Opinion Paper

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The next step: intelligent digital assistance for clinical operating rooms

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Abstract: With the emergence of new technologies, the surgical working environment becomes increasingly complex and comprises many medical devices that have to be taken cared of. However, the goal is to reduce the workload of the surgical team to allow them to fully focus on the actual surgical procedure. Therefore, new strategies are needed to keep the working environment manageable. Existing research projects in the field of intelligent medical environments mostly concentrate on workflow modeling or single smart features rather than building up a complete intelligent environment. In this article, we present the concept of intelligent digital assistance for clinical operating rooms (IDACO), providing the surgeon assistance in many different situations before and during an ongoing procedure using natural spoken language. The speech interface enables the surgeon to concentrate on the surgery and control the technical environment at the same time, without taking care of how to interact with the system. Furthermore, the system observes the context of the surgery and controls several devices autonomously at the appropriate time during the procedure.

Keywords: intelligent operating assistance; natural spoken language; operating room of the future (ORF); surgical environment; voice interaction system.

Introduction

In his article "Digital communications and social media use in surgery – how to maximize communication in the digital age", M.S. Karpeh has impressively demonstrated how digital technology is changing the way surgeons communicate with colleagues and patients to the benefit of both the caregivers and the patients [1]. Nonetheless, digitalization is not only confined to human communication. The next step is the direct dialogue between humans and machines. Up to now, interaction with devices is mostly mechanical: pushing a button or writing commands. Most probably, this will be substituted soon by directly addressing the machine by voice.

For humans, speech is one of the most intuitive and most natural ways to communicate. Speech control provides a significant simplification when using an application, as no hands or eyes are needed anymore [2]. Therefore, scientists and engineers aim to realize methods and systems that enable not only interpersonal communication but also interaction with machines through natural spoken language. Today, we are able to communicate with various computer applications via speech and research focuses on user-adaptiveness to enable more natural and human-like dialogues (e.g. [3, 4]).

Until now, the whole topic has only been scarcely researched in medical applications, although the benefits seem obvious. In surgery, the operating room (OR) is the most value-creating factor. However, being the most cost-intensive and complex one as well, any effort in research in digital assistance for the OR is justified [5]. With the emergence of new technologies, the surgical working environment becomes increasingly complex and comprises many medical devices that have to be monitored and controlled. However, the goal is to reduce the workload of the surgical team to allow them to fully focus on the actual surgical procedure. Therefore, new strategies are needed to keep the working environment manageable. In this context, the OR of the future (ORF) is a keyword often used [6]. It describes the application of new technologies such as computer-enhanced systems to create an intelligent OR [7] that facilitates work and reduces the staff needed to assist during a surgical intervention. This reduces personnel cost and promises to lessen the rate of avoidable incidents caused by human error.

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During a procedure, the surgeon needs his hands to operate on the patient and his eyes for being aware of what he is doing. Furthermore, the surgeon as well as the whole surgery team must not be disturbed by the usage of complex interfaces. Therefore, the human-computer interface has to be designed simple and intuitive [8]. Thus, any graphical and gesture-based systems are not well suited for this purpose. Being hands- and eyes-free, speech turns out to be the modality of choice. Moreover, speech is the modality used by the surgeon to communicate with their staff. Therefore, using speech to control the technical devices does not pose an additional mental burden. The surgeon can focus on the surgery and control the technical environment at the same time without taking care of how to interact with the system. Enabling the operating surgeon to control devices inherent to the OR by himself reduces the staff needed to assist during a surgical intervention.

Voice interaction systems

Apple's Siri, Amazon's Alexa, Microsoft's Cortana, Google Now and other virtual assistants have become a firm part of everyday life. Bager [9] reported that there has been a significant development in computing science and voice interaction systems. The current digital assistants not only answer user questions via speech but also provide information autonomously and user-oriented. The systems hear and reply in native tongue using a friendly voice and combine the user's available data automatically with contextual knowledge of linked databases. However, until now, the aforementioned virtual assistants only follow a question answering paradigm and do not focus on intelligent interaction over a longer period of time. If the user asks a question, the system combines available data and tries to respond to the user's inquiry. After the system's response, the user can start further requests but not related to the preceding query. This means that there is no coherent dialogue over several dialogue turns but only single system-user exchanges. In contrast, the aim of our system for intelligent voice interaction is to track the complete interaction during the ongoing surgery, recognize the user's context and react accordingly through intelligent subdialogues and proactive interventions. An example for a spoken dialogue system allowing adaptive dialogues over several dialogue turns and representing the state-of-the-art in research is the OwlSpeak Dialogue Manager, which has been developed for intelligent environments by Heinroth et al. [10] and further extended by Ultes and Minker [11].

Voice interaction in the OR

Our goal is to develop an intelligent system that takes care of the surgical environment. To increase the productivity and reduce the workload of the operating staff, it ought to act active-cooperatively and support the surgeon autonomously during the procedure. From our point of view, the system should escort the surgery team throughout the whole procedure and provide assistance where necessary.

We have developed the concept of intelligent digital assistance for clinical ORs (IDACO). Its main functionalities include:

- providing data about surgery type, session team, general patient data, pre-diseases, medical treatment and laboratory data;
- saving preferred device settings for each surgeon, reading and changing the pre-settings, as well as transmitting the parameters to the devices (e.g. OR table, room light, insufflator, suction and irrigation unit);
- automatically controlling surgical devices (e.g. starting the insufflator, increasing the gas insufflation, turning off and on the light and tilting the table);
- tracking the usage of several materials (e.g. trocars, different types of clips and suturing material) and warning if the usage differs from the schedule; and
- emergency mode for unforeseen incidents during a procedure, which allows furthermore the option of a "silent mode" to prevent further distractions by the system.

Technical requirements for voice interaction in the OR

Enabling an intelligent operating assistance system to follow a surgery and control surgical devices automatically bears several challenges.

First of all, modules for automatic speech recognition (ASR) and text-to-speech synthesis (TTS) in medical applications need to be developed, supporting the full range of medical and surgical vocabulary. Common ASR and TTS modules are not trained for such specific applications.

Moreover, for keeping track of the procedure and automatically controlling surgical devices, the system needs to know when to perform which action on which device and when to stay in the background. Therefore, it has to be aware of the whole context of the surgery, i.e. the current point of the procedure, all past and future actions. At every point of the procedure, the system needs all relevant information to infer whether the surgery goes as

scheduled or not. This means that developers have to find a reliable method for tracking the course of the surgery, thus allowing to detect unscheduled events during the procedure. Moreover, it has to be clear how the system is supposed to react in tenuous situations. For this purpose, standardized surgeries need to be modeled in detail, allowing the system to compare the actual course of the procedure to the schedule [12]. Using this medical domain knowledge, rather exact models of the complex surgery structure need to be created, which can be applied by the voice interaction system. However, the multitude of existing surgical procedures makes it impossible to implement each one individually. Consequently, the goal is to find a generic method for modeling the surgery control.

Finally, an interface needs to be designed and implemented, which allows intercommunication between the voice interaction system and the surgical devices as well as the clinical information system. More precisely, the interface has to allow accessing necessary data such as surgery type and session team as well as patient data including pre-diseases, medical history and laboratory data. Moreover, the actual controlling of surgical devices such as the OR table, OR lights and peripheral devices (e.g. insufflator and electrosurgical instrument) needs to be enabled. Hereby, regulatory concerns will pose a way bigger barrier than the technical possible implementation.

Conclusion

We present the concept of a voice interaction system for the OR that enables speech-based communication with an intelligent OR. To the best of our knowledge, the presented scheme is the first intelligent spoken language operation assistant, putting together several functionalities that provide the surgeon assistance in many different situations before and during an ongoing procedure.

Using a speech interface, the surgeon can concentrate on the surgery and control the technical environment at the same time, without taking care of how to interact with the system. The aim of our system is to assist during the preparation for the surgery and escort the operating staff through the entire surgery. The system listens to each of the surgeon's instructions and compares the observed course of the procedure to the surgery schedule. In case of a deviation from the schedule, it reacts proactively and thus acts as a human-like assistant in an intelligent surgical environment.

Author Statement

Research funding: Authors state no funding involved. Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent is not applicable. Ethical approval: The conducted research is not related to either human or animals use.

Author Contributions

Juliana Miehle: Conceptualization; Investigation; Methodology; Project administration; Software; Writing – original draft. Daniel Ostler: Conceptualization; Methodology; Writing – original draft. Nadine Gerstenlauer: Investigation; Methodology; Software; Writing – original draft. Wolfgang Minker: Conceptualization; Supervision; Writing – review and editing.

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Supplemental Material: The article (https://doi.org/10.1515/iss-2017-0034) offers reviewer assessments as supplementary material.

Reviewer Assessment

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Reviewers' Comments to Original Submission

Reviewer 1: anonymous

Jul 14, 2017

Reviewer Recommendation Term:	Accept
Overall Reviewer Manuscript Rating:	100

Custom Review Questions	**Response**
Is the subject area appropriate for you?	4
Does the title clearly reflect the paper's content?	5 - High/Yes
Does the abstract clearly reflect the paper's content?	5 - High/Yes
Do the keywords clearly reflect the paper's content?	4
Does the introduction present the problem clearly?	4
Are the results/conclusions justified?	4
How comprehensive and up-to-date is the subject matter presented?	5 - High/Yes
How adequate is the data presentation?	N/A
Are units and terminology used correctly?	N/A
Is the number of cases adequate?	N/A
Are the experimental methods/clinical studies adequate?	N/A
Is the length appropriate in relation to the content?	5 - High/Yes
Does the reader get new insights from the article?	5 - High/Yes
Please rate the practical significance.	4
Please rate the accuracy of methods.	N/A
Please rate the statistical evaluation and quality control.	N/A
Please rate the appropriateness of the figures and tables.	N/A
Please rate the appropriateness of the references.	5 - High/Yes
Please evaluate the writing style and use of language.	4
Please judge the overall scientific quality of the manuscript.	4
Are you willing to review the revision of this manuscript?	Yes

Comments to Authors:

Excellent paper which shows what needs to be the direction towards real digitalisation of the OR! Technically, it is probably much “easier” than overcoming regulatory and/or political obstacles.
Two recommendations which do not require a second peer-review:
- Key words: add “Operating Room of the Future (ORF)”.

Reviewer 2: anonymous

Aug 02, 2017

Reviewer Recommendation Term:	Accept
Overall Reviewer Manuscript Rating:	90

Custom Review Questions	**Response**
Is the subject area appropriate for you?	5 - High/Yes
Does the title clearly reflect the paper’s content?	5 - High/Yes
Does the abstract clearly reflect the paper’s content?	5 - High/Yes
Do the keywords clearly reflect the paper’s content?	4
Does the introduction present the problem clearly?	5 - High/Yes
Are the results/conclusions justified?	4
How comprehensive and up-to-date is the subject matter presented?	5 - High/Yes
How adequate is the data presentation?	N/A
Are units and terminology used correctly?	N/A
Is the number of cases adequate?	N/A
Are the experimental methods/clinical studies adequate?	N/A
Is the length appropriate in relation to the content?	4
Does the reader get new insights from the article?	5 - High/Yes
Please rate the practical significance.	4
Please rate the accuracy of methods.	N/A
Please rate the statistical evaluation and quality control.	N/A
Please rate the appropriateness of the figures and tables.	N/A
Please rate the appropriateness of the references.	4
Please evaluate the writing style and use of language.	5 - High/Yes
Please judge the overall scientific quality of the manuscript.	4
Are you willing to review the revision of this manuscript?	Yes

Comments to Authors:

The author presents in this excellent paper a very interesting view in surgeons future regarding the implementation of next generation digital and interactive devices in the surgical environment. The current speed of intelligent digital evolution comprises the opportunity of modulating assisting systems to improve surgeons performance and reduce avoidable incidents - not only in the OR. It will be fascinating to observe how fast this general development will be transferred into medical respectively surgical domains.