FUZZY LOGIC: PREDICTING POWER FOR CONTAINER CRANE CONTROLLER

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ABSTRACT

A container crane has the function of transporting containers from one point to another point. The difficulty of this task lies in the fact that the container is connected to the bridge crane by cables, causing an opening angle while the container is being transported, interfering with the operation at high speeds due to oscillation that occurs at the endpoint, which could cause accidents [1].
This study presents a dataset that comprises of the two predictive attributes namely angle and speed to generate a rule set using the Decision Tree technique [3] to predict the power of the Crane. The above rules generated are used in implementing a "Fuzzy Logic" approach to the dataset. In this report, a Mamdani style Inference system is built using scikit-fuzzy. The implemented method illustrates the power of fuzzy logic to describe the complex behavior from a set of expert rules. The results are found to be encouraging indicating the potential for implementation of fuzzy methodologies in practice [5,7].
Keywords: Decision Tree, Fuzzy Logic , Fuzzy Inference System, Mamdani style Inference System, Scikit-Fuzzy, If-else Rule-Set

INTRODUCTION

The container crane is widely used to transfer heavy loads in ports and shipyards. This transfer is desirable that the container crane transport the loads to the desired position as quickly and as accurately as possible without colliding with any other equipment. This rapid movement naturally induces undesirable balance of the container, which could cause damage to the load and other types of hazards, also reducing the performance of the operation. Therefore, these oscillations in the track must be damped before another container come into operation. Thus, the performance transshipment loses the desired efficiency, increasing the cost involved in the operation and the risk of accidents with heavy loads that are transferred continuously throughout the operation [1].
Fuzzy Logic is a mathematical representation of uncertainty and approximate way of imitating the human ability to generate decisions in uncertain environments. In this report, we use a simple fuzzy classifier that takes the set of rules that classifies them into broad, coarse groupings.

DATA

The dataset includes two predictive attributes namely speed and angle that can be used to determine the power of the Container Crane Controller. The record includes 15 different univariate instances.
However, for Fuzzy Classifier, the speed and power of the moving container crane are represented as low, medium and high each while the angle for the crane movement is represented as large negative, small negative, zero, small positive and large positive angle. The dataset has been modified for fuzzy logic which is largely based on intuition and domain knowledge.The instances are changed as follows:For speed: low, medium and high(low: 1,2,3; medium 6,7,8 ;high 9,10). For angle: large negative (-5), small negative (-2), zero, small positive (2) and large positive angle (5). For power: low, medium and high(low: 0.3; medium :0.5; high :0.7).

DECISION TREE CLASSIFICATION-ID3 ALGORITHM

To produce the set of rules for classifying on the basis of the indicator we use the C4.5 algorithm. This program includes the ID3 algorithm which is a machine learning algorithm for building classification trees developed by Ross Quinlan in/around

1986. The algorithm is a greedy, recursive algorithm that partitions a data set on the attribute that maximizes information gain.[2]To produce a decision tree, the class attribute(target attribute) is considered to be the **leaf node**. The entropy of the target attribute is calculated using,

$$H(S) = \sum_{x \in X} -p(x) \log_2 p(x) \tag{1}$$

Here, 1. S is the class attribute
2. H(S) is Entropy of the class attribute

Then for each attribute, information gain is calculated using,
Information Gain= Entropy of Class Attribute- Entropy of (each) attribute

$$IG(A,S) = H(S) - \sum_{t \in T} p(t)H(t) \tag{2}$$

To construct the decision tree we calculate the entropy for the class attribute and entropies for all other attributes. Then we calculate the information gain for each attribute. The one with the highest gain is considered as the **root node.**

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IF Angle EQUALS small positive angle AND Speed EQUALS low THEN medium
IF Angle EQUALS large positive angle AND Speed EQUALS low THEN low
IF Angle EQUALS angle zero AND Speed EQUALS low THEN high
IF Angle EQUALS small negative angle AND Speed EQUALS medium THEN low
IF Angle EQUALS small negative angle AND Speed EQUALS high THEN low
IF Angle EQUALS angle zero AND Speed EQUALS high THEN medium
IF Angle EQUALS small negative angle AND Speed EQUALS low THEN medium
IF Angle EQUALS small positive angle AND Speed EQUALS high THEN low
IF Angle EQUALS large negative angle AND Speed EQUALS low THEN low
IF Angle EQUALS large positive angle AND Speed EQUALS medium THEN medium
IF Angle EQUALS large negative angle AND Speed EQUALS medium THEN medium
IF Angle EQUALS large positive angle AND Speed EQUALS high THEN medium
IF Angle EQUALS large negative angle AND Speed EQUALS high THEN medium
IF Angle EQUALS small positive angle AND Speed EQUALS medium THEN low
IF Angle EQUALS angle zero AND Speed EQUALS medium THEN high
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Fig 1 Decision Tree generated

In this report, the Decision Tree technique can be used to generate the set of 'if-else' rules which forms the knowledge base for the fuzzy classifier [3].

FUZZY INFERENCE SYSTEM

Fuzzy inference provides a good way of dealing with uncertainty. Fuzzy inference is a method that interprets the input value and based on the rule set, assigns the output value. The mechanism used here is a list of 'if-else' rules. The real world data do not have sharply defined boundaries where information is unreliable. A fuzzy classifier is proven to be effective in handling such complex information [4,5]. In this modified dataset, the speed and angle are fuzzy in nature. Thus, problems of this kind can be modeled using a fuzzy system [5]. In this report, the Fuzzy Inference technique used is the Mamdani Method.

Membership Function

A membership function is a curve that defines each point in the input space is mapped to a membership value between 0 and 1 [6].In this report, the range of all three membership functions have been chosen from 0 to 100 and triangular membership function is used. The selection of this membership function and the range is to some extent arbitrary.

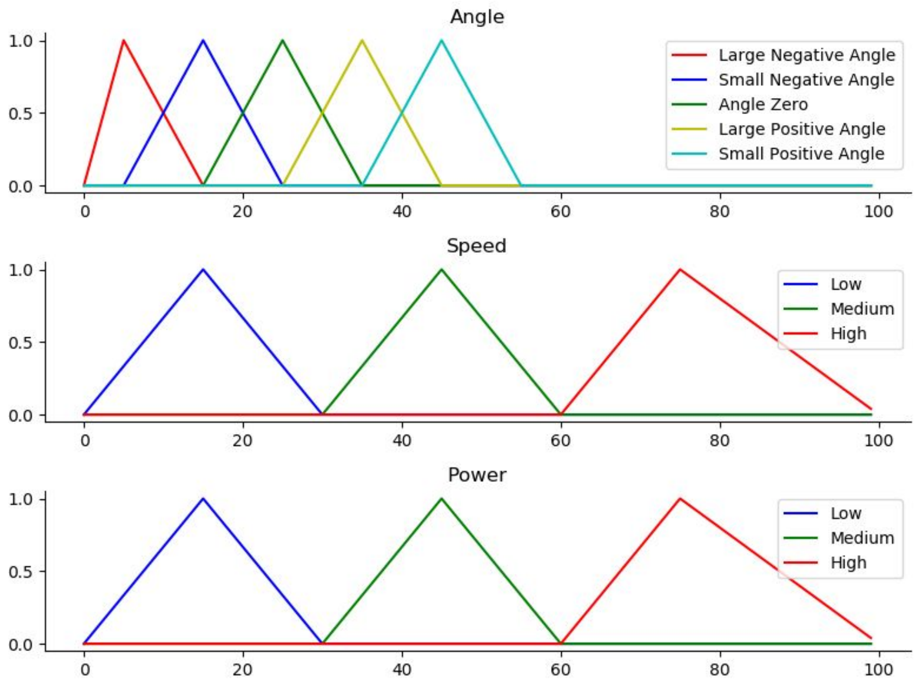

Fig 2 Membership Functions for (a) Angle (b) Speed and (c) Power

Fuzzy Rules

Fuzzy rules can be described as a key tool for expressing pieces for knowledge in "fuzzy logic'. To understand the concept of Fuzzy Rules, it will be useful to understand the concept of non-fuzzy rules, that is, " if x is A then y is B". In crisp logic, the premise x=A and/or y=B can either be true or false. However, in fuzzy logic, the premise can be true or false to a degree Now in order to make the membership functions useful, we describe a relationship between the input and output attributes. Here Fig 1, represents all the if-else rules generated using the Decision Tree technique.

Now, to determine the power for the controller crane, the activation for the fuzzy memberships have been calculated using the membership function, *fuzz.interp_membership.*
The membership value calculated corresponds to a discrete value on the universe of input variables (that is not corresponding to the input variable) [8].

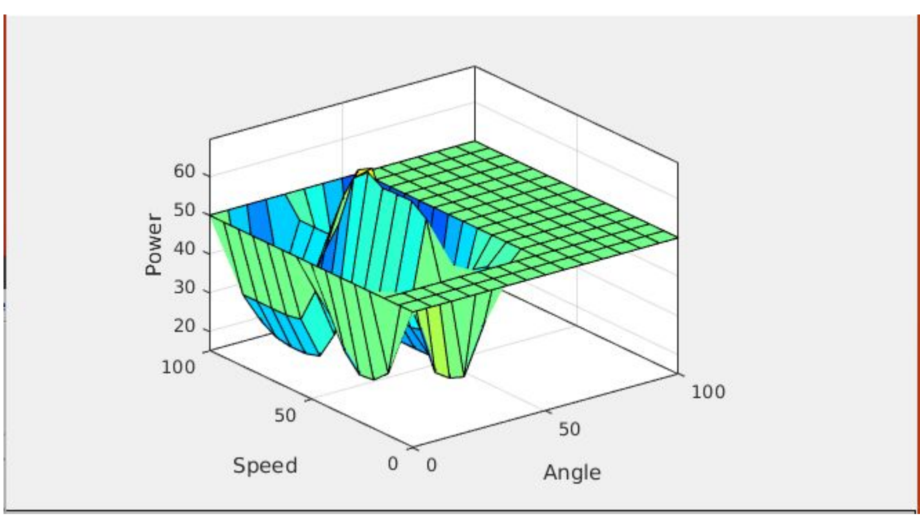

Fig 3 The surface view for Fuzzy Rule

Here in fig 3, the x-axis represents Angle, the y-axis represents Speed (predictive attributes) and the z-axis represents Power(target attribute) for all the rule set generated.

Aggregation of the Fuzzy Rules

After building the membership functions and generating the if-else rules, the next step is to take the membership functions of all rules (previously clipped) and combine them into a single fuzzy set.

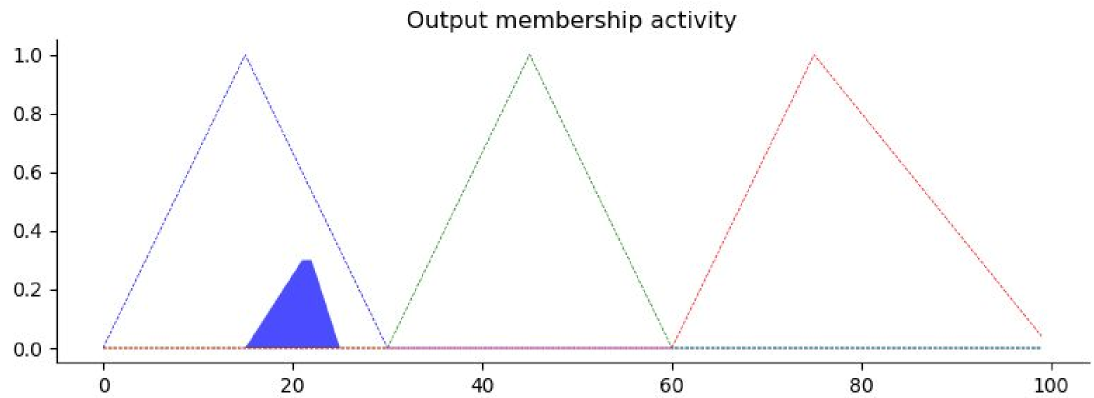

Fig 4 Aggregation of the Fuzzy Rules

In this study, when each attributes membership function is known all the output membership functions are combined using the *maximum operator* as seen in Fig 4.

Defuzzification

The last step in the fuzzy system is defuzzification. It can be described as the process of producing a crisp result in fuzzy logic, *given fuzzy sets and corresponding membership functions.* It is typically needed in fuzzy inference systems. The input for the process is the aggregated fuzzy rule and output is a single number.

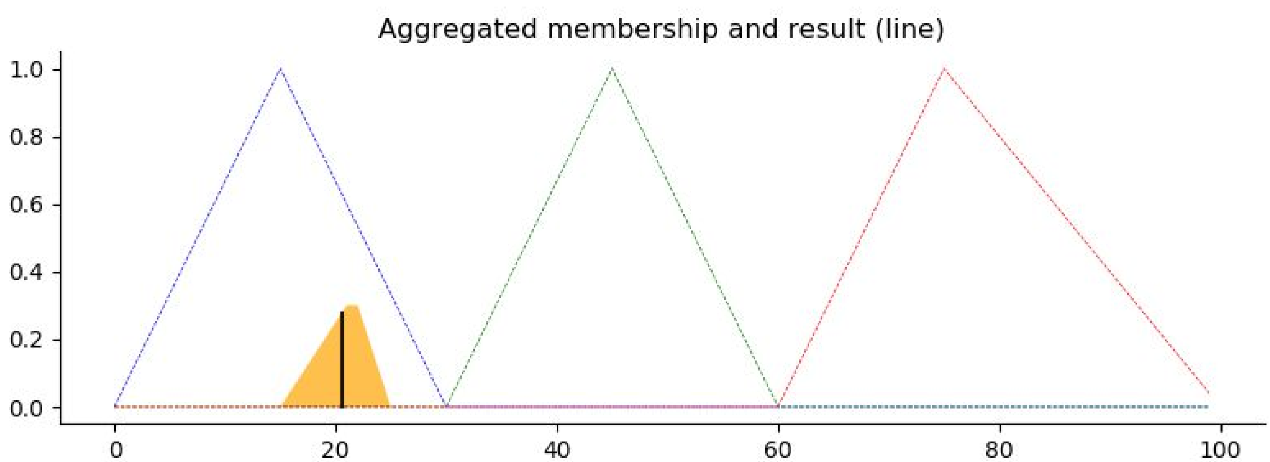

Fig 5 Fig 5 The Crisp Output - Defuzzification

In this report, in order to get a real-world answer, a defuzzification method based on the centroid method is used to return a crisp value. Here in Fig 5, the x-intercept gives the result which is the power of 20.583 % (approximately).

RESULTS

Each branch of the Decision Tree generated is converted into an 'if-then' rule and inputted as a knowledge base to a fuzzy inference system. A fuzzy control system for investigating the power of control container is built. The dataset consisting of 15 instances generates 15 different rules, which are presented in Fig 6. The rule viewer is implemented using the MATLAB ToolKit.

Fig 6, illustrates the rule viewer for given inputs and the corresponding output. From the present study, it can be said that fuzzy logic is an intelligent approach with simplicity and easy to implement. It can be observed that this study can be used to pre-project the power for the container crane.

It can also be said that Fuzzy logic provides a more "human-reasoning" approach to the dataset.

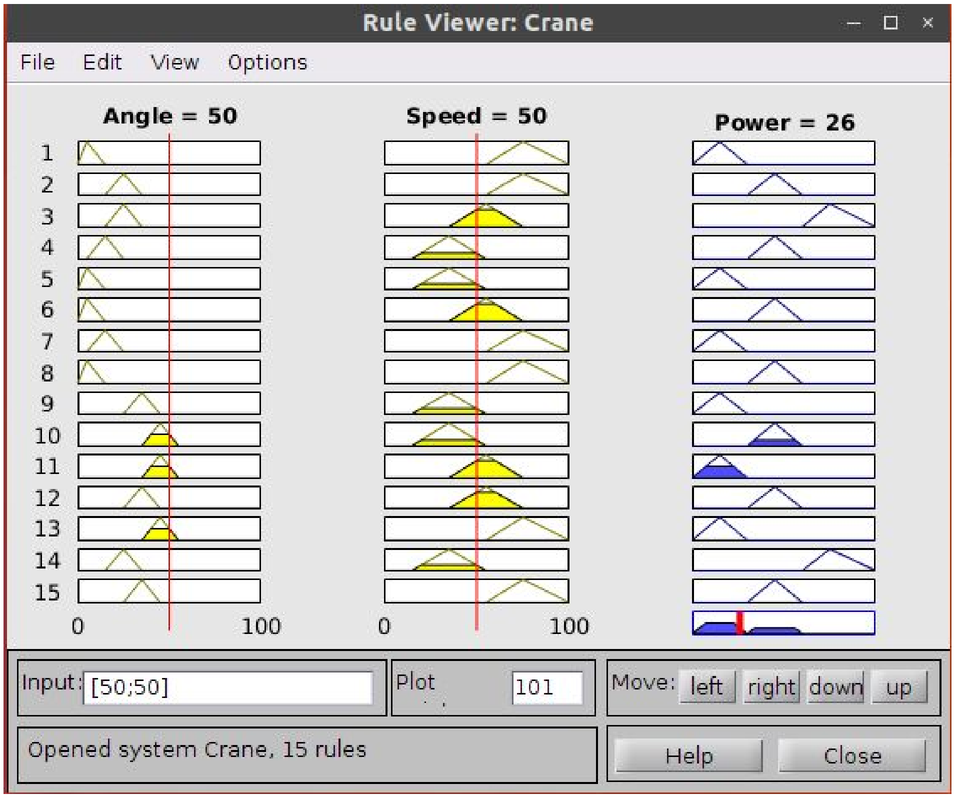

Fig 6 Rule Viewer

CONCLUSION AND FUTURE WORK

The use of Fuzzy logic has been growing in several areas of knowledge, as in the application of electronics, robotics etc. The growth in the use of fuzzy logic is due to its simplicity of implementation, and require little tired in its modeling, which provides both for the manufacturer, which reduces their costs, and the final consumer who acquires a more efficient product.[1].

This paper presents an algorithm-based method to perform the fuzzy logic approach and rules generated from a decision tree. The system's performance was found to be encouraging. The rule generation is performed using a decision tree as they are done by an algorithm with a strong mathematical background [5].

However, the limitation of the algorithm is that ID3 does not guarantee an accurate solution as it may get stuck in the local optima. It is a greedy, recursive algorithm by selecting the best attribute to split dataset on each iteration. Smaller decision trees are preferred over larger ones. This algorithm usually produces small trees, but it does not always produce the smallest possible tree. Thus, the predicted accuracy can be verified and improved by using other classification techniques.[9] and a fuzzy system can only be used to solve a problem if knowledge about the solution is available in the form of linguistic,*that is,* if-then rules.

Thus, the predicted output can be improved by using other techniques. These techniques can be combined to generate the so-called hybrid systems which give us an advantage since two or more techniques are combined. This gives us a system which is more powerful and with fewer disabilities. This interesting combination that combines an ANN with Fuzzy Logic can give us better results [1]. For future studies, we can also intend to refine the fuzzy membership functions in order to improve the performance of Neural Fuzzy Network (ANN and Fuzzy Logic)[1].

REFERENCES

1. Ferreira, R. P., Martiniano, A., Ferreira, A., Romero, M., & Sassi, R. J. (2016). Container Crane Controller with the Use of a NeuroFuzzy Network. In IFIP International Conference on Advances in Production Management Systems (pp. 122-129). Springer, Cham. DOI: 10.1007/978-3-319-51133-7_15.
2. Quinlan, JR C4.5: Programs for Machine Learning, Morgan & Kaufmann, 1993.
3. Bustos, R. A., & Gedeon, T. D. (1995). Decrypting Neural Network Data: A GIS Case Study. In Artificial Neural Nets and Genetic Algorithms (pp. 231-234). Springer, Vienna.
4. E. Cox: The Fuzzy Systems Handbook-A Practitioner's Guide to Building, Using, and Maintaining Fuzzy Systems, Academic Press, New York (1994)
5. V. Sugumaran,K.I. Ramachandran : Automatic rule learning using decision tree for fuzzy classifier in fault diagnosis of roller bearing, Mechanical Systems and Signal Processing, July 2007
6. Lotfi A. Zadeh, 1995 Fuzzy Logic Toolbox, Available at https://edoras.sdsu.edu/doc/matlab/toolbox/fuzzy/fuzzytu3.html (Accessed at 26 May 2018)
7. Scikit: skfuzzy 0.2, Available at https://pythonhosted.org/scikit-fuzzy/auto_examples/plot_tipping_problem.html
8. Scikit: skfuzzy 0.2, Available at https://pythonhosted.org/scikit-fuzzy/api/skfuzzy.html#skfuzzy.interp_membership
9. Fernandes, K., Cardoso, J.S., Fernandes, J.: Temporal segmentation of digital colposcopies. In: Pattern Recognition and Image Analysis. Springer (2015) 262–271
10. ID3 ALGORITHM program URL: https://github.com/tofti/python-id3-trees
11. Fuzzy Logic SciKit URL: https://github.com/scikit-fuzzy/scikit-fuzzy