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# Mood Based Building Automation Using Fuzzy Petrinets

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**ABSTRACT** *This paper deals with MOOD based building automation system. It categorises various aspects of MOOD and its relationship with dynamic setting of the environment. It uses Fuzzy Petrinets to fine tune the environment setting if it exists. Error and error Dot membership function based on Rule Matrix. Workflow is defined to generate the algorithm.*

***Keywords:*** *MOOD Environment, Emotional Analysis, Fuzzy Petrinets.*

## Introduction

There is rapid increase in mobile communication technology with affordingly easily reaching to the masses. There are various automation devices (Yagyasen, D., Darbari, M., Shukla, P. K., & Singh, V. K., 2013; Dhanda, N., Darbari, M., & Ahuja, N. J., 2012) available but the most simple and cheaper option is ZigBee based automation.

ZigBee is an open source hardware device which can be programmed for specific need. Secondly which is the most important issue is low power solution for automation it can receive signal wirelessly from a device and can respond to it. Thirdly it provides a good collaboration among its peers working as a Multiagent System.

Figure 1-1 shows the connectivity between sensor camera interfaces to ZigBee board for processing which are finally connected to Control Centre.

Cloud services consist of external services which can be utilized if needed.

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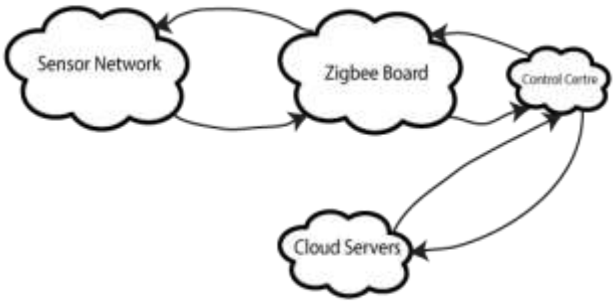


**Figure 0-1** Architecture of Building Automation System (BAS)

The novelty of this paper is Fuzzy mood based environmental dynamics (Prakash, S., & Darbari, M., 2012; Ahmad, F., Darbari, M., & Asthana, R., 2015; Darbari, M., Yagyasen, D., & Tiwari, A., 2015).

## Ambient Dynamics using fuzzy mood based Detection system

There are various emotional models being applied to judge the person's mood using the basic descriptors like "Depressing", "Energetic", "Jovial", "Palm".

The main difficulty comes in when we change from one mood another than how to set the ambience during that situation.

In order to analyze the emotional model providing the continuous connectivity we first of all deal with Emotional Categorization and its relationship with fuzzy Petrinets.

### Emotional Analysis

Emotional analysis can be classified into various types of mood which need to judged and analyzed. We can classify it into two parts:

- Categorical
- Dimensional

Thayer described various categories of mood under some quantitative dimension defined in figure2-1:

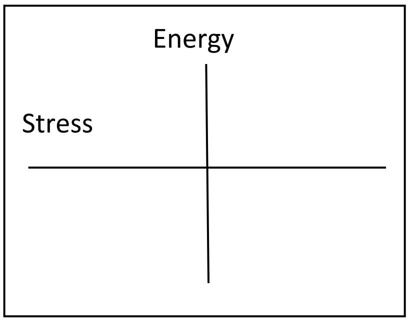


**Figure 0-1** Thayer's energy stress model

Each quadrant in Thayer's model represents set of Moods.

According to Thayer mood is divided into two basic categories:

- Stress (Happy / Anxious)
- Energy (Calm / Energetic)

In order for our system to judge efficiently between various combinations of stress and energy using facial expression we have used Fuzzy Petrinets.

The figure 2-2 describes how the ambient environment can be changed according to his MOOD based on Fuzzy Rule base relation.

## Application of fuzzy Petrinets for Mood detection and Ambient Setting

### Introduction to Fuzzy Petrinets

During process simulation by Petrinets we have to time to time illustrates the status which we are not sure whether that event will happen or not. For modeling an unpredictable situation like

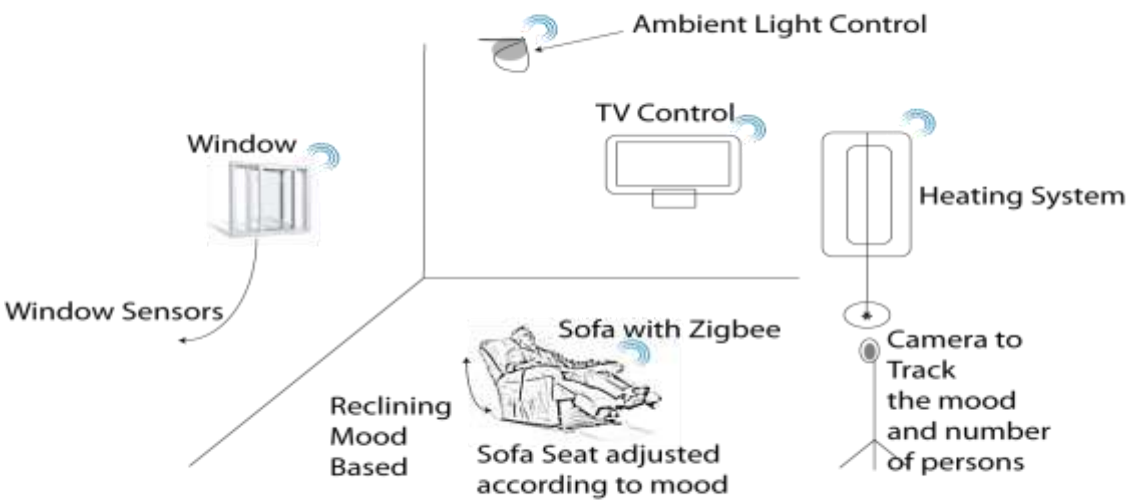


**Figure 0-2** Mood based ambient setting

Mood Setting it is not always possible to simulate by assuming certain conditions that are normally considered as "Ideal". These limitations of Petrinet (Darbari, M., & Sahai, P. Article, 2014; Darbari, M., & Asthana, R., 2013; Darbari, M., Ahmed, H., & Singh, V. K., 2011) can be resolved by introducing fuzziness (Espara, 1990; Darbari, M., Asthana, R., Ahmed, H., & Ahuja, N. J., 2011; Shukla, P. K., Darbari, M., Singh, V. K., & Tripathi, S. P., 2011; Darbari, M., Singh, V. K., Asthana, R., Prakash, S., & Kendra, D., 2010; Yagyasen, D., & Darbari, M., 2014) in its outcome. Any IF-THEN rule (Knybel, 2005) of the previous function can be defined by the help of petrinet as:

The set of IF-THEN rules, which forms the linguistic description:

R1 : = IF X1 is A11 AND ..... Xn is AIn THEN Y is B1

:

:

Rm : = IF X1 is Am, AND .......... Xn is Amn THEN Y is Bm.

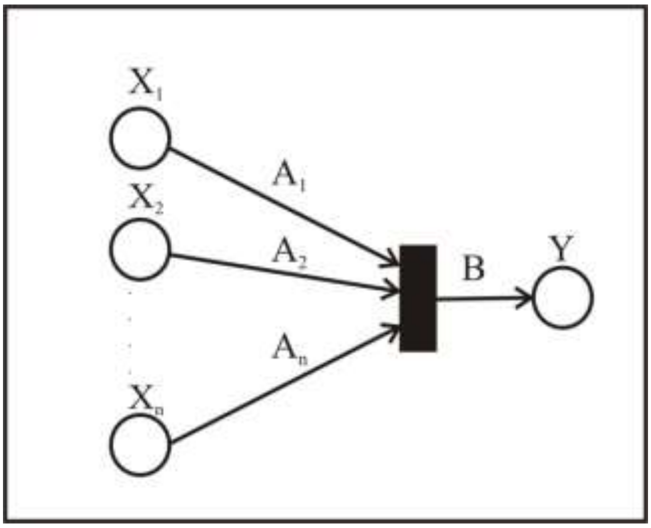


**Figure 0-3** Simple Model of Fuzzy Petrinets

The above condition (figure 2.3) corresponds to the simple situation of decision making (Darbari, M., Karn, B., & Ahmad, H., 2008) but in some cases when some edges are missing, then we have to introduce undefined condition as "UNDEF" is (figure 2.4) :

R1 : IF Xi is A1 AND X2 is UNDEF THEN Y is B1

R2 : IF X, is UNDEF AND X2 is A2 THEN Y is B2

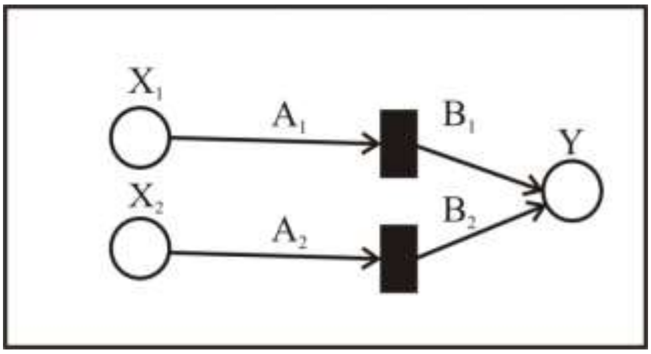


**Figure 0-4** Fuzzy Modeling when one of the edge is missing

Similarly for a decision stage when more than one output variable are possible.

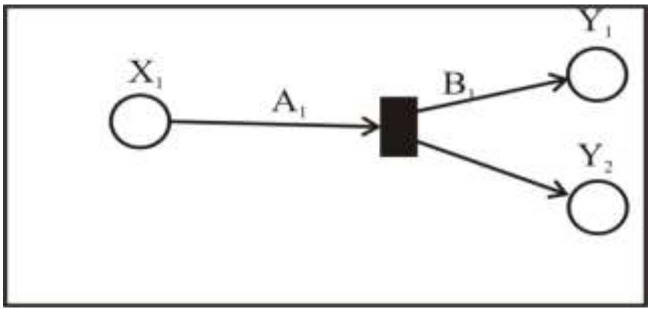


**Figure 0-5** More than one output variables

The corresponding mathematical description is represented as (Figure : 2.5)

R : = If X1 is A, THEN Y , is B1 and Y2 is B2

We can define the membership function as graphical representation of the magnitude of participations of each Input. It associates a weighting link of the inputs that are processed, defining functional overlap between inputs and finally determines an output response. The rule uses the input membership values as weighting factor to determine their influence on the fuzzy outputs sets of the final output conclusion. Once the functions are inferred, scaled and combined, they are defuzzified into crisp output which drives the system. There are different membership functions associated with each input and output response shown in Fig. 2.6.

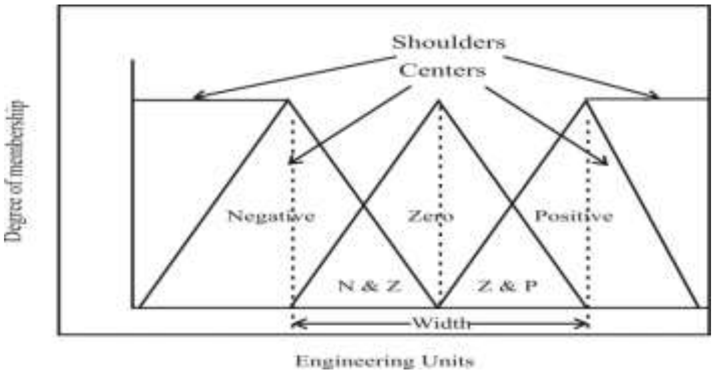


**Figure 0-6** Features of Membership Functions

The degree of Membership (DOM) is determined by plugging the selected input parameter (error or error, dist.) Onto the horizontal axis and projecting vertically to the upper boundary of the membership functions.

## Error and Error Dot Memberships

The degree of membership for an "error" of -1.0 projects up to middle of overlapping part of the "negative" and "zero" function so the results is "negative" membership = 0.5 and "zero" membership = 0.5. It can derived from figure 2.6. This particular input condition indicates that the feedback has exceeded the command and is still increasing.

Thus, there is a unique membership function associated with each input parameter. The membership associate a weighting factor with values of each input the effective rules. By computing the logical product of the membership weights for each active rule, a set of fuzzy output response magnitudes are produced.

## Formal verification of MOOD using Fuzzy Petrinets

Consider a situation of Mood Detection where stress (e1) occurs more than once within period T2, this situation concerns the case where multiple occurrences of one event within a certain time period causing another single event to occur. This situation introduces the motion of expiration time of events . If an event is not consumed by a rule, it may expire after a time interval. The Petrinet model pertaining to these events can be defined by placing tokens e' and e'', (Figure 2.7) the transition t2 and t3 are enabled, but they cannot be fired immediately. When there are two tokens arriving in place e', and e'' (figure 2.7), transition t1 fires immediately and produces the event e2 is “Notification to Control Centre".

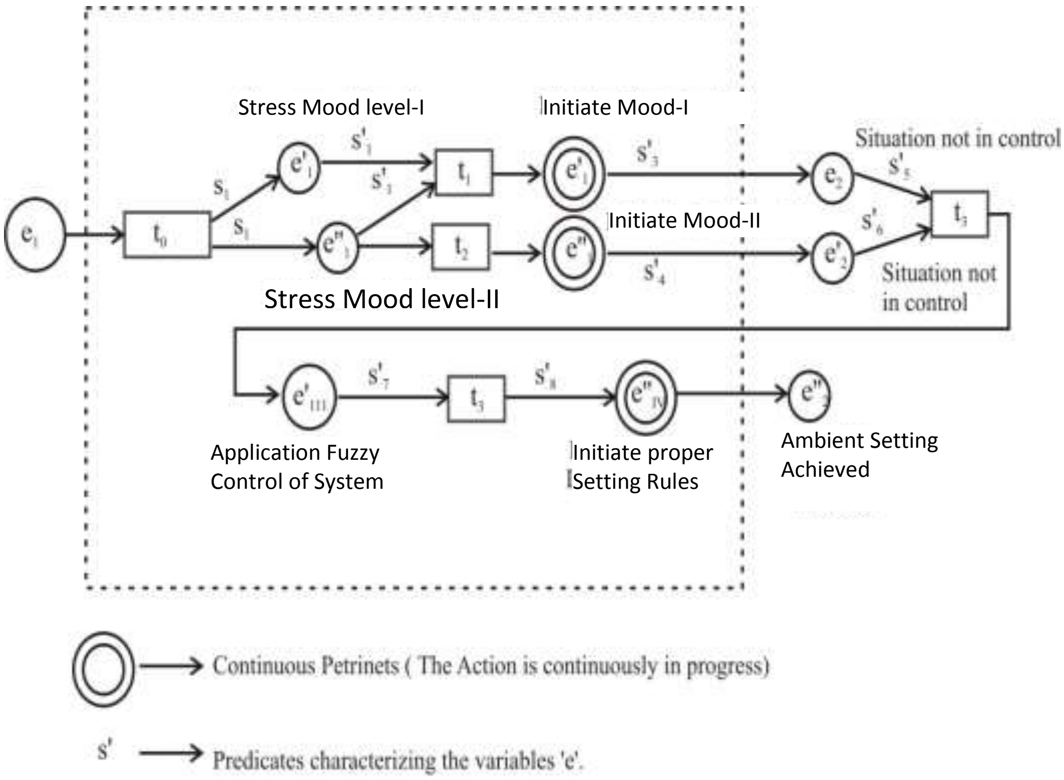


**Figure 0-7** Petrinet Decision Model

After transition fires, two tokens are returned to place e', and e'', leading two situations, either the control centre will know about the current situation and take necessary action before the severity of stress mood will increase/decrease.

Under this condition the control efforts to change the ambient setting according to the mood level. Fuzzy Nets are used to model this Mood dynamics by using IF_THEN Fuzzy rules (Figure 2.8).

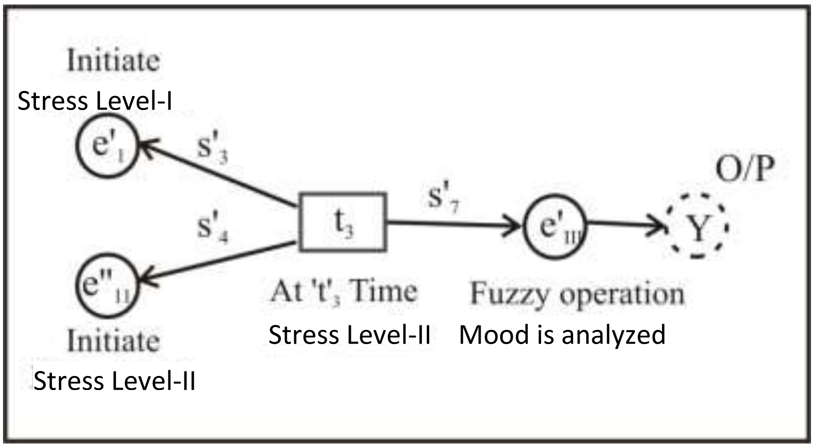


**Figure 0-8** Fuzzy Net representation

The condition can be expressed in the linguistic format (Saastamoinen, 1995; Ahmad, S. S., Purohit, H., Mohammed, F. N., & Darbari, M., 2013) as:

R1 : IF e'1 is s'3 AND e'11 is s'4t3 THEN e'111 is s'7t3.

Where s'3, s'4 and s'7 set of rules under which an event can occur.

We can write an algorithm for the above condition where the decision of ambient setting can be initiated as :

```
input: mood based ambient control: mbac
output: set of output rules : sorl
sorl = ϕ ;
for each output place e' of sort do // creates set of input variables on whose e depends.
for each input transition e of sorl e' do
// add all inputs of transition 's' to input set e
inputs = inputs Us inputs ;
end
for each input transition e of sorl
do
// construction of rule corresponding to the transition 's'
rule = ϕ // rule belongs to mood based ambient settings
for each element in from inputs
do
if rule ≠ ϕ, then rule = rule + AND;
if in ∈ s, inputs then
rules = rule + in.name is edge (s, it).value;
else
rule = rule +  in.name is UNDEF;
end
rule = rule + THEN e'. name is edge (in , e').value;
rb → rule database
rb → rbUrule ; // add rule of ambient settings to Database for further reference.
end.
```

The above algorithm rules can be quantified in the form of Rule Matrix Workflow of Fuzzy Petrinets (Sen, 2007; Sethi, 2000).There will be some combination of variables which is represented as:

e'N = Stress level changing dynamically

e'P = Fine tuning of Stress Mood being Resolved

eZ = Zero_error

e'I = Stress Level-I

e'II =Stress Level-II

"-" = No change in Mood

cmd = Mood Resolved

M_S =Mood

Error = Cmd_Tr (+ = only Stress Level-I, - = only Stress Level-II)

Error_dot = Time derivative or Error ( + = getting, - = getting worst)

Output = Controlling Stress Level-I or No change or Stress Level-II

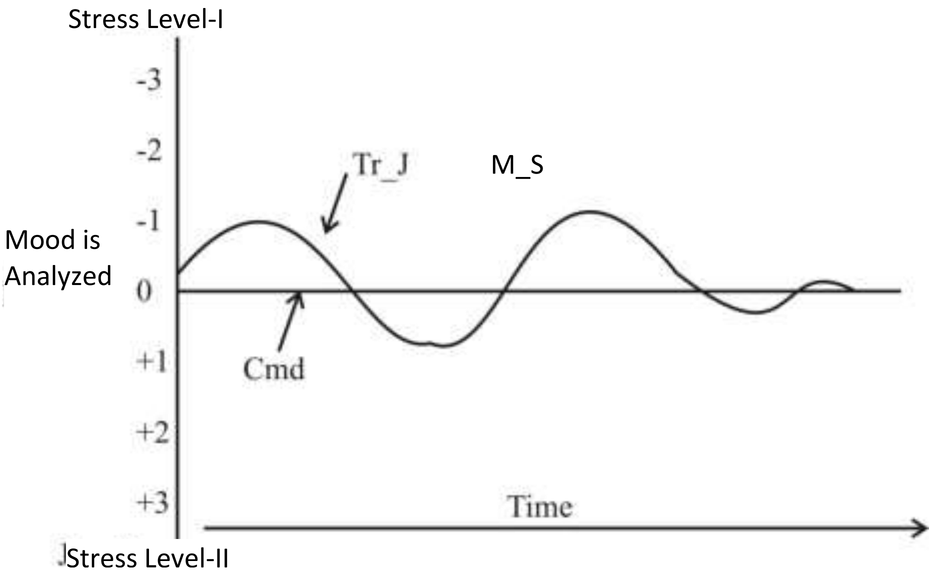


**Figure 0-9** Stress Level

Fig. 2.9 shows what command and error look like in a typical control system relative to command set points as the system hunts for stability. We have to define some value in order to design fuzzy workflow nets.

## Definitions of Error dot and Error function

INPUT # 1 : ("Error", positive (e'1, p) , Zero (-), negative (e'1, N)

INPUT # 2: ("Error-dot", positive (e'1, p) , Zero (-), negative (e'1, N)

CONCLUSION :

("Output", Setting Stress Level-I (e'1), No change (-), Controlling Setting Stress Level-II (e'11))

OUTPUT

e'1 = Call for Setting Stress Level-I

"-" = No change in controlling levels

e'11 = Call for Setting Stress Level-II only.

We can develop Rule Matrix from the above situation with errors and Error -dot functions shown in Table 2.1.

In order to apply the rule Matrix derived above we have to use membership function. The membership function is a graphical representation of the magnitude of participation of each input. It associates a weighting with each of the inputs that are processed, defining functional overlap between inputs, and ultimately determining an output response. Once the functions are inferred, scaled and combined they are defuzzified into a crisp output which drives the system.

**Table 0-10** Rule Matrix of Ambient Settings

| Error-dot | $e'_I N$ | $eZ$ | $e'_{II} P$ |
|---|---|---|---|
| $e'_I N$ | $e'_{II}$ | $e'_I$ | $e'_I$ |
| $eZ$ | $e'_{II}$ | - | $e'_I$ |
| $e'_{II} P$ | $e'_{II}$ | $e'_{II}$ | $e'_I$ |

Error - function

## Input Degree of Freedom

We can draw the membership function by considering the degree of membership from an "error" of -1.0 so the middle of the overlapping part is a negative and zero function. For an error-dot of +2.5, a "zero" and "positive" membership of 0.5 is indicated.

"error" = - 1.0 ; "negative" = 0.5 and "zero" = 0.5 and "error-dot" = +2.5; "zero" = 0.5 and "positive" = 0.5 . We can defuzzify to return to the crisp off rule for (e) = error and (er) = error-dot.

If (e<0) AND (er<0) then e'11 0.5 & 0.0 = 0

If (e=0) AND (er<0) then e'1 0.5 & 0.0 = 0.0

If (e>0) AND (er<0) then e1' 0.0 & 0.0 = 0.0

If (e<0) AND (er=0) then e'11 0.5 & 0.5 = 0.5

If (e=0) AND (er=0) then '-' Chng 0.5 & 0.5 = 0.5.

If (e>0) AND (er=0) then e' 0.0 & 0.5 = 0.0

If (e<0) AND (er>0) then e' 0.0 & 0.5 = 0.0

If (e=0) AND (er>0) then e'11 0.5 & 0.5 = 0.5

If (e>0) AND (er>0) then e'1 0.0 & 0.5 = 0.0

The inputs are combined logically using the AND operator to produce output response values for all expected inputs. The active conclusions are then combined into a logical sum of each membership function. A firing strength for each output membership function is computed. They are then combined into logical sums in a defuzzification process to produce the crisp output.

## Conclusion

Paper suggests verification of the Mood Based ambient setting control. It discusses various aspects of MOOD model and how it can be categorized into basic parts: Categorial and Dimensional. Using fuzzy control system we have developed an algorithm derived from Sen (2007) generating Matrix Workflow of Fuzzy Petrinets.

Lastly all the functions generated are defuzzified into crisp output value which represents exact setting of the Ambient and MOOD.

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