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Emerald Article: Framework for detailed workflow analysis and modelling for simulation of multi-modal image-guided interventions

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Abstract

Purpose – The purpose of this paper is to provide a framework for analysing and modelling detailed workflow of image-guided interventions to facilitate simulation and the re-engineering process for the development of new procedures in multi-modal imaging environments.

Design/methodology/approach – The methodology presented includes a literature review on workflow simulation in surgery, focussing on radiology environments, an assessment of simulation tools, a data gathering and management framework and research on methods for conceptual modelling of the processes.

Findings – The literature review reveals that few authors attempted to analyse the phases within image-guided interventions, and those that did, only did so partially. The framework developed for this work intends to fill the gap found in the survey. It allows the maintenance and management of large amounts of data, one of the most critical factors when modelling detailed workflow. In addition, selecting the appropriate simulation software plays an important role, saving time in later stages of the project.

Originality/value – The framework presented for endovascular interventions can be extended to other types of image-guided interventions. Moreover, modelling the workflow processes in a modular way facilitates the re-engineering process when integrating different imaging modalities during the same procedure.

Keywords Work flow, Modelling, Simulation, Computer software, Image-guided interventions, Radiology

Paper type Research paper

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1. Introduction

Computer simulation provides an effective method for assessing prospective changes in the processes of health systems without involving high costs or safety issues for patients and staff members. Among the techniques applied for computer simulation, discrete event simulation (DES) is considered particularly appropriate for simulation in health care and more especially in surgical environments (Brailsford *et al.*, 2009; Katsaliaki and Mustafee, 2011).

A recent survey (Sobolev *et al.*, 2011) reviewed eight bibliographic databases of the last five decades until 2007, finding 34 publications about flow management for surgical patients in which most of the works (26) chose DES as a modelling and simulation technique. In the last years, the number of publications investigating ways to improve efficiency in surgical processes has increased considerably, as operating theatres (OT), together with emergency departments are considered the most costly facilities in a hospital. However, despite this increment of different approaches to improving operation management in OT, still few health systems have used simulation for re-engineering surgical processes. There is a need of an strategy, enough detail of the processes and new knowledge in order to inform the next stage of decision (Young *et al.*, 2009).

The purpose of this paper is to provide a methodological framework for analysing and modelling detailed workflow of image-guided procedures (IGP). This methodology contributes to facilitate the re-engineering process for the development of new procedures in multi-modal imaging environments.

This work is part of a larger project, the Integrated Interventional Imaging Operating System (IIIOS). The IIIOS project is a European Framework Program 7 (FP7) funded Initial Training Network (ITN). IIIOS comprises ten partners and intends to provide technology for the integration of different imaging modalities such as magnetic resonance imaging (MRI), X-ray, ultrasound (US), computed tomography (CT) or positron emission tomography (PET), defining the specifications of an integrated imaging-operating suite (www.iiios.eu, accessed 28 May 2012). As part of the IIIOS project, this work investigates current scenarios of IGP, focusing in endovascular and cardiovascular interventions, with two challenges: first, to understand through an exhaustive analysis of workflow of those current scenarios to help the optimisation of procedures and second, to give guidelines for workflow design and for the development of new procedures under multi-modal imaging guidance.

This paper is organised in four sections. The next section presents a review about modelling and simulating workflow in surgical environments, focusing mainly in radiological procedures, giving a summary of the most critical factors to take into account when approaching the problem. The third section provides a framework designed to aid the study in detail of IGPs, focusing on cardiovascular and endovascular interventions. This framework is divided in four blocks: the technique chosen for simulating, software assessment methodology, data gathering and management, and conceptual modelling of workflow. The forth section presents a summary of the software evaluation and the web site implemented for the data management. In addition, it shows the case of study of iliac angioplasty and stenting (IAS), one of the procedures being analysed within this project. The last section provides a discussion about the limitations and findings of this research.

2. Literature review on workflow modelling in radiology environments

The demand of smooth processes in the OTs has increased prompting hospitals' stakeholders to become very interested in applying workflow modelling and simulation to analyse and improve their facilities. However, the approach given to the problem varies depending on different factors.

One of the critical factors influencing the workflow analysis is the amount and detail of data available. Hospitals usually hold databases with information about the operations performed and these databases are normally different for each department. In most cases, those records are usually limited to just a few metrics of the surgical process such as waiting time, surgery time or recovery time. Studies focused on improving the efficiency of using OTs, and reducing waiting lists of patients, need a large amount of data to find significant results (Stahl *et al.*, 2006; Torkki *et al.*, 2006). Some authors have dedicated most of the project period to data collection in order to have enough data to implement realistic models (Denton *et al.*, 2007). However, in cases where a more detailed workflow description of the intervention events is needed, it is unusual to find databases with the kind of required information available. Some authors have completed database records by interviewing experts or taking measurements, over a not inconsiderable amount of time (Baumgart *et al.*, 2007). Other authors, such as Nara *et al.* (2009); Padoy *et al.* (2010), introduced new technology in the OTs to help the data gathering. The first used an ultrasonic sensor system to track clinicians' positions during neurosurgery operations. The second studied the feasibility of introducing a signal-based modelling system able to recognise signals from the different devices used during the intervention, collecting information about the devices, and their use at each time step of the procedures. Although they presented the statistical modelling for the signal and phases recognition, the information was recorded with synchronised videos. This is a complex data collection and analytical process in surgical rooms, which required exhaustive planning and was time consuming. This supports the argument that obtaining enough information for optimal re-engineering of OT management, requires a systematic framework for collecting data in order to track inefficiencies in the process (Zoeller *et al.*, 2006).

Another important factor in workflow modelling is the type of surgery being analysed. Urgent surgery, for instance, is not scheduled. Therefore, other types of data are taken into account to improve flow in the OTs. Some approaches include the reorganisation of the patient flow and the guidance of the process, re-distributing tasks among the clinicians and moving phases of the operation to decrease waiting times (Torkki *et al.*, 2006). On the other hand, there are operations that have a high variability in their requirements such as open cardiac surgery with an average duration of four to five hours (Peltokorpi *et al.*, 2008). The authors agreed that for more accurate modelling to help predict OT usage, the data was too limited and a specific project would be required.

Despite the limitations that appeared in many studies, the effort made towards better modelling of workflow in OTs has been extended to many disciplines such as cataract surgery (Reindl *et al.*, 2009), trauma (Marjamaa *et al.*, 2008; Torkki *et al.*, 2006), endoscopy (Denton *et al.*, 2007), laparoscopy (Padoy *et al.*, 2010) and also radiology.

In 1971, Garfinkel (1971) published a study about applications of computer simulation to improve patient scheduling in health systems, which included radiology as one of the highlighted fields. A year later, Jeans *et al.* (1972) presented a work about simulation in an X-ray department in Bristol (UK). Both authors modelled the workflow describing human resources, equipment, arrivals and waiting times, types of examinations and overall time that patients spent in the department. Their simulations evaluated workload and resources used in order to predict probable improvements achieved by trying different alternatives. In 1981, O'Kane (1981) provided another simulation model introducing new factors such as staff breaks. The model distinguished the time of examination and the time in which the rooms or radiographers would be available for the next patient, taking into account that an examination can be finished but the room might need some work before other patients could use it. It also considered that radiographers have certain duties regarding to dealing with records and checking images. Lev *et al.* (1976) developed a similar work during the same period about scheduling patients. All these authors emphasised that improvements in radiology should be directed towards the optimal design of the management system and not to reduce the staff or other facilities.

The problem of improving scheduling practises, waiting times and resource utilisation is still treated in some recent papers. These authors used more refined modelling techniques for workflow simulation such as Markov decision processes and DES (Johnston *et al.*, 2009; Kolisch and Sickinger, 2008). Other authors have focused their work on the integration of information systems in radiology departments and hospitals, including the Picture Archiving and Communication System (PACS) (Crowe and Sim, 2009; Wendler and Loef, 2001).

A review about the use of simulation in radiology environments was published in 2008. This study highlighted how this technique has the potential to support proper planning and use of personnel, space and equipment resources. However, it also revealed that there are a lack of studies that fully explore simulation as a tool to facilitate changes and integration of standards (DICOM, HL7) or different imaging technologies (MRI, CT, PET, US) (Lindsko?ld *et al.*, 2008).

3. Framework

As shown in the last section, many researchers are making significant efforts to improve workflow in radiology. Nevertheless, few authors analysed interventions in detail. The most relevant example is the study done by Padoy *et al.* (2010). The authors based their analysis on laparoscopy using statistical modelling and monitoring the use of instruments during interventions. This approach would not be suitable for a radiological procedure due to the enormous variety of instruments, such as catheters, guide wires, introducers and stents, different in size and shape, involved in the procedures.

The approach presented in this paper, describes the work aimed at extending the existing workflow management studies in radiological scenarios.

3.1 DES

DES is a technique that can assist decision makers in health systems allowing the investigation of complex systems. In addition, it is more flexible than other modelling methods to test different alternatives and scenarios, playing "what if" games, changing rules and policies without the associated risks to costs and safety (Jun *et al.*, 1999).

The system to be modelled maintains a clock, demarking events with timestamps. Other common components that feature in these systems are buffers, where components accumulate while awaiting processing; processes that perform operations;

and sinks that allows the parts exit the system. When modelling, data is collected on frequencies of parameters, arrival rates and process times. This information is then analysed to determine the statistical distributions of event timings and that is then introduced to the simulation models (Johnston *et al.*, 2009). There are two usual approaches in health applications. The first, called event scheduling, samples the moments when events occur from predefined distributions of times. The second approach, process interaction, describes the chronology of actions associated with the events, modelling the process as a sequence of serial and concurrent activities operating on, what some experts call, passive entities (e.g. patients or clinicians). In the second of these approaches, discrete event models are found to be the most used for modelling workflow in surgery (Sobolev *et al.*, 2011; Wainer, 2009), and are therefore applied in this project.

3.2 Software assessment

In 2000, a survey about simulation software showed that, in the UK, simulation was applied to health systems in more than 27 per cent of the academic studies (Hlupic, 2000). Companies are increasing their use of simulation for workflow management in health care leading to the emergence of dedicated software packages. The large variety of tools now available can make it more difficult to decide which software is the most suitable to meet the requirements of the system.

Selecting a non-appropriate software package can affect negatively the workflow simulation, bringing extra costs and it may not meet the requirements of the model implementation. For that reason, it is essential to have an assessment of simulation packages. In this project, evaluation was based on a general method for software selection described by Jadhav (Jadhav and Sonar, 2009):

(1) determine the need for acquiring the software and preliminary research of availability of suitable software in the market;
(2) shortlisting of candidates;
(3) eliminate candidates that do not have required features;
(4) evaluate remaining packages (through the ranking and testing of trial versions, for example);
(5) negotiate a contract with specifications such as price, licenses, functional specification and maintenance; and
(6) acquire the software.

This method can be applied to any type of software but it does not establish the features we should require for the simulation software. In the survey conducted by Hlupic in 2000, the authors studied the main limitations and the main features requested by the users. The users gave more importance to the flexibility and compatibility with other type of software packages, along with being easy to learn and with good visual facilities. In addition, Hlupic presented in 1999 an evaluation framework of simulation software for general purpose, giving a list of features divided into several groups of criterion (Hlupic *et al.*, 1999). More recently, Swain and MacGinley (2009) analysed a number of simulation packages with an updated list of features, including some of those indicated by Hlupic (2000).

Apart from these general characteristics, it is essential to add any special requirements that accomplish the objectives within the IIIOS project. For this reason, the evaluation criteria for this particular work included more than 17 features and requirements. These embraced both general and specific ones, such as operating system, RAM, run time debug, output analysis, real-time viewing, graphical model construction, model building using programming, model optimisation, code reuse, animation, CAD drawing import, micro-ergonomics design, statistics data import, 2D/3D modelling and import, model packaging, interface user friendly and experimental design.

3.3 Data gathering and management framework

Several centres are collaborating in the data collection such as clinical radiology and cardiology departments at Ninewells Hospital (Dundee, UK) and the Intervention Centre (IC) at Oslo University Hospital (Oslo, Norway). Due to the nature of this study, the data collection had to be done in person, attending the interventions in most of the cases, as the detailed data required were not usually available in databases.

Table I shows the type of data being collected and highlights the differences between this set of data and the records usually taken for workflow studies in radiological scenarios. A template was designed based on the records collected in the cardiology department in Ninewells Hospital. There, the data is collected by a technician during the intervention and stored on an internal, proprietary database. The radiology department in Ninewells Hospital and the IC in Oslo do not keep such records so all the information had to be collected manually.

Once the data were collected, it was necessary to analyse it. Two main challenges arose at this point. First of all, the data set is heterogeneous depending on the type

Data set	Description
Patient Data	Gender
	Age
	Height
	Weight
Procedure details	Name
	Previous similar interventions
	Images used prior the intervention
Staff	Role
	Number
	Sterilised
	Experience
Supplies	Type
	Model
	Manufacturer
Event log	Time
	Summary
Contrast agent	Contrast details
	Total amount
	Comments
X-ray dose	Emitted dosage
	Absorbed dosage
	Dosage period
Complication	Time
	Summary of complication
	Other comments

Table I.
Data collection template

of intervention and the type of patient, so many variations can be found in the notes taken during the procedures. Second, the centres collaborating with the project perform different types of interventions with different requirements in terms of personnel and equipment. To overcome these difficulties a database and a web site were implemented for data gathering.

3.4 Conceptual workflow modelling

In the study by Aguilar-Savén (2004), the author states that to use the right model, it is essential to understand the purpose of the analysis and to know the tools and techniques for process modelling. Conceptual modelling prior to implementation of the modelled workflow facilitates that understanding and re-engineering of the processes. However, choosing the right technique is a complex task due to the large range of approaches. A review was done over the most common conceptual modelling techniques used for business process modelling: flow charts, data flow diagrams, role activity diagrams (RAD), Petri nets (PNs), Unified Modelling Language (UML) and Soft Systems Methodology (SSM).

The requirements of this project are mainly subjected to the nature of the information recorded from the interventions. In this respect, this paper does not give an assessment of the techniques but the reasons why some techniques were selected over others: the possibility to indicate roles and interactions between them, simplicity, and the capability to show decision points and sub-activities. Consequently, a combination of flow diagrams and RAD was used to model the process flows and the interactions among clinicians in the different phases of the procedures.

In Patel (2000), the author demonstrated how RADs can be applied to activities of health care organisations such as the National Health System (NHS, UK), contributing to a better understanding of the processes and determination of information requirements. This method takes into account the roles and interactions happening during the process, in contrast to PNs or flow charts. In addition, in contrast to UML, RAD gives a view of the whole process in a unique diagram and it has a well-defined and documented notation, unlike SSM (SPRINT, 2009).

Other studies on workflow of radiology departments used flow diagrams or PNs for the conceptual modelling (Johnston *et al.*, 2009; Zhang *et al.*, 2009). However, they did not represent staff roles or detailed events during interventions, which is essential to achieving the objectives of this project. A combination of both types of diagrams to model image-guided workflow results in a better-balanced solution for understanding the process at a glance and at the same time provides a flexible tool to facilitate the re-engineering process of the workflow.

4. Software assessment and study case

4.1 Software assessment

The software assessment included 13 simulation software packages: Analytica, AnyLogic, Arena Simulation Software, Delmia, Emergency Department Simulator, ExtendSim Suite, Flexsim HC, Medmodel Optimization Suite, Micro Saint Sharp, Simcad Pro-Patented Dynamic Process Simulator, Simio, SIMUL8 Professional and Witness. After the evaluation, five of them (Delmia, ExtendSim, Flexsim HC, Medmodel and Micro Saint Sharp) were tested through demo versions or online demonstrations done by the company in the cases where the demo version was not possible to obtain. Table II shows a summary with the assessment of the prioritised list

Table II. Simulation software packages evaluation summary

Software package	Real time viewing	Graphical model implementation	Model building using programming	Animation	CAD drawing import	Micro-ergonomics design	Statistics	Experimental design/ optimisation
Analytica	Not possible	Possible	Possible	Not possible	Not possible	Not possible	Output analysis	Not possible
AnyLogic	Possible	Possible	Possible	Possible[b]	Possible	Not possible	Output analysis	Possible
Arena Simulation Software	Possible	Possible	Possible	Possible[b]	Possible	Not possible	Output analysis/ export[c]	Possible
Delmia	Possible	Possible	Possible	Possible	Possible	Possible	Data import and output analysis/ export[d]	Possible
Emergency Department Simulator	Possible	Possible	Not possible	Not possible	Not possible	Not possible	Output analysis	Possible
ExtendSim Suite	Possible	Possible	Possible	Possible	Possible	Not possible	Output analysis	Possible
Flexsim HC	Possible	Possible	Possible	Possible	Possible	Not possible	Output analysis	Possible
Medmodel Optimisation Suite	Possible	Possible	Possible	Possible[b]	Possible	Not possible	Output analysis/ export	Possible
Micro Saint Sharp	Possible	Possible	Possible	Possible	Possible	Possible – separate package	Output analysis	Possible
Simcad Pro-Patented Dynamic Process Simulator	Possible	Possible	Possible	Possible	Possible	Not possible	Output analysis	Possible
Simio	Possible	Possible	Possible[a]	Possible	Possible	Not possible	Output analysis	Possible
Simul8 professional	Possible	Possible	Possible	Possible[b]	Possible	Not possible	Output analysis/ export	Possible
Witness	Not possible	Possible	Possible	Possible[b]	Possible	Not possible	Output analysis	Possible

Notes: [a]Limited features to add restrictions to interactions among entities; [b]limitations for the 3D environment; [c]statistical data can be exported to external applications such as Excel or Access; [d]statistical data can be imported from external applications such as Excel or Access features that met the project's requirements. This assessment was completed on December 2010 so the current software versions might be different.

Delmia by Dassault Syste?mes (www.3ds.com accessed 28 May 2012) was selected from all the simulation tools studied. The academic version of Delmia comes with two packages: Quest for workflow modelling and simulation and human ergonomics simulator. Quest offers a 3D environment for process flow simulation, analysis and optimisation. The human ergonomics package allows having life-like human models to simulate tasks and analyse postures for a better understanding of the activities that are being performed. Although Delmia is general purpose software oriented mainly to the manufacturing industry, numerous examples can be found where Delmia has been used for workflow analysis in health care systems such as the trauma operating unit of the Helsinki University Central Hospital (Marjamaa *et al.*, 2008) or the trauma orthopaedic department at the Skaraborg Hospital in Sweden (Moris, 2010).

Figure 1 shows two of the 3D models we have implemented with Delmia Quest: one of the angiography rooms of the clinical radiology department in Ninewells Hospital (Dundee, UK) and the facilities at the Institute for Medical Science and Technology (IMSaT) in Dundee, UK. The layout available at IMSaT, dedicated for research, shows two rooms, one as an intervention room with X-ray and the other with a 1.5 Tesla MRI scanner, separated through a sliding door. This model will be useful to test new procedures under multi-modal image guidance.

4.2 MIDAS: medical interventional data analysis system

As outlined before a database and web site were implemented to facilitate efficient data submission and management. The web application is called Medical Interventional Data Analysis System (MIDAS) and is in its second major version. Implementation of a desktop software application instead of a web interface was considered but rejected due to some of the possible disadvantages such as incompatibility among operating systems and probable restrictions on the installation on certain computers (e.g. in hospitals). Figure 2 shows on the left a partial view of a completed record and on the right an analysis. The web pages dealing with the analytics are a recent update, and the first step towards a descriptive statistical analysis tool. This preliminary version shows the mean and the standard deviation of a set of timings associated with an interval indicated by the user. The graph provides a quick visual tool of the range of timings associated with that interval. This version also allows selection of procedure by type, to filter that dataset by type of device used. The web site is user friendly, as the forms resemble the template for manual collection, and it works in all major browsers. Other adds-in are validation of data during the submission and auto complete feature in most of the form fields. Users can access and modify previous records until marked as complete; the administrator is then updated and maintains privileges for modifying records even when marked as completed.

4.3 Conceptual workflow modelling for IAS

Percutaneous angioplasty and stenting is a technique widely used to treat iliac artery occlusion. The procedure starts with the placement of a sheath introducer to facilitate catheter exchanges, usually through the femoral artery. Then, the occlusion area is crossed using a combination of catheters and guidewires. In the case of total occlusion, an antegrade approach from the contralateral femoral artery is performed. Once a

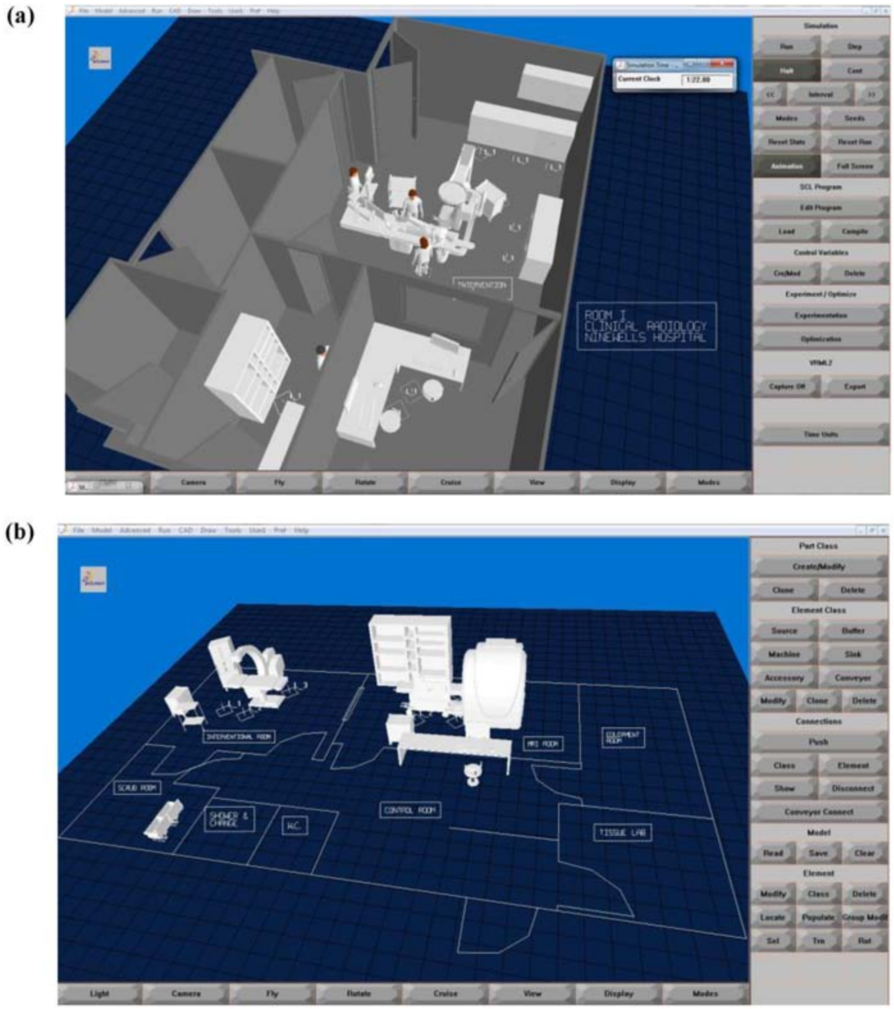

Figure 1.
(a) Schematic view of angiography room at the clinical radiology department in Ninewells (Dundee, UK) (b) multipurpose MRI and Surgical Suite at IMSaT facilities

Note: Both models implemented in Delmia Quest

guidewire has crossed the lesion and lies in the external iliac artery lumen, the clinicians (radiologist) select the appropriate balloon catheter or stent diameter to treat the occlusion. The balloons are used to dilate the lesion applying enough pressure for the artery to remain open. In the case of the stents, they are implanted permanently in the vessel maintaining open (Brountzos and Kelekis, 2004).

In Figure 3, the standard procedure of IAS is described together with the main types of supplies that are used in each phase. This description takes into account the possible treatments of the disease, balloon catheter, self-expanding stents or balloon-expanding stents, and the way they are performed during the intervention. Fluoroscopy images are taken for the guidance of the devices during the procedure. In addition, some of the main blocks of the process description, can be divided into sub-activities such as the

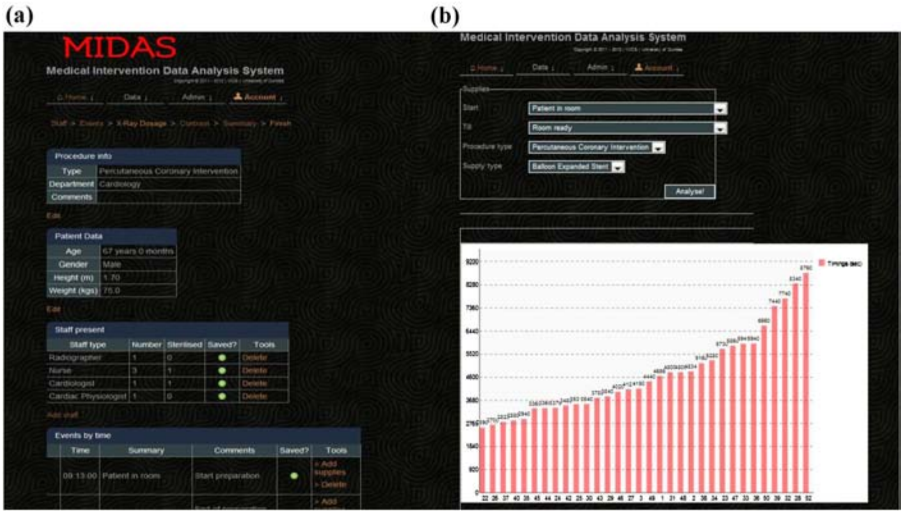

Figure 2.
(a) Partial view of a completed record (b) analysis web page with graph

sheath introducer placement that involves, for example, to use US in the area of incision to visualise the femoral artery.

Although this might be seen as a complete description of the IAS, it does not take into account the interactions of the different types of medical staff and their roles during the interventions. Figure 4 shows an RAD for a standard procedure of stent implantation, based in observation and data collected from peripheral angioplasties and stentings, e.g. IAS. From the observations, usually four persons participate in the intervention. The radiologist is the medical doctor that performs the procedure, helped first hand by a sterilised nurse, known as scrub nurse in some cases that deals with the devices and rest of instruments placed in a trolley. A second nurse, known usually as circulating nurse, assists the radiologist and the scrub nurse in anything they need that is not in the trolley apart from other tasks such as checking periodically the patient's monitor. The radiographer is the figure that operates the C-arm, the X-ray generator and detector equipment, changing the position or type of image acquisition as required during the intervention. The radiographer is also in charge of the registration of images and X-ray dose in the patient's record once the procedure has finished.

This conceptual modelling of the workflow allows identifying easily phases (events) and interactions among entities (clinicians and patients). Therefore, it facilitates the later implementation of the model using DES technique. The analysis tool added to MIDAS web site allows calculating the time intervals for each event and for each patient record. MIDAS can calculate the statistical distribution associated to an event when a particular procedure is chosen from the database.

5. Discussion and conclusions

This paper provides a framework for analysis and modelling of workflow for simulation of image-guided interventions. The framework has included a literature review, a simulation software assessment, a data gathering and management framework and a review of techniques for conceptual modelling of the workflow. Although, the project focuses on endovascular and cardiovascular procedures, the

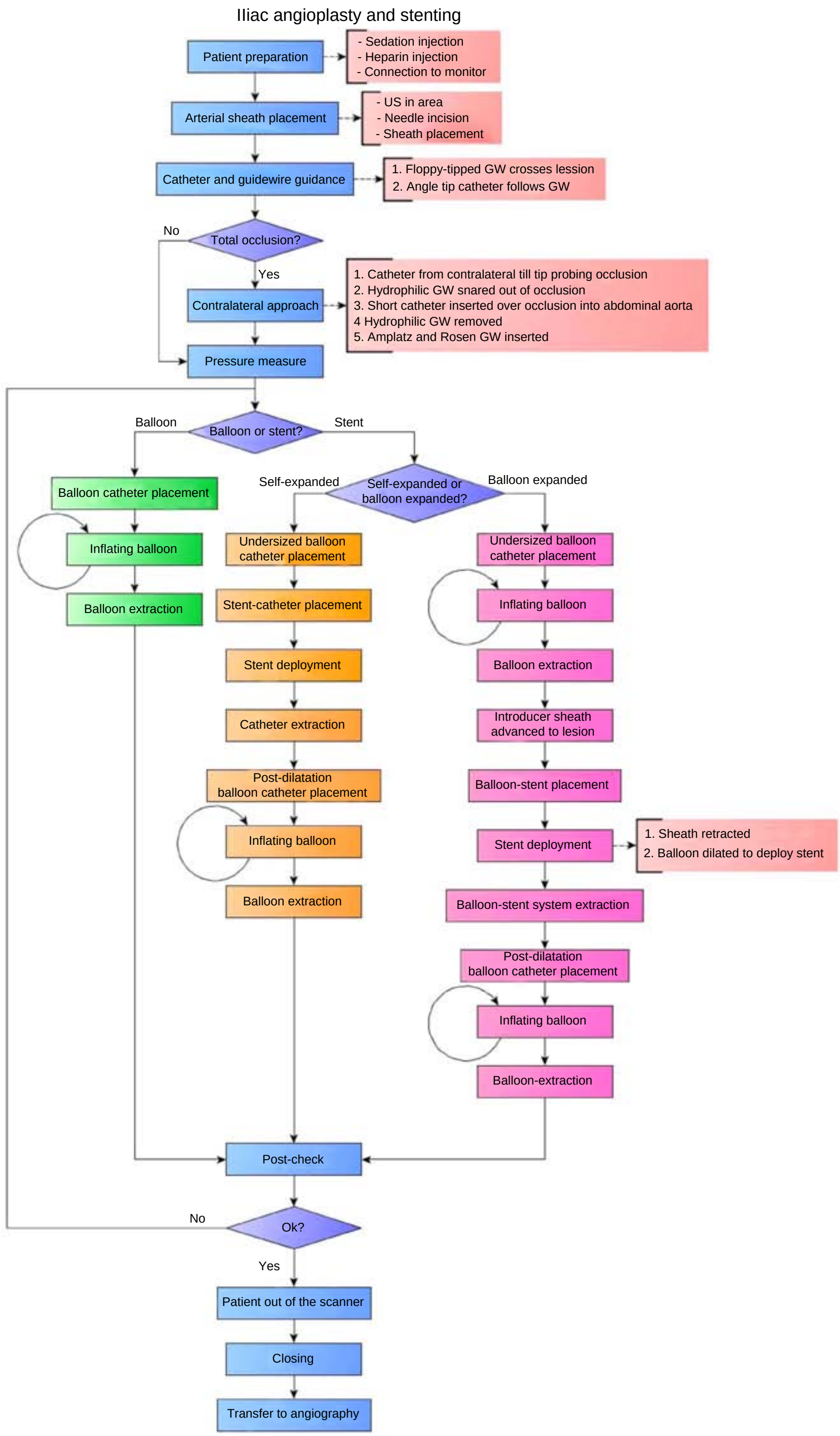

Figure 3.
Flow diagram of an iliac angioplasty/stenting procedure

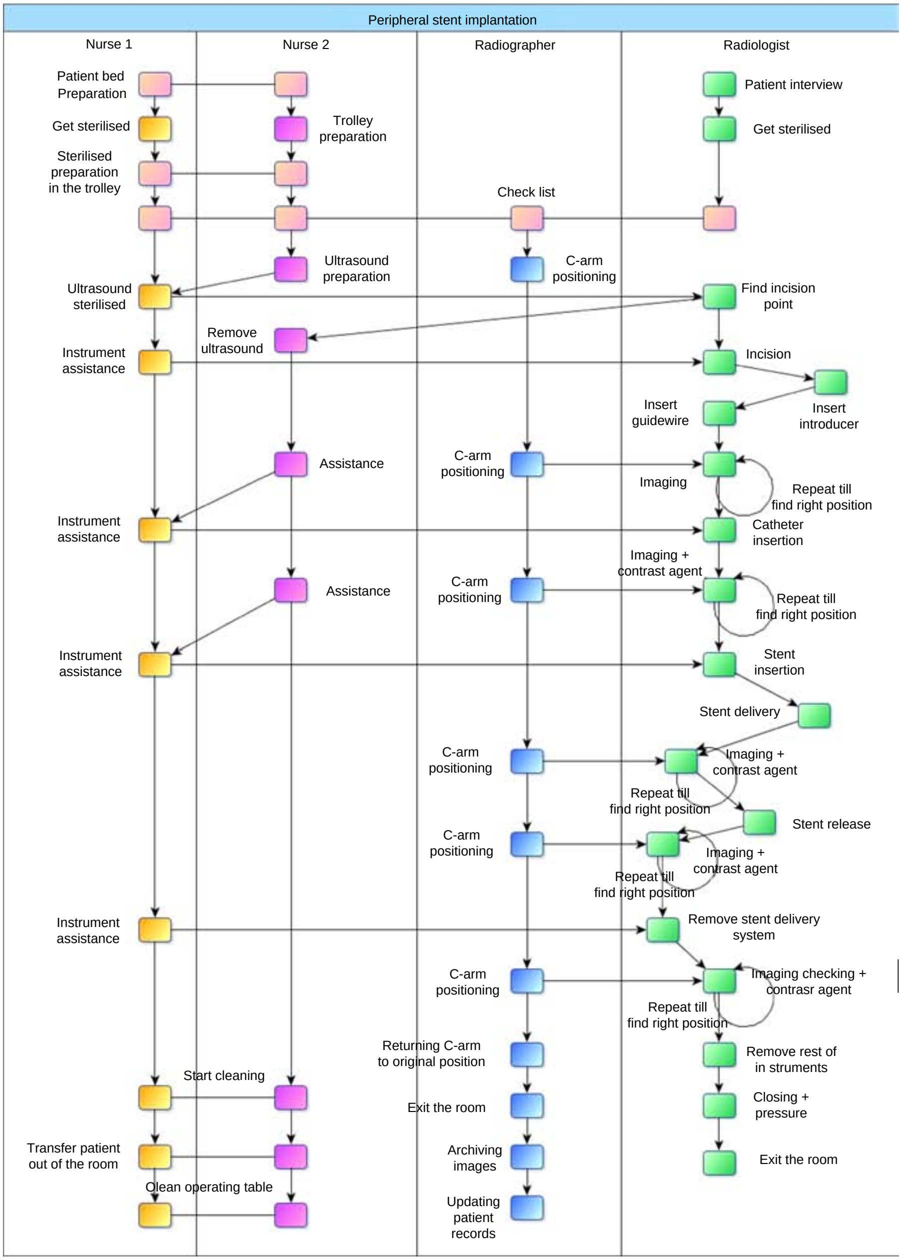

Figure 4.
RAD of a standard stent implantation procedure

framework can be extended to image-guided procedures in general. The methodology applied not only allows a detailed study of current radiological scenarios, but also aids in the development of new procedures in a multi-modal imaging environment.

Literature review revealed that previous studies only provided tools for detailed characterisation of processes in the cases where the number of instruments and equipment are limited and well defined (Padoy *et al.*, 2010). This has been one of the challenges to overcome in this research. Moreover, differences in the execution of the procedures were observed in each of the hospital centres collaborating, which increased the difficult of the data collection. This is managed in the web application described, which has the ability to manage heterogeneous data. In addition, the importance of describing in detail the workflow in health environments, whether it is an emergency department or a surgical suite, lies in trying to understand better the process in order to find bottlenecks in the flow. Then, the workflow can be improved through optimisation tools applied to the alternatives proposed by the experts in the field, which in health systems would be the clinicians involved.

The ultimate goal of this project is the development and optimisation of new complex procedures under a multi-modal image guidance. The integration of different imaging techniques such as MRI, X-ray, PET/CT or US during a procedure implies a large number of safety issues, ergonomics, compatibility and requirements for the rooms, the equipment and the personnel. Many hospitals are trying to implement different installations for multi-modal IGP. Several of the different layouts are being analysed within this project. For instance, the Clinical Research Centre (CRC, Dundee, UK) that has a PET/CT scanner room and a MRI scanner room, both connected through an interventional room. In addition, the already mentioned IC (Oslo, Norway) which has a high-tech intervention room, and a two-room layout consisting of an OT provided with angiography and US equipment, with an MRI room, connected through a sliding door. This layout is similar to the IMSaT one, which as a research environment, provides a useful layout to test and verify workflow models for new procedures. A similar installation with MR and angiography suite has recently been opened at our partners' site at University Hospital Homburg Saar (Homburg, Germany).

Data from the centres mentioned have been collected and analysed. This paper has concentrated in the qualitative aspects of the analysis and the quantitative analysis of simulations will be presented in future papers. The next steps for the project include the implementation of the scenarios where the data has been collected. The simulation of procedures in a realistic 3D version of the real intervention rooms will help to verify that the collection of the data has led to accurate representations of those interventions.

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