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Flood Early Warning System with Informational Technology for Reducing Risk of Loss in Sustainability of City

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Abstract—Palembang is divided by Musi-river consisting of two parts of city called Hulu and Hilir. it has a height of Musi tide surface about 0.7 m to 2.2 m and average high rainfall 101.48 mm/hrs in a year so that it always happen flood every year. In tackling flood, Palembang goverment has did rehabilition of canals, river dredging, creation of retention ponds, demolition of illegal building on the banks of river and the extension services provided to the public about the cleanliness of the river. In addition in this study, it has been also applied infomational technology to tackle the flood in Palembang as early warning system. The flood early warning system that was built for measuring rainfall and water level, predicting flood condition using fuzzy logic and conveying data containing rainfall, water level and flood condition via short message service to people. In test, it was succesfull measuring water level up to 5 metres and rainfall up to 380 ml/minutes and more, forecasting the flood conditions namely standby 2, standby 1 and flood. Hence, it was also successfull sending short message service containing rainfall, water level and flood conditions automatically. In addition, the increase of rainfall caused the increase of water level and change of flood condition. Meanwhile, it was based on study that the flood early warning system was the key element of disaster risk reduction. From the results, it can be concluded that flood early warning system resulted on flood for 5.0 m, 320.31-418.33 ml/minutes, S1 for 4.0-5.0 m, 243.33-647.5 ml/minutes, S2 for less than 3.6 m, 414.17 ml/minutes. It succeeded in sending data of rainfall, water level and flood as much as 15 times to community's cellulerphone automatically so that it is reducing risk of loss againts flood and maintaining sustainability of city.

Keywords—flood early warning system, fuzzy logic, rainfalls, sustainability of city, sea water tide.

I. Introduction

Loss of settlements and agricultural for flood 25 year's in Indonesia was IDR.720 and 68 millions as presented on Sisi at al. [1] and based on another [2] that flood disaster 2002-2005 was 35 % of all events. Palembang is one of metropolitan that often floods due to high rainfall and tides of the Musi river and fewer low settlements that are almost close to the surface of the river, especially Palembang Ulu with original and flat topography under maximum high tide as presented on Belladona [3] in Supani [4]. It is essential that flood must be mitigated. There are some means that had been conducted in mitigating flood such as building dam or reservoir [5, 6]. It still has weakness because there is no early warning yet, while early warning is a key element of disaster risk reduction as presented on Fakhruddin et al. [7].

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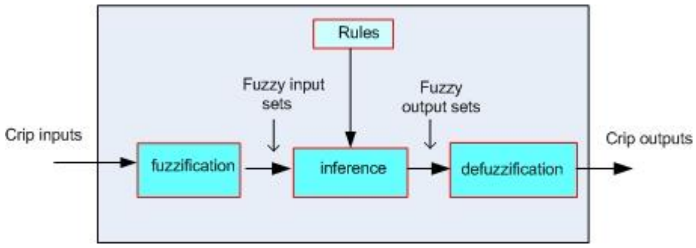

Fig. 1. Fuzzy logic architecture [13]

The applying of a information technology system to cope flood can be conducted as early warning. In previous research, early warning systems with informational technology has been conducted as presented on [8-10], but they are only simulation of software. There are also ways of flood management system for reservoirs [11] and advanced river flood monitoring, modelling and forcasting [12], but these two ways were also conducted in software simulation. The five ways were not automatic to measure rainfall, water level and flood condition and to convey them to community in real time. They are a management policy as decision support.

In this paper, it was studied in building a flood early warning system measuring rainfall and water level of river by sensors automatically, prosesing them using fuzzy logic to get the predicted flood condition results and conveying predicted results as flood condition by system using short message service gateway.

II. Methods

A. Study Approach

The research had limited the scope of the study within two system inputs which are the water level and rainfall of Musi. These parameters commonly cause flood in Palembang especially the settlements are close to the surface of Musi. Since the study was focusing on building a flood early warning system that is capable of conveying three flood conditions via sms gateway to people, the study had used fuzzy logic to predict the flood conditions.

Fuzzy logic system consists of four parts, namely fuzzification, rules, inference engine and defuzzification. Fig. 1 shows the general architecture of the system components and fuzzy logic as presented on Singhala et al. [13].

Three variables of fuzzy logic was designed in system which were water level (X), rainfall (Y) and flood forecasting (Z). X and Y is inputs of system and Z is output of system as shown in Table 1.

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Table 1. Fuzzy variables

Functions	Variables	Ranges	Units
Input	X	[0, 5]	metres
	Y	[0 500]	ml/minutes
Output	Z	[1, 5]	seconds

Source : research document

Table 2. Fuzzy sets

Variables	Fuzzy set names	Domains	Units
	Low (L)	[0, 2.5]	metres
X	Medium (M)	[1, 4]	metres
	High (H)	[2.5 5]	metres
	Light rain (LR)	[0 0 70 190]	ml/minutes
Y	Normal rain (NR)	[70 190 310]	ml/minutes
	Heavy rain (HR)	[190 310 380]	ml/minutes
	Flood	[0 1 1.5]	seconds
Z	S1	[1 1.5 2]	seconds
	S2	[1.5 2 5 5]	seconds

Source : research document

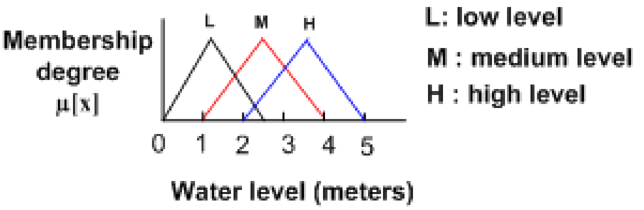

Fig. 2. Membership function of water level

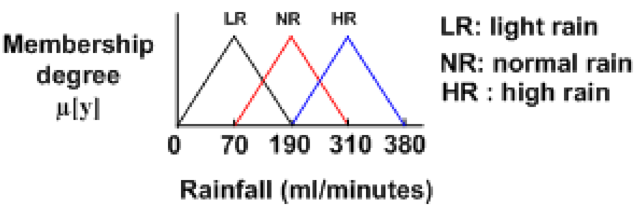

Fig. 3. Membership function of rainfall

Fig. 4. Membership function of flood conditions

The variable of X with ranges of 0-5 metres was water level where values of X were gotten from sensor of water level. And Y with ranges of 0-500 ml/minutes was rainfall where values of Y were gotten from sensor of rainfall. And Z was for time determination of flood condition which was set to 1-5 seconds. Every variables was determined the fuzzy sets as shown in Table 2.

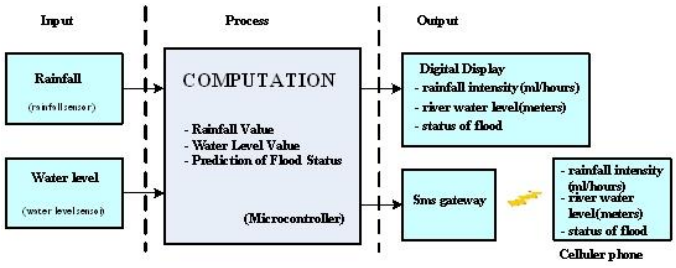

Fig. 5. A designed block diagram

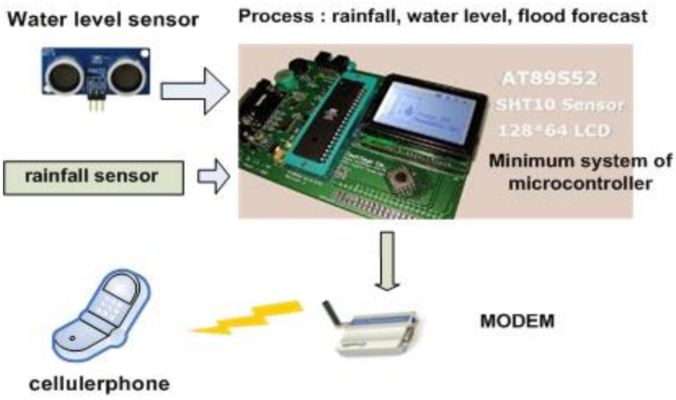

Fig. 6. An actual block diagram

Every variable in Table 2 has three fuzzy sets. X was designed having L, M and H fuzzy sets with domain ranges of 0-2.5 metres for L, 1-4 metres for M and 2.5-5 metres for H. Y was also designed having LR, NR and HR fuzzy sets with domain ranges of 0-190 ml/minutes for LR, 70-310 ml/minutes for NR and 190-380 ml/minutes for HR. Hence, Z was also designed having Flood, S1 and S2 fuzzy sets with domain ranges of 0-1.5 seconds for Flood, 1-2 seconds for S1 and 1.5-5 seconds for S2.

Menwhile, fuzzy set of water level was depicted as shown in Fig. 2. Hence, fuzzy set of rainfall was depicted as shown in Fig. 3. Lastly, fuzzy set of flood conditions was depicted as shown in Fig. 4. A block diagram of flood early warning system was built as shown in Fig. 5 having input, process and output parts as presented on Supani [14].

Rainfall in part of input was a sensor of rainfall with specifications that was selected based on data from both Climatology Station of Stage I Kenten and Sultan Mahmud Badarudin II airport Station. Water level in part of input was also a water level sensor having specifications that selected based on data from Climatology Station of Stage I Kenten. A designed block diagram was implemented into a actual block diagram aiming to see physically shape of device as shown Fig. 6.

B. Field observation

The study was conducted on Musi river which is in Palembang city South Sumatera Indonesia. Musi had water level on tide time which was 2.7 m and -0.2 m based on Climatology Station of Stage I Kenten captured as online on May 20th, 2016 local time: 16.00. Meanwhile, rainfall was low on September, October and November 2015, but on December 2015 was high.

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Table 3. Rain grouping

No.	rainfall (ml/hours)	Rainfall status
1.	0 - 100	low
2.	101 - 300	medium
3.	301 - 500	high
4.	> 500	very high

Source : Sultan Mahmud Badarudin II airport Climatology station

Table 4. Rainfall for ten years

No.	Years	Rainfall Average (ml/hours)
1.	2002	172,2
2.	2003	82,8
3.	2004	119,4
4.	2005	127,2
5.	2006	143,3
6	2007	121,2
7	2008	122,1
8	2009	102,8
9	2010	133
10	2011	133

Source : Sultan Mahmud Badarudin II airport Climatology station

Average rainfall was 101.48 ml/hrs in a year and grouped as shown in Table 3. While the rainfall based on Sultan Mahmud Badarudin II airport Station was medium for ten years as shown Table 4.

These data those was from two stations was used in the study as representation to make prototype of flood early warning system. Hence, it was carried out testing of flood early warning system built by means of measuring values of rainfall and water level directly. It was made simulation of rain and water level in a container having size of volume 40 x 60 x 50 cm. The height of container was 50 cm that had a scale of 1:10. So, 50 cm in height is similar to 5 m.

III. Results And Discussion

The testing result of water level (X), rainfall (Y) and flood prediction (Z) was presented on Table 5. Table 6 was testing results of early flood warning system sending and recieving measured data consisting of rainfall, water level and flood condition via short message service (SMS). Flood condition was data which prosessed by fuzzy in flood early warning system.

Based on the data on Table 5, variable values of Rainfall (Y) are a constant 190 ml/minutes and variable values of water level (X) were increased from 2.5 m to 5 m gradual. Z was resulted increase from 1.5 at level 2.5 m to be 3.34 at level 3.5 m but constant at level 4 m and 5 m were 3.38 and this flood condition was standby 2. And then, Y was set to constant 250 ml/minutes. X was increased from 2.5 m to 5 m. Z was resulted 0.926 at level 2.5 m and constant 2.55 at every level 3-5 m. At level 4 m and 5 m, the flood conditions were standby 2 and standby 1. Meanwhile, Y was set to constant 310 ml/minutes. X was increased from 2.5 m to 5 m. And Z was gotten contant 0.621 for every level from 2.5-5 m. At level 3 m, 4 m and 5 m, the flood conditions were standby 2, standby 1 and flood consecutively.

Table 5. Testing results by an increased water level every rainfall

Y (ml/minutes)	X (metres)	Z	Remarks
190	2.5	1.5	
	3.5	3.34	
	4	3.38	
	5	3.38	standby 2 (S2)
250	2.5	0.926	
	3	2.55	
	4	2.55	standby 2 (S2)
	5	2.55	standby 1 (S1)
310	2.5	0.621	
	3	0.657	standby 2 (S2)
	4	0.621	standby 1 (S1)
	5	0.621	Flood
380	2.5	0.621	
	3	0.657	standby 2 (S2)
	4	0.621	standby 1 (S1)
	5	0.621	Flood

Source: research document

Table 6. Testing results sent and recieved data via SMS

No.	Rainfall (ml/minutes)	Water Level (m)	Sent-Recieved Flood Condition Message
1.	183.75	5.0	Standby 2
2.	252.50	5.0	Standby 1
3.	275.94	5.0	Standby 1
4.	320.31	5.0	Flood
5.	342.81	5.0	Flood
6.	347.50	3.4	Standby 2
7.	414.17	3.6	Standby 2
8.	647.50	4.2	Standby 1
9.	280.83	3.0	Standby 2
10.	346.67	3.0	Standby 2
11.	454.17	4.0	Standby 1
13.	243.33	5.0	Standby 1
14.	418.33	5.0	Flood
15.	335.00	5.0	Flood

Lastly, Y was set to constant 380 ml/minutes, X was increased from 2.5 m to 5 m and Z was gotten constant 0.621 for every level from 2.5-5 m. At level 3 m, 4 m and 5 m, the flood conditions were standby 2, standby 1 and flood consecutively.

Both Y and X were increased similarly so that Z that was resulted was decrease. Z was gotten constantly which was 3.38 at Y=190 ml/minutes, X=3.5-5 m. Z was gotten constantly which was 2.55 at Y=250 ml/minutes, X=3-5 m. Z was gotten decrease previously and constantly which was 0.621 at Y=310-380 ml/minutes and X=2.5-5 m. So, flood early warning system that has been tested resulting that both Y as rainfall and X as water level which were getting more increase, flood condition was getting more approach Standby 2 (S2), Standby 1 (S1) and Flood based on fuzzy sets of X and Y those were implemented. And X was gotten increase which was caused by Y that was increased.

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Table 6 was a testing result of flood early warning system pumping water into the container and sending three data consisting of rainfall, water level and flood condition directly via short message service (SMS). Sent message testing were 15 times repeatedly which resulted on three recieved flood condition messages, water level and rainfall on reciever or people smartphone. 15 testings were sent data by flood early warning system and were recieved same 15 times with same data by community's cellulerphone in real time.

The higher rainfall and water level caused flood on 320.31 ml/minutes, 342.81 ml/minutes, 335.00 ml/minutes, 418.33 ml/minutes and 50 cm, as on Table 6. Recieved flood condition message for Standby 1 were 40 cm up to 50 cm and 243.33 ml/minutes up to 647.5 ml/minutes. Hence, recieved flood condition message for Standby 2 were less than 36 cm and 414.17 ml/minutes, especially 50 cm in height and 183.75 ml/minutes in rainfall. So, flood early warning system resulted on that higher rainfall and water level caused flood. And it has three flood condition and SMS gateway to convey data of rainfall, water level and flood condition.

Based on that, once the flood early warning system applying short message service gateway would be implemented to Indonesia's people especially Palembang community in future, the risk of loss towards victim of properties and deaths will reduce or delete. Therefore, sustainability of city againts flood can be achived.

IV. Conclusion

Flooding occurs at level 5 m and rainfall is more than 320.31 ml / minutes. And for standby 1 condition, water level is always almost 5 m. Others, there are 2 conditions for standby 1 at a height of 4.0 m and 4.2 m with a rainfall of 647.5 ml/minutes causing fuzzy computes standby 1 condition. Standby 2 condition occurs at water level 3-3.4 m and range of waterfall is 280.83-347.5 ml/minutes but it also occurs at water level of 5 m and waterfall of 183.75 ml/minutes. All results predicted by fuzzy are sent to communities via sms gateway.

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