

A Simulation Technique: Petri Net Used in Manufacturing Application: A review

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Abstract—Advancement in manufacturing field is being fast. So the evaluation of performance is essential time to time. Many techniques used in past to determining the performance of whole system. Petri net is one the technique by which we can model the manufacturing system and also the analysis the system for performance. There are many type of problem occurred in manufacturing field like deadlock, searching problem. So Petri net is useful in quantitative and qualitative types of performance measure. We are going the review the articles published in (2000-2015) time span mainly in this paper.

Index Terms— Petri net, modeling, Simulation

INTRODUCTION

Now a days most of industries in our country practice the traditional production system. Effective management of the steady state operation is no longer enough to ensure the survival, let alone the success of organization. The performance of operations has to improved continually in all its aspects, and it is driven by the quest for increase productivity, flexibility and continuously changing environment.. These feature need for continuous performance analysis and improvement of manufacturing system. Therefore, the key to stay at the apex of global competition is to meet the dynamically changing need of customers.

It is difficult to predict the behaviour the manufacturing system without modelling, analyzing and control techniques. Performance analysis of manufacturing system using Petri Net (PN) is one of the promising tools employed for accessing, Petri net are a powerful graphical tool for modelling and analyzing concurrent, parallel, simultaneous, synchronous, and distributed and resource sharing. Petri net can be analyzing quantitative and qualitative aspect of manufacturing system[11,44]. There are various types of analysis comes under qualitative aspect like the deadlock analysis, overflows analysis, and conflict condition analysis or resource sharing analysis. Under the quantitative aspect throughput analysis, average queue length, performance index, and completion time analysis can be done. In this paper articles published in (2000-2015) have reviewed. For the understanding purpose applications is divided in to mainly five sections. These sections are deterministic Petri net, stochastic Petri Net, Fuzzy timed Petri net, Deadlock problem occurred in manufacturing field and Problem solved using CPN software.

PETRI NET

Petri net are well known for their modelling potential and for their ability to implement optimization techniques. Karl Petri developed this technique in 1962 for communication system analysis. Its use has been extended to application like manufacturing [1]

In seventies Grafset tool (Petri Net) based was introduced in order to specify validate and implement logic controller in production system. Grafset has been recognised all over Europe and implemented in many countries. [2]

Petri net is a set of node and arc. There are two types of node (place and transition) which represent the state of system and occurrence of event respectively. In manufacturing system place would represent operation (e.g., process, transportation, reparation), and transition symbolize events (Termination of job processing or a machine breakdown). The firing process includes a tokens flow among places, when transition fires token all input places are removed and put into output places. A transition can only be fired if it has been enabled (i.e. there are sufficient token at its input places).

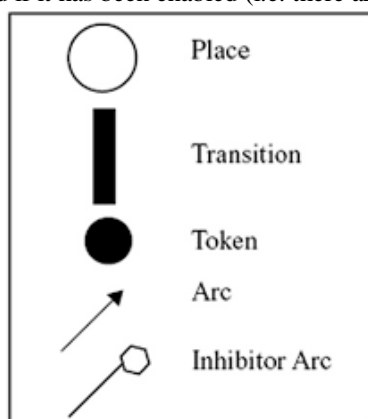


Fig. 1: Tool used for Petri Net Modelling

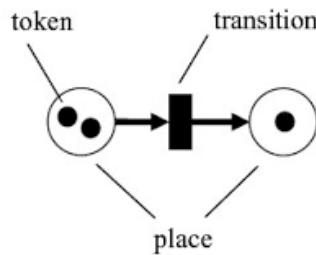


Fig. 2: Firing the Token

Places which are drawn as circles possible states or conditions of the system while transition which is shown by bars or boxes describe event that modify the system states. The relationship between places and transition are represented by set of arcs which are only connectors between places and transition in either direction. The dynamic behaviour of system can be represented using token which graphically appear as a black dots [3]

Manufacturing system is a discrete event system. So modelling can be done and also by this we can check various types of analysis before whole system establish.

FORMAL DEFINITION OF PETRI NET

A Petri net can be formally defined as five-tuple; $PN = (P, T, I, O, M)$, where

P is a finite non- empty set of places $P = \{P_1, P_2, \dots, P_n\}$

T is a finite non-empty set of transition $T = \{T_1, T_2, \dots, T_n\}$

I is an input function. $I: (T \times P) \rightarrow \{0,1\}$, $I(T, P) = 1$ if there exists an arc from P to T . If so, P is an input place for T ; O is an output function. $O: (T \times P) \rightarrow \{0,1\}$, $O(T, P) = 1$ if there exists an arc from T to P . If so, P is an output place for T ; $M: P \rightarrow N$ is a initial marking that assigns a non-negative integer to each place. Such a number represents the number of tokens in the place. $\langle P, T, I, O, M \rangle$ represents a marked Petri net.

For example in fig .2 a operation of drilling being done left circle and right circle represent the loading and unloading station respectively. And transition means drilling process can be represent by rectangular bar. The token is available loading station represent material ,resource, information. Token will be fired on meeting of appropriate condition. So note that in a Petri net model the transitions may immediate or timed and conflict or in concurrent. When a token is located in a place, the place is said to be “enabled”. In timed transition there can be delay present in firing. A timed transition may be deterministic or exponential fuzzy uniform or any discrete and continuous probability distribution.

APPLICATION OF PETRI NET IN MANUFACTURING AREAS

Petri Net has used in various ways in manufacturing areas. So we will distribute past work in mainly five sections. These sections are deterministic Petri Net, Stochastic Petri Net and Fuzzy Petri Net, deadlock problem solved by Petri Net and some application in Coloured Petri Net.

Deterministic Petri Net

The deterministic Petri Net is used when the time limit is finite not probalistic. Deterministic Petri Net is used in many applications. Performance is critical aspect of production line. Right dispatching rule should be used for best performance. So various technique being used for dispatching rule and find the performance measure in terms of number of late job, Total weighted tardiness, makespan, system total time and resource utilization. For dispatching rule he has used WSPT, SPT,MS, LPT,EDD, CR,MS and ATC. Evaluate and compare different schedule for the same production Plan according company Preference.[4]. Jain, A. Also work in measuring the performance of FMS system. In this paper FMS system has modelled by Petri net tool. And also by timed Petri net several performance measure (makespan, mean flow time , maximum flow time and variance of flow time) have been evaluate. Performance have evaluate in two types of manufacturing enviournment (virtual batch and virtual line).By changing the constraints we will find various types of variation in performance measure.[5] So Petri net is very useful in modelling and determining performance of manufacturing system. A efficient heuristic algorithm is proposed to test the reliability a target schedule based upon Petri net model. It was tested by a case study.[12]. Petri net also used for modelling the chain between maker to customer in this respect Jongwook Kim modelled a semiconductor plant using timed Petri net and analyzing it for maximizing the profit.[13].

Now a day various software are using in analyzing the manufacturing system. Mainly MATLAB, Visual slam, CPN Tool and Queuing Models are in this race. Abdulziz M. El-Tamimi determined the utilisation index of machine engage in various FMS setup. These analysis have done by MATLAB, Visual slam and Bottleneck technique. And also done comparison of three techniques. Petri Net by MATLAB gives the best result out of three.[6] We can also compare the cost aspect by using Petri Net. By this we have been able to tell which configuration has minimum and maximum cost and also facility available in it. Jan Jadlovská have done work in this area. In this paper utilisation factor and production cost

determined of FMS Set up. By using reachability property we can check the various operation.[7] In this raw Hassan Haleh also determine the performance analysis of machine cell and prove that Petri net have best facility for modelling.[8]

In Petri net modelling we can change time interval of marking. We either extend and reduce the time engaging the operation. F.Basile work in this area. In this paper model repair of timed Petri net model with temporal anomalies is considered. And observe time sequence is given. Initial condition will remain same and duration of activity will change with help of mixed inter linear programming [9]. Several algorithms also developed for making modelling more effective. Latefa used Continuous Petri Net with Hybrid Automata for analysis the manufacturing System. Continuous Petri net is best in modelling and Hybrid Automata is best for analyzing the factor of Performance. He developed a structural algorithm for using both them.[10]. The modified branch and bound and timed place Petri net (MBBTE) solution algorithm is proposed. It was used for doing scheduling of multi product batch chemical plant.[14]

There are number of papers in literature in which simulation tool and optimisation tool used differently and using both tools together seems very effective. S.L. Stebel use Petri net as a simulation tool and mixed inter linear programming tool used for optimisation and it gives a better result.[23,]

In 2004 optimisation of cycle time of FMS system and minimisation of work in process is done by using timed Petri net. In this paper hybrid property is used of Petri net [24,27].In 2005 used timed Petri net for modelling of flexible assembly system. In minimization of completion time for a batch of product has shown in this paper. Task scheduling done dynamic programming algorithm.[25,2005]. One of another author used Petri net modelling with genetic algorithm. Genetic algorithm used for sequencing of job [26]. For the development of automated manufacturing system a new modelling language Geometry-driven Petri net (GPN) is introduced. It is combination of high level Petri net and data structure used in state of art virtual enviournment.[28]

Stochastic Petri Net

Stochastic Petri nets (SPNs) and generalized stochastic Petri nets (GSPNs) are two popular extensions of Petri nets. Both have been vastly used in modelling, controller and analysis of manufacturing system. There are several studies in the areas of manufacturing system. Stochastic Petri net will be used when time duration is probalistic not deterministic. For modelling and simulation a enhance stochastic high level Petri net is introduced. So product development of any product can done easily [39].By using stochastic we can optimise the cost and time also. In this raw a author use stochastic Petri net technique for modelling the semiconductor manufacturing system and optimise it for time and cost. [40]. A stochastic model is prepared of flexible manufacturing cell and various performance measure is checked like utilisation rate production output. So stochastic is also alternative to deterministic Petri net.[41]

Fuzzy timed Petri Net

The artificial intelligence and by using fuzzy logic a abject oriented knowledge based Petri net is developed and by which we can ergonomics and assembly design process planning simulation can be done during design stages. Knowledge based expert system and In literature many studied founded in deadlock present in manufacturing industry. Many advance algorithm developed for detection the deadlock and also give the solutions for prevent the deadlock condition. Following section related to deadlock problem occurred in manufacturing.

fuzzy logic into ordinary place transition Petri net is used. By using intelligent integrated design and assembly planning system we can do product design and assembly design simultaneously. The developed methodology and system have been successfully applied to assembly design and planning of micro switch.[29] One of author use knowledge base Petri net function for flexible assembly planning.[31] fuzzy set is used for expert decision support system. In this area Alexander Fay used fuzzy expert system in controlling the railway traffic. [30]

Concurrent engineering is very useful technique in now days. Because launching a product with new specification is essential for compete in market. So an artificial intelligence based method was proposed for doing assembly design, planning, evaluation and also simulation simultaneously. Here a unified class of Petri net is defined in which object oriented Petri Net approach is used [32].in this raw another author introduced a mechanism for hybrid the knowledge based system and coloured Petri net. So by using this we can obtain different sequencing for assembly of any product. And can find out the optimal schedule of sequencing.[34]

A new class of Petri Net is introduced for enhancing the modelling capability. Buffer- Net is used for FMS modelling and for scheduling approach heuristic approach based on AI used.[33]

PETRI NET USED IN DEADLOCK PROBLEMS

In literature many studied founded in deadlock present in manufacturing industry. Many advance algorithm developed for detection the deadlock and also give the solutions for prevent the deadlock condition. Following section related to deadlock problem occurred in manufacturing.

Deadlock detection and recovery

A methodology for modelling and analyzing fault torrent manufacturing system that not only optimizes normal productive processes but also perform detection and treatment of fault.[15] hierarchical class based Petri net approach is used for detection the fault and also its treatment done. Hierarchical modelling have done on (Factory, cell, machine level and component level) and all fault are find out and also simulation done for the verification [37]

In this field Wensong Hu, Yuyuan Zhu have given the two method for deadlock detection and also recovery of it. First one based on Petri net structure and other one based on reachability tree. He also used method based upon siphon theory for detection of deadlock in manufacturing system.[16] In this row Bidyut Biman Sarka developed a decision support system for distributed retail beer game in which studied about deadlock being done effectively.[17]

Deadlock avoidance

Deadlock is main problem occurred in FMS system. Many methods developed for deadlock avoidance so system runs without interrupt. Viswanadham, N. Used Petri net modelling for deadlock avoidance. Reachability tree used for this and required result comes out.[18]. Another author tested the algorithm on manufacturing system with unreliable machine. Deadlock avoidance concept applied here.[36] In this row Zhiwang Qian give the light on bottleneck problem occurred in production logistic. Petri net used for avoiding deadlock present in logistic chain.[19]

Deadlock prevention

Deadlock prevention is also important field Petri net section. A algorithm introduces by which deadlock prevented in manufacturing field. In this algorithm only affected section of model by deadlock is considered and rescheduling of affected section is done.[35] on another paper author have studied about the reduction of set up cost of any manufacturing firm is reduce automatically the sequence of working also changes so all the fault can check by using reachability tree and just in time policy used here to reduce the inventory.[42]. In this row for the finding the optimum scheduling artificial intelligence base heuristic search technique used in reachability tree. And result are compared to previous research.[43] As the optimal cost of scheduling we have founded , search space also reduced by heuristic technique. So a new technique introduced which is hybrid of minimum search space and heuristic search algorithm. And it has implemented in reachability tree. Result have come better.[45] A timed based modelling have done of manufacturing system and by using heuristic search in reachability tree problem of deadlock have solved.[46]

By using Coloured Petri Net the modelling of dynamics of railway station have done and the deadlock prevention is assumed during this modelling and coloured Petri net used in this paper[38]. ZhiWu Li reviewed the problem occurring the manufacturing line and also related to deadlock. There are three main tool for study the deadlock problem namely Graph theory, Automata and Petri Net. Petri Net is most effective in last decade. Several solution provided by Petri net.[20] in this row another author developed a Generalized stochastic Petri Net Model of Manufacturing System and analyzed it with Markovian method. By using reachability tree the transition probability matrix of reduced embedded markov chain is computed. Matlab function used to get the routing probabilities and then steady state probabilities are calculated various performance measures were computed for the entire model developed. GSPN also a alternative to model the system.[21].

Ajay M. Patel also developed a model based on Petri net for stand by redundancy system and analyzed it by using reachability tree. So Petri net is very effective tool of detection of deadlock [22].

PROBLEM SOLVED BY CPN (COLOURED PETRI NET)

Many problem solved by CPN Software. And it is very essential and effective software for modelling and analysis. Task analysis is essential part of Petri net. For differentiating the task in modelling different coloured have been used. And this formalism can be say use for coloured Petri Net. New software for analysis the performance measure the system and also for modelling has introduced. And task analysis can be done by this.[47]. By CPN Modelling we can the efficiency of every task and expediently it has in one of the paper. Author has modelled the work flow of plastic process plant and efficiency of every section have found out. In this way, the time and cost for the development and maintenance of the shop floor operation model can be reduced [48] hierarchical modelling is special part of CPN modelling. This type of modelling has done. A manufacturing system has modelling by high level Petri net and also simulation will be done and compare the result of performance in which CPN modelling gives better result.[49]. The FMS system with AGV with multi stage and multi line is modelled by CPN. And by assuming the cost factor optimal guide path selected and improve in throughput and minimisation of cycle time can be done.[50] for the determine the cost on basis of optimised makespan a CPN modelling have done and state space technique have used.[51]. Hierarchical concept have been used in material flow modelling in mechatronic manufacturing system and the simulation also done in this .CPNT is very effective tool of Petri Net based modelling[52] and one author also done hierarchical modelling for finding the optimal material flow and energy flow in his plant. And 11 percent energy saved by this.[53]

CONCLUSION

Petri Net is very effective technique for analysing the system. Heuristic technique coloured Petri net software give the advancement in this field. Artificial Intelligence also play its important role in this area and hybrid technique based problem. The reviewed paper shows the literature published in 2000-15. Matlab, CPN , PIPE are software for modelling

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