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MULTI-LOGICAL FUZZY PETRI NETS

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ABSTRACT

This paper introduces a new method of empowering Logical Petri Nets (LPN) and Fuzzy Logical Petri Nets (FLPN) [1] using multiple logic. In this paper we proposed a Multi-Logical Petri Nets (MLPN) and Multi-Logical Fuzzy Petri Nets (MLFPN) based on Logical Petri Nets (LPN) and Fuzzy Logical Petri Nets (FLPN). Here we have showed that, how multiple logic is implemented in MLPN and MLFPN. The proposed method also works to model such linguistic description which is not possible by classic Petri Nets or by FLPN. We have showed the implementations of this model. We have also presented an algorithm for decomposition of MLFPN.

Keywords: Multi-logical petri net (MLPN), multi-logical fuzzy petri net (MLFPN), logical petri net (LPN), fuzzy logical petri net (FLPN), linguistic description.

1. INTRODUCTION

Specification serves as the foundation for subsequent system engineering activities [2]. In other words, system specification is one of the fundamental system process activities where customer and engineers define the system to be produced and the constraints on its operations [3]. Even though PNs model certain aspects of system specification quite well, their use in applications has revealed some weaknesses when they are used in software applications. First, they are – like FSMs – a control-oriented model. Tokens typically represent the flow of control in the execution of several actions. The tokens however are anonymous. For Example, the presence of a token in a place may denote only the presence of a message in a buffer, not what the message says. PN suggests that the choice between alternatives is nondeterministic. However, the selection of alternatives depends on the contents of the message. It can be mathematically proven, however, that, in the general case, PNs do not have the ability to describe a selection policy [4]. To eliminate these problems Fuzzy Petri Nets were proposed. Then Fuzzy Logical Petri Nets were proposed as modification. Now we are proposing Multi-Logical Fuzzy Petri Net in which we show how Logical Petri-Net works with multiple inputs and produces multiple outputs and select one output from alternatives. The problem of validation of knowledge bases is an important and difficult problem. Ordinary and high level Petri Nets have been proposed as knowledge representation formalisms where structural and behavioural properties of the net can be used to prove properties of the system being modelled or, to verify the knowledge base integrity [5-12]. Reference [7] presented a validation method for Horn logic. The validation problems of Horn logic have been further researched in [8-10]. The G-net model was based on the knowledge table representation [11]. In a fuzzy environment, the issues of concern when talking about integrity checking are the definition of concepts such as inconsistency, redundancy and completeness, and the investigation of suitable similarity measures for comparison of fuzzy propositions [12-19]. One of the most successful applications of fuzzy logic has been in the area of processes control [20-22]. A generalized fuzzy Petri net model was introduced in [23]. A representational model for the knowledge base (KB) of fuzzy production systems with rule chaining based on the Petri net formalism was developed in [19]. The High-level fuzzy Petri net (HLFPN) model (introduced by the authors in [24], [25]) as opposite to other approaches found in literature, derived from high-level Petri nets such as predicate/transition nets [26] and coloured Petri nets [27]. In Reference [28] a new reasoning algorithm for high-level fuzzy Petri nets was proposed. The Petri nets models and reasoning algorithms of neural nets were researched in [29], [30]. In Reference [31] the solving method of neural nets was given for problems of Petri nets.

This paper proposes a model named Multi-Logical Fuzzy Petri Net which works with several input and output.

2.1. Multi-Logical Petri Nets

8-tuple MLPN = $(P, T, F, M0, D, h, I, O, FO)$ is called a Multi-Logical Petri Net if:

1. $N = (P, T, F)$ is a net.
2. $M0: P \rightarrow \{0, 1\}$ is called an initial marking of LPN.
3. D is a finite set of propositions.

4. $h : P \rightarrow D$ is an association function, representing mapping from places to positions.
5. I is the set of input to the transition.
6. O is the set of output from the transition.
7. FO is a member of O, is final and selected output.
8. $T \varepsilon T1 \cup TAND \cup TOR \cup TXOR$.

2.2. Multi-Logical Fuzzy Petri Nets

12-tuple MLFPN = (P, T, F, MO, D, h, I, O, FO, α, θ, λ) is called Multi-Logical Fuzzy Petri Net if:

1. MLPN = (P, T, F, $M0$, D, h, I, O, FO) is a Multi-Logical Petri Net.
2. α is an association function, representing a mapping from place to real values between 0 and 1.
3. $\theta, \lambda: T \rightarrow [0, 1]$ are association functions, representing a mapping from transition to real value between 0 and 1.
4. t ε TAND, M is a marking of Σ, and t is said to be M-enabled if $\forall p\varepsilon{*}\cap P{:}M(p) = 1 \curlywedge p\varepsilon t{*} \cap P{:}\ M(p) = 0$; and t can be fired from M if t is M-enabled.
5. t ε TOR, M is a marking of Σ, and t is said to be M-enabled if $\exists p\varepsilon{*}t\cap P{:}M(p) = 1 \curlywedge p\varepsilon t{*}\cap P{:}M(p) = 0$; t can be fired from M if it is M-enabled.

2. MODELLING MULTI-LOGICAL FUZZY PETRI NET AND' COMPARISON WITH PETRI NETS SEMANTIC AND FUZZY LOGICAL PETRI NETS

Here we will show the modelling technique of Multi-Logical Fuzzy Petri Net and present a comparison with PN semantic and FLPN. We have showed this for several cases.

Case 1: When the linguistic description is of the form: IF $X1$ is $A1$ AND .... AND Xn is An THEN Y is B Modelling this linguistic description by PN semantic is given in Figure 1:

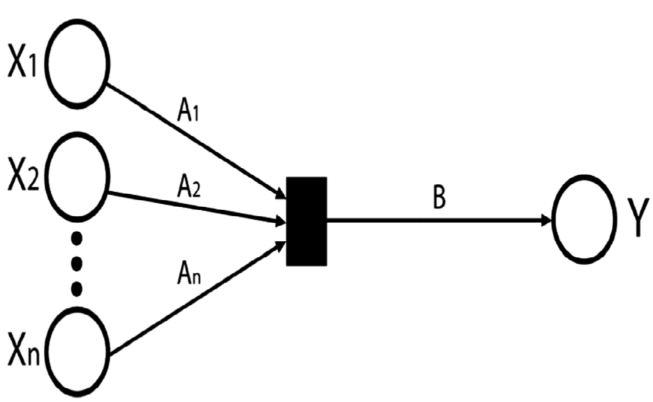

Figure 1: Example of PN.

Modelling the above linguistic description by FLPN is given in Figure 2:

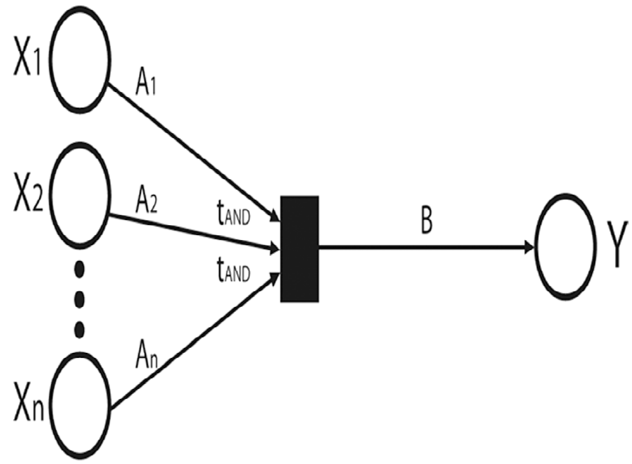

Figure 2: Graphical Representation of Linguistic Description of Case 1 by FLPN.

In the case of above linguistic description there is no difference between FLPN and MLFPN.

Case 2: When the linguistic description is of the form:

IF $X1$ is $A1$ OR .... OR Xn is An THEN Y is B Modelling this linguistic description by PN semantic is given in Figure 3:

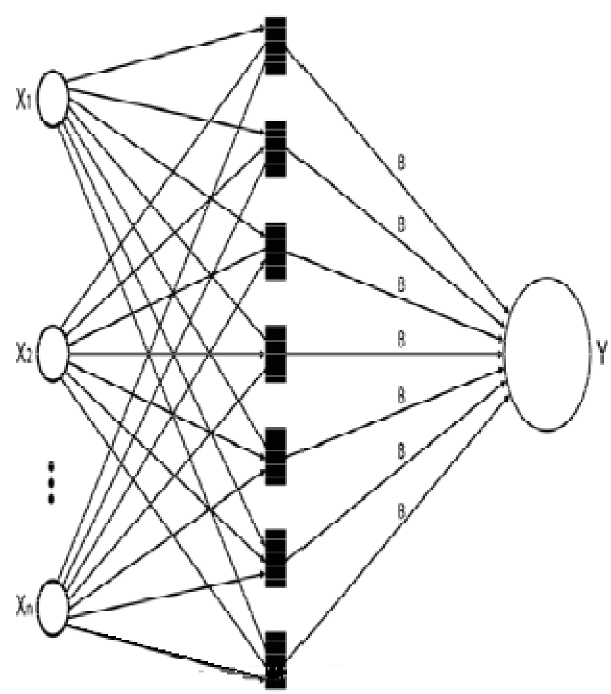

Figure 3: Graphical Representation of Linguistic Description of Case 2 by PN.

Modelling this linguistic description by FLPN is given in Figure 4.

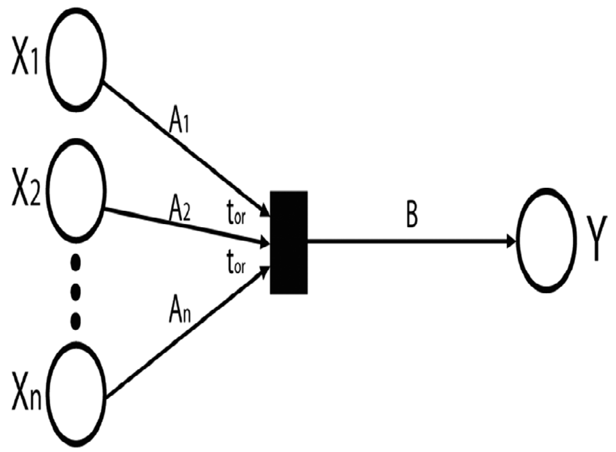

Figure 4: Graphical Representation of Linguistic Description of Case 2 by FLPN.

Also in the case of above linguistic description there is no difference between FLPN and MLFPN.

Case 3: When we have to make a choice between alternatives and the linguistic description is of the form:

*R*1: IF *X*1 is *A*11 AND .... AND *Xn* is *A*1*n* THEN *Y* is *B*1.

....

Rm: IF *X*1 is *Am*1 AND................AND *Xn* is *Amn* THEN *Y* is *Bm*.

Modelling this linguistic description by PNs is not possible as we mentioned earlier that it is mathematically proved that PN does not have the ability to describe the selection policy.

It is also impossible to model this linguistic description by FLPN as in Reference [1] authors did not specify any policy to do so. But modelling this linguistic description by our proposed MLFPN is possible and easy one. The modelling by MLFPN is given in Figure 5:

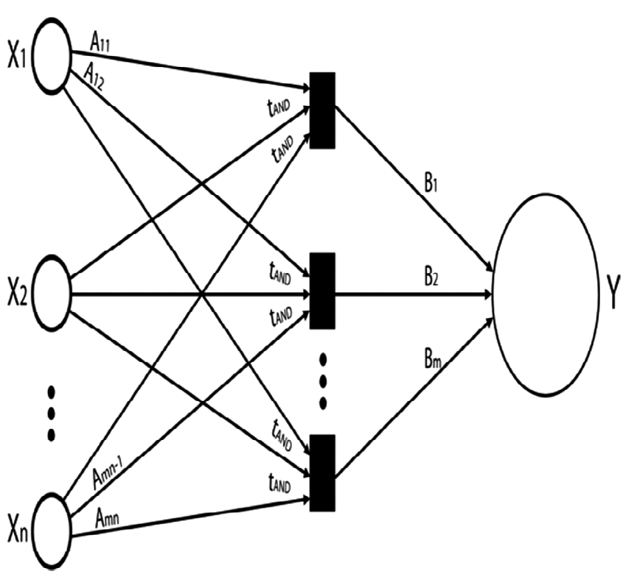

Figure 5: Graphical Representation of Linguistic Description of Case 3 by MLFPN.

Case 4: When the linguistic description is of the form:

*R*1: IF *X*1 is *A*11 OR .... OR *Xn* is *A*1*n* THEN *Y* is *B*1.

....

Rm: IF *X*1 is *Am*1 OR .... OR *Xn* is *Amn* THEN *Y* is *Bm*.

Modelling this linguistic description by PNs is not possible as we mentioned earlier that it is mathematically proven that PN does not have the ability to describe the selection policy. It is also impossible to model this linguistic description by FLPN as in Reference [1] authors did not specify any policy to do so. But modelling this linguistic description by our proposed MLFPN is possible and easy one. The modelling by MLFPN is given in Figure 6.

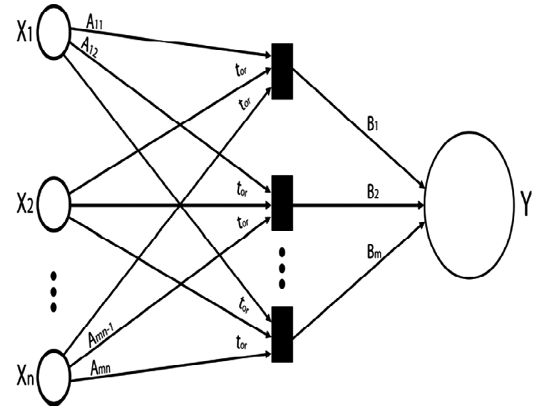

Figure 6: Graphical Representation of Linguistic Description of Case 4 by MLFPN.

Case 5: We may have to model linguistic description like this:

IF (*X*1 is *A*1 OR *X*2 is *A*2) AND *X*3 is *A*3 THEN *Y* is *B*.

PN does not specify any rule to model such situations. So, it is impossible to model such linguistic description by PN.

It is also impossible to model this linguistic description by FLPN as in Reference [1] authors did not specify any policy to do so. But modelling this linguistic description by our proposed MLFPN is possible and easy one. The modelling by MLFPN is given in Figure 7.

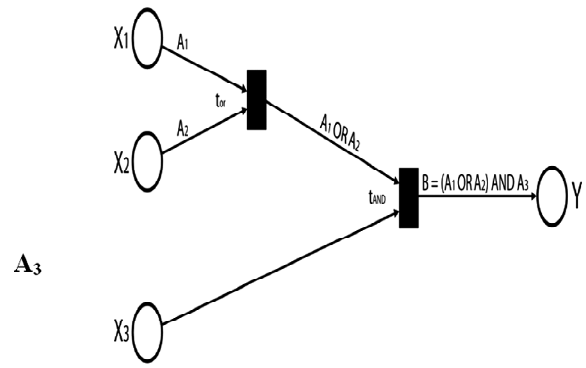

Figure 7: Graphical Representation of Linguistic Description of Case 5 by MLFPN.

Case 6: When the linguistic description is of the form:

*R*1: IF(*X*1 is *A*11 OR .... OR *Xn* – l is *A*1 *n* – l) AND (*Xn* – l + 1 is *A*1 *n* – l + 1 AND................AND *Xn* is *A*1*n*) THEN *Y* is *B*1.

....

Rm: IF(*X*1 is *Am*1 AND .... AND *Xn* – l is *Am n* – l) OR (*Xn* – l + 1 is *Am n* – l + 1 AND ....AND *Xn* is *Amn*) THEN *Y* is *Bm.*

Modelling this linguistic description is not possible by both PN and FLPN, as mentioned earlier they did not specify any rule for modelling this type of linguistic description.

Modelling this linguistic description by the proposed MLFPN is shown in Figure 8.

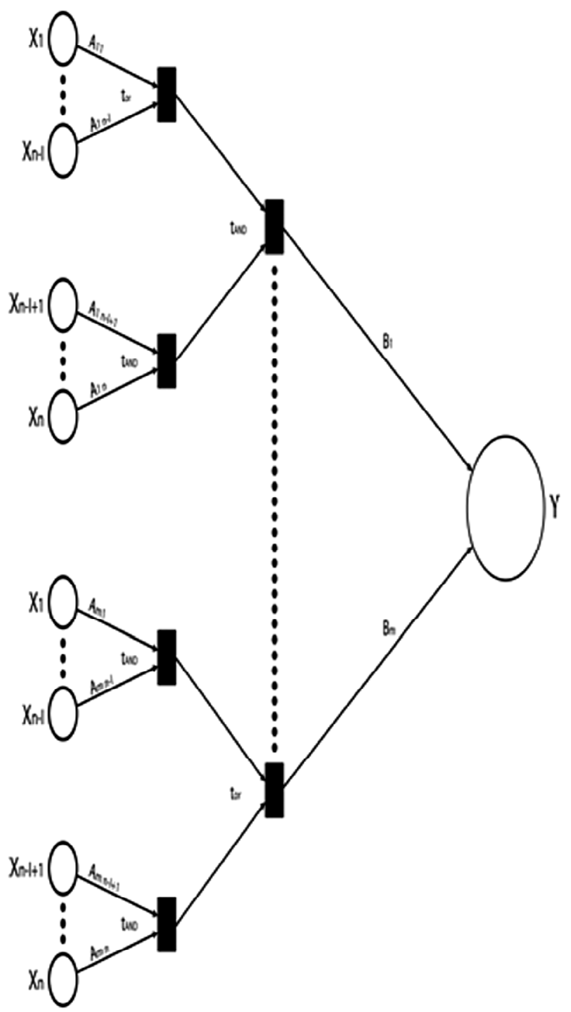

Figure 8: Graphical Representation of Linguistic Description of Case 6 by MLFPN.

3. ALGORITHM FOR DECOMPOSING OF MULTI-LOGIC FUZZY PETRI NET

Now the exact algorithm for decomposing Multi-Logical Fuzzy Petri Net into set of linguistic descriptions which form Linguistic Multi-Logic Fuzzy Petri Net (LMLFPN) will be shown. The following algorithm gets Multi-Logical Fuzzy Petri Net as an input and creates set of linguistic descriptions corresponding to each output place of Multi-Logical Fuzzy Petri Net:

Input: Multi-Logic Fuzzy Petri Net: mlfpn

Output: set of linguistic descriptions: lmlfpn

lmlfpn = ∅;

for each output place op of mlfpn do

/*create linguistic description create set of input variables (places) on whose op depends*/

inputs = ∅;

for each input transition it of op do

//add all inputs of transition it to inputs set

inputs = inputs U it.inputs;

end

// construct linguistic description (set of rules)

rb = ∅;

for each input transition it of op **do**

// construct rule corresponding to transition it

rule = (; **for each** element in from inputs **do**

if rule = tOR then rule = rule + OR;

else if rule = tAND then rule = rule + AND;.

if in ε it.inputs then

rule = rule + in.name is edge (in.it). value;

end

rule = rule+);

end

if rule = rule + THEN op.name is edge(it,op).value;

rb = rb U rule;//add rule to rule base

end

lmlfpn= lmlfpn U rb; // add rule base to set of linguistic descriptions

end

4. CONCLUSION

This paper proposes a new method and also an implementation algorithm to model Multi-Logical Fuzzy Petri Net. We have showed several implementations of our proposed method. While implementing, it has been seen that for some cases our new method is similar to the Fuzzy Logical Petri Net such as in case of 1 & 2. But the proposed method models such linguistic description which can't be modelled by classic Petri Nets or Fuzzy Logical Petri Nets such as case No 3, 4, 5 & 6. Thus our developed method achieves better modelling power over the existing methods. Especially case No 5 and 6 is the new concept of Fuzzy Petri Net Modelling.

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