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PERFORMANCES OF FUZZY ALGORITHM AND WIRELESS SENSOR NETWORKS FOR OUTDOOR LOCALIZATION IN FLOOD ALERT SYSTEM TECHNOLOGY

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Abstract

This paper purpose to enhance the performance of fuzzy logic and wireless sensor networks (WSNs) in flood alert disasters. Therefore, there is a need for the establishment of a flood WSNs devices to gain accuracy of the flood forecasting that produces warnings as accurately and as far ahead as possible. Through developing method to determine flood forecasting models associated with the WSNs in the outdoor localization of environments such as river, basin, or lake in order to detect the height water level and velocity water, one should take actual data daily. The initial forecasting models are capable of determines the central location to spread the flood WSNs. The factors that would leverage the height's water are population density of people living near the prone area, watershed, land slope, altitude, and rainfall. Considering the outdoor localization with utilized the outstanding of GPS within localized the object in a large area. For instance, to detect the WSNs devices in a harmful situation. Beforehand by first assess the area with the fuzzy logic system.

Keywords: Flood alert, Fuzzy logic, Outdoor localization, Performances, Wireless sensor network.

1. Introduction

One of the major topics to be investigated in this field is the unpredictability of weather patterns in the world caused by climate change due to global warming. Extreme changes in rainfall are connected to monsoons. In general, dry season from June to September influenced by the Australian continental air masses. Meanwhile, rainy season from December to March is a result of the Pacific Ocean and mainland Asia air masses. On the other hand, northern and western parts of Indonesia undergo the most rainfall, since the north- and westward-moving moisture-heavy monsoon clouds reach further regions. Moreover, few studies have focused on the flooding effects, such as human, material, economic, and infection from waterborne diseases and contaminated water, as well as social losses in flooded areas. Therefore, carrying out monitoring as an isolated task will not end the and financial and human losses [1]. From that case, the proposed Mamdani fuzzy algorithm [2] in order to forecast the flood and its application to determine the flood-prone area. It needed an automatic system to reads the flood data directly and then send alerts to utilized the Short Message Service, which contained water level in any rivers and the location of the rivers using a global positioning system.

This work aims to fusion among the fuzzy logic, SMS module, and GPS that called with Fast Alert System Technology (FAST) based on the principle of Wireless Sensor Networks (WSNs) as real implementation. The WSNs are a set of nodes that have the ability to communicate through wireless transmission and anchor node [3]. WSNs have the properties of data processing, sensing, and broadcasting can be applied in various areas such as intrusion detection, target tracking, wild animal monitoring, energy-efficient routing, deep water, underground, and other space explorations [2-11].

2. Design Methods FAST

2.1. Identification of variables

The first step to determine the raw data by identifying the origin list of twenty-four variables was selected through reviewing the literature for forecasting flood-prone areas. Moreover, corresponding also to regulations for such government agency and further discussion with floods experts. The evaluation of those data presented in this work lead into five main variables input, and one variable output that consists are the human density population (PD; The Population body of the district in which the people is located) scale area of drainage or watershed (LW; The location of land that drains all the streams and rainfall to a common outlet.), the slope of an area (SL; A location of ground that tends evenly upward or downward), altitude (EL; The radius above sea level of the land, mountain, seabed, or any other place), and the rainfall (RF; The rainfall concentration is confidential according to the rate of precipitation) as well as the flood vulnerability (VL; The incompetence to prevent a flood when the flood has occurred).

2.2. Data sets

The data reveal significant differences in the population density, watershed, slope, altitude, and rainfall data used in this study were gained from two provinces with three districts such as West Java, including Bojongloa Kaler, Gedebage, along with Cibiru districts, as shown in Table 1.

Table 1. Data set of districts in two provinces 2014.

Provinces	Districts	PD (people/km^2)	LW (acres)	SL (%)	EL (amsl)	RF (mm)
West Java	Bojong-loa kaler	39817	2122	8	694	198.8
	Gede-bage	3732	400	8	666	198.8
	Cibiru	11086	22481	15	706	198.8
Central Java	Bulu Lor	25283	145	2	2	105
	Bandar-harjo	5990	185	2	0	105
	Purwo-sari	18521	281	2	2	105

2.3. Fuzzy sets and membership function

Table 2 describes six inputs, namely population density, watershed, slope, altitude, rainfall, as well as output as the vulnerability, were used to classify the flood-prone area. After breaking down the variables, each linguistic variable was defined by a membership function, as shown in Table 2. Established training set, the experts' experience and knowledge, as well as trapezoidal membership function were selected for output and input variables, respectively. It represents the linguistic variables more effectively.

2.4. Fuzzy rule base and based model

Several researchers have reported strategies for deciding rules such as fuzzy classifiers, neural networks, genetic algorithms, and knowledge of expert. According to their perspective, the rules were formulated. Mamdani fuzzy inference engine was utilized to be used as the fuzzy rule-based model.

3. Results and Discussion

3.1. Mamdani fuzzy logic system

Figure 1 represents the design of Mamdani Fuzzy for the flood vulnerability in Central. This block applies to two provinces, and each province employs three districts for the research. The first province in Central Java and three districts in that province are Bulu Lor, Bandarharjo, and Purwosari. Later, other provinces in West Java include the three districts are Bojongloa Kaler, Gedebage, Cibiru. For each province have a different rule of Mamdani fuzzy.

3.1.1. Output variable of Mamdani fuzzy

The results on the flood vulnerability consist of three states: normal, alert, or danger.

$$\mu_{VFNORMAL}[x] = \begin{cases} 1, & x \leq 220 \\ \frac{248-x}{28}, & 220 \leq x \leq 248 \\ 0, & x \geq 248 \end{cases} \quad (1)$$

$$\mu_{VFALERT}[x] = \begin{cases} 0, x \leq 220 \ or \ x \geq 402 \\ \frac{x-220}{28}, 220 \leq x \leq 248 \\ \frac{402-x}{28}, 374 \leq x \leq 402 \\ 1, \quad 248 \leq x \leq 374 \end{cases} \quad (2)$$

$$\mu_{VFDANGER}[y] = \begin{cases} 0, & x \leq 374 \\ \frac{x-374}{28}, & 374 \leq x \leq 402 \\ 1, & x \geq 402 \end{cases} \quad (3)$$

where x is the result of vulnerability variable in the Mamdani fuzzy process, $\mu_{VFNORMAL}[x]$ is the value under normal conditions in the flood vulnerability variable, $\mu_{VFALERT}[x]$ is the value under an alert in flood vulnerability variable, $\mu_{VFDANGER}[x]$ is the value under dangerous conditions in the flood vulnerability variable.

Table 2. Parameters for input and output variables.

Variables	Term	Range	Domain
PD	Very Low	0 – 3750	[0 0 2250 3750]
	Low	2250-18750	[2250 3750 15000 18750]
	High	15000-30000	[15000 18750 26250 30000]
	Very High	26250– 30000	[26250 30000 30000 30000]
WL	Micro	0 – 10	[0 0 9 10]
	Mini	9 – 100	[9 10 90 100]
	Sub	90 – 500	[90 100 400 500]
	Macro	400 – 1500	[400 500 1400 1500]
	River basin	1400 – 1500	[1400 1500 1500 1500]
SL	Very Low	0 – 8	[0 0 5 8]
	Low	5 – 15	[5 8 12 15]
	Moderate	12 – 25	[12 15 22 25]
	Steep	22 – 40	[22 25 35 40]
	Very Steep	35 – 40	[35 40 40 40]
EL	Low	0 – 200	[0 0 175 200]
	Middle	175 – 400	[175 200 300 400]
	High	300 – 400	[300 400 400 400]
RF	Light	0 – 20	[0 0 15 20]
	Moderate	15 – 50	[15 20 40 50]
	Heavy	40 – 100	[40 50 90 100]
	Very Heavy	90 – 100	[90 100 100 100]
VL	Normal	123 – 248	[123 123 220 248]
	Alert	220 – 402	[220 248 374 402]
	Danger	374 – 402	[374 402 402 402]

3.1.2. Design hardware of FAST

Figure 2 describes the design system of proposed research consists these materials, namely power supply for the system using two batteries with Ni-MH rechargeable type. The TP-4056 is the battery charger, and the DC converter used to convert the battery voltage from 2.4 up to 5 V. The solar cells has the function of providing additional electricity to batteries coming from sunlight. Microcontroller: this is the center of controller all components such as sensors, GSM, and GPS. The input part consists of an ultrasonic sensor and a flows meter sensor. The ultrasonic sensor serves to detect the water level in the river, and the flow meter is used to calculate the velocity of the water. The output part consists of an LCD, LED, and Buzzer. Communication module contains two parts those are GSM module has the same function with LCD; the different is GSM module could send the status on the system through a mobile network from FAST to many of the listed phones. GPS module has a function to read the location of the sensors in the outdoor environment. It provides data including the longitude and latitude. These data are sending to the microcontroller from satellites in space and by microcontroller will be displayed on the LCD and SMS module.

3.1.3. Design software of FAST

The transmitter part has a function in sensing the water level, flow meter, and read the position or location of the sensor in the outdoor environment and then send the data to the receiver part. Figure 3 is the flowchart of the transmitter part. If the water level has status alert the system activated the short beep. If the water level has status danger, the system activated long beep buzzer. The status sending from transmitter to receiver.

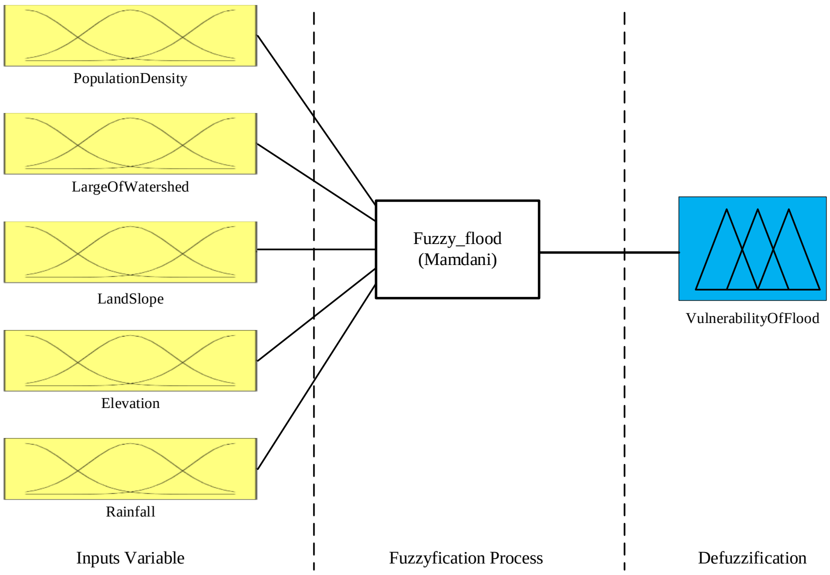

Fig. 1. Mamdani fuzzy block system.

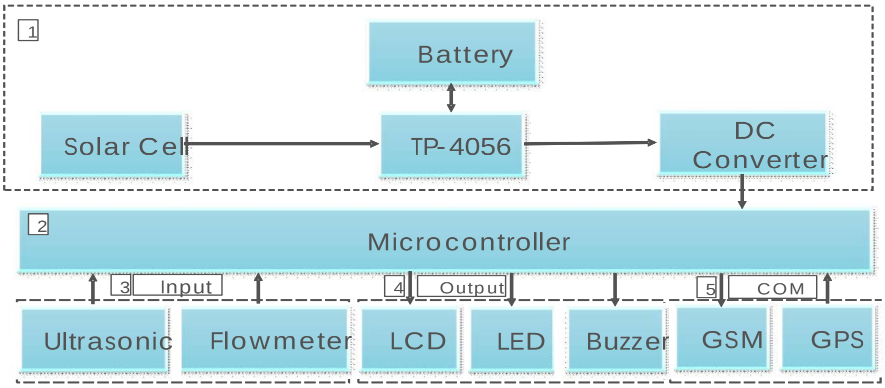

Fig. 2. Block system of FAST.

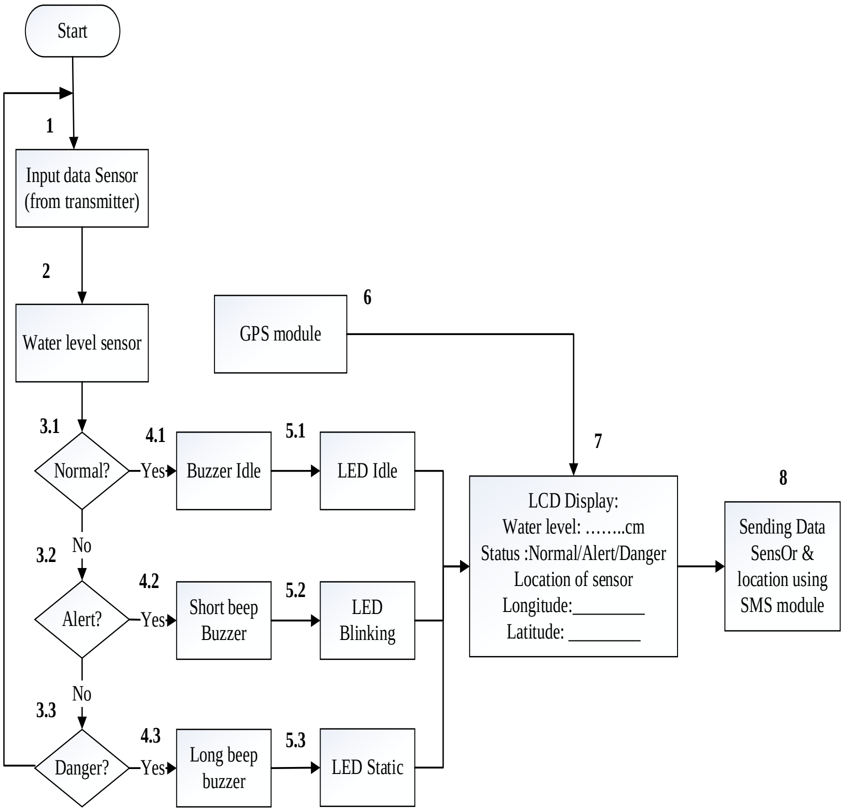

Fig. 3. Transmitter of FAST.

3.2. Mamdani Fuzzy in Danger Setup

The Population density variables obtained membership degrees for 25283 people/km2 that are $\mu_{PNP}[25283]=0, \mu_{PLP}[25283]=0, \mu_{PHP}[25283]=1$, $\mu_{POP}[25283]=0$. It means that the density of population is a high value with a membership degree of 100%. The watershed variables obtained membership degrees for 145 acres that are $\mu_{WSM}[145]=0$, $\mu_{WS}[145]=0$, $\mu_{WM}[145]=1$, $\mu_{WW}[145]=0$, $\mu_{WH}[145]=0$. It means that the watershed is a sub with a membership degree of 100%. The slope variables obtained a membership degree for 2% that are $\mu_{SLP}[2]=1$, $\mu_{SLSL}[2]=0$, $\mu_{SLST}[2]=0$, $\mu_{LSS}[2]=0$, $\mu_{LSEX}[2]=0$. It means that the slope is shallow, with a membership degree of 100%. The altitude variables obtained of membership degree for two above mean sea level (AMSL) that are $\mu_{EL}[2]=1$, $\mu_{EM}[2]=0$, $\mu_{EH}[2]=0$. It means that the altitude is low, with a membership degree of 100%. The rainfall variables was obtained for 105 mm that are $\mu_{RFL}[105]=0$, $\mu_{RFM}[105]=0$, $\mu_{RFH}[105]=0$, $\mu_{RFEX}[105]=1$. It means that the rainfall is weighty with a membership degree of 100%. The implication function is MIN function, by taking the minimum membership degree of the input as the output variables.

The output is the total of conclusion by taking maximum membership degree of each consequences implications function and aggregating of all the conclusion of each rule. Therefore, fuzzy solution area is obtained:

$\mu_{sf}(x) = maks\{\mu_{VF}(x)\} = maks\{1\}$

Rule of intersection node is if μ_{VF}= 1, therefore the value of *x* is determined:

$x = 374 + 28\ (1) = 374 + 28 = 402$

Thereby obtained the area solution of membership function is:

$\mu_{VF} = \{1\,; 402\ \leq x\ \leq 499\}$

The defuzzification used in determining the flood vulnerabilities are centroid, MOM, LOM, SOM, and Bisector.

a. Centroid. The value of the flood vulnerability is 450.5 and represent the danger category.
b. LOM (Large of Maximum Method). Take the most significant *z* value of the maximum membership degree value$(\mu(z))$. LOM is 499. Thus, based on the calculation of vulnerability in Bulu Lor, district is a danger category.
c. SOM (Smallest of Maximum Method). Take the smallest of *z* value of the maximum membership degree value $(\mu(z))$ according to Table 3 obtained, the SOM value is 402. Hence, based on calculation of vulnerability in Bulu Lor district is a danger category.

Table 3. Degree of membership $\mu(z)$ of central Java.

Rule	$\mu(z)$	Z
1	1	402
2	1	499

d. MOM (Mean of Maximum Method). Taking the mean z value of the maximum membership degree value $(\mu(z))$ in Table 3 obtained, the MOM value is 450.5. So, according to that calculation, the flood vulnerability in Bulu Lor district is a danger category
e. Bisector. As for the bisector value obtained by dividing two areas of membership degree and taking the *z* value higher than the result of the division value of membership degree in Table 3. The bisector value is 499. So, according to that calculation, the flood vulnerability in Bulu Lor district is a danger category.

3.3. Performance of SMS and GPS modules

Figure 4 show that data gathered through the SMS process. The data is manually interpreted by the user or local authority to declare the situation according to the sensor output. The notifications of the data obtained through SMS. The SMS notification consists of sensor location, water level, flow meter value, and the status of the river in real-time. By using programming, all the data can be interpreted directly when the sensor is detecting the water level and flow meter, whether in an alert or a danger state. In the development of the water level sensor, the data collected giving alert status when the distance range between 6 cm to 10 cm. The integration testing system with GPS receiver to lock onto a particular location of FAST, at least three such satellites are needed. Those satellites undergo a process called triangulation.

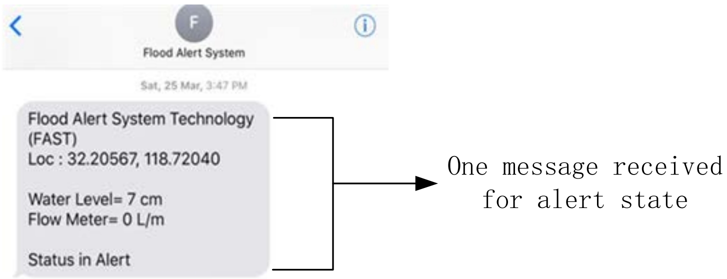

Fig. 4. Notifications of the data obtained through SMS determined status and location.

4. Conclusion

Based on testing the system of the flood disaster, the sensor to the object reads 0, 8, and 13 cm then the condition of the LED and buzzer indicates the next danger of flooding the modem send SMS «flood danger» and get to destination phone in 5 seconds. In the hardware, there are input devices in the form of ultrasonic sensor and flow meter where are functioned as water level reader and velocity of water then forwarded to the next device in the form of minimum system microcontroller that serves to process the input with the knowledge base that has been cultivated by the programmer and ordered the output device to turn on buzzer, indicator light and send SMS to destination phone in case of flood alert and flood danger.

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