Flood Annunciator Innovation Based on Artificial Intelligence Technology

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Abstract. Flooding is a natural disaster phenomenon that often occurs in Indonesia. It is not only caused by high rainfall that causes an increase in river water volume, but also by other factors such as obstructed river flow due to accumulation of garbage. Floods can negatively impact the surrounding environment, causing damage to river ecosystems, economic losses that disrupt economic activities, property damage, and even loss of life. This research is an innovative approach combining Artificial Intelligence with image classification technology that can recognize objects in images and overcome the urgency of flood disaster problems by applying Fuzzy Logic as a decision-maker. The innovation target of this research is to apply image processing using Convolutional Neural Network, where the system will read comparison data in the form of videos to determine whether the area is flooded or not. These analysis parameters will be combined with other sensors, including a tipping bucket rain gauge sensor to detect rainfall, a JSN-SRT04 ultrasonic sensor to measure river water level, and an FS300A sensor to measure flowing water discharge. Integrating these four input parameters uses fuzzy logic to produce consistent decision outputs. The flood detection system is also equipped with a real-time monitoring feature through the website, allowing remote monitoring of flood conditions. Thus, through several innovative steps that have been designed in this research, can contribute to efforts to reduce and even eliminate the impact of flood disasters in the form of economic losses, environmental damage, and even casualties.

Keywords: Flood, Artificial Intelligence, Fuzzy Logic.

1 Introduction

Floods are one of Indonesia's most common and frequent types of natural disasters. During the period 2021 to 2023, 1804 floods were recorded in Indonesia, with 99 floods recorded in South Sumatra. The top three countries are China, the United States, and the Philippines, followed by Indonesia. The most significant types of disasters that occurred in Indonesia in 2008 were hydrological disasters related to flooding, as well as geophysical disasters related to earthquakes. Floods are not only

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triggered by high rainfall that causes an increase in river volume but can also be caused by a less-than-optimal drainage system and the geographical condition of the environment located in low-lying areas, which causes puddles on the streets [1].

One study applied the principle of Archimedes' Law using a cork. When the water rises, the cork will lift the copper piercing to touch the resistor due to buoyancy. The resistor functions as a switch that indicates a flood detection alarm. In addition, several studies focus on using sensors controlled by microcontrollers to read water levels in rivers or other water storage areas. Upon detecting that the water level has crossed the specified setpoint limit, the system responds with a warning. The system has a limited coverage area, as it can only identify rivers, reservoirs, or other water storage areas. However, a similar method cannot be used in some places with no water reservoirs, requiring an alternative solution.

One form of solution to these problems is to build an artificial intelligence-based system that can learn independently (Machine Learning). It can distinguish conditions where there are flood inundations and during normal conditions. This system uses image processing methods. Image processing techniques can manipulate images to improve image quality or extract information from the image. This research includes low-level processing because it uses basic operations to process images. Image processing itself is a derivative science of artificial intelligence [2]. One method that is quite popular and in great demand to date is the Convolutional Neural Network (CNN). The CNN method itself has evolved to reduce the level of difficulty in detecting images independently.

CNN algorithms are often used to classify and detect objects. CNN is a more complex artificial neural network architecture because it includes deep learning and many hidden layers. The CNN approach itself is most efficiently used in image processing because it trains data with a specific epoch on each hidden layer that performs various functions to determine the characteristics of the data entered without having to create a network of neurons one by one manually. CNNs can process image data at a relatively fast speed and automatically extract important features from images without requiring manual coding. The technique can also cope with variations in size, rotation, and shift in the image, which allows image classification to be performed more accurately [3].

Contour analysis parameters will be added to devices that provide input categories. These include a tipping bucket rain gauge sensor to detect rainfall, a JSN-SRT04 ultrasonic sensor to calculate the height of the river water level, and an FS300A sensor that provides input in the form of a flowing water discharge value. So that the four input parameters with different categories can be integrated to provide the desired decision output, the combination of the four will undergo a fuzzy logic process. Fuzzy logic has an ability similar to reasoning in the human brain, where a set can represent four linguistic variables at once based on the value of the degree of membership with a particular membership function. This is done so that each input component does not provide different decisions but has considered each parameter so that it provides a result value following the expected range. In addition, this

real-time flood detection system device also has an additional feature where any information from the resulting output can be monitored via the website remotely, making it easier to provide the latest information about the state of flooding in the environment around which the device is placed.
Given the many flood phenomena that occur, this research is of critical importance to be carried out to build a precise and actual flood detection early warning system using image processing based on convolutional neural network (CNN) and fuzzy logic so that it is expected to reduce and/or eliminate the impact of flood disasters in the form of property losses, environmental damage, and even the emergence of casualties as a form of community obligations in carrying out disaster management.

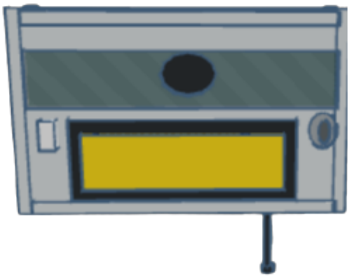
2 State of The Art

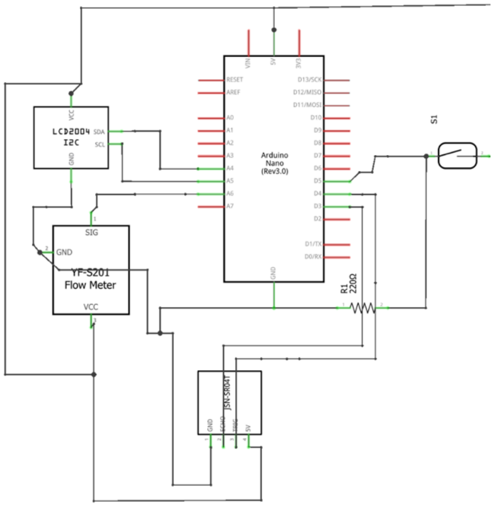
Image processing is a critical component in the development of flood annunciators, focusing on converting images into a digital format for analysis. This involves treating images as 2D signals and applying predefined signal processing methods. The process begins with per-pixel image processing, where operations are performed sequentially on each pixel of the image. The output from these operations can provide valuable information about the state of the environment, making it essential for real-time flood detection systems [2].
Neural Networks (NN) and Artificial Neural Networks (ANN) draw inspiration from the human nervous system, consisting of input, hidden, and output layers. They are particularly effective in processing complex data, making them suitable for image classification tasks in flood detection. Building upon this foundation, Convolutional Neural Networks (CNNs) have emerged as a powerful tool in image processing, featuring multiple layers such as convolutional, pooling, and fully connected layers. Initially developed for handwriting recognition, CNNs are now widely applied in various domains, including flood detection, due to their ability to learn and extract features from images efficiently [4].
In contrast to the structured approach of neural networks, fuzzy logic provides a method for mapping input spaces to output spaces using linguistic variables and membership degrees. Introduced by Lotfi A. Zadeh in 1965, fuzzy logic allows for more nuanced decision-making, particularly in uncertain conditions, such as those encountered during flooding. This capability is crucial for flood annunciators, as it helps to interpret sensor data and make informed decisions based on varying degrees of certainty [5].
The integration of various sensor technologies enhances the functionality of flood annunciators. The FS300A water flow velocity sensor utilizes the Hall Effect to detect changes in water flow, providing critical data for flood monitoring. Similarly, the Tipping Bucket rain gauge measures rainfall intensity, serving as a primary input for hydrological models [6]. The JSN SR-04T ultrasonic sensor, designed to be waterproof, employs ultrasonic waves to measure water levels accurately. These

sensors collectively provide essential data for real-time flood detection and management systems [7].
The Internet of Things (IoT) plays a vital role in modern flood annunciator systems, enabling connectivity between various devices and the internet. With advancements in technology, including affordable microcontrollers and wireless communication, a wide array of devices can now collect and share data in real-time. This connectivity allows for the integration of sensor data, image processing results, and machine learning outputs, facilitating timely alerts and improved decision-making in flood management. The combination of these technologies represents the cutting edge of flood annunciator systems, enhancing their effectiveness and responsiveness to flood events [6].

3 Methods

This research integrates image processing and fuzzy logic. This approach involves collecting training data through photos and videos in flood and non-flood conditions, which can be measured quantitatively. The detection method used is a Convolutional Neural Network (CNN), which is trained to obtain the best weights in a "best.pt" file for detection. The quantitative data generated includes numbers of test results displayed on the computer, while fuzzy logic is used for decision processing. In addition, qualitative data in the form of text is shown in real-time on the computer screen for the flood detection system.
The real form of the flood detection system tool with this image processing method is part of the mechanical design, as shown in **(a).** Meanwhile, the electronic circuit design can be represented by a schematic design drawing of the components, as shown in **(b)**.





(a) (b)

Fig 1. (a) Mechanical Device Design and (b) Schematic Layout Design

The system design stage includes mechanical and electronic design, using several hardware devices such as FS300A flow sensor, Tipping Bucket Rain Gauge rainfall sensor, and JSN-SRT04 waterproof ultrasonic sensor, which are connected to Arduino Nano microcontroller and Mini PC. Mini PC is connected to a webcam to identify environmental conditions, while sensor readings are displayed on a 20x4 LCD and sent to the website via IoT.

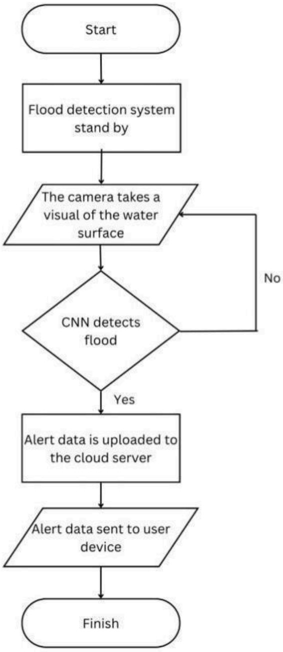


Fig 2. Flowchart of Flood Detection System

The system flowchart shows that the process starts with component initialization, then the camera captures the image to be processed by the minicomputer using the CNN algorithm. The detection results are uploaded to the cloud server for users to access. The system consists of three parts: Input (camera, discharge sensor, rainfall sensor, and ultrasonic sensor), Process (minicomputer and Arduino), and Output (website and LCD).

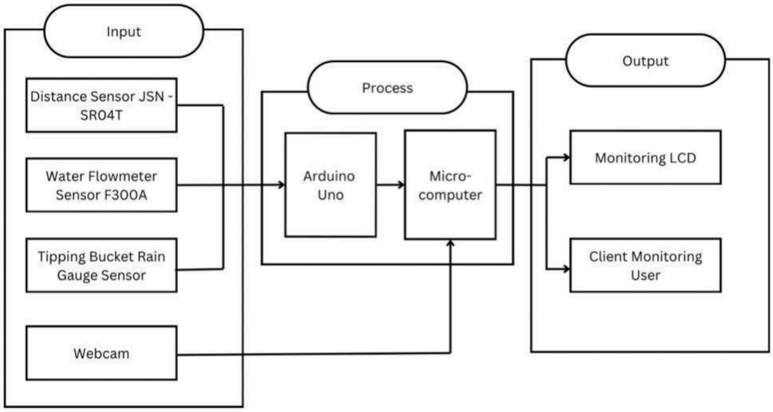


Fig 3. Diagram Block of Flood Detection System

The methodology used includes image processing methods, which manipulate images to enhance and analyze, and the CNN algorithm for object classification. Training data in the form of flooded and non-flooded photos are used to train the CNN model. Fuzzy logic is embedded in the Arduino Nano to process the input values and produce an output indicating the flood condition, which is then sent to the cloud server to be displayed to the user.

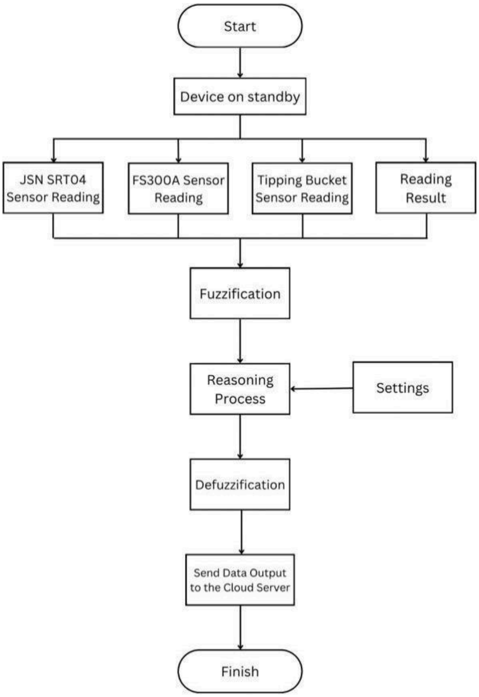


Fig 4. Flowchart of Fuzzy Logic Method

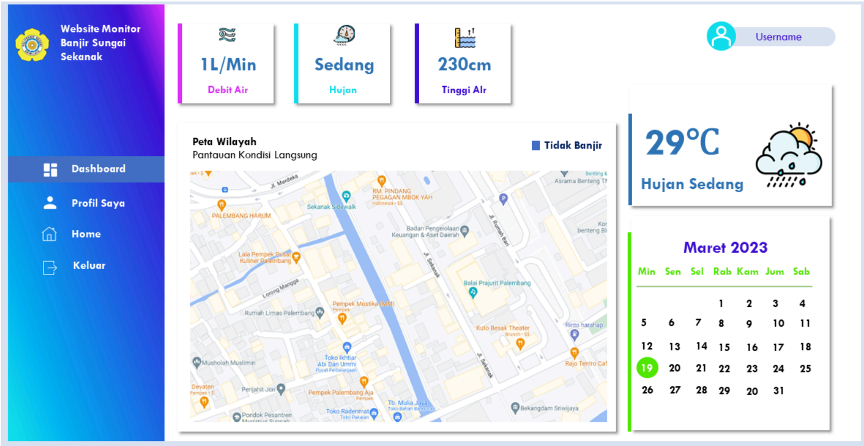


Fig 5. Dashboard Display

4 Results

Model testing is done by predicting environmental conditions directly. Video shooting is done in 3 different locations to test whether the model created can adapt to environmental conditions and can continue to provide accurate prediction results. This detection result table includes the confidence score or the level of the model's tendency to determine a prediction in a predetermined class. The model's accuracy will be the correct value if the tendency of the model to detect the proper state is also significant. Table 1. shows the reading results of the model with a distance of 30 fps each. In this study, limits the amount of data taken as the sample used.

Table 1. Result of Testing Models

Location	Image	Prediction	Confidence Score	
			Flooding	Normal
Lunjuk Jaya St.		Flooding	73,05077	26,94923

		Floding	72,48735	27,51265
		Normal	27,18292	72,81708
		Floding	73,0845	26,9155
		Floding	72,99083	27,00917
		Normal	27,22368	72,77632
		Floding	73,08037	26,91963
		Floding	73,05077	26,94923
		Floding	73,04521	26,95479
		Floding	73,05211	26,94789
		Floding	73,05476	26,94523

		Floding	73,04804	26,95196
		Floding	73,04553	26,95448
		Floding	72,48735	27,51265
		Floding	72,508	27,492
		Floding	72,5247	27,4753
		Floding	72,49322	27,50678
		Floding	70,59625	29,40376
		Floding	70,39365	29,60635
		Floding	63,48786	36,51214
Dr. M. Isa St.		Floding	73,06193	26,93807

		Floding	73,06097	26,93903
		Floding	73,08022	26,91978
		Floding	73,08446	26,91554
		Floding	73,08716	26,91284
		Floding	73,08851	26,91148
		Floding	73,08717	26,91283
		Floding	73,08732	26,91268
		Floding	73,08694	26,91306
		Floding	73,08573	26,91427
		Floding	72,99459	27,00542

		Flooding	72,98124	27,01876
		Flooding	72,94395	27,05605
		Flooding	73,06857	26,93143
		Flooding	73,0653	26,9347
Taman Kenten St.		Flooding	73,06752	26,93249
		Flooding	73,06645	26,93354
		Flooding	73,10272	26,89728
		Flooding	73,09057	26,90943
		Flooding	73,03943	26,96057

It took at least 40 data samples that experienced changes to the test. From the results obtained, at least two fps images have errors in detection. Thus, that the accuracy value based on the number of detections is shown below.

$$Model\ Accuracy = \frac{Number\ of\ correct\ predictions}{Total\ predictions} \times 100\%$$
$$Model\ Accuracy = \frac{38}{40} \times 100\%$$
$$Model\ Accuracy = 0,95 \times 100\%$$
$$Model\ Accuracy = 95\%$$

Testing the real-time flood inundation detection device was carried out in stages. The process begins with preparing the sensor circuit, which is then connected to a Mini PC, ending with integrating all devices. Tests were conducted with different times and parameters, generating detection data under normal conditions and flood inundation via webcam. The script used allows live detection, recording the results into a file in PyCharm.

The results showed the model's reliability, although there were detection errors in two sample images. However, in the tests at the second and third locations, the model showed optimal ability to detect flooding without reading errors, even though the camera view was obstructed by vehicles.

Furthermore, tests were conducted by integrating the circuit into a web system for streaming videos and detection results using the Flask module. However, the inadequate specifications of the Mini PC caused the loading process to be slow. After successfully connecting to the server, field testing was conducted, with attention to the Wi-Fi connection and IP address, for smooth operation of the remote PC.

The detection results with the Mini PC were slower, with decreased fps and lag in the video recordings. This is due to Flask and SocketIO programs that transmit data simultaneously. Despite this, the model could still perform detection with good accuracy. A comparison with previous research shows that using live environmental photo datasets gives more accurate results than dummy data. This study's more significant number of datasets (480) supports a more sophisticated training scheme.

5 Conclusion

Based on the model, the accuracy of flood inundation detection using CNN is 98% in the best training and validation. In field use, the device is able to detect flooding for every fps that the webcam camera can display. However, the device's lack of capability reduces the accuracy value to 95%. The model results in the study have significant developments by using live environmental datasets.

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