A MOBILE APPLICATION FOR COLLECTING EARTHQUAKE DATA: CITIZEN SEISMOLOGY

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Abstract

Citizen science is a collaborative research approach involving researchers and citizens in scientific projects, encompassing various activities from data collection to analysis and interpretation of results. Citizen seismology, a branch of citizen science in seismology, engages citizens in scientific projects alongside seismologists. During earthquakes, affected individuals serve as the primary source of information regarding the felt shaking and observed damages. The data provided by citizens holds dual significance: it aids in sociological and risk management analyses, elucidating "how the population reacted to the event," and contributes to seismological analyses by documenting visible earthquake effects. Thus, citizen seismology fosters collaboration between seismologists and non-scientists, facilitated by advancements in connection technologies such as the internet, social media, and mobile applications. Here, we introduce a mobile application developed in collaboration with ARK IT for collecting earthquake data, focusing on citizens' perceptions of seismic events. We also discuss potential avenues for future research and development in this field.

Key words: *Citizen seismology, earthquake data collection, mobile application, collaborative research, sociological analysis*

Përmbledhje:

Shkenca e bazuar në përfshirjen e publikut, përfshin bashkëpunimin midis studiuesve dhe qytetarëve në projekte shkencore, duke përfshirë mbledhjen dhe analizën e të dhënave. Sizmologjia publike angazhon qytetarët në projekte së bashku me sizmologët për të mbledhur informacion gjatë tërmeteve. Kjo ndihmon si në analizat sociologjike, duke treguar reagimin e popullatës, ashtu edhe në analizat sizmologjike. Prezantojmë një aplikacion mobil për

mbledhjen e të dhënave të tërmetit të zhvilluar me ARK IT dhe diskutojmë mundësitë për kërkime të ardhshme në këtë fushë.

Fjalë kyçe: *Sizmologjia e bazuar në përfshirjen e publikut, mbledhja e të dhënave të tërmetit, aplikacion, kërkim bashkëpunues, analizë sociologjike,*

Introduction

Albania is located in the Alpine-Mediterranean seismic belt, where the seismic risk is significant concerning socio-economic impacts. Historically, strong earthquakes have frequently affected the country. From 1900 to 1988, Albania experienced 19 strong earthquakes with magnitudes ≥ 5.5, ten of which had magnitudes ≥ 6.0, causing loss of lives and substantial economic and social disasters. On average, Albania could be hit annually by an earthquake with a magnitude of 4.5, every four years by one with a magnitude of 5.0, and every 30 years by one with a magnitude of 6.0. Strong earthquakes (M > 6.0) repeat approximately every 90 years, often resulting in disastrous impacts.

Communities and individuals are the first to experience seismic shocks and play a crucial role in reporting the effects of seismic events. The dissemination of information from the seismologic network to affected people and communities is vital for minimizing damage and risk. As "witnesses" of seismic events, communities provide critical information regarding the effects and perceptions of the shock, as well as their spatial variations. This information, converted from qualitative to quantitative through a well-defined procedure, leads to precise estimations of earthquake intensity on any of the macroseismic scales in use. These scales correlate well with instrumental parameters like magnitude, maximum ground acceleration (PGA), maximum ground displacement (PGD), and maximum ground velocity (PGV). Collecting, evaluating, and processing this information as a new practice helps minimize the impact of earthquakes and estimate seismic hazard and risk. Including citizens in earthquake study processes is known also as "*Urban Seismology*", achieved through modern applications, enhancing data amount and quality, resulting in a more comprehensive, uniform, and statistically representative database.

As an successful example the LastQuake app, developed by the European-Mediterranean Seismological Center (EMSC), serves as a critical tool in crowdsourcing earthquake data. It gathers felt reports, geo-located pictures, and videos from eyewitnesses, which are then integrated with other data sources to create rapid impact scenarios.

During the November 26, 2019, M6.4 earthquake in Albania, the app played a vital role in collecting real-time data. Users of the LastQuake app submitted 28,220 intensity felt reports between November 25th, 2019, and January 11th, 2020 (Bossu et al., 2020). Its accuracy to describe the effects of Durres earthquake on November 26, 2019, is also described in Contreras et al. (2020).

The LastQuake system leverages visual communication to overcome language barriers, using cartoons to represent different shaking and damage levels, corresponding to intensity levels of the European Macroseismic Scale (Bossu et al., 2020). This approach has been validated against other macroseismic systems like the USGS's DYFI, ensuring reliable data collection from diverse populations. The app's ability to rapidly crowdsource and process felt reports enhances situational awareness and provides crucial information to civil protection agencies, helping mitigate the impact of earthquakes (Bossu et al., 2020).

Building on the success of LastQuake and with the consent to utilize its reliable visual cartoon reporting method, the development of a localized application such as AlbQuake aims to address specific seismic challenges in Albania. The data collected through the LastQuake app during the 2019 Albania earthquake underscored the importance of timely and accurate citizen reports in understanding and responding to seismic events (Bossu et al., 2020). The AlbQuake app aims to leverage similar technologies and methodologies, tailored to the Albanian context, to enhance earthquake monitoring and response.

Albania's seismic activity and the socio-economic impacts of past earthquakes highlight the necessity for a robust system that can rapidly collect and analyze felt reports from the local population. By utilizing a dedicated app, AlbQuake, citizens can provide real-time data on earthquake impacts, which can then be used to improve ShakeMap accuracy and support emergency response efforts.

The integration of AlbQuake into Albania's seismic risk management framework would ensure that local data is promptly available for analysis, leading to more effective risk mitigation strategies.

Moreover, the collaboration between research and academic institutions such as the Institute of Geosciences (IGEO) under the Polytechnic University of Tirana (PUT) and the Department of Physics of the Faculty of the Natural Sciences, University of Tirana, with private IT enterprises such as ARK IT, fosters innovative research while maintaining timelines and achievements

optimal to the social and policy needs to ensure a resilient civil protection environment in Albania. This is also a novel approach and the first one evidenced so far in Albania.

Citizen seismology represents a transformative approach to earthquake monitoring and response. By combining the efforts of traditional seismic networks with public participation and advanced technologies like AI and social media, it offers a comprehensive and resilient framework for dealing with seismic events. This integrated approach enhances rapid detection and response and empowers communities to better understand and manage earthquake risks.

The DYFI portal and similar systems allow for a participatory experience, where users are empowered to become data providers by contributing valuable observations. Such systems provide important human perspectives on earthquakes, documenting how people behave, respond, and perceive risk, which is crucial for improving public safety and preparedness.

Furthermore, these systems offer emotional support to citizens who have just experienced a frightening or traumatic event. By allowing them to share their experiences and contribute to a general understanding of the phenomenon, these platforms provide a form of catharsis and validation. The educational aspect of these systems also helps the public understand seismological concepts better, fostering a more informed and resilient society (Quitoriano and Wald, 2020).

The development and implementation of the AlbQuake app represent a significant step forward in enhancing earthquake monitoring and response in Albania. By building on the successes and methodologies of the LastQuake app, AlbQuake aims to provide real-time, accurate data on earthquake impacts, directly from the affected population. This approach not only improves the accuracy of seismic hazard assessments but also empowers local communities to actively participate in earthquake response efforts. The collaboration between academic institutions and private enterprises ensures that the app remains at the forefront of innovative research, meeting the social and policy needs of Albania's civil protection framework.

Literature (Reference) review

Citizen involvement in earthquake data collection has been highlighted by Bossu and Earle (2011) and Bossu et al. (2011) as integral to enhancing situational awareness and rapid response. They emphasize the utilization of

internet platforms for real-time information gathering, emphasizing its effectiveness in augmenting traditional seismic monitoring systems. Similarly, Guy et al. (2010) underscore the importance of integrating citizen-reported data with seismically derived information through social network technologies, emphasizing the value of crowdsourced data in enhancing earthquake response strategies.

The power of citizen seismology in both scientific and social realms has been explored by Chen, Bossu, and Liang (2020). Their study underscores the profound impact of citizen engagement on seismic science and its broader societal implications. Furthermore, the study by Quitoriano and Wald (2020) reflects on two decades of citizen science-based macroseismology, highlighting the evolution and lessons learned from initiatives like the USGS "Did You Feel It?" project.

Beyond data collection, citizen engagement extends to post-disaster recovery efforts and sentiment analysis. Contreras Mojica et al. (2020) examine post-disaster recovery in various earthquake-stricken regions, utilizing sentiment analysis to gauge community resilience and response effectiveness. Moreover, Contreras Mojica et al. (2021) delve into intensity-based sentiment analysis following the 2020 Aegean earthquake, shedding light on the nuanced interplay between seismic events and community sentiment.

In addition to seismic events, the broader context of disaster communication and crisis management is explored. Palen and Liu (2007) anticipate a future of ICT-supported citizen participation in crisis communication, emphasizing the role of information and communication technologies (ICTs) in facilitating citizen-driven responses to crises. Furthermore, Zook et al. (2010) present a case study of volunteered geographic information and crowdsourcing disaster relief efforts in the aftermath of the Haitian earthquake, highlighting the potential of citizen-driven initiatives in disaster response.

The racialized dynamics of cyberscapes post-disaster are examined by Crutcher and Zook (2009), shedding light on the role of digital platforms in shaping post-disaster narratives and perceptions. Their study underscores the need for critical examination of digital representations of disasters to address underlying socio-political dynamics.

Methodology

The core philosophy behind citizen seismology is "democratizing" science by involving non-experts in data collection and analysis. This approach not only

increases data volume but also enhances public understanding and engagement with seismic risks. Methodologically, it relies on several key components:

- *Crowdsourcing*: Gathering data from a large number of participants to increase the reliability and granularity of information (Zook et al., 2010).
- *Real-time Data Collection*: Using mobile apps and internet platforms to collect and share seismic data instantly.
- *Qualitative and Quantitative Data*: Combining qualitative reports from citizens with quantitative data from sensors.

The primary goal of our methodology is to inform the public and institutions in real-time about seismic activity and strong seismic events in Albania. Additionally, it aims to upgrade the monitoring, operational, and research activities of seismology, directly assisting communities and civil emergency structures for more efficient cooperation during seismic crises.

Based on the latest achievements in Europe and beyond, such as the "Citizen Seismology" projects of EMSC, ETHZ, INGV, and the Earthquake Hazards Program of USGS, we have developed the **AlbQuake** application in collaboration with ARK IT. This application is inspired by the "Did You Feel It?" (DYFI) program by USGS and incorporates the European experience from similar initiatives by EMSC, ETHZ, and INGV, which exemplify citizen seismology in action.

DYFI collects and maps reports from people who experience earthquakes, translating subjective experiences into objective intensity measurements (Wald et al., 2011). This data helps detect minor earthquakes that traditional sensors might miss and provides immediate information, offering valuable situational awareness for emergency responders and the public. DYFI tool contribute to rapid earthquake detection and response by supplementing seismic networks, enabling fast alerts, and improving risk management. Detailed intensity maps from DYFI can guide resource allocation and emergency planning.

AlbQuake is available for Android and iOS, focused on collecting earthquake data from citizen's perceptions of seismic events. The application's development and functionality emphasize user engagement and data processing. The IGEO Department of Seismology employs an extensive network of seismologic stations connected to a central database. For data acquisition, processing, distribution, and interactive analysis, IGEO uses SEISMO and SEISCOMP software. In collaboration with ARK IT, IGEO has

developed a bidirectional communication interface between the institution and citizens, providing services such as informing citizens and institutions about seismologic events and enabling citizens to report damages and experiences during significant seismic events (Figure 1).

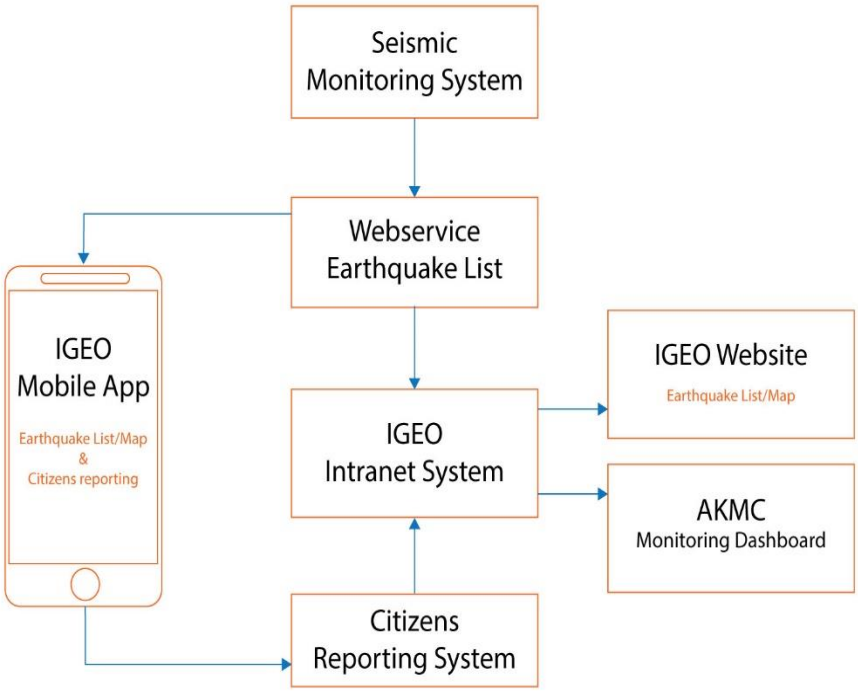


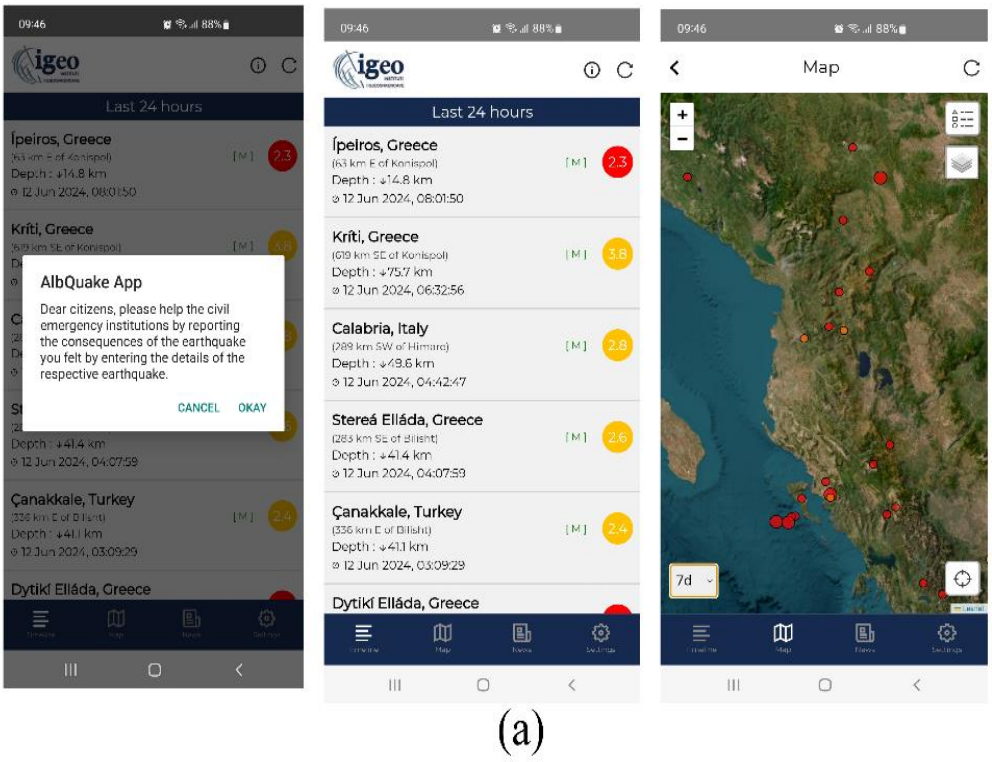
Figure 1. The architecture schema of the bidirectional communication interface application's development and functionality.

To ensure the security of the central database and seismological systems, a dedicated web service has been built to communicate with these systems and retrieve data for the last seven days of seismic events. This data is then transmitted to the IGEO Mobile App and an intranet system designed for IGEO institutions, where it is also made available on the IGEO website. During significant seismic events, high resource usage due to simultaneous access by many citizens can lead to performance issues.

To prevent resource exhaustion and ensure service continuity, web service data is cached using AWS Cloud. This implementation leverages serverless

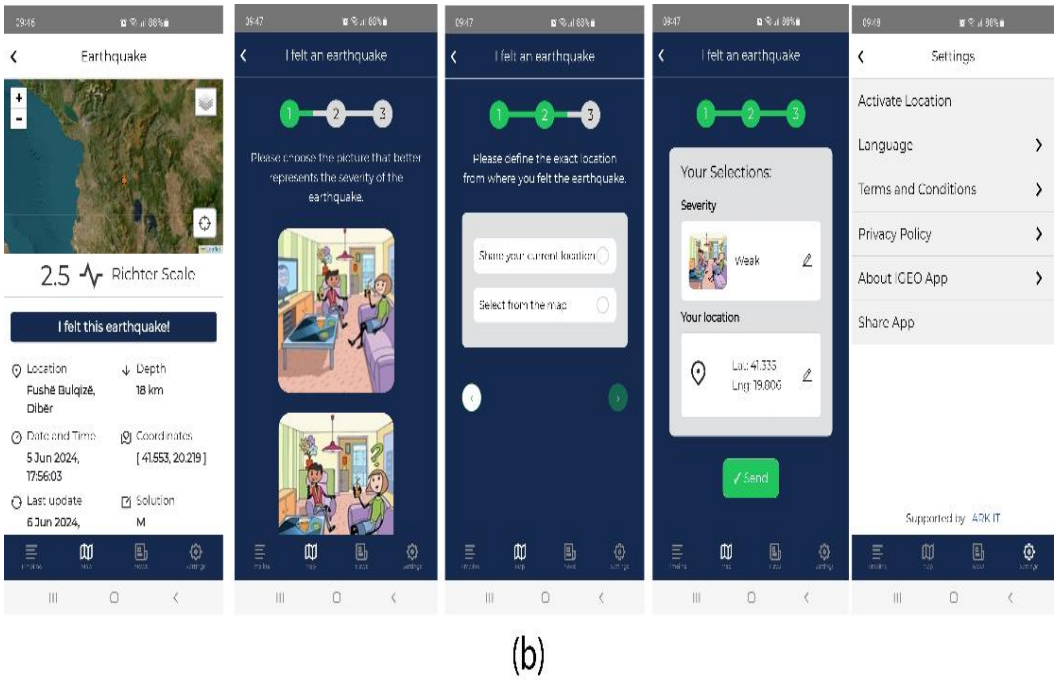
technology and elastic scaling to meet varying resource demands, ensuring uninterrupted service.

The mobile application provides several features: it displays earthquake data on a dynamic map (Figure 2, a), and allows citizens to report their experiences of an earthquake in a measurable manner (Figure 2, b).



(a)

Figure 2-a. *AlbQuake* earthquake dynamic map.



(b)

Figure 2-b. *AlbQuake* citizens experience report system (DYFI).

Citizen reports are collected in a dedicated database and processed through the "*Citizens Reporting System*". This processed data is then fed back into the SHAKEMAP (ver. 4.0) system, and are further made available to national emergency institutions to aid in their response efforts. SHAKEMAP visualizes ground shaking following an earthquake, providing crucial information for emergency response and risk assessment. DYFI data is integrated into this service, enhancing its accuracy and detail by filling data gaps, especially in areas with sparse sensor coverage, and refining intensity estimates with combined data from sensors and DYFI reports.

Artificial Intelligence (AI) and social media play pivotal roles in modern citizen seismology. AI algorithms analyze large volumes of social media data, detecting patterns indicative of earthquakes. The rapid spread of earthquake information, serves then as both a source of real-time data and a medium for disseminating alerts (Crutcher and Zook, 2009)

All data collection from citizens complies with the "Protection Of Personal Data Law," and necessary measures are implemented to ensure that data is used and processed solely for the declared purposes, maintaining citizens' privacy and data security.

Results and discussion

The deployment of the LastQuake app long before the November 26, 2019, M6.4 earthquake in Albania set a strong foundation for its dramatic increase in usage during this significant seismic event. The app's robust framework allowed for rapid scaling and efficient data collection during the earthquake, demonstrating the effectiveness of citizen seismology in enhancing situational awareness and emergency response. Users of the LastQuake app submitted 28,220 intensity felt reports between November 25th, 2019, and January 11th, 2020, providing a comprehensive dataset for rapid impact assessment (Bossu et al., 2020). Specifically, a subset of 1,678 reports written in Albanian on the day of the earthquake highlighted the app's capability to collect localized data in real-time (Contreras et al., 2020).

The analysis of the felt reports revealed the geographic distribution of earthquake impacts, showcasing variations in perceived intensity across different regions. This data was crucial for validating the European Macroseismic Scale (EMS) intensity levels and comparing them with instrumental measurements. The integration of visual communication tools, such as cartoons representing different shaking levels, effectively overcame language barriers and ensured accurate data collection from diverse populations (Bossu et al., 2020).

The collected reports were processed using AI and machine learning algorithms to classify and validate the data. The accuracy of these models was tested against manually verified reports, showing high reliability in automatically categorizing intensity levels. This approach not only expedited data processing but also reduced the workload on seismologists, allowing for faster dissemination of critical information to the public and emergency services.

Building on the success of LastQuake, the AlbQuake app was developed to address the specific seismic challenges in Albania. The local adaptation of the app incorporated similar technologies and methodologies, tailored to the linguistic and cultural context of the region. This localized approach ensured higher user engagement and more accurate data collection.

The integration of AlbQuake into Albania's seismic risk management framework provided several benefits. Firstly, it facilitated the rapid collection and analysis of felt reports from the local population, enhancing the accuracy of ShakeMaps and supporting emergency response efforts. Secondly, it empowered local communities by involving them in the data collection process, thereby increasing public awareness and preparedness for seismic events.

The collaboration between the Institute of Geosciences (IGEO), the Polytechnic University of Tirana (PUT), the University of Tirana, and private IT enterprises such as ARK IT, was instrumental in the development and implementation of AlbQuake. This partnership ensured that the app remained at the forefront of innovative research while meeting the social and policy needs of Albania's civil protection framework. The bidirectional communication interface developed by ARK IT enabled real-time data exchange between citizens and seismological institutions, enhancing the overall efficiency of the seismic monitoring and response system.

Conclusions

The implementation of citizen seismology through mobile apps like LastQuake and AlbQuake represents a significant advancement in earthquake monitoring and response. These apps leverage crowdsourced data to provide real-time insights into the impacts of seismic events, thereby improving situational awareness and supporting emergency response efforts.

The success of LastQuake during the 2019 Albania earthquake highlighted the potential of such technologies in rapidly collecting and analyzing felt reports. The development of AlbQuake further exemplifies how localized applications can address specific regional challenges, ensuring more accurate and timely data collection.

The integration of AlbQuake into Albania's seismic risk management framework is a vital step towards enhancing the country's resilience to earthquakes. By involving local communities in the data collection process, the app not only improves the accuracy of seismic hazard assessments but also fosters a more informed and prepared public.

Overall, the collaboration between academic institutions and private enterprises, supported by innovative technologies and methodologies, underscores the importance of citizen seismology in mitigating the impacts of earthquakes and enhancing public safety.

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Notes on Contributors

Prof. Asoc. Dr. Edmond Dushi: Senior seismologist researcher. Contributed to the seismological aspects and text formatting.

Prof. Margarita Ifti: Physicist. Contributed to the statistical context.

Ing. Gentian Ruci: Project Manager overseeing conceptualization, business analysis, Agile Scrum processes, and final deployment for mobile app development.

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