Petri Net Recommender System for Generating of Perfect Binary Tree

Gajendra Pratap Singh, School of Computational and Integrative Sciences, Jawaharlal Nehru University, New Delhi, India
Sujit Kumar Singh, School of Computational and Integrative Sciences, Jawaharlal Nehru University, New Delhi, India

ABSTRACT

In modeling a discrete event driven system, Petri net recommender systems can play a very important role in describing the structural and behavioral properties of complex and tricky networks. The finite and infinite perfect binary tree forms a predictive model which can map the input information to output information based on the inputs’ attributes. A perfect binary tree can be used for three types of recommender systems such as: collaborative filtering, a content-based approach, and a hybrid approach. In this article, the authors show the existence of a Petri net whose reachability tree is a Perfect Infinite Binary Tree (PIBT).

KEYWORDS

Binary Tree, Petri Nets, Reachability Tree, Recommender System, Safeness

INTRODUCTION

Petri net is one of the mathematical language tools used especially for the modelling of concurrent distributed discrete event systems (Murata, 1989; Thong et al., 2015). It was first defined by Carl Adam Petri in his dissertation (Petri, 1966). Since then lots of theories have been recommended (Bobadilla et al., 2013; Lü et al., 2012; Ricci et al., 2015) and are used to implement Petri net in many areas such as biological networks and pathways (Chaouiya, 2007; Frainay et al., 2018; Marwan et al., 2011; Wan & Che, 2014), health study (Gaur & Singh, 2016), social networks, computer science, mathematical science, drug designing (Alaimo et al., 2016), transportation, workflow and business process model (Hornung et al., 2009), network optimizations, information forecasting, music system (Katarya & Verma, 2018), system modelling (Murata, 1989; Reddy et al., 1993). In Petri net theory, reachability graphs and tree plays an important role because of its reachability property. In earlier studies, authors have constructed a 1-safe Petri net that generates all the binary \( n \)-vectors, possibly with repetitions and exactly once (Kansal et al., 2010; 2011). Besides that, the problem of characterizing the 1-safe Petri nets that generate all the binary \( n \)-vectors as marking vectors once (Kansal et al., 2015) have also been shown. Petri nets have been demonstrated as a family of formalisms which can be used sometimes with the advantage of improving the communication between stages of the life cycle in manufacture process (Silva & Teruel, 1997). Pal and Skowron have shown its main concepts and its characterizing features of rough set theory with its integration to fuzzy set theory, to develop an efficient soft computing strategy for machine learning (Pal & Skowron, 1999). Set-indexers of a graph and set-graceful graphs have also been developed and discussed (Acharya, 2001). Salimifard and Wright proposed the application of coloured Petri nets in the modelling of workflow management systems using an integration method to show the flow (Salimifard & Wright, 2001). It has been shown that fuzzy graph theory has an increasing application in the modelling real-time systems in

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which the level of information is inherent and varies with different levels of precision values (Pasi et al., 2004). Various methods and applications of Petri net for the modelling and analysis of molecular networks and system biology have been explained recently (Chaouiya, 2007; Koch, 2015). Class of finite and infinite binary trees have been used to study in many hierarchical structures (Clempner, 2014). In this article, a mathematical theorem-based method for Petri net recommender system to study and generate the levels and nodes of a perfect binary tree as the reachability tree is discussed. This type of study can be recommended to study model-based approach in decision science to explain the variables involved in decision-making processes (Cho et al., 2002; Bouza et al., 2008).

PRELIMINARIES OF PETRI NETS

In this section, the basic definitions and properties related to Petri nets have been discussed. The underlying structure of PNs is based on graphs. A Petri net C is directed bi-partite graph which is a collection of places and transitions. Many scientists have defined the Petri net according to their needs and requirements. Its basic structure is mainly represented by 5-tuple namely \( C = (P, T, I, O, \mu_0) \) (see Figures 8 and 9 in Appendix), where \( P \) represents a non-empty finite set of places and graphically, a place is represented by a circle or ellipse. A place can accumulate or store the information or token. A place has always discrete states. The set \( T \) represents a non-empty finite set of transition. A transition is represented by a square or rectangle shape. After firing, a transition can produce the change of states. Places and transition are connected by arcs and represented by an arrow. An arc never connects two places or two transitions, i.e., an arc is connected from place to transition or transition to places. I is input function from place to transition and \( O \) is output function from transition to places and a marking \( \mu \) is an assignment of token to the places of Petri net. \( \mu_0 \) is the initial marking for the place nodes.

Firing rule: The number and position of the token may change during the execution of the Petri net. Any \( j^{th} \) transition of \( T \) is said to enable at \( \mu \) if and only if the number of arcs from places to transition is less than equal to the number of tokens in that place, i.e.

\[
\mu(p_i) \geq \#(p_i, I(t_j)) \quad \forall \ p_i \in P
\]

An enabled transition can be fired depending on the happening or non-happening of the event. After firing, the new state can be obtained by the following rule,

For every place,

\[
\mu'(p_i) = \mu(p_i) - \#(p_i, I(t_j)) + \#(p_i, O(t_j))
\]

New state (new marking) = Old state (old marking) – Number of arcs from place to transition + Number of arcs from transition to a place.

A perfect binary tree is a special tree in which every internal node has exactly two child node besides that all leaves have the same level and depth. A perfect binary tree is infinite if a number of nodes are infinite and infinite tree can be seen as the infinite reachable tree of a Petri net which never terminates. In graph theory, a node \( v_i \) is reachable from node \( v_j \) if there exists a sequence of adjacent nodes which start and end with nodes. In Petri net, a reachable graph without cycle along with its marking is called reachability tree. A transition in a Petri net is said to be sink if it has no output places and it is called source transition if there are no input places.
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