Fuzzy Logic Implementation on Enemy Speed Control to Raise Player Engagement

Abdiansah[1], Anggina Primanita[2], Frendredi Muliawan[3]
Facultyof Computer Science, Sriwijaya University (UNSRI)
Palembang, Indonesia
[1]abdiansah@unsri.ac.id
[2]angina.primanita@gmail.com
[3]akahito.summer@hotmail.com

***Abstract*—Shoot em' up game is the sub-genre of action game. Action game is attractive because the game play usually use the interesting user interface and easily affect human emotion. With the aim to eliminate all the enemy, this kind of game will be boredom the player if the enemy behavior are monotones. This game needs a controller to add dynamic system into the enemy such as the artificial intelligence. Therefore, this paper proposes Fuzzy Takagi Sugeno method that will take several input and give the response as the output. So, the game will manipulate the enemy behavior that make the game more challenging and interesting to be played.**

***Keywords*—Component; Challenging Rate, Fuzzy Takagi Sugeno, Action Game, Artificial Intelligence (AI), and Aircraft Game**

I. INTRODUCTION

Good games are expected not only to give pleasure to the players, but the game should also have other positive values. One of the positive side is it can be the development of the human brain performance [1]. The game itself is a system where players are involved in the regulation and the prevailing culture in it, the player interacts with the system and the conflict in the form of artificially engineering.

One of the genre of game is an action game. One of the subgenre of action game is the shoot 'em up[2]. Shoot em 'up is a shooting game that can be done between players to players or players with the artificial intelligence enemy. The purpose of this game is pretty simple, where player shoot all the enemies while try to survive from enemy attacks.

This project will be represented the space craft motion speed while they are airing in the field and keep trying to kill the player. To make the game more interesting, the enemies in the game shoot em 'up is given artificial intelligence so that the game is more challenging to solve especially the response time of the enemy itself [3]. It can be guessed when they shoot, evade and so on so this likely the player become an auto machine by just memorizing the time of the enemy behavior. Shoot em' up game is a game that will be designed to target the enemy with the help of artificial intelligence to control the level of difficulty.

Existing shoot em' up game need tohave a control that makes the differences among gameplay scenario. Because the constant speed of the enemy in this game makes player easy to guess enemy motion. So, speed controller by an artificial intelligence is necessary to make player difficult to guess enemy motion.

One example of the artificial intelligence that can modify the game is the fuzzy method. The actual research that already uses the implementation of fuzzy method in a shoot em 'up is "the application of Intelligent Behavior in Object in Flash Tower Defense Game" (Penerapan Perilaku Cerdas Pada Obyek di Dalam Game Flash Tower Defense) by algorithms fuzzy Nuvem[4].

Beside Fuzzy Nuvem, fuzzy Takagi - Sugeno also can be used to control enemy speed patterns that were given artificial intelligence in the game shoot em 'up with objects such as space craft. Due to is the ability to tune certain variables easily by varying the linguistic rules or input variables, the algorithm is suitable for use the advantage of fuzzy logic[5]. Fuzzy Takagi Sugenouse several parameters as the input for the game and then there will be a collection of an output depends on the parameters. This more suited as anonlinear control system[6].

II. APPLIED TECHNIQUE

Fuzzy logic can make computer to reasoning about linguistic terms and rules like a human. To represent "wide" or "tight" of linguistic terms there will use the fuzzy set. The fuzzy set can be described as black, gray, and white. The fuzzy set enables values be assigned to set to a degree thing that called it fuzzification process. So, with fuzzied values, the computer can understand linguistic rules and make the output that consist of the fuzzy set to be defuzzified to give the crisp value[7].

Fuzzy set defined as a membership function. The function explains about the gradual transition from the region completely that on the outside within the set, so that enable a value to have partial membership in a set[7].

A. *Fuzzy Linguistic Variable (FLV)*

FLV is the composition ofone or more fuzzy sets to represent a concept or domain qualitatively. In this process, there will determine the values that made a linguistic value of the input sets and the output sets that will proceed. And after that, there will start to make a membership function for each linguistic value. The collection of the membership function that comprise the FLV will be called as fuzzy manifold or fuzzy surface[7].

B. *Fuzzification*

Fuzzification is the process to change a crisp value in to the quantity fuzzy linguistic set or membership degree[8]. The interface of fuzzification will be explained by following steps [9]:

i. Measure input variable value
ii. Performs mapping scale that transfers range of input values into the variables in the corresponding universe of discourse
iii. Performs fuzzification that converts a crisp function into a corresponding linguistic variable so it can be viewed as fuzzy sets

C. *Fuzzy Rules*

Fuzzy rules advocated as key tool to express pieces of knowledge in "fuzzylogic"[10]. The antecedent describes a condition and the consequences the represents consequence if the condition is satisfied.

The difference with fuzzy rules from conventional rules where the consequent either fires or not, in fuzzy systems the consequent can fire to a matter of degree. The antecedent, can be found as a single fuzzy term or the set that is the result of a combination of several fuzzy terms.[7]

Each time a fuzzy system iterates through its rule set it combines the consequents that have fired and defuzzifies the result to give a crisp value.

D. *Fuzzy Evaluation and Fuzzy Aggregation*

This is the process where will present the system with some values to see which rules fire and to what degree. Fuzzy inference follows these steps:

1. For each rule,
   a. For each antecedent, calculate the degree of membership of the input data.
   b. Calculate the rule's inferred conclusion based upon the values determined in a.
2. Combine all the inferred conclusions into a single conclusion (a fuzzy set).
3. For crisp values, the conclusion from 2 must be defuzzified.

There are a few ways to handle multiple confidence. The two most used ways are bounded sum (sum and bound on one) and maximum value (equivalent to OR-ing all the confidences).

The next step is to combine the inferred results into a single fuzzy manifold. The outcome that will be obtained is the composite fuzzy set representing the inferred conclusion of all the rule base. The next step is going to process around and convert this output set into a single crisp value. This is can be acquired by a defuzzification process.

E. *Defuzzification*

Defuzzification is the process turninginference results into crisp value[11]. For fuzzy Takagi Sugeno use Weighted Averagetechnique[12]. This method each output of the rule sets stored in the knowledge base of the system. The function of the weighted average defuzzification technique explained as (1):

$$x^* = \frac{\sum_{i=1}^{n} m^i w_i}{\sum_{i=1}^{n} m^i} \quad (1)$$

Where x^* is the defuzzified output, m^i is the each rule output membership, and w_i is the weight associated with each rule. This method is fast, easy and gives accurate result for the computerization process[13].

III. Game Mechanic Dynamic and Aestethic

Dynamic Mechanic and Aesthetics (MDA) is a formal approach to understand the game that is trying to bridge the gap between game design and development process, as well as technical game research.[14]

Mechanic describe the specific components of the game at the level of data representation and algorithms. Mechanics are a variety of actions, behaviors and mechanisms of control given to the player in the game context. Dynamics describe the run-time behavior of the mechanics who worked on player input and each output from time to time. Aesthetics describe the emotional response want raised against players when interacting with the gaming system.[14]

Mechanic made in this game when the player able to move in the direction forward, backward, left, and right, and can shoot some bullets. While the object of the enemy will continue to move forward. This game features two type enemy that shaped in the form of asteroids and plane shaped. Asteroid type only move forward when the plane shaped enemy will try to shoot player. The game will over when the condition fulfilled.

The dynamic that will be used later in a variety of battlefield conditions. Enemy will fight player's avatar object that continue to move forward while shooting it. Player's avatar which shooted by the enemy will be crushed and reduce remaining life new players then this object will respawn back. When there is no more life left, then the game over condition occurred. Whereas when enemy objects shooted, then enemy health point will decreases. When health point of enemies running off, then this object will immediately destroyed in battle. In addition, there are also cases when the object of the enemy left the battlefield then the object with some health remains still disabled regardless. Not only up to here, when enemy bullets and player bullet collide each other then that bullets willdisappear from the game. Then the last condition when objects collide with objects enemy players, this will result in the destruction of enemy objects and the player object while reducing the player remaining lives.

The impact of the expansion of the implanted artificial intelligence game hopefully lead players seem to be handling the aircraft pilot, who must shoot down the enemy while try to survive. The purpose of aesthetics could be expanded to include the challenges that may limit the conquest game. Players are expected to respond in the coordinated movement patterns of expression may be far away even more difficult to catch. That will make the player must disclose the fear and hatred of the presence of their enemies.

IV. Applying the Fuzzy Takagi Sugeno

In this project model, fuzzy logic used to compute the enemy movement speed. As described in Figure 1, this control system shown relative simple. This fuzzy method will activate when the game starts. First of all, the method is embedded into every object the enemy space craft that will receive several inputs.

Input in this case is the distance, enemy Health Point and the rest are enemy unit on field. Distance in this case is the form of the distance between the object space craft of the player space craft object. Then enemy health Point here refers to the rest of the health point which is owned by the enemy

before the plane dispose. Then the last factor is the number of enemy unit on the field when the game still played.

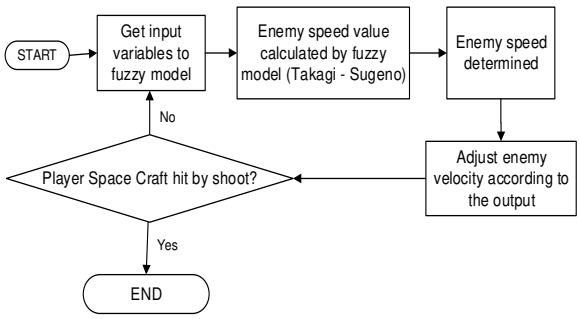

Fig.1 Fuzzy enemy speed control system

The output from this fuzzy process has one output variable. This value will determine the value of the speed of enemy space craft. After becoming crisp value, this value has become a value to determine the speed of the enemy. The enemy speed value which has three different linguistic values. For example, the three linguistic values are slow, medium, and fast.

The desired system behavior of the enemy speed can be defined through the rules and the FLV. The fuzzy sets variables and their ranges as illustrated in Figure 2.

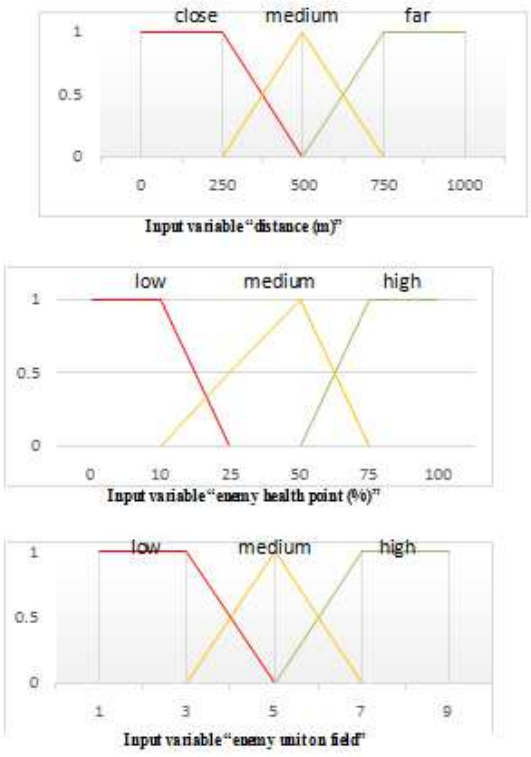

Fig. 2 Membership function and their input variables

Distance: The distance between the enemy and the player varies from 0 to 1000 meters. A distance between 0 and 250 meters is considered as definitely close whereas a distance between 750 and 1000 meters is considered as definitely far.

TABLE I
LIST OF THE FUZZY IF-THEN RULES

R1:	IF distance is far and enemy HP is high and enemy unit is high THEN enemy speed is slow
R2:	IF distance is far and enemy HP is high and enemy unit is medium THEN enemy speed is medium
R3:	IF distance is far and enemy HP is high and enemy unit is low THEN enemy speed is medium
R4:	IF distance is high and enemy HP is medium and enemy unit is high THEN enemy speed is medium
R5:	IF distance is high and enemy HP is medium and enemy unit is medium THEN low enemy speed is slow
R6:	IF distance is high and enemy HP is medium and enemy unit is low THEN enemy speed is slow
R7:	IF distance is high and enemy HP is low and enemy unit is high THEN enemy speed is slow
R8:	IF distance is high and enemy HP is low and enemy unit is medium THEN enemy speed is slow
R9:	IF distance is high and enemy HP is low and enemy unit is low THEN enemy speed is medium
R10:	IF distance is medium and enemy HP is high and enemy unit is high THEN enemy speed is slow
R11:	IF distance is medium and enemy HP is high and enemy unit is medium THEN enemy speed is medium
R12:	IF distance is medium and enemy HP is high and enemy unit is low THEN enemy speed is fast
R13:	IF distance is medium and enemy HP is medium and enemy unit is high THEN enemy speed is slow
R14:	IF distance is medium and enemy HP is medium and enemy unit is medium THEN enemy speed is medium
R15:	IF distance is medium and enemy HP is medium and enemy unit is low THEN enemy speed is fast
R16:	IF distance is medium and enemy HP is low and enemy unit is high THEN enemy speed is slow
R17:	IF distance is medium and enemy HP is low and enemy unit is medium THEN enemy speed is medium
R18:	IF distance is medium and enemy HP is low and enemy unit is low THEN enemy speed is fast
R19:	IF distance is low and enemy HP is high and enemy unit is high THEN enemy speed is slow
R20:	IF distance is low and enemy HP is high and enemy unit is medium THEN enemy speed is medium
R21:	IF distance is low and enemy HP is high and enemy unit is low THEN enemy speed is medium
R22:	IF distance is low and enemy HP is medium and enemy unit is high THEN enemy speed is slow
R23:	IF distance is low and enemy HP is medium and enemy unit is medium THEN enemy speed is fast
R24:	IF distance is low and enemy HP is medium and enemy unit is low THEN enemy speed is fast
R25:	IF distance is low and enemy HP is low and enemy unit is high THEN enemy speed is medium
R26:	IF distance is low and enemy HP is low and enemy unit is medium THEN enemy speed is fast
R27:	IF distance is low and enemy HP is low and enemy unit is low THEN enemy speed is fast

Enemy Health Point (HP): The enemy health point bar are varies from 0% to 100%. Low amount of health point described between 0% and 25% is considered as definitely low and the health point between 75% and 100% is considered as definitely high.

Enemy Unit on Field: The enemy unit on field life are varies from 1 to 5.If the unit number on the field between 1

and 2 is considered as definitely low and the number of unit between 4 and 5 is considered as definitely high.

Enemy Speed: only use three linguistic that distinguish the enemy speed: *fast, medium, slow*. In this paper each value is by increment of3 (slow = 4, medium = 7, fast = 10).

Table I is the list of the sixteen rules that will be implemented into the model. Note that these rules have been set up without any particular expert knowledge.

When the enemy motion speed already computed using these input, the motion speed value of the enemy space craft will be adjusted accordingly. With that speed, the enemy will move closer to the player space craft while they shoot it. If the enemy fails to shoot the target space craft, the operator will modify the input and try again until they shoot the player or they pass the player space craft.

To apply the fuzzy to the game, the first step is to identify where the method to be placed. There area varietyof scripts thatsetthe control ofthe game. One of them isa script tosetthe directionorspeed of enemy movement. Throughthisscriptthis methodwill beembedded.

The second step is to design the rule of this technique. The Fuzzy Takagi Sugeno method is executed in the game in progress. The input will be analyzed and taken each time the frame change. After the process of defuzzification, the speed of the enemy will be modified.

After that, the third step will talk about the game development. This game will use C# code that provided by Unity. Another code except the Fuzzy Takagi Sugenois just about general script of game.

The lastly step is to integrate the method to the script. The logic that has been developed is imported to the game script so the game can compile the method when we play the game.

V. Fuzzy Reasoning

In this paper, using the AND operation and the OR operation. The AND operation is the minimum value of the membership values. The OR operation is the maximum value of the membership values.[12]. As described before the defuzzification method is using weighted average method. For example, the input will be set as following:

Distance: 572 meters
Enemy HP: 73 %
Enemy Unit: 4

After all the input is entered, from the process of the evaluation as figure 3 and thendefuzzification for all singleton value is calculated by the previous function, we will get8.16 m/s.

VI. Experimental Result

Testing techniques in this study is use questioner technique. The game created successfully and tested its gameplay to the player directly to 15 years old and above. The player will play the game with and without the use of Fuzzy Takagi Sugeno method embedded into the game. Once the players play, the player will be given gameplay questioner about the quality of game. With 20 players as the respondent.

There is a question that indirectly aimed to compare the level of satisfaction, the level of intelligence of the game, and the natural level of game between artificial intelligence game and the conventional game. From 20 players to be asked about conventional games distributed in 0% not satisfied, 5% less satisfied, 50% of normal respond, 40% quite satisfied, and 5% satisfied. Difficulty level is described in more detail in Figure 3.

Fig. 3 Satisfaction level of Conventional Game

The level of satisfaction derived from player by the game that has been embedded by artificial intelligence distributed in 0% of not satisfied, 15% less satisfied, 15% of normal respond, 55% of quite satisfied, and 15% of satisfied. Difficulty level is described in more detail in Figure 4.

Fig. 4 Satisfaction level of Game with AI

The survey also obtained results with the majority of players have increased in satisfaction.From the survey the data obtained 45% of the vote increased satisfaction, 40% of votes were unchanged and 15% of the vote decreased satisfaction with the method have been embedded.

The disatisfaction vote is the result of the planned game is too difficult to be solved make player happy to play a game without method. While the vote unchanged were according to vote the gameplay is too simple, does not recognize the changes that caused by the embedded AI, and less satisfied with some of the mechanics and dynamics that still lacking. Then the vote promoting increased satisfaction in the form because player have aesthetic challenge, competition and a sense of curiosity about the game, be aware of changes of the dynamics of the game by the method, the satisfaction of effects and gameplay interface, realizing that the game becomes more natural and realistic.

Results of the survey and the analysis then it can be concluded that the development of the game after embedded Takagi-Sugeno fuzzy method can increase satisfaction when compared with conventional game that more monotonous.

VII. CONCLUSION

From the survey results and its analysis, there can be concluded that the game had been developed after implanted Takagi-Sugeno fuzzy method is able to improve the satisfaction when compared with conventional game that tends to be more monotonous. Applied fuzzy Takagi-Sugeno method can be used to improve the dynamics of the game manipulate enemy movement speed in the game shoot em 'up.

From the results of the questionnaire that has been done can be concluded that the addition of artificial intelligence affect the level of players satisfaction with 45% more satisfied with the game that has been implanted artificial intelligence and 15% more satisfied with the vote for conventional game.

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REFERENCES

[1] K. Durkin and B. Barber, "Not so doomed: Computer game play and positive adolescent development," *Journal of Applied Developmental Psychology,* vol. 23, pp. 373-392, 2002.

[2] S. Egenfeldt-Nielsen, "Mapping online gaming: Genres, characteristics and revenue models," ed, 2006.

[3] J. Laird and M. VanLent, "Human-level AI's killer application: Interactive computer games," *AI magazine,* vol. 22, p. 15, 2001.

[4] M. I. Arif, I. Kuswardayan, and R. Soelaiman, "Penerapan Perilaku Cerdas pada Obyek di Dalam Game Flash Tower Defense," 2006.

[5] P. Mattavelli, L. Rossetto, G. Spiazzi, and P. Tenti, "General-purpose fuzzy controller for dc/dc converters," in *Applied Power Electronics Conference and Exposition, 1995. APEC'95. Conference Proceedings 1995., Tenth Annual*, 1995, pp. 723-730.

[6] T. Taniguchi, K. Tanaka, H. Ohtake, and H. O. Wang, "Model construction, rule reduction, and robust compensation for generalized form of Takagi-Sugeno fuzzy systems," *Fuzzy Systems, IEEE Transactions on,* vol. 9, pp. 525-538, 2001.

[7] M. Buckland, *Programming game AI by example*: Jones & Bartlett Learning, 2005.

[8] R. K. Sharma, D. Kumar, and P. Kumar, "Systematic failure mode effect analysis (FMEA) using fuzzy linguistic modelling," *International Journal of Quality & Reliability Management,* vol. 22, pp. 986-1004, 2005.

[9] Y.-H. Song and A. T. Johns, "Applications of fuzzy logic in power systems. I. General introduction to fuzzy logic," *Power Engineering Journal,* vol. 11, pp. 219-222, 1997.

[10] D. Dubois and H. Prade, "What are fuzzy rules and how to use them," *Fuzzy sets and systems,* vol. 84, pp. 169-185, 1996.

[11] T. A. Runkler, "Selection of appropriate defuzzification methods using application specific properties," *Fuzzy Systems, IEEE Transactions on,* vol. 5, pp. 72-79, 1997.

[12] J. Y. Bae, Y. Badr, and A. Abraham, "A Takagi-Sugeno Fuzzy Model of a Rudimentary Angle Controller for Artillery Fire," in *Computer Modelling and Simulation, 2009. UKSIM'09. 11th International Conference on*, 2009, pp. 59-64.

[13] S. N. Pant and K. E. Holbert, "Fuzzy logic in decision making and signal processing," *Powerzone, Arizona State University,* 2004.

[14] R. Hunicke, M. LeBlanc, and R. Zubek, "MDA: A formal approach to game design and game research," in *Proceedings of the AAAI Workshop on Challenges in Game AI*, 2004, pp. 04-04.