These communities can be well established (e.g. association, schools) or spontaneously formed such as the eyewitnesses of natural disasters. In this latter case, one can harness the teachable moments, that time frame where witnesses are ready to share their experience and are more likely to participate to citizen science projects.

Our experience shows that there are several types of communities that are very different from each other and that must be considered: structured communities (e.g. birding associations), emergent communities (e.g. eyewitnesses of a natural disaster), concerned people (e.g. regarding disease, pollution), amateurs (e.g. Raspberryshake) and students. The targeted community will influence the development, the communication and the whole engagement strategy.

On a technical point of view, most citizen science projects use widespread and advanced technologies such as the Internet and smartphone Apps. Apps will certainly play a growing role in

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[1] Quake Catcher Network ; http://quakecatcher.net/

[2] http://www.raspberryshake.org/

[3] https://www.emsc-csem.org/service/application/

citizen sciences project in the future but the pitfall is that there are so many Apps available that their average lifetime can be very short; the vast majority of the Apps available in the App stores never get any audience.

The chances of success of a citizen science project are also greatly improved when using open source software and databases as well as sustainable archiving systems to ensure data access and management over the long term. The scientific outcome and the societal impact of the project must be assessed and communicated. Then, citizen science facilitators like the ECSA (European Citizen Science Association) can help in enlarging the audience of the project and getting funding.

Finally, citizen science will soon have a tangible impact on decision making. For this, the ECSA (European Citizen Science Association) recommends that common platforms for environmental citizen science data acquisition and harmonisation are a prerequisite, as well as access to an overarching open access data archive for European Science data. Here, projects like ENVRIplus have a real role to play in order to push in this direction and influence policy makers at the EU level.

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TERMINOLOGY

A complete project glossary is provided online here: https://envriplus.manageprojects.com/s/text-documents/LFCMXHHCwS5hh

PROJECT SUMMARY

ENVRIplus is a Horizon 2020 project bringing together Environmental and Earth System Research Infrastructures, projects and networks together with technical specialist partners to create a more coherent, interdisciplinary and interoperable cluster of Environmental Research Infrastructures across Europe. It is driven by three overarching goals: 1) promoting cross-fertilization between infrastructures, 2) implementing innovative concepts and devices across RIs, and 3) facilitating research and innovation in the field of environment for an increasing number of users outside the RIs.

ENVRIplus aligns its activities to a core strategic plan where sharing multi-disciplinary expertise will be most effective. The project aims to improve Earth observation monitoring systems and strategies, including actions to improve harmonization and innovation, and generate common solutions to many shared information technology and data related challenges. It also seeks to harmonize policies for access and provide strategies for knowledge transfer amongst RIs. ENVRIplus develops guidelines to enhance transdisciplinary use of data and data-products supported by applied use-cases involving RIs from different domains. The project coordinates actions to improve communication and cooperation, addressing Environmental RIs at all levels, from management to end-users, implementing RI-staff exchange programs, generating material for RI personnel, and proposing common strategic developments and actions for enhancing services to users and evaluating the socio-economic impacts.

ENVRIplus is expected to facilitate structure creation and improve quality of services offered both within single RIs and at the pan-RI level. It promotes efficient and multi-disciplinary research offering new opportunities to users, new tools to RI managers and new communication strategies for environmental RI communities. The resulting solutions, services and other project outcomes are made available to all environmental RI initiatives, thus contributing to the development of a coherent European RI ecosystem.

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GUIDELINES FOR DEVELOPING CITIZEN SENSOR OBSERVATORIES AND EDUCATION PLATFORMS

Introduction

This report first aims at presenting the recent developments carried out at the EMSC in relation with citizen seismology, their achievements and the planned developments.

In the second section, we made a review of scientific articles dealing with citizen sciences guidelines and best practices. Considering our experience in citizen seismology and the achievements of other citizen seismology projects, we present the most important points to consider maximising the chances of success and the sustainability of a citizen sensors observatory.

Recent results in Citizen Seismology at the EMSC

In this section, we present the recent developments and achievements performed by the EMSC in terms of citizen seismology.

Quake Catcher Network

Since the EMSC launched its call for volunteers in April 2016 (Mazet-Roux et al.; 2016), 43 new sensors have been connected to EMSC's QCN server. At the time of this report, a total of 108 sensors worldwide have been active at least once since April 2016. A QCN sensor is either a small accelerometer connected to a desktop PC via USB or an accelerometer embedded in a laptop.

We notice that most of these sensors are rarely active. Over a one-week period, we see that only 30 sensors are regularly active and many data are missing (see blue intervals on Figure 1). The main cause for missing data comes is that QCN sensors are connected or embedded in personal computers that need to be running. When the computer is not running or offline, the data are not transmitted anymore.

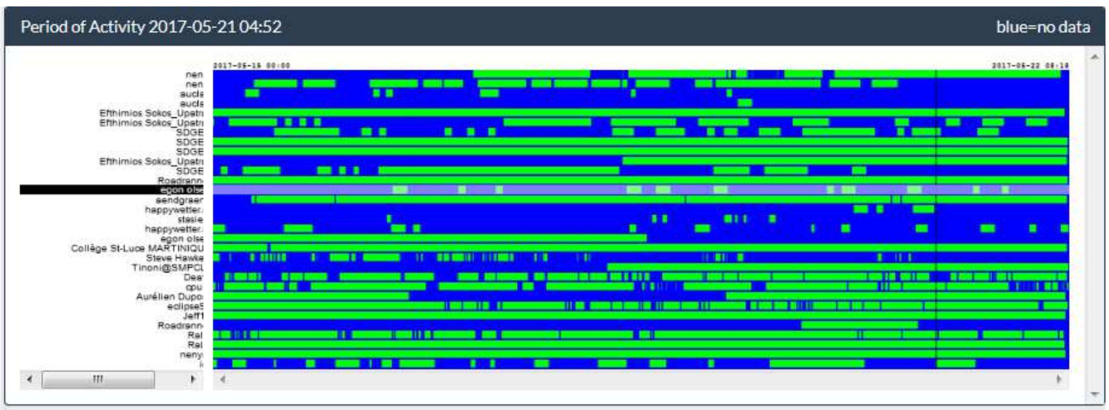


FIGURE 1: DATA AVAILABILITY OF THE 30 QCN SENSORS THAT WERE ACTIVE DURING A ONE WEEK PERIOD (15-21 MAY 2017).

The GUI developed by the EMSC in the framework of ENVRIplus (Mazet-Roux et al.; 2016) in order to visualize and query QCN data has proved to be useful to view active sensors and highlight data losses. However, we think that this platform was probably developed too late to really have an impact on the success of QCN. Indeed, as mentioned in our previous deliverable (Mazet-Roux et al.; 2016), the future of QCN is already compromised due to lack of funding.

However, in the next section, we present a new type of sensor, which could represent the future of citizen seismology sensors.

Raspberryshake

Raspberryshake is sensor-digitizer developed by OSOP[4], which interfaces a commercial 4.5Hz geophone with a Raspberry Pi single board computer. This sensor presents many alleged advantages that we verified. The EMSC bought a Raspberryshake and tested it extensively.

Contrary to the sensors used in the framework of QCN, Raspberryshake sensors:

- Embed a very sensitive sensor and is therefore capable of recording small local earthquakes and also large remote ones
- Do not need to be connected to a desktop computer but only to the Internet (via a modem/router). This way, the sensor can run 24/7.
- Provide seismic data though standard seismic data format.

Deployment status

OSOP sells the complete ready-to-go sensor at a price of 375 $US which makes it mostly dedicated to amateurs and schools. However, in 9 months, almost 300 sensors have joined the community. A build it yourself option for DIY enthusiasts of just the geophone sensor and digitizer can be bought for $140.

Online sensors

Figure 2 shows the sensors that are online at the time of this report. The colour represents the level of noise spanning from dark blue (very low noise level) to red-brown (very high noise level).

This map is only a snapshot and it's important to notice that the level of noise varies a lot depending on the human activity in and near the sensor location. Actually, given our experience with our sensor we assume that most Raspberryshake sensors are installed in the users' home, probably in the living room, close to the Internet box. Indeed, the current version only allows a connexion to the Internet box via an Ethernet cable. Future versions should allow WIFI connections.

As a result, many sensors have a high noise level during the day time and a low noise level during night time.

[4] http://www.osop.com.pa/

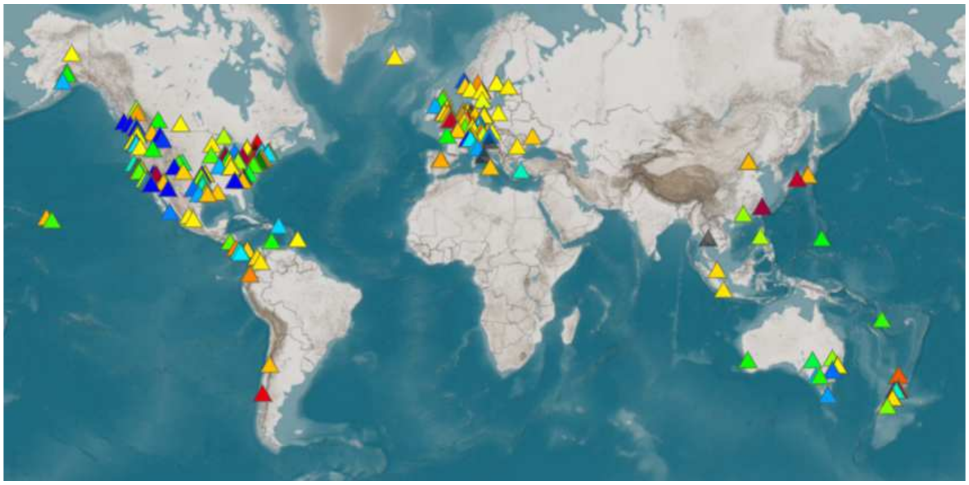


FIGURE 2: ONLINE RASPBERRYSHAKE SENSORS AT THE TIME OF THIS REPORT

Raspberryshake community

Raspberryshake has been funded via a Kickstarter campaign which raised $99,258 from 597 backers (The Magpi; 2017). We know that crowdfunding campaigns are more likely to attract educated people and mostly in developed countries. We observe that more than 90% of Raspberryshake users are either North American, European, Australian or come from New-Zealand (Figure 2). The rest of the world is barely represented.

As the project has been crowdfunded, the participants have been involved in the development from the beginning. A discussion forum[5] is at their disposal to share their results with the community or to ask technical questions to the developers. For example, this forum allowed the users to rapidly warn the developers that the very first version of the Raspberryshake software did not work for several users. A patch was then rapidly released by the developers.

Tests and results

Our Raspberryshake sensor has been online since December 15th, 2016 and is located 15 km south of Paris, France, at the 3rd and last floor of a residential building, in an urban area.

Recording large remote earthquakes

Given the location of the sensor, in the middle of Paris basin, we did not intend to record any local earthquake. But interestingly, in barely one month, we recorded several earthquakes worldwide which is rather surprising for a sensor located in an urban environment. Figure 3 shows the comparison of the seismic signal provided by our Raspberryshake sensor (top) and a professional short-period seismometer (bottom), both located approximately at the same epicentral distance.

5 https://groups.google.com/forum/#!forum/raspberryshake

Although the ratio signal/noise is much weaker for the Raspberryshake, both PKP phases are clearly visible.

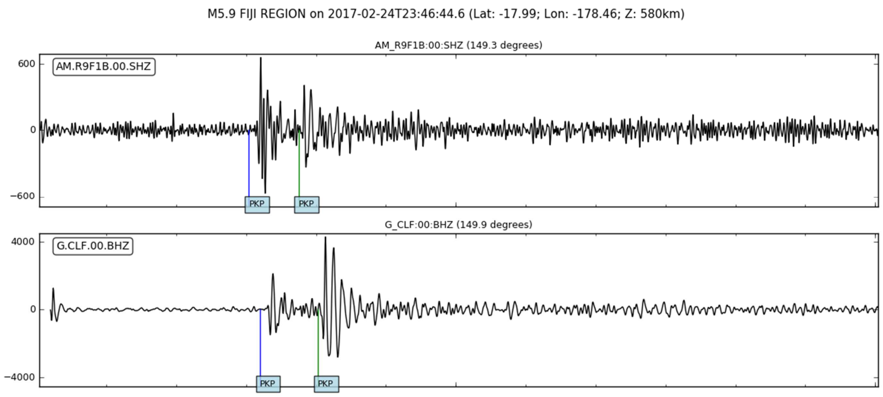


FIGURE 3: MAGNITUDE 5.9 EARTHQUAKE IN FIJI ISLANDS ON 24TH FEBRUARY 2017 RECORDED BY (TOP) THE RASPBERRYSHAKE INSTALLED BY THE EMSC 15 KM SOUTH OF PARIS AND BY (BOTTOM) A PROFESSIONAL SHORT-PERIOD SEISMOMETER INSTALLED IN A QUIET RURAL ENVIRONMENT. BOTH SENSORS ARE APPROXIMATELY AT A DISTANCE OF 16,500 KM FROM THE EPICENTER. PKP FLAGS STAND FOR THEORETICAL ARRIVAL TIMES OF DIFFERENT PKP PHASES. BANDPASS FILTER [0.5-3HZ].

Recording regional earthquakes

As OSOP makes available the real time data of the Raspberryshake online, we plotted the signal provided by eight Raspberryshakes following a magnitude 4.6 earthquake in Switzerland (Figure 4) on March 6th 2017 at 21:12 local time. All sensors show a clear seismic signal and as a seismologist would expect, the amplitude is decreasing with the epicentral distance.

Moreover, the arrival times of the theoretical seismic waves match well with the observed ones. This shows that the time of the sensors is correctly synchronized.

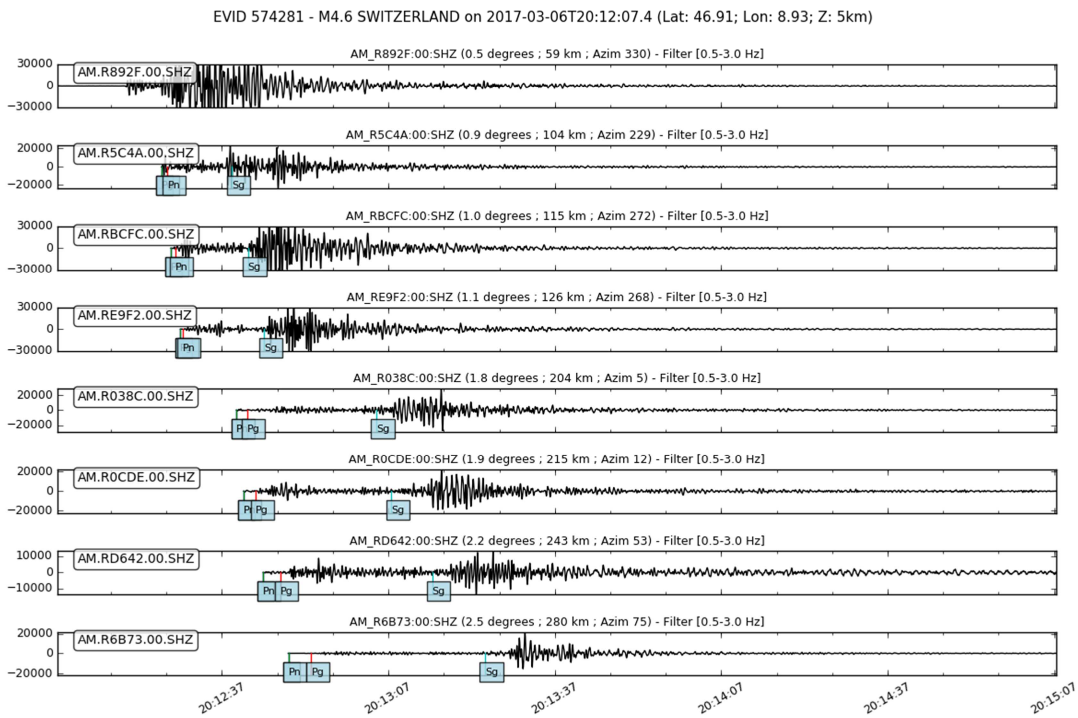


FIGURE 4: MAGNITUDE 4.6 EARTHQUAKE IN SWITZERLAND ON 6TH MARCH 2017 AS RECORDED ONLY BY RASPBERRYSHAKE SENSORS AT EPICENTRAL DISTANCES SPANNING FROM 59 KM TO 280 KM. PG, PN AND SG STAND FOR THEORETICAL ARRIVAL TIMES OF RESPECTIVE PHASES. ON THE VERTICAL AXIS, 1,000 COUNTS CORRESPOND TO A VELOCITY OF APPROXIMATELY 2μM/SECOND. BANDPASS FILTER [0.5-3HZ].

Recording small local earthquakes

Raspberryshake sensors are also efficient in recording local events such as small earthquakes or quarry blasts. Indeed, the embedded geophone gives good performance at high frequencies.

The Swiss Seismological Service[6] reported a magnitude 1.1 earthquake which has been recorded at a distance of 25 km by a Raspberryshake sensor (Figure 5). This result shows the potential of such sensors to record local events such as induced earthquakes or artificial events (quarry blasts, explosions …)

[6] http://www.seismo.ethz.ch/fr/home/

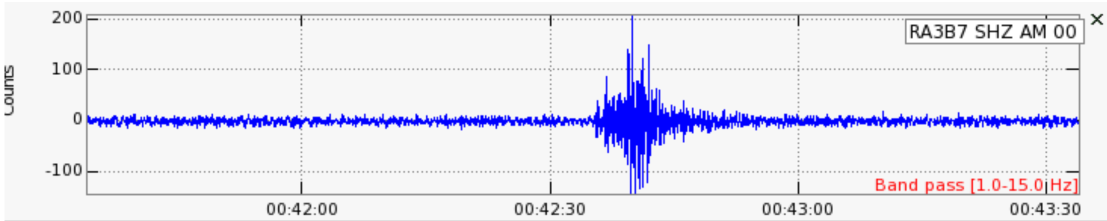


FIGURE 5: MAGNITUDE 1.1 EARTHQUAKE NEAR CHAMPÉRY, SW OF SWITZERLAND, ON 6TH MAY 2017 AS RECORDED ONLY BY RASPBERRYSHAKE SENSORS AT AN EPICENTRAL DISTANCE OF 25 KM. ON THE VERTICAL AXIS, 1,000 COUNTS CORRESPOND TO A VELOCITY OF APPROXIMATELY 2µM/SECOND. BANDPASS FILTER [1.0-15HZ].

Amplitude measurements and magnitude computation

As for the magnitude computed with a Raspberryshake sensor, it turns out to be consistent with the ones computed with professional sensors (Figure 6 and Figure 7). The instrument response provided by the manufacturer is correct.

Finally, Raspberryshake sensors represent a good opportunity for seismic network operators to complement their networks with a limited investment.

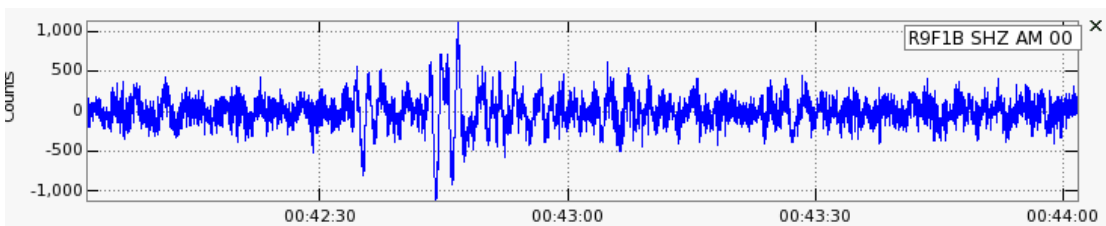
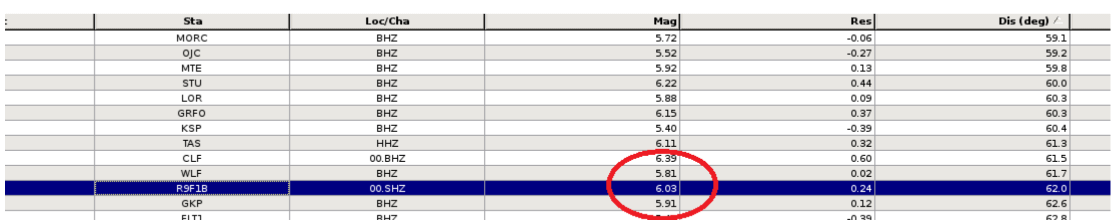


FIGURE 6: SEISMIC SIGNAL RECORDED ON EMSC'S RASPBERRYSHAKE SENSOR FOR A MAGNITUDE 5.6 EARTHQUAKE IN ZAMBIA ON 24/02/2017. EPICENTRAL DISTANCE: 62.0 DEGREES.



Sta	Loc/Cha	Mag	Res	Dis (deg)
MORC	BHZ	5.72	-0.06	59.1
OJC	BHZ	5.52	-0.27	59.2
MTE	BHZ	5.92	0.13	59.8
STU	BHZ	6.22	0.44	60.0
LOR	BHZ	5.88	0.09	60.3
GRFO	BHZ	6.15	0.37	60.3
KSP	BHZ	5.40	-0.39	60.4
TAS	HHZ	6.11	0.32	61.3
CLF	00.BHZ	6.39	0.60	61.5
WLF	BHZ	5.81	0.02	61.7
R9F1B	00.SHZ	6.03	0.24	62.0
GKP	BHZ	5.91	0.12	62.6
FLT1	BHZ	[illegible]	-0.39	62.8

FIGURE 7: TRAVEL TIME RESIDUALS (RES) AND MAGNITUDE (MAG) COMPUTED ON SEVERAL SEISMIC STATIONS USED TO LOCATE AN EARTHQUAKE OF MAGNITUDE 5.6 IN ZAMBIA ON 24/02/2017. DESPITE A LOW SIGNAL/NOISE RATIO (FIGURE 6), THE MAGNITUDE COMPUTED ON THE RASPBERRYSHAKE SENSOR (HIGHLIGHTED IN BLUE) IS CONSISTENT WITH THE ONES COMPUTED ON PROFESSIONAL SENSORS.

Conclusions

Autonomy:

As the sensor is only connected to a low cost and low power single board computer it can easily be run 24/7 without worrying about power consumption, or noise or constant security updates.

Sensitivity:

As alleged by the manufacturer, Raspberryshake sensors are good at recording small local earthquakes, but they also turn out to give good performance when recording regional and large remote earthquakes. According to the manufacturer, the vertical short-period sensor embedded in the Raspberryshake provides a flat response for frequencies between 0.8 and 23 Hz[7]. The main difference with the accelerometers used in the framework of QCN for example, which can only record strong motion, Raspberryshake records velocities and is therefore comparable with classic short-period sensors and can record very weak ground motion.

Use of standard formats and protocols:

The output data provided by the Raspberryshake and the associated response instrument are fully compatible with the standards used in seismology. This makes very easy the use of Raspberryshake data in operational seismology for data processing, earthquake location or data plotting. The EMSC has already integrated the real time data of a set of Raspberryshakes into its earthquake location routine.

User-friendly:

The installation and the configuration of a Raspberryshake are straightforward and don't require any technical skill.

After the installation, Raspberryshake users are invited to use ***Swarm***, a freeware software tool developed by USGS that allows easy access and plotting of the data of a given sensor but also of all the other sensors deployed around the world. *Swarm* also allows easy plot spectra and spectrograms (time vs. frequency).

Through the discussion forum, Raspberryshake users share their experience not only regarding earthquake recording but also when they observe a non-seismological signals on their sensor. For instance, the sensor is particularly efficient at recording rinse and spin cycles of a washing machine. ***Swarm*** allows plotting the spectrogram and illustrates this phenomenon (Figure 8).

The forum and the funny or unusual experiences that the users may have with their sensors play a great role in user retention. The users understand they belong to a community which can answer their questions and bring them new knowledge. Recent developments have included the support for

[7] http://manual.raspberryshake.org/_downloads/SpecificationsforRaspberryShakeV4.pdf

users of ***jAmaseis***[8] software (free datalogging and analysis software developed by IRIS in the USA for use by schools) and ***SEISGRAM2K***[9] (free data analysis software).

<u>Sustainability</u>:

Another advantage is that the update of Raspberryshake firmware can be performed remotely by the manufacturer, without the user's intervention.

However, the main drawback could be the weakness of the SD card that hosts the OS and the data. SD cards are cheap Flash memories which have limited write cycles which may be a problem when deploying a large number of sensors. In case of failure of the SD card, it is possible to burn a new one following the notice available through Raspberryshake online documentation[10].

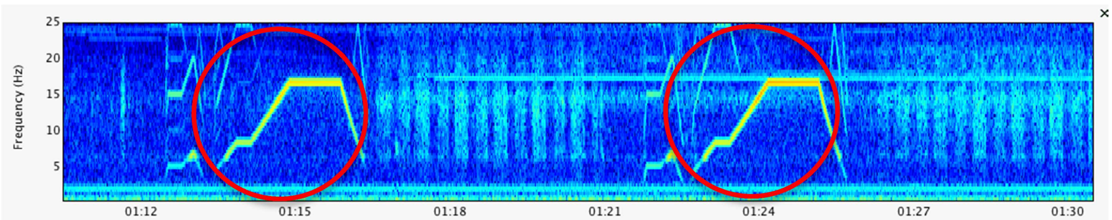


FIGURE 8: SPECTROGRAM SHOWING RINSE AND FINAL SPIN CYCLES OF A WASHING MACHINE AS RECORDED BY A RASPBERRYSHAKE SENSOR.

Finally, as mentioned in Deliverable D14.3 (Mazet-Roux et al; 2015), there is still a concern about long term data availability that still needs to be clarified with the manufacturer. Currently, OSOP ensures that all data that the owner agrees to open will be made available without constraint on one of its servers. We have no insurance at the moment that such a service will be offered for free on an open ended basis and we do not know what would happen in case of bankruptcy or other unpredicted developments.

Earthquake competition game

In Deliverable D14.3, we presented the citizen seismology project carried out by the Taiwan Earthquake Research Center (TEC), of the Academia Sinica in Taiwan, who developed a near-real time earthquake games competition dedicated to schools (Liang et al.; 2016).

In the framework of the collaboration between EMSC and Taiwan TEC, it was decided to develop a new platform, inspired from this earthquake game, but dedicated to the general public and to an international audience. The idea was to make the platform as simple as possible and to improve it step by step.

[8] http://www.iris.edu/hq/jamaseis/

[9] http://alomax.free.fr/seisgram/SeisGram2K.html

[10] http://manual.raspberryshake.org/

In March 2017, Taiwan TEC released a beta version of the platform which proposed a selection of large recent earthquakes and the associated worldwide seismic stations that recorded these earthquakes.

With this platform, the user could:

- Select a station and view the associated signal (Figure 9)
- Pick a P and an S seismic phase
- Repeat this process on few other stations (3 at least)

Then by applying a very simple earthquake location method, the user can get an approximate epicenter location. The epicenter actually lies in the area where arcs meet each other on the map (Figure 10). To refine the location, the user can pick phases on other stations. If the picks are correct, this will reduce the size of the area where the epicenter lies.

At the end of the process, the platform tells the user how far from the actual epicenter the guessed epicenter is. The user has the opportunity either to refine his picks or to pick other stations.

The development of the platform is still on its way and Taiwan TEC is not able to give a deadline as they are not funded for this development.

Along with the platform, TEC plans to provide a series of short videos in order to explain what the platform is for and what we expect from the users. The first public release of the platform will be proposed to a list of identified users. The quality and quantity of the feedback we will get from them will influence the next developments.

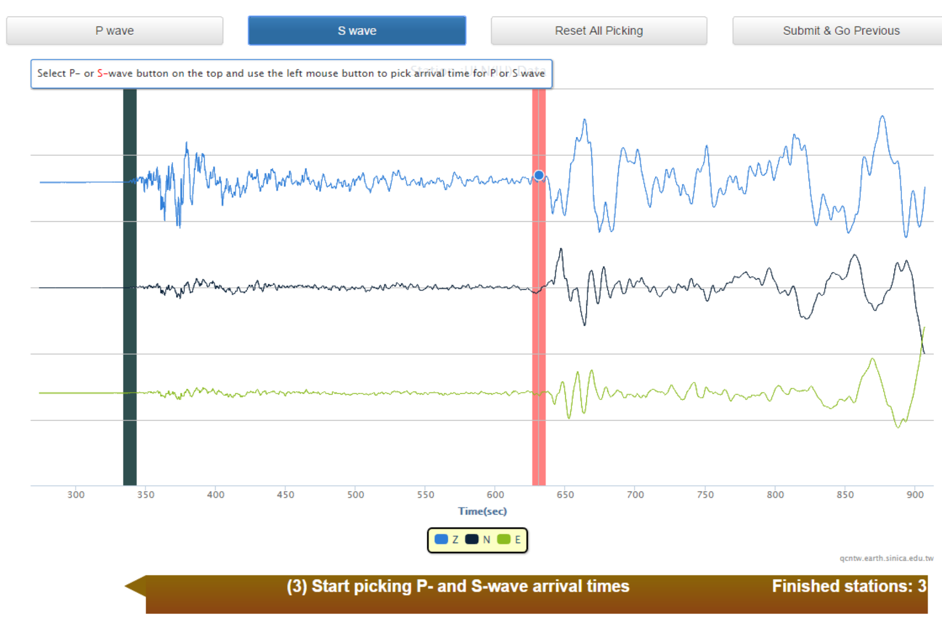


FIGURE 9: SEISMIC SIGNAL OF THE SELECTED STATION AND INVITATION TO PICK A P AND S PHASES.

FIGURE 10: ARCS DERIVED AFTER PICKING P AND S PHASES ON 3 STATIONS. IF PICKED CORRECTLY, THE EPICENTER LIES IN THE AREA WHERE THE 3 ARCS MEET.

LastQuake App

Since the release of our LastQuake App in July 2014, we observe a constant improvement of the rapidity in collecting testimonies following felt earthquakes via the application. As a result, in 2016, **50% of the thumbnail-based testimonies have been collected within 10 minutes of earthquake occurrence** (Figure 11). And more than 1,000 testimonies were collected within 10 minutes of the M5.6 earthquake that struck Romania on 27/12/2016 (Figure 12 and Figure 13).

This clearly shows the need from the public for very rapid information after felt earthquakes. It forces us to improve our robustness and rapidity to be able to always provide quick and reliable data in these very first minutes after the earthquake occurrences.

In terms of citizen seismology, the added-value of earthquake eyewitnesses is clearly the fact that they allow us to quickly and reliably assess the effects of an earthquake. What the eyewitnesses can bring to the scientific community is extremely valuable as there are the first and most concerned people. Their observations (e.g. transient phenomenon) and feelings are useful to characterize the effects of a natural disaster, in a way no scientific observation or sensor could do.

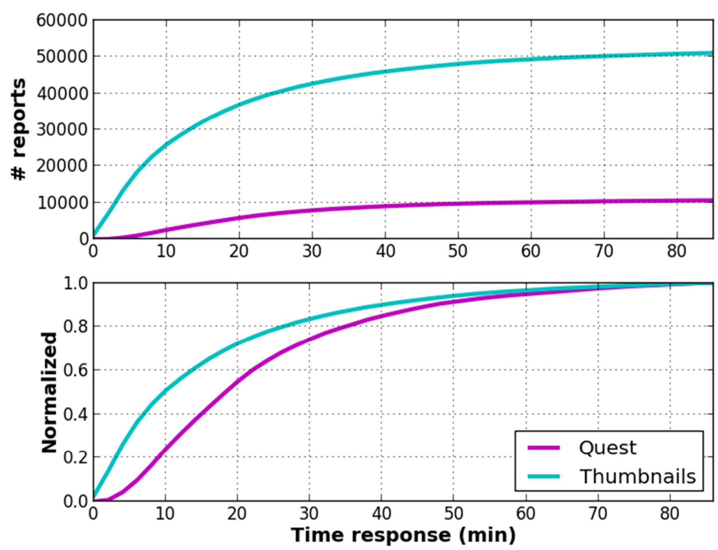


FIGURE 11: NUMBER (TOP) AND PERCENTAGE (MIDDLE) OF TESTIMONIES COLLECTED IN 2016 BY THE EMSC, WITH RESPECT TO TIME ELAPSED SINCE EARTHQUAKE OCCURRENCE, BY THUMBNAILS-BASED AND ONLINE QUESTIONNAIRES.

FIGURE 12: MAP OF TESTIMONIES FOR A MAGNITUDE 5.6 EARTHQUAKE IN ROMANIA ON 27/12/2016 AT 23:20 UTC.

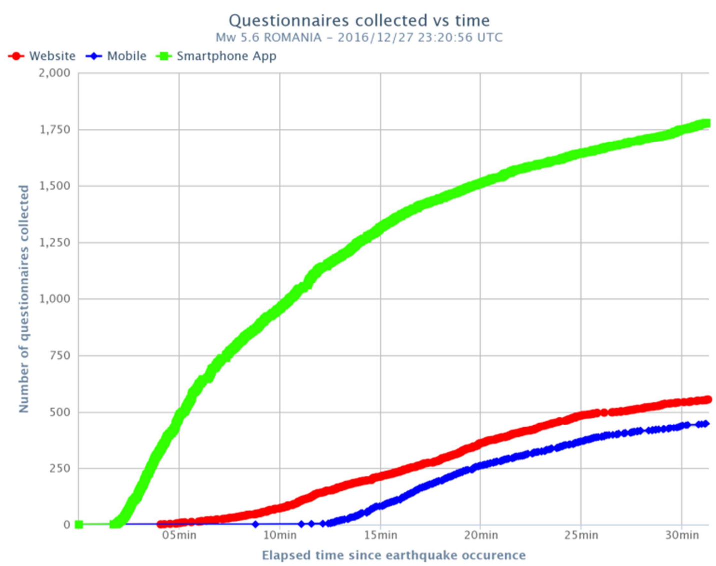


FIGURE 13: NUMBER OF TESTIMONIES COLLECTED BY THE EMSC AS A FUNCTION OF TIME ELAPSED SINCE EARTHQUAKE OCCURRENCE FOR MAGNITUDE 5.6 EARTHQUAKE IN ROMANIA ON 27/12/2016 AT 23:20 UTC. MORE THAN 1,000 TESTIMONIES WERE COLLECTED IN 10 MINUTES, MOSTLY VIA LASTQUAKE APP (GREEN CURVE).

Guidelines for the development of a Citizen Sensor Observatory

In this section, we use our experience in citizen seismology along with the achievements of other citizen science projects and in the literature to present guidelines for the development of citizen sensor networks.

There are several reports and scientific papers available in the literature dealing with guidelines and best practices in citizen sciences. The references we found the most relevant are presented in Appendix page 33.

We summarize what we think to be the most important points to consider and present below a cookbook for people interested in developing a citizen sensor observatory, though most of these recommendations are applicable to any kind of citizen science project.

Projects objectives and the target users

In order to maximize the chances of success, a project must have clear and feasible objectives. Most studies of citizen science guidelines and best practices strongly suggest to identify what the scientists and what the participants will benefit from the project. Therefore, it is important to target the right people, to identify the communities that might already exist and to understand the users' motivations. All these recommendations aim at maximizing participant retention over time.

1. Define the objectives of the project

The objectives of a citizen science project must be considered for both parties: the scientists and the volunteers. In their *Guide to citizen science,* Tweddle et al. (2012), propose a list of simple questions to be answered before starting the project. For example:

- What will participants have to do?
- What scientific output do we expect?
- How long will the project last?
- What will success look like?
- What funding and resources are required to develop and maintain the project?

2. A mutual benefit

It's crucial that a citizen science project benefit to both parties. The White Paper on Citizen Science for Europe (Serrano Sanz et al.; 2014) makes the two following statements:

- Researchers ask themselves: "What do I gain by working with volunteers?"
- Volunteers ask themselves "What do I gain by working with scientists?"

These questions look trivial but thy must be kept in mind during the definition and development of the project.

On the scientists' side, the project needs to aim at a clear and reachable scientific outcome. On the volunteers' side, they must obtain something: knowledge, confidence, satisfaction …

3. Understand the users' motivations

We still understand fairly little about who is participating in citizen science efforts, why they are participating, and how others might be drawn into the efforts in a fair and equitable manner (Jason et al.; 2013).

Relatively little research has been published about what influences people to start participating or what encourages them to continue their involvement. However, West et al. (2016) propose an interesting list of motivations to participate a citizen science project:

- understanding (they want to learn)
- values (they want to help)
- social (they want to meet new people and join a community)
- enhancement (they want to improve themselves through volunteering)
- protective (they want to address a personal problem)
- career (they want to benefit their professional life)

To better understand users' motivations, citizen project managers can carry out surveys before and during the project. Understanding the change in users' motivations helps in retaining participants over time.

4. Target an existing community or build one

The topic of the project and what task is expected from the participants will define which people are targeted: Do we need a large community that could increase the amount of data collected, which could not be collected through a classical scientific approach? Or do we need a small but skilled community?

The targeted community will influence the development of the project as well as the engagement strategy.

We distinguish five types of communities:

Structured community: A community who already exists, who can easily be contacted (e.g. an association). It is necessary to contact them in order to benefit from their experience and their network of volunteers.

Emergent community: A community which appears spontaneously after an external event (e.g. a natural disaster) or following a media coverage. It can appear within seconds for fast onset event (e.g. earthquakes) or days or weeks in case of mediatic events (e.g. help search for MH370 flight through satellite images[11]).

In the case of an earthquake, the participants did not have the intention to become volunteers in the first place but are ready to share their testimonies during a limited period of time (i.e. teachable moments) that may be difficult to harness. Here, the tasks the participants will have to perform must be quick and easy and should not require a specific skill.

Concerned people: People feeling concerned for personal reasons. They have personal motivations. At the beginning, the community is poorly structured. If the community doesn't exist yet, it is necessary to identify relevant forums, social media, authoritative websites that deal with the same topic (e.g. people concerned about diseases or about pollution).

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[11] http://www.tomnod.com/campaign/malaysiaairsar2014/map/15fx0y0

Amateurs: Amateurs represent people who are interested in sciences and can remain active in the long term. They are ready to spend time and money on a specific subject. They are passionate and likely to test new tools, participate in projects and become users of dedicated tools or games. But their community is not necessarily structured. Potential amateurs are isolated from each other. The challenge is to find ways to reach them.

Students: The last type of community encompasses high schools or students in Earth/Ocean sciences. Here the success relies on enthusiastic and skilled teachers and students that dedicate part of their time on the topic. Their contribution to the scientific community is less crucial than the one provided by the witnesses but can be very valuable for seismic prevention and awareness purposes.

5. Retaining participants

Retaining participant consists in several things:

- Understanding the change in users' motivations and in taking them into account by adapting the project's objectives and the participants' mission.
- Providing feedback and answering questions.
- Thanking the participant and maybe considering a way to reward the most active ones.
- Showing to the participants what is the scientific added-value of their contributions.

Participant retention is an issue in citizen science projects that is always difficult to tackle. West et al. (2016) bring together key theories from the volunteering literature with examples from the environmental volunteering and citizen science studies to describe the factors that influence people to start and continue participating in citizen science projects (Figure 14).

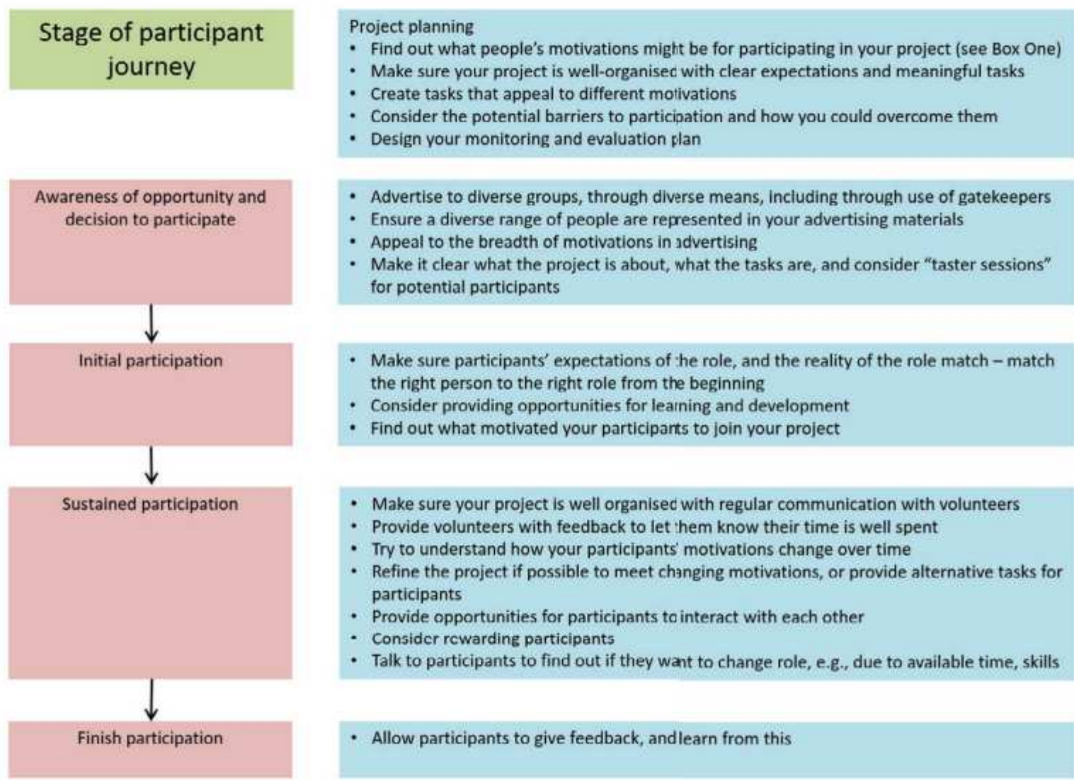

FIGURE 14: THE JOURNEY THAT A PARTICIPANT TAKES WHEN PARTICIPATING IN A PROJECT (LEFT SIDE), WITH A CHECKLIST FOR PROJECT (FROM WEST ET AL; 2016)

Technology and data policy

The technology chosen for the development phase will strongly influence the success. but also its sustainability.

1. **Which technology to choose?**

Most of the citizen science projects have something in common as they use widespread and advanced technologies such as the Internet and smartphone Apps.

In their report on *Understanding Citizen Science and Environmental Monitoring,* Roy et al. (2012) made a thorough review of more than 250 citizen science projects in the UK in relation with biodiversity but their conclusions are relevant for any kind citizen science.

Roy et al. (2012) reviewed all the technologies that play a role in citizen science and the questions that arise by considering the following:

- Front-end for data collection and visualisation (website, apps, …)
- Back-end (database, data flow, data archive)
- Crowdsourcing tools (crowd tasking, game playing, …)
- Future risks of using a given technology (excluding people, financial risks, …)

Their conclusions and recommendations are worth considering before starting any development. More specifically, they identify several risks of using technology in citizen science:

- Excluding people: Not everyone is technology savvy.
- Financial cost: Technological innovations and their maintenance have a financial cost.
- Variation in mobile connectivity: Gap between well-connected urban centres and isolated rural areas might increase as mobile connectivity improves.
- Volunteer confusion and fatigue: Too many citizen science projects might dissuade potential volunteers to participate.
- Increased centralisation: The rapid growth of citizen science attracts more and more companies from the private sector. This can be a threat on the public involvement in the governance of citizen science projects.

2. **Data policy and ethics**

There are several aspects about data policy and ethics that can look tedious and require a lot of effort to implement, but they should not be ignored by citizen science project managers.

- Data quality

Becker-Klein et al. (2016) underline the necessity for citizen science projects to determine their participants' capacity to learn and successfully perform scientific observations, collect and analyze data, and share findings. Such a skill is essential not only to ensure high quality data that can be used in scientific research but also to improve participant's motivation and retention.

- Standard data and protocols

All authors strongly recommend the use of standard data and protocol as much as possible in order to increase the chance of sharing the data and the scientific output with other partners or with other citizen science projects. Standardization also helps in monitoring and evaluation processes that are necessary to give more credibility to the project and convince policy makers.

- Open source, open data, data archiving

Likewise, the use open source software (i.e. Leaflet) and open database (i.e. Openstreetmaps) will ensure the data access and management over the long term and avoid licence issue. The data will remain available in the long term by using performant and redundant archiving systems.

- Privacy and ethics

Finally, it is crucial to take into consideration legal and ethical issues like copyright, intellectual property, privacy and environment impact. This is the 10th point of the *Ten Principles of Citizen Science* elaborated by the ESCA (ESCA; 2015) and ignoring them might have legal consequences.

Evaluation and communication

There is no standardized measurements indicator that can be applied for citizen science projects. However, it is necessary to provide means to validate the scientific output, to assess the data quality and to evaluate the participants' experience.

On the one hand, scientists and policy makers need clear and credible material to assess the quality of the results. On the other hand, media and press need catchy phrases and short videos. But it is also necessary that the results are communicated to the participants so that they feel involved in the project from the beginning until the first scientific outcomes.

Connect with Citizen Science facilitators

Three professional associations supporting citizen science have emerged recently: the Citizen Science Association (CSA; www.citizenscience.org), the European Citizen Science Association (ECSA; www.ecsa.citizen-science.net), and the Australian Citizen Science Association (ACSA; www.citizenscience.org.au/). All three work in collaboration with each other in order to set up a clear framework for citizen science and to facilitate the development of citizen science projects by networking them and defining best practices. The ESCA recently endorsed the White Paper on Citizen Science for Europe (Serrano Sanz et al.; 2014) and set up a list of recommendations (ECSA Policy Paper #2; 2016).

Being in contact with those organisations will foster the development of the project, enhance its visibility and help to get funding.

More about guidelines and best practices

Within ENVRIplus WP14, the deliverable D14.3 made a review of existing citizen science tools (Best et al; 2016) and provided an important list of references in citizen science.

We complete this list with other references that specifically provide interesting and abundant guidelines and best practices for the development of citizen science projects:

Understanding Citizen Science and Environmental Monitoring. Final Report on behalf of UK Environmental Observation Framework. (Roy et al; 2012) http://www.ukeof.org.uk/documents/CitizenScienceReport.pdf
Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK (Tweddle et al.; 2012) http://www.ukeof.org.uk/documents/guide-to-citizen-science/at_download/file
A collection of Citizen Science guidelines and publications. European Citizen Science Association. https://ecsa.citizen-science.net/blog/collection-citizen-science-guidelines-and-publications
McKinley Duncan C. et al. *Investing in Citizen Science Can Improve Natural Resource Management and Environmental Protection*. 2015. Issues in Ecology. ESA. Report N°19. https://www.esa.org/esa/wp-content/uploads/2015/09/Issue19.pdf

Conclusions and perspectives

The EMSC has several years of experience in citizen seismology through projects like QCN, Raspberryshake and LastQuake.

Whereas the future of QCN is compromised due to lack of funding, Raspberryshake proposes a very good alternative for citizen seismology sensors networks, as it presents a lot of advantages compared to QCN: standard data format, very sensitive sensor, almost plug-and-play device and it just needs an Internet box. We tested these sensors and the results were beyond our expectations. Today many of these sensors around the world are used by the EMSC in its earthquake location routine. However, the price of Raspberryshake sensors might limit the growth of its deployment and restrict them to a community of amateurs. It would be good to have other manufacturer proposing this type of sensors to avoid a monopoly issue, not compatible with the spirit of Citizen Science.

The success of the LastQuake App shows the need of the public for very rapid information after felt earthquakes. In terms of citizen seismology, the witnesses' contribution is extremely valuable to the scientific community. Their observations and feelings are useful to characterize the effects of the shaking in a way no scientific observation or sensor could do.

There are several studies in the scientific literature which propose guidelines and best practices in citizen sciences. We derived the main conclusions to present a cookbook for the development of citizen sensors observatory.

Most studies conclude that, in citizen science, participant retention is a key element. The success of a citizen science project is not a technical issue but rather a matter of defining a clear and feasible engagement strategy. The authors provide many clues to improve participant retention and to make the project more sustainable.

We propose additional recommendations like the necessity to identify pre-existing communities in relation to the project's topic. We describe several types of communities which influence the development and the engagement strategy of the project.

IMPACT ON PROJECT

This report provides guidelines for scientists interested in starting a citizen science project, which are derived from EMSC's experience and several studies of guidelines and best practices in citizen seismology.

IMPACT ON STAKEHOLDERS

Citizen science will at some point have a tangible impact on decision making. For this, the ECSA (European Citizen Science Association) recommends that common platforms for environmental citizen science data acquisition and harmonisation are a prerequisite as well as the access to an overarching open access data archive for European Science data.

In this context, a project like ENVRIplus has a real role to play to push in this direction and influence policy makers at the EU level.

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APPENDIX

Comparisons of the strategies of several citizen seismology projects

In this appendix we compare several citizen seismology projects in terms of objectives, audience, communities, engagement strategies, scientific benefit and risks.

Quake Catcher Network

The Quake Catcher Network was born at Stanford University and aimed to use computer-based accelerometers to detect earthquakes. QCN uses the BOINC[12] volunteer computing platform.

Apart from the original QCN network, several other QCN networks are in operation in Taiwan, Mexico and at the EMSC.

QCN California and world wide	http://quakecatcher.net/
QCN Mexico	http://www.ras.unam.mx
QCN Taiwan	http://qcn.twgrid.org/
QCN Euro-Med (EMSC)	http://qcn.emsc-csem.org http://vigogne.emsc-csem.org/qcn/

- Objectives: Build a seismic sensor. Increase amount of data
- Target audience: Amateurs + people concerned by seismic risk.
- Community: Poorly structured.
- Engagement strategy: None
- Scientific benefit: Access to additional accelerometric data mostly in urban environment.
- Risks: Uses accelerometers, so some sensors will never record any earthquake. Need a PC running 24/7. Now outdated.
- Future potential: Low. Not sure it has a future in its current form.

Raspberryshake

Crowdfunded project which interfaces a commercial 4.5Hz geophone with a Raspberry Pi card.

Home page	http://www.raspberryshake.org/
User's manual	http://manual.raspberryshake.org/
Real time online sensors	http://raspberryshake.net/
Discussion forum	https://groups.google.com/forum/#!forum/raspberryshake

- Objectives: Build a seismic sensor. Increase amount of data

[12] https://boinc.berkeley.edu/

- Target audience: The price of the sensor (375 $US for the complete ready-to-go sensor) restricts the community to amateurs.
- Community: Currently in building phase though the discussion forum. Users are invited to participate to this forum, share their questions and problems.
- Engagement strategy: Through the discussion forum. There are funny things that can be observed with these sensors (Figure 8). Raspberryshake users might be interested in other citizen seismology projects.
- Scientific benefit: Real benefits for the seismological community because these sensors have the same performance as professional ones and can easily be integrated in classic seismological networks.
- Risks: Price of the sensor. Not affordable to the general public.
- Future potential: Complement classic seismological network. Opportunity to build an active community like for the weather.

Earthquake competition game

Near-real time earthquake games competition dedicated to schools, developed by Taiwan TEC.

Presentation	http://katepil6.wixsite.com/earthquake-school/slideshow

- Objectives: Awareness, prevention, education.
- Target audience: Teachers, schools.
- Community: Already exists. Easy to reach.
- Engagement strategy: Ensured by teachers.
- Scientific benefit: Can provide an educated public, some of whom may become seismologists.
- Risks: Will the public find earthquake location funny enough?
- Future potential: Low potential in its current form but it could be interesting to link it with the Raspberryshake community. These Amateurs are likely to be interested in this platform.

LastQuake

Smartphone App dedicated to earthquakes eyewitnesses, developed by the EMSC.

Presentation	https://www.emsc.eu/service/application/
For Android	https://play.google.com/store/apps/details?id=org.emsc_csem.lastquake
For iOS	https://itunes.apple.com/us/app/lastquake/id890799748

- Objectives: Increasing the amount of data. Providing real time services.
- Target audience: Earthquake eyewitnesses. General public.
- Community: Emergent. The community emerges when the earthquake strikes.
- Engagement strategy: Answers the need of rapid information. It's a real time service.
- Scientific benefit: Real benefit for the seismological community witnesses provide rapid and valuable information that couldn't be obtained through a classic scientific approach.
- Risks: Technical maintenance requires resource and money.

- Future potential: Early detection of felt earthquakes. Rapid characterization of earthquakes effects. Participate to earthquake awareness and prevention via notification for nearby users and safety check feature.

Seismology at school

Over the last 20 years, several projects which aimed at bringing seismology at school took place in several countries in Europe: Italy, Switzerland, France, UK … Several EU projects (EduSeis, NERA) funded their development. In the US, the school network is supported by the IRIS which federates other school networks in Europe (e.g. in UK and in Ireland) and make the data available on their website.

France	*Sismos à l'Ecole* : http://www.edusismo.org/
Switzerland	http://stations.seddbd.ethz.ch/fr/networks/s/
UK	http://www.bgs.ac.uk/schoolseismology/schoolSeismology.cfc?method=viewLatestQuake
USA	http://geoserver.iris.edu/stations

- Objectives: Awareness, prevention, education.
- Target audience: Teachers and students.
- Community: Small and already structured.
- Engagement strategy: The success of these initiatives is largely due to the dynamism and the cohesions of its teams.
- Scientific benefit: Weak.
- Risks: The sustainability depends on the teachers' enthusiasm and the scientific and technical support of the local seismological community.
- Future potential: Contributes to earthquake awareness and prevention.

Earthquake Network

Earthquake Network is a research project which aims at developing and maintaining a crowdsourced smartphone-based earthquake warning system at a global level. Smartphones made available by the population are used to detect the earthquake waves using the on-board accelerometers. When an earthquake is detected, an earthquake warning is issued in order to alert the population not yet reached by the damaging waves of the earthquake (source: Wikipedia).

Presentation	http://wp.earthquakenetwork.it/
Android App	https://play.google.com/store/apps/details?id=com.finazzi.distquake&hl=en

- Objectives: Build a seismic sensor. Provide a real time service.
- Target audience: People concerned by earthquake risk.
- Community: Not structured.
- Engagement strategy: Not clear.

- Scientific benefit: Weak
- Risks: Like for QCN, participants might lose interest over time due to lack of feedback and the too rare earthquakes recordings.
- Future potential: Not clear at this stage. It could contribute to early warnings in high seismic hazard regions (e.g. California).

MyShake

MyShake is an Android app that has the ability to recognize earthquake shaking using the sensors in every smartphone.

Presentation	http://myshake.berkeley.edu/
Android App	https://play.google.com/store/apps/details?id=edu.berkeley.bsl.myshake

- Objectives: Build a seismic sensor. Provide a real time service.
- Target audience: Witnesses. People concerned by earthquake risk.
- Community: Not structured.
- Engagement strategy: Large media coverage at the start of the project.
- Scientific benefit: Weak.
- Risks: Like for QCN, participants might lose interest over time due to lack of feedback and the too rare earthquakes recordings.
- Future potential: Not clear at this stage. It could contribute to early warnings in high seismic hazard regions (e.g. California).