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Knowledge Based Systems using Fuzzy Logic

Final Report

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Abstract

Fuzzy logic introduced a new era for knowledge based systems and expert systems in particular. Fuzzy logic is being integrated in many expert systems for real world problems. It has brought the notion of degrees membership between complete membership and non-membership. With fuzzy logic it is now possible to emulate human thinking using computers.

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1. Introduction:

Knowledge based systems are systems that are designed to emulate human thinking to solve problems and provide advices. One kind of knowledge based systems is Expert System. Although it is widely used in various applications, such systems are not able to model real world problems which are full of ambiguities and vagueness. When fuzzy logic was introduced by Lotfi Zadeh at 1965, it did not get the attention of expert system's researchers. According to Zadeh ," The initial reception of the concept of a linguistic variable was far from positive, largely because my advocacy of the use of words in systems and decision analysis clashed with the deep-seated tradition of respect for numbers and disrespect for words." [1] . The idea of fuzzy logic was to show that there is a world behind conventional logic. This kind of logic is the proper way to model human thinking. Although is has been introduced forty years ago, fuzzy logic is recently getting the attention of artificial intelligence researchers. It is being used to build expert systems for handling ambiguities and vagueness associated with real world problems. The expert system that uses a collection of fuzzy sets and rules to facilitates reasoning is called a Fuzzy Expert System. This paper is organized as follows: the second section will cover fuzzy logic, third section will be on fuzzy expert systems, fourth section will on different fuzzy expert systems in the literature , fifth section will discover some fuzzy expert systems and the last section is the conclusion.

2. Fuzzy logic :

Fuzzy logic was developed by Lotfi Zadeh a professor at the university of California, Berkley. It is useful for real world problems where there are different kinds of uncertainty[21]. One kind of uncertainty is fuzziness that is no sharp transition from complete membership to non membership. In human reasoning much of the logic is not based on two values ,it is not even multi-valued but fuzzy truth [21]. In conventional logic everything is considered true or false, black or white but nothing in between. Fuzzy logic on the other hand takes into consideration all values in between.

2.1 Fuzzy Sets:

Fuzzy logic is based on fuzzy sets, "A fuzzy set is a class of objects with a continuum grades of membership" [16]. A fuzzy set is an extension of a conventional set. A fuzzy set has elements belonging to it to some degree of membership. For example, the set of beautiful women is a fuzzy set. This degree varies from 0 to 1. In conventional logic the degree of membership is either 0 for non membership or 1 for complete membership. Fuzziness results from imprecise boundaries of fuzzy sets [9] [16].

It is based on emulating human thinking where elements are linguistic variables. Linguistic variables are variables whose values are sentences not numbers. The value of a linguistic variable is a combination of atomic terms. There are different categories of linguistic values. They could be primary terms, which are labels for specific fuzzy sets or could be hedges such as *very* regarding the atomic value [21].

So fuzzy sets are actually properties and fuzzy logic provides a way of finding conclusions for ambiguous inputs. Fuzzy sets represent commonsense linguistic labels like slow, fast, small, large, heavy, low, medium, high, tall, etc. A given element can be a member of more than one fuzzy set at a time[2] .

Various types of fuzzy membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions. Of these, the simplest and most frequently used is the triangular ,it represented by three points. The membership at the apex is 1 and the two ends have a membership 0. On the other hand trapezoid member function provides more information. It has a flat top and really is just a truncated triangle curve. It is similar to the triangular but with four points. It has an interval where the membership value is 1 [2].

Fuzzy logic is distinguished by three features. First of all, the use of linguistic variables. The second feature is the use of conditional statements to represent relations between variables. Lastly, the use of fuzzy algorithms for complex relations [21] .

2.2 Fuzzy Operations:

To show some fuzzy logic operation ,let $f_A(x)$ be the grade of membership of x in A.
The notion of **complement** or **negation** of the fuzzy set A is A' and is defined by

$$f_{A'}(x) = 1 - f_A(x) \quad (1)$$

given a two fuzzy sets A and B ,the notion of **containment** is defined by

$$A \subset B \leftrightarrow f_A \le f_B \quad (2)$$

The **union** (corresponds to **or**) of two fuzzy sets A and B is the maximum of their membership functions and is given by

$$\mathrm{Max}[f_A(x), f_B(x)\ ] \quad (3)$$

It is equivalent to

$$f_A \vee f_B \quad (4)$$

The **intersection** (corresponds to **and**) of two fuzzy sets A and B is the minimum of their membership functions and is given by

$$\mathrm{Min}[f_A(x), f_B(x)\ ] \quad (5)$$

It is equivalent to

$$f_A \wedge f_B \quad (6)$$ [16].

Beside the basic operations above, fuzzy logic has some operations used to represent linguistic hedges. **Concentration** operation, which results in a fuzzy subset of A with reduced magnitudes of membership, is defined by :

$$CON(A) = A^2 \ (7).$$

An operations which has the opposite effect of the concentration operations is called **Dilation** and is define by:

$$DIL(A) = A^{0.5} \ (8).$$ [21]

The **fuzzification** operation when applied to a non-fuzzy set it transform it into a fuzzy set $A^{\sim}$, by fuzzifying its boundaries. It also has the effect of increasing the fuzziness of a fuzzy set, the wavy bar is called **fuzzifier**. This operation is defined by :

$$\int_v \mu_A(y)\, K(y) \quad (9)$$

Where $\mu_A(y)$ is the degree of membership y have in A and K(y) is the fuzzy set resulting from applying the fuzzifer to 1/y [9] [21].

To compute the meaning of linguistic variables, hedges are regarded as operators. Let x be an atomic linguistic variable then *very* x is given by :

$$very\ x = x^2 \ (10)$$ [9].

2.3 Fuzzy Systems:

The most well known fuzzy system today is the subway in the Japanese city of Sendai. In addition to this they have a wide verity of other applications that use fuzzy logic. To name a few, character and handwriting recognition, robots and optical fuzzy systems. Japan was of the first to adopt fuzzy logic and now has become the world's leading developer of commercial fuzzy logic applications. Sony also has a fuzzy TV set that automatically adjust contrast, brightness and color. Big names such as Nissan and Mitsubishi have also made use of fuzzy logic [8]. Moreover, fuzzy logic has been used to develop learning tools and weather forecasting tools[23]. Fuzzy logic is also applicable in a lot of fields such as geology where geological entities have their own variety of vague features.

2.4 Fuzziness and Probabilities:

A distinction need to be made between fuzzy membership function and probability function. Probability function involves the use the Excluded Middle Law. It is about likelihoods of events. An event either occurs or does not. Or an element is either belongs to A or B where A and B are different sets. it is a measure of uncertainty of membership. the sum of the probabilities must be one which does not hold in fuzzy logic. Fuzziness occurs when information has no clear boundaries. An element has degrees of membership to sets A and B [16] [31] [9].

3. Fuzzy Expert Systems

A fuzzy expert system is an expert system that uses fuzzy logic instead of conventional logic. It uses a collection of fuzzy membership functions and rules to facilitate reasoning [31]. Since it uses rules, it falls into the category of rule-based expert systems [2]. Rules can easily demonstrate human thinking as they are easily formulated [18] . Fuzzy expert systems are used to provide non experts with some expert's skills [2] .

According to [2] fuzzy expert systems are categorized into two types. First is fuzzy control systems. Which accepts inputs as numbers. The input number is then translated into a linguistic term. In fuzzy control systems the application domain is defined. The second type is fuzzy reasoning. Which are systems that attempt to emulate human thinking where the domain is not defined. Such systems deal with numbers and linguistic variables.

The group of rules in a fuzzy expert system is called *knowledge base* or *rule base*. Such rule has the form of *If x is low and y is high then z=medium*. Where low is a fuzzy set defined on x , high is a fuzzy set defined on y and medium is a fuzzy set defined on z. The part of the rule that follows *If* is called the *antecedent* and the part following *then* is called the *consequent.* The *antecedent* consists of tests need to be made on the data. The *consequent* consists of actions to be made if the data passed the test [2] [30] .

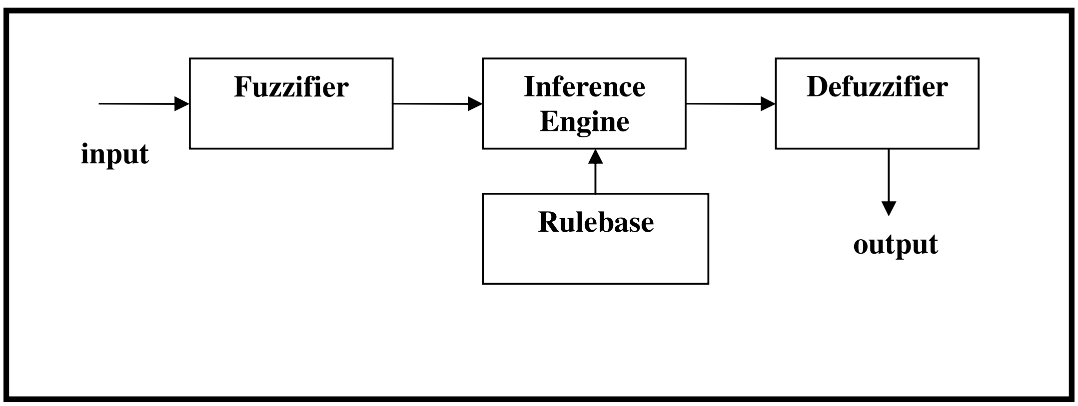


Figure 1. A fuzzy expert system architecture

3.1 How it Works:

In a fuzzy expert system, the process of reasoning consists of three steps [4].

3.1.1 Fuzzification Process:

According to [2] fuzzifying has two meanings. The first is the process fining the fuzzy value of a crisp one. The second is finding the grade of membership of a linguistic value of a linguistic variable corresponding to a fuzzy or scalar input. The most used meaning is the second. Fuzzification is done by membership functions.

3.1.2 Inference Process:

The next step is the inference process which involves deriving conclusions from existing data [2] . The inference process defines a mapping from input fuzzy sets into output fuzzy sets. It determines the degree to which the antecedent is satisfied for each rule. This results in one fuzzy set assigned to each output variable for each rule. MIN

is an inference method. According to [4] MIN assigns the minimum of antecedent terms to the matching degree of the rule.
Then fuzzy sets that represent the output of each rule are combined to form a single fuzzy set. The composition is done by applying MAX which corresponds to applying fuzzy logic OR, or SUM composition methods[2] .

3.1.3 Defuzzification Process:

Defuzzification is the process of converting fuzzy output sets to crisp values [2]. According to [31] there are three defuzzification methods used : *Centroid*, *Average Maximum* and *Weighted Average*. Centroid method of Defuzzification is the most commonly used method. Using this method the defuzzified value is defined by:

$$Centroid = \int x\mu(x)dx \Big/ \int \mu(x)dx$$

Where μ(x) is the aggregated output member function. In the *Average Maximum* method ,if the maximum grade of membership stretches from xmax1 to xmax2 then the defuzzified crisp value is computed by :

Average Maximum=(xmax1+ xmax2)/2 (11).

In the *weighted average* method, uses all local maxima and computes the weighted average by:

$$\text{Weighted Average} = \sum_{i=1}^{n}((xmaxi * \mu(xmaxi)) / \sum\mu(xmaxi)) \quad (12)$$

That is the average maximas is computed , multiplied by its grade of membership,and add the products, and divide this sum by the sum of the grades of membership [2].

3.2 Membership Function Determination:

Membership functions can be defined in many different ways according to [11] they include the following:

3.2.1 Polling:

Asking number of expert to give their point of view on a certain question like " Do you agree that Michael Jordan is tall?". The average of their responses in taken and used to construct the membership function.

3.2.2 Direct Rating:

Randomly select members of the fuzzy set. The expert is then asked for example " How tall is Michael Jordan".

3.2.3 Reverse Rating:

In this method, the subject is given a membership degree and then asked to identify the object for which that degree corresponds to the fuzzy term in question.

Finding the membership function for the fuzzy set tall by asking individuals to identify a man who they think has degree 0.5 of membership to tall.

3.2.4 Exemplification:

Building a membership function from samples. If we would like to define a membership function for tallness, experts would be asked to describe a number of heights using linguistic terms and then assign Linguistic terms to membership values.

4. Fuzzy Expert Systems Applications:

Fuzzy logic has been widely employed in the development of expert systems. Resulting in fuzzy expert systems that emulate human thinking and reasoning. A lot of fuzzy expert systems are reported in the literature, we will point out some of them.

4.1 Landfill Operations:

A successful web based fuzzy expert system described in [12] was developed to help inexperienced managers to estimate the possibility of the occurrence of different problems and give them advise to prevent these problems or reduce the effect if they happened. It allows managers to express the way they feel about a certain thing such as the degree of mud in a road using linguistic values rather than numbers. The reason landfill operations are considered fuzzy that there are no previous data available on landfill component, no measurements and factors that trigger landfill problems are not clear.

4.2 Power Quality Problems:

[26] describes a fuzzy expert system for power quality problems. Since many factors contribute to the deviation of power quality, the system obtains information location and equipment information. Metering information such as current, frequency and voltage are collected from the user as fuzzy facts. Using the collected information the system gives the proper recommendations. This system was developed using FuzzyClips.

4.3 Medical Systems:

In [27] an expert system for the diagnosis of abnormal vaginal bleeding ABVAB is described . This system uses the expressions by the patient, which are linguistic values, to draw the causes of the abnormal vaginal bleeding. This system was developed using SYSTEM Z-11. other fuzzy medical applications are described in [19] and [20]. In [19]a fuzzy expert system for the analysis of umbilical cord blood is described. In [20] a fuzzy expert system for lung disease diagnosis is described.

4.5 Hotel and Tourism Industry:

Fuzzy logic did not receive great attention from tourism and hotel industry. A fuzzy expert system for hotel selection is described in [28]. The purpose of this system is o help tourists find hotels according to their preferences. It allows them to express their preferences as linguistic values for different linguistic variables. For example, hotel price can have the following values : cheap, moderate and expensive. The system has been developed using Visual Basic 6.0.

4.6 Water Supply Forecast:

In [13] a fuzzy expert system for water supply is discusses. The motivation for the development of this system was the need for a system whose performance is independent of the volume of historical data available. The system was built using MatLab fuzzy logic toolkit. Expert knowledge and three years of historical data were incorporated in the system. The developed system was found better than traditional water supply forecast methods.

4.7 Oil Industry:

SmartDrill is a fuzzy expert system described in [15]. It is designed to diagnose and solve the most common problem in drilling that is lost circulation problem.

4.8 Meteorological Applications

Meteorological data are fuzzy in nature. Information on weather are vaguely defined. This makes fuzzy expert systems suitable for weather forecasts development. [17] introduces a fuzzy expert system called SIGMAR to help in weather watch. The purpose of the system is to monitor winds and alert forecasters when wind is higher than made forecasts. Forecasters reported that the system is useful specially in winter . In Alberta , Canada, ice jam flooding costs million of dollars. The ice jam flooding is triggered by several vague factors. Thus there is a need for a tool to help forecasting ice jam. [14] a study on the applicability of fuzzy expert systems for forecasting ice jam risk. Although the results from the preliminary system seems promising, there is a need for more research in this area.
In [3], MEDEX is a fuzzy expert system used to forecast specific gale wind events in the Mediterranean. MEDEX is unique in its domain and in handling subjective inputs. The output of MEDEX is almost like human expert estimation.

5. Fuzzy Expert System Shells and Toolkits:

A Fuzzy Expert System Shell the software that facilitates fuzzy expert systems building. A brief description of some well-known fuzzy expert systems is given in this sections.

5.1 SYSTEM Z-11:

SYSTEM Z-11 is a fuzzy expert system shell. Developed to handle exact and fuzzy facts. it can deal efficiently with fuzziness and uncertainty. It has been successfully used in for the development of medical diagnosis systems, risk analysis systems and psychoanalysis systems [5].

5.2 Fuzzy Logic Production System (FLOPS):

It is a fuzzy expert system shell for the development of fuzzy expert systems. It was originally developed for medical image analysis. It employs fuzzy set theory to handle ambiguity [30]. It has been also used to develop radar signal identification, and mineral component identification systems.

5.3 FuzzyCLIPS:

FuzzyCLIPS is a fuzzy expert system shell. It is an extension to CLIPS (C Language Integrated Production System). This extension handles the reasoning of fuzzy facts. It was developed by the Integrated Reasoning Group of the Institute for Information Technology of the National Research Council of Canada [32] . One advantage FuzzyClips has is its high portability.

5.4 FuzzyJ Toolkit:

FuzzyJ Toolkit is a set of Java classes that provide the capability for handling fuzzy concepts and reasoning. It is appropriate for developing simple systems [22].

5.5 FuzzyJess:

FuzzyJess is an extension to the expert system shell Jess(Java Expert System Shell).FuzzyJess was developed to enable reasoning of fuzzy facts by allowing users to use FuzzyJ Toolkit with Jess. It is used for developing large systems[22].

5.6 Fuzzy Logic Inferencing Toolkit (FLINT):

FLINT is a product by Logic Programming Associates (LPA). It is a Toolkit that supports incorporating fuzziness in the development if expert systems and decision support systems. When integrated with LPA Felx , it provides a way of handling fuzziness [29].

5.6 EDIP:

According to [33] EDIP is a fuzzy expert system Shell for Windows 3.x. It is used for developing simple fuzzy expert system.

Table 5.1. FESs and tools used in their development

FES	Development Tool
LOMA [12]	LPA's Win Prolog v 4.100
ABVAB [27]	System Z-11
Water Supply Forecast [13]	MatLab
Power Quality [26]	FuzzyClips
Task Distribution [25]	FuzzyClips
Diagnosis of Periodontal Diseases [34]	FuzzyClips

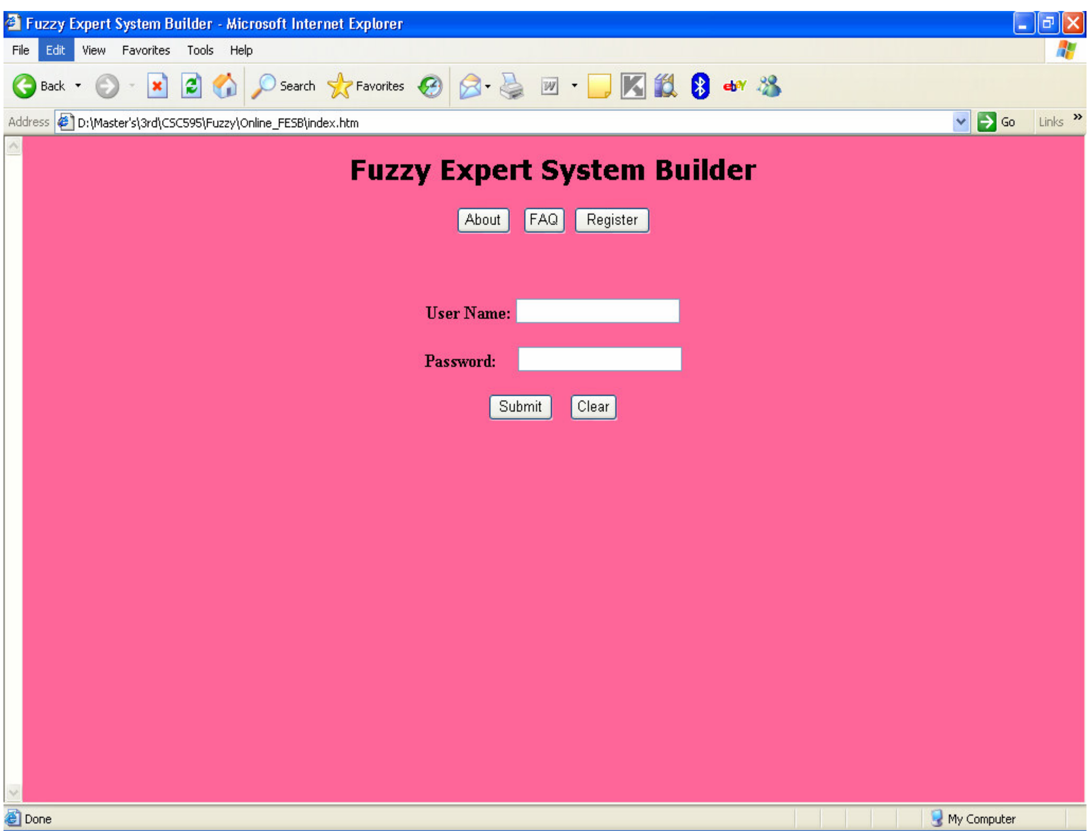
6. Conclusion

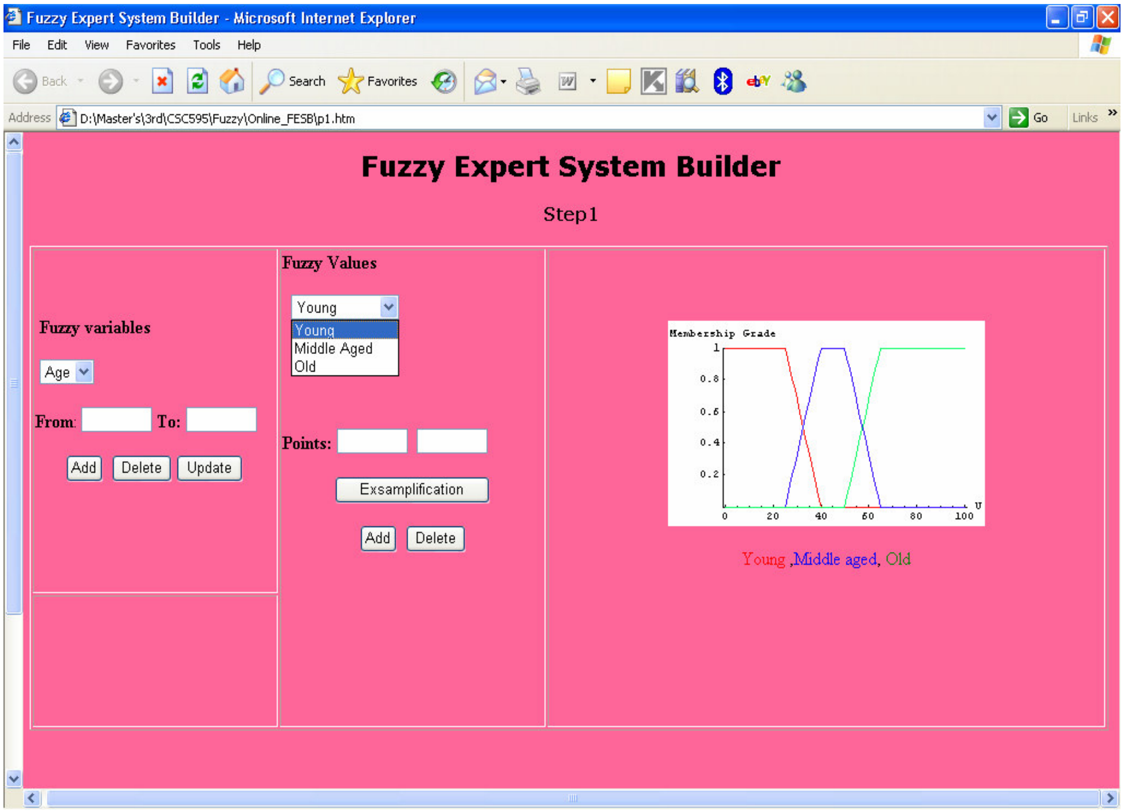
When the knowledge is complicated and little is known about the relationship between variables, Fuzzy Expert Systems are useful. Moreover, fuzzy expert systems are suitable when no enough measurements and previous data are available. In fact fuzzy logic is getting more attention now days. Many successful applications reported in the literature took the advantage of fuzzy logic in building expert systems.

One issue related to building fuzzy expert systems needs to be considered, the determination of membership function. Experts are needed to find relationships between data so rules can be built successfully. In fact there is a need for a way that facilitates membership function determination.

7.Future Work:

Here I'd like to propose the idea of an online fuzzy expert system builder that could help students and new researchers in fuzzy expert systems understand the idea behind fuzzy expert systems. This tools will have templates users can run to demonstrate how fuzzy expert systems work. Users can build their own fuzzy expert systems using built in membership functions to facilitate member function determination or can define their own membership functions. This tool also gives the users the chance to define rules and choose the inference process they want to use. Also use. All these features are accessible though Graphical User Interface online. To imagine what this tool looks like, below are two snapshots of the tool created in FrontPage.





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