1. Introduction
Flooding is an event that occurs when water overflows, caused by various factors. For example, in drains or sewers that experience blockage or excessive water discharge or overflow of river water that overflows because the water clogged the others are human activities, land use and climatic condition etc. [1]. Sometimes the river is not only clogged, but also a lot of water discharge can also cause flooding such as uncontrolled dumping of solid waste and siltation [2]. Rivers do not only form one stream but usually, the river will split into several river branches. So that the water flow from upstream does not always go to the same river. The flow can split into several another river branch [3]. The River is a part of the landscape that trough from upstream to downstream. River can’t be separate from world landscape such as cities [4]. Water that flows on the river comes from several forms such as water sources, groundwater, rain, drainage disposal, precipitation, dew, underground runoff, snow that melt etc. [5, 6, 7]. Because of this, the water flowing in the river comes from several sources so it is very difficult to predict, hold, overcome or avoid water that adds volume to the river so it will be difficult to predict the flow of water that passes through.

One of the biggest causes of flooding is rain discharge which is difficult to predict from climate change [8]. For example, if it is on a rainy highland river, while the lowland does not rain, it will cause a surge in water discharge in the river branch in the lowlands. So that if there is rain on the main river in the rainy highlands, then rain also with high discharge in the lowlands can cause flooding in the lowlands. While in another river branch that is not raining, the river water flow will remain stable. This is a problem because the water discharge from the highlands cannot be divided properly.
In urban areas in the lowlands, rivers play an important role in the city’s ecosystem [9]. So that some cities have implemented sluice gates to keep the passing water flow from causing flooding. So that the sluice is a very important instrument to maintain stability in control of river conditions. The sluice the way it works is by opening and closing. If the water debit is high, the sluice gate will be opened. But if the water debit is considered low, it will be closed. This sluice opening and closing system is often done manually and only considers the water level factor, but does not consider rainfall in the core and river branch. Sluice doors are often made close to the city or downstream of the river in the lower stream. This is a problem because the water from the core river has already gone to one of the river branch, not to another river branch [10]. Here shows the problem that is often found in the definition of water level parameters and the placement of sluices that are less precise. The parameter that causes the water level in this problem is the amount of water discharge and rainfall, and the laying of sluices not on the branching between the Core River and river branch.

The research that works on how to control the water flow route use some parameters on local hydrologic condition and habitat suitability criteria. But the research is not directly control the water flows [3]. The other research is only predict the climate change that caused flooding [9, 11, 12] but not directly control the river condition. The river water flow can be modelling by some engineering models [6, 7], one of the following models is by changing hydrological condition [8].

The sensor that can be used to detect water level is using an ultrasonic sensor [13]. One type of sensor is a water level sensor, which has fairly good performance is the Solu Water Sensor. Whereas to detect rain level is the Rain Sensor Arduino Module [14]. This sensor can work well if integrated with Arduino. So that Arduino is used in this study. Arduino Mega 2650 is the most reliable type of Arduino itself for the prototyping process [15]. This type of Arduino has a large enough memory, so it can process more data than other types of Arduino. Whereas for the opening or closing of floodgates, a DC servo motor is used. The flow of water through rivers varies greatly so that in the computational process it will cause dynamic values. One algorithm to overcome this difference value is Fuzzy Logic [12]. Fuzzy logic is one of the best algorithms to overcome value differences to overcome the ambiguity of values obtained. So that the output of this algorithm is judged to be maximal. But Fuzzy Logic has not been able to regulate the opening of doors properly to divide fair values across multiple outputs. So that further weighting is needed to process the output. One algorithm that can provide good weighting is Simple Additive Weighting (SAW) [16].

So we need a system that can detect water levels and rainfall so that the sluice opening and closing can be done automatically. In this research, we will make a prototype of how to design a system for controlling water flow based on water discharge and rainfall for river flow. Where the river is divided into the main river or Core River and several tributaries. So that the water flow through the tributary will be well divided. So that the potential for flooding in a location where flowing tributaries will decrease. The algorithm used to calculate water discharge and rainfall as well as the river door closure system is Fuzzy Logic and SAW. Fuzzy logic will process input data from rainfall and water discharge. Then after the output from Fuzzy Logic is obtained, it will be processed again with SAW to carry out the process of opening and closing the sluice gates so that the river water level can be maintained properly and the potential for flooding can be reduced.

2. Research Method
This research will be carried out gradually among other river modeling, model inputs, model-Fuzzy Logic, Simple Additive weighting model and the last model the output of the servo motors. For the modeling of its steps can be seen in the following system Block Diagram in Figure 1.

![Figure 1. System Block Diagram.](image-url)
For datasets use values obtained from data from observations around river flows in Jakarta, Indonesia. The place was made to model because Jakarta is the capital of Indonesia and one of the major cities in Indonesia. Water level sensors model water levels and the Rain Level Sensor models rainfall. For the river model it uses 3 river branches. The branching of the river itself has used 3 branches of the river because this form is often found in river branches that can be seen in Figure 2. Even though river branches sometimes only have 2 branches or more than 3 branches. In a river that has 3 branches as modeled on the image. Flow Control System position are in river branch or upstream branches, not placed on the downstream branch. This is because so that the distribution of water discharge can be done early on the branching, so that the distribution of water discharge can be carried out in the branching rather than downstream of the river branch so that the water flow can be divided earlier.

On the Flow Control System, a Servo Motor is installed to control the water discharge that passes through the river branches. The placement of the sensor itself is placed differently, for water level, placed on the Flow Control System. But the placement of the Rain Sensor is not on the Flow Control System but is placed on the Lower River, which is marked with the letter B in Figure 2. Because the rain that occurs in the area around the downstream of the river will be able to increase the water river flow. This research models use a 1:10 scale.

![Figure 2. River Models.](image)

2.1. Fuzzy Logic
The next step is to model-Fuzzy Logic. Generally Fuzzy Logic divided into several steps, i.e. mapping the membership function, rule evaluation, and then defuzzification process. Generally, the steps in Fuzzy Logic are the same, but in a different defuzzification process. This study, using Fuzzy Mamdani type to control the opening height of Servo Motor. The models created from data by Indonesian Ministry of Public Works [17].

![Figure 3. Water Level Membership Function.](image)
The first thing is to model the membership functions based on data from the dataset that owned. The scale of this study is 1:10 to model the actual conditions. So that the membership will be given the same scale as well. Suppose for the condition of "Low" in the real condition is 0-150 cm, so this prototype is used 1-150 mm for variable water level. The membership function for Water Level can be seen in Figure 3.

As with water level, for rainfall variables a scale of 1:10 is also given. For data obtained for example for membership "Low" is 0-5 mm. So if the scale is adjusted it will be 0-50mm that could see on Figure 4. The dataset created from data that provided by BMKG [18].

Each for height and rainfall is modeled in four (4) membership functions. After the membership function is formed, a Rule Evaluation will be created. If of two (2) variables each of which has four (4) membership. Then the Rule obtained is a combination of 16 Rule as in Table 1. The rule that obtained, processed by “and” function to process the maximum value.

| Rules Number | Water Level | Rainfall Level | Rules |
|--------------|-------------|----------------|-------|
| 1            | Low         | Very High      | Mid   |
| 2            | Low         | High           | Mid   |
| 3            | Low         | Mid            | Low   |
| 4            | Low         | Low            | Low   |
| 5            | Mid         | Very High      | High  |
| 6            | Mid         | High           | High  |
| 7            | Mid         | Mid            | Mid   |
| 8            | Mid         | Low            | Low   |
| 9            | High        | Very High      | Very High |
| 10           | High        | High           | Very High |
| 11           | High        | Mid            | High  |
| 12           | High        | Low            | Mid   |
| 13           | Very High   | Very High      | Very High |
| 14           | Very High   | High           | Very High |
| 15           | Very High   | Mid            | High  |
| 16           | Very High   | Low            | Mid   |
Next to Fuzzy Logic is modeling membership from defuzzification. In this model, we use four (4) models also for Servo Motor membership.

![Graph showing Servo Motor Defuzzification](image)

**Figure 5.** Servo Motor Defuzzification.

From "Low" to the opening that is very wide to "Very High" for the condition of the door that completely closed. In Figure defuzzification a scale of 1:10 is also used. If the real condition uses 140 cm, then the prototype will use 140 mm. This defuzzification model is using the Mamdani Mean of Maximum (MoM), the models can be seen on Figure 5 and the equation (1). The models created by data that served by Indonesian Ministry of Public Works [17].

\[
Z = \frac{\sum_{j=1}^{n} z_j}{i} \tag{1}
\]

### 2.2. Simple Additive Weighting (SAW)

After doing the model from Fuzzy Logic, the results released by Fuzzy Logic will be entered into the SAW. SAW is often called the weighted sum, this method is often used to perform Multi-Attribute Decision Making (MADM) because it is very possible if the Sluice has a different height level. At SAW the decision matrix normalization process (X) is carried out on a scale compared to all available alternative sources. The total score for opening the door is an alternative by summing all the multiplication results between ratings (obtained from the entire Flow Control System) and the weight of each attribute. The SAW matrix equation (2).

\[
r_{ij} = \begin{cases} 
\frac{x_{ij}}{\max_i x_{ij}} & \text{if } j \text{ is benefit} \\
\frac{\min_i x_{ij}}{x_{ij}} & \text{if } j \text{ cost} 
\end{cases} \tag{2}
\]

On this research, the function used is cost. So we use Min function to operate the Servo Motor. The equation input used from membership output from Fuzzy Logic, “Min” used to calculate the minimum function to operate servo motor/floodgates, “xij” used to calculate water level “i” and rainfall “j”. After the minimum cost calculated, that cost calculate with the function on equation (3).

\[
V_i = \sum_{j=0}^{n} W_j r_{ij} \tag{3}
\]

This function (2) as a preference, used to calculate each floodgate opening height. So from three “3” floodgates could operate together with different opening height.

### 3. System Testing
This section will explain how the system is tested along with the test results. The test results will show how the system's capabilities are produced. Testing will be carried out in various stages including testing of Water Level Sensors, Rain Level Sensors, Testing Methods, and Functional Testing Scenarios. The hope is that the prototype of this system will provide an overview of suitability between problems with research methods. So the results can be further developed.

3.1. Rain Level Testing Scenario
This test scenario is carried out as before. Rain Level Testing scenario is used to test whether Rain Sensor can work properly or not. For the classification of the amount of rainwater discharge based on dataset. So that refers to the previous table that the classification is done, then the test results are as in the following table. The table shows that Rain Sensor is capable of producing data and can be used for system prototyping. The classification is not easy to create, the classification conducted by trial error from prototyping tool. Tests are carried out 80 times and that can be seen on Table 2.

| Test number | Data Set | Sensor Result |
|-------------|----------|---------------|
| 1           | 1020     | Not Rain      |
| 2           | 223      | Very High     |
| 3           | 481      | Average       |
| ...         | ...      | ...           |
| 78          | 311      | Very High     |
| 79          | 732      | Low           |
| 80          | 253      | Very High     |

3.2. Water Level Sensor Testing Scenario
This test was done to test the water level. This test is done by inserting the sensor into the water and measuring the water level with a digital ruler. Each sensor was tested 16 times. So that the total test for the Water Level sensor is 64 times. The test results in the table show that the biggest error produced is 0.664% and the smallest is 0.332%. The average error given is 0.396%. The error given is quite small, so the system prototyping is very good that can be seen in Table 3.

| Sensor Number | Average Error (%) |
|---------------|-------------------|
| Sensor 1      | 0.664             |
| Sensor 2      | 0.605             |
| Sensor 3      | 0.583             |
| Sensor 4      | 0.332             |
| Grand Average Error | 0.396 |

3.3. Servo Motor Testing
Testing on this servo motor is used to calculate the degree of accuracy of the servo. Servo in this system is used as a means for opening and closing water gates. In Table 4, the test is carried out 176 times, with each sensor given a test 44 times. For all tests, the average angle of the servo gets an error of 4.79%. The numbers obtained still allow for system prototyping.
Table 4. Servo motor testing result.

| Servo Number | Average Error (Degree) | Average Error (%) |
|--------------|------------------------|-------------------|
| Servo 1      | 2.4                    | 3.78              |
| Servo 2      | 2.9                    | 4.11              |
| Servo 3      | 2.8                    | 5.03              |
| Servo 4      | 3                      | 6.24              |
| Grand Average Error |                  | 4.79%            |

3.4. Functional Testing Scenario
This test is done to get the suitability of the input with the output function. Tests are carried out as a whole to assess the performance of the system. Starting from sensor readings, Fuzzy Logic processes, SAW processes to the opening process of Servo Motor. The testing scenario is carried out in four stages. This is done by giving river and rainwater water discharge. Then do measurements with different water loads. In Table 5 are the results of the functional testing scenario. The table shows that the overall error generated by the system is 0.099%. So this prototype can work really well.

Table 5. Functional testing scenario result.

| River               | Average Error (%) |
|---------------------|-------------------|
| Main River          | 0.196             |
| 1st River Branch    | 0.089             |
| 2nd River Branch    | 0.093             |
| 3rd River Branch    | 0.017             |
| Overall Average Error | 0.099         |

4. Conclusion and Future Works
Based on the results obtained from the design and implementation of the system, a number of things can be concluded. The first is to anticipate the occurrence of flooding due to water discharge and rainfall by making a Flood Control System. The laying of the system is in river branches, not downstream. But the sensor also has a different placement, for water level sensors placed in the same area as the Flood Control System. For Rain Level sensors, given to the area around the downstream of the river.

The results of this system are quite good, for Water Level Sensors given an average error of 0.396%, Rain Level Sensor can work well, Servo Motor Sensor error 4.39, and the overall function is 0.099%. In total, the error given to this prototype is quite good, but for Servo Motors, the error is still quite large. This gives a significant impact on the errors generated. This research is good enough to model floods because it has accommodated water levels and rainfall.

However, this research still does not fully accommodate the problem of flooding, but can still be further developed from various things. Suppose the addition of parameters given by the culvert of a settlement or other problems. Then parameters such as water speed can also be added to further research. But it does not rule out the possibility if there are additional other parameters or other algorithms that are better than the combination of Fuzzy Logic and SAW.

5. References
[1] Rawshan Othman Ali; Zhao Chunju; Zhou Yihon; Muhammad Imran Azam, "The effects of human activities, climatic conditions and land-use factors on water resources development in
huai river basin northeast china," International Journal of Hydrology, vol. 2, no. 2, pp. 112-113, 2018.

[2] Tanaya Sarmah; Sutapa Das, "Urban flood mitigation planning for Guwahati: A case of Bharalu basin," Journal of Environmental Management, vol. 206, pp. 1155-1165, 2018.

[3] Maloney, Kelly O.; Talbert, Colin B.; Cole, Jeffrey C.; Galbraith, Heather S.; Blakeslee, Carrie J.; Hanson, Leanne; Holmquist-Johnson, Christopher L., "An integrated Riverine Environmental Flow Decision Support System (REFDSS) to evaluate the ecological effects of alternative flow scenarios on river ecosystems," Fundamental and Applied Limnology, vol. 22, pp. 171-192, 2015.

[4] Maraja Riechers; Jan Barkmann; Teja Tscharntke, "Perceptions of cultural ecosystem services from urban green," Ecosystem Services, vol. 17, pp. 33-39, 2016.

[5] John KanayoChukwu Nduka; Vincent Nwalieji Okafor; Isaac Omoche Odiba, "Impact of Oil and Gas Activities on Acidity of Rain and Surface Water of Niger Delta, Nigeria: An Environmental and Public Health Review," Journal of Environmental Protection, vol. 7, pp. 566-581, 2016.

[6] Mu-Hao Sung Wang; Lawrence K. Wang, "Environmental Water Engineering Glossary," Advances in Water Resources Engineering, vol. 14, pp. 471-556, 2014.

[7] Nicolas R. Dalezios; Andreas N. Angelakis; Seyed Saeid Esalman, "Water scarcity management: part 1: methodological framework," International Journal Global Environmental Issues, vol. 17, no. 1, 2018.

[8] Shahar Rozalis; Efrat Morin; Yoav Yair; Colin Price, "Flash flood prediction using an uncalibrated hydrological model and radar rainfall data in a Mediterranean watershed under changing hydrological conditions," Journal of Hydrology, vol. 394, no. 1-2, pp. 245-255, 2010.

[9] Laurent Pfister; Jaap Kwadijk; André Musy; Axel Bronstert; Lucien Hoffmann, "Climate change, land use change and runoff prediction in the Rhine–Meuse basins," River Research and Application, 2004.

[10] J. Kalpakian, Identity, Conflict and Cooperation in International River Systems, London: Routledge, 2004.

[11] M. K. Alsmadi, "Forecasting River Flow in the USA Using a Hybrid Metaheuristic Forecasting River Flow in the USA Using a Hybrid Metaheuristic," Scientific Journal of King Faisal University (Basic and Applied Sciences), vol. 18, no. 1, 2017.

[12] Edangodage Duminda Pradeep Perera; Livia Lahat, "Fuzzy logic based flood forecasting model for the Kelantan River basin, Malaysia," Journal of Hydro-environment Research, vol. 9, no. 4, pp. 542-553, 2015.

[13] Konstantinos Loizou; Eftichios Koutroulis, "Water level sensing: State of the art review and performance evaluation of a low-cost measurement system," Measurement, vol. 89, pp. 204-214, 2016.

[14] A. Y. Ardiansyah; R. Sarno; O. Giandi, "Rain detection system for estimate weather level using Mamdani fuzzy inference system," in 2018 International Conference on Information and Communications Technology (ICOIACT), Yogyakarta, Indonesia, 2018.

[15] Carlos Morón; Jorge Pablo Diaz; Daniel Ferrández; Pablo Saiz, "Design, Development and Implementation of a Weather Station Prototype for Renewable Energy Systems," Energies, vol. 11, no. 9, p. 2234, 2018.

[16] Mukesh Raj Kafle; Narendra Man Shakya, "Multi-Criteria Decision Making Approach for Flood Risk and Sediment Management in Koshi Alluvial Fan, Nepal," Journal of Water Resource and Protection, vol. 10, no. 6, 2018.

[17] I. M. o. P. Works, "Standar Door Irrigation Manager: Planning, Installation, Operation and Maintenance," Jakarta, Indonesia, 2013.

[18] "BMKG Official Website," Meteorological, Climatological, and Geophysical Agency (BMKG), [Online]. Available: http://www.bmkg.go.id/. [Accessed 19 7 2018].
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