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RESEARCH ARTICLE

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DESIGNING OF FUZZY EXPERT SYSTEM FOR CONTROL OF AIR CONDITIONERS

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ABSTRACT

The task of dehumidification and temperature decrease goes hand in hand in case of conventional AC. Once target temperature is reached AC seizes to function like a dehumidifier. Also complex interactions between user preference & actual room temperature and humidity level are very difficult to model mathematically. But in this work this limitation has been taken into cogitation and overcome to a great extent using fuzzy logic to represent the intricate influences of all these parameters. The optimal limits of comfort zone, typically marked at a temperature of 25°C and dew point 11°C, are used as the targets. Conventional AC system controls humidity in its own way without giving the users any scope for changing the set point for the targeted humidity unlike the scope it offers to change the set point for the targeted temperature through a thermostat. This causes a significant level of flexibility as well as efficiency loss especially in hot and humid countries like India. For instance at higher humidity level (say at dew point 18°C) an occupant may perceive same comfort level at 22ºC as he would perceive at 26º C at dew point 15°C. This translates to huge energy and monitory saving in terms of reduced compressor/fan duty cycle. In the developed scheme, the sensor captured temperature, user temperature preference and humidity readings are fuzzified. These are used to decide the fuzzy qualifier, which is decoded into a crisp value that in turn controls different aspects of the AC. In the problem dew point (Td) temperature is used to measure humidity instead of relative humidity (RH), this is because RH is a function of both temperature and moisture content while Td is a function of moisture content only. Hence it becomes very easy to model comfort level on the basis of Td. In this present work MATLAB fuzzy tool is used for experimental results.

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1. INTRODUCTION

1.1 Fuzzy Logic

Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.

Fuzzy logic began with the 1965 proposal of fuzzy set theory by Lotfi Zadeh. Fuzzy logic has been applied to many fields, from control theory to artificial intelligence. The reasoning in fuzzy logic is similar to human reasoning [4]. It allows for approximate values and inferences as well as incomplete or ambiguous data (fuzzy data) as opposed to only relying on crisp data (binary yes/no choices). Fuzzy logic is able to process incomplete data and provide approximate solutions to problems other methods find difficult to solve [3].

A basic application might characterize sub ranges of a continuous variable. For instance, a temperature measurement for anti-lock brakes might have several separate membership functions defining particular temperature ranges needed to control the brakes properly. Each function maps the same temperature value to a truth value in the 0 to 1 range. These truth values can then be used to determine how the brakes should be controlled [1] [6].

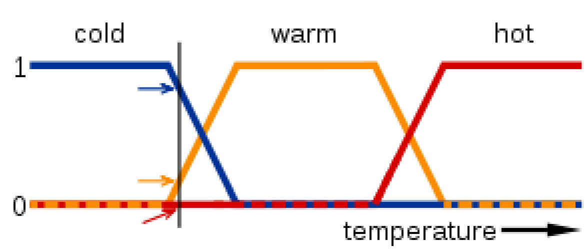

Fig.1.1 Membership function for temperature

In this image, the meanings of the expressions cold, warm, and hot are represented by functions mapping a temperature scale. A point on that scale has three "truth values"—one for each of the three functions. The vertical line in the image represents a particular temperature that the three arrows (truth values) gauge. Since the red arrow points to zero, this temperature may be interpreted as "not hot". The orange arrow (pointing at 0.2) may describe it as "slightly warm" and the blue arrow (pointing at 0.8) "fairly cold".[2]

1.1.2 Example of Fuzzy Logic

Fuzzy set theory defines fuzzy operators on fuzzy sets. The problem in applying this is that the appropriate fuzzy operator may not be known. For this reason, fuzzy logic usually uses IF-THEN rules, or constructs that are equivalent, such as fuzzy associative matrices.

Rules are usually expressed in the form:

IF variable IS property THEN action

For example, a simple temperature regulator that uses a fan might look like this:

IF temperature IS very cold THEN stop fan

IF temperature IS cold THEN turn down fan

1.2 Introduction to Fuzzy Logic Control

Fuzzy logic control is widely used in machine control. The term itself inspires certain skepticism, sounding equivalent to "half-baked logic" or "bogus logic", but the "fuzzy" part does not refer to a lack of rigour in the method, rather to the fact that the logic involved can deal with concepts that cannot be expressed as "true" or "false" but rather as "partially true". Although genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans [7][5].

1.2.1 What is a Fuzzy Logic Controller?

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value [8].

2 Problem Statement

The task of dehumidification and temperature decrease goes hand in hand in case of conventional AC. Once target temperature is reached AC seizes to function like a dehumidifier.

Also complex interactions between user preference s, actual room temperature and humidity level are very difficult to model mathematically. But in this work this limitation has been taken into cogitation and overcome to a great extent using fuzzy logic to represent the intricate influences of all these parameters. The optimal limits of comfort zone, typically marked at a temperature of 25°C and dew point 11°C, are used as the targets. Conventional AC system controls humidity in its own way without giving the users any scope for changing the set point for the targeted humidity unlike the scope it offers to change the set point for the targeted temperature through a thermostat. This causes a significant level of flexibility as well as efficiency loss especially in hot and humid countries like India. For instance at higher humidity level (say at dew point 18°C) an occupant may perceive same comfort level at 22ºC as he would perceive at 26º C at dew point 15°C. This translates to huge energy and monitory saving in terms of reduced compressor/fan duty cycle. In the developed scheme, the sensor captured temperature, user temperature preference and humidity readings are fuzzified. These are used to decide the fuzzy qualifier, which is decoded into a crisp value that in turn controls different aspects of the AC. In the problem dew point (Td) temperature is used to measure humidity instead of relative humidity(RH), this is because RH is a function of both temperature and moisture content while Td is a function of moisture content only. Hence it becomes very easy to model comfort level on the basis of Td. Human reaction to different levels of dew point*…

Dew Point	Reaction
Above 20C (68F)	Oppressive
18C (64F)	Sticky
16C (61F)	Humid
13C (55F)	
Comfortable	
10C (50F)	
Refreshing	
Less than 10C (50F)	Dry.

Work Methodology

In work methodology the following steps are followed-

i) Assign all the input & output parameters.
ii) Define the membership function for the first input variable.
iii) Define the membership function for the second input variable.
iv) Define the membership function for the first output variable.
v) Define the membership function for the second output variable.
vi) Define the membership function for the third output variable.
vii) Define the membership function for the fourth output variable.
viii) Formation of rule block & Surface viewer.

Experimental Results

In the current work there are two input parameters & four output parameters. The input parameters are User temperature preference" (Ut),&"Temperature difference" (Tdiff). Similarly the output parameters are "Compressor speed (Sc)", "Mode of operation" (Mo), "Fin direction" (Fn), & "Fan speed (Sf)". In this work MATLAB fuzzy tool is used for the experimental results.

Assigning Inputs and Outputs

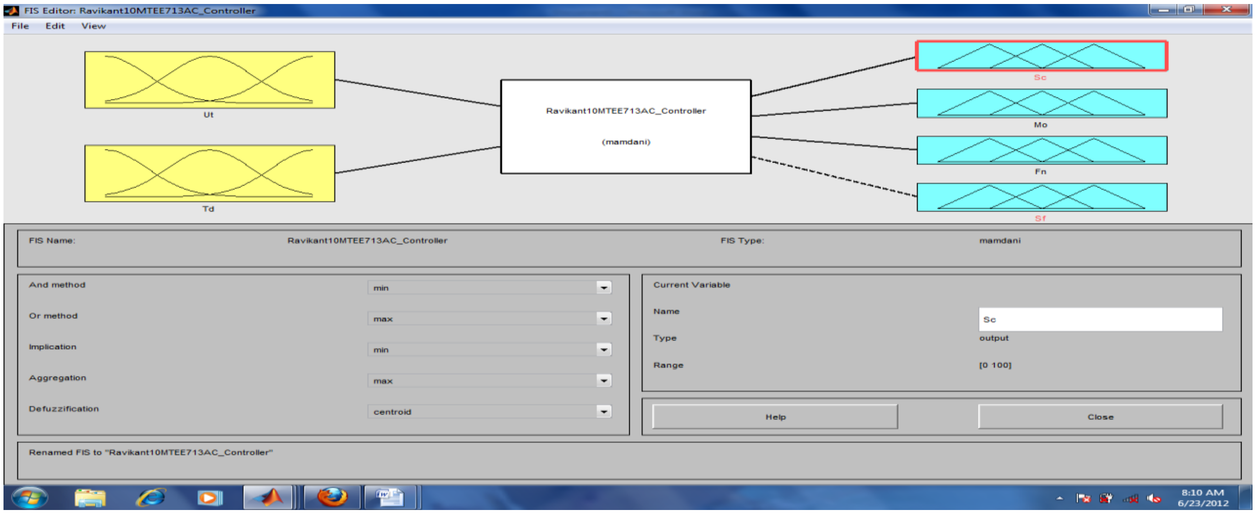

Fig. 1.2 Assigning Inputs and Outputs

Input variables

Defining the membership function of the first input variable.

"User temperature preference" (Ut) holds user's preferred temperature received by remote/front control unit. The control unit allows user to set temperature on a continuous dial over full range of 18C to 30C. Membership functions for Ut are shown in figure.

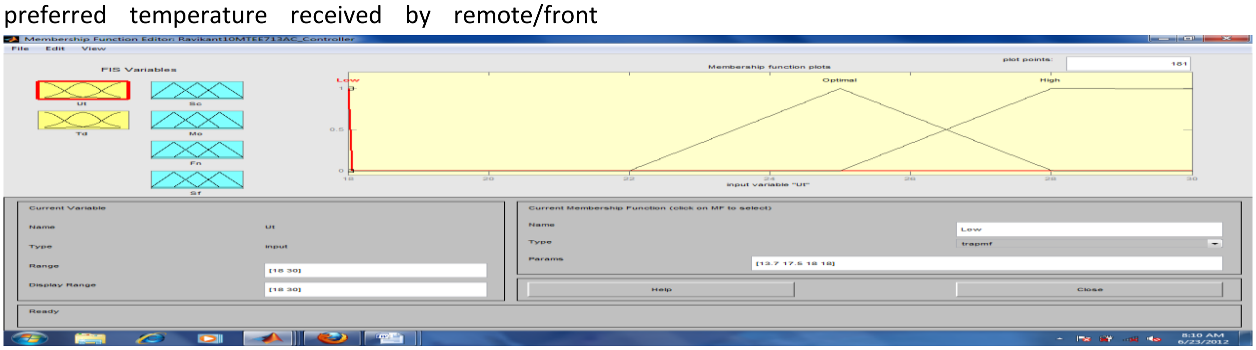

Fig. 1.3 Defining the membership function of the first input variable.

Defining the membership function of the second input variable

"Temperature difference" (Tdiff) gives information on difference between actual room temperature as received by electronic thermostat and Ut. The thermostat range should be wide enough to take care of climatic and regional fluctuation. In this case range is taken to be 17C to 45C, which constraints Tdiff between -1C to 27C. Please note that the AC in consideration cannot reverse its operation and act like a heat pump, so once Tdi ff goes out of range AC is switched off. Memberships functions for Tdiff is partly shown below; note that membership function "large" continues with value 1 from 2C to 27C.

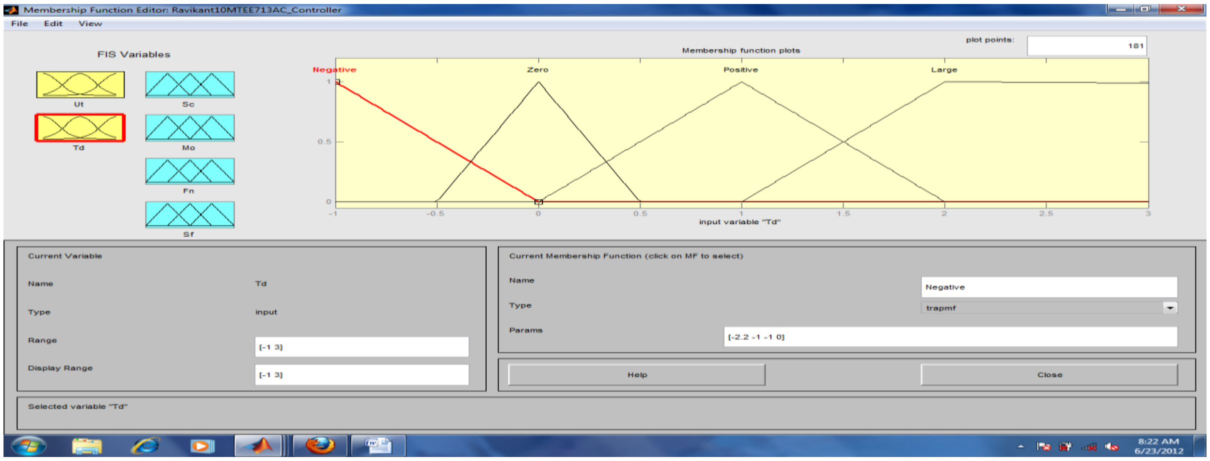

Fig. 1.4 Defining the membership function of the second input variable

Defining the membership function of the first output variable

"Compressor speed (Sc)" can be either off or can be varied between 30 to 100%. Membership functions as shown below.

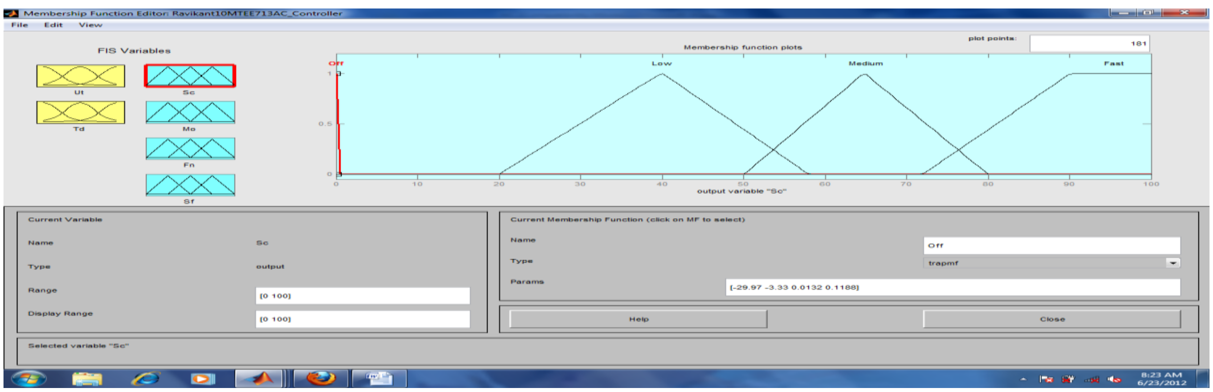

Fig. 1.5 Defining the membership function of the first output variable

Defining the membership function of the second output variable

"Mode of operation" (Mo) decides whether AC works like a dehumidifier only or normal AC. The control valve shown in figure illustrates that the AC can work anywhere between these two modes. Naturally when AC acts like a dehumidifier only, it won't cause any change in temperature. Membership functions for Mo is shown below.

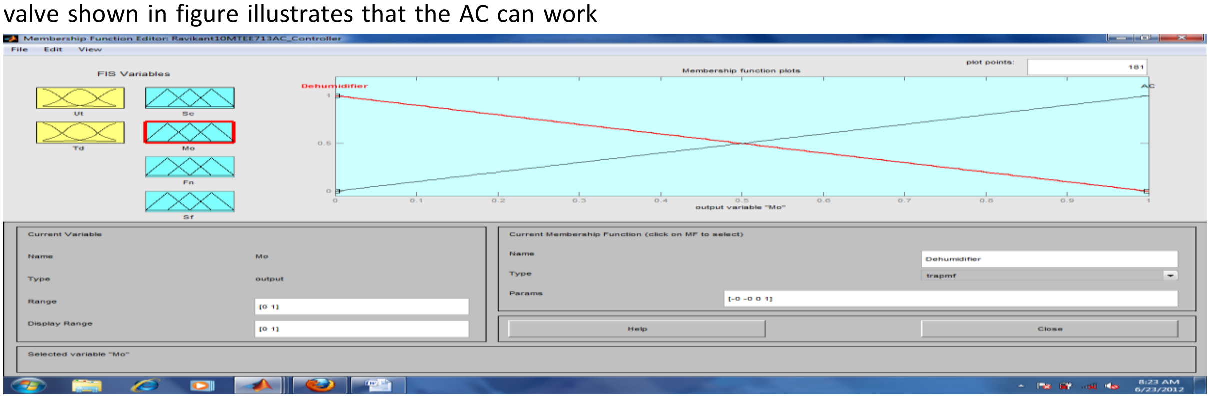

Fig. 1.6 Defining the membership function of the second output variable

Defining the membership function of the third output variable

"Fin direction" (Fn) directs air from the AC towards or away from occupants. Assuming top mounted AC, θ = 0º can be considered as towards and θ = 90º as away from occupant. Membership functions for Fn are shown below

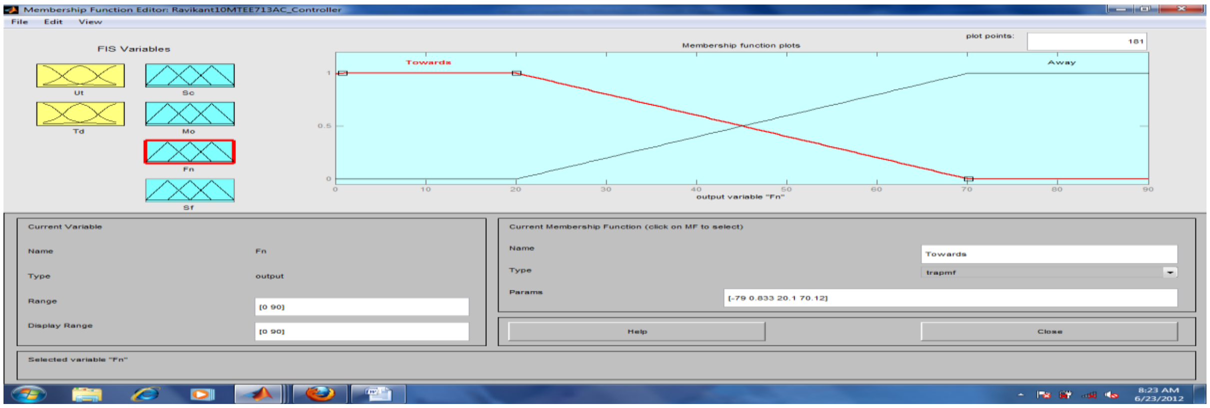

Fig. 1.7 Defining the membership function of the third output variable

Defining the membership function of the fourth output variable

"Fan speed (Sf)" can be either off or can be varied between 30 to 100%. Membership functions as shown below.

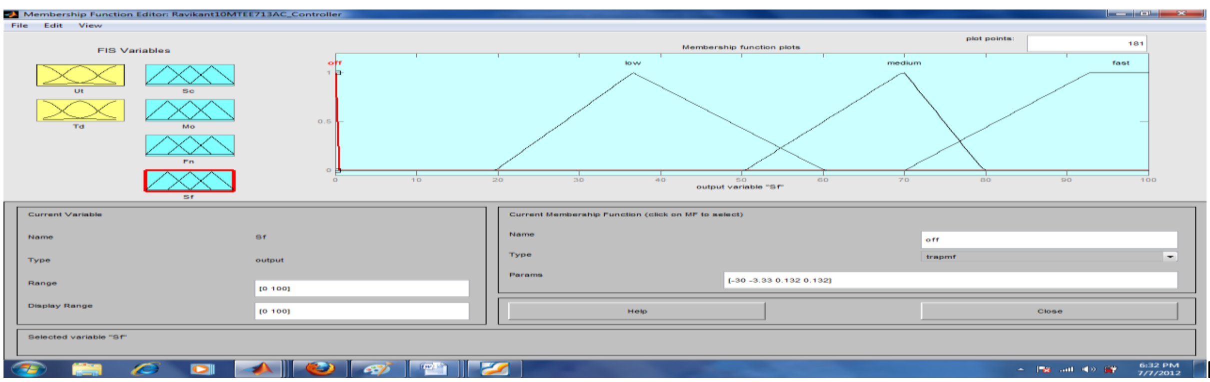

Fig. 1.8 Defining the membership function of the fourth output variable

Rule Viewer

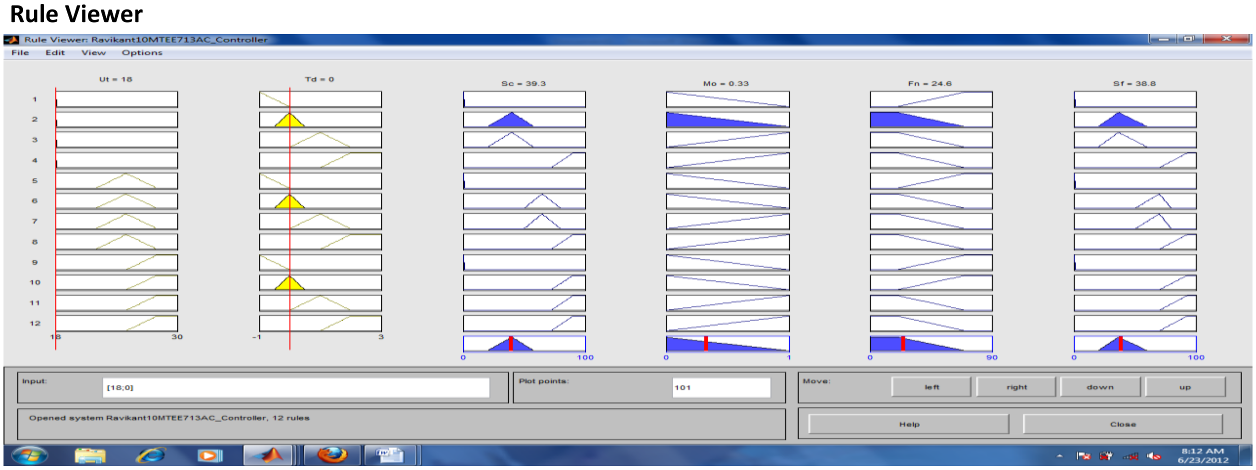

Fig. 1.9 Rule Viewer

Surface viewer

Note that Ut is bound to be within range, but actual room temperature (Tact), Tdiff and Td can surely go out of range. To tackle this problem when Tdiff or Tact goes out of range AC simply switches off and when Td goes out of range it is forced to nearest boundary point. This ensures correct operation over very wide range of climatic conditions. Moreover this ensures AC protection from overheating when room temperature is above working range (45C in this case). Again note that AC cannot reverse its operation and act like a heat pump nor can it act like a humidifier. Figure below shows response curves for Ut fixed at 25C.

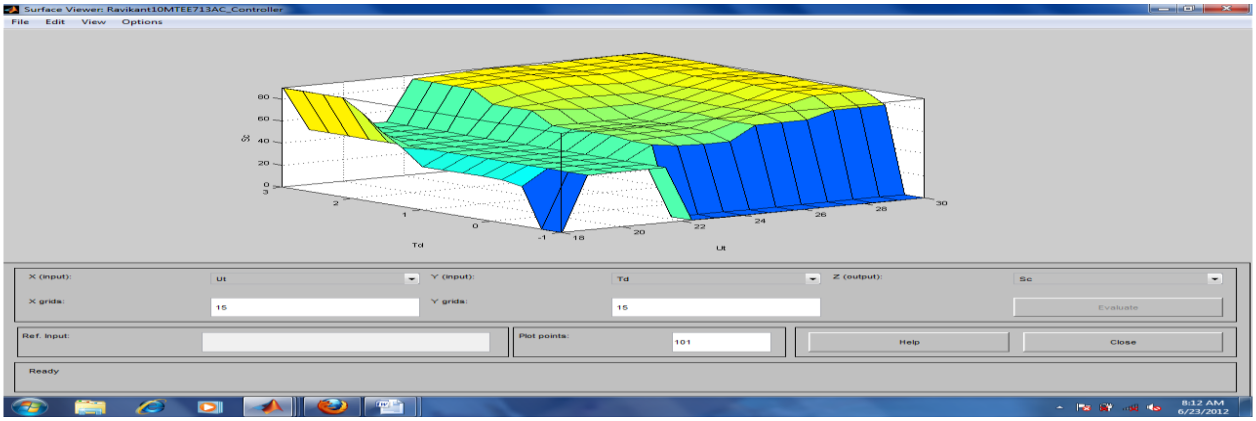

Fig. 1.10 Surface Viewer

Conclusions & Future Scope

The performance of the controller was very good as observed from MATLAB simulations. Fuzzy logic helped solve a complex problem without getting involved in intricate relationships between physical variables. Intuitive knowledge about input and output parameters was enough to design an optimally performing system. Although the analysis in this thesis neglected many finer details, but it clearly maps out advantage of fuzzy logic in dealing with problem that are difficult to study analytically yet are easy to solve intuitively in terms of linguistic variables. With most of the problems encountered in day to day life falling in this category, fuzzy logic is sure to The project simplified the problem by not allowing AC to reverse operation and act like a heat pump and humidifier. By eliminating these restrictions we can go for an all weather AC that would work in almost any part of the world. Also by adding infra red sensors to detect presence of occupants we can go one step ahead in user satisfaction. These sensors can aggregate data such as occupant location and body temperature. These data can further help control temperature, humidity and fin direction automatically for maximum comfort while reducing energy consumption. Application of neural networks and genetic algorithm will allow the controller to adapt to individual user, room environment and weather. An AC that will be "intelligent" in true sense!

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