Implementation of Support Systems for Determination of Amphibious Vehicle Landing in Disaster Emergency Response Using Fuzzy Takagi Sugeno

Abdurahman\textsuperscript{1}, G Harsono\textsuperscript{2}, Y Prihanto\textsuperscript{3} and R A G Gultom\textsuperscript{4}

\textsuperscript{1} Department of Sensing Technology Defense, Faculty of Technology, Indonesia Defense University, Indonesia
\textsuperscript{2} Hydrography and Oceanography Center Indonesian Navy, Indonesia
\textsuperscript{3} Department of Research, Geospatial Information Agency (BIG), Indonesia

Abstract. Amphibious vehicle is a vehicle that can maneuver from the mainland to the sea. Amphibians are divided into certain characteristics according to their use. The use of amphibians for disaster emergency response because amphibians have the ideal ability to cross various fields. Amphibious vehicle maneuvers require an understanding of oceanographic and geographical aspects. Amphibians require certain criteria in determining the ideal landing location. The ideal location for amphibious landings is examined in two main variables namely the sea and land variables. Amphibian operations that are currently applied do not utilize information technology that can analyze geographical aspects. Researchers build a system that can analyze the destination area of a landing mission that is assessed according to the ideal parameters in making a landing. In this study the determination of the landing site uses an artificial intelligence method that can help determine the ideal position in making an amphibious landing. Fuzzy Is a method that is in the sub-section of reasoning in the science of artificial intelligence. Fuzzy is used to process data for each variable and adjust to the rule base of that variable. The variable used to input the fuzzy membership function is the beach gradient and current variable. These two variables determine the level of suitability of the amphibious vehicle landing mission.

1. Introduction

Indonesia's coastal areas are vulnerable to tsunami and tidal waves [1]. The impact of damage caused by natural disasters such as earthquakes, tsunamis and floods has a very high level of damage. In the tsunami in Aceh, Mentawai, Palu and Banten the impact of damage to air landing infrastructure and road infrastructure was so high that logistical distribution was not possible by land and air. The earthquake and tsunami continued in 2010 in Mentawai with a magnitude of 7.2 SR at a depth of 10 km and resulted in 530 fatalities and resulted in infrastructure losses reaching 349 billion [2]. The study and analysis of the coastal area is needed to create a system of deterrence against natural disasters that originate from the sea and have an impact on cities in the coastal region.

Natural disaster management efforts are carried out through building a logistics distribution system through sea access because land evacuation routes are predicted to experience high damage because the distance to the source of the disaster is relatively close and unpredictable. Disaster management through access to coastal areas is considered to be very strategic because the sea area is an area that can be accessed during natural disasters. The role of the military in disaster mitigation efforts has been reviewed in research in Myanmar in dealing with the effects of the flood disaster. The military aspect has the readiness of infrastructure, capability, and military resources to carry out disaster mitigation efforts so that the integration of civilian and military resources is being developed in various
countries [3]. Utilization of military resources in disaster mitigation efforts has been implemented in Indonesia such as BNPB, BASARNAS and various disaster mitigation agencies.

Amphibious vehicles are vehicles that can adjust the terrain of the environment. Amphibious vehicles are divided into two types in general namely armed amphibious vehicles and unarmed amphibious vehicles. The use of amphibious vehicles in logistical distribution mission efforts is considered ideal and effective because it can maneuver from sea to land or vice versa. The ideal amphibious vehicle maneuver requires precise geographical information. Geographical information on amphibious vehicle maneuvering routes is divided into two main variables: sea area variables and land area variables. Land area variables include land cover, land slope, and soil type. Sea area variables include wave height, beach depth, surface current velocity, and seabed substrate.

Spatial data processing using fuzzy methods has been applied to process digital maps for analysis into geographic information systems [4]. In general, the fuzzy logic system has three methods. The three methods are the Mamdani method, Tsukamoto method and the Takagi Sugeno method. The use of Fuzzy systems in spatial analysis can facilitate the processing of data that is certain or uncertain in determining the results of spatial analysis that is desired. The application of the Sugeno fuzzy method in determining the best path to the tourist site can produce optimal decisions. The use of fuzzy systems in determining the path to tourist sites is processed from 3 main variables, namely distance, time and road density. The output of fuzzy-based geographic information systems can provide recommendations to tourists who are visiting[5]. In other research, the use of fuzzy inference systems in processing spatial data that is uncertain and complex. fuzzy system is used to map the level of pollutants in an area[6].

2. Literature Study
2.1. Amphibious Vehicles

Amphibious vehicles are vehicles that can adjust the situation at sea or land conditions. The concept of amphibious vehicles is basically to optimize the limitations of a vehicle in an operating field such as the sea field and terrain. The concept of amphibious vehicles is a vehicle that can adjust two environmental conditions or terrain in a particular operation. Utilization of amphibious vehicles is usually used in the military and commercial fields. Amphibious vehicles are divided into two main categories such as armed amphibious vehicles and amphibious transport vehicles or unarmed [7]. Types of armored amphibious vehicles are divided into Landing Ship Tanks (LST), Landing Craft Tanks (LCT), Landing Craft Mechanized (LCM), and Landing Craft Vehicle Personnel (LCVP). The ideal type of amphibious vehicle to distribute logistics is (LST). Amphibious vehicles that are ideal in carrying out disaster response are of the LST type [8]. Amphibious vehicle type LST has a size and payload that is large enough, but LST can not maneuver directly into the mainland.

2.2. Geographical Information System

Geographical information system is an information system that processes data related to the earth’s surface viewed from geographical, geological, and various other scientific disciplines. Every geographic information data must have coordinates as reference position of an object. Commercial satellite imagery is usually corrected and has coordinate references. The process of image correction is divided into 2 types of correction in general, Geometric and Radiometric [9]. The use of Geographic Information Systems as a system that can analyze and evaluate coastal areas has been carried out in the determination of dock construction [10]. The parameters used are a combination of oceanographic and geographical aspects. Geographic information systems are used to process a wide range of data and various aspects of science to be analyzed and presented as needed but have geographical references.
2.3. Amphibian Landing Appropriate Parameters

Amphibians landings have a number of defining parameters in terms of both the time and space dimensions. The ideal regional suitability parameters for amphibious vehicle landings can be seen in the following table [8].

| No | Defined Factors         | Defined Criteria                                      |
|----|-------------------------|-------------------------------------------------------|
| 1. | Type of beach           | Straight Beach                                        |
| 2. | Beach Gradient          | a. Type LST: Gradient : 1:51                          |
|    |                         | b. Type LCT: Gradient : 1:88                          |
|    |                         | c. Type LCM : Gradient : 1:104                         |
|    |                         | d. Type LCVP : Gradient : 1:120                        |
| 3. | Beach Back Terrain      | a. Flat against an elevated beach background           |
|    |                         | b. There are walks out into the back coast             |
| 4. | Beach Base Composition  | a. Sand                                                 |
|    |                         | b. Gravel                                               |
| 5. | Long Landing Beach      | >250 Meter                                             |
| 6. | Beach width for maneuver| >4 Meter                                               |
| 7. | Breaking Wave Type      | Spilling                                               |
| 8. | Tidal                   | a. Highest Tide                                        |
|    |                         | b. Double Tidal Daily Type and Mixed Tilt to Double    |
| 9. | Current                 | Beach level (<1 Knots)                                 |
| 10. | Landing Point Reference | The Point is Known                                     |
|    | Reference               | Position                                               |
| 11. | Obstacle Beach          | Minim Obstacle                                         |
| 12. | Escape                  | Beach With Way Out                                     |

2.4. System Fuzzy Model

Fuzzy system is an area in artificial intelligence that is used to build systems based on knowledge base systems. Fuzzy-based systems generally have three main stages: fuzzification, inference and defuzzification. Fuzzy system there are many rule models including the Mamdani and Takagi Sugeno Kang (TSK) models. Defuzzification stages have five general models including Centroid Method, Height Method, First (or Last) Maxima, Mean-Max Method and Weighted Average. Weighted Average method is a method that processes the average value by weighting. Weighting is done by making a degree of membership of the defuzzification system[11].

3. Methodology

Amphibians that will be modeled for suitability are LST vehicles. The research framework for amphibious landing support systems can be seen in the following figure 1.

![Research Framework](image)

The variables used in this study are beach gradient and current. This variable will be simulated for the system to be built according to table 2 above. Fuzzy has three general stages, namely: fuzzification, inference and rule base, and defuzzification. The beach gradient and current variables are converted to the fuzzy membership function system to be built. The fuzzification stage requires a table that explains the functions of the type of membership parameters of the fuzzy system. The membership function for each parameter used in the system can be seen in table 2 below.

| Parameter Type       | Conditional | Corresponding | Not_Corresponding |
|----------------------|-------------|---------------|-------------------|
| Beach Gradient (BG)  | 1:41        | 1:51          | 1:161             |
| Current (C)          | 1 knot > C < 2 Knot | 0,1-1 Knot     | >2 Knot           |

Based on the table above, there are three types of linguistic variables, they are vulnerable, ideal, and dangerous. The Fuzzy Membership function equation for the beach gradient variable can be written in Equations 1 through Equation 3 below.
The above equation is designed based on the linear equation of the ascending line and descending line. The Equation 1 for \( a \leq x < b \) is describe descending line and Equation 2 for \( a \leq x < b \) is describe the ascending line. The visualization of the membership function of the beach gradient variable in the graph as shown in the following figure 2.

![Beach Gradient Variable Membership Function](image)

Beach Gradient Membership function based on the picture above the system is designed using the triangular membership function. fuzzy set \( G_{\text{Rawan}} \) has an ideal value 1:41, \( G_{\text{Ideal}} \) fuzzy set has an ideal value 1:41 and fuzzy set \( G_{\text{Bahaya}} \) has an ideal value 1:61 Based on table 2. The equation of the Fuzzy Membership function for the current variable can be written in the following Equations 4 through Equation 6 below.

\[
\mu [G_{\text{Rawan}}] = \begin{cases} 
\frac{1}{(b-x)} & \text{For } < a \\
\frac{(b-x)}{b-a} & \text{For } a \leq x < b \\
1 & \text{For } a \leq x < b \\
\end{cases} 
\]

(1)

\[
\mu [G_{\text{Ideal}}] = \begin{cases} 
\frac{(x-a)}{b-a} & \text{For } a \leq x < b \\
\frac{(c-x)}{c-b} & \text{For } b \leq x < c \\
1 & \text{For } b \leq x < c \\
\end{cases} 
\]

(2)

\[
\mu [G_{\text{Bahaya}}] = \begin{cases} 
\frac{(x-b)}{c-b} & \text{For } b \leq x < c \\
1 & \text{For } > c \\
\end{cases} 
\]

(3)

\[
\mu [A_{\text{Ideal}}] = \begin{cases} 
\frac{1}{(b-x)} & \text{For } < a \\
\frac{(b-x)}{b-a} & \text{For } a \leq x < b \\
1 & \text{For } a \leq x < b \\
\end{cases} 
\]

(4)

\[
\mu [A_{\text{Rawan}}] = \begin{cases} 
\frac{(x-a)}{b-a} & \text{For } a \leq x < b \\
\frac{(c-x)}{c-b} & \text{For } b \leq x < c \\
1 & \text{For } b \leq x < c \\
\end{cases} 
\]

(5)

\[
\mu [A_{\text{Bahaya}}] = \begin{cases} 
\frac{(x-b)}{c-b} & \text{For } b \leq x < c \\
1 & \text{For } > c \\
\end{cases} 
\]

(6)
The visualization of the membership function of the current variable in the graph as shown in the following figure 3.

![Figure 3. Current Variable Membership Function](image)

Current Membership function based on the picture above the system is designed using the triangular membership function. fuzzy set $A_{Ideal}$ has an ideal value 1 knot, $A_{Rawan}$ fuzzy set has an ideal value 2 and fuzzy set $A_{Bahaya}$ has an ideal value 3. Fuzzy Rule base is used to determine the basic rules in determining the ideal level of an area to be achieved in an amphibious landing mission while the fuzzy rule base that is built can be seen in the following table 3.

| No | Variable Beach Gradients and Currents | Output |
|----|-------------------------------------|--------|
| 1  | G_Ideal                             | A_Ideal Corresponding |
| 2  | G_Rawan                            | A_Ideal Conditional   |
| 3  | G_Bahaya                           | A_Ideal Conditional   |
| 4  | G_Ideal                             | A_Rawan Corresponding |
| 5  | G_Rawan                            | A_Rawan Conditional   |
| 6  | G_Bahaya                           | A_Rawan Not_Corresponding |
| 7  | G_Ideal                             | A_Bahaya Conditional   |
| 8  | G_Rawan                            | A_Bahaya Not_Corresponding |
| 9  | G_Bahaya                           | A_Bahaya Not_Corresponding |

The implication function used on this system uses the Max-Min operator. Max Min Implication is applied by finding the minimum value of the fuzzyfication stage then looking for the maximum value of that value to be entered into the rule base system. The fuzzy system output membership function can be seen in the following table 4.
Table 4. Crisp Value Based on Linguistic Variables

| Duty Cycle(%) | Linguistic Variables |
|---------------|----------------------|
| 10            | Not_Corresponding    |
| 40            | Conditional          |
| 100           | Corresponding        |

Crisp Value from the table explains the value of the crisp value 10 has an ideal value of Not_Corresponding linguistic name, 40 has an ideal value conditional linguistic name, and 100 has an ideal value Corresponding linguistic name. The Fuzzy output set uses singleton with a range of 0 to 100. defuzzification stage in this system uses the average weight method.

4. Result and Discussion

The system was created using visual studio 2010 using C# language. The appearance of the system design can be seen in the following figure 4.

The application system is designed based on console and GUI Program. Gui Program for the process of input and output visualization. Program Console to explain the processes and stages of the fuzzy being carried out. testing is done by giving a random value into the gradient beach textbox and the speed of the current in accordance with the rule base table that has been built. GUI program output is a percentage value from Singleton output and the condition based on rule base system. The System Testing Phase can be seen in the following figure 5 below by entering a random value on two variables.
Figure 5. Display Program Support System for Determination of Amphibian LST Location

Based on the figure above the system is tested by entering a value of 1:51 for the gradient and a value of 0.4 for the current. System testing is done by inserting a random value to the parameter beach gradient and current as in the following table 5 below.

| No | Testing (Gradient, Current) | Average Weight | Output          |
|----|-----------------------------|----------------|-----------------|
| 1  | (1:51, 0.4)                 | 100            | Corresponding   |
| 2  | (1:59, 2)                   | 68             | Conditional     |
| 3  | (1:90, 10)                  | 10             | Not_Corresponding |
| 4  | (1:60, 3)                   | 22             | Not_Corresponding |
| 5  | (1:57, 0.8)                 | 76             | Conditional     |

Based on the table above the system experiment was conducted by entering 5 random values on the gradient beach and current beach. It can be concluded from the table that the system can classify and translate output according to the rulebase system designed.

5. Conclusions
The conclusions of this study are:
1. The application of the Takagi Sugeno fuzzy system in determining the ideal position based on variable beach gradients and current can be applied.
2. Five times experiment the results of the suitability and rule base are very good
3. The more variables used in the building of rule base the more accurate the determination of the ideal position but the more complex the computational system.

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