A Study on the Implementation and Simulation of Petri Net Models based on Manifold Learning and Topological Game Theory

Junxia Ma, Zhifeng Zhang*

Zhengzhou University of Light Industry, Zhengzhou China.

***Abstract* — Petri nets are an important language in the mathematical modelling of events. They are a composition of the arcs, places and transitions. In this paper we propose efficient models of game playing using Petri net modelling language. The concept of game theory finds multiple applications ranging from science and engineering to social, psychological, economic fields, while gaming theory refers to decision making to determine the shortest possible path to reduce computational complexity and cost, especially in cases of complicated problems. Contributions of this paper include novel gaming theory models using petri net modeling language.**

Keywords — Game theory, petrinet modelling, machine languages, UML.

I. INTRODUCTION

With advent of science and technology, especially with the avenues for artificial intelligence and decision making models growing in leaps and bounds on a day to day basis, need for research in effective models to evaluate the performance of day to day applications have been increasing ever since. A recent trend is the high scale boost achieved in the gaming industry which follows a AI based approach to be interactive to the user as well as decide based on the users preferences. The concept of gaming theory has evolved to be omni present in many decision making applications or part of larger applications. Their applications range from gaming right down to power sector for deciding upon sharing of loads for effective distribution of power, statistical analysis of economic models to aid in prediction and classification. Petri net has emerged to be an effective tool in modelling such complex mathematical systems. It is an abstract, formal model effectively depicting the flow of information from one node to another. They find great utilization in asynchronous system which is not globalized by a single clock signal. In such cases, the information regarding flow of information obtained by pertinent prove to be of great use in providing the necessary synchronization and coordination of different activities in the given system model. Another application of Petri nets could be found in concurrent systems which are event based and work on constraints including frequency of occurrences. A Petri net (PN) is a graphical and mathematical tool for describing and studying systems that are characterized as being concurrent, asynchronous, distributed, and stochastic. As a graphical tool, Petri nets are used as a visual communication aid similar to flow charts and networks. In addition, tokens are used in these nets to simulate the dynamic and concurrent activities of systems. Petri net could be thought of as a simple mathematical tool which provides solutions by equating the given problem to simple algebraic state equations which are closely correlated with behavior of the systems under study. Petri nets model a complex system as an interconnection of several sub systems which communicate through nodes in the form of token exchanges. PN models can be readily used to describe a combined system model of several interacting subsystems. Each subsystem may interact with the other subsystems via token exchange. The models interact with each other by exchanging tokens. PNs are logical models derived from the knowledge of how the system works and allow the simulation of uncertainties via stochastic transitions [12].

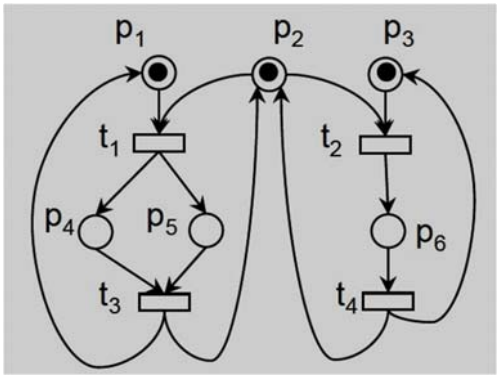

Figure 1. Illustration of simple Petri net model with arcs and transitions

Important properties of petri nets include liveness, boundedness and reversibility. Liveness is the probability of occurrence of an event described by the transition. Boundedness specifies the boundaries in the infinite sub space dimension while reversibility refers to the ability to recover from any reachable point. A PN basically consists of two types of nodes, called “places” (P) and “transitions” (T) as shown in figure 1. The above figure has 6 places specified as P1, P2, P3, P4, P5 and P6. Places are depicted as circles and transitions are drawn as bars or boxes. Arcs are labelled with their weights (W),

which take on positive integer values. Petri nets are nothing but the family of nets which have weights greater than one. When the weights are exactly equal to one, such Petri nets are known as normal Petri nets. Another important parameter in Petri nets is marking which is denoted by the parameter M. The initial marking for the system represents the initial condition of the system and is denoted as M_0.

TABLE 1. GENERAL ILLUSTRATION OF PLACES AND TRANSITIONS

Input Places	Transition	Output places
Conditions	Event	Post conditions
Resources needed	Clause	Conclusion
Preconditions	Task	Resources released

In an ordinary Petri net, if all the places that are inputs to a transition have at least one token, then the transition is said to be enabled and it may fire. When an enabled transition fires, a token is removed from each of the input places and a token is placed in each of the output places.

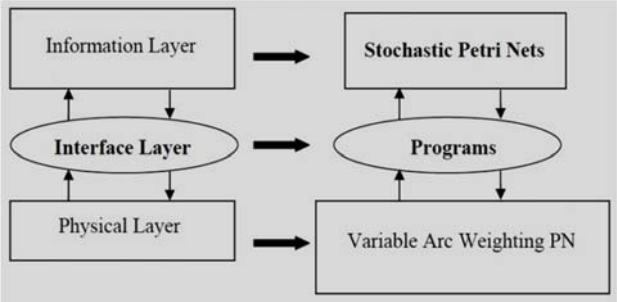

Figure 2. Multilayered Petri net model

An effective study of literature reveals several research contributions and algorithms towards efficiently modeling a gaming technique. Literature reveals the usage of Unified Modeling Language (UML) which is a modeling language widely used in software specification and design for modeling such gaming techniques. There are a number of UML classes found in the literature out of which six categories have been implemented in [9]. The works model the cases as actors and their actions or interactions with the system. They can be used to identify and collect requirements in the early stages of conception. The research contributions of Bernard and Cannon have been found to investigate the use of an emoticon based instrument. This technique has been applied to a set of undergraduate students taken as the data set. It is found to be a motivation based experiment where the motivation levels of each of the players have been recorded in their process of achieving the target. The motivation levels have been recorded prior and post decision making processes to study the percentage of deviation from the ideal line. This gaming technique has been implemented by a recording the observations by putting forward questions to the data sets under study. Emoticons are found to be used in this work which simplifies the computational method in this paper. Another category of research has been observed in [4] [12] [16-17] where virtual games and simulation based models for educational applications which are also based on motivation based analysis and found to enhance the effort and frequency of play among the users. These classes of simulation techniques are categorized under enhanced virtual games and simulation (EVGS) [2] [10] [16] where higher levels of success have been measured by the intrinsic motivational factors created by the activity. Research has also been conducted to study the EVGS methodologies and their methods to be easily controllable which consequently could increase the motivation levels thus increasing the effectiveness.

Research contributions of Derbali and Frasson et al have reported the investigation and implementation of a gaming technique based on player's motivation levels. The assessment of motivation was made using questionnaire as seen in most of research contributions in which 33 candidates have been chosen as the candidates for the implementation. In the paper, it is found that each subject is seated in front of two computers in which one is used for playing while the other serves the purpose of answering the questionnaires. The result shows that the EEG wave's patterns are correlates with the increase of motivation during certain parts of a serious game play. The motivation research in the game [13] [16] is an extrinsic motivational. Thus, the motivation measurement process is still done separately of the game.

An important finding in previous work is the parameter known as pay off function which is assigned to certain responses in the modelled mathematical system. These functions are chosen carefully such that they directly reflect the intuitive advantage that arises from each of the output response nodes. But it is found from literature [14] that validation of payoff functions are quite not possible to be validated and hence treated to be notional. An important advantage of going in for pay off functions is that they directly correlate with the objective of attackers and hence could be very much utilized in developing in hacker proof and defensive systems.

.

II. PROPOSED WORK

A Petri net model of a dynamic system is composed of a net structure that represents the static part of the system, and a marking that represents a distributed overall state on the structure. The net structure is a weighted-bipartite directed graph specified as a four tuple:

$$N = < P, T, F, W > \quad (1)$$

The variable P denotes the finite subspaces of places, T representing the finite non empty subsets of transitions, F denotes the arcs and W denotes the weights which are

labelled to each arc. Arcs on the other hand are subdivided into two categories such as input and output arcs. Input arcs are defined as:

$$I = Px\,T \rightarrow 0,1,2\ldots. \quad (2)$$

The arcs described in (2) are used to direct transition from places to transitions while output arcs are directed from transitions to places and denoted by:

$$O = TxP \rightarrow 0,1,2\ldots. \quad (3)$$

Further in the proposed work, a transition is enabled if and only if every input node from the source has tokens whose number is nearly equal to the weights W assigned to each node in the three. Once this condition is satisfied, firing of transition takes place which results in removal of the assigned weight and consequently gets added up with the output place.

An enabled transition gets fired as mentioned above and the update equation is specified as:

$$O_k(x) = O_{k-1}(x) + S(x,t) - T(x,t) \quad (4)$$

The incidence matrix for the above update equation is defined as:

$$I(x,t) = O(x,t) - T(x,t) \quad (5)$$

A three place two transition model has been used as the base model for developing the proposed formulation to model the gaming model. The base model is depicted in figure 3 shown below.

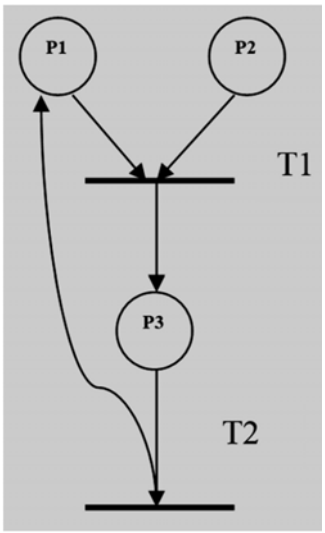

Figure 3 Base model for the proposed work

The matrices for the proposed base model are given below:

$$P = \{p1, p2, p3\} \text{ and } T = \{T1, T2\} \quad (6)$$

The input and output matrices are formulated as:

$$T(p1,t1) = T(p2,t1) = T(p3,t2) = 1 \quad (7)$$

$$\text{and } T([p3,t1) = T(p1,t2) = T(p2,t2) = 0 \quad (8)$$

$$O([p1,t1) = O(p2,t1) = O(p3,t2) = O(p2,t2) = 0 \quad (9)$$

$$O([p3,t1) = O(p1,t2) = 1 \quad (10)$$

The initial marking is given as:

$$M_0 = \begin{bmatrix} 1 \\ 2 \\ 0 \end{bmatrix} \quad (11)$$

And is generalized by

$$x^T M_0 = 1 \quad (12)$$

III. RESULTS AND DISCUSSION

To begin with, the gaming technique which is based on the motivational activity of players in achieving a given target, the Petri net model briefed in above sections have been implemented using a request and decide strategy in which the player starts the game placing the request to move on to neighboring nodes. The nature of request is taken to two fold which can be either a pleasant or unpleasant approach. The requesting player is acknowledged using the same two fold approach in which the response of the neighbor node could be pleasant or unpleasant depending on the nature of the request received from the parent node.

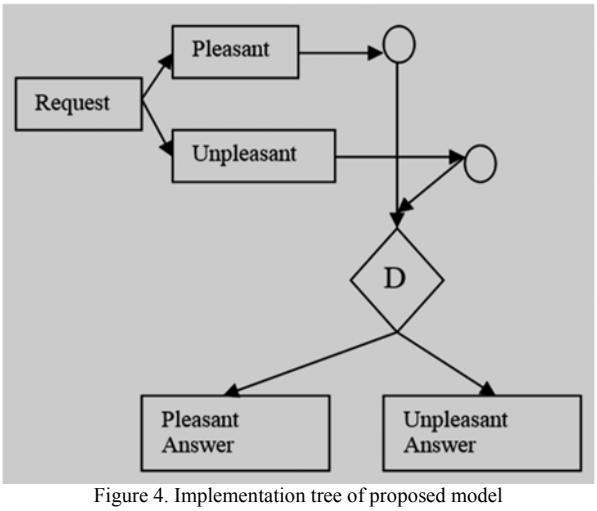

Figure 4. Implementation tree of proposed model

The transition of the node takes place from left to right in the clock wise direct using the same request and proceeds approach. In the process, the key parameters such as level of persistence of the player, the effort taken by the player to convince the neighbor to give a pleasant

reply and the decision making ability to route through the shortest path. A parallel implementation is approach for a n+1 players in the game. The proposed work measures the parameters on a 3 level scale with the change of state on axes and number of players in the other axes. The implementation of the proposed work is depicted in figure 4.

In figure 4 D denotes the decision making box while the circles represent the nodes through with the transition takes place. As mentioned in previous sections, the transition occurs from left to right and the illustration takes in to consideration a single player trying to proceed on a request and proceed approach. A parallel implementation is depicted in figure 5 based on Petri net model.

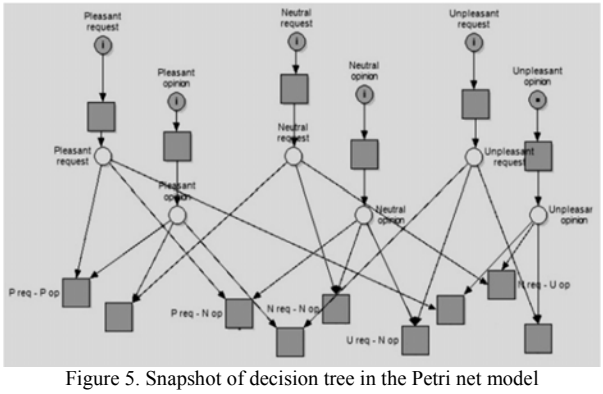

Figure 5. Snapshot of decision tree in the Petri net model

The output of the proposed work is divided into three objective formulations namely persistence, effort and decision making. Given a mission to be accomplished, persistence denotes the perseverance or technically the rate of close tracking with respect to meeting the objective. It could be seen persistence has a direct bearing on the time consumed and higher the persistence lesser the time taken to meet the objective. The second objective is effort which denotes the degree of motivation of the players in completing the given problem formulation. The last parameter is the decision making capability of the players during the course of their path to meeting the objective. The characteristic of active choice including tendency to search information, always respond to get the questions and low efficiency in solving the problem thoroughly.

Figure 6 denotes the motivation level of the players in the game using the proposed Petri net model. The motivation level is measured on a three scale basis starting from low, semi to maximum motivation level. The motivation level differing between players as the level of the game progresses denoted by the horizontal axes could be seen from figure 6.

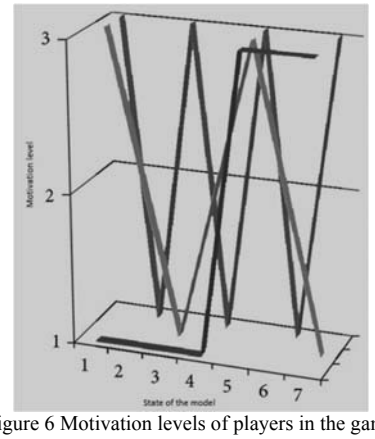

Figure 6 Motivation levels of players in the game

TABLE 1. DEVIATION LEVEL ANALYSIS OF PROPOSED WORK

Quality measures	Deviation	Total no. of players	Percentage contribution
Persistence	0	21	59
	Less than 25	34	94
	Less than 50	22	61
	Less than 75	19	54
Effort	0	18	53
	Less than 25	33	93
	Less than 50	14	40
	Less than 75	16	42
Decision making	0	11	30
	Less than 25	16	38
	Less than 50	24	66
	Less than 75	15	42

Analysis of the previous equations depicts that the deviation level of persistence of the players is quite consistent with minimum range of deviation from their objective. Hence they are considered to be valid observations.

IV. CONCLUSION

This research paper has been on an experimentation of an application of game theoretic methods using petri net models which could be used in analysis and implementation of realistic games before their actual implementation and testing. Branch tree methods have been effectively utilized in this paper for deciding upon possible moves and false moves. The proposed petri net model for the game application has been experimented and observations justify and indicate that the resulting decisions made by the model are intelligent resulting in computational cost and complexity. Petri nets have been successfully used in the analysis of many flexible manufacturing systems involving both assembly and planning applications. They also find wide applications in analyzing the scheduled based models to intimate to the control unit that the certain resources required are unavailable.

ACKNOWLEDGEMENT

Key scientific research project of Henan higher education (NO. 16A520030). Science and technology research industrial projects of Henan Provincial Science and Technology Department (NO. 152102210357).

REFERENCES

[1] Y. Inal and K. Cagiltay, "Flow experiences of children in an interactive social game environment," British Journal of Educational Technology, vol. 38, no. 3, pp. 455–464, 2007

[2] J. Clempner, "Modeling shortest path games with Petri nets: a Lyapunov based theory," International Journal of Applied Mathematics and Computer Science, vol. 16, no. 3, pp. 387–397, 2006

[3] Che C. R, Tsai L T and Yang C C, "A neural network approach for random samples to stratified psychometrical population", in proceedings of the WSEAS international conference on sociology, psychology, philososphy, pp. 51 – 54, 2010.

[4] M. A. Syufagi, M. Hariadi, and M. H. Purnomo, "A cognitive skill classification based on multi objective optimization using learning vector quantization for serious games," ITB Journal of Information and Communication Technology, vol. 5, no. 3, pp. 189–206, 2011

[5] R. E. Clark and S. Choi, "Five design principles for experiments on the effects of animated pedagogical agents," Journal of Educational Computing Research, vol. 32, no. 3, pp. 209–225, 2005.

[6] H. Ndahi, "The use of innovative methods to deliver technology education laboratory courses via distance learning: a strategy to increase enrollment," Journal of Technology Education, vol. 17, no. 2, pp. 33–42, 2006.

[7] H. C. Arnseth, "Learning to play or playing to learn—a critical account of the models of communication informing educational research on com puter gameplay," The International Journal of Computer Game Research, vol. 6, no. 1, 2006.

[8] Khaled A, Hosseini S, "Fuzzy adaptive imperialist competitive algorithm for global optimization", Neural Computing Applications, Vol. 25, pp. 1–13, 2014.

[9] R. E. Mayer, "Should there be a three-strikes rule against pure discovery learning? the case for guided methods of instruction," American Psychologist, vol. 59, no. 1, pp. 14–19, 2004.

[10] P. A. Kirschner, J. Sweller, and R. E. Clark, "Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching," Educational Psychologist, vol. 41, no. 2, pp. 75–86, 2006.

[11] Song, M. , Tarn, T.-J. and Xi, N. , Integration of task schedulling, action planning, and control in robotic manufacturing systems, Proc. of the IEEE, 2000, 88 (7), 1097-1107.

[12] J. B. Park, "A continous strategy game for power transactions analysis in competitive electricity markets", IEEE transactions on power systems, Vol. 16, pp. 847- 855, 2001.

[13] Lu N, Chow J. H, Desrochers A A, "Generator bidding strategies in a competitive deregulated market accounting for availability and bid segments" in proceedings of specialists in electric operational and expansion planning, 2002.

[14] Lu N, Chow J H, Desrochers, "A multilayer petri net model for deregulated electric power systems", in proceedings of ACC, pp. 513 – 518, 2002.

[15] Bai X, Shahidepour S M, Ramesh V C and Yu E, "Transmission analysis by Nash game method", IEEE transactions on power systems, Vol. 12, pp. 1046 – 1052, 1997.

[16] X. Liang and Y. Xiao. Game theory for network security. IEEE Communications Surveys & Tutorials, Vol. 15, No.1, pp. 472–486, 2013.

[17] Roy S, Ellis C, Shiva S, Dasgupta D, Shandilya V and Wu Q, "A survey of game theory as applied to network security, in proceedings of system sicences, 2010.

[18] Julia Padberg, Kathrin Hoffman, "A survey of control structures for reconfigurable petrinets", Journal of computer and communications, Vol. 3, pp. 20 – 28, 2015.

[19] Bi, Chujian, et al. "SAR image restoration and change detection based on game theory." Intelligent Computing and Internet of Things (ICIT), 2014 International Conference on. IEEE, 2015.

[19] Modica, T. and Hoffmann, K. (2010) Formal Modeling of Communication Platforms Using Reconfigurable Algebraic High-Level Nets. Electronic Communications of the EASST, 30.

[20] Ehrig, H., Golas, U. and Hermann, F. (2010) Categorical Frameworks for Graph Transformation and HLR Systems Based on the DPO Approach. Bulletin of the EATCS, 102, 111-121.

[21] Gottmann, S., Nachtigall, N. and Hoffmann, K. (2012) On Modelling Communication in Ubiquitous Computing Systems Using Algebraic Higher Order Nets. ECEASST, 51.