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VOLUME II

Session 6 - Environmental Systems: Management and Optimisation
Session 7 - New Methods and Technologies for Medicine and Biology
Session 8 - Embedded System Design and Application
Session 9 - Image Processing, Image Analysis and Computer Vision
Session 10 - Mobile Communications
Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

Table of Contents

C O N T E N T S

7 New Methods and Technologies for Medicine and Biology

8 Embedded System Design and Application

10 Mobile Communications

11 Education in Computer Science and Automation

T. Neumuth / A. Pretschner / O. Burgert

Surgical Workflow Monitoring with Generic Data Interfaces

Introduction

During the next years the digital operating room (DOR) and its future requirements will emerge and influences the technical development in the medical engineering field [1]. Workflow management systems (WfMS) supporting the data flow between surgical assist systems (SAS) during the surgical treatment of the patient are strongly involved in the future scenarios. WfMS can contribute to intraoperative interventions by synchronizing the surgical treatment of the patient with surgical process models (SPM) [2, 3] and by providing the relevant parts of patient models. The SPM represent knowledge of the general treatment support and the support of patient specific surgical decisions.

Due to the multiplicity of operating room equipment, and thus multiple heterogeneous data sources, no unique methodology for the acquisition, storage and analysis of data in operating rooms was established in practice. The already available data structures and communication protocols originate from the field of Picture Archiving and Communication Systems (PACS) related to radiology, and are standardized in DICOM [4], an ISO-standard for the description and exchange of images that aims at the interoperability of vendor-specific PACS systems. The DICOM-standard is currently extended for the use in surgical scenarios, currently ongoing as *Surgical-DICOM*-developments [1, 5].

One emerging issue related to WfMS is the situational awareness in the OR [1]: The WfMS has to recognise which part of the surgical procedure is being performed at the moment, and which parts have already been performed.

The definition of generic interfaces to the surgical workflow monitoring system and the connection to the peripheral systems are essential. Both of them are caused by the integration efforts for the infrastructure in the operating room and the need for workflow monitoring on a higher abstraction level during surgical interventions.

The objective of this publication is the proposal of a subpart for the infrastructure for the integration of device-specific metadata and higher-level sensor data into the Surgical

Workflow monitoring system offering a generic interface to the process.

Infrastructural Scenarios and Use Case

Currently, the interoperability between SAS in operating rooms is very limited. Existing network capabilities are restricted either to data transfer capabilities such as DICOM, or to vendor specific conformance initiatives for interfaces between a few number of devices such as tracking and navigation devices. The existing infrastructure cannot be used for surgical workflow monitoring because of missing interfaces and networking capabilities of the systems.

Lemke and Vannier [1] proposed a Therapy Imaging and Model Management System (TIMMS, cf. Fig. 1) for the digital operating room (DOR). The functional support of model guided therapy and the added user value originating from advanced networking capabilities are essential to this infrastructure.

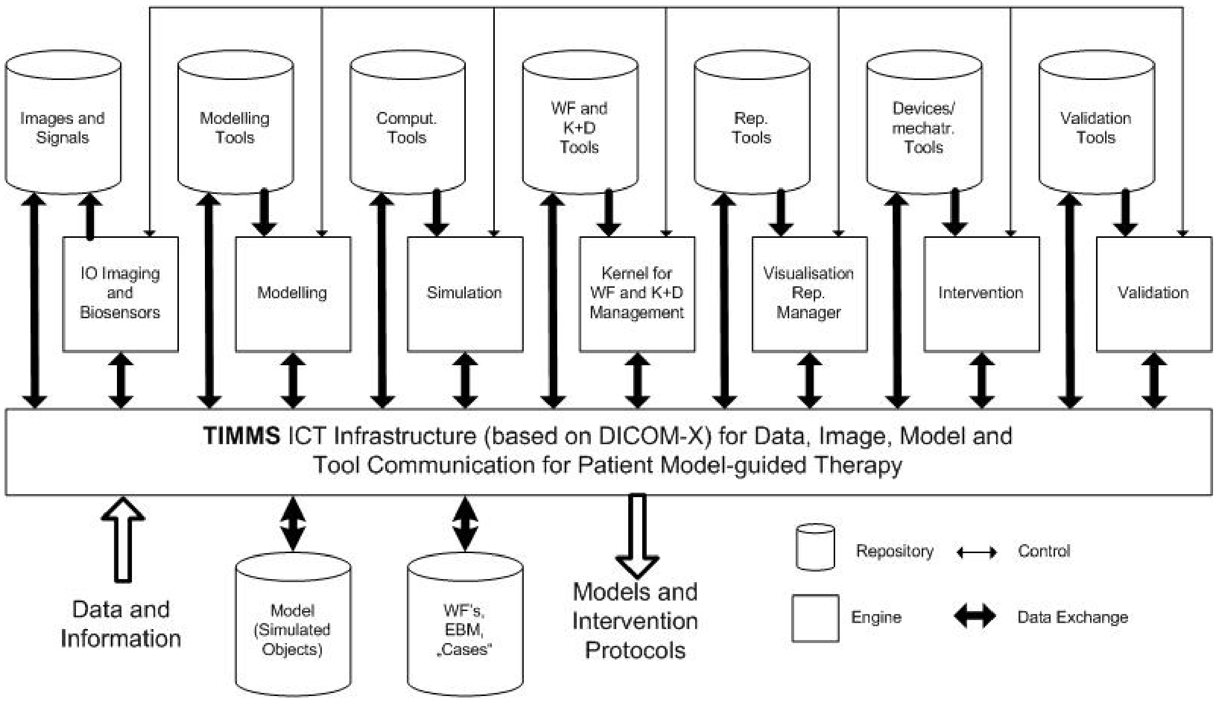

Figure 1: Therapy Imaging and Model Management System (TIMMS) [4]

One functional unit of the TIMMS infrastructure should be a module providing situational awareness [1]. For an intraoperative treatment this can be realized by a surgical workflow monitoring system.

The surgical workflow monitoring system receives messages from peripherally distributed sensor systems and relates them to one another to form a higher description context of the surgical treatment. The methodology is based on a structured transfer of metadata from stand-alone devices into the Surgical Workflow Monitoring system. Metadata designates the capabilities and interfaces of devices as well as (higher level) parameters and data types.

A simplified cut-out from the TIMMS infrastructure is shown in Fig. 2. To illustrate the cooperation of a surgical workflow monitoring system with the peripheral equipment in the OR, we present our approach with a use case of platform-variant tracking devices. The use case example adds distribution capabilities to situation recognition approaches such as proposed in [6, 7]. In the surgical workflow both approaches aim at the detection of phases based on machinery sensory data. The low level tracking data are obtained by sensor systems and need to be interpreted in a higher context. The decision which data have to be transferred over the network relies on the design of the overall system.

For the example set-up shown in Fig. 2 the following communication scenarios are possible:

1. Non-interpreted low-level sensory data are transmitted from the tracking device to the surgical workflow monitoring system and they are integrated into the actual surgical process model.
2. Non-interpreted low-level sensory data are transmitted from the tracking device to the reasoner and interpreted by the reasoner.
3. Interpreted higher level data are transmitted from the reasoner to the surgical workflow monitoring system and are integrated into the surgical process model.

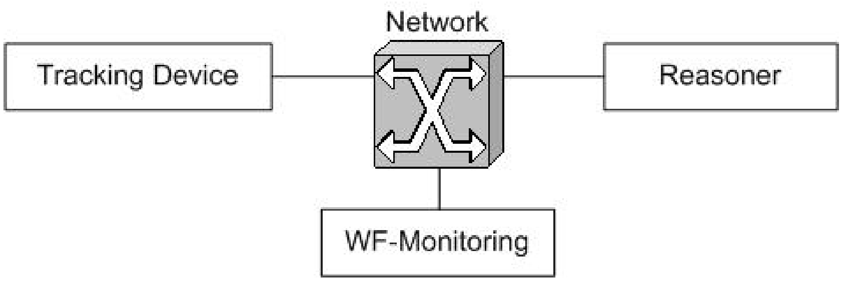

Figure 2: Infrastructural Scenario for Surgical Workflow Monitoring

Although it is possible to transmit non-interpreted low-level sensory data to the monitoring system, it is not useful in every case. A motion tracking system monitoring the movement of an instrument in the surgeons main working hand might either transmit detailed data of the x-/y-/z-trajectories over time or just the context “cutting from … to …” that was interpreted by the reasoner. To transmit abstracted data such as the context would require reasoning capabilities of the tracking system. If no reasoning capabilities are available, the low level sensor data might be transmitted to a reasoning module in the same or different network, interpreted, and then transferred into the monitoring system. In the latter case, one more component participates in the “process chain”.

Technical Approach to Solution

The proposed use case demands a high flexibility originating from the multiple roles every participating system can play. Units need to behave as clients or servers, for some scenarios as both. The high complexity requires the use of established technologies.
A technical approach designed for this challenge is OPC Unified Architecture [8]. OPC stands for *Object Linking and Embedding for Process Control* and was formerly based on the Microsoft component model (COM/DCOM). OPC Unified Architecture (OPC UA) is a platform independent standard for the communication of a multitude of systems and applications. Servers and clients are able to communicate beyond network environments. OPC UA defines service groups that are placed at disposal by a server which can furthermore be supported by clients. The specification of OPC UA especially emphasizes the independence of platforms and operating systems. A special communication interface enables server/client communication as well as a communication amongst various servers. The OPC UA server application programming interface (API) and the OPC client API divide the client and the server application on the one hand, and the communication stack on the other. Thereby, a high level of modularity is made available to the user. OPC - UA allows for the choice of the protocol: if both devices support OPC, than the binary protocol might be chosen; if that is not the case, one can fall back on Simple Object Access Protocol (SOAP). The interface lies underneath the user program and it is implemented via software. Due to this fact, it does not compete with field bus systems such as PROFIBUS or CAN, but combines application programs and sub-assembly drivers. The fact that the protocol between clients and servers can be chosen as binary protocol or web-service provides the system engineer with advanced design opportunities. Thus, the decision of using only pure middleware approaches such as Remote Procedure Calls (RPC), Common Object Request Broker Architecture (CORBA), Component Object Model (COM/DCOM), or Java Remote Method Invocation (Java RMI) or a pure web-services solution such as Simple Object Access Protocol (SOAP) turns into a choice for combining the advantages

of both worlds. The design choice relies especially on the required flexibility, advanced networking for passing firewalls, and the time-criticalness of transmission.

Conclusions

The operating room of the future has a need for enhanced inter-device communication. Surgical Workflow Monitoring systems for high-level monitoring and data collection will become an important future part of the OR. These systems need to deal with a variety of devices, messages, and processes.

We propose the use of OPC UA as Service Oriented Architecture for Surgical Workflow Monitoring systems. The use of OPC UA enables the implementation of a standardized software interface for data exchange between applications of different vendors. OPC services can be extended to any platforms with XML and HTTP support as web service. Complementary to OPC UA several technologies necessary for networked ORs can be applied from already existing device description languages such as Field Device Tool (FDT) or Electronic Device Description Language (EDDL) [9]. That would also contribute to an integration of devices. Furthermore, a uniform interface for data acquisition and data analysis is available to the Surgical Workflow Monitoring system via OPC UA.

The approach highlights the abstraction of the device- and vendor-specific operating systems. That has several consequences, such as the unification of the heterogeneity of the used computer platforms; the concealment of the distribution of applications due to local transparency and uniform namespaces; and basic mechanisms for distribution, such as directory service, tracing service, and interface adoption.

The application is only achievable by agreement of different manufacturers. The design of the boundary conditions should reach two aims: on the one hand it should ensure the specific internal know-how of the manufacturers and on the other hand the surplus value of this new interface should lead to increased user value or saving of expenses.

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