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# 퍼지 로직을 이용한 문화 패러다임 기반의 로봇 성격 개발

# Development of a Robot Personality based on Cultural Paradigm using Fuzzy Logic

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## Abstract

Robotics has emerged as an important field for the future. It is our vision that robots in future will be able to transcend these precincts and work side by side humans for the greater good of mankind. We developed a face robot for this purpose. However, Life like robots demands a certain level of intelligence. Some scientists have proposed an event based learning approach, in which the robot can be taken as a small child and through learning from surrounding entities develops its own personality. In fact some scientists have proposed an entire new personality of the robot itself in which robot can have its own internal states, intentions, beliefs, desires and feelings. Our approach should not only be to develop a robot personality model but also to understand human behavior and incorporate it into the robot model. Human's personality is very complex and rests on many factors like its physical surrounding, its social surrounding, and internal states and beliefs etc. This paper discusses the development of this platform to evaluate this and develop a standard by a society based approach including the cultural paradigm. For this purpose the fuzzy control theory is used. Since the fuzzy theory is very near human analytical thinking it provides a very good platform to develop such a model.

**Key Words** : Face Robot, Robot Personality, Social Intelligence, cultural paradigm, Fuzzy Theory.

## 1. Introduction

We live in an industrialized and a mechanized world. However for human society a touch of its own innocence is important. The robot's acceptability to the society depends upon its outer appearance. We have always dreamt of this scenario, that is, Intelligent, dedicated, hard working and non tiring workers. However, life like robots demands a certain level of intelligence. It is both an ethical and a practical problem. But as time progresses such fears will be transcended so that a new era arises requiring communication between the robot and its surrounding beings (robots and human both). The robot should be societal and social both [1]. To accept an artificial entity it is very important from the human psycho logistic point of view that the robot is as close to human as possible. For this purpose it is quite important that the expressions are natural. Ekman have suggested the famous FACS (Facial Action Coding System) [2] which helps us in deciphering facial expression.

However, the action units only state the static displacement of characteristic points; it does not give an account of the actual skin deformation. Therefore the human expression is basically the combination of the human face muscle, its skull and the skin [3]. Keeping that in to our mind we made a face robot as shown in fig 1.

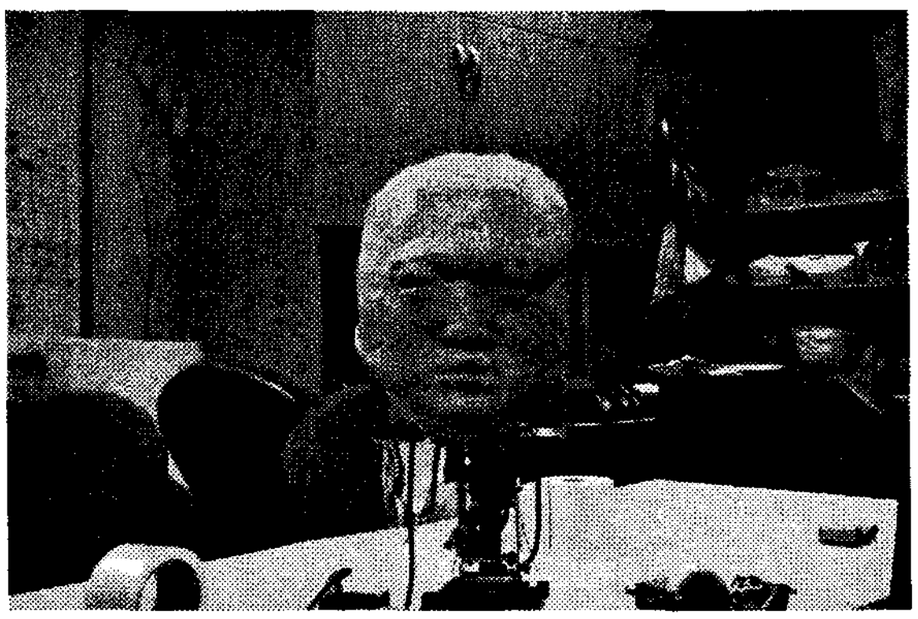

fig. 1 Our Face Robot

Now that face robot, has to live in a hostile environment where it has friends and foes both. A robot has to interact, socialize and co-ordinate with a human being. For this different kinds of approaches have been developed. Many scientist have suggested different kind of approaches for this purpose. Some scientists have proposed an event based learning approach, in which the robot can be taken as a small child and through learning from surrounding entities develops its own personality. In fact some scientists have proposed an entire new personality of the robot itself in which robot can have its own internal states, intentions, beliefs, desires and feelings[4].

In Section 2 we describe psychological model of facial expression and the concept of cultural paradigm. Next, we look into the importance of the previous concept in robotic expression and its promulgation in our system. In the next step we describe the input membership function. Then we give the fuzzy rule base for expression inference and expression actuation. Lastly; we discuss our results and conclusions and present an outline for future works.

## 2. Facial Expression and Inference

Facial actions and Facial expressions provide us the best way of promulgating our internal states. It is one of the bests forms of non-verbal communication. Our facial gestures helps us in understanding verbal communication and correctly comprehend them effectively. Certain Facial expressions are innate and are universal across all cultures [5][6]. Universally it has been acknowledged that there are six basic facial expressions, i.e, joy, fear, anger, disgust, surprise and sadness. Basic emotions can be displayed and recognised consistently by different literate groups in cross cultural studies [7]. But there are indications that cultural groups can differ in the extent to which they accurately perceive emotions [8]. Consequently, human have sometime overlapping emotions [9]. Therefore across different cultures we have different evaluation of emotions, i.e, internal states can be read differently and inferred differently in different cultures. Accordingly human societies in the present world are segregated in their overall themes. We have conservative, moderate and liberal societies. The Asian societies are very much different from western societies. They can be considered more conservative, whereas the western societies more liberal in their social behavioral context [8]. This basic ideology has a profound effect in the behaviour patterns of the people in this environment . Now how to ascertain the spirit of a society. We based our theory on the chinese culture. A survey of chinese people perception of six basic emotion was used [10]. Accordingly for other inputs we conducted some other surveys.

## 3. Fuzzy System for Facial Expression in a Social Robot

In humanoid type social robots, scientists have been always faced with a dilemma as to how to integrate such robot well into the human environment [11]. It is really a test of robot ability to do the job what it is suppose to do. Now, we know our societies are very

complex and different in their behaviour patterns. Therefore, the stigma of making a robot that is able to cope with all environments and adapt to the surrounding is a very difficult problem. But we have to make a start somewhere. Now how to ascertain the spirit of a society. Fuzzy systems ([12], [13], [14]) have been successfully in modelling real-life phenomena involving uncertainty [15][16]. Fuzzy system has a human inference system inbuilt into it, therefore, it has the ability to incorporate into it the human cultural paradigm.

We have decided to use the fuzzy lookup table method for this purpose. A person's response to an expression depends on many factors like what kind of expression is coming from the stimulus (i.e. any other robot or human), then what is the relationship with that person, what is the internal state and belief of the person itself, what is the stimulus saying, then what is the society norms and many other factors some of whom are even not explainable. Sometimes, we humans behave in a certain way without any reason. Therefore, sometime we consider the human mind is impossible to emulate in a robot. But these can be considered as exceptions. In general terms we should consider how a majority in an environment behave to a situation. From there we can get a better idea how to construct our robot personality. Therefore our argument is fully illustrated in fig.2, we have,

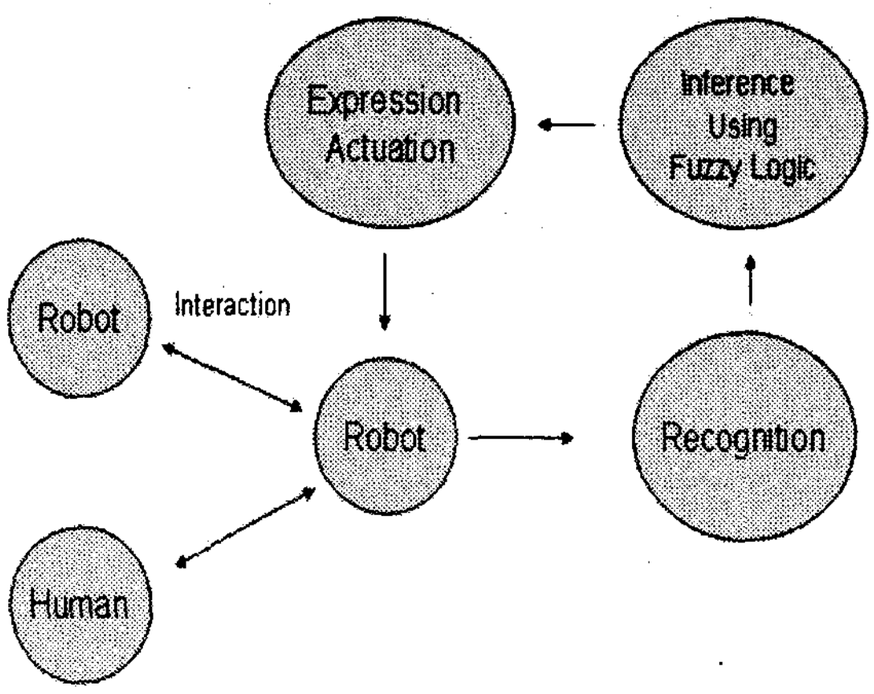


Fig 2. Overall description of the system

This system depicts what is the overall scenario in a robot. Many people have done much work in the field of recognition [17][18][19][20][21]. So in this paper we are not going to touch that, infact our approach is on the end of determining what should be the response of the robot, i.e. expression inference and then expression actuation. Our argument lies in the fact that people response to a certain emotion lies in what he/she perceives of the emotion and how they relate that to their environment. The action is always in response to the kind of stimulus received.

## 4. Fuzzy Modelling

In this paper we try to keep our approach simple. We start our effort with three inputs and there is two outputs and fuzzy rule base is handled with fuzzy look-up tables. The fuzzy system is composed of the fuzzifier, defuzzifier, fuzzy rules and the fuzzy inference engine.

### 4.1 Fuzzy Input Membership Functions

We have a expression recognition system whose output comes in the form of a fuzzy set with seven terms defined as Facial Expressions(FE) = {Happiness, Surprise, Fear, Sadness, Disgust, Anger and Happiness}. These expressions are scaled on the expression band from 1-30 [10], this is basically as illustration of expression in different percentages. It consists of 30 morphed images. In the studies of Paul Ekman six basic facial expressions are considered universal, i.e, anywhere in the world they are recognized as same. But the confusion and difference arise in the mixed expressions. So in these morphed images each pair of adjacent expression was blended into five morphed images in the proportion of 90:10, 70:30, 50:50, 30:70 and 10:90 with 90:10 image representing that universal basic expression. Now according to the survey this data can be represented as follows in fig.3

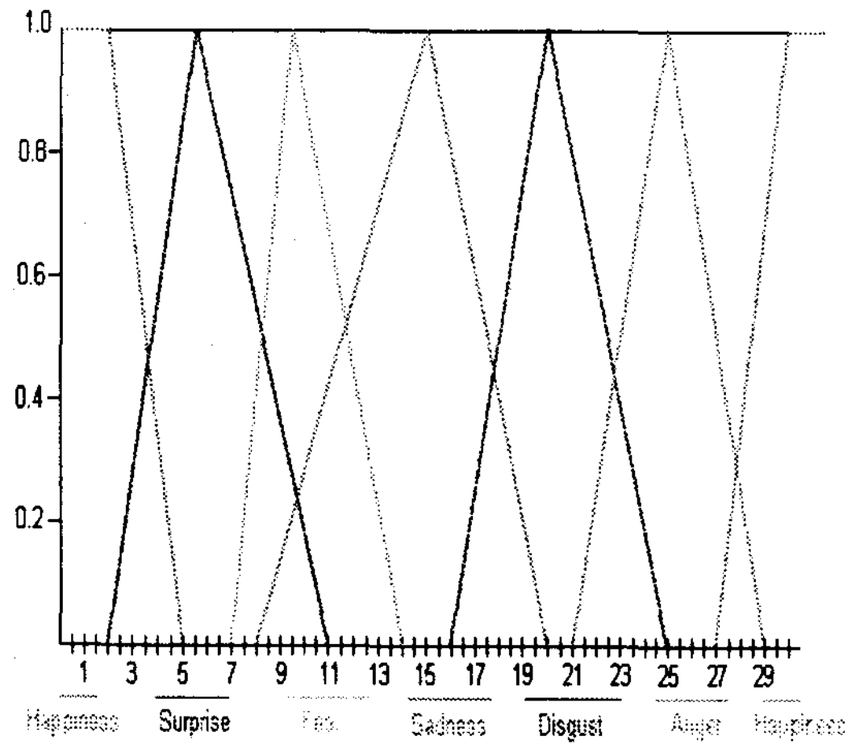


Fig.3 Expression Membership Function

This membership is constructed according to the survey conducted in [10] and according to the approach assumed by Mufti [17]. Here anger and disgust are commonly confused, which is also evident from survey in [23], similarly sadness is also confused with disgust. However, as it is evident the chinese behaviour on the evaluation of expression is quite different from Mufti as he used data from research conducted by people in the west. However the general trend is same as it should be for the human race. Similarly fear is often confused with surprise [24].

The second Input comes in the form of intensity of each expression, the fuzzy set are defined for intensity (IE) with three terms viz LOW, MEDIUM and HIGH. These fuzzy sets are defined by fuzzy sets with triangular membership functions defined on the scale of 0 - 10. Fig 4. represents the diagrammatic representation of the membership function for various terms associated with a expression.

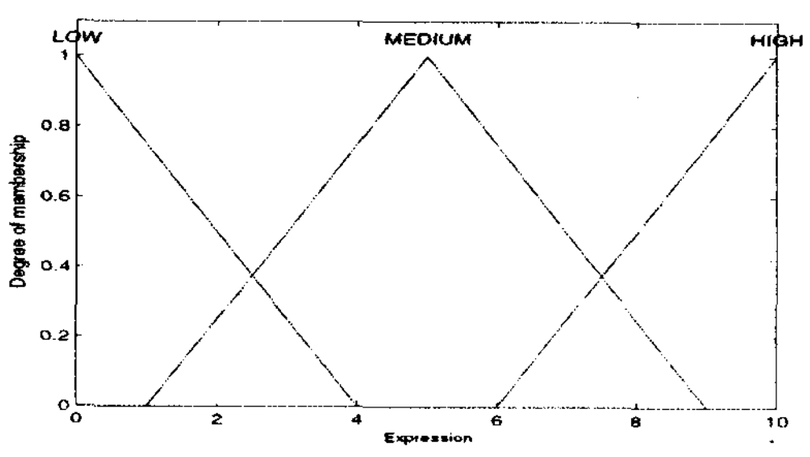


Fig 4. Expression Membership for Expression Intensity [17]

Now the third input, this input is one of the most important input as it changes the dynamics of our response. We call this input as the degree of sociality (DS). As a child when it is growing in our society it gradually learns or is being told by its elders about its relations with the surrounding beings. This is an important part of a robots ability to understand emotions in a culture and act according to the requirements. For this a database was created to understand relationships of chinese people with their surrounding beings. A survey was conducted and data was collected. The whole relationship paradigm can be broadly arranged into three main categories, very near blood relation, middle relations or acquaintances and Hostile or Unknown relations. In near relations we have considered the parents, grand parents, both sexes siblings, mate, progeny and best friend. In near relations Uncle, Aunts, cousins, friends and class mates or coworkers. And in Hostile or Unknown relations come everyday acquaintances, strangers and criminals or thugs. As the chinese have limited families because of china one child policy (most people have a single sibling) and general trends in public, they are easy to model.

For this survey, chinese people were asked to rate their relationship with these people. And also organize them in their order of preference. To investigate further similar survey was conducted with korean and other nationalities and it was intriguing to find similar trends in all people. We collected all the data and then we took an average mean value to develop a singleton input for this as shown in the fig. 5

| Name of Relation | Degree of Sociality |
|---|---|
| Parents | 100% or 1.0 |
| Grand Parents | 100% or 1.0 |
| Siblings | 90% or 0.9 |
| Mate | 95% or 0.95 |
| Progeny | 100% or 1.0 |
| Best Friend | 85% or 0.85 |
| Uncle | 60% or 0.6 |
| Auntie | 65% or 0.65 |
| Cousins | 70% or 0.7 |
| Just friend | 60% or 0.6 |
| Class Mate or Coworker | 55% or 0.55 |
| Acquaintance | 35% or 0.35 |
| Female stranger | 20% or 0.2 |
| Male stranger | 5% or 0.05 |
| Criminal or thug | 0% or 0 |

Fig. 5 Degree of sociality for the robot

Although we know this is everybody's own preference varying from male to female also. Our main aim is to capture the general trend of the society since it has a lot of effect on the general evaluation of a person about his/her relationship patterns. We don't intend to do any psychological survey, our basic intention is to develop the personality according to the trend of that society.

### 4.2 Fuzzy Output Membership Functions

This system will have two outputs that is the final output facial expression (OFE) from the robot and second is the extent or degree of the expression [17] as shown in fig.6.

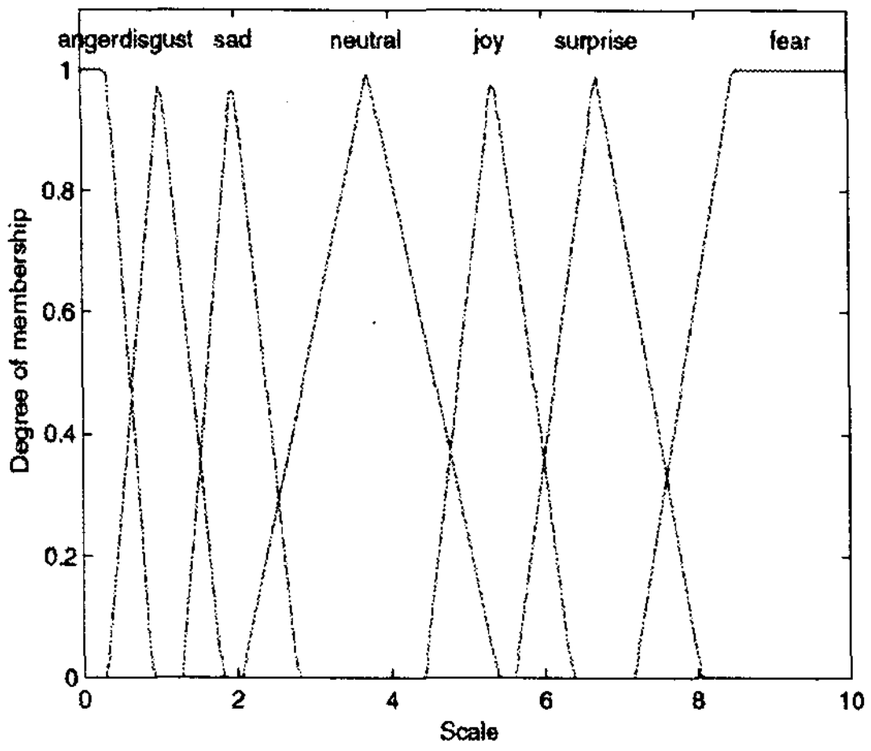


Fig.6. Expression Membership Function [17]

These expression are scaled on a band from 0-10.

Similarly the extent of the emotions can be measured from the following Output Intensity (OI) membership function as shown in fig 7.

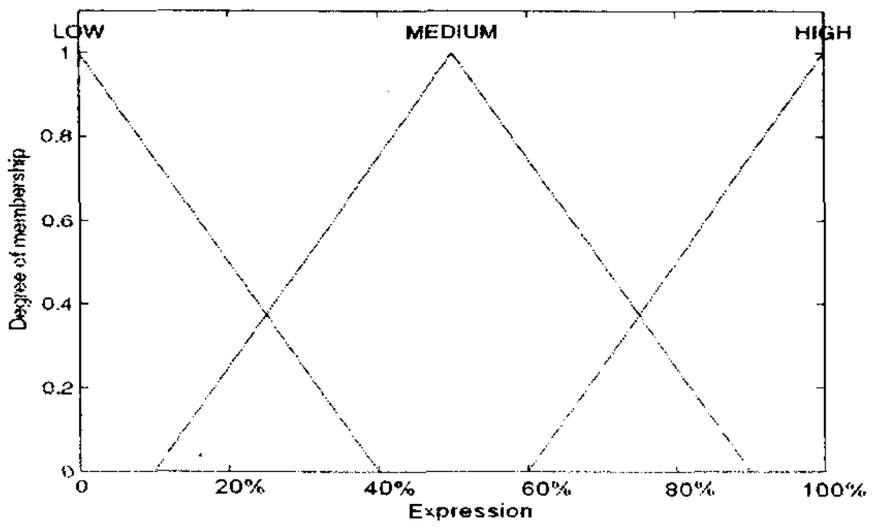


Fig.7. Expression Membership Function for Intensity

### 4.3 Fuzzy System

Each of the expressions are implemented in the form

*IF* $FE_1^l$ *IS* $F_1^l$ *AND*.....$FE_n^l$ *IS* $F_n^l$ *AND* $IE_1^l$ *IS* $I_1^l$ *AND*.....$IE_n^l$ *IS* $I_n^l$ *AND* $DS_1^l$ *IS* $S_1^l$ *AND* $DS_n^l$ *IS* $S_n^l$ *THEN OFE IS* $\Omega^l$ *AND OI IS* $I^l$

where $1 < l < M$ with M being the number of rules, OFE $\in$ {*joy, anger, fear, surprise, neutral, disgust, sadness*} and OI $\in$ { *low, medium, high*} is the fuzzy term indicating expression intensity and FE $\in$ {The expression recognized by the recognition system, given by the numbers from 1 to 30} and IE $\in$ {*low, medium, high*} and DS $\in$ {*parent, sibling,...., stranger*}

Fuzzy inference maps a fuzzy set A in the input space to a fuzzy set B in the output space. A product fuzzy inference engine is represented as follows :

$$\mu_B(y) = \max[\mu_{A'}(x)\prod_i \mu_{A_i^l}(x_i)\mu_{B^l}(y)] \qquad (1)$$

We used singleton fuzzifier

$$\mu_{A'}(x) = \begin{cases} 1 & \text{if } x = x^* \\ 0 & otherwise \end{cases} \qquad (2)$$

And centre of gravity defuzzifier,

$$y^* = \frac{\sum_{l=1}^{M} y^l w_l}{\sum_{l=1}^{M} w_l} \qquad (3)$$

Putting these components together, we obtain a fuzzy system which is a nonlinear function of real variables.

### 4.3 (a) Fuzzy System

We have used the table lookup method to design the fuzzy system for the input output pairs were obtained by consulting with an expert. Let us consider there are N input-output pairs:

$(x_0^p; y_0^p), p = 1,2,.....,N$ (4)
$x_0^p \epsilon U = [\alpha_1, \beta_1] \times ..... \times \subset R^n$
$y_0^p \epsilon V = [\alpha_y, \beta_y] \times ..... \times \subset R^n$

From these pairs we define fuzzy sets $A_i^j (j = 1,2,...,N)$ which cover entire input output space. Then we generate the IF-THEN rules:

$IF\ x_1\ is\ A_i^{j^*}, ..., \text{and} x_n\ is\ A_n^{j^*}, THEN y\ is\ B^{l^*}$ (5)

Since the number of input output pairs is usually large and each pair generates one rule, it is highly likely that there are conflicting rules. To resolve this conflict we assign a degree to each rule and keep only one rule from a conflicting group that has the maximum degree. For this purpose again a consultation with an expert was required.

$$D(rule) = \prod_{i=1}^{n} \mu_{A_i^j}(x_{0i}^p) \mu_{B^{l^*}}(y_0^p) \quad (6)$$

This rule base has no conflicts so it can easily be used for the purpose described so far.

## 5. System Overview

Fig 8. presents the system data flow

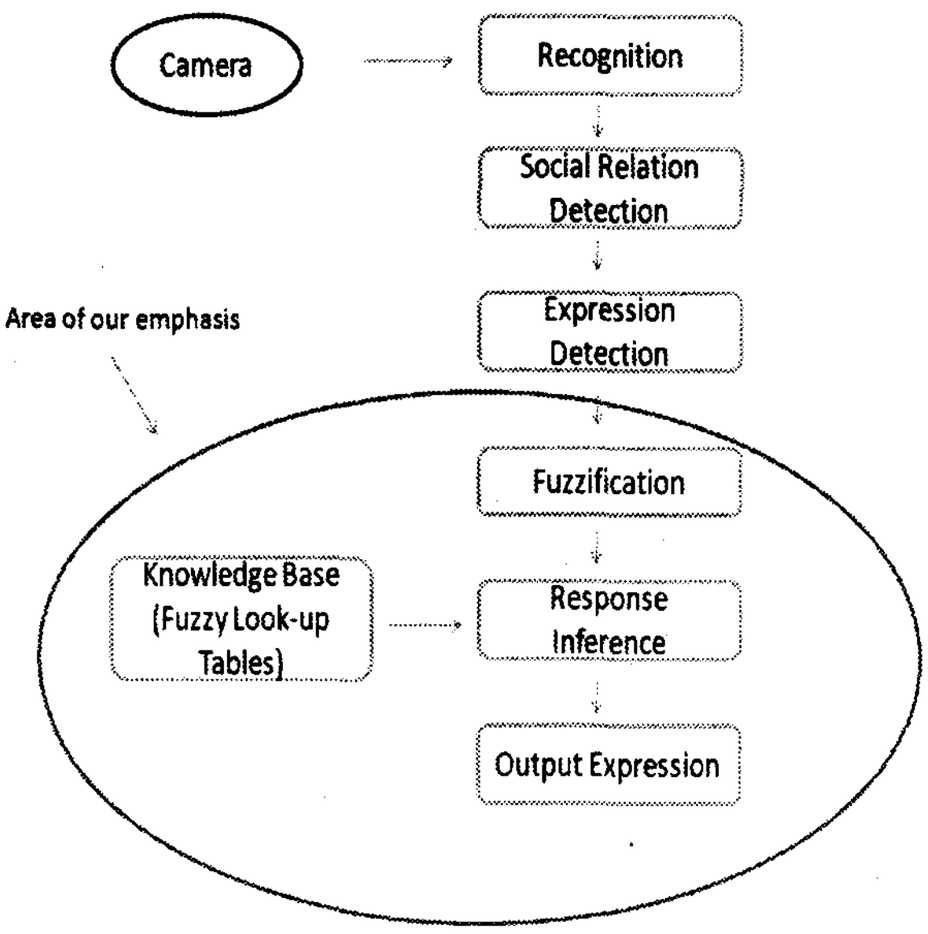


*fig 8. System Overview*

## 5. Result And Conclusions

The above fuzzy rule system can be used in two ways. It can be used to control the action units AU in a real life face robot or it can be used to control the feature points in a 3-D avatar.

In face robot, a program was created on a avr micro-controller with fuzzy logic implemented into it and then manual input was given into the system. The output came for Output Expression as a unique number on the scale which infact gives an indication on what type of Expression response should be given, the number can indicate to the set of angles the motors of the said robot should take to achieve the designated expression. Also the Output intensity came in the form of a percentage which can be multiplied with the critical motors required to make the expression to reduce or increase the intensity.

Consequently, Similar approach can be taken up with a 3-D avatar.

## 6. Future Work

In the future we intend to improve the system by incorporating more inputs into it. And making a real time database into the system so that it can store all information and gradually move towards a more efficient system. We also intend to work on the Recognition system on the pattern of Mufti[17].

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