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Discrete Event Models of Medical Emergencies

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INTRODUCTION

As modern society consists of large social networks there is a lot of places where infectious diseases are easily spreading, and therefore these processes have been widely studied using different approaches as did Shah and Zaman (2010), (2011), and Lappas et al. (2010).

An Artificial Social System (ASoS) is a set of restrictions on agent's behavior in a multi-agent environment (Moses & Tennenholtz, 2002). ASoS allows agents to coexist in a shared environment and pursue their respective goals in the presence of other agents. A plan (Evans,Gor, & Unger, 1996) is said to guarantee the attainment of a particular goal starting from a particular initial state. In controlling the actions, or strategies, available to an agent, the social law plays a dual role. By reducing the set of strategies available to a given agent, the social system may limit the number of goals the agent is able to attain. By restricting the behavior of the other agents, however, the social system may make it possible for the agent to attain more goals and in some cases these goals will be attainable using more efficient plans than in the absence of the social system. A semantic definition of artificial social systems gives us the ability to reason about such systems. In order to be able to reason properly, we need a mathematical model and a description language. Different approaches were proposed for modeling these tasks in order to minimize the mentioned time: (Shah & Zaman, 2010; Anderson & May, 1991; Gaspar, 1991; Balloni, 2004; Ministerio da Ciencia, 2011). The proposed methods concern mostly drastic administrative duties which cannot be generalized as well as a versatile model like ASoS. As we see in different organizations, also in hospitals, informational technologies utilization on different levels varies and depends among other things, on the intelligence of hospital management. It is well known that in these processes are involved many variables and one hardly finds a universal pattern to all possible situations, data basis (even huge ones) will provide only partial solutions. In this work we address a new approach based on artificial social systems modeled with timed Petri nets. The novelty of our approach resides not only in stating the theoretical support for it, but also in the involvement of this tool for saving human lives. Discrete event formalisms are addressed to efficiently solve this problem. The content of the article is as follows: section 2 introduces a class of Petri nets for modeling artificial social systems; section 3 illustrates the concepts discussed in the previous article, section 4 frames the cyclic time of Petri nets which model artificial social systems for medical emergency scheduling; section 5 proposes an algorithm for verifying the optimum cyclic time of an ASoS model, and section 6 concludes the approaches given in this work and also suggests some possible research development.

BACKGROUND

Many other related work into areas deal with epidemic/cascade-style processes and problems related to them like epidemic immunization and influence maximization: (Chakrabarti, 2008), (Ganesh, 2005); there are also studies about blog propagation were conducted in (Prakash, 2011), (Richardson & Domingos, 2002), and analysis of viral marketing and product penetration is found in (Kempe, 2003), (Goyal, 2011), (Shah & Zaman, 2010). Virus propagation under epidemic threshold, and finding the conditions for break it up are discussed, modeled and analyzed in (Bikhchandani,

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1992), (Goldenberg;, 2001), (Leskovec, 2004). Other very important problems of the viral spreading are the influence maximization problem (Gruhl, 2004), (Leskovec, 2004), (Kephart & White, 2001), (Pastor-Santorras & Vespignani, 2001), and its outbreak detection (Goyal, 2011). Immunization e.g. the problem of finding the best nodes for removal to stop an epidemic, is modeled using marked graphs in (Chen, 2010), (Leskovec, 2007), (Tong, 2010), (Briesemeister, 2003), (Prakash, 2010).

A CLASS OF PETRI NETS FOR MODELING ARTIFICIAL SOCIAL SYSTEMS

Petri nets as a mathematical and graphical tool, provide a uniform environment for modelling, formal analysis, and design of discrete - event systems. One of the major advantages of using Petri nets is that the same model can be used for the analysis of behavioral properties as well as for the performance evaluation. We may notice that, even if design model can be constructed fairly rapidly by using predefined objects, checking the model for its logical correctness may still be a hard task. Although, logical correctness of an object can be established separately from other objects, the need to check the correctness of the interactions (social laws) between objects requires the whole model of the system to be considered. One possible solution to the complexity problem is to replace the "mechanism" which realizes the functionality of an object by a simplified "mechanism" which retains the required functionality. This functionality defines the way an object (e.g. agent) responds to its inputs (e.g. stimuli). The replacement objects are called functional abstractions. We notice that the mechanism of an abstraction no longer bears resemblance to that of the actual object. However, the fact that functional abstractions retain the functionality of the actual objects is sufficient to study the correctness of the interactions among components of the system (e.g. the behavior of an artificial social system), without paying attention to the correctness of the components themselves. We define functional abstractions of Petri net models in general terms.

Let PN = (P, T, IN, OUT) be a Petri net model of an object.

Let $P_I = \{P_{I1}, P_{I2}, ..., P_{Im}\}$ be a set of interface places of the model. The interface places are the places via which the model interacts with its environment.

Let $P_i = \{P_{i1}, P_{i2}, ..., P_{in}\}$ be a set of internal places of the model. We have, $P = P_I \cup P_i$ and $P_I \cap P_i = Ø$.

Let $T = \{t_1, t_2, ..., t_k\}$ be a set of transitions of the model where $P \cap T = Ø$ and $P \cup T \neq Ø$.

Let f be the functionality of the object represented by PN.

$f = f_{FA}$ Functionality of PN and PN_{FA} are identical.

The functionality of a PN_{FA} can be described by the following semantic (Zurawski & Zhon, 1994): (PN_{FA}, f); where f is a formula having the following syntax:

1. Propositions: p, t_{fir}, and t, where $p \in P$ and $t \in T$, are atomic propositions;
2. Atomic propositions are formulas;
3. If f and g are formulas, then so are -g, f + g, f · g, $f \Rightarrow g$, of, [ ] f, < > f.

The atomic propositions *p*, t_{fir}, and *t*, mean that there is at least one token in place *p* in the current marking, that transition *i* can fire in the current marking, and that transition *t* fires in the current marking, respectively.

Symbols -, +, · , and $\Rightarrow$ represent the Boolean connectives. The formula of, "next," means that *f* becomes true in the next marking.

The formula [ ] f, "henceforth" means that *f* becomes true in every marking reached from the current marking.

The formula $\langle \ \rangle$ f, "eventually," means that *f* becomes true at some marking reachable from the current marking.

Let S be dependent automata system. Let, also, α, β be sequences of elements of S. $|\alpha|$, $|\beta|$ denote the length of $\alpha, \beta \in S$.

Let L(PN,M), where M is a marking of a finite PN, be a set of all firing sequences from M. For a formula f, $\langle M, \alpha \rangle \models$ means that f is satisfied by the pair of M, and α where $\models$ denotes a valid formula.

The following properties, which were proved in (Zurawski, 1994), hold:

$$\langle M, \alpha \rangle \models f + \text{of implies } \langle M, \alpha \rangle \models \langle \ \rangle f \quad (1)$$