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A new reengineering methodology for the product-driven system applied to the medication-use process

Jean-Charles Huet [a,b,*], Jean-Luc Paris [b], Khalid Kouiss [b], Michel Gourgand [b]

[a] University Hospital of Clermont-Ferrand, 58 rue Montalembert, 63003 Clermont-Ferrand CEDEX 1, France
[b] Clermont Université, LIMOS CNRS UMR 6158, Campus des Cézeaux, 63173 Aubière CEDEX, France

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ABSTRACT

The aim of the medication-use process (MUP) of a hospital consists in preparing the medicines for each patient every day. The reengineering of the MUP is an important challenge in order to reduce medication errors and costs for the pharmacy. This paper deals with a new methodology of modeling the interactions with the hospital information system (HIS). This methodology is inspired by component-based approach, the paradigm of system of systems (SoS) and the methodology ASDI (analysis–specification–design–implementation). First, the paper shows how the MUP can be compared to a holonic manufacturing system (HMS). So then, the goal of the new methodology proposed consists of designing easily a library of components for an HMS and more specifically for a MUP in a hospital. Finally, an example of the application of this modeling to the hospital of Clermont-Ferrand is presented. The goal is to help the pharmacists to make up their decisions in order to reorganize and design a new pharmacy of a hospital.

1. Introduction

The official recommendation document "Informatisation du circuit du médicament dans les établissements de santé"[1] [13] indicates the need to reduce the amount of work time spent by nurses in the medication administration process, and to reduce the medication consumption. In this context, the University Hospital of Clermont-Ferrand decided to study the reengineering of its existing central pharmacy and of a new pharmacy branch which opened recently in a new hospital.

We explain in this paper how we see the interoperability between the medication-use process (MUP) and the hospital information system (HIS). We use two concepts used for manufacturing systems to develop a model of this interaction: holonic manufacturing system (HMS) and system of systems (SoS). The modeling is based on the Component-based approach. Indeed, we demonstrated in [21] that the MUP can be compared to an assembly system. The final goal is to design a process that can be driven by the preparation of doses for each patient (the product), from the prescription to the administration in order to allow a better traceability and flexibility using identification technology as RFID or bar-code. However, the idea of incorporating intelligent information systems in the healthcare domain is not new [32,35]. But the aim of our work is to generalize the approach and to develop a generic decision making tool to help pharmacists and managers to organize the MUP.

In a few years, the hospital of Clermont-Ferrand will reorganize its pharmacy and its MUP. The robots will be installed in order to reduce dispensing error rates and to give more time to pharmacy staff to manage medicines at the care unit level. The aim of this paper is to prepare this transition and to propose a methodological approach to analyze and design the management organization in health care system and especially the closed-loop medication process in a context where operations could be performed either by human operators or by robots. Therefore, the goals are triple: economical, technical and decision helping (reengineering). Nowadays, many hospitals in Europe are studying the possibilities of using a robotic system for medication dispensing [10]. In fact, the use of automated drug dispensing devices and robotic systems in pharmacies have proliferated since the 1990s, partly because of the need to reduce costs and to expand the pharmacists' functions from drug distribution to the delivery of comprehensive pharmaceutical care. Automated drug dispensing devices used in hospitals include centralized cart-filling systems, decentralized systems located on patient care units and point-of-care information systems [2]. The cost will be reduced because of a decrease of medicine errors (decrease of deceased and injured people) and a best use of medication stock. Indeed, these optimizations of the MUP will improve the respect of the patient's five rights concerning the medication administration, which are:

- The right medicine;
- The right dose;
- In the right form;
- At the right time;
- For the right patient.

* Corresponding author at: University Hospital of Clermont-Ferrand, 58 rue Montalembert, 63003 Clermont-Ferrand CEDEX 1, France. Tel.: +33 1 3075 6180.
E-mail addresses: jc.huet@epmi.fr (J.-C. Huet), paris@ifma.fr (J.-L. Paris), kouiss@ifma.fr (K. Kouiss), gourgand@isima.fr (M. Gourgand).

[1] Computerization of medication-use process in health institutions.

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The aim of our work is to develop a generic decision making tool to help pharmacists and managers to organize the MUP. This paper proposes a methodological approach, based on ASDI (analysis–specification–design–implementation) and a component-based approach, to develop a library of generic components that can be, instantiated into a modular model based on the holon concept, i.e., a component with a physical part and a decisional part [9]. The component-based approach is used to have a large flexibility. This methodology could be generalized and used for the design of any holonic manufacturing system (HMS).

The paper is structured as follows: Section 2 explains all the concepts used, Section 3 presents the interoperability between an information system (IS) and an HMS, Section 4 presents the ASDI methodology proposed, Section 5 applied the analysis step of this methodology for the domain of the MUP, Section 6 presents the specification step using the methodology, Section 7 proposes an example of the design and implementation, Section 8 proposes another example of implementation with a simulation software and Section 9 presents a study of an application to the hospital of Clermont-Ferrand. Finally, Section 10 presents conclusions and perspectives for future works.

2. Related work

Nowadays, many works have as objectives to reach a maximum of flexibility in order to allow the industry to have a better adaptability and to customize products. We consider that the concept of component-based, the concept of holon and the concept of system of systems, are one of the most promising.

2.1. The component-based approach

The component-based approach is a generalization of the development of object approach and its interest is that it allows the reuse of the code (reduced cost and time). Many authors proposed methods for the design of a component software and also methods to assemble, modify and choose components [8]. Blobel [6] used this approach for health information systems and explained how to create a middleware to connect the components with each other in accordance with the Health regulation. The component-based approach consists in two stages: in stage 1, a black box view of components which shows the interaction with each other and in stage 2, a white box view which splits up this component showing its internal behavior and structural elements [22]. Azevedo and Sousa [4] introduced the distributed object oriented technology and a component-based architecture in order to have the most flexibility and modularity to organize production and operations planning of a distributed enterprise (a multi-site company). These two papers propose to start the study by a use-case (it describes the system from the user's point of view) in order to isolate the subsystems and the components. Chiron [12] deals with the automation systems engineering and intends to use techniques from software design areas in order to specify physical systems. He uses methods inspired by the OOA (object-oriented design) and object-oriented modeling with UML (unified modeling language). The target is a late specialization and a code generation according to the chosen technology, as it is the case in the MDA (model driven architecture) [18,29]. He proposes an analysis process for the design and the reusability of multi-aspect components for the design of automatic systems (MBCSA)[2] (Fig. 1).

The modeling language used is SysML [30] which is an extension of UML. This methodology is based on the component-based approach. The analysis is driven in two directions: the downward analysis consists in defining the component for a system and the upward analysis consists in creating a reusable generic component. The downward direction allows the obtainment of the Automata program code. Refs. [5,28] considered that the MDA ontology uses an approach of four conceptual levels. This four-level approach is presented in Fig. 2.

[2] Méthodologie Bidirectionnelle de Conception des Systèmes Automatisés: Bidirectional Methodology for the Design of Automatic Systems.

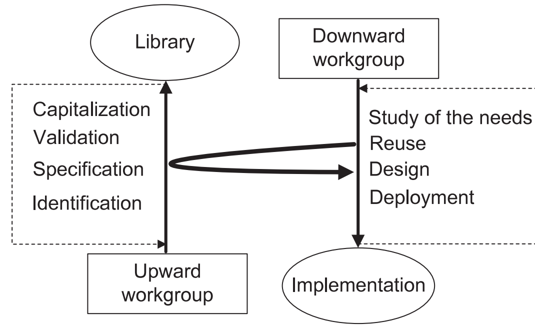

Fig. 1. Process of a bidirectional analysis [12].

The lowest level M0 presents different subjects for modeling, called universe of discourse. The level M1 contains different models of each of the universes of discourse. The next level M2 presents domain specific meta-models. And finally, M3 level presents a meta-meta-model designed to allow the definition of all the existing scopes of the meta-models.

2.2. Holonic manufacturing system

A holon is an identifiable part of a system that has a unique identity, it is made up of subordinate parts and in turn is a part of a larger whole [23]. A holonic manufacturing system (HMS) is an autonomous and co-operative building block of a system for transforming, transporting, storing and/or validating information and physical objects. Baïna and Morel [5] proposed to adapt the holon concept definition to solve the problem of synchronization between physical and informational views of the same objects. They proposed a model driven approach, based on the MDA, for holonic models' interoperability. The use of UEML (unified enterprise modeling language) and MEGA suite as modeling tools illustrate their work. In the HMS reference architecture PROSA [9], the types of holons are resource-holons, order-holons, staff-holons and product-holons (Fig. 3). The staff-holon is used to have a centralized coordination between the other holons.

This last concept shows explicitly the active role of a product. Gouyon et al. [20] used these conceptual guidelines of HMS. With this approach, they focused on the design of a product-driven distributed control system. This conception of an HMS corresponds to the level M3 of the MDA description in Fig. 2, i.e., the meta-meta-model of our modeling approach.

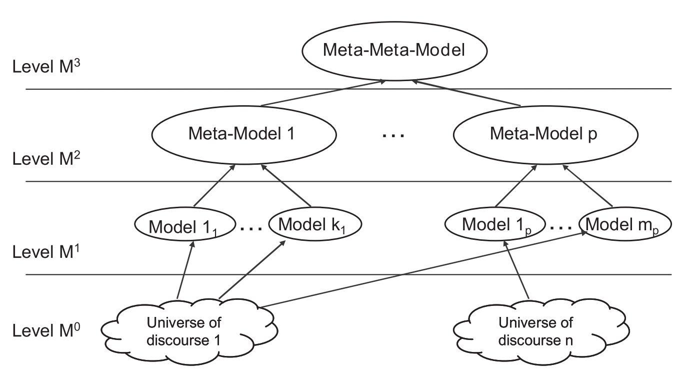

Fig. 2. The four-level ontological approach [5].