

Fuzzy Logic Controller Design for A Robot Grasping System with Different Membership Functions

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Abstract. This paper investigates the effects of the membership function to the object grasping for a three fingered gripper system. The performance of three famously used membership functions is compared to identify their behavior in lifting a defined object shape. MATLAB Simulink and SimMechanics toolboxes are used to examine the performance. Our preliminary results proposed that the Gaussian membership function surpassed the two other membership functions; triangular and trapezoid memberships especially in the context of firmer grasping and less time consumption during operations. Therefore, Gaussian membership function could be the best solution when time consumption and firmer grasp are considered.

1. Introduction

Robot grasping system has several issues to be solved such as the position control, the force control, the hybrid control, and the grasping control[1]. To ensure better performance and efficient grasping, artificial intelligent techniques are always the best choice to be included in the grasping system. The method is selected as it could reacts and decides effectively as what human will do during picking or lifting an object.

Since 1990's, Fuzzy Logic has been proposed to provide alternative solutions for grasping purposes which analyzed a number of identified issues[2, 3, 4, 5]. The earliest contribution in determining the Fuzzy Logic in robot grasping system was proposed by R.Alberto et al[6]. They discussed the performance of the system in two cases; known and unknown conditions. Based on their findings, Fuzzy Logic can guarantee better results as they mimics the human behavior very well during the operation. Their results was supported and demonstrated by others that suggested fuzzy logic technique could provide good results by determining initial pattern of objects to be lifted[3]. N.I. Glossas et al.[7] proposed the fuzzy logic grasping system by using a subtractive clustering algorithm for their two fingers gripper. By considering three inputs and an output, they adjust the gripper motion through tactile sensors through very minimum rules. Their experimental results expressed that the fuzzy logic with clustering algorithm perform well than any other fuzzy based system.

Not limited to the standalone technique, the control system for the robot grasping system has also combined two different methods. For example, L.Minzhuo et al.[8] demonstrated that a robot grasping system in a space exploration can achieve better results when a number of heterogenous sensors are attached to the gripper with designated control strategies when Fuzzy Logic and Artificial Neural Network are hybridized. Other than this paper, there are also a number of books that analyze the robot grasping system. A.M Zaki et al.[9] studied the

performance of fuzzy logic technique and ANFIS system for an intelligent gripper. Triangular and trapezoid memberships are used for the system to investigate the behavior of the gripper. Some guidelines on building the gripper was also proposed and they mainly analyzed the gripper system that used two fingers gripper. They claimed that the time consumption can be decrease as well as improved the slip displacement of the gripper.

This paper attempts to examine the performance of Fuzzy Logic Control to lift known objects considering an object shape. Our work extends the analysis performed by [3] to understand the effects of membership function to the grasping system. Besides, the work considers three fingers type gripper compared to the literatures presented above. Until now, in our best knowledge the analysis is still unavailable even though the membership function is known to be one of the factors that leads the decision. This is probably due to the triangular membership function is easier and has faster computation time when compares to other membership types. In contrast to these claims, our work has identified that the computation time also can be faster for gaussian membership. Therefore other membership function should also examine to understand how they behave in different conditions. It was also claimed that the triangular membership is lacking of linguistic interpretation in comparison to gaussian approach[10]. Hence, the gaussian membership could provide better results in pursuing better grasping for the system by incorporating the human-like behavior in the system in the sense of decision making.

To demonstrate the results, three different cases of different fuzzy sets effects are observed to identify the Fuzzy Logic Controller influence in controlling the gripper. The analysis through MATLAB Simulink and SimMechanics Toolboxes virtually identifies the best selections of fuzzy sets design to be incorporated into the grasping system when a cube shape and rectangle shape objects are lifted. The selections are based on the time consumed during operation. Analysis through SimMechanics is still unavailable which considerably makes this investigation become interesting as designer could design the system with exact parameters before realizing the design. Hence, the design will improve the performance with less expenditure.

2. Fuzzy Logic Controller Design

In our system, we divided the analysis into two different parts. The first part will only consider the object shape as our only input and the output is the angle orientation while the second part analyzes the performance when two inputs are fed into the system. These cases are organized in order to demonstrate easier on how actually the fuzzy sets membership affects the performance of the system. The fuzzy logic is designed based on three stages as listed below;

- Fuzzification

This stage defines the fuzziness of the object size. Three fuzzy set boundaries are designed for the object shapes; small, medium and large and ranges between $0cm$ to $10cm$. For the output, the thumb finger angle has also three fuzzy set; small, medium and large which ranges between 20° to 50° . This range was identified in correspond to the object size. Based on these memberships, the fuzzy rule are constructed. The fuzzification is shown in table 1. The simplest fuzzification is considered to easily shown the impact of the fuzzy condition to the robot grasping system.

Table 1. Fuzzy Logic : Fuzzy sets Input

| Cube size | Angle movements |
|-----------|-----------------|
| Small | Large |
| Medium | Medium |
| Large | Small |

- Rule Evaluations

This step calculates the fuzziness of the system. By using the Mamdani technique in Fuzzy Logic toolbox in Simulink, the rules are evaluated to identify the best position of robot fingers to be allocated. It is expected that, based on the evaluations, the robot can grasp effectively without dropping the object. Notice that, the rules are constructed to control the robot finger angle to move in the specified value. Only three rules are considered as shown in table 2. The fuzzy set membership for the inputs which are the cube dimensions or sizes is classified into three categories as mentioned in above. Similar settings are done for the other two fingers.

Table 2. Fuzzy Rule for the thumb finger

| |
|---|
| IF cube is small THEN angle movement is large |
| IF cube is medium THEN angle movement is medium |
| IF cube is large THEN angle movement is small |

- Defuzzification

This process determines the output of the system. The results must be able to identify the best gripping angle that the robot can perform. The simulink and fuzzy logic toolbox are used to simulate the performance of our design.

The work only focusses on a three fingers robot grasping system that has a thumb finger and two other fingers. Each of the finger has two degree of freedom(d.o.f) which we would like to examine based on the proposed fuzzy membership function. As explained above the fuzzy logic steps, the system attempts to understand the performance of different fuzzy sets membership in selecting the best method for use in the grasping system. Even though the fuzzy rules are seems very simple, but it provide a general pictures that by choosing appropriate membership function, the result would become better especially when a best grasping is considered. In addition, remark that the works do not examine in details about the force being applied when lifting the object using the gripper to examine the robustness of the system.

3. Preliminary Results and Discussion

In this first session, an object with a cube shape is only considered as an input for analysis purposes of the fuzzy controller design. The three fingers gripper is designed through MATLAB Simulink and SimMechanics toolboxes with specific weights and dimensions. The model developed by SimMechanics is shown in fig.1 stating the initial position of the gripper and fig.2 for the final position of the gripper. The initial position describes the position of the gripper before grasping the object. To grasp the given object, the gripper then moves as shown in fig.2. At the same time, each finger is configured to pick the objects with pre-described force which is priorly defined to avoid any damage to the object. The gripper is also has been programmed to be at least able to lift the object. Remark that the gripper and objects are located in a known position before task operation. This work does not considers any sensors input for the system to operate but only depends on the pre-determined size of the cube size or dimension. Besides, the gripper is expected to be able to grasp the object with suitable force without damaging the object.

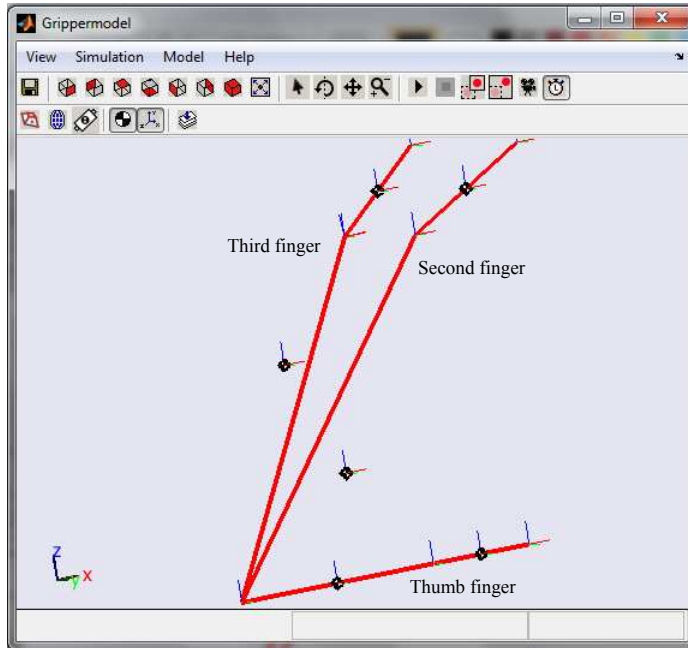


Figure 1. Gripper initial position

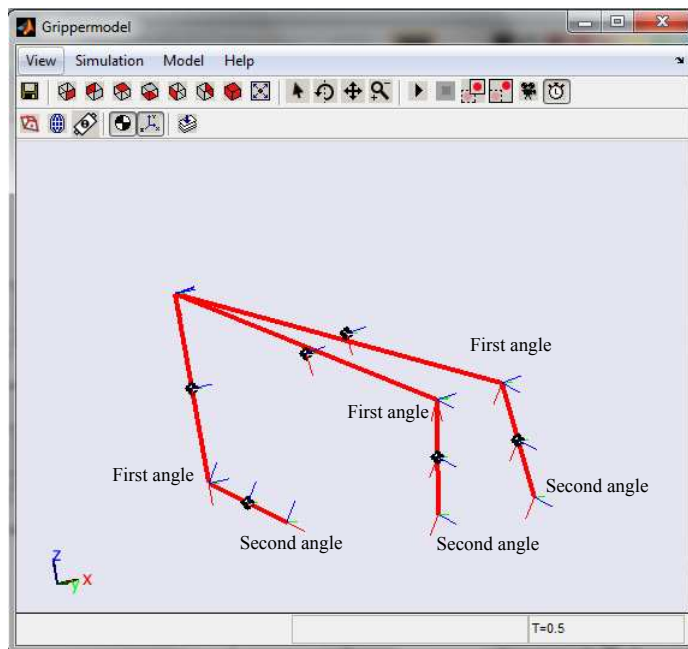


Figure 2. Gripper final position

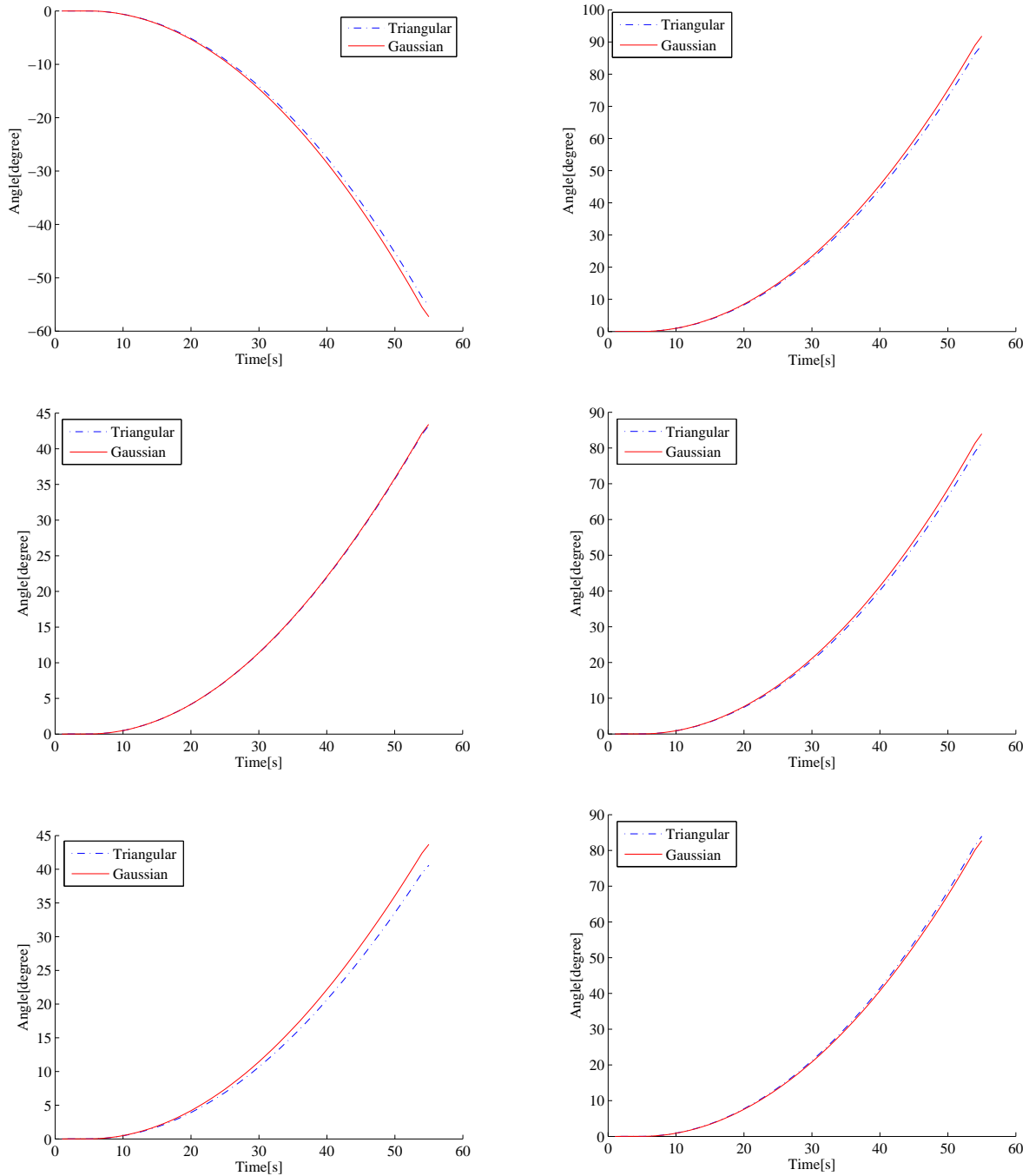


Figure 3. The performance comparison between gaussian membership and triangular membership fuzzy sets for robot thumb and fingers. The first upper two figures demonstrate the thumb fingers for first(left) and second angle(right). This is then followed by the other two fingers with each of it angle position

Figure 3 describes the angle movements for each fingers for the three fingered gripper when the gripper attempts to grasp a cube. The angle movements for the gaussian membership shows slightly bigger movements compared to the triangular membership. In other words, the gripper has better and firm grasp to the object if the gaussian membership is applied.

One of the other factors to be examined is the time required for the grasping system to operate. This issue is very significant in pursuing lower cost and increasing the products lifting especially in manufacturing industries that employs the gripper system. Our investigation has find that the average times taken for the robot to grasp the objects are shown in Table 1. The time consumption is calculated based on the average results of simulation after examining the results for five different simulation outputs.

Table 3. Comparison of time consumption for different fuzzy membership types

| Fuzzy Membership functions | Gaussian | Triangular | Trapezium |
|----------------------------|----------|------------|-----------|
| Time consumed[s] | 2.637038 | 2.9293148 | 2.8996832 |

The works also explored the conditions when trapezoid membership function is used for fuzzy set membership. Our findings are still consistent with the our previous results which illustrated that the gaussian membership is the best solution even if the trapezoid function is referred.

To support and further evaluates the performance, system with two inputs was also taken into account for verifications. Other than the cube dimension as input, the analysis is also looking into the effects of material types whether soft or hard type. The fuzzy rules are created to demonstrate how the gripper will moves if both of these inputs are feed into the system. The fuzzy rules are listed as below.

- IF the cube is small AND material type is soft, THEN theta is large
- IF the cube is small AND material type is hard, THEN theta is very large
- IF the cube is medium AND material type is soft, THEN theta is medium
- IF the cube is medium AND material type is hard, THEN theta is large
- IF the cube is large AND material type is soft, THEN theta is small
- IF the cube is large AND material type is hard, THEN theta is medium

The surface viewer for both fuzzy membership types are shown in fig.4 below. From the simulations, the angle movements and final position for thumb finger do not show too much differences. However, it is recognized that the second finger has exhibit better pictures of the performance as presented in fig.5. Both angle 1 and angle 2 on the second finger for gaussian membership function shows better grasping when a hard cube is lifted. It is also expected that even if the fuzzy sets for the input is increased especially for the material type, then the merely same results should be achieved. The same outcomes is also possible for the number of fuzzy sets in input 1; cube dimension. It can be concluded by referring to these figures that the gaussian membership offers better solution for researcher in robot grasping system in terms of reducing operation time and better decision of the fingers movement when collecting a cube size objects. The main reason to this results could be due to the interpretation of linguistic variable as been explained in the previous section that the triangular membership function cannot appropriately simulates the variable. Furthermore, the gaussian membership function is somehow very near to the human behavior in making decision. Even though many researcher has used the triangular membership for their system, now they should also consider the gaussian membership in pursuing their expected outcomes.

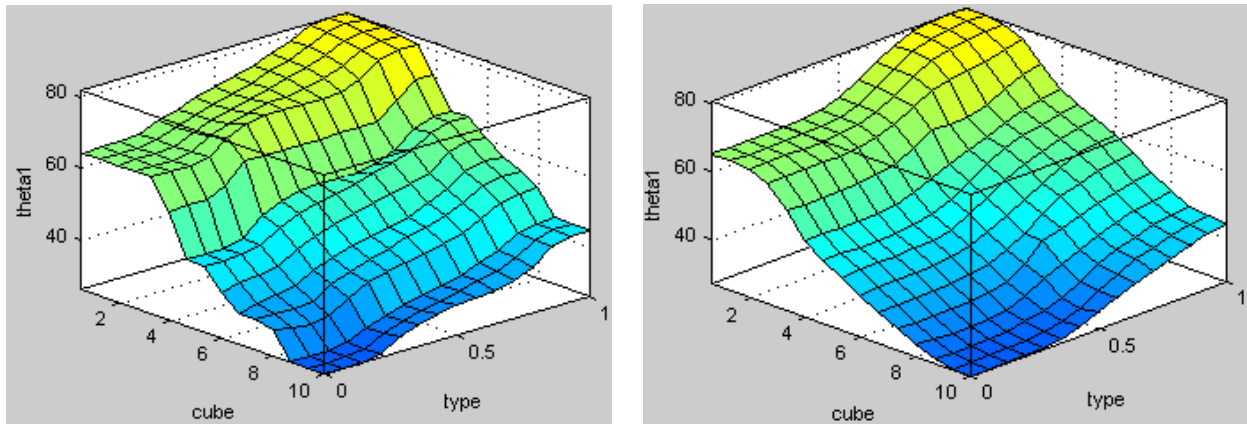


Figure 4. The surface viewer for both triangular membership(left) and gaussian membership(right)

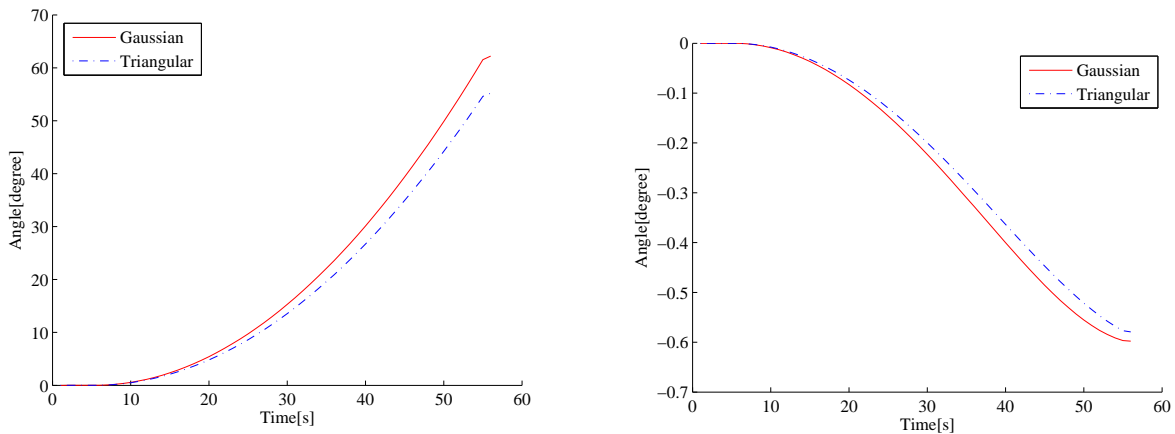


Figure 5. The performance comparison between gaussian membership and triangular membership fuzzy sets for second finger. The left side figure show the movements for first angle and the right side figure illustrate the second angle of the finger

4. Conclusion

This paper discussed the performance evaluation between fuzzy set membership function in a robot grasping system by using fuzzy logic controller. A fuzzy logic based robot grasping system that has three fingers are used for evaluations which consists of a thumb finger and other two normal fingers. There are two types of memberships that was mainly analyzed which are the triangular membership and the gaussian membership. The investigation falls into two aspects, which first determines the performance when only one single input is considered and then proceed to a case when two inputs of the system. Both cases suggested that gaussian membership can provide better results in comparison to the triangular membership function or the trapezoid membership function. Nevertheless, further analysis must be carried in analyzing the actual force exhibit by each fingers especially when fragile objects needs to be lifted.

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