Smart Citizen Science in pluvial flood disaster risk reduction: Building a mobile application as one tool for drain path identification (Work in progress)

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Abstract: Over the last years, flood risk has increased, and the threat of flooding has caused severe damages for economy, society and infrastructure. Hence, the project Urban Flood Resilience- Smart Tools (FloReST) was initiated by six partners from the field of civil engineering, informatics and hydrology to research on tools for high-resolution drain path identification and risk mapping. In this context, a mobile application shall be developed for crowdsourced data collection in civil society. Still being in the early stages of development, a first requirement catalogue for the application is presented and discussed, showing that especially data control is a problematic issue in Citizen Science.

Keywords: Citizen Science, mobile application development, crowdsourced data collection, flood risk management, pluvial flooding, surface runoff, drain path

Addresses Sustainable Development Goal 11: Sustainable cities and communities

1. Introduction

The threat of flooding has increased during the last years and poses not only economic damages but also social and infrastructural ones. Therefore, various projects are being carried out that aim to address the topic of flooding from different perspectives. Whereas in the past, research was mostly focused on *fluvial* flooding, there is still a lack of research carried out on *pluvial* flooding. Fluvial flooding describes floods that result from raising water levels, pluvial flooding is caused by heavy rainfalls. Especially the latter often leads to so-called flash floods, floods that emerge from heavy rainfalls in a short time. In July 2021, large areas of North Rhine Westphalia and Rhineland Palatinate in the western part of Germany have been hit by such flash floods, leading to enormous damages and loss of lives.

Since various research focuses on the observation of water levels, little one is carried out on drain paths. The latter describes water runoffs[2], mostly flash floods, that run naturally and above ground. However, due to increasing urbanization, the natural streams are blocked and thus turn into cellars, houses, etc. which causes severe damages. This problem

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[2] In this research proposal the terms water runoff and drain path are similarly used.

is tackled by the project *Urban Flood Resilience – Smart Tools (FloReST)*, funded by the German Federal Ministry of Education and Research. A group of six partners from the fields of civil engineering, IT and hydrology is working together to develop tools for high-resolution drain path identification and risk mapping in five different pilot communes in Rhineland Palatinate, Western Germany. One of these tools is planned to be a mobile application that allows citizens of the different pilot communes to actively engage in data collection. Their local expertise and knowledge about past flood events and potential places at risk during floods shall help to develop a high-resolution mapping for local drain paths.

This approach of including citizens into the research process is known as *Citizen Science* and mostly common in environmental monitoring, as bird observation. Wisner, O'keefe and Westgate [WOW1977] already mentioned the early concept of people`s science, in which communities are encouraged to contribute to the observation and documentation of a certain phenomenon of scientific interest. In brief, Citizen Science describes the involvement of non-scientists into a scientific process, in which the level of involvement can vary from data collection to a full involvement into the design process [Se19][Bo09]. In literature, there is also the expression *crowdsourcing*, which is often used in such context, meaning "the outsourcing of tasks to a crowd that would otherwise be too large to accomplish by a single organization" [Se19,2].

The following research statement is developed by the Institute for Software Systems of Umwelt-Campus Birkenfeld, part of University of Applied Science Trier, in the context of the FloReST project, mainly addressing the issue of building a mobile application for the usage of collecting crowdsourced data for drain path mapping. As the project is still in its early stage, the application has not yet been developed. Rather, the team of scientists has started with scanning different mobile applications in the field of early warning and flood detection as well as diving deeper into the topic of Citizen Science and related application development. Based upon the collected information together with survey and interview data from the pilot communes, a requirement analysis for the mobile application shall be carried out in the future process.

As this research proposal is a work-in-progress-statement, the authors aim at providing information about the status quo on the project work as well as receiving qualified input that can be included in the current research. Thus, the research question of this paper is the following: *Which preliminary features should be included in the FloReST Citizen Science mobile application?*

In the following, the case study will be outlined (section2), literature about Citizen Science and surface runoff will be reviewed (section 3), as well as an overview of several pre-selected apps will be presented (section 4.1). Further, application requirements will be analysed, and a first requirement catalogue will be drafted (section 4.2). Finally, limitations and an outlook of will be presented (section 5).

2. Case Study

Five pilot communes in Rhineland Palatinate were selected as target areas based upon historic flood experiences: Mendig, Altenahr, Trier, Linz (Rhine), Herrstein-Rhaunen. Within these areas, the app shall be tested and further developed. The citizens are requested to take part as data-collectors about local drain paths. The underlaying idea is to have a mobile application that allows the citizens to mark spots at risk, as potential drainage blockage in rainy situations, etc. within an interactive map, similarly to a risk detector. Pictures and a categorization of the risk shall be asked in addition. The data will be stored in a data warehouse developed by one of the project partners (Disy).

By sending such information citizens support the data collection of drain path identification within the target areas and add important information to the final risk mapping. An interactive map shall facilitate the positioning of the data collector as well as the handling for potential users. Due to the expected high average age in some of the target areas, the app-usage shall be easy, intuitive and without any greater obstacles. An easy-to-understand layout and contextual description are therefore of great importance.

3. Literature Review

3.1 State of the art: surface runoff

Literature about surface runoff in general is rooted in the field of environmental engineering, as the research of green roof performance in water runoff management [BBJ09][Be10][BNR09][MCR13] or research about harvesting rainwater [St20]. Moreover, research was undertaken in the field of hydrology/ hydromechanics, mostly measuring the quality of water runoff dependent on different surface types [Bu11][CCO21][GDC07][PLC00]. However, neither a human-geographical perspective of water runoff pathways is existing nor participatory approaches for drain path identification.

3.2 (Smart) Citizen Science

In literature, Citizen Science faces great popularity due to its awareness creating approach as well as its impact on the improvement of science-society dialog [Go21][Ke21][Vi21][Wo21]. As Benjamin Franklin stated, "*Tell Me and I Forget; Teach Me and I May Remember; Involve Me and I Learn*" [Fr22], people's involvement in research creates awareness leading to effective public learning and thus ends up in a call for action and resilience building [Be19][We16]. Further, citizens receive the chance to be actively engaged with research, as they might be involved in the design, elaboration and implementation of the latter. In such scenario, citizens act as "collaborators" within the research process. Haklay [Ha13] distinguishes between "collaborators" and "sensors"

(p.116). In contrast to the former, the latter describes a rather passive research behavior of the local community. By using a crowd-sourcing approach, for example, citizens act as "sensors" as they take a contributory role. Citizen Science is a broad terminology; therefore, it is important to define the approach in an early stage related to the research context. In the context of the FloReST project, citizens shall assist in data collection about drain paths in the local communities. Thus, citizens will act as "sensors".

Especially digitalization has become an engine for Citizen Science as it has improved the process of collecting and accessing citizen-generated data [Ka20][Wo21]. Because of increasing internet access, mobile applications as means for data collection have gained popularity. Examples are Open Street Map[3], ornitho[4] or Scent[5]. Especially in the field of environmental monitoring, Citizen Science is a well-known and popular approach, even before digital transformation and thus mainly experiences a revival as smart Citizen Science [DBZ10].

However, scholars argue that the most critical aspect in Citizen Science is the insurance of data quality [Co08][DBZ10][Di12][Ge21][Ko16]. It is debated in how far a non-scientific data base can be compared to the standards of a scientific one [RP13]. Scholars question if Citizen Science can be considered as a reliable approach to science, arguing that lay scientists are lacking training and knowledge in scientific data management or research methodology and thus might not understand how to properly collect and record data [Co08][DBZ10][Di12]. Crall, Newman and Stohlgren [CNS11] found out, that Citizen Scientists showed a lower ability in correctly identifying invasive plant species compared to professional scientists. Due to an increasing facilitated access to Citizen Science data collection tools, as web and mobile applications, it can be assumed that the risk of unreliable data entries is raising.

Nonetheless, according to Geyer [Ge21], Citizen Science does not aim at competing with science, it rather aims at extending scientific data bases. Citizen Science can be seen as a tool to collect data in research projects, in which a scientific data base might not be representative or hardly to exercise. Kosmala et al. [Ko16] argue that data sets produced by Citizen Scientists show relatively high-quality data compared to scientific research as well as similar biases to professional data collection.

The quality of the data can be validated through different control mechanisms, as community control, through Artificial Intelligence as well as manually. To sum up, although the issue of data validation, Citizen Science faces great interest as it can be considered as a cheap mean to gather on-the-ground-data and to include local knowledge and expertise [Ha15][NLR22].

3.3 Smart Citizen Science for urban flood risk management

[3] https://www.openstreetmap.de/
[4] https://www.ornitho.de/
[5] https://scent-project.eu/about-scent

Citizen Science is considered promising within the field of flood risk assessment [Go21][Ke21][Sc21][Vi21]. Due to the active inclusion of local knowledge and expertise, Citizen Science has shifted the approach in flood risk reduction from a top-down to bottom-up [Pa18]. According to See [Se19], smart Citizen Science has the potential to contribute to the development of early warning systems. In this context, social media plays an increasing role in flood risk assessment. Arthur et al. [Ar18] analyzed Twitter as source for real-time flood mapping. Twitter is perceived by various scholars as instrument to detect, cluster, categorize and map flood events based on the crowd-sourced information [AS17][FS18][Li18][PN16].

Most of the mobile applications found for Citizen Science in flood risk management are such reporting on fluvial flooding. Examples are the application *CrowdWater*[6] by the University of Zurich or a do-it-yourself water level measurement tool developed by the Umwelt-Campus Birkenfeld [Um22]. Citizens are encouraged to involve in water level management by building their own measurement tool using the instructions online.

Although Citizen Science is considered promising within flood risk management it is still limited to simple applications, as the validation of prediction models or emergency assessments [Sc21][Wo21]. Thus, more opportunities for Citizen Science in flood risk management need to be developed. Until today, numerous applications and platforms have been developed for citizens to report in fluvial flood events [Se19]. Research was thus undertaken in the fields of water level measurement ([Fa18][We19]) or water quality monitoring ([Fa17][He21][Le17][Th17]). Considering pluvial flood events, research is mostly limited to Citizen Science in rainfall monitoring ([ACC15][Sh20][We19]). According to See [Se19], little research has been carried out for Citizen Science activities in pluvial flooding. No research was found for Citizen Science in the field of drain path identification.

4. Methodology and results

The following section will provide an overview of the methodological approach used in the current research. In a first step, existing flood warning and Citizen Science mobile applications in flood risk management were identified and analyzed based upon their goals and features [Ap22]. The latter were retrieved from the development intention described in section 2. Drawn from this evaluation, it was assessed in how far the applications fit to the described research aim of mobile application development in the context of the FloReST project. In a second step, Lemmens et al.'s [Le21] criteria for mobile application development in Citizen Science projects were reflected and applied to the current research case.

[6] Described in section 4.1 State of the art: mobile applications

4.1 State of the art: mobile applications

Twelve applications treating flooding or rainfall warning were identified[7] and characterized, from which three were selected for a closer examination, as they appeared the most suitable for our research case. As described in section 1 and 2, the FloReST mobile application aims at crowdsourced data collection by the citizens of the pilot communes, similarly to a risk detector. Tab. 1 provides an overview of the twelve mobile applications identified. The applications nbs. 3, 5 and 6 appeared to be of great interest for the current research, as they are dealing with data crowdsourcing. Hence, they were given a deeper investigation. No mobile application could be identified that deals with drain paths.

Nb.	Name of application	Editor	Goal
1	Alertswiss[8]	Federal Office for Civil Protection Switzerland	Warning
2	BIWAPP[9]	Marktplatz GmbH	Warning
3	Crowdwater[10]	SPOTTERON/University of Zurich	Water level measurement
4	Disaster Alert[11]	Pacific Disaster Centre	Warning
5	Floodcheck[12]	Credia Communications GmbH	Pre-Warning
6	FloodCitiSense[13]	JPI Urban Europe	Pre-Warning
7	MeinPegel[14]	Hochwasserzentralen	Water level measurement
8	MeteoSwiss[15]	Federal Office for Meteorology and climatology	WeatherService
9	NINA[16]	Federal Office for Civil Protection and Disaster Assistance Germany	Warning
10	PegelAlarm[17]	SOBOS	Water level measurement
11	RiverApp[18]	Florian Bessière	Water level measurement
12	WarnWetter[19]	German Weather Service	Weather Service

Tab. 1: Overview mobile applications

[7] The applications were identified based on geographical requirements (only Europe) and based on accessibility.
[8] https://www.alert.swiss/de/app.html
[9] https://www.biwapp.de/
[10] https://crowdwater.ch/de/start-2/
[11] https://disasteralert.pdc.org/disasteralert/
[12] https://www.eglv.de/
[13] http://www.floodcitisense.eu/
[14] https://www.hochwasserzentralen.info/meinepegel/
[15] https://www.meteoswiss.admin.ch/home/services-and-publications/beratung-und-service/meteoswiss-app.html
[16] https://www.bbk.bund.de/DE/Warnung-Vorsorge/Warn-App-NINA/warn-app-nina_node.html
[17] https://pegelalarm.com/
[18] https://www.riverapp.net/de
[19] https://www.dwd.de/DE/leistungen/warnwetterapp/warnwetterapp.html

CrowdWater (3)

Crowdwater works twofold to gather data about fluvial flooding: observing water levels and indicating rainfall intensity. Concerning the first, users are requested to take photos of different water areas (e.g. a river) and demonstrate the water level by adding a measurement scale into the photo. Repeating this process at different points in time, the differences in water levels can be examined. For transparency and visuality, the different spots are marked within a map. As far as the rainfall intensity is concerned the application provides icons showing different rainfall scenarios. By clicking the accurate scenario, citizens provide data about rainfall intensity at a specific location. For data quality control, a gamification approach is used. Every month, users can compete in a community championship with the aim to control and correct as many data entries as possible. Points are distributed for each comment and/or correction and the three first placed are rewarded. Though, it is not clear how Crowdwater verifies the corrected data within the championship. Crowdwater is functioning in the city of Zurich solely.

FloodCitiSense (5)

The mobile application FloodCitiSense aims at using Citizen Science to develop an exact and well-functioning early warning system for pluvial flooding. Citizens are able to provide information about the rainfall intensity via a mobile application. In addition, low-cost rainfall sensors were distributed to citizens to report on rain gauges and complement the official rainfall data collected by the authorities. Nonetheless, the application is only running in three pilot cities in Europe: Rotterdam, Brussels and Birmingham. Data control mechanisms were hardly to examine.

Floodcheck (6)

Floodcheck rather serves as flood risk management tool for house-owners than a Citizen Science application. With the help of Floodcheck, house-owners are able to identify the flood risk for their properties as well as receive information about property securing. The mobile application is a project of the German regional cooperation *Emscher Genossenschaft und Lippe Verband* and thus solely available for house-owners within the regional environs.

4.2 Reflecting on Citizen Science mobile application criteria and first draft requirement catalogue

Within this step, the information gathered in section 4.1 as well as the mobile application's intention described in section 2 were taken up and applied to Lemmens et al.'s [Le21] criteria for Citizen Science mobile application development. In the following, a brainstorm of application features is presented as a first draft requirement catalogue, which the authors perceive as appropriate for a Citizen Science mobile application within the context of FloReST. Lemmens et al. [Le21] proposes in their work seven criteria: Look and Feel, Re-use, Co-creation, User Interface Design, Participant Motivation, Supporting

Infrastructure, Testing and Maintenance. At the current research stage, three of these criteria (Participant Motivation, Re-use, supporting Infrastructure) were taken up for the beginning, the remaining will be deeper investigated in the future research process. Moreover, two further criteria were added, namely Functionality and Data control [Ge21], as they appeared important to the researchers to elaborate on in the context of the research project. Tab. 2 presents an overview of the selected criteria and the corresponding brainstormed features. It needs to be pointed out that the following table is not a final requirement catalogue but rather a brainstorm of thoughts and ideas for the further application development process.

Functionality	**Participant Motivation**	**Re-use**	**Supporting Infrastructure**	**Data control**
What can be entered in the application?	*How to motivate citizens to use the application?*	*Is the app only applicable to FloReST?*	*Which technical infrastructure is needed?*	*How can data control be guaranteed?*
Points, lines and surfaces	User journey	Communi-cation tool	Map services	Data protection
Selection (text, photos, icons)	Appetizer	Data collection	Meteorological data	Manual control
Photo upload	Understandable	Data for internal purpose	Hybrid	Contact person
Free text entries	Transparency		Free software	
Problem report Fix location	Illustrative		Angula, React	

Tab. 2: Overview criteria and features

5. Limitations and outlook

The inspection of different mobile applications marked a first step in the process of Citizen Science mobile application development and in answering the question of which preliminary features should be included in the FloReST Citizen Science application. Accordingly, this information built the base of the follow-up brainstorm described in section 4.2. Being complemented with literature, a first draft of a requirement catalogue was produced.

The current research proposal is mainly focusing on the topic of Citizen Science, as this was the initial step in the early beginning process of Citizen Science application development. Since no mobile application for drain path identification was found, the issue of drain path awareness needs to be deeper investigated in the future in order to find interesting and inspiring ways to attract users to report on such. Regarding this aspect, further research is also needed in the field of citizen attraction and how to make them using

such an application.

In addition, the issue of data quality control is indispensable to be reflected in the further research process, from a theoretical but also from a practical perspective. As false data might distort the final drain path identification and risk mapping, a control is of great importance. In the case of the FloReST project, it can be assumed that the number of Citizen Scientists participating in the data collection process might be manageable. Thus, a manual control could be a low-cost and viable option.

Further, the discussion of the user interface design and testing process remains open. The application development process has not yet reached that point. This short paper is a report of the current stage of work and first thoughts considering the task of developing a mobile application in the context of the FloReST project. It cannot be understood as a full and completed work.

Nonetheless, this paper gives a first impression of the challenges within a Citizen Science mobile application development in general as well as first insights into the research of the Institute for Software Systems, especially into the FloReST project. In the future process of research, the questions of data control and validation, as well as data privacy, user attractiveness and prototyping will be addressed.

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