Implementation of Flood Emergency Response System with Face Analytics

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***Abstract*—Disaster management system is developed to monitor flood, tsunami and earthquake, which is effectively preparing for and responding to the disaster. In fact, Malaysia is building the emergency response system for managing the flood disaster since it is highly occurred. However, the current flood emergency response system has limitations, which, has no integration that data entered into spreadsheets and transferred to different storages, and, data analytics that assist in data collection and decision-making. Even though flood emergency response system have been improved, which introducing sirens and loudspeakers to reach flood victims but still difficult to access the basic facilities and receive flood responses. Therefore, this study implements a flood emergency response system with face analytics to assist data acquisition, which analyze flood victim's faces using CCTV infrastructure with HOG algorithm that incorporated with a dashboard. The dashboard categorizes the number of flood occurrence, maximum flood period (days), the number of displaced flood victims and loss assessment. Findings have shown that the dashboard helps the enforcement agencies to implement the real-time information about flood victims. Based on the number flood frequency occurrence in Malaysia from 2017 to 2021, the percentage produced was 27%, 19%, 12%, 19% and 23%. Moreover, the duration of floods has been decreased from 30% to 17% in 5 years that shows the flood emergency response helps the Malaysia government to improve the infrastructure. The significant of this study beneficial to the local enforcement unit and evacuation centers in identifying the flood victims.**

Keywords—Disaster management system; flood emergency response system; flood emergency response system with face analytics; flood emergency response system with face analytics using HOG algorithm; flood emergency response system dashboard

I. INTRODUCTION

Malaysia is located in Southeast Asia, bordering Thailand, Brunei and Indonesia, which geographically is located outside the ring of fire and south of major hurricanes. However, Malaysia is often affected by other natural disasters such as floods, landslides, haze, earthquakes, droughts, tsunamis and other man-made disasters. Floods cause the most frequent and severe damage every year, causing loss of life, disease, property, and other damages [1]. In Malaysia, flooding has become a major disaster problem. From July 2012 to January 2019, Malaysia's population was the most highly affected by floods among ASEAN members [2].

As a result, in 2015, the National Disaster Management Authority (NADMA), under the Prime Minister's Office, became the premier disaster management agency for disaster management efforts in the national and international level. The organizational structure of disaster management continues at three levels: federal, state, and county [3].

NADMA provides Flood Early Warning Systems (FEWS) that divided into five classifications as pre-internet, internet of content, internet of services, internet of people and IoT (internet of things) that warn the public about disaster risks going to happen [4], [5]. Due to the unpredictable estimation of flood occurrence, several methods have been proposed to enhance the FEWS.

The first solution is to create a monitoring tool that observes the occurrence of floods and warns victims before trap in the flood area. The importance of this tool is to reduce the number of flood victims in the flood areas, enable rapid evacuation of victims, and prevent loss of life and save more flood victims from flood injuries [6].

The second solution proposes a new dashboard to provide latest information about flood victims, which comes from face images of flood victims that been capture from CCTV. The propose system called as flood emergency response system with face analytics will verify the captured face image from CCTV with the stored face image using HOG algorithm. The face analytics acts as a back end engine for the proposed system.

The rest of the paper is organized as follows: Section II describes the literature review of flood and its causes. Section III explains on methodology used to design the propose system. Section IV explains about the architecture and techniques. Section V explains about the results and discussion. Section VI summaries the implementation of the flood emergency response system with face analytics for better performance in identifying flood victims.

II. LITERATURE REVIEW OF FLOOD

Flood is a dynamic phenomenon with wide geographical and temporal variation. Furthermore, changes in the flood system, such as levee breaches or the adoption of emergency measures, might alter flow patterns and cause unexpected deviations from pre-planned contingencies. Even though floods

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may affect human activities and assets in a number of ways, disaster management must be aware of which regions are flooded when and how intensely. In contrast, flood impact assessment is mainly concerned with the greatest flooding extent and maximum inundation depths that occurred during the storm [7].

In Malaysia, flooding is categorized into three types, which are river floods, pluvial floods, and coastal floods.

Fig. 1 depicts a river flood, also known as a fluvial flood, which occurs when the water level in a river, lake, or stream rises and overflows onto the banks, beaches, and neighboring land. Significant rain or snowmelt may have caused the rise in water levels.

Fig. 2 shows a pluvial flood occurs when a heavy rainfall event generates a flood that is not produced by an overflowing water body. A common misconception about floods is that you must be near a body of water to be impacted. Nonetheless, pluvial flooding may occur everywhere, urban or rural, and even in areas where there are no adjacent bodies of water. There are two forms of tributary flooding:

- When an urban drainage system gets overflowing, water rushes onto streets and surrounding structures, resulting in surface water flooding. It happens gradually, giving people time to flee to secure locations, and the water level is usually shallow (rarely more than 1 meter deep). It does not endanger people's lives immediately, but it has the potential to cause significant economic harm.
- Flash floods are categorized as a violent, high-velocity torrent of water generated by heavy rain falling in the region or on surrounding higher terrain in a short period of time. A fast release of water from an upstream levee or dam creates a dangerous and catastrophic situation. This is because of the force of the water produce the hurling debris.

Fig. 3 explains about coastal flooding or named as storm surge, which is the inundation of land near the coast by seawater. Windstorms that coincide with high tide (storm surge) and tsunamis are common causes of coastal flooding. Storm surge occurs when high winds from a windstorm cause water to wash ashore; it is the most prevalent cause of coastal flooding and, in certain cases, the deadliest threat associated with a windstorm. Windstorms during high tide cause damaging storm surge floods; windstorms during low tide cause disastrous storm surge floods. In this type of flood, water overwhelms low-lying regions, resulting in significant loss of life and property. Other factors that influence the strength of a coastal flood include the windstorm's power, magnitude, speed, and direction. Furthermore, the onshore and offshore geographies are another critical factor of coastal flood that bring severe damages. Coastal flood models employ this information, as well as data from previous storms in the region, to determine the likelihood and severity of a storm surge.

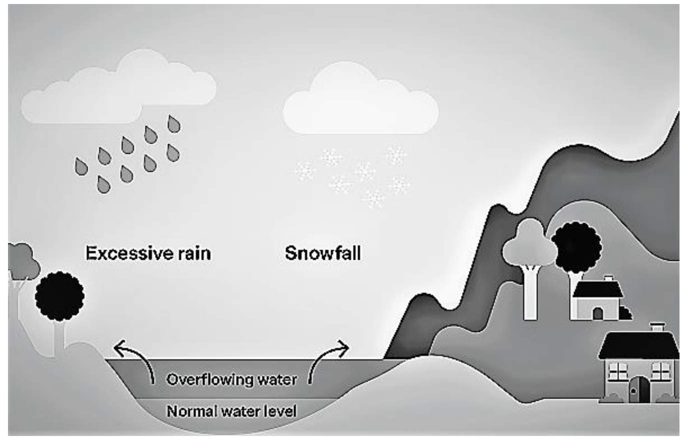

Fig. 1. River floods (fluvial floods).

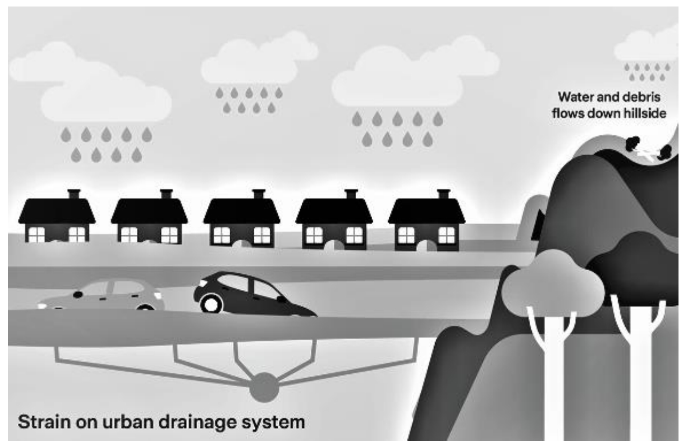

Fig. 2. Pluvial floods (flash floods and surface water).

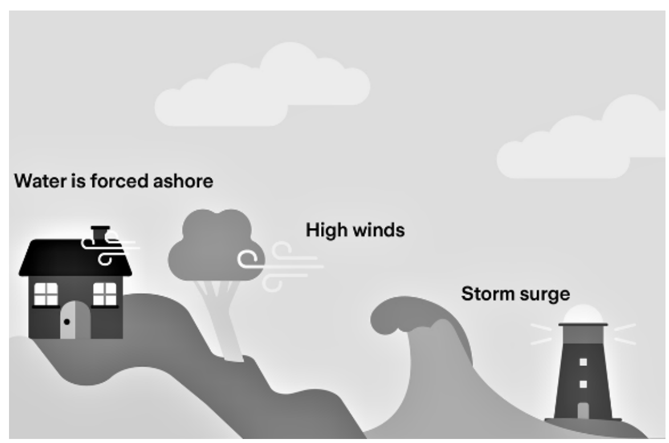

Fig. 3. Coastal flood (storm surge).

A. Causes of Flood in Malaysia

Regardless of the type of flood exist; it is always brought on by the same basic event and the effect typically harmful. Meanwhile different types of floods have different causes, most floods are caused by one of the following events [8] [9]:

1) Heavy rain: This is the most common source of floods. When there is too much rain or it falls too rapidly, it literally does not have anywhere to go. This can result in floods, including flash flooding.

2) River flooding: River flooding is not necessarily caused by heavy rain. As previously said, river flooding can occur when there is debris in the river or dams that restrict the flow of water.

3) Broken dams: Older infrastructure may fail when heavy rains fall and water levels increase. When dams collapse, torrential rains fall on unsuspecting populations.

4) Storm waves and tsunamis: Hurricanes and other tropical storms may cause sea levels to rise and bury normally dry coastal areas in many feet of water. Tsunamis, on the other hand, are gigantic waves caused by earthquakes or volcanic eruptions beneath the sea. As these waves approach inland, they acquire height and have the potential to drive a huge volume of water inland in coastal areas.

5) Channel with cliffs: When there is fast runoff into lakes, rivers, and other basins, flooding is prevalent. This is frequent in rivers and other bodies of water with steep banks.

6) Lack of vegetation: Vegetation can help to slow down runoff and prevent flooding. When there is a lack of vegetation, there is little to prevent water from rushing back and flooding rivers, lakes, and streams.

7) Moon "Wobble": The moon wobble is caused by fluctuations in the moon's elliptical orbit and the related gravitational pull on Earth.

III. Flood Management System

Flood management system (FMS) has been used across the world to accomplish the goals of the Framework for Disaster Risk Reduction and the Sustainable Development Goals, which the Disaster Risk Reduction (DRR) strongly recommends. The four fundamental aspects of a comprehensive FMS are risk information, monitoring and forecasting, warning, dissemination, and communication, and reaction capabilities. The complexity of operational FMS varies based on the data given, the technology employed, and the know-how [1].

There are substantial differences in maturity between FMS in developed nations that have the financial resources, technological infrastructure, and human resources, and those in poor countries who have less sophisticated FMS. Fortunately, advances in remote sensing, artificial intelligence (AI), information technology, and social media are creating substantial changes in FMS processes, allowing all FMS to obtain enhanced capabilities. These technologies enable underdeveloped nations to overcome the technological hurdles that FMS have previously encountered. The difficulties that FMS confront, as well as technological improvements and their consequences for flood forecasting and disaster response is explored [4].

Flood risk can be assessed by reviewing the historical record of flooding in a certain location, monitoring the people and property damaged by the flood, and use predictive modelling, expertise, or a combination of the above [16]. It is also necessary to understand the possibility and repercussions of floods. The availability of extended hydrological data series frequently limits the utility of previous flood data. Understanding risks necessitates costly maps and research, which must be updated as dynamic cities expand. Collecting geographical data sets such as topography, land use, soil, and exposure is the first step in predictive modelling. We also require competent individuals to simulate and evaluate the outcomes. As a result, of these challenges, risk awareness is lacking in the majority of FMS covered locations.

To effectively estimate the development of flood water levels, FMS operators must have a thorough understanding of the present and historical values of important hydraulic parameters in the watershed upstream of the area of interest, as well as their likely future evolution. Water levels, discharges, snowfall, precipitation, and temperatures are all often observed factors. The present and historical values of these parameters are available via a monitoring system, which is typically comprised of a network of ground stations supplemented by occasional field surveys. Ground stations typically measure variables of interest at a single location, providing FMS operators with only limited information on the state of the watershed, especially if the monitoring network has insufficient geographic coverage. Approximately 75% of the flood forecasters polled stated that their river basins lack sufficient gauging stations for rainfall, water level, and streamflow information. Fifty percent of the FCCs who answered disclosed that their measurement equipment, gauges, and data transmission devices are outdated. Another challenge is data transfer from stations to forecasting centers, as a considerable proportion of stations in the developing world rely on human observers, hindering the accuracy and timely transmission of data. As a result, most poor nations struggle to capture the amount, distribution, and change of essential variables like precipitation and streamflow during extremes. Weather radars and remotely sensed rainfall have the potential to improve watershed monitoring by providing geographical, real-time, or near real-time data. However, the data they supply is of lesser quality than observed data, and these approaches are too young to have long enough time series to develop credible hydrological models [17].

The acquired hydrological data should ideally be kept in a database and analyzed in real-time using hydraulic models. Not all nations have a centralized, continually updated database. Data is sometimes stored in spreadsheets for quality assurance before being transferred to a central database a few days or months later. One of the most significant issues confronting operational systems is a shortage of technical competence and human resources. CTFs should have people with considerable flood forecasting training and a large enough forecasting team to successfully deliver timely warnings 74% of flood forecasters, however, admit that their centers lack expertise and personnel capable of integrating data, formulating predictions, and distributing information. This might be owing to a lack of expert specialists in job areas, as well as an increase in the demand for disaster recovery and rescue operations after large floods. The shortage of committed permanent personnel in underdeveloped nations is a key impediment to the efficient operation of FMS. Overall, study results suggest that forecasters have mostly technical expertise but lack understanding of flood vulnerability assessment, warning communication, and downstream resilience, including evacuation preparations [18].

The rapid change of meteorological variables, particularly precipitation, is a critical input for flood forecasting. Meteorologists employ complex computer models to forecast the weather, in addition to ground and satellite data of the land and atmosphere. Numerical weather predictions (NWP) use current weather measurements and combine them using computer models to estimate the weather's future condition. Understanding the present status of the land, ocean, and atmosphere, which effects modelling initialization at local, regional, and global scales, is a significant problem for quantitative precipitation forecasting. In addition, forecasters in industrialized nations have access to fine resolution modelling using ensemble projections to reflect variability and uncertainty in forecasts. Nationally operated meteorological stations in industrialized nations give worldwide predictions from global NWP systems available in underdeveloped countries, such as the Global Forecasting System. This output, however, has a relatively limited spatial resolution. National authorities should scale these forecasts down to greater geographic resolutions [5].

Some nations, however, are unable to make high-resolution predictions due to a lack of critical skills and resources. Even if the prediction is lowered, residual inaccuracies and a fundamental lack of weather forecasting capabilities may result in the failure to detect approaching severe floods or false positives. Even the weather prediction is intelligent. The quality of the data assimilation technique used to derive the beginning conditions of the hydraulic model influences those forecasts. It is also influenced by the hydraulic model configurations described in the model structure, physical process simplification, and calibration quality, as illustrated in Fig. 4, which shows the impact on the performance of the flood forecasting model. Almost half of study that claim the model utilized to produce early warnings is insufficiently accurate or sophisticated for this purpose. As a result, anticipated hit rates varied among model systems and river basins in various climatic zones [19].

Therefore, the new flood management system contains the cutting-edge technology that can easily discover victims as shown in Fig. 4. Moreover, the method of biometric authenticates the specific victim in order to confirm that victim identity. As a logical consequence, physical papers are increasingly becoming obsolete and being replaced with biometric identification. It may also be claimed that current technology has advanced significantly such as allowing consumers to unlock mobile devices using fingerprints or transfer money using voice commands. In order to develop a victim's identification, a biometric analyze unique biological and physiological traits is used. Fingerprints, face, voice, iris, and palm or finger vein patterns are the most frequent biometric identifiers. Banks, for example, require the biometric data in order to perform their numerous services remotely. People have to go to a branch to create an account or make a loan, but now user access numerous services using the newest technology such as a phone, i-watch, laptop, and so forth.

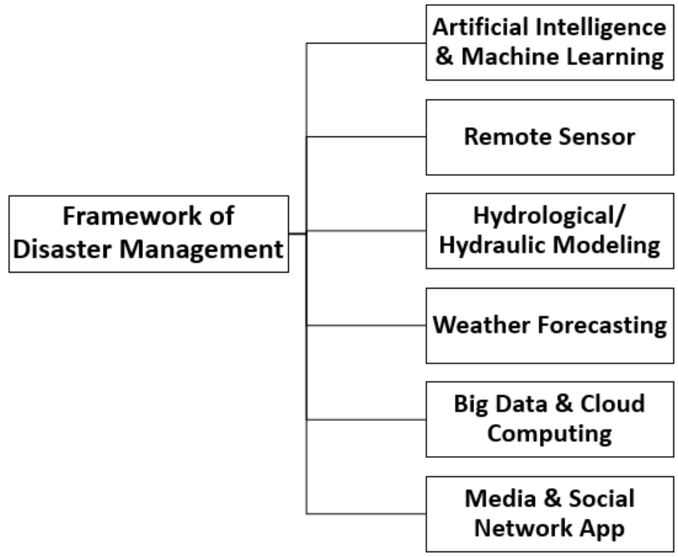

Fig. 4. Potential of new technologies for flood management system [15].

Fig. 5 states about the physical biometrics, in contrast to behavioral biometrics, which relies on measures of the human body for identification or verification. Face geometry, fingerprints, certain areas of the eye, vein patterns, and other physical characteristics are examples of this. It is simply said that physical biometrics substitutes "things you know" (passwords and PINs) with "things you are". This sort of biometrics employs a hybrid approach of analysis that combines human experience with the power of artificial intelligence to provide findings with a high degree of accuracy. The most prevalent approach for authentic user identification nowadays is static physical biometrics. They are utilized by the vast majority of firms (almost 80% globally) that collect and retain physical biometric data to validate identities for a variety of purposes [10]. Thus, the physical biometric is suitable for flood victim identification.

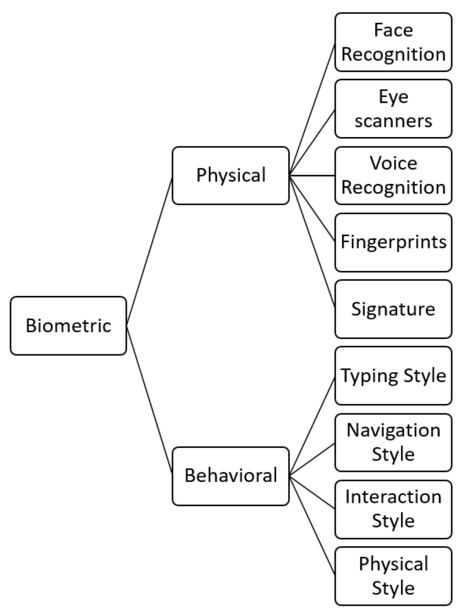

Fig. 5. Types of biometric template.

IV. FLOOD EMERGENCY RESPONSE SYSTEM WITH FACE ANALYTICS DASHBOARD (FERSFAD)

The design used for FERSFAD is similar to the laboratory attendance dashboard website based on face recognition system [11] and the technique used for the FERFAD is HOG. CCTV is an idea to overcome problem in contactless criteria that help for a long distance detection [11] [12].

The design of Flood Emergency Response System (FERS), is divided into two parts: facial analytics which is one of the physical biometric and the dashboard that using Power BI. In the facial analytics contains the face analytics components, which are the back end as well as front end of the system of the flood emergency response system dashboard (FERSFAD). The FERSFAD system uses a CCTV camera to send video footage to the computer server that acts as a database for storing image records and calculating face templates using HOG algorithms.

Facial biometrics remains the favored biometric standard due to its ease of deployment and implementation for long distance coverage. In fact, there is no direct contact with the end user and reduces the number of touchpoints on the surface. Furthermore, the face detection and face matching processes is vital for rapid verification or identification, which aids in the search for missing individuals.

In the FERSFAD system, the dashboard creation provides standard requirements of development. Moreover, a huge amount of data from other centers is utilized to give accurate information about the flood. In addition, a quick reference of information about the flood easy to be share among the society and prevent from fake flood information. The propose dashboard has the potential to improve society by boosting safety and security, preventing crimes, and decreasing victim contact.

Therefore, the process starts with capturing the image of the flood victim at the evacuation center. The image of the flood victim is captured using CCTV that has been located at the area of evacuation places [12]. CCTV assists in the data collection phase either the data collection is done during day or night. In the server, the HOG algorithm calculates frames of facial images of the flood victims.

In the enrolment phase, the HOG algorithm involves several steps, which start with Step 1 that is image preparation and color normalization. In the Step 1, the original image is resized to be [8 x 16] metrics and [128 x 64] metrics and the color normalization process transform the resized metrics to be greyscale format. In Step 2, the resized and normalized image metrics are calculated using magnitude and angle of gradients in order to make the image appear closer, which called as face structure. Furthermore, Step 3 implements binning of face structure with gradient calculation using spatial formula that is vital for the matching process. The binning process transforms block normalization into a single-cell normalization that is done in the Step 4. Step 5 involves the HOG feature vector and Scale Invariant and Feature Transform (SIFT) algorithm to search the similar features and save into a database [20].

The HOG algorithm has several methods of detection and matching phase for flood victim faces. The matching technique involves SIFT process that find the similar features in victims' face captured.

Formula for HOG is magnitude (μ) = $\sqrt{[(Gx)_2 + (Gy)_2]}$ and angle($^{\theta}$) = tan -1 (Gy / Gx). Benefits of using HOG algorithm in the FERSFAD system is using the SIFT to extract local features, whereas HOG is used to extract global features [13].

To implement the FERSFAD system, the flowchart is designed in estimating overview of the whole process. Fig. 6 illustrates about the flowchart. In the flowchart, it begins with image stored in system database. The image stored in the database is collected from the CCTV that has been collected earlier. The data comes from various units such as evacuation center (indoor) and (outdoor). The CCTV camera detects the victim's face and compare with victim's face image in the database. Once the victim's face match, it proceeds to the recognition process. If the victim's face not matches with the image in the database, person-in-charge of the system needs to add victim's details in system database to update the database. The dashboard displays the detail information about the flood victims.

The programming languages used for the FERSFAD system is Pycharm, which is a Python-specific Integrated Development Environment (IDE) that provides a wide range of necessary tools for Python developers [12]. These tools are tightly integrated to offer a pleasant environment for productive Python, web, and data science development at the back-end of the system. The dashboard connects with phpMyAdmin because it is a web-based utility for managing the MySQL database [12],[13]. Moreover, phpMyAdmin provides an easy-to-use graphical interface for running SQL commands and performing SQL operations. Therefore, at the front-end of the system, the Power BI platform is used to visualize the dashboard for representing the information of the flood victims.

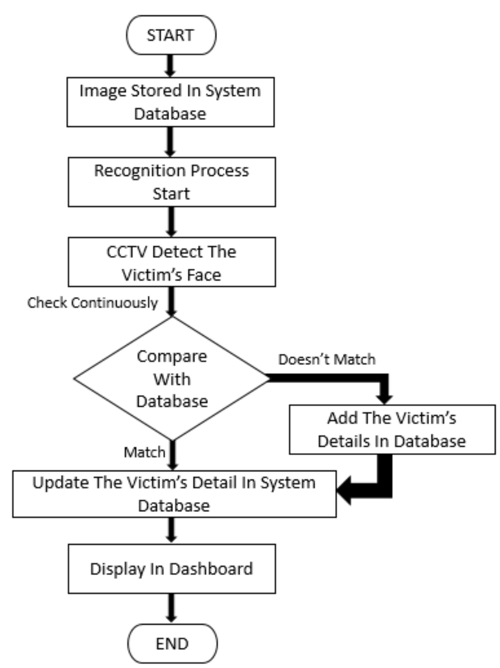

Fig. 6. Flowchart of flood emergency response system with face analytics.

The dashboard website is used to provide analytical data such as the number of people in the shelter, video footage of facial recognition results, and the identities of the people in the evacuation center. This analytical data is used to identify the victims' faces. The dashboard is developed to visualize data [21],[22] for easy to be understand, producing interesting and colorful diagram to distinctive the flood occurrence, maximum flood duration, number of affected flood victims and estimated loss [14].

V. Results and Discussion

Based on findings of the FERSFAD system, most researchers and users used for verify or identify the flood victim using their face. The CCTV camera help to capture, analyze and compares pattern based on the victim's facial details [11]. Other than that, the CCTV detects the victim faces to process with other step in detecting and localizes the victims face in images [11], [12]. The process of the capture the victim's face transforms analog into a set of digital information such as database on the victim's facial features. If the victims face match, it verifies the similar faces that belong to the same person. When compare with other biometric technologies such as RFID card, fingerprint scanner and iris templates, the face recognition gives faster detection to verify the flood victim face over an overall victim at the evacuation center [10]. Fig. 7 illustrates the architecture of the FERSFAD system.

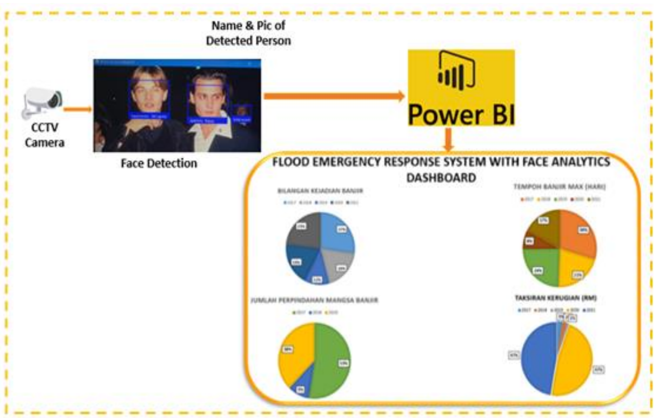

Fig. 7. Flood emergency response system with face analytics architecture.

For instance, there are 230 victims at the evacuation center. Face recognition detects a victim's face using face recognition takes roughly about a second (0.8 second) that is faster compared to fingerprint recognition and took more than two seconds in time (2.3 second). Nonetheless, recognition using an RFID card or fingerprint scanner would take longer time to identify each victim.

The HOG algorithm is included into the system because color data is less important in matching phase for subsequent processing, since the enrolment phase begins by converting the flood victim face image to monochrome in order to detect the victim's face. It evaluates each pixel individually and looks for pixels that are directly connected to (around) the selected pixel. It captures how dark the selected pixel is in comparison to pixels immediately around it. An arrow denotes the magnitude in which the image is darker. The image receives an arrow in every pixel by repeating this technique for every pixel in the image. These arrows are known as gradients, and they indicate the transition of light to dark throughout the whole image [11-20].

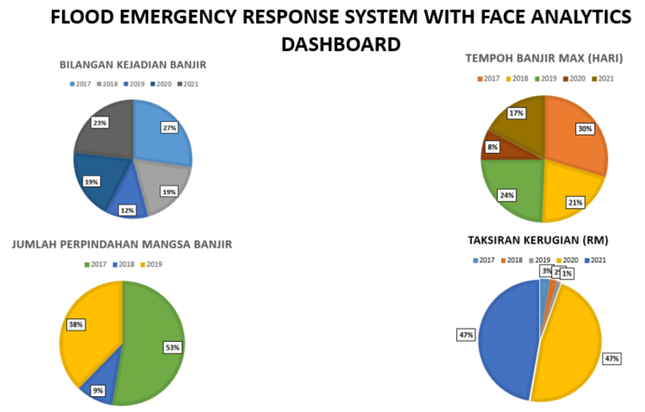

Fig. 8. Dashboard of flood emergency response system with face analytics.

Fig. 8 shows the pie charts in the flood emergency response with face analytics. The pie charts are divided into four parts which are the number of flood occurrence, maximum flood period (Days), the number of displaced flood victims and loss assessment for five years starting from 2017, 2018, 2019, 2020 and 2021. The upper left most section in the pie chart describes about the amount of flood occurrence, which in the highest percentage of the flood occurrence occurred in 2017. Meanwhile, the lowest percentage of the flood occurrence happened in 2019. Thus, in 2017 many flood victims have been affected by the flood disaster.

The upper right most section of the pie charts shows the flood duration in days. To compare data in 2017 and 2019, there are 6% of different between of these two years. The minimum of the flood period (days) in 2020 is with 8%. However, the information about the flood duration has shown a decrement of percentage value due to improving the infrastructure done by the community such as higher dam, enlarging the water channel and making a concrete at the river banks.

The lower left most chart compares for three years of number of affected flood victims which in 2017, 2018 and 2019. In 2017 is the highest percentage of number of affected flood victims, which is 53%. In the second stage in 2019, gives 38 % and the lowest percentage is 9% that is in 2018. The highest number of affected flood victims happened due to no preparation for dealing with flood disaster that the flood victims not aware about the flood disaster.

The lower right most side of the pie charts explains about the estimated loss. Based on the estimated loss information, it is stated that in 2020 and 2021, the amount of loss is 42% and this value is the highest percentage among other values. Even though the duration of floods has been reduced, however, the affected area of flood consists of huge locations in Malaysia since monsoon season, moon's elliptical orbit and the related gravitational pull on Earth. Therefore, many flood victims have been affected tremendously by the flood disaster.

VI. Conclusion

As a conclusion, a flood emergency response system with face analytics has been implemented for flood disaster management system in Malaysia. The flood emergency response system with face analytics has aided evacuation centers in identifying flood victims, strategies to improve the infrastructure and for budget planning. The dashboard displays the actual result of flood victims that gathered from various evacuation centers in Malaysia. The benefit of employing a flood emergency response system with face analytics can aid in data analytics and provides real-time information. Furthermore, the dashboard enables the community to monitor the current situation of flood using their gadgets, phone, tablet, laptop, and other devices. The significant of the dashboard assist victims, police, fire department, and NADMA in preparation for facing the flood disaster. In fact, the flood prediction is estimated and planned to be further investigated in the future.

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