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Three-Dimensional Fuzzy Logic Controller Applied to Rocket Target Traction

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ABSTRACT

This paper deals with the three-dimensional fuzzy logic technique applications on target traction, where Rocket target traction is a complex process that requires precise control systems to ensure accurate targeting and trajectory. Traditional control systems have limitations in their ability to account for complex and nuanced conditions, leading to less accurate targeting and less efficient use of resources. Three-dimensional fuzzy logic is an advanced approach to control systems that allows for more precise and nuanced evaluations of conditions, leading to more accurate targeting and more efficient use of resources. In this article, we'll explore the application of three-dimensional fuzzy logic to rocket target traction, the benefits of this approach, and examples of its application in real-world scenarios using Matlab.

1. INTRODUCTION

Rocket or Missile trajectory tracking is a critical technology used to guide missiles towards moving targets. The primary objective of missile trajectory tracking is to optimize (minimize) the distance between the missile and the target by calculating the optimal missile trajectory based on the current position and velocity of both the missile and the target. The key component of the guidance system is the tracking algorithm, and it plays a crucial role in achieving high-precision tracking of the target.

There are several types of guidance systems utilized for missile trajectory tracking, including radar, infrared, and laser guidance systems. Each system has its own strengths and limitations based on the flight conditions and target characteristics. Recent research has focused on developing advanced tracking algorithms to improve the precision of missile trajectory tracking. For example, researchers have investigated the use of machine learning techniques to enhance the accuracy of the tracking algorithm. In a recent study, convolutional neural networks were utilized to improve the accuracy of missile trajectory tracking [1].

In addition to developing advanced tracking algorithms, researchers have also explored the use of new sensors and trajectory calculation techniques to improve the recision a of missiles. For instance, a recent combination of missiles. For instance, a recent combination of fuzzy logic controller and a linear quadratic regulator to improve the guidance precision of the missile [2]. Another study proposed a new guidance algorithm based on a sliding mode control approach to improve the control accuracy of the missile [3].

Furthermore, researchers have also investigated the use of multi-sensor fusion techniques to enhance the tracking accuracy of missiles. For example, a recent study proposed a novel multi-sensor fusion algorithm based on a Kalman filter to improve the tracking accuracy of a missile guidance system [4].

So missile trajectory tracking is a critical technology for guiding missiles towards their targets. Advanced tracking algorithms, new sensors, and trajectory calculation techniques are being developed to improve the precision and range of missiles. Future research is expected to focus on developing more sophisticated tracking algorithms and novel guidance techniques to further improve the effectiveness of missile trajectory tracking. And for that this work is devoted to present a new Algorithm based on more developed control technique using the tree-dimensional fuzzy logic[5]-[9].

2. TREE-DIMENSIONAL FUZZY LOGIC

Fuzzy three-dimensional logic, also known as 3D fuzzy logic [10], is an extension of traditional fuzzy logic that allows for modelling three-dimensional systems using three-dimensional fuzzy sets.

Where Fuzzy logic was first introduced in the 1960 as a mathematical framework for dealing with uncertainty and imprecision in data. It was originally developed for use in control systems, where precise, binary decisions were impractical. Fuzzy logic allowed for the creation of control systems that could make more flexible, nuanced decisions based on a range of input data.

In the early 1990s, researchers began to explore the use of fuzzy logic for modelling three-dimensional systems. One of the key challenges in this area was how to represent three-dimensional fuzzy sets mathematically. In 1992, Kaoru Hirota proposed a solution to this problem in a paper titled "Three-Dimensional Fuzzy Control".

Hirota's approach involved dividing a three-dimensional fuzzy set into a series of two-dimensional slices, each of which represented a different level of membership in the set. By representing the fuzzy set in this way, it was possible to perform calculations more efficiently and accurately.

2.1 Description of the Three-dimensional fuzzy logic

Three-dimensional fuzzy logic is an extension of traditional fuzzy logic that allows for the representation of fuzzy sets and membership functions in a three-dimensional space. This approach allows for more complex and nuanced evaluations of degrees of membership. Fuzzy logic is a mathematical approach that deals with uncertainty and imprecision by assigning degrees of truth rather than simply true or false. Traditional fuzzy logic represents fuzzy sets and membership functions in a two-dimensional space. In contrast, three-dimensional fuzzy logic represents fuzzy sets as volumes, called "3D membership functions." 3D membership functions are defined by mathematical equations that describe their shape and position in space. The fuzzy set is then determined by the intersection of several volumes. The fuzzy set of FLC and Type 2 FLc are represented in figure(1) below

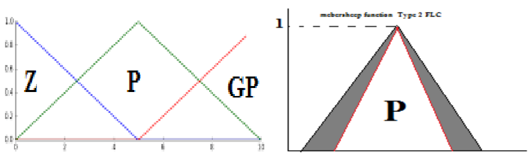

Figure.1classical fuzzy logic set

Where fig 2 represent a tree dimensional fuzzy logic set

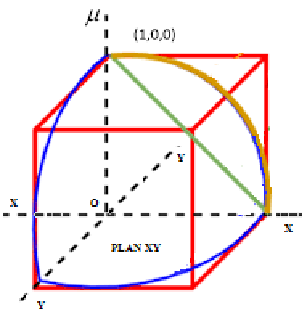

Figure.2 Tree dimensional fuzzy logic set

For the three dimensional axes X, Y, Z each axe has him three dimensional fuzzy set and the controller will use them all in the same time to locate the position of either rocket and target and calculate the optimal estimated trajectory for the rocket.

2.2 Three-dimensional fuzzy logic advantages

The benefits of three-dimensional fuzzy logic include more accurate control and more efficient use of resources. Traditional control systems have limitations in their ability to account for complex and nuanced conditions, leading to less accurate control and less efficient use of resources. Three-dimensional fuzzy logic allows for more precise and nuanced evaluations of conditions, leading to more accurate control and more efficient use of resources but this need more complex algorithms and calculator more powerful to analyse the big data include in lesser time possible.

2.3 Three-dimensional fuzzy logic control principle

The most bases of the fuzzy logic controller are applied on three-dimensional fuzzy logic control but with three dimensional fuzzy set and the needed adaptation on fuzzification, inferences and defuzzification steps as shown on figure(3) below proposed by Volodymyr MORKUN and Olha KRAVCHENKO on 2021 in [11]

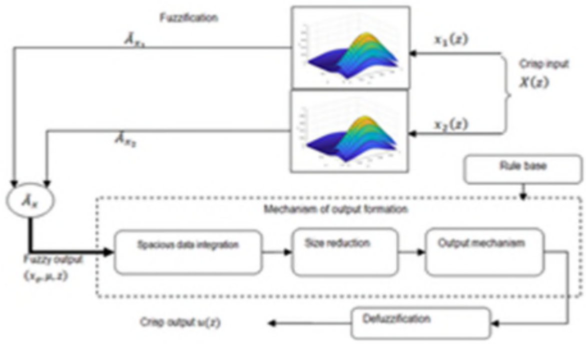

Figure.3 Three-dimensional fuzzy logic control principle [11]

Three-dimensional fuzzy logic is based on mathematical principles, including set theory, fuzzy set theory, and fuzzy logic. Set theory is used to define the universe of discourse, or the set of all possible values of a variable. Fuzzy set theory is used to define fuzzy sets, which are sets that have degrees of membership. Fuzzy logic is used to determine the degree of membership of a value in a fuzzy set.

Where the general basic control structure is represented on fig.4 describe the different parts of the fuzzy logic controller

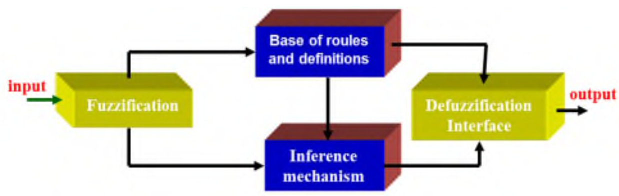

Figure.4fuzzy logic controller structure

Also we can use the different bases rules of the traditional fuzzy logic with the three-dimensional fuzzy logic controller with the consideration of the three dimensional member sheep set function.

3. THREE DIMENSIONAL FUZZY CONTROLER ALGORITHM

Three-dimensional fuzzy logic can be integrated into control systems using mathematical algorithms and programming languages. The algorithms are used to perform calculations and make decisions based on the input data and the fuzzy rule-based system. The programming languages are used to implement the algorithms and create the user interface for the control system.

The proposed controller algorithm steps are described on 7 points below:

Input and output variables definition

1) Member sheep function definition for each variable
2) Member sheep function plot
3) Control rules definition
4) Control rules aggregation
5) Global control rule plot
6) Command calculation
7) Command application to the system

For the input variable we have taken error on position and the error variation with the integral of the error as third input variable

Obtained results are represented in figures 5, 6 and 7

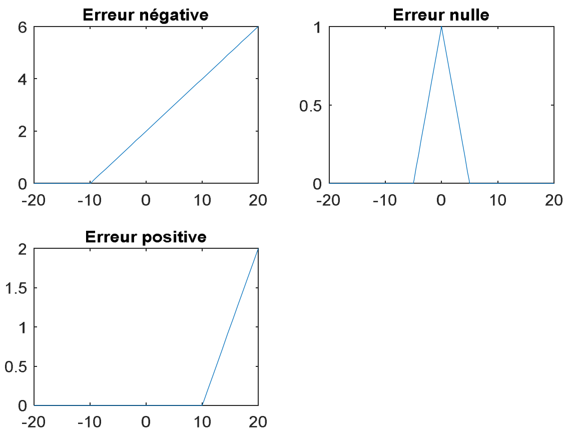

Figure.5 Three-dimensional fuzzy logic control input set ‘’error’’

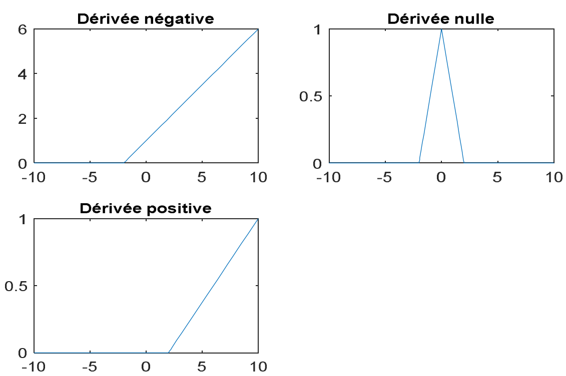

Figure.6 Three-dimensional fuzzy logic control input set’’de’’

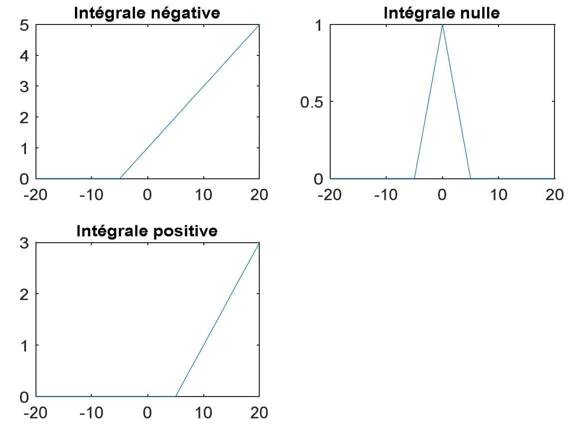

Figure.7 Three-dimensional fuzzy logic control input set ‘’error integral’’

Where the command output is represented by figure.8

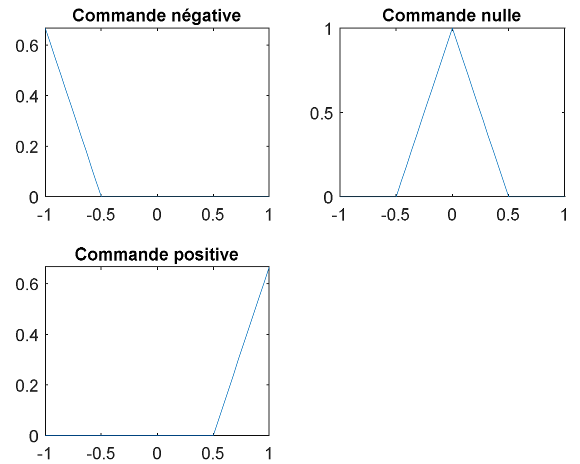

Figure.8 Three-dimensional fuzzy logic control output set ‘’u’’

And the control rules are represented on figure.9

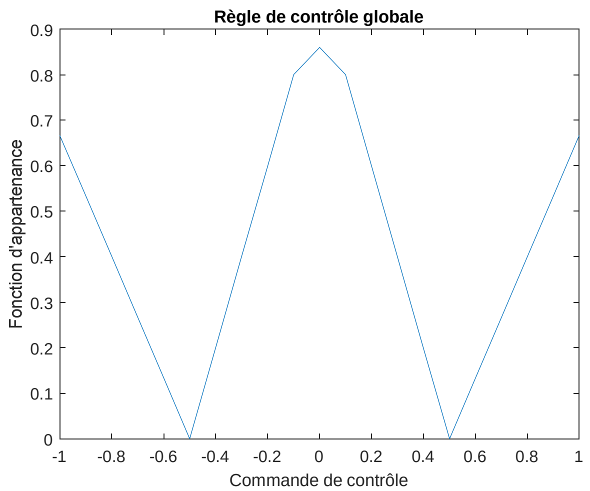

Figure.9 Three-dimensional fuzzy logic global control rules

4. THREE-DIMENSIONAL FUZZY LOGIC APPLIED TO ROCKET TARGET TRACTION

Three-dimensional fuzzy logic can be implemented in rocket target traction by creating 3D membership functions for each variable that affects the trajectory of the rocket. These variables may include altitude, velocity, trajectory, wind speed, and direction. The 3D membership functions are then combined to create a fuzzy rule-based system that determines the optimal thrust, angle, and direction of the rocket.

As example of the application of three-dimensional fuzzy logic to rocket target traction is the landing of the Mars Rover on the surface of Mars. The landing process involves multiple stages, including entry, descent, and landing. During the descent stage, the rocket engine must be controlled to ensure a safe and accurate landing. Three-dimensional fuzzy logic can be used to regulate the thrust of the rocket engine based on observed measurements, such as altitude, velocity, and trajectory. It can also be used to adjust the angle and direction of the rocket in response to changing conditions, such as wind speed and direction.

The Mars Pathfinder mission, launched in 1996, utilized fuzzy logic to control the descent of the spacecraft onto the surface of Mars. The fuzzy logic system was used to adjust the thrusters of the spacecraft to keep it on course as it descended towards the surface. The system was able to adjust to unexpected wind gusts and keep the spacecraft on target, resulting in a successful landing.

5. CONCLUSIONS

Three-dimensional fuzzy logic is an advanced approach to control systems that allows for more precise and nuanced evaluations of conditions, leading to more accurate targeting and more efficient use of resources. It can be applied in many fields, including rocket target traction, where it can be used to regulate the thrust, angle, and direction of the rocket engine based on observed measurements.

The mathematical integration of three-dimensional fuzzy logic in control systems is based on set theory, fuzzy set theory, and fuzzy logic, and can be implemented using mathematical algorithms and programming languages. With its ability to handle complex and nuanced conditions, three-dimensional fuzzy logic has the potential to revolutionize the field of control systems and improve the accuracy and efficiency of many processes.

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