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# A Fuzzy Logic Model of Early Warning System for Typhoon Preparedness

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**Abstract:** The early warning system for typhoon preparedness using Matlab Fuzzy Logic toolbox simulation is focused on the identified parameters, which affect the community regarding the condition of the weather. Flood and wind speed are the main factors for devastation during typhoon occurrences. Using the Matlab software, Fuzzy Logic Sugeno-style of inference system was used to program and simulate the said study. The parameters – water level and wind speed, were used as the input data for the program. The output data termed as Typhoon Alert Level identifies whether a certain condition, based on the inputs, is on its normal or alarming state. The acquired inputs have its certain values depending on the level of condition. Both input parameters have five levels of condition. The output parameter, on the other hand, makes use of constant values ranging from 1 to 5. Through Fuzzy logic, 25 conditions were achieved according to the five conditions of each input to provide precise and accurate data. The study aims on helping citizens to be prepared and knowledgeable whenever there is a typhoon. The novelty of this work falls under utilization and simulation of fuzzy logic in decision-making, which were never done in cited literature of direct application. The rules were constructed by the proponents in reference to observe ranges and specification limits maintained and prescribed by PAGASA. The paper envisions helping flood-prone areas which are common in the Philippines. Indeed, it is relevant and important as per needs of safety and welfare of the community.

**Key Words:** Fuzzy Logic; water level; wind speed; early warning system; typhoon preparedness; MATLAB Fuzzy logic toolbox

## 1. INTRODUCTION

It has been normal scenery, not only in places nearby a body of water but also to urban areas, where some of the populated places in the Philippines are experiencing severe floods whenever there is a heavy rain or storm signal. These floods bring devastation to houses, livelihood and worse, it can costs many lives.

Fatalities during typhoons are caused by people's unpreparedness, lack of knowledge about the situation and negligence. Even though there are many components in the environment that may cause death during typhoon, it is still on the residents' actions and preparations on how they will survive a typhoon.

Typhoons are tropical storms with sustained winds of 74 miles per hour or greater. The strongest ones, every year, five to six in the Philippines cause a lot of damage to houses and all that lives (Web – 1). One of the most devastating typhoons that hit the Philippines is the Typhoon Yolanda that affected 1,473,251 families, with a casualty count of 6,300 in the Visayan region on November 8, 2013 (Web – 2). Another is the Tropical Storm Thelma that unleashes flash floods on the central city of Ormoc on Leyte Island on November 15, 1991, killing more than 5,100 people (Web – 3).

Mostly, during the typhoon, the flood took lives while the strong wind brushed houses. There are other components why an area suffers too much from typhoons.

According to World Bank, a lot of people live on low-lying coastal islands in the Philippines, with an estimated of more than 60 percent of the population living in the coastal zones.

According to National Geographic, the young, poor population of the Philippines has increasingly shifted to coastal regions, where rapidly constructed housing and inadequate evacuation plans may have played a role in a typhoon disaster. Over the long term, the Manila Observatory says that the combination of poverty and population shift puts the Philippines among the Top 10 worldwide nations at risk of coastal flooding.

This proposal will present a design project that will help provide sufficient real-time information on the current flood water level and wind speed on a chosen flood prone area. This project will also widen the coverage of people that can receive the information to improve the emergency measures during typhoons.

## 1.1 Objectives of the Study

This project aims to create a system that will aid a community with up-to-date information about the current water level and wind speed in their area. It also aims to provide a system for the Fuzzy Logic Model of Early Warning System for Typhoon Preparedness.

The following are the specific objectives the researchers focused on:

- To create a system that will monitor water level and wind speed
- To inform the citizens about the current water level and wind speed
- To create a fuzzy logic that will interpret the water level and wind speed data

# 2. METHODOLOGY

## 2.1 Proposed Design

The project "A Fuzzy Logic Model of Early Warning System for Typhoon Preparedness" is proposed to build a flood level and wind speed sensor which provides information for the local. As soon as the model is finished, it will undergo several tests and experimentations to check the effectiveness of the system.

The model is processed through the Fuzzy Logic system of Matlab software. Two parameters which are the Water Level and Wind Speed will be the input of the system. The output is termed as the Flood Alert Level which decides about the following inputs, then produces a decision according to action about the situation.

The inputs have several sub-parameters to obtain accurate data. Both inputs have five options to consider. In water level, there are the Emergency, Alert, Advisory, Light and Ideal states. While in wind speed, the states are categorized as Very Strong, Strong, Moderate, Windy and Normal. The output, Flood Alert Level, has the categories as Evacuation, Warning, Preparation, Standby and Typical. The following categories depend on the input data.

The main function of the Fuzzy Logic system is the decision making. It decides about the incoming inputs on what certain output will it supply.

The fuzzy inference system used in the Fuzzy Logic Model of Early Warning System for Typhoon Preparedness is shown below:

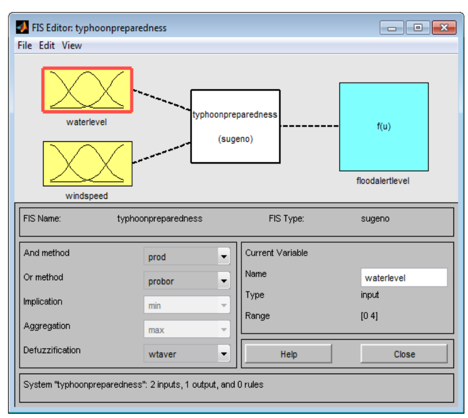


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**Figure 1**. FIS of the Fuzzy Logic Model of Early Warning System for Typhoon Preparedness

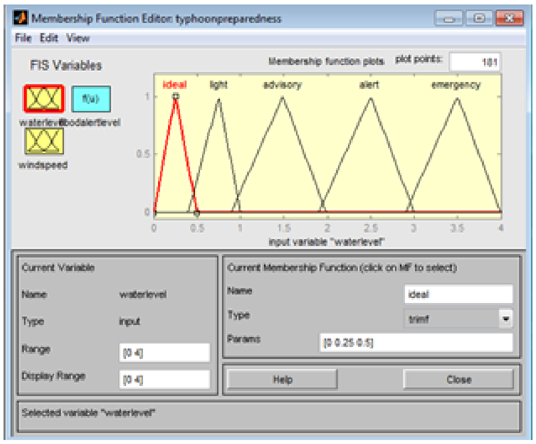


**Figure 1a**. Membership function of water level

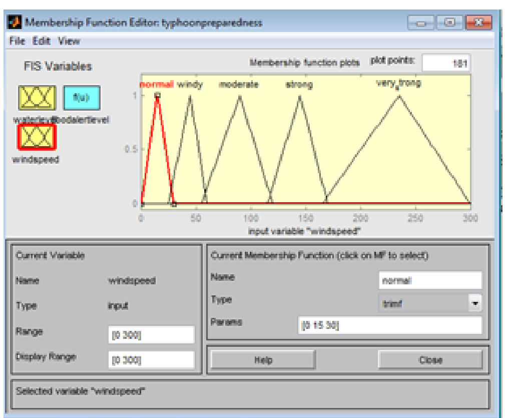


**Figure 1b**. Membership function of wind speed

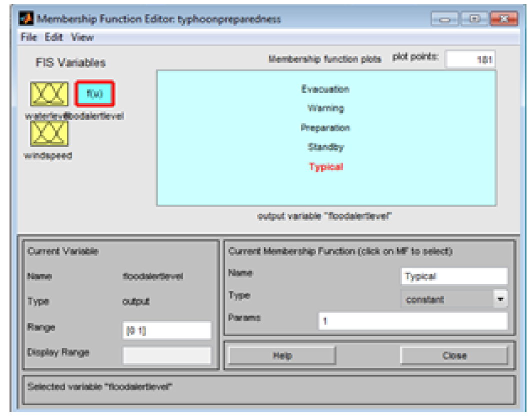


**Figure 1c**. Membership function of typhoon alert level

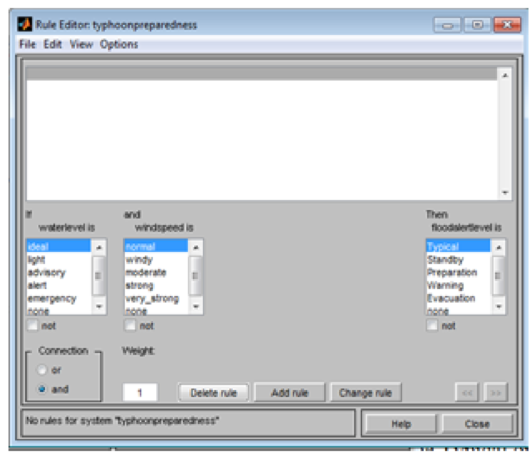


**Figure 1d**. Fuzzy rules

Within the fuzzy inference system, shown in Figure 1 the inputs are fuzzify into membership functions that are shown in Figure 1a and Figure 1b respectively. Membership functions such as level 1 or Ideal, level 2 or Light, level 3 or Advisory, level 4 or Alert and level 5 or Emergency for the water level and level 1 or Normal, level 2 or Windy, level 3 or Moderate, level 4 or Strong and level 5 or Very Strong for the wind speed. These fuzzy sets of inputs are combined to give a specific Typhoon Alert Level by means of averaging technique that is classified by using the fuzzy rules specified by the proponents as shown in Figure 1d and checked using the truth table on Figure 1e. The Alert Levels can be Typical or level 1, Standby or level 2, Preparation on level 3, Warning or Level 4 and Evacuation or level 5 that is shown in Figure 1c.

| Count | Weights | Water Level | Wind Speed | Flood Alert Level (Classified Value) |
|---|---|---|---|---|
| 0 | w1 | 5 | 5 | 5 |
| 1 | w2 | 5 | 4 | 5 |
| 2 | w3 | 5 | 3 | 4 |
| 3 | w4 | 5 | 2 | 4 |
| 4 | w5 | 5 | 1 | 3 |
| 5 | w6 | 4 | 5 | 5 |
| 6 | w7 | 4 | 4 | 4 |
| 7 | w8 | 4 | 3 | 4 |
| 8 | w9 | 4 | 2 | 3 |
| 9 | w10 | 4 | 1 | 3 |
| 10 | w11 | 3 | 5 | 4 |
| 11 | w12 | 3 | 4 | 4 |
| 12 | w13 | 3 | 3 | 3 |
| 13 | w14 | 3 | 2 | 3 |
| 14 | w15 | 3 | 1 | 2 |
| 15 | w16 | 2 | 5 | 4 |
| 16 | w17 | 2 | 4 | 3 |
| 17 | w18 | 2 | 3 | 3 |
| 18 | w19 | 2 | 2 | 2 |
| 19 | w20 | 2 | 1 | 2 |
| 20 | w21 | 1 | 5 | 3 |
| 21 | w22 | 1 | 4 | 3 |
| 22 | w23 | 1 | 3 | 2 |
| 23 | w24 | 1 | 2 | 2 |
| 24 | w25 | 1 | 1 | 1 |

**Figure 1e**. Truth table of Flood Alert Level (Classified Value)

| Count | Weights | Water Level | Wind Speed | Flood Alert Level (Linguistic Classification) |
|---|---|---|---|---|
| 0 | w1 | Emergency | Very Strong | Evacuation |
| 1 | w2 | Emergency | Strong | Evacuation |
| 2 | w3 | Emergency | Moderate | Warning |
| 3 | w4 | Emergency | Windy | Warning |
| 4 | w5 | Emergency | Normal | Preparation |
| 5 | w6 | Alert | Very Strong | Evacuation |
| 6 | w7 | Alert | Strong | Warning |
| 7 | w8 | Alert | Moderate | Warning |
| 8 | w9 | Alert | Windy | Preparation |
| 9 | w10 | Alert | Normal | Preparation |
| 10 | w11 | Advisory | Very Strong | Warning |
| 11 | w12 | Advisory | Strong | Warning |
| 12 | w13 | Advisory | Moderate | Preparation |
| 13 | w14 | Advisory | Windy | Preparation |
| 14 | w15 | Advisory | Normal | Standby |
| 15 | w16 | Light | Very Strong | Warning |
| 16 | w17 | Light | Strong | Preparation |
| 17 | w18 | Light | Moderate | Preparation |
| 18 | w19 | Light | Windy | Standby |
| 19 | w20 | Light | Normal | Standby |
| 20 | w21 | ideal | Very Strong | Preparation |
| 21 | w22 | ideal | Strong | Preparation |
| 22 | w23 | ideal | Moderate | Standby |
| 23 | w24 | ideal | Windy | Standby |
| 24 | w25 | ideal | Normal | Typical |

**Figure 1f**. Truth table of Flood Alert Level (Linguistic Classification)

## 2.2 System Block Diagram

The model is functioned by a FLC-based system. The parameters to be considered were processed as inputs to the FLC and are then passed to the next operation. MATLAB software is used for the FLC operation.

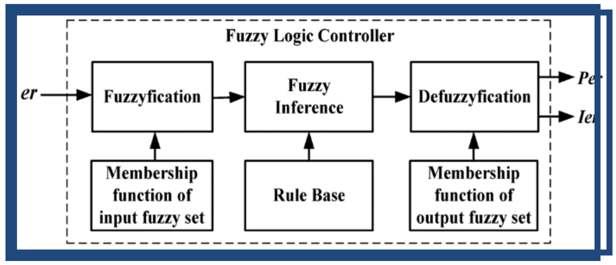


**Figure 2a.** Block diagram of a fuzzy logic controller

Figure 1 shows a block diagram of a fuzzy logic—a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1.

The input variables in a fuzzy control system are in general mapped by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "*fuzzification*".

Given "mappings" of input variables into membership functions and truth values, the microcontroller then makes decisions for what action to take, based on a set of "rules", each of the form:

IF water level IS Ideal AND wind speed IS Very Strong

THEN Flood Alert Level IS Warning.

In this example, the two input variables are "water level" and "wind speed" that have values defined as fuzzy sets. The output variable, "Flood Alert Level" is also defined by a fuzzy set that can have values like Typical, Standby, Preparation, Warning and Evacuation.

This rule by itself is very puzzling since it looks like it could be used without bothering with fuzzy logic, but remember that the decision is based on a set of rules:

- All the rules that apply are invoked, using the membership functions and truth values obtained from the inputs, to determine the result of the rule.
- This result in turn will be mapped into a membership function and truth value controlling the output variable.
- These results are combined to give a specific ("crisp") answer, the actual brake pressure, a procedure known as "*defuzzification*".


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This combination of fuzzy operations and rule-based "inference" describes a "fuzzy expert system".

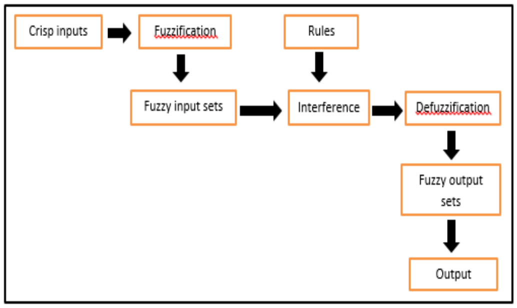


**Figure 2b.** Block diagram of a fuzzy logic controller

## 3. RESULTS AND DISCUSSION

### 3.1 Project Description

The normalized fuzzy logic comprises of two gathered inputs which is the water level and the wind speed. Water level is divided into 5 stages namely as Ideal, Normal, Advisory, Alert and Emergency as Ideal being the lowest and Emergency as the maximum water level and for the wind speed which signifies as Normal, Mild, Moderate, Strong and Very strong, Normal as the lowest and Very strong as the highest. These inputs have their own desired ranges in order to identify its specifications with the aid of the fuzzy logic's Sugeno-style. By the rules set by the user to identify the classification of the typhoon intensity that it belongs to, these classifications are Typical, Trivial, Standby, Preparation and Evacuation.

#### 3.1.1. Fuzzy Logic Controller

The concept of Fuzzy Logic is introduced by Lotfi Zadeh, a professor at the University of California at Berkley. It was presented in a way of processing data by allowing partial set membership rather than crisp set membership or non-membership.

#### 3.1.2. Structure of Fuzzy Logic

The most important modelling tool based in fuzzy set theory is the Fuzzy Interference System. Fuzzification method converts the crisp input into fuzzy. After this process occurs in formulates a rule base. It is similar to a knowledge base. To convert fuzzy value to the real world value, defuzzification is the process.

#### 3.1.3. Input

The inputs are most often hard for crisp measurement. This is because some measuring equipment is converted into fuzzy values for each input fuzzy set with the fuzzification block.

#### 3.1.4. Fuzzification

The first block inside the controller is fuzzification process, which converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block matches the input data with the conditions of the rules to determine. There is degree of membership for each linguistic term that applies to the input variable.

#### 3.1.5. Rule Base

The collection of rules is called a rule base. The rules are in “If Then” format and formally the “If” side is called the conditions and the “Then” side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error (e) and change in error (dE). In a rule based controller, the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non-specialist end-user and an equivalent controller could be implemented using conventional techniques.

#### 3.1.6. Output

The output gain can be tuned and can be used as an integrator. Center of gravity or weighted average is use to solve the output crisp value.

### 3.2. Functions of the System

#### 3.2.1. Basis of the Flood

Table 1. Table describing the basis of a warning system (source: PAGASA)

| | | | |
|---|---|---|---|
| Red | More than 30 mm of rain observed in an hour and expected to continue in the next two hours | Serious flooding expected in low lying areas | Response: Evacuation |
| Orange | 15-30 mm of rain (intense) rain observed in an hour and expected to continue in the next two hours | Flooding is threatening | Response: Alert for possible evacuation |
| Yellow | 7.5-15 mm of rain (heavy) rain observed in the next two hours | Flooding is possible | Response: Monitor the weather condition |

The above figure explains how a warning system of a typhoon looks like. The yellow response is for the respondents to monitor the weather condition and be alerted as it goes up or down. The orange response is for the respondents to be alert for the possible evacuation because of the continuous rise of the water level. And lastly, the red response is for the respondents to evacuate from their place and move to a place where it is safe.

### 3.2.2. Classification of Tropical Cyclones

Tropical cyclones are classified in accordance with the World Meteorological Organization's recommendation by the maximum sustained wind speeds near the centre. In Hong Kong, the classification is defined in terms of wind speeds averaged over a period of 10 minutes as follows (Web – 7):

Table 2. World meteorological organization classification of tropical cyclones

| Tropical Cyclone Classification | Maximum 10-minute mean wind near the centre |
|---|---|
| Tropical Depression | up to 62 km/h |
| Tropical Storm | 63 to 87 km/h |
| Severe Tropical Storm | 88 to 117 km/h |
| Typhoon | 118 to 149 km/h |
| Severe Typhoon* | 150 to 184 km/h |
| Super Typhoon* | 185 km/h or above |

*New categories starting 2009

### 3.2.3. Super typhoon, major hurricane and intense hurricane

"Super-typhoon" is a term utilized by the U.S. Joint Typhoon Warning Center for typhoons that reach maximum sustained one-minute surface winds of at least 65 m/s (130 kt, 150 mph).

"Major hurricane" is a term utilized by the National Hurricane Center for hurricanes that reach maximum sustained one-minute surface winds of at least 50 m/s (96 kt, 111 mph).

"Intense hurricane" is an unofficial term, but is often used in the scientific literature. It is the same as "major hurricane" (Web – 8).

## 4. CONCLUSIONS

The model contributes towards economy and the citizens. It envisions a safe, prepared and less casualty community before, during and after typhoon devastation. The model also promotes the use of Fuzzy Logic as an easy medium in programming field and enhances the awareness of people about the system. The use of categories under given parameters gives a more accurate and precise output about the situation.

## 5. ACKNOWLEDGEMENT

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