

PETRI NET REPRESENTATION WITH CIPHERED SUBNETS: DEFINITION OF PNML EXTENSIONS FOR SUBNETS REPRESENTATION AND USE OF XMLENCRIPTION FOR CIPHERING.

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ABSTRACT

With Petri Nets we can model a great amount of systems. However, they are described in a comprehensive way, so we need to have the hole Petri Net to work with it. We are going to take advantage from previous works presented in EMSS 2011 and EMSS 2013 in which we defined subnets of a Petri Net and extract the interface in order to cut Petri Nets in disjoint subnets. We have two aims for this work. By one side, we want to choose a way of representation of Petri Nets that allows to include all this information. In this case we are going to select PNML for this objective, but it hasn't a way to represent subnets, so we will have to extend this language with an extension that allows it. By the other side, we will use XMLEncryption [4] in order to hide subnets only exposing only its interface, hiding the rest of the subnet for every non receiver of the Petri Net.

1. INTRODUCTION

We start from a Petri Net $R = \langle P, T, \alpha, \beta \rangle$ where P is the set of places (Samaniego et al., 2011, 2013), T is the set of transitions, α is the pre-incidence function and β is the post-incidence function. We define $R' = *P'$, T' , α' , β'^* such that $P' \in P$ and $T' \in T$, α' and β' are restrictions of α y β over $P' \times T'$ (P' and T' are not empty).

$$C' = \begin{matrix} & \begin{matrix} t_1 & \cdots & t_s & t_{s+1} & \cdots & t_r \end{matrix} \\ \begin{matrix} p_1 \\ \vdots \\ p_m \\ p_{m+1} \\ \vdots \\ p_n \end{matrix} & \left(\begin{array}{c|ccc} \begin{matrix} a_{11} & \cdots & a_{1s} \\ \vdots & R' & \vdots \\ a_{m1} & \cdots & a_{ms} \end{matrix} & \begin{matrix} a_{1(s+1)} & \cdots & a_{1r} \\ \vdots & HN & \vdots \\ a_{m(s+1)} & \cdots & a_{mr} \end{matrix} \\ \hline \begin{matrix} a_{(m+1)1} & \cdots & a_{(m+1)s} \\ \vdots & HT & \vdots \\ a_{n1} & \cdots & a_{ns} \end{matrix} & \begin{matrix} a_{(m+1)(s+1)} & \cdots & a_{(m+1)r} \\ \vdots & \ddots & \vdots \\ a_{n(s+1)} & \cdots & a_{nr} \end{matrix} \end{array} \right) \end{matrix}$$

Is shown (Latorre et al., 2011b; Latorre and Jimenez, 2013a, 2013b) that we can reorder the rows and columns of the incidence matrix without loss of generality in order to put in the first rows and columns the places and transitions belonging to R' .

So we have separated the original Petri Net in to disjoint subnets R' and the rest. This process can be

repeated every time you want in order to separate the original Petri Net in several disjoint subnets (Jiménez, 2010; Jiménez et al., 2005; Jiménez et al., 2014). Once this is done, we can analyze the inputs and outputs of R' in order to extract the interface. For example, starting from this Petri Net, we want to extract R_1 and its interface (Biel et al. 2011; Latorre et al., 2013b, 2013d):

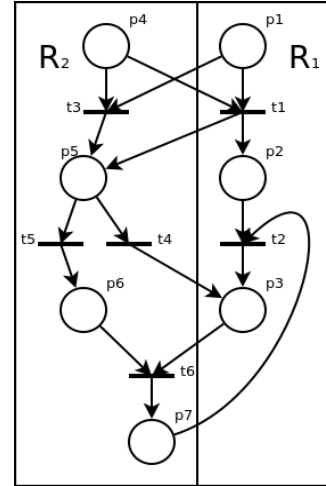


Figure 1: Petri Net divided into two subnets

This is the R_1 's interface extracted from the original Petri net [3]

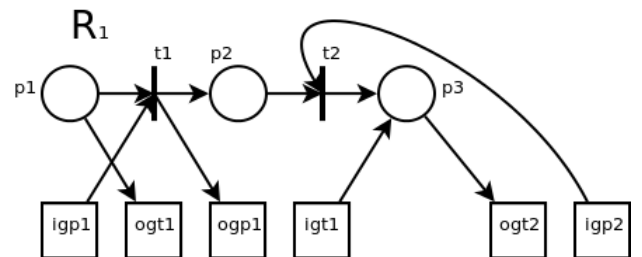
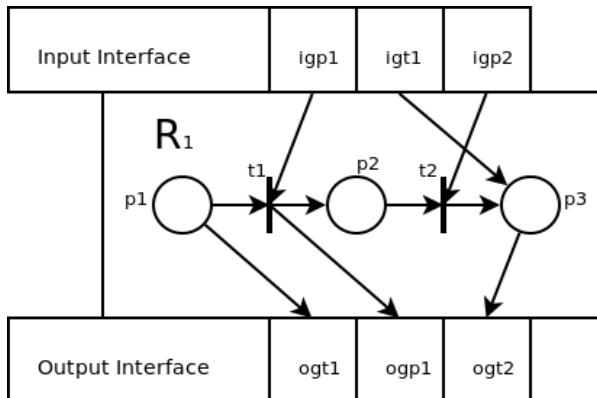


Figure 2: R_1 with its interface

At this moment we have this Petri Subnet inputs and outputs. In the same way we can extract R_2 's

interface, but the process is the same. In order to have a more clear vision, we separate the input interface and the output interface in this way.

Figure 3: R_1 with its input and output interface.



Once we have this interface extracted, the next step is to implement this information in a Petri Net representation in such way that we could hide the subnet, exposing only the interface. For this objective, we are going to use PNML.

2. PNML

Petri Net Marked Language (PNML) is an XML language created for represent Petri Nets (David and Alla, 2005; Jensen and Kristensen, 2009; Latorre et al., 2014). With this language we can take a Petri Net and store it into an XML file without loss of information.

But PNML hasn't got a way to represent subnets. So we are going to extend PNML language in order to get several goals:

1. Represent subnets of a Petri Net [3].
2. Include input and output interfaces for every subnet.

If we take the PNML grammar, there are lots of tags, but we are going to take some of them, without loss of generality. The official grammar is described and can be downloaded from the official page of PNML (www.pnml.org).

Inside a PNML document there are three main elements. This elements have required tags:

- place: define a place in the petri net with an id and a name. This corresponds with a column in the incidence matrix

```
<place id="p1">
  <name>
    <text>Place one</text>
  </name>
</place>
```

- transition: define a transition in the petri net, with an id and a name too. This corresponds with a row in the incidence matrix.

```
<transition id="t2">
  <name>
    <text>Transition 2</text>
  </name>
</transition>
```

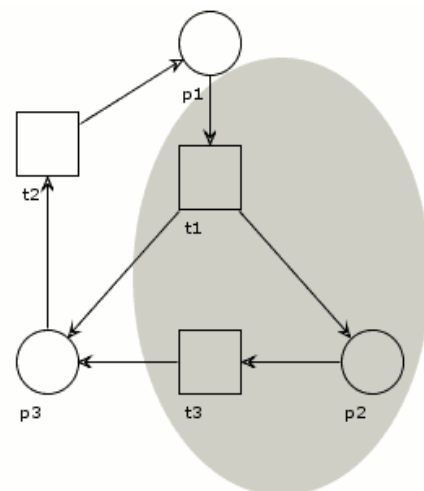
- arc: define an arc with an id, form a place to a transition or from a transition to a place, defined by their own. It corresponds with a non zero element in the incidence matrix. Here we have the arc source and target.

```
<arc id="a2" source="t1" target="p2">
  <inscription>
    <text>1</text>
  </inscription>
</arc>
```

There are other tags associated to each one of this elements, but, for simplicity, we obviate them because the process is exactly the same, but with more information.

In order not to occupy too much space in the article, let's take a simple Petri Net like this in which the subnet to be hidden is the gray ellipse.

Figure 4: Petri Net example



The PNML file representing this net is the one shown in Table1.

We want to specify that the elements inside the grey ellipse form a subnet, so we define a new tag for this objective `<subnet>`. The arcs joining elements inside the subnet are included inside the subnet. The arcs outside the subnet and the arcs entering or exiting the subnet stay outside the tag `<subnet>`. And we have this other PNML extended file (Table2):

Table 1: PNML file representing PN in Figure 4

| | |
|--|--|
| <?xml version="1.0" encoding="UTF-8"?> | <text>1</text> |
| <pnml> | </inscription> |
| <net id="myNet"> | </arc> |
| <place id="p3"> | <arc id="a11" source="p2" target="t3"> |
| <name> | <inscription> |
| <text>p3</text> | <text>1</text> |
| </name> | </inscription> |
| </place> | </arc> |
| <place id="p2"> | <arc id="a1" source="p1" target="t1"> |
| <name> | <inscription> |
| <text>p2</text> | <text>1</text> |
| </name> | </inscription> |
| </place> | </arc> |
| <place id="p1"> | <arc id="a2" source="t1" target="p2"> |
| <name> | <inscription> |
| <text>p1</text> | <text>1</text> |
| </name> | </inscription> |
| </place> | </arc> |
| <transition id="t3"> | <arc id="a3" source="t1" target="p3"> |
| <name> | <inscription> |
| <text>t3</text> | <text>1</text> |
| </name> | </inscription> |
| </transition> | </arc> |
| <transition id="t2"> | <arc id="a4" source="p3" target="t2"> |
| <name> | <inscription> |
| <text>t2</text> | <text>1</text> |
| </name> | </inscription> |
| </transition> | </arc> |
| <transition id="t1"> | <arc id="a7" source="t2" target="p1"> |
| <name> | <inscription> |
| <text>t1</text> | <text>1</text> |
| </name> | </inscription> |
| </transition> | </arc> |
| <arc id="a9" source="t3" target="p3"> | </net> |
| <inscription> | </pnml> |

Table 2: PNML extended file

| | |
|--|---------------------------------------|
| <?xml version="1.0" encoding="UTF-8"?> | <name> |
| <pnml> | <text>p3</text> |
| <net id="myNet"> | </name> |
| <subnet id="sn1"> | </place> |
| <place id="p2"> | <transition id="t2"> |
| <name> | <name> |
| <text>p2</text> | <text>t2</text> |
| </name> | </name> |
| </place> | </transition> |
| <transition id="t1"> | <arc id="a1" source="p1" target="t1"> |
| <name> | <inscription> |
| <text>t1</text> | <text>1</text> |
| </name> | </inscription> |
| </transition> | </arc> |
| <transition id="t3"> | <arc id="a3" source="t1" target="p3"> |
| <name> | <inscription> |
| <text>t3</text> | <text>1</text> |
| </name> | </inscription> |
| </transition> | </arc> |
| <arc id="a6" source="p2" target="t3"> | <arc id="a4" source="p3" target="t2"> |
| <inscription> | <inscription> |
| <text>1</text> | <text>1</text> |
| </inscription> | </inscription> |
| </arc> | </arc> |
| <arc id="a5" source="t1" target="p2"> | <arc id="a7" source="t2" target="p1"> |
| <inscription> | <inscription> |
| <text>1</text> | <text>1</text> |
| </inscription> | </inscription> |
| </arc> | </arc> |
| </subnet> | <arc id="a8" source="t3" target="p3"> |
| <place id="p1"> | <inscription> |
| <name> | <text>1</text> |
| <text>p1</text> | </inscription> |
| </name> | </arc> |
| </place> | </net> |
| <place id="p3"> | </pnml> |

The elements inside the tag `subnet` are the elements of my subnet. For more clarity we will put, when possible, with dots the content of the subnet and the rest of the net.

Now we have to determinate how to represent the input and output interfaces. We define for this purpose five new tags called `interface`, `outside the subnet`, and `igp`, `igt`, `ogp` and `ogt` for input gates and output gates inside the subnet. In this case we have:

- One input gate from a place (`igp1`) from `p1` to `t1`
- Two output gates to a place from `t1` to `p3` (`ogp1`) and from `t3` to `p3` (`ogp2`)

In the same way we would define Input gates from transitions and Output gates to transitions (Latorre et al., 2011a, 2011c, 2014). It is clear that the only things that should be exposed outside the subnet are the gates, not the source of the output gates neither the target of the input gates. So we define in the PNML content the public interface elements inside the subnet. The rest of the subnet is encapsulated in a `<content>` tag. So we have the code in Table 3.

Table 3: PNML extended file

| | |
|---|---|
| <pre> <?xml version="1.0" encoding="UTF-8"?> <pnml> <net id="myNet"> <subnet id="sn1"> <interface> <igp id="igp1"/> <ogp id="ogp1"/> <ogp id="ogp2"/> </interface> <content> <place id="p2"> <name> <text>p2</text> </name> </place> <transition id="t1"> <name> <text>t1</text> </name> </transition> <transition id="t3"> <name> <text>t3</text> </name> </transition> <arc id="a6" source="p2" target="t3"> <inscription> <text>1</text> </inscription> </arc> <arc id="a5" source="t1" target="p2"> <inscription> <text>1</text> </inscription> </arc> </content> </subnet> <place id="p1"> <name> <text>p1</text> </pre> | <pre> </name> </place> <place id="p3"> <name> <text>p3</text> </name> </place> <transition id="t2"> <name> <text>t2</text> </name> </transition> <arc id="a1" source="p1" target="t1"> <inscription> <text>1</text> </inscription> </arc> <arc id="a3" source="t1" target="p3"> <inscription> <text>1</text> </inscription> </arc> <arc id="a4" source="p3" target="t2"> <inscription> <text>1</text> </inscription> </arc> <arc id="a7" source="t2" target="p1"> <inscription> <text>1</text> </inscription> </arc> <arc id="a8" source="t3" target="p3"> <inscription> <text>1</text> </inscription> </arc> </net> </pnml> </pre> |
|---|---|

The last step is to cut the arcs that enter or exit the subnet in the same way explained in the creation of the interface [3]. So we are going to have:

3. In case of an arc that enters into the subnet, we change the arc from the original source to the input gate associated to it (defined in the interface) and a new arc appears inside the subnet from the gate above to the original target.
4. In case of an arc that exits the subnet, we change this arc's original target to the output gate associated to it (defined in the interface) and a new arc appears inside the subnet from the original source to the gate above.

To represent the gates' ids, we take the subnet id and concatenate the gate's id, separated by '/'

So this is the final aspect of the PNML content that represents the example Petri net containing the described subnet in Table 4.

Table 4: PNML extended file

| | |
|---|--|
| <pre> <?xml version="1.0" encoding="UTF-8"?> <pnml> <net id="myNet"> <subnet id="sn1"> <interface> <igp id="igp1"/> <ogp id="ogp1"/> <ogp id="ogp2"/> </interface> <content> <place id="p2"> <name> <text>p2</text> </name> </place> <transition id="t1"> <name> <text>t1</text> </name> </transition> <transition id="t3"> <name> <text>t3</text> </name> </transition> <arc id="a6" source="p2" target="t3"> <inscription> <text>1</text> </inscription> </arc> <arc id="a5" source="t1" target="p2"> <inscription> <text>1</text> </inscription> </arc> <arc id="a9" source="sn1/igp1" target="t1"> <inscription> <text>1</text> </inscription> </arc> <arc id="a10" source="t1" target="sn1/ogp1"> <inscription> <text>1</text> </inscription> </arc> <arc id="a10" source="t3" target="sn1/ogp2"> <inscription> </pre> | <pre> <text>1</text> </inscription> </arc> </content> </subnet> <place id="p1"> <name> <text>p1</text> </name> </place> <place id="p3"> <name> <text>p3</text> </name> </place> <transition id="t2"> <name> <text>t2</text> </name> </transition> <arc id="a1" source="p1" target="sn1/igp1"> <inscription> <text>1</text> </inscription> </arc> <arc id="a3" source="sn1/ogp1" target="p3"> <inscription> <text>1</text> </inscription> </arc> <arc id="a4" source="p3" target="t2"> <inscription> <text>1</text> </inscription> </arc> <arc id="a7" source="t2" target="p1"> <inscription> <text>1</text> </inscription> </arc> <arc id="a8" source="sn1/ogp2" target="p3"> <inscription> <text>1</text> </inscription> </arc> </net> </pnml> </pre> |
|---|--|

We have to notice that the subnet elements are only included inside the content of the subnet, so, outside the subnet, there is no mention to them: there are only mentions to the subnet interface. Now we can cipher the content and nothing is going to give clues about what there is inside the subnet.

This is the PNML extended format that we propose for separate a subnet from the original net. But this is only a process over an example Petri net. In further works, we will modify the PNML grammar rules (www.pnml.org) for a more formal study. PNML grammar consists in several rng files. These files are RELAX NG files. RELAX NG is a schema language for XML. Its specifications have been developed within OASIS by the RELAX NG Technical Committee.

3. XMLENCRYPTION

The next step in this study is to hide the private part of the subnet. For this goal, we are going to use standard technologies like XMLEncryption [4].

XMLEncryption (<http://www.w3.org/TR/xmlenc-core>) is a XML files standard cipher. We can use symmetric or asymmetric encryption, but in this case it's preferable to use symmetric ciphering because it is computationally less expensive.

The idea of this encryption is to replace the XML elements that we want to be encrypted by another piece of XML that contains the encrypted data and information about the algorithms used for encryption.

When a non XML file is encrypted, we only have not the option of encrypting it completely. When the encryption is applied to an XML file, this technology enables to define specific parts of the document to be encrypted or even transform the document before applying encryption.

Regardless of data source, the result is always an XML element. Typically, this document has all the information needed to be deciphered. Among this information can be found:

- Encryption Algorithm: The name of the method chosen to encrypt the information. It may not be included. Still need to be known by cipher and decipher.
- Ciphered information: It has been to be present always.
- Name of the password used: It is optional. Used when a set of keys known by both the part ciphering as the deciphering.
- Encrypted password: It is optional. The party that encrypts the document must have a public key and a private key. With this key you can encrypt the password used to encrypt the content. The party decrypts the document must have the other key.

Once we've got the PNML file in this extended format, we can apply XMLEncryption to the subnet <content> tag. The final file is shown in Table 5.

Table 5: PNML extended file

```
<?xml version="1.0" encoding="UTF-8"?>
<pnml>
  <net id="myNet">
    <subnet id="sn1">
      <interface>
        <igp id="igp1"/>
        <ogp id="ogp1"/>
        <ogp id="ogp2"/>
      </interface>
      <content>
        <xenc:EncryptedData
          xmlns:xenc="http://www.w3.org/2001/04/xmenc#"
          Type="http://www.w3.org/2001/04/xmenc#Element">
          <xenc:EncryptionMethod
            Algorithm="http://www.w3.org/2001/04/xmenc#aes128-cbc"
            xmlns:xenc="http://www.w3.org/2001/04/xmenc#" />
          <xenc:CipherData
            xmlns:xenc="http://www.w3.org/2001/04/xmenc#">
            <xenc:CipherValue
              xmlns:xenc="http://www.w3.org/2001/04/xmenc#">
                WrlnjyJlYYOM9lAYqcgCWkw2L4pUjQD2GGVoU
                9lVZ0wKqHY8y3l3GY8FY4i5K3G8grIe1HRFqe
                7RtkFiXZgGMeYnQp6oB6ckKp3KFKHVqtucc9
                rAVzOgC7XAw/oe6lHRFqe6RRVzXjNM GY8FY4i5K
                dId8NVPQmUSDx7NRtnRXZgGMeYnQp6oB6ckKp3
                SWrlnjyJlYYOM9lAYqcgCWkw2L4pU6ckKp3KFK
                9hlVZ0wKqHY8y3l3GY8FY4i5K3G8grIe2xN4u7x
                7fRtkFiXZgGMeYnQp6oB6ckKp3KFRRVzXjN
                AtVzOgC7XAw/oe6lHRFqe6RRVzXjNMLU5ZgGMeYn
                Iy8NVPQmUSDx7NRtnR6YnQp6oB6GY8F
                dWrlnjyJlYYOM9lAYqcgCWkw2L4pUjQ3l3GY8FY
                v9lVZ0wKqHY8y3l3GY8FY4i5K3G8grIe2xN4u7x
                b7RtkFiXZgGMeYnQp6oB6ckKp3KFKG8grIe2
                nAVzOgC7XAw/oe6lHRFqe6RRVzXjNMLU5T1HRFqe
                LI8NVPQmUSDx7NRtnR68=
              </xenc:CipherValue>
            </xenc:CipherData>
          </xenc:EncryptedData>
        </content>
      </subnet>
      <place id="p1">
        <name>
```

CONCLUSIONS

The conclusion of this work is to show that its possible to hide part of a Petri net in an easy way so that nobody can read the full Petri net unless he has the correct key to access it. This is a very important issue in some industrial applications such as automation systems, design of manufacturing plants (Biel et al. 2006; Jiménez et al., 2006; Macias and Parte, 2004), decision making based on simulation of the models (Bruzzone and Longo, 2010), etc.

Other applications may by the digital signing of a subnet in a similar way. Once signed the information we want, we will detect any non authorized modification.

FURTHER WORKS

The next steps to continue this work are:

- Complete the PNML grammar for a more formal specification of the extended PNML described.
- Extend this process to more complex Petri nets.
- Apply digital signature ensure integrity, authentication and non repudiation of the content

```
<text>p1</text>
</name>
</place>
<place id="p3">
  <name>
    <text>p3</text>
  </name>
</place>
<transition id="t2">
  <name>
    <text>t2</text>
  </name>
</transition>
<arc id="a1" source="p1" target="sn1/igp1">
  <inscription>
    <text>l</text>
  </inscription>
</arc>
<arc id="a3" source="sn1/ogp1" target="p3">
  <inscription>
    <text>l</text>
  </inscription>
</arc>
<arc id="a4" source="p3" target="t2">
  <inscription>
    <text>l</text>
  </inscription>
</arc>
<arc id="a7" source="t2" target="p1">
  <inscription>
    <text>l</text>
  </inscription>
</arc>
<arc id="a8" source="sn1/ogp2" target="p3">
  <inscription>
    <text>l</text>
  </inscription>
</arc>
</net>
</pnml>
```

REFERENCES

- Biel, J. I. L., Macías, E. J., & De La Parte, M. P. (2006). Comparison of optimization techniques applied to a flexible manufacturing system. Paper presented at the International Mediterranean Modelling Multiconference, I3M.
- Biel, J. I. L., Macías, E. J., & Pérez De La Parte, M. (2011). Simulation-based optimization for the design of discrete event systems modeled by parametric Petri nets. Paper presented at the Proceedings - UKSim 5th European Modelling Symposium on Computer Modelling and Simulation, EMS 2011.
- Bruzzzone A.G. and Longo F. 2010. An advanced system for supporting the decision process within large-scale retail stores. *Simulation*, 86: 742–762.
- David R and Alla H. 2005. *Discrete, Continuous and Hybrid Petri Nets*. Berlin: Springer.
- Jensen, K., Kristensen, L.M. 2009. *Colored Petri nets. Modelling and Validation of Concurrent Systems*, Springer.
- Jiménez, E. (2010). Modeling and simulation of periodic systems by ISS continuous PN. Paper presented at the 22th European Modeling and Simulation Symposium, EMSS 2010.
- Jiménez, E., Pérez, M., & Latorre, I. (2005). On deterministic modelling and simulation of manufacturing systems with petri nets. Paper presented at the International Mediterranean Modeling Multiconference, I3M 2005, European Modeling Simulation Symposium, EMSS 2005.
- Jiménez, E., Pérez, M., & Latorre, I. (2006). Industrial applications of petri Nets: System modelling and simulation. Paper presented at the International Mediterranean Modelling Multiconference, I3M.
- Jimenez, E., Martinez, E., Blanco, J., Perez, M., & Graciano, C. (2014). Methodological approach towards sustainability by integration of environmental impact in production system models through life cycle analysis: Application to the Rioja wine sector. *Simulation-Transactions of the Society for Modeling and Simulation International*, 90, 143-161.
- Latorre-Biel, J. I., & Jiménez-Macías, E. (2011a). The exclusive entities in the formalization of a decision problem based on a discrete event system by means of Petri nets. Paper presented at the 23rd European Modeling and Simulation Symposium, EMSS 2011.
- Latorre-Biel, J. I., & Jiménez-Macías, E. (2011b). Matrix-based operations and equivalente classes in alternative Petri nets. Paper presented at the 23rd European Modeling and Simulation Symposium, EMSS 2011.
- Latorre-Biel, J. I., & Jiménez-Macías, E. (2011c). Petri net transformation for decision making: Compound Petri nets to alternatives aggregation petri nets. Paper presented at the 23rd European Modeling and Simulation Symposium, EMSS 2011.
- Latorre-Biel, J. I., & Jiménez-Macías, E. (2013a). Comparison of incidence matrices to detect common patterns in petri nets. Paper presented at the 25th European Modeling and Simulation Symposium, EMSS 2013.
- Latorre-Biel, J. I., & Jiménez-Macías, E. (2013b). Modelling, analysis, and simulation of manufacturing processes with alternative structural configurations by parametric Petri nets. *Advanced Science Letters*, 19(2), 665-669.
- Latorre-Biel, J. I., Jiménez-Macías, E., & Pérez-Parte, M. (2014). Sequence of decisions on discrete event systems modeled by Petri nets with structural alternative configurations. *Journal of Computational Science*, 5(3), 387-394.
- Latorre-Biel, J. I., Jiménez-Macías, E., Pérez De La Parte, M., Blanco-Fernández, J., & Martínez-Cámara, E. (2014). Control of discrete event systems by means of discrete optimization and disjunctive colored PNs: Application to manufacturing facilities. *Abstract and Applied Analysis*, 2014.
- Latorre, J. I., & Jiménez, E. (2013a). Petri nets with exclusive entities for decision making. *International Journal of Simulation and Process Modelling*, 8(1), 66-73.
- Latorre, J. I., & Jiménez, E. (2013b). Simulation-based optimization of discrete event systems with alternative structural configurations using distributed computation and the Petri net paradigm. *Simulation*, 89(11), 1310-1334.
- Latorre, J. I., Jiménez, E., & Pérez, M. (2013). The optimization problem based on alternatives aggregation Petri nets as models for industrial discrete event systems. *Simulation*, 89(3), 346-361.
- Macías, E. J., & de la Parte, M. P. (2004). Simulation and optimization of logistic and production systems using discrete and continuous Petri nets. *Simulation*, 80(3), 142-152.
- Samaniego, I. L., Jiménez-Macías, E., & Latorre-Biel, J. I. (2013). Analysis of information partial encryption options for exchanging petri nets systems. Paper presented at the 25th European Modeling and Simulation Symposium, EMSS 2013.
- Samaniego, I., Pérez, M., Martínez-Cámara, E., (2011). Security in sending and storage of petri nets by signing and encryption. Paper presented at the 23rd European Modeling and Simulation Symposium, EMSS 2011.