Presenting a New Method for Converting Fuzzy Colored Petri Net (FCPN) to the Fuzzy Extended Markup Language (FXML)

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Abstract

One way for study about properties of a system, is its modeling. Petri nets, by modeling of system behaviours and by applying mathematic principles are considered as ways for system modeling. Since, knowledge presentation in real world, in addition of uncertain and fuzzy values, has high complexity, fuzzy color petri nets (FCPN) are considered as a developed version of petri nets. In the other hand, petri net marking language (PNML) is a version according to expanded marking language (XML) for better description of Petri nets. Important application of PNML according to classic logic and for description of petri nets related to systems with discrete events, and does not support FCPN. Thus, for supporting of such version in this research, a marking language, by the name of Fuzzy color petri net marking language (FCPNML) is presented. So, the language structure which is offered in this research, has consider uncertain and ambiguous data in modeling of complicated real world systems and satisfy a today user’s needs for description of FCPN by a standard language.

Keywords: Fuzzy color petri nets, Petri net marking language, Expanded marking language, Fuzzy color petri net marking language.

I. Introduction

Petri net ideas were suggested in 1962 by Carl Adam Petri in his P.h.D thesis (Petri, 1962). A Petri net is a math description which at the same time is a graphical display and it can be used for providing important information about a model system structure. Petri nets are usually applied for modeling of systems which are accurately described and are improper for those which are facing with ambiguous and uncertain data. Considering that, ambiguous data can be presented by fuzzy logic, merging the fuzzy logic theory with petri net is seemed to be useful for increasing petri net modeling power. So, during the time, vast investigating has been performed in this field and different methods for combination of petri net and fuzzy set concepts, which all of them create fuzzy petri nets (FPN) (Cheng et al, 1997) (Pedrycz et al 1994) (Tsui, 2000). After the time, and since possibilities of usual petri net, were not always sufficient for presenting and analysis of complex system behaviours, fuzzy color petri net (FCPN) as developed version of petri net was considered (Yeunget al, 1996). In the other hand, XML, as most complete and valid data format have capabilities for supporting formal models such as petri net. So that, according to this, new version of XML can be suggested for description of Petri nets, such language has name of PNML. Important application of PNML is according to classic fuzzy and for description of petri nets related to discrete events and it does not support FCPNs. FCPNs uncertain data which uncertainity exist in different scenarios in dynamic complicated system. Therefore need for a forma language for explanation of
uncertain data in this model is essential. For supplying of this version a marking language by the name of fuzzy color petri net marking language (FCPNML) is presented which in addition of fuzzy concepts covering in FCPNs, explain its structure in fuzzy marking language.

The rest of article is organized as follow: in section II, the works done along description of petri nets according to XML, application of FCPNs, and XML concepts, is studied. In section III, suggested language structure related in description of FCPNs description is presented. In section IV accuracy of suggested language by explanation of a valid example is presented and in section V, a comparison between suggested language structure and previous work is discussed. Finally, in Section VI we provide conclusions and recommendations.

II. Related Works

One of required specification for petri net tools, are some functions for petri net changes among these tools. Due to vast types of petri nets and various tools and file profiles, in international congress, standardizing of converting profiles according to XML was performed (Jungel et al, 2000). Converting petri net to XML (PNML) was one of these suggestions. Up to now, much work has been performed on different parts and PNML semantic, in association of implied principles and basic design which their aim is PNML mechanism presenting, and fuzzy concepts are not included (Billingto et al, 2003) (Kindler, 2006) (Weber et al, 2003). During the years, PNML has been developed. Therefore, it is needed to unify PNML different faces and its related standard applying should be deployed. In ago, PNML concepts is focused in a way which Standard15909-2 defines (Hillah et al, 2009). Standard15909-2 specifies different petri net types. In this basic standard, a PNML document according to PNML core model is defined. PNML core model is a UML pack which defines fundamental structure of petri net types and it is deployed by UML packs related to various network types. PNML language elements are obtained by mapping each intrinsic class in PNML core model to a XML element. These XML elements are PNML keyword and they are used for description of petri net hardware which is equal for various types. In work done by Riahiet al (Riahi et al, 2011), an integrated method based on formal modeling of human computer interaction in a mobile form is presented which make it possible to analysis an environment everywhere by ontology. In this method, specified environment according to a combination of petri net and XML as a usual PNML is modeled which is not in fuzzy form. Westergaard agohas presented a definition of high level petri nets by application of XML tags for presenting a common exchange form with various tools which is not in fuzzy form (Westergaard, 2011). Besides, here few number of common structure combination transfers for modeling of usual PNML concept is explained which is not in fuzzy form. Verf and Pust in ago, have defined extended petri net marking language (EPNML) as a format according to XML for defined petri net which has applications in web such as web petri or Yasperpetri net editors (Werf et al, 2004). EPNML is an application of PNML which at first, was developed by the name of EPNML in 2003 octobre, and during the time, features of this version according to errors and shortcomings in it, was reviewed several times. Currently, update version by the name of EPNML 1.2 exist which does not cover fuzzy concepts. Hali et al in ago suggested extensible petri net markup language (XPNML) (Lee et al, 2007). XPNML is made on base of PNML concepts which by changing its lable, it has overcome on limits related to PNML structure for creation of model for simulation and analysis of petri net and it supports module

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1 Unified modeling language
concepts for creation of specified model. However, XPNML like PNML, does not cover fuzzy concepts. In the other hand, many works on subjects related to petri net and fuzzy merging theory have been studied (Liu, 1998) (Barzegar et al, 2011). In ago a model in a combined agreeable based on color petri net, fuzzy logic and learning automatic for more effective controlling of guiding lights has been presented by Barzegar et al; But there has no description of these cases by XML (Barzegar et al, 2011). Zung Ma, also in ago presents XML model for fuzzy data base (Ma, 2005).

III. Methods

Language structure which is offered in this research has name of FCPNML which is a new combination according to fuzzy extended markup language (FXML) for explanation of FCPN. This language structure in addition of PNML keyboard has some tags which are presented in followings.

A. Keyboard of PNML

A FCPNML has name of “net” and it includes one or few petri nets. For definition of a petri net, <net> element by “type” features is used. Type feature specifies network type which is determined by DTD document in XML. Besides, “id” feature is a unique identification which its usage in elements such as <net>, <page>, <place>, <transition>, <arc>, <referenceplace>, <referencetransition> make it possible to refer to related elements. <toolspecific> element contains specified element for sub element in related element. Two feature of version and tool in this element determine its tool and type name, respectively. <graphics> element is an arbitrary element containing geographical information about coordination axis (x, y) which contains one of these elements:

- For objects, it is used for displaying their location and have sub element of <position> with two feature of “x” and “y”.
- For annotations, it is used to show relative location respect to its related object and it contains at least on sub element of <offset> which has two features of “x” and “y”.

A <name> element contains related object name which is not obligatory unique and it is specified by sub element of <text>. On the other hand it is possible that a petri net composed of pages which have used various tools. If so, <page> element contains following subelements:

- <referenceplace>: which shows a reference location and it contains “ref” feature to refer to a location of network.
- <referencetransition>: this element is used to show a reference transition to work and it has “ref” feature to refer to a transition in network.

B. Language tags are defined in FCPNML

In this language <net> element, in association of <page> and <statement> sub elements are used. Arbitrary subelement of <statement> is used to show an explanation. Explanations are some general tags related to petri nets or its pages which can show a type of subelement of <kind> with applied variables in whole of network by <variable> subelement. <variable> subelement in addition of related type, by application of <kind> subelement, contains set of names which determine each name by application of subelement of <name>. <kind> element by application of <text> subelement specifies a data type which can be a decimal number, subset and etc. In addition, to define a new type in
A petri net document, at least, consists of one page, in which sub element of <page> is used to show it. Besides, subelement <statement>, subelements related to element <page> includes: <place>, <transition>, <arc>, <if>, which in the following, each of these elements are explained in association of related subelements.

- A place, which is defined by <place> element which includes these sub elements:
  o Element <kind>: an annotation of location which specifies allowable marking type on a location by applying of sub element of <text>.
  o Element <initialmarking>: an annotation of location which shows initial marking of place and it has subelements of <collection>. Subelement of <collection> shows sets of related types to a parent element by applying of sub element of <value> in format of amount or lists of amounts. Subelement <value> is explained by <text> and if it be a parent element of one place then it has feature of “no”. This feature includes a positive decimal number as an amount and its number shows color repetition. Besides, in fuzzy locations, subelements of <value> is used and it includes amount of membership of each marks in its related location. This amount of membership is explained by <text> element.
  o Element <β>: This element includes fuzzy statement in the fuzzy location which is explained by <text> element.

- Element <transition> make it possible to show a transition and includes following conditions and elements:
  o <condition> element: this element includes series of conditions related to transition which make it possible to fire. The amount of this element is explained by subelement of <text> which includes statement about a transition for creating some condition for it.
  o <Transformation> element: determines marking types by related transition. It is an arbitrary element which is explained by <text> sub element. If it includes related transition for set of changes, and then we will have set of <text> subelements.
  o <cf> element: specifies assurance factor related to fuzzy transition by this element and it is determined by subelement of <text>.
  o <kind> element: is annotation of transition which shows allowable type of mark by application of <text>.

Note: If there is any color used in transition, has an assurance factor and a condition, then instead of elements of <condition> and <cf>, elements of <collectioncondition> and <collectioncf> are used respectively. <collectioncf> element is set of related types to a parent element which in association of assurance factor and by applying of sub element <cf> and <name> is specified and <collectioncondition> determines additional condition related to each types by applying of subelements such as <name> and <condition>. It is needed to say, in each of two element <name> related color name is included.

- <arc> element: defines an arc which has subelement of <inscription>. <inscription> by applying of subelement of <collection> is an annotation related to an arc. In this state, subelement of <value> includes “cardinality” feature which includes any positive number as an amount and it shows color number. Besides, this element of <arc> has two feature of “source” and “target” which specifies source and the target respectively.

- Element <if>: it is prior part of a fuzzy rule existing in network by applying of following features:
  o “β” feature for definition of statement related to prior part of fuzzy rule is used.
“transitioned” feature by considering identification amount related to transition fuzzy rule is used to refer to transition.

“conditiontransitionid” feature by true constant amount, studies additional condition accuracy of related transition, which if there are few conditions for colors, then this feature is used few times.

“fulinitialmarking” feature by a constant amount of one, consider required marking by performing fuzzy rule in input locations.

Besides, element of <if> has sub element of <then> which is follower part of a fuzzy rule existing in network by application of “β” feature and it has following sub elements:

- <newinitialmarking>: in association of “placeid”, shows new related location marking, after firing by subsets of <collection>. In this state element <collection> includes “placeid” feature and subelement of <newvalueno>. Feature of “placeid” is for referring to related location and subset of <newvalueno> in association of colored feature, explains number of new color repeating related to location after executing of fuzzy rule and transition firing by application of <text> subelement. Default “colorid” feature amount is name of existing colors in network which will refer to related color, if used.

- Element of <newα>: this element shows amount of new membership amount of color marking in related location and after firing, it is shown by subelement of <text>. <newα> has three feature of “placeid”, “colorid” and “no”. which show reference to related location, related color and number of color repeating respectively.

**IV. Implement and evaluate the proposed method**

In this research, a facilitating banking system for executing and assessment of this method is studied. Process of this system is controlled by a set of seven rule of fuzzy which are as follows:

- If \( p_1 \) Then \( p_2 \)
- If \( p_4 \) and \( p_5 \) Then \( p_6 \)
- If \( p_2 \) Then \( p_3 \)
- If \( p_3 \) and \( p_6 \) Then \( p_7 \)
- If \( p_2 \) and \( p_6 \) Then \( p_9 \)
- If \( p_6 \) Then \( p_{10} \)
- If \( p_7 \) and \( p_{10} \) then \( p_8 \)

Graphical part of this modeling in CPN software and by FCPN network is modeled (figure 4-1), and fuzzy part of it is executed by MATLAB software. For description of this network, a suggested structure in section 3 is used. Therefore, main elements in this network such as places, arcs and transitions, are explained as elements of <place>, <transition> and <arc> and in association of features and related subelements, by application of determined tags are described in suggested language. For example, coding of \( p_1 \) place in figure 4-2 is provided. Also, figures of 4-3 and 4-4 coding of \( a_1 \) arc and \( t_1 \) transition are shown.
Figure 1. Fuzzy color petri net, is corresponding to bank facilitating

![Diagram of Fuzzy Color Petri Net]

**Figure 2.** Coding corresponding to p₁ place

```xml
<place id="p1">  
  <name>  
    <text>  
      a  
    </text>  
  </name>  
  <graphics>  
    <offset x="1" y="1"/>  
  </graphics>  
  <kind>FUZZY</kind>  
  <graphics>  
    <offset x="1" y="2"/>  
  </graphics>  
  <initialmarking>  
    <collection>  
      <value no="1">  
        <text>red</text>  
        <offset x="1" y="3"/>  
        <value>0.5</value>  
      </value>  
      <value no="1">  
        <text>blue</text>  
        <offset x="1" y="4"/>  
        <value>0.3</value>  
      </value>  
    </collection>  
    <position x="1.3505" y="2.5657"/>  
  </initialmarking>  
  <text>red</text>  
  <graphics>  
    <position x="1.3505" y="2.5657"/>  
  </graphics>  
  <offset x="1" y="3"/>  
  <offset x="1" y="4"/>  
  <variable>  
    <text>q</text>  
    <graphics>  
      <offset x="1" y="5"/>  
    </graphics>  
    <offset x="1" y="5"/>  
  </variable>  
  <text>0.3</text>  
  <graphics>  
    <offset x="1" y="5"/>  
  </graphics>  
</place>
```

**Figure 3.** Coding corresponding to a₁ arc

```xml
<arc id="a1" source="p1" target="t1">  
  <graphics>  
    <position x="1.3505" y="2.5657"/>  
    <position x="3.0592" y="2.5330"/>  
  </graphics>  
  <inscription>  
    <collection>  
      <value cardinality="1">  
        <text>C</text>  
        <graphics>  
          <offset x="1" y="1"/>  
        </graphics>  
        <offset x="1" y="1"/>  
      </value>  
      <value cardinality="1">  
        <text>C</text>  
        <graphics>  
          <offset x="1" y="1"/>  
        </graphics>  
        <offset x="1" y="1"/>  
      </value>  
    </collection>  
  </inscription>  
  <arc>  
    <cf>0.2</cf>  
  </arc>  
</arc>
```

**Figure 4.** Coding corresponding to a₁ arc

```xml
<transition id="t1">  
  <name>  
    <text>t1</text>  
  </name>  
  <graphics>  
    <position x="3.0592" y="2.5330"/>  
  </graphics>  
  <kind>FUZZY</kind>  
  <graphics>  
    <position x="3.0592" y="2.5330"/>  
  </graphics>  
  <transformation>  
    <cf>0.2</cf>  
  </transformation>  
</transition>
```
<if β="c and d" transitionid="t3" condition.transitionid="true">
  <fulinitialmarking="1">
    <new placeid="p4" colorid="blue" no="1">
      <text>0</text>
    </new>
    <new placeid="p5" colorid="blue" no="1">
      <text>0</text>
    </new>
    <new placeid="p6" colorid="blue" no="1">
      <text>min(\alpha.p4.blue.no, \alpha.p5.blue.no)*CF(\mu).t3</text>
    </new>
    <newinitialmarkingplaceid="p4">
      <collection placeid="p4">
        <newvaluenocolorid="blue">
          <text>Valueno.blue – 1</text>
        </newvalueno>
      </collection>
    </newinitialmarking>
    <newinitialmarkingplaceid="p5">
      <collection placeid="p5">
        <newvaluenocolorid="blue">
          <text>Valueno.blue – 1</text>
        </newvalueno>
      </collection>
    </newinitialmarking>
    <newinitialmarkingplaceid="p6">
      <collection placeid="p6">
        <newvaluenocolorid="blue">
          <text>Valueno.blue + 1</text>
        </newvalueno>
      </collection>
    </newinitialmarking>
  </new>
</if>

Figure. 4. Coding corresponding to \(t_1\) transition

Similarly fuzzy rules used in modeling of this network are described by tags of <if> and <then> in association of sub elements and related features. As an example figure 4-5 shows coding of fuzzy rule :If \(p_4\) and \(p_5\) Then \(p_6\).

V. Comparison of the proposed language with the language

Table 1-5 shows a comparison between suggested and existing methods for description of petri net types. As it is shown in this table, PNML, EPNML and EPXNML languages which were studied in past researches like other marking language have capabilities for adding new tags and presenting a data valid format; but clear shortcoming is seen in three languages, i.e. ability of these language is only in description of usual petri nets and according to classic logic, which does not support implementation of the fuzzy logic, assurance factor allocating in transitions, weight allocating to prior suppose. FPNML as another method considers mentioned limits, but it does not consider weight color markings in network locations and generally it does not support FCPN network description. Therefore, according to requirement for overcoming of such shortcomings, it was suggested in this research that, in addition of covering general concepts of colored petri net, fuzzy concepts also be supported in these networks.

### Table I

<table>
<thead>
<tr>
<th>Language</th>
<th>Add new tags</th>
<th>Presenting a data valid format</th>
<th>Implementation of the fuzzy logic</th>
<th>Allocation of certain factors in transitions</th>
<th>the Weight of prior assumptions</th>
<th>Considering a weighted colored tokens</th>
<th>described FCPNs</th>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
VI. Conclusions and future work

XML as most valid data language has possibility to make connection with language types such as inquiry languages and modeling languages. In this research, extended version of petri net (FCPN) according to XML as a FCPNML, is explained and by applying of a case study description, their usage was emphasized.

According to FCPN by FCPNML, extension of this subject to other types of petri net such as SPN, GSPN and OOPN, creation of a tool for mapping of fuzzy color petri net to fuzzy marking language and presenting more application is seemed to be useful.

References


