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MERGING DESIGN ACTIVITIES AMONG DIFFERENT APPLICATION FIELDS: FROM MEDICINE AND CULTURAL HERITAGE TO INDUSTRIAL ENGINEERING

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1. Introduction

Nowadays, enterprises are focused on continuous product innovation and on process improvement in order to reduce time to market and production costs. The Collaborative Prototyping Group of the University of Udine is involved in studying and testing the effects of the adoption of CSCW (Computer Supported Cooperative Work) strategies in different application fields.

The aim of this research is to define a uniform work methodology suitable for the resolution of design problems or for problem solving issues in heterogeneous fields. The procedure has arisen from the analysis of two different processes that were pointed out in previous research works.

To maintain a good degree of context independence, one medical process (referred to maxillo-facial surgery) and one cultural heritage preservation process (restoration of archaeological finds) have been chosen. Both processes had been previously optimized by the introduction of Reverse Engineering (RE) and Rapid prototyping (RP) techniques. The paper describes at first the modelling instruments adopted to represent processes; after that, the analysis procedure adopted to highlight similarities is presented step by step. Then, the new work methodology is introduced and, finally, conclusions are illustrated and a test case to validate this uniform work methodology is planned.

2. Modelling Method adopted

Several modelling methods could be used for analysing and designing manufacturing systems or processes. Most of them allow to obtain static representations of processes and systems. Only few methods also permit to have a dynamic model of the whole system.

In this research, the Integrated DEFinition (IDEF) methodology has been used to obtain a static model of the studied processes. IDEF was developed during the 1980s by the U.S. Air Force Integrated Computer Aided Manufacturing (ICAM) program, for increasing manufacturing productivity through systematic application of computer technology [FIPS PUB 183 1993], [Colquhoun 1993].

In this case, the method has been chosen to obtain a complete structured process model representation. In fact, IDEF methodology is based on the decomposition principle, which consists in breaking down each activity into more detailed activities from top level until necessary.

2.1 IDEF0 method for functional modelling

Initially, IDEF was developed as a set of methodologies, IDEF0, IDEF1, IDEF1x, IDEF3 and IDEF4 for function, information, data, dynamic analysis and object oriented design respectively [FIPS PUB 183 1993]

In particular, IDEF0 method is a graphical method used to produce a functional model of an organization, system or process. The result of IDEF0 representation is a hierarchical functional decomposition. There are five basic elements in an IDEF0 functional model: activities or functions, inputs (I), outputs (O), controls (C) and mechanisms (M). The activities are represented by boxes which have a name that indicates what must be accomplished. The constraints I, O, C, M are represented by arrows. Input data enter the left side of the box, output data exit from the right side of the box. Controls enter the top side of the box and mechanisms enter the bottom side of the box as shown in figure 1. Thus, a single box represents only one function. Inputs indicate parameters that are modified by the function, while outputs represent the results. Controls indicate factors that constrain the activity and mechanisms are the means used to perform the function.

3. Activities

In order to develop this work methodology, two different kinds of process have been chosen for analysis. The first is related to medical field (maxillo-facial surgery), while the other is related to cultural heritage preservation field (restoration of archaeological finds), see figure 1. These two processes have been previously optimized by the introduction of Reverse Engineering (RE) Rapid Prototyping (RP) and Computer Supported Cooperative Work (CSCW) techniques [Otto 2000][Lee 1999][Gatto 1998][Sriram 2002].

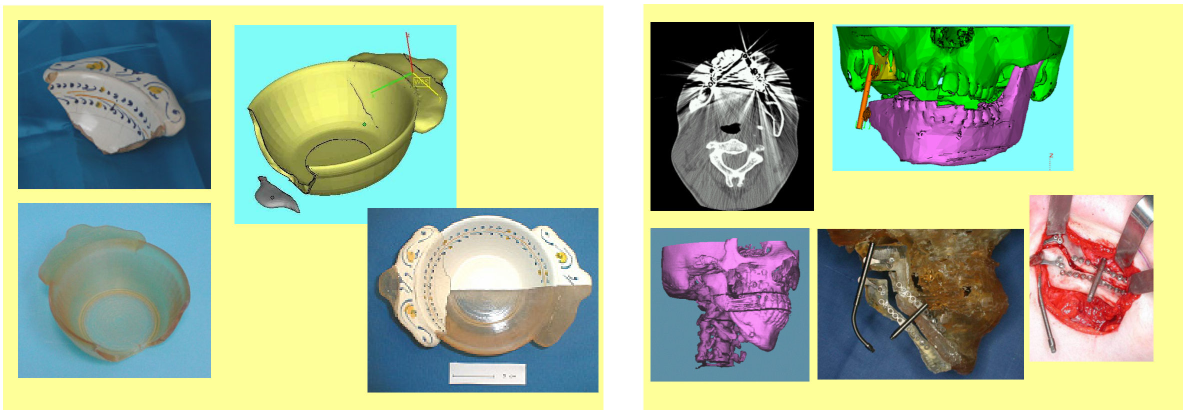

Figure 1. Pictures from medical process and cultural heritage preservation process

3.1 First process: maxillo-facial surgical activities planning

The traditional operation planning procedure is usually based on the simulation of the operation by using anatomical facsimile models of patient's skull, derived by CT data. Our introduction of RE and RP techniques in a collaborative environment has allowed to obtain 3D digital models and 3D prototypes of the real anatomy of patients directly from their CT data by using software elaboration of the data volume. The availability of 3D digital models has provided the surgeon a better surgical planning and the virtual or practical simulation of the operation.

The main activities of this optimized process can be summarized as follows: 1) CT data acquisition; 2) 3D digital model reconstruction; 3) prototype building; 4) simulation accomplishment; 5) solution selection; 6) surgical operation [Bandera 2003].

3.2 Second process: restoration of archaeological finds

The cultural heritage preservation process for archaeological finds restoration usually does not involve the use of virtual reality and prototyping instruments. In our reviewed version of this process, the enlargement of work environment - due to the introduction of CSCW strategies, RE and RP techniques - has extended its application: virtual restoration, reproduction of exact copies of the relics, production of original artworks inspired to ancient objects, etc.

The process analyzed can be decomposed in the following activities: 1) 3D digitize of the archaeological find; 2) 3D model reconstruction, 3) virtual Simulation; 4) prototype building; 5) discussion; 6) making intervention [Bandera 2002].

3.3 Models of the processes

After the identification of process activities, it has been possible to start the development of their IDEF0 models. The first step, when developing an IDEF0 model, is to establish the purpose and the viewpoint of the model. In this case, the purpose of these models was to identify the stream of activities and to evaluate the flow of knowledge and information. For the descriptions of these processes, the viewpoint of an external observer has been used. To realize the IDEF0 functional models the AI0win software by Knowledge Based System's, Inc has been used [KBSI 2003].

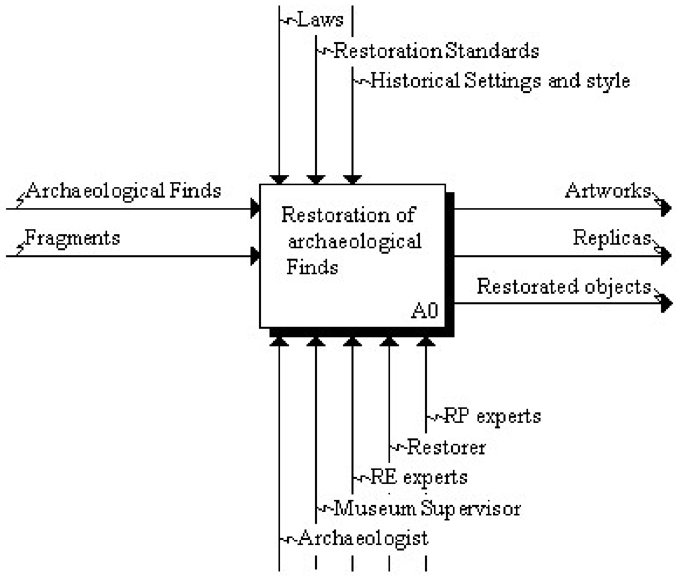

Figure 2. Context diagram A0 of the cultural heritage preservation process

At first step, every process has been described by a context diagram (A0 activity) which contains the top level function being modelled and its inputs, outputs controls and mechanisms. In figure 2, the context diagram A0 of the Cultural Heritage preservation process. At second step, the A0 context has been decomposed into single activities.

After decomposition into activities, it has been necessary to introduce inputs, outputs, controls and mechanism for each function.

The main mechanism to support function execution of both the processes has been the presence of experts (medical experts, archaeological experts) directly related (connected) to the particular process, near to technical experts (engineers) usually involved in design processes. Another important mechanism, also present in the processes, has been the use of Computer Supported Cooperative Work (CSCW) tools, as a link between these experts coming from different contexts and places. Figure 3 shows the IDEF0 model of surgery operation planning process.

In order to increase the level of detail, every single function has been decomposed further into sub-activities and in child diagrams. This decomposition has allowed to identify a large number of similar sub-functions.

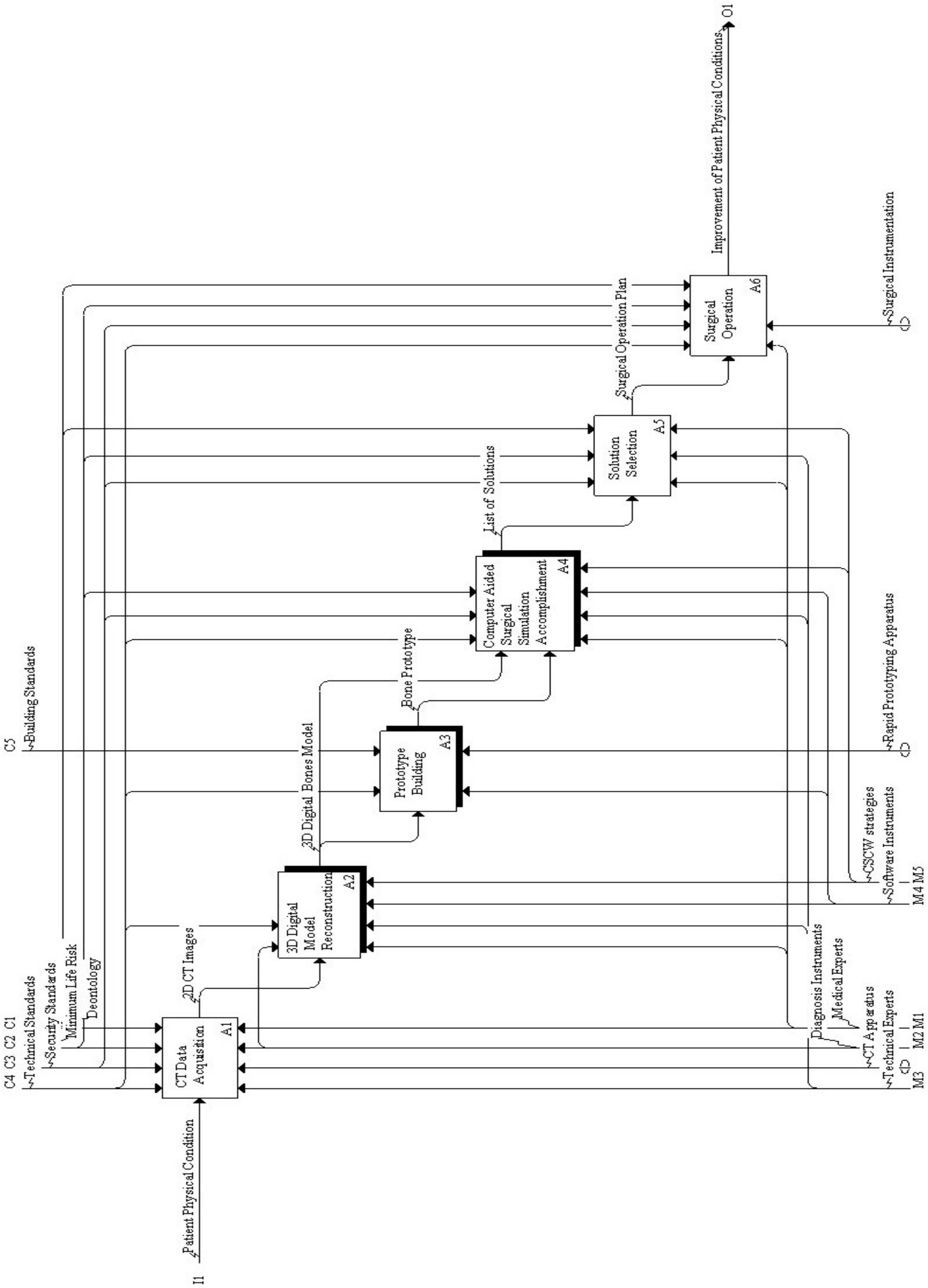

Figure 3. IDEF0 model of Planning Surgical Operation process

3.4 Developing a uniform work methodology

After the decomposition of the two processes, it has been easy to identify similar activities, mechanisms or controls because IDEF0 models have allowed to describe these two processes in a clearly graphical way and with a simple but structured notation.

At first sight, by analysing the processes decomposition, it has been possible to individuate a quite good overlap of some functions like 3D Model Reconstruction (A2), Prototype Building (A3), Virtual Simulation (A4) and Solution Selection (A5). This good correspondence is also due to the previous optimization of the procedures and to the introduction of RE and RP techniques and tools. Besides, by analysing the controls, it has been possible to notice the presence of standards and norms as bonds for procedure accomplishment in both cases. Also by analyzing mechanisms we could identify in both processes the presence of software and CSCW tools. Therefore by extracting these common objects from their contexts and exporting them into a neutral one it has been possible to individuate a new sequence of activities that can be used to obtain a more general process.

Table 1. Activities matching and merging

MERGED ACTIVITIES		CULTURAL PROCESS	MEDICAL PROCESS
A1	Data acquisition	3D Object digitize	CT Data Acquisition
A2	Elaboration of 3D digital model	3D Model Reconstruction • Data Analysis • Data Elaboration • Data Conversion	3D Model Reconstruction • Format Conversion • Data Analysis • Data Elaboration
A3	Prototype building	Making finds prototype • Slicing • Building • Finishing	Making bone prototype • Slicing • Building • Finishing
A4	Simulation	Simulation of restoration • Virtual Reconstruction • Object reconfiguration • Virtual Restoration	Computer Aided Surgical Simulation • Virtual simulation of operation • Simulated Operation on Prototype • Surgical Equipment Preparation
A5	Solution selection	Solution Selection	Solution Selection
A6	Solution application	Restoration Operation	Surgical Operation

4. Results

After similarities recognition and common objects extraction from both processes, we have defined a new uniform work methodology easy customizable.

The main activities of this new methodology can be individuated as follows: A1) Data acquisition (via RE techniques or directly from design); A2) Elaboration of 3D digital model; A3) Prototype building; A4) Simulation; A5) Solution selection; A6) Solution Application.

Software instruments and CSCW scenarios have proven to be a good link between these functions. In fact, the possibility to work in a collaborative environment extends the application of this method and maintains a good degree of independence from context.

Moreover, in order to validate this methodology, we plan to apply it to investment casting process. The goal is the realization of a particular kind of centrifugal pump impeller. In this case, the elaboration of a digital model of the object starts from the redesign of an old version of the impeller. After the realization of a new digital mock up it will be possible to realize a RP prototype of the object in order to define the exact configuration of the object. Furthermore, the prototype is built in a ‘Quick

Cast' particular style that allows to use the prototype as a wax die for reproducing object by investment casting.

5. Conclusions

The choice to analyze some processes coming from heterogeneous fields, but presenting similar activities with IDEF modelling technique, has allowed to individuate and extract common activities. IDEF0 method has allowed to obtain a rigorous structured approach to process model development thus to reduce its complexity. Then these activities have been joint in a uniform, context-independent, work methodology based on RE, RP and CSCW instruments.

The development of that uniform work methodology, easily customizable given the application context, allows a more large usability of it and drives to improvements in several application fields.

The general work methodology, derived from heterogeneous experiences, extends the use of knowledge, tools and techniques closely related to industrial applications or to completely different realities. The complete documentation will be produced after the final testing.

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