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A Machine Learning-based Decision Support System for Disaster Response: A Mobile Approach

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Abstract
Machine learning has become one of the most evolving innovations in the field of technology which has a great wide variety of applications. While disaster management, in the hope of the urgent response to the affected communities, the concept of the latter is attributed. The disaster is a serious disturbance in a society that causes human life, physical resources, financial and environmental losses that result from concerns on the ability of the community to handle using its own means and properties. Generally, the objective of this research is to develop a machine learning mobile-based system for disaster management that can respond in a timely manner and provides decision support on evacuation mapping, relief good operations, school allocation, and job assistance. The proponents considered the existing process of the various local government agencies on reaching out to the affected communities. The Agile method was employed on system development to ensure the efficiency and transparency of the actual system design. Based on system and unit testing, it was revealed that the system meets the specified requirements of the various agencies. Hence, the K-Means Clustering was utilized to produce information that enables the organization to efficiently make decisions, validate the results and improve the activities that support the risk reduction management. The study proved that the application of machine learning in Disaster Management can dramatically improve the actions and can manage the data in decision making for future references.

Keywords: *Machine Learning, Decision Support System, Disaster Response, Mobile-Based.*

1. Introduction

Machine learning is one of the most disruptive innovating applied technologies that have an extremely broad range of applications. This enables the machine to perform its tasks skillfully by using intelligent software (Mohammed, 2016). Artificial Intelligence (AI) could have a tremendous impact on disaster management regarding quickening recovery and response times. Machine learning and AI are now used to develop tools and insights that optimize disaster preparation efforts and predict somehow the behavior of natural disasters.

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Natural calamities happen at various places around the world and they can occur at any time and at any place. These natural disasters can be experienced to those countries that are known as disaster-prone areas. The Philippines is a typical example of a disaster-prone area in the world. The natural disaster cannot be predicted accurately on when and where it will occur(Arceneaux K, 2006) and after the adverse, the effects on the economy and the community are undeniably massive(S., 2014). The consequences of the calamity were not only a direct cause of loss of human life and properties, but also a major damage to the sanctuary of our societies. Therefore, efforts should be taken to alleviate natural disasters. Quicker and proper disaster responses are required.

Disaster response capability is the capacityof one community to take any action to handle calamity disruptions effectively as they occur. Specific disaster response operations were carried out during the period starting with the occurrence of a disaster and ending with the normalization of the situation(M, 2002). The main objectives of disaster response are to save and protect lives and to keep property safe by deploying disaster equipment and supplies, evacuating potential victims, providing food, water, shelter and medical care to those in need, and restoring vital community services(Manoj BS, 2007). A disaster response decision support system plays a significant tool for authorities in enhancing their disaster response capabilities. The primary use of the Disaster Response Decision Support System (DRDSS) is to organize emergency early warning preparation, coordinate and execute disaster response operations, manage resources and provide information to the public. It is one key factor in whether disaster management will be successful (Peng Y, 2011).

This study's objective is to create a mobile-based DRDSS platform based on which to construct an operational DRDSS. The main components of DRDSS are the Evacuation Mapping Shelter Allocation Module, Distribution of Relief Goods, School Allocation Module, Job Assistance, and the Management Module.

2. Related Works

2.1 Machine Learning

There are computer algorithms and statistical models which involve the learning process in order to improve operations automatically based on the experience, and/ or inferences, and patterns. Most of these algorithms adopt the given instances which are represented in numerical vectors(Koen, Da, Li, & Wets, 2009).Humanitarian groups are hoping to fast track the creation of map with the use of machine learning to extract& examine objects such as buildings and roads from aerial images(Minges, 2019).Most of the Disaster management organizations are gradually using various innovations like machine learning algorithms to gather better data about threats and vulnerabilities.

2.2 Mobile-based Disaster Response

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The growth of mobile devices and geospatial technology has now been followed by a new level of use in the field of disaster management of geographic information applications (Yuanrong Hea, 2017). .Tsai et al. (Ming-Kuan Tsai, 2012) developed a Mobile Escape Guidelines (MEG) software that incorporates geographical data and augmented reality techniques to promote people's evacuation from nuclear sites. Kalabokid is et al. (K. Kalabokidis, 2016) have developed a web-based and mobile-based AEGIS App that incorporates wildfire prevention and mitigation tools to handle wildfire threats in Greece. Such advanced technologies have significantly enhanced the performance of disaster management. Nevertheless, the general portability (i.e. connectivity from multi-platforms or multi-devices)and functionality of such applications under extreme conditions, either during or after disasters, that constitute a critical requirement for good disaster management, is not well established.

In a study conducted by Passarella, R. et.al, the proponents developed a mobile-based disaster mitigation system in Indonesia that used the geo-fencing technique to sense the position of the users through mobile devices. The program is called a MISSION that used mobile-based disaster mitigation system as a way to communicate critical information to victims during an emergency when they are in disaster zones using virtual fences (Rossi Passarella, 2018)

As mentioned in the literature, it reveals that a mobile information system can be useful in a variety of ways to those who respond to and coordinate the disaster response. First, the portable devices enable respondents to make faster and more appropriate &effective decision-making. Second, the advancement of wireless / mobile technologies and connectivity patterns offers a pervasive framework for application in a variety of fields.(S. Kim, 2008).

2.3 Disaster Response Decision Support System

Decision Support System is an integration of computer hardware and software that is intended to assist & support the rational process of humans in their decision making (Wiliam A. Wallace, 2014)

The research focus of this study on disaster response decision support systems is on program structures, development criteria, methods, essential factors and implementations.

Many forms of program structures are provided through various studies. The framework suggested by Xie et al. is for team emergency decision-making focused on network technologies (Xie KF, 2011). The team decision-making framework proposed by Yu and Lai is remote and perfect for the management of unorthodox multi-person emergency / disaster multi-criteria decision-making problems(Yu L, 2011)

The Decision Support System provides the organization with great dynamics in decision-making activities. It aids the government, operations and planning phases of the organization involved in disaster management to make decisions

that may quickly change and not easily specified in advance (Raju, Decision Support System in griculture using Quantitative Analysis, 2016). The observed evidence recommends that the acceptance of DSS results in positive behavioral deviations, substantial error reduction, and the saving of cost and time.

3. Methodology

3.1 Data Collection

The proponents used the interview and questionnaire process to obtain information on the project. A face to face survey was conducted and both visual and audio cues were available (Shibin Tad, January 2014). Focal persons of each different department concerning disaster management were interviewed to discuss the operations performed during calamities and disaster period. In this process, the respondents took the survey in the easiest way that the questions could be well understood. The proponents assured that the questions were constructed within the level of the participants' level of comprehension. The research methods used are questionnaires, associated literature reviews and primary informant interviews with different heads of the Disaster Risk Reduction and Management Office and members of local barangay officials. This was used to gain more knowledge about the research project. The gathered data from this survey was used as the basis of the inputs for the various operations of the system modules (Sakurai, 2014). The collected data, observations and some surveys were used as the triggering component to produce significant information. It was clustered into various groups such as age, gender, student status, and employment status through employing the K-Means algorithm. The method used decision tree and regression models in the context of a tree framework to create a category of data (Sayad, n.d.). The dataset was breakdown into smaller and smaller subsets that were incrementally developed within the associated decision treeThe key algorithm used to create a decision tree is ID3, which utilizes a top-down, greedy search of alternative divisions with no backtracking. The result of system evaluation was computed using the weighted mean.

3.2 Structure of the System

Figure 2. System Structure

3.2.1 **Evacuation Mapping Shelter Allocation Module**

Data analysis from the collected data of the affected community. The shelter mapping design or shelter-in-place within the evacuation center is generated by the system. Various data analytics are employed to display the graphical representation of the data.

3.2.2 **Distribution of Relief Goods Module**

This module performs automatically the operations in arranging the distributions of relief goods within the affected community. This module also supports the generation of simple inventory lists of required and released relief goods.

3.2.3 **School Allocation Module**

Various students from the affected community can be arranged and grouped

according to grade levels, gender, track and or degree programs. This module can also generate the numerical vectors of affected students according to their group or cluster. Graphical representation of the generated reports is also displayed to easily visualize the data.

3.2.4 **Job Assistance Module**

This data-driven module generates a list of jobs that are available from the neighboring companies or institutions and can give sustainable support to the affected family or community.

3.2.5**Management Module**

Various users can be deployed on the system through user management such as admin and other users. The admin or the superuser can perform all operations within the system. This gives the admin user to take full control over all of the system processes. Similarly, with system utilities, the admin can be the only user that can be granted to modify significant configurations of the system.

3.3 System Development

The researchers used the Agile method in system development. This method helps to produce an efficient system and it can respond to the unpredictability of constructing the system. The mobile-based system was developed to showcase the features of the system. The different phases of the Agile model and the proposed framework requirements served as the basis for setting the scope of the project (Hernandez, 2017). The iteration process was observed within each phase of the Agile model.

For the project timeline, while additional features may be fed into the system development backlog, the rest of the process is a matter of repeating the steps over and over until all of the items in the system development backlog have been accomplished. As a result, the process flow is more on iterative process and not a sequential process.

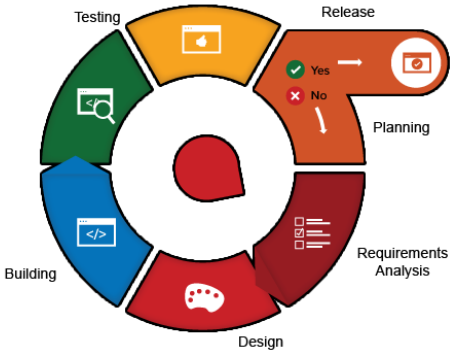

Figure 3. Phases of the Agile Model

3.4 **Tools and Techniques**

3.4.1 **Data Analytics**

As the practice of evaluating raw data to identify patterns and answer questions, the concept of data analytics encompasses its wide area of operation (2U Inc., 2019). Nevertheless, it includes a number of strategies with many different objectives.

It can assess the status of the affected area with a particular focus on Education Employment conditions of the students and workers as well as the population per location and the distribution of relief goods. It also includes the data of different schools and companies from neighboring cities or communities. This technique was used to explore more the gathered data in a various and meaningful way. It can easily forecast the data for future references such as the number of population from affected communities with a high risk of casualties, the size of the evacuation center, and the supply of relief goods.

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3.4.2 **Data Visualization**

Data visualization is a graphical representation of data that could express significance and then be used for decision making. Data visualization applications provide an accessible way to see and appreciate trends, outliers, and anomalies in information by using visual elements such as tables, graphs, and maps.(Data visualization beginner's guide: a definition, examples, and learning resources, 2019). This was used by the management for decision making and future references. This module significantly supports the various type of stakeholders in visualizing a large amount of data in an easier and effective way. The mobile-based system generates various visualization based on the data collected. It displays the map of the Batangas Province that provides information on mapping points of the affected area according to town or city with its corresponding barangay. It also shows the type of calamities, profile of the affected persons and generates trends analysis according to the disaster and demographics profile.

3.4.3 **Clustering Algorithm**

Data science is the process or method of inspecting the data in order to come up with knowledge or information through the use of various tools. This information enables the organization or community to efficiently make decisions, validates the results for future references, improves the activities that will support disaster risk reduction management, and can respond more quickly in a real-time manner.

K-Means is an iterative clustering algorithm that aims in each iteration to find local boundaries.K-Means clustering attempts to separate n objects into k clusters where each entity belongs with the closest mean to the cluster.This approach provides the greatest possible difference between exactly k separate clusters. The best number of k clusters leading to the greatest distance or separation is not established as a priori and must be determined from the results. The K-means method, though, uses equations of distance. The attributes should be quantitative and all values should be standardized to the standard range in advance if possible. The goal of K-Means clustering is to reduce maximum variance in the cluster, or the feature of squared error:

$$j = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2$$

Equation 1

Using the K-Means algorithm, the data can be clustered with the known and an initial number of groups or clusters. This kind of operation can be used to arrange the data accordingly based on the requirements of the system such as evacuation mapping, distribution of relief goods, school allocation, job assistance, and management.

3.4.4 **Work Breakdown Structure (WBS)**

The different stages of the Agile method were accomplished constructed on the identified needs Figure 4 explains the job overview layout of the different system design behavior. This consists of various tasks and the breakdown of project activities into a smaller and more detailed task level (Schwalbe, 2012).

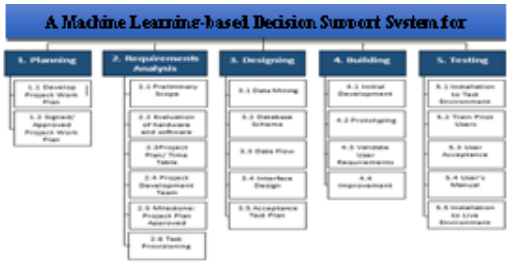

Figure 4. Work Breakdown Structure

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3.4.5 **MVC Framework**

MVC is short for Model, View, and Controller. MVC is a popular way of organizing code. The big idea behind MVC is that each part of the code has a meaning, and those objectives differ from one segment to another.Some of the code includes the information of the app called the Model some of the code makes the app appear good, called the View, and some of the code governs how the app works called the Controller.This is used for storing and modifying information in the system and displaying those data in the view element. Different frameworks provide it type of components on system development methodologies like Laravel, Code Igniter, Angular, and many others.

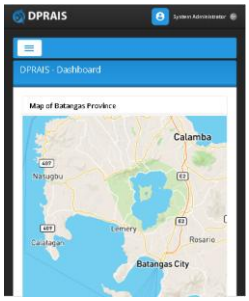

Figure 5. Map of Batangas Province

The figure above Figure 5 shows the map of Batangas province. The system can easily generate a map where the affected area is located.

Figure 6. Analytics of Calamities per Area

Figure 6 shows the number of calamities in eight (8) various municipalities and cities within Batangas Province. This includesAgoncillo, Alitagtag, Balayan, Balete, Malvar, San Jose, Talisay, andTanauan.

Table 1 Number of Affected Persons per Area

#	Area	Affected					
		2014	2015	2016	2017	2018	2019
1	Agoncillo	6	7	7	5	4	3
2	Alitagtag	5	6	7	7	6	3
3	Balayan	8	6	5	7	5	4
4	Balete	4	8	7	6	6	2
5	Malvar	5	8	7	7	6	5
6	Sanjose	2	8	9	5	6	2
7	Talisay	6	9	7	6	5	3
8	Tanauan	3	7	9	7	7	5
Sub-total		**39**	**59**	**58**	**50**	**45**	**27**
Total		**278**					

Table 1 shows the available number of affected persons per area within 6yearsof duration from 2014 to the present.

Figure 7. Analytics According to Age & Gender

Figure 7 shows the visualization reports using graphs according to gender, age, employment reports, and student reports from affected areas. With this, the system can easily inform the government as to which action should be done in a timely manner. This includes but not limited to emergency response resource allocations such as evacuation mapping shelter allocation, school allocation, and job

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assistance. It can be easily viewed and prioritized the persons in evacuation deployment based on age and gender as well as the status of students and employees from the affected areas. Based on the information obtained from disaster response organizations, strategic analysis approaches are used by DSS to provide an ideal solution to mobilize and distribute resource allocations.

4. Results and Discussion

The management council as the primary stakeholder of the system benefited the system's outcomes of the different features such as evacuation mapping, school allocation for students and generating of necessary reports.

Table 2 – Affected Profile by Age per Area

#	Area	Child	Teenager	Adult
1	Agoncillo	6	5	8
2	Alitagtag	5	7	5
3	Balayan	6	6	8
4	Balete	8	7	6
5	Malvar	11	8	8
6	Sanjose	7	6	8
7	Talisay	6	10	7
8	Tanauan	9	9	6
	Total	58	58	56

Table 3 – Status Profile per Area

#	Area	Student	OSY	With Job	No Job
1	Agoncillo	15	3	10	4
2	Alitagtag	17	4	11	2
3	Balayan	13	5	13	4
4	Balete	16	5	8	5
5	Malvar	17	5	12	4
6	Sanjose	14	4	12	2
7	Talisay	16	5	11	3
8	Tanauan	18	4	14	1
Total		126	35	91	25

Table 2 – 3 show the profile of the affected areas classified by age, students, and employment. The data in Table 2 shows the number of affected individuals per Area with age classifications of the child, teenager, and adult. This enabled the system on which to provide disaster response with a great priority.

4.1 System Testing &Evaluation

Several test cases were checked and placed some necessary adjustments on the various modules of the system. ISO 25010 or also known as the System Quality Requirement & Evaluation was adopted to test the following attributes:

4.1.1 **Reliability** – this attribute guarantees the system to perform under the specified condition for a specified period of time.

4.1.2 **Portability** – this attribute guarantees the system to perform on various types of hardware, software or other operational environment.

4.1.3 **Compatibility** – this attribute guarantees the system to perform in exchanging or sharing of information with other hardware or software environment.

4.1.4 **Functionality** – this attribute guarantees the system to meet the stated and implied needs when used under specified conditions.

After testing the system, comparison of the different system components was conducted and the advantages were easily identified compared to the different system characteristics. Table 4 shows the results of the 46 respondents ' system analysis.

Likert scale method was used to check and validate the various system attributes. The respondents chose thedesired value from 1 to 5 as the range of scores

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where 1–Strongly Disagree; 2 – Disagree, 3 – Neutral; 4 – Agree and5 – Strongly Agree.

Table 4 – System Evaluation Results

System Attributes	Average
° Reliability	4.70
° Portability	4.74
° Compatibility	4.67
° Functionality	4.65
Average	4.69

It was clearly revealed in the evaluation conductedthat the portability attribute got the highest averagescore among others which has a weighted mean of 4.74.

5. Conclusions

The research developed and presented a model of decision aid for disaster response focused on machine learning.The built methodology will assist disaster management organizations not only in successfully conducting disaster response operations, but also in the scheduling of disaster resources.In regards to the disaster management process, consistency, portability, flexibility and usability is necessary to ensure full functionality in extreme situations either during or after disasters.

The machine-based learning support system was combined with a framework for collecting information on disaster response in real time. It may be a wide-ranging approach to disaster response resource management.

Based on the test conducted, it has proved that the system performed on various types of hardware, software, and the other operational environment. Among the attributes, portability gained the highest average score with 4.74 which indicates that the system is highly operational on various setup and environment. It was followed by the reliability with 4.70 average scores, compatibility with 4.67 average scores and functionality with a 4.65 average score.

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