Title:
The Use of PLM to Improve Collaboration and Data Sharing in the Treatment Process

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Introduction:
Medical domain is more interested in the social today. In general, it is divided into four main areas: Diagnostic service, Treatment service, Healthcare service and Medicine. But within the limits of this study, the paper only focuses on the treatment process, in case of needing prosthesis implantation.

Firstly, the paper describes in general a treatment process for patients requiring prosthesis from the beginning to the end. Then the research analyzes and points out the limitations in terms of data, information sharing, knowledge reuse and collaborations between involved stakeholders. Based on this, the paper proposes a proposition based on PLM that can improve these problems. To do this, two lifecycles (Disease lifecycle for medical point of view and prosthesis lifecycle for engineering point of view) are described. These are two separate lifecycles but always having the exchange of information and data between stages of this lifecycle to stages of another one described by the links. Then these links are opened and analyzed in details based on 5 main dimensions: flow, tool, process, stakeholder and requirement. Finally, the paper illustrates propositions by implementing them into Audros software, one of popular PLM tools in the current market.

The Treatment Process:
The treatment process requiring prosthesis is one of the important and complex processes that includes many activities fulfilled by different stakeholders [3]. Fig. 1 shows entire process in general. It is described in details as follows:

After interviewing and conducting some initial checking on the patient by the medical doctor, the radiologist will scan the concerned part of body. Conventional radiology image, 3D computed tomography (CT) or Magnetic resonance imaging (MRI) are used for such purpose depending on the kind of symptom [6, 11]. After analyzing medical images obtained from the scan, the design and realization of the needed prosthesis is achieved. Nowadays, several technologies are currently used for the manufacturing of prosthesis depending on its kind and material. It can be manual molding, by using conventional CNC (Computer Numeric Control) machining, or more recently, using additive manufacturing through 3D printing machines [2, 10]. Finally, before implanting the prosthesis on the patient's body, a strong quality approval process is achieved involving prosthetists, medical doctors and surgeons [11]. The last process after implantation is then rehabilitation and recovery.

Problematic:
The accuracy and completion time of each sub-process has a strong influence on the success of the whole treatment process. For instance: with better quality of the prosthesis, risk of incidents during surgery process could be reduced. Post-treatment and related costs can be also reduced if the geometry of the prosthesis is completely adapted to the patient morphology. The patient will be recovered after surgery quickly in this case [13, 14].

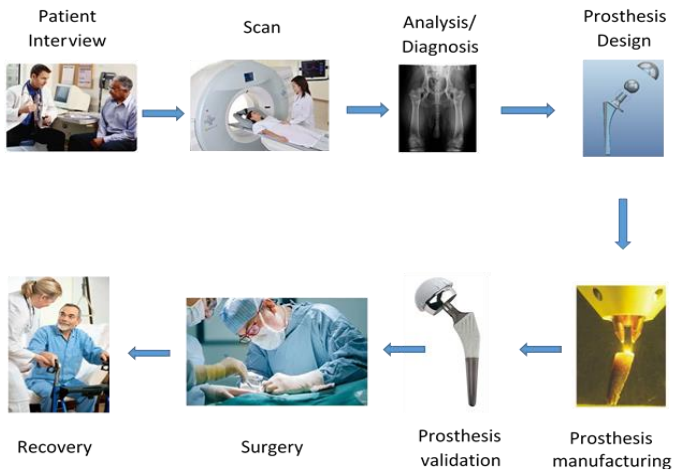

Fig. 1: The treatment process requiring prosthesis.

There are many factors influencing accuracy and completion time of the patient treatment process. Some of them can be mentioned such as: the collaboration, information sharing, and knowledge sharing between all stakeholders, sub-processes during the whole patient treatment process. However, there are no optimum methods to achieve the efficient collaboration between stakeholders. They often use ad-hoc network and email to share the data together or even the data is archived to CDs/DVDs, then supply for related sub-processes. These data sharing methods usually lead to potential errors and delays [4]:

- Potential errors: The data size is normally very large (up to 300 MB). Therefore, using ad-hoc network or email can cause the corrupted or incomplete data.
- Delays: The stakeholders in one sub-process want to receive the data from another sub-process. They must send a request and wait for accepting from another stakeholder. The data is then sent by the internet or saved to a CD/DVD. This method is not optimal. It causes delay in the data exchange between the sub-processes. Consequently, the completion time of the whole process is lengthened.

Therefore, the main issue in this research work is to propose new solutions based on PLM (Product lifecycle management) concept to improve data sharing, collaboration between stakeholders. In addition, knowledge capitalization and reuse facilities are needed as part of the PLM approach to support medical problems resolution. In the next part, the paper will introduce about PLM.

Product Lifecycle Management (PLM):

PLM is defined as a systematic concept for the integrated management of all product-related information and processes through the entire lifecycle, from the initial idea to end-of-life [5, 8]. It works in collaboration with other business software such as SCM, ERP, CAD, CAM, KBS, etc. [7]

In order to remain competitive, the main objective of PLM is to provide the right information to the right users in the right context and at the right time throughout the product lifecycle in order to reduce the production cost [1]. PLM has become a new paradigm for design and manufacturing, because the challenge is not only to manage the product technical data but also to manage the concepts associated with the product [9].

Proposed Method:

From the problems identified and the functions of PLM, the proposition is that using PLM approach to enhance efficiency of collaboration, information and knowledge sharing between stakeholders related. The idea is that all disease data, prosthesis data, actors, tools of both sub-processes inside hospital (interview patient, do exam, do surgery, etc.) and outside hospital (design and fabricate prosthesis) will

be connected through PLM hub. With this proposition, actors can share data, knowledge to each other. Furthermore, they can view, modify data or only give comments depending on their roles.

Links Representation between Stages of Two Lifecycles:
Through analysis of treatment process in details, the research identified two separate lifecycles: Disease lifecycle and prosthesis lifecycle. The relationship between two these lifecycles is described by links (numbered from L1 to L6 in
Fig. 2). Each link represents the connection of two stages. It implies that there is data exchange, collaboration between them.

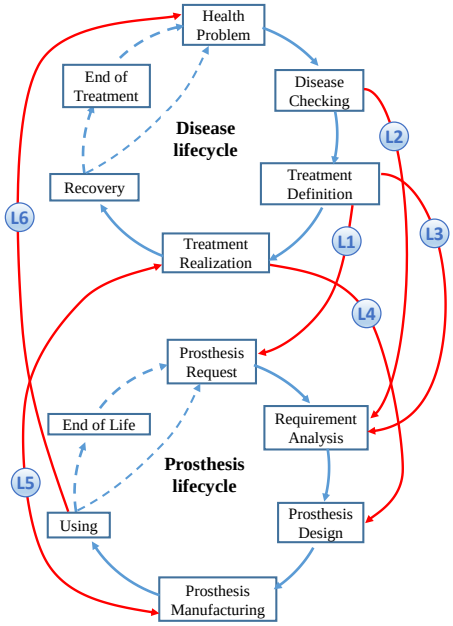

Fig. 2: Linking between disease lifecycle and prosthesis lifecycle.

Link L1 implies that after analyzing medical data at stage “treatment definition”, medical doctor will decide patient needs prosthesis or not. The decision will send to stage “prosthesis request”.

Before starting the design process, the collection of data (patient data, medical image) as well as the requirements of the doctors is necessary. Then engineers will design prosthesis based on this collection process that is described through links L2 and L3.

In order to finish process of prosthesis design, after completing the virtual prosthesis prototyping, the surgeon and prosthetist will validate the virtual prosthesis prototyping to ensure that it meets all the requirements before going to manufacturing process. This collaboration is described by link L4 that connects between 2 stages: treatment realization and prosthesis design.

Two arrows in link L5 that describes collaboration and data sharing of stakeholders in 2 stages: prosthesis manufacturing and treatment realization, the first arrow implies surgeon and prosthetist validate the real prosthesis after fabricating. The second arrow means that the producer notifies the delivery date of prosthesis for surgeons to prepare the surgery process.

Finally, after surgery process, prosthesis exists on the patient body. Link L6 displays the feedback of patient (customer) during the using process. Based on this feedback, the doctor will follow up and propose next treatment direction.

In order to understand the nature of six links in more details, they will be analyzed based on 5 main dimensions: Flows, processes, stakeholders, tools and requirements. For example, link L2 (connection between “disease checking” and “requirement analysis” lifestage) are opened as follows:

- Tool: CT/MRI machine, 3DMIP tool.

- Flow: Patient medical image (DICOM file)
- Process: Scan process, design process.
- Stakeholder: Radiologist, design engineer.
- Requirement: Respect constraints of bone morphology, other prosthesis, special allergy for some material, etc.

In the next part, the propositions based on PLM will be implemented into Audros.

Implementation of the Propositions in Audros:

Audros is one of popular PLM software available in the market [12]. It has functions that can meet the requirements of the system. For instance, it can establish collaboration between actors, reuse knowledge, make traceability, etc. Especially, it can integrate with other software such as MS office, CAD software.

In order to fulfill the implementation of proposition, this research uses five main modules in Audros as follows:

- ModelShape: using this module to create all classes (objects), attributes, actors and the relationship between them (Fig. 3a). This module also grants access right for actors depending on their role.
- View designer: using this module to design the interface of classes according to the attributes created by ModelShape
- SE manager: creates lifecycles, manages the position of subfolders and files
- Audros Applet: The ultimate goal is to build an optimal treatment system. This system consists of a variety of processes that operate according to workflows. In each workflow, it shows series of activities as well as the actors involved. In this research, the system operates base on 6 workflows: Medical folder workflow (for objective: Medical data collection), Disease workflow (for objective: Disease identification), Requirement workflow (for objective: Functional specification and Technical specification), Prosthesis workflow (for objective: Design prosthesis, Prototype validation and Prosthesis fabrication), Surgery workflow (for objective: Prosthesis implantation), Post-surgery workflow (for objective: Post-surgery). In order to create and manage these workflows, the research uses Audros Applet. (Fig. 3b)
- AWS creation: with this module, actors can enter data, information and consult data and BOMs from an Intranet or an Extranet.

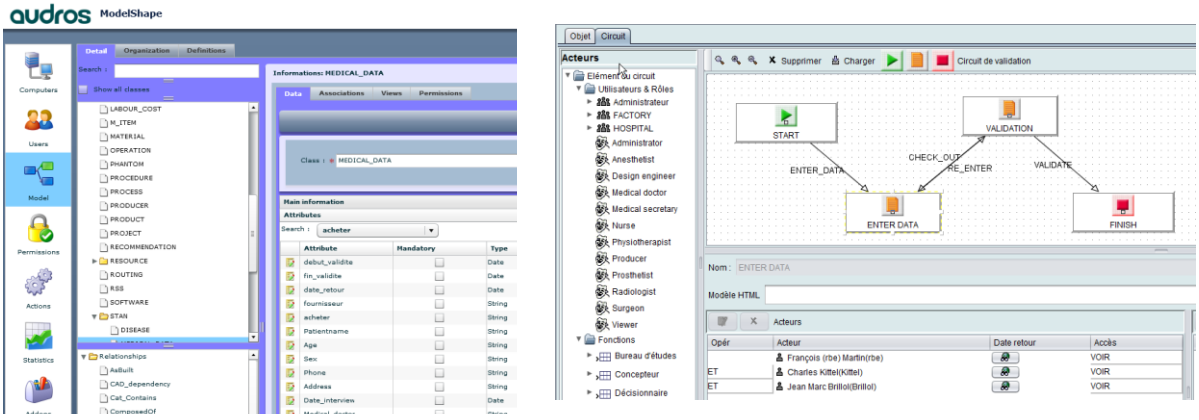

Fig. 3: Working interfaces in Audros: (a) Set up the attribute of classes in ModelShape, (b) Create medical folder workflow in Audros Applet.

Conclusion:

In this paper, we described in general a treatment process requiring prosthesis, then we indicated the problems concerning information exchange, knowledge sharing and collaboration between stakeholders, sub-processes. Based on these problems, combined with the functionalities of PLM, we proposed a solution using the PLM to solve them. In addition, the paper indicated need of lifecycle

integration between the disease lifecycle and prosthesis lifecycle. The relation between these two lifecycles are represented by links in terms of data and knowledge exchange. Then these links were analyzed in detail based on 5 main concepts identified. Finally, the proposition was implemented in Audros software (PLM tool) to illustrate operation of the system.

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