Artificial Intelligence in Medicine 62 (2014) 153–163

Contents lists available at ScienceDirect

Artificial Intelligence in Medicine

journal homepage: www.elsevier.com/locate/aiim

Operation room tool handling and miscommunication scenarios: An object-process methodology conceptual model

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ARTICLE INFO

Article history:
Received 26 December 2013
Received in revised form 15 October 2014
Accepted 23 October 2014

Keywords:
Surgical robots
Concept formation
Conceptual modeling
Operative surgical procedures
Process model

ABSTRACT

Objective: Errors in the delivery of medical care are the principal cause of inpatient mortality and morbidity, accounting for around 98,000 deaths in the United States of America (USA) annually. Ineffective team communication, especially in the operation room (OR), is a major root of these errors. This miscommunication can be reduced by analyzing and constructing a conceptual model of communication and miscommunication in the OR. We introduce the principles underlying Object-Process Methodology (OPM)-based modeling of the intricate interactions between the surgeon and the surgical technician while handling surgical instruments in the OR. This model is a software- and hardware-independent description of the agents engaged in communication events, their physical activities, and their interactions. The model enables assessing whether the task-related objectives of the surgical procedure were achieved and completed successfully and what errors can occur during the communication.
Methods and material: The facts used to construct the model were gathered from observations of various types of operations miscommunications in the operating room and its outcomes. The model takes advantage of the compact ontology of OPM, which is comprised of stateful objects – things that exist physically or informatically, and processes – things that transform objects by creating them, consuming them or changing their state. The modeled communication modalities are verbal and non-verbal, and errors are modeled as processes that deviate from the "sunny day" scenario. Using OPM refinement mechanism of in-zooming, key processes are drilled into and elaborated, along with the objects that are required as agents or instruments, or objects that these processes transform. The model was developed through an iterative process of observation, modeling, group discussions, and simplification.
Results: The model faithfully represents the processes related to tool handling that take place in an OR during an operation. The specification is at various levels of detail, each level is depicted in a separate diagram, and all the diagrams are "aware" of each other as part of the whole model. Providing ontology of verbal and non-verbal modalities of communication in the OR, the resulting conceptual model is a solid basis for analyzing and understanding the source of the large variety of errors occurring in the course of an operation, providing an opportunity to decrease the quantity and severity of mistakes related to the use and misuse of surgical instrumentations. Since the model is event driven, rather than person driven, the focus is on the factors causing the errors, rather than the specific person. This approach advocates searching for technological solutions to alleviate tool-related errors rather than finger-pointing. Concretely, the model was validated through a structured questionnaire and it was found that surgeons agreed that the conceptual model was flexible (3.8 of 5, std = 0.69), accurate, and it generalizable (3.7 of 5, std = 0.37 and 3.7 of 5, std = 0.85, respectively).
Conclusion: The detailed conceptual model of the tools handling subsystem of the operation performed in an OR focuses on the details of the communication and the interactions taking place between the surgeon and the surgical technician during an operation, with the objective of pinpointing the exact circumstances in which errors can happen. Exact and concise specification of the communication events in general and the surgical instrument requests in particular is a prerequisite for a methodical analysis of the various modes of errors and the circumstances under which they occur. This has significant potential value in

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http://dx.doi.org/10.1016/j.artmed.2014.10.006

both reduction in tool-handling-related errors during an operation and providing a solid formal basis for designing a cybernetic agent which can replace a surgical technician in routine tool handling activities during an operation, freeing the technician to focus on quality assurance, monitoring and control of the cybernetic agent activities. This is a critical step in designing the next generation of cybernetic OR assistants.

1. Introduction

Verbal and non-verbal miscommunications have a critical effect on the surgical outcomes of a procedure, sometimes being the direct cause of errors, inefficiencies and delays during the operational process. While other high-risk/high-stake disciplines, such as aviation, have adopted methods for systematic characterization and identification of communication errors, healthcare still lags behind in this regard. In the operating room (OR), aspects of communication events that have been observed include the content of the communication, the modality in which the communication is presented (gestures, verbally or implicit), and its direction, i.e., who the initiator and the recipient of the event are. The primary goal of this study is to define and characterize these communications events, through a conceptual model, so insights can be used to streamline certain aspects of the tasks in the OR. The final objective of this work is to use a well-defined conceptual model to re-assign mechanistic tasks to cybernetics solutions to enhance overall efficiency and safety during surgical procedures [1]. Since the analysis of communications events is too broad and complicated, the focus of this paper is about modeling the communication events around the handling of surgical equipment.

Modeling communication events in the OR is complicated since there is not a clear standard about how the communications need to be conveyed, it is highly cultural and biased by the members of the surgical team. Moreover, additional factors shape the communication such as the patient's condition, workload, time-pressure, individual skills and the equipment setting. These types of events may be evoked by any member of the surgical team (e.g. resident, a scrub nurse, a circulation nurse, an anesthesiologist, and a surgical technician) through a number of modalities, including explicit (e.g. verbal, gestures, proxemics, gaze) or implicit (prediction). In such an uncontrolled setting, a conceptual model will allow gaining insights about communication exchanges and how/when mistakes occur.

Automated solutions are increasingly being use to support surgical tasks, and are meant to improve the quality of patient care and reduce costs, while improving the patient's well-being. Recently some of the automation based technologies explored the feasibility of replacing certain mechanistic tasks occurring frequently in the OR. These tasks are initiated by verbal or non-verbal commands, or are a result of some type of communication exchange among the surgical team. Having a machine responding to communication events may be difficult, as is applying a ballistic sequence of actions to a specific surgical procedure. A conceptual model based cybernetic system has the potential to address this problem. A prerequisite for developing such as system is developing computer interpretable representation of all the forms of communications exchanges contained in surgical procedures.

Effective integration of automation into the OR can potentially reduce the number of communication problems. For example, by placing in the OR a robot which can recognize and interpret the voice and gesture commands of the surgical team, and predict the required tool, the length of verbal communication chains in the OR could be reduced. Some major benefits might be shortening of procedure time, reducing surgeons' cognitive load, monitoring the use of instruments, and avoiding retention of surgical instruments within the patient's body. However, there are challenges with implementing a cybernetic solution of this nature. First, communication among the members of the surgical team is complex, involving verbal and non-verbal forms of communication. While speech recognition algorithms have shown recognition performance over 95%, there are still neither satisfactory technologies nor algorithms that can deliver performance comparable to using gaze, gestures and body interaction. Second, robots would need to have performance that is comparable to human surgical technicians in terms of such parameters as speed, prediction of action, and response to unexpected situations.

To address an important part of the human–machine communication challenge, we have characterized and modeled the communication involving instrument handling between surgeons and the surgical staff via both verbal and non-verbal modalities. In this paper we present and discuss the conceptual model which encompasses the structure and behavior of an operation carried out in an OR with focus on surgical tool handling. The model can serve as a baseline for eliciting requirements of an automated cybernetic solution to tool handling in the OR and designing a robotic system that shall meet these requirements. Thus, the conceptual model presented in this study has a direct application to automation of delivery, retrieval, disposal and tracking of surgical instruments. This conceptual model is implemented through Object-Process Methodology (OPM) [2], a conceptual modeling language and approach which is currently in final process of becoming ISO 19450 Publically Available Specification and ISO standard. In this modeling environment, communication events around the use of instruments are modeled as objects, processes and relations between them. The outcomes, potential pitfalls and overall assessments, together with two observational case studies are discussed in the rest of this paper.

2. Background

Errors in the delivery of medical care are the principal cause of inpatient mortality and morbidity, accounting for some 98,000 deaths annually. Ineffective team communication is often at the root of these errors [3–7]. Recent research assessing verbal and non-verbal exchanges in the operating room (OR) has shown that communication failures are frequent; commands are delayed, incomplete, or not received at all, and frequently left unresolved [3]. Firth-Cozens [4] found that 31% of all communications in the OR represent failures, a third of which had a negative impact on the patient. Halverson et al. [5] found that 36% of communication errors were related to equipment use. Some causes of these errors are team instability, e.g., nurses and surgeons that hardly know each other [8], lack of resources, which results in minimal staffing, and distractions. Poor communication among the surgical team can result in higher likelihood of instrument count discrepancies, which can point to surgical instruments retained in the patient's body, among which sponges and towels are the most common [9]. Research conducted in this area so far has focused on the development of taxonomies and modeling tools to describe verbal communications in the OR. For example, Moss and Xiao [10] captured communication patterns in the OR to characterize the information needs for OR coordination using verbal