PETRINET BASED MODELING AND CONTROL IN A SMART HOME AUTOMATION FRAMEWORK

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Abstract-The paper aims in developing a smart home automation framework for integrating new advanced technologies and conventional systems to achieve a comfortable environment, optimum temperature control thereby ensuring profitability. Here in this paper, a three stage smart control framework, which allows controlling room temperature according to the user's preferences, is implemented using Petrinets. The three stages includes user identification process in the first stage followed by a monitoring process to identify the number of users in the second stage and which sends their preferred temperatures to the third stage for control. For the first and second stages, unique models are developed in Petrinet environment comprising of Discrete, Continuous and Hybrid Petrinets for effective understanding. The Discrete Petrinet model gives a clear understanding of all the stages and process flow with respect to the operation. Based on the understanding about the total working, the above system is modelled using Continuous Petrinets which helps in understanding frequency operation along with qualitative analysis. Finally the total system is analysed as hybrid systems using Hybrid Petrinets to give understanding. PID controller is implemented in the final stage to regulate room temperature. The interconnected sensing and actuating devices in this smart environment are configured to provide users with comfort and energy saving functionality.

Keywords: Energy-saving framework, Discrete Petrinets, Continuous Petrinets, Hybrid Petrinets, PID

I. INTRODUCTION

Petrinets were introduced in 1939 by Dr. Carl Adam Petri. Petrinets are powerful modeling formalism in computer science, system engineering and some other discipline. Petrinets combine a well-defined Mathematical theory with a graphical representation of the dynamic behavior of systems. Petrinet is a particular kind of Bipartite directed graph populated by three types of objects. These objects are Places (P), Transitions (T) and directed arcs. Directed arcs connect places to transitions and transition to places. In its simplest form, a petri nets can be represented by transition together with an input place and an output place. Graphically, places in a petri net may contain a discrete number of marks called tokens. Any distribution of tokens over the places will represent a configuration of the net called a marking.

By modelling systems using Petrinets, frequency analysis, mathematical modeling, graphical analysis can be done effectively. In this paper, three types of Petrinets have been utilized for modeling the processes. They are Discrete Petrinets, Continuous Petrinets and Hybrid Petrinets. Discrete Petrinets are used for the modeling the logic involved in the process flow. Continuous Petrinets are used for the frequency analysis and for mathematical modeling of the dynamics of the process flow. And Hybrid Petrinets which Combination of Discrete and Continuous Petrinets are helpful in providing the total information of the process flow and for the performing total performance analysis. The typical applications of Petrinets are in Business modeling, Diagnosis and Simulation and systems etc..

II. SYSTEM DESCRIPTION AND MODELLING

As mentioned in the previous section, there are three stages used in this paper. First is user identification process. This is used to check whether there is any user's presence in the room. The total details of the framework created for the process flow is shown in Fig 1.

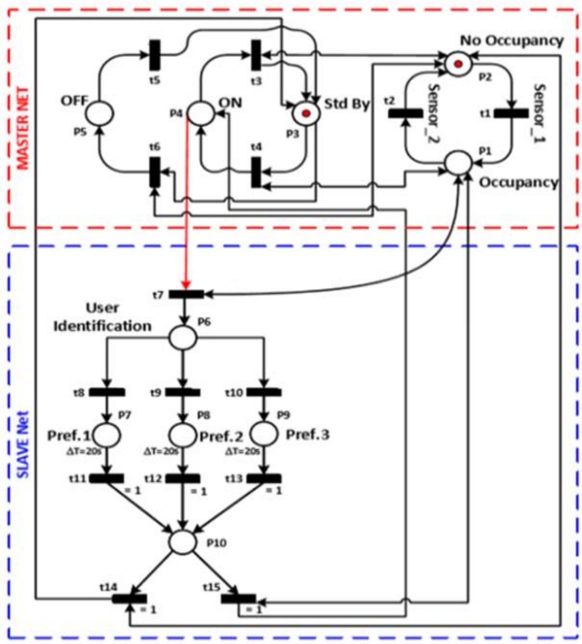


Fig 1 Process flow diagram using Petrinets

Here, there is master net and slave net. Master net has ON state, Standby state and OFF state. Master net goes to ON state when any user is identified in the room. And if no new user is identified, the master net will be in standby state. Here, the referral temperature will be maintained in 30^0C.

The slave network starts when the master net goes to ON state and the the fast user identification process starts. Three case studies have been discussed which is as follows: The first case is the identification of the person 1 and then the preferred temperature T_1 of person 1 will be send to the third stage. The second case is the identification of the person 2 and the preferred temperature T_2 which will be sent to the next stage. The third case is the identification of the persons 1 and 2 simultaneously and then their preferred temperature T_3 will be sent to the next stage. The process of sending the preferred temperature to the third stage will be activated for certain time limit, which is chosen by the system manager. The first stage is when the occupancy is detected in the room which is followed by identification process and finally followed by sending the preferred temperature of the identified user and then so on. And if there is no occupancy detected it will be in the standby mode. The flow diagram as shown in Fig. 1 works based on these all conditions. This type of proposed system has the energy saving framework.

III. SOFTWARE REALIZATION

In this paper, for modeling and analysis an open source software Sirphyco tool is used. The main reason for developing the models using Sirphyco tool is that Mathematical modeling, Simulation and Analysis can be done simultaneously. The three types i.e. Discrete, Continuous, Hybrid petrinets models developed in Sirphyco are shown in Figures 2, 3 and 4 respectively.

As discussed the model developed in Sirphyco using Discrete Petrinets is shown in Figure 2. The model comprises of 12 Places shown in circles and 15 Transitions shown as rectangular boxes and are interconnected using directed arcs

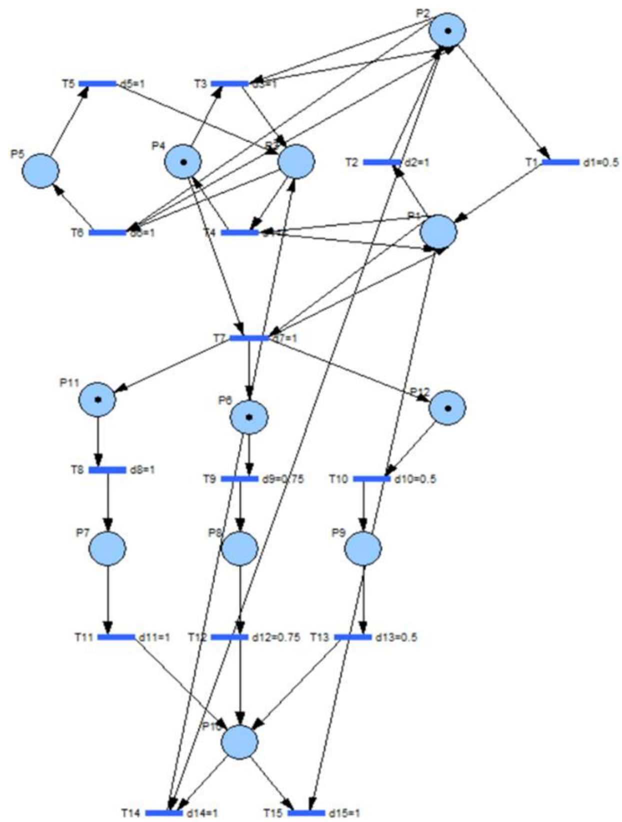
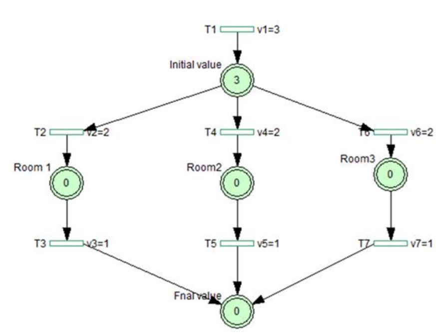


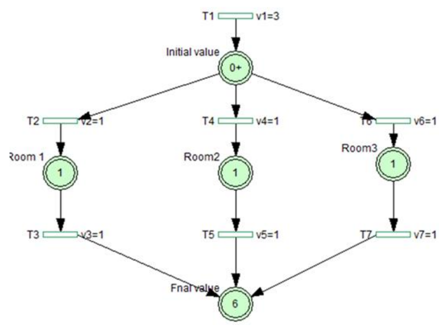
Fig. 2 Process flow diagram in Sirphyco using Discrete Petrinets

The flow diagram as shown in Fig. 2 works similar to the normal flow diagram based on the conditions.

The development of the model framework using Continuous Petrinets are shown in Figures 3a and 3b respectively. Using this model the frequency of flow of persons in the rooms can be identified and modeled as a process flow. Figure 3a depicts the model developed in Sirphyco before simulation and similarly Figure 3b shows the working of the model after simulation.



(a)

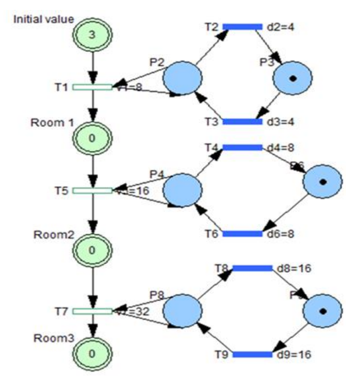


(b)

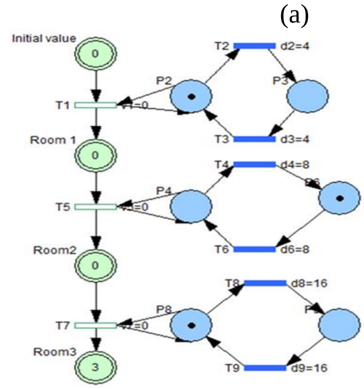
Fig. 3 Continuous Petrinets flow diagram in Sirphyco (a) Before Simulation and (b) After Simulation

The development and analysis of a combined mathematical framework for better and efficient understanding and is done through Hybrid Petrinets wherein the models developed are shown in Figures 4a and 4b respectively. The model effectively depicts the flow of the persons from a particular room as modelled as Continuous Petrinets and the control is through a logic as modelled using Discrete Petrinets. The combination is as referred to as Hybrid Petrinets and is shown in Figures 4a and 4b respectively.

As discussed earlier the model before simulation as developed in Sirphyco is shown in Figure 4a whereas the model after simulation is shown in Figure 4b.



(a)



(b)

Fig. 4 Hybrid Petrinets flow diagram in Sirphyco (a) Before Simulation and (b) After Simulation

IV. RESULTS AND DISCUSSION

As discussed in the earlier sections the models developed using Discrete, Continuous and Hybrid Petrinets are highly helpful in analysing the both graphically and mathematically. The simulated graphical output of the output places for the model developed using Continuous Petrinet is shown in Fig 5.

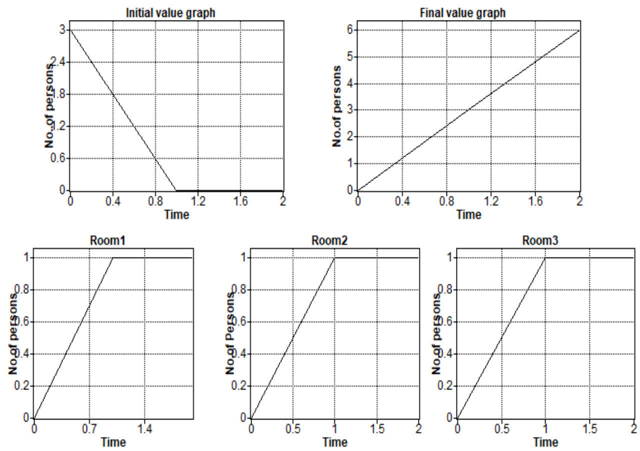
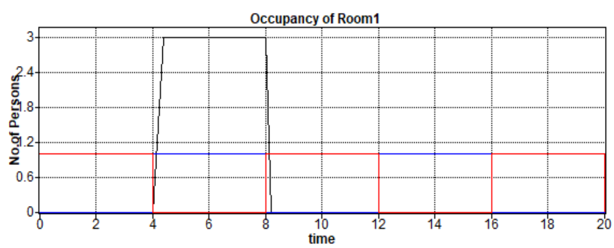
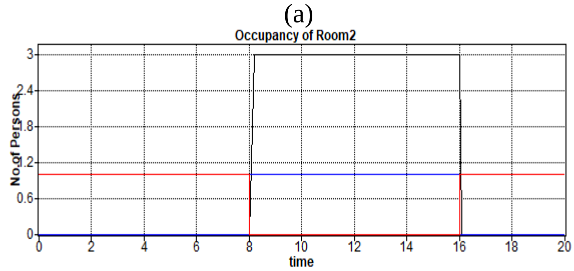


Fig. 5: Results of the Continuous Petrinet model

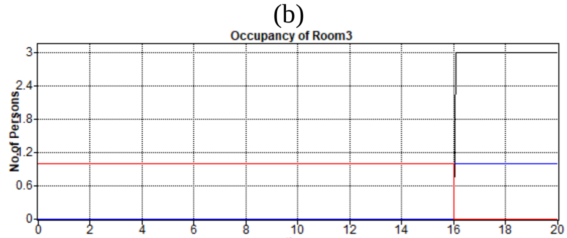
The Hybrid Petrinets as shown in Fig. 3 is used for the total performance analysis. This model since is a combination of both Discrete and Continuous Petrinets, it gives a better depiction of the process flow. The simulation output obtained for the Hybrid Petrinet model is shown in Figures 6a, 6b and 6c respectively.



(a)



(b)



(c)

Fig. 6 Results of Hybrid Petrinet model

For performng mathematical analysis which is another imporatnt aspect of Petrinet model the concept of matrices are used. Hence the analysis of the models developed can be done by developing the three matrices namely, Pre- incidence matrix, Post –incidence matrix and Incidence matrix as denoted as W^-, W^+ and W. The developed matrices usng the above are shown in Figures 7a, 7b and 7c respectively.

The Pre-incidence matrix have p*t values. p indicates number of places and t indicates number of transitions. For each position in [i,j] in the matrix,1 will be in the position if transition i has input from position j. And 0 is placed in position if position I has no input from position j. The same is followed in the case of Post-incidence matrix wherein the matrix the 1 and 0 will be with respect the output connection of every transition. The incidence matrix W is obtained by subtracting W^- from W^+. It is computed by $(W^+) – (W^-) = W$.

$W^- =$

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15
p1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
p3	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
p4	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
p5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
p6	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
p7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
p8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
p9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
p10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

(a)

$W^+ =$

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15
p1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
p2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p3	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
p4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
p5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
p6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
p7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
p8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
p9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
p10	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0

(b)

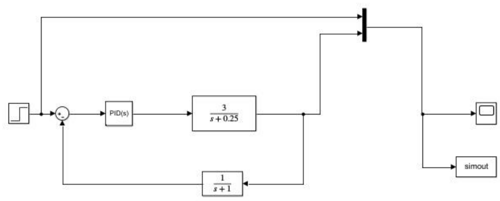
W=

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15
p1	1	−1	0	0	0	0	0	0	0	0	0	0	0	0	0
p2	−1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
p3	0	0	1	−1	1	−1	0	0	0	0	0	0	0	1	0
p4	0	0	−1	1	0	0	−1	0	0	0	0	0	0	0	1
p5	0	0	0	0	−1	1	0	0	0	0	0	0	0	0	0
p6	0	0	0	0	0	0	1	−1	−1	−1	0	0	0	0	0
p7	0	0	0	0	0	0	0	1	0	0	−1	0	0	0	0
p8	0	0	0	0	0	0	0	0	1	0	0	−1	0	0	0
p9	0	0	0	0	0	0	0	0	0	1	0	0	−1	0	0
p10	0	0	0	0	0	0	0	0	0	0	1	1	1	−1	−1

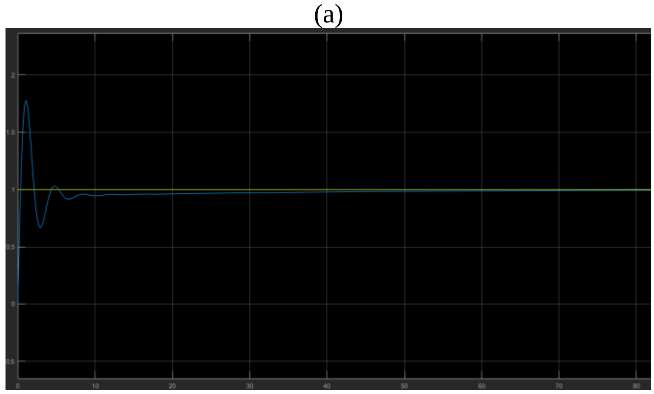
(c)

Fig. 7 The depiction of development with respect to (a) Pre-incidence, (b) Post-incidence and (c) Incidence matrices

The last part of the paper discusses the modeling and simulation of the process using a Proportional-Integral-Derivative (PID) controller in MATLAB environment. The PID controller is a control loop mechanism employing feedback that is widely used in industrial control system. PID controller controls the process variables and are the most accurate and stable controller. PID controller is used to regulate the temperature. Through the analysis done from above Petrinet modeling the details are fed as input to model developed along with the PID controller in MATLAB environment. Using the details developed in the Petrinet environment the transfer function for the system is identified as a first order transfer function whose equation is **K/(s+a).** Here 'K' indicates the number of person in the room and 'a' indicates the time the person remains in the room. The transfer function model developed in MATLAB along with the simulated results are shown in Figures 8a and 8b respectively.



(a)



(b)

Fig. 8 (a) Transfer Functon model of the system along with (b) Output response graph

From the details obtained and the analysis done using the above it can be understood that the analysis could be effectively utilized for the studies to be done for understanding energy consumption i.e. how it can be reduced and thus the how energy can be saved.

V.CONCLUSIONS

In this paper an effective strategy to develop and energy-saving framework in order to achieve comfortable environment and an optimum temperature control thereby ensuring profitability is discussed. For this purpose the modelling and analysis are done in Petrinet environment wherein the process flow is modelled and analysed as Discrete, Continuous and Hybrid Petriinets. The Petrinet models developed were highly helpful in analysing the framework structure which was followed with a temperature regulatory control framework developed n MATLAB and effectively analysed to obtain the preferred regulated temperature through which the energy saving mechanisms can be devised and studied in the future.

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