Computer Standards & Interfaces 36 (2014) 672–685

Contents lists available at ScienceDirect

Computer Standards & Interfaces

journal homepage: www.elsevier.com/locate/csi

Development of context-aware workflow systems based on Petri Net Markup Language ☆

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ARTICLE INFO

Article history:
Received 11 September 2011
Accepted 23 August 2013
Available online 30 August 2013

Keywords:
PNML
Context-aware
Workflow
Petri net
User interface
Resource allocation

ABSTRACT

The Petri Net Markup Language (PNML) is originally an XML-based interchange format for Petri nets. Individual companies may specify their process models in Petri nets and exchange the Petri nets with other companies in PNML. This paper aims to demonstrate the capabilities of PNML in the development of applications instead of an industrial interchange format only. In this paper, we apply PNML to develop context-aware workflow systems. In existing literature, different methodologies for the design of context-aware systems have been proposed. However, workflow models have not been considered in these methodologies. Our interests in this paper are to propose a methodology to automatically generate context-aware action lists for users and effectively control resource allocation based on the state of the workflow systems. To achieve these objectives, we first propose Petri net models to describe the workflows. Next, we propose models to capture resource activities. Finally, the interactions between workflows and resources are combined to obtain a model for the whole processes. Based on the combined model, we propose architecture to automatically generate context-aware graphical user interface to guide the users and control resource allocation in workflow systems. We demonstrate our design methodology using a health care example.

1. Introduction

The Petri Net Markup Language (PNML) [19,37] is originally an XML-based interchange format for Petri nets. Individual companies may specify their process models in Petri nets and exchange the Petri nets with other companies in PNML. Existing literature rarely addresses or studies whether the PNML may be applied in development of software or applications. This paper aims to demonstrate the capabilities of PNML in the development of applications instead of just an industrial interchange format. In this paper, we apply PNML to develop context-aware workflow systems.

Context-aware computing becomes more and more important with the wide deployment of ubiquitous/pervasive computing infrastructure. It refers to an application's ability to adapt to changing circumstances and respond based on the context of use. Dey defines context as "any information that can be used to characterize the situation of an entity", and an entity as "a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" [12]. Among the main types of contextual information considered relevant are identity, time, activity, and location which are known as primary context [33]. A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task [11]. Context-aware computing aims to provide relevant information/services to users. A variety of prototypical context-aware applications have been created. Well-known examples include context-aware guides that present tourists with information tailored to their location [9] and context-aware environments such as classrooms, meeting spaces and smart homes that are instrumented with sensors to enable tracking of the occupants and their activities and supporting independent living of the elderly or disabled [8,13,35]. Readers may refer to [3,4,15,20,21,23,25,26,36] for a comprehensive survey on context-aware technologies and systems.

The requirements of context-awareness pose challenges in modeling, analysis and design of applications/systems. Different methodologies for supporting the modeling of context and design of context-aware systems have been proposed. [30] proposed a model of context called Activity-Centric context and illustrated it via a detailed example. Henricksen & Indulska address software engineering challenges in developing context-aware pervasive computing applications. They proposed context modeling techniques, a preference model for representing context-dependent requirements and two programming models and a software infrastructure that can be used in conjunction with the proposed models [14]. Achilleos, Yang, Georgalas proposed a model driven approach that facilitates the creation of a context modeling framework and simplifies the design and implementation of pervasive services [1]. Serral, Valderas, Pelechano introduced a model driven development method for developing context-aware pervasive systems

☆ This paper is supported in part by a project of the National Science Council of Taiwan under Grant NSC102-2410-H-324-014-MY3.

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http://dx.doi.org/10.1016/j.csi.2013.08.014

[34]. Their method allows one to specify a context-aware pervasive system by means of a set of models, which describes both the system functionality and the context information, and generate code based on the models. Riva and Toivonen have investigated a hybrid approach that enhances context-aware service provisioning with peer-to-peer social functionalities in the DYNAMOS project [31]. Chaari, Ejigu, Laforest and Scuturici propose a generic adaptation framework that involves content adaptation and presentation adaptation to guarantee adaptation of applications to the context in a pervasive computing environment [7].

Many information systems in the real world involve complex workflows. An example is the medical information systems of hospitals. Ardissono, Di Leva, Petrone, Segnan and Sonnessa present the architecture of a framework integrating workflow management and context-aware action execution to support the personalized management of medical guidelines in home health care assistance services [2]. Hospital workers are highly mobile; they constantly change location to perform their daily work, which includes visiting patients, locating resources, such as medical records, or consulting with other specialists. The information required by these specialists is highly dependent on their location, role, time and activity. Health care has been recognized as an important and promising field of context-aware research [6]. How to streamline the processes by providing timely information to health care workers and exploit the advantage of handheld devices is an important research issue. Although contextual elements such as location, role and timing have been considered in the system proposed in [32,22], other contextual elements such as the workflow state are not addressed. However, typical medical processes usually involve workflows. To enable effective modeling of the medical processes, the workflow contextual elements must be taken into account. All the health care prototype systems mentioned above have not addressed the design of context-aware workflow management systems. Our interests in this paper are to propose a methodology to automatically generate context-aware user interface and effectively control resource allocation in workflow systems.

The Workflow Management Coalition (WfMC) defines a workflow management system (WFMS) as: a system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of Information-Technology (IT) tools and applications [24]. In the existing literature, many workflow specification languages have been proposed, e.g. XPDL [38], BPMN [29] and WS-BPEL [28]. However, these workflow specification languages lack formal semantics and explicit representation of the process state. To propose a methodology to design context-aware workflow systems, a model for capturing workflows is required. Petri nets [27] are an effective model for modeling and analysis of workflows. The advantages of applying Petri net formalism are summarized as follows. First of all, the graphical nature of Petri nets can visualize sequences of firing via token passing over the net. Second, Petri nets have well-established formal mechanisms for modeling and analysis of systems. Third, the mathematical foundation of Petri nets can analyze structural and dynamic behaviors of a system. These advantages make Petri nets a suitable modeling and analysis tool. The application of Petri nets to workflow management have been studied by W.M.P. van der Aalst in [41]. Advances in

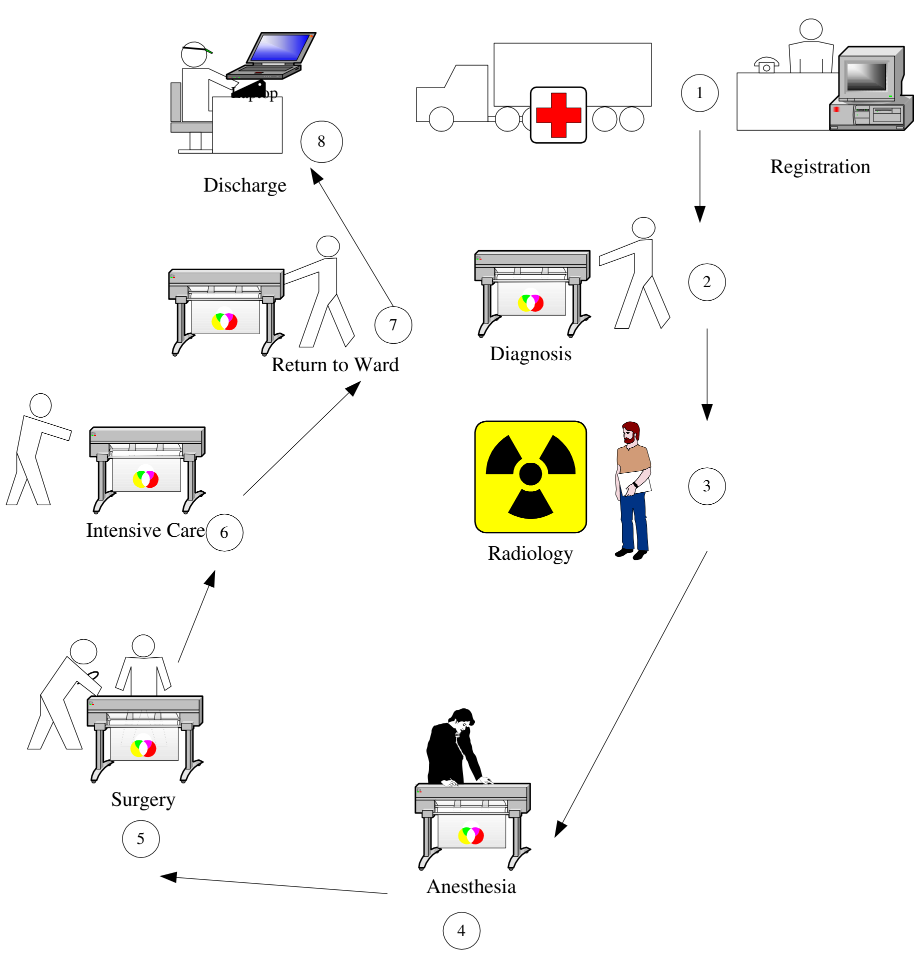

Fig. 1. A medical process.