Integration of Human Factors in Surgery: Interdisciplinary Collaboration in Design, Development, and Evaluation of Surgical Technologies

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ABSTRACT

Research in surgical intervention and technology development is increasingly interdisciplinary. Despite the great potential of working in this way, recent research suggests that interdisciplinary collaborations and competing stakeholder interests can be challenging to initiate and manage, with the result that knowledge and expertise from different fields are not always well integrated. The aim of this workshop is to bring together stakeholders from HCI, surgical science, and surgical practice and technology to investigate the potential of interdisciplinary collaboration, specifically identifying actionable strategies to coordinate and improve efforts towards designing, developing, evaluating, and iterating on the next generation of surgical solutions. The workshop will address current limitations in interdisciplinary collaboration, and identify opportunities for surgical technology stakeholders to make contributions across the entire development life cycle. In the longer term, the workshop will contribute towards the development of a pragmatic collaboration framework encompassing diverse research paradigms, compatible with surgical practice, and supportive of longitudinal evaluation.

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CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Collaborative and social computing theory, concepts and paradigms**; **Collaborative and social computing design and evaluation methods**; • **Applied computing** → **Health care information systems**.

KEYWORDS

Human Computer Interaction; Surgical Technology; Patient Safety; Human Factors; Collaboration

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1 BACKGROUND

Surgical interventions and technology developments increasingly rely upon interdisciplinary research efforts throughout the research lifecycle: from identifying user needs, through designing and developing solutions, to implementation and testing [2, 20]. This joint effort relies on coordination between surgical practitioners, human-computer interaction (HCI) researchers and surgical technologists

across healthcare centres, academia and industry with each of these roles bringing unique expertise to the process. Such collaboration brings challenges. Not only do each of the contributing groups draw upon their own disciplinary traditions, research focuses and methodologies [1], but research and working routines can vary significantly raising practical issues for coordinating collaboration [4]. The different research practices and work environments between disciplines bring a growing need to build understanding and patterns of collaboration between the surgical practitioners and researchers who must work together to ensure the potential of these technologies is achieved [18].

Responding to this need, several research and education centres [15, 22, 23] have recently been established, focusing on fostering interdisciplinary research between HCI researchers, surgical practitioners, and surgical technologists to improve surgical technology for better surgical practice and patient safety. However, in a broader sense, there are still challenges in coordinating collaboration between surgical stakeholders. One type of challenge has resulted from misunderstandings and miscommunications across disciplines, as discussed in [2]. Another illustrative issue concerns differences in working routines between HCI researchers, technologists and surgical practitioners. Surgical practitioners are primarily responsible for the treatment of patients, and it is natural that this must always take priority. As such their routines are determined mostly by patients' conditions and surgical facilities' availability [18]. This contrasts with the schedules of researchers which tend to follow the academic calendar and routines. Addressing these scheduling differences can prove challenging when coordinating research activities which require the collocated expertise of both groups.

A recent review paper, addressing this kind of interdisciplinary research, discussed seven areas of contrast between HCI and Health research approaches, concerning research life cycles, design methods, implementation, and evaluation. [3]. The authors responded to these areas of difference by articulating seven lessons for improving mutual understanding across disciplines, and adopting complementary methods for health intervention collaboration. In this workshop, we aim to bring these high-level lessons, and other lessons identified by practitioners, under discussion, to work towards actionable guidelines and a pragmatic framework to guide collaborative activities among surgical stakeholders.

2 WORKSHOP GOALS

This workshop will bring together a range of surgical stakeholders, to discuss opportunities and barriers in interdisciplinary surgical technology research, with the aim of forging a pragmatic framework to improve and further develop interdisciplinary collaboration on advanced surgical technologies. Specifically:

- **Goal 1:** Build mutual understandings on current challenges and limitations in research collaboration among HCI researchers, surgical practitioners, and technologists around the design, development, and evaluation of technology.
- **Goal 2:** Discuss strategies and best practices to address limitations in surgical technology research collaboration; and forging a pragmatic framework which allow stakeholders to contribute effectively at all stages of the development life cycle [12].
- **Goal 3:** Construct a platform for collaboration which is compatible with surgical practitioners' routines, accommodates diverse research paradigms and supports longitudinal evaluation and iteration.

Stakeholders invited will include surgical researchers and practitioners, HCI researchers, Human Factors practitioners, as well as technologists. The longer term goal of the workshop is to develop a collaborative framework and nurture an ecosystem for the development of new technologies for surgical intervention, which we address via post-workshop activities (stated in section 6). To structure discussion at the workshop, and also lay the foundation for this future collaboration, we propose three broad themes related to collaborative integration.

3 THEMES

3.1 Theme 1: Building Mutual Understanding Between the Fields of HCI, Surgical Science, and Technology

Work in HCI has identified areas of miscommunication and potential misunderstanding between HCI researchers, surgical practitioners, and technologists [3]. However, we are not aware of such work which addresses this question from the point of view of surgical practitioners and technologists. It is not clear whether from their perspective certain methodologies, goals, and jargon common in HCI [7, 14] are transparent, and vice versa. We also believe there is value in bringing the findings from HCI into discussion between the different groups to verify their comprehensiveness, and identify any further areas of misunderstanding. As such the first theme of the workshop is to build and develop mutual understandings and common language, which address goal 1.

3.1.1 Research traditions and paradigms across disciplines. Different disciplines and research communities hold distinct consensuses on goals, methods, evaluation paradigms and approaches to interpreting data [9, 16]. For example, research in medical science and surgical technology solutions focuses on the outcomes of the intervention in the population [5]. The randomised controlled trial (RCT) is often applied to understand the causal effect of interventions, assuming that the intervention will work well as long as end-users use the intervention as intended [19]. HCI focuses on usability and user experience in the context of individual cases. Mixed quantitative and qualitative methods are often applied to evaluate whether interventions are fit for purpose, recognising contextual constraints and human errors. Beyond these issues, in the experience of members of our organising panel, these consensuses can vary between cultures, regions and healthcare institutions.

Discussion under this sub-theme encourages interdisciplinary researchers and practitioners to address the diversity of paradigms in research and the different goals, assumptions, and focuses found in practice. It also encourages reflections on the pros and cons of these different research methods, how they complement each other, and how they can inform one another and be coordinated across both individual and institutional levels.

3.1.2 Understanding research practice and working routines. The primary responsibility of surgical practitioners is always the treatment for patients. Even before engagement with research, their working routines are very busy, with consultation, supervising/training, surgical arrangements and on-call sessions, which are mostly determined by patients' conditions and the availability of surgical resources. As a result, surgical practitioners are often constrained by external factors and lack flexibility in collaborative engagement [18, 19]. While researchers, technologists and HCI practitioners often have more flexible routines and more autonomy in scheduling research, design, and development, they have a different schedule of constraints including teaching, publication pipelines, office hours, and the academic calendar. These diverse working routines pose challenges in collaboration. Under this theme participants will be encouraged to discuss how human-centred and context-sensitive design research can be conducted around surgical routines, while minimising interruptions to surgical practice. This will be achieved through investigating the question; How can we conduct RCTs on technology in surgical practice with minimal confounding factors from contingent factors? Discussion under this sub-theme will encourage all stakeholders to recognise and understand these diverse working routines in different contexts and to coordinate research and practice.

3.2 Theme 2: Discussing and Developing Practical Guidelines for Integrated Collaboration

Building on our first theme, current understandings and recommendations identified in HCI research have been high level. There is a need to discuss and deepen these lessons with the benefit of everyday practical experience, and a need to identify actionable, practical guidelines for research. Theme 2 thus discusses strategies to address limitations in surgical technology research collaboration and propose actionable guidelines and framework for research (addresses goal 2 and 3). In this regard, we encourage topics including, but not limited to:

1- How can we support learning each other's terminologies and reducing misunderstandings in collaboration? For example, the term 'feedback loop' in design research and control science holds different meanings. Another example is the term 'implementation' in HCI and medical research refers to different stages in a development life cycle.

2- How can we effectively organise research activities that accommodate different focuses and investigation approaches? For example, by making use of approaches from human factors which generate insights into user needs, usability, fitness-for-purpose, making use of methods such as co-design, expert review, lab studies, and in-the-wild studies, etc. Technologists research focuses are on designing a robust solution that is reliable and can deliver repeatable results whilst performing optimally. Medical research focuses on outcomes of technology interventions and clinically- and cost-effective implementation at wide-scale, tested through RCT. Therefore, we need to understand where and how these approaches can complement each other in practice, and how each organisation can support each other.

3- How can we coordinate research collaborations around surgical routines to broaden opportunities for conducting research projects?

4- Can we identify approaches that afford surgical stakeholders greater ability to contribute throughout the life cycle of technology development? A counter-example is that many surgical technologies are often developed, and human factors are considered an afterthought, if at all. This increases the risk of sub-optimal solutions as the users are not fully considered in the development.

5- How should we address ethical and regulatory restrictions? Ethics and regulations in healthcare centres are strict, with limited applicable space for research and evaluations, especially when applying human factor methods. Therefore, how can HCI and surgical technology research adapt their approaches to these standards? Do healthcare centres favour certain research methods over others?

6- What challenges stand in the way of longitudinal evaluations on surgical technology innovations? What challenges arise regarding the coordination of surgical stakeholders and research resources?

3.3 Theme 3: Human Factors, Technology, and Complexity, in the Surgical Environment

Our third theme addresses the challenges in creating design and development processes which are well adapted to the complex interdependencies of the operating room's workflow. Under this theme we will address the challenges of adapting human-factors approaches to the particular demands of surgical practice, engaging with the second of our workshop goals. Perhaps the clearest illustration of this challenge can be seen in the conditions of the operating room. An operating room is a complex adaptive system where multiple actors and variables interact with and influence one another [21]. When designing and developing new surgical interventions, it is thus important to understand the potential impacts on the behaviour of the system as a whole. Whenever new surgical technologies are introduced into the operating room addressing some goal, they have the potential to have further impacts in the way they alter the environment of the operating room. At an individual level, this can result in unexpected drawbacks as when mixed reality introduced to offer improved visualisation of medical imagery can result in increased cognitive overload and inattentional blindness [8, 17]. Technologies may also have wider effects across the whole team, reshaping not only the work practice of individual members but affecting team dynamics in the operating room [6]. As such when a new technology is introduced, surgical professionals may not only need to master the technology itself, but also adjust themselves to a new working environment.

Despite this, most research has focused on design for surgeons. This leaves a potential gap in understanding how new technologies impact other surgical practitioners including assistant surgeons, residents, nurses, anaesthetists, and technicians — practitioners who may not be the main operators, but nevertheless interact with the interventions. It is important to ensure that technologies introduced into the operating room facilitate overall improvements in operating room performance, and important to understand any wider risks and challenges which may be introduced alongside targeted benefits.

Discussion under this theme will address the ways that surgical interventions can be designed with the contributions of diverse groups of surgical practitioners supporting better understanding of the ways that these interventions will shape the socio-technical environments of the operating room. This may include discussion of evaluation methods which address the operating room as a complex adaptive system, responding to the way that surgical practitioners pursue "balance thoroughness and control with flexibility and adaptations [10]." A challenge here will be to build and generalise experimental conditions that can narrow the gap between surgical practitioners' everyday work and the ideal scenarios of work.

Addressing these issues may involve identifying existing methodologies which might better reflect the complex flow of interactions in the operating room — for example evaluation in the wild, and time-series evaluation — and understanding how these and other human factors approaches might be better adapted to the specific circumstances of the operating room. By beginning with the microcosm of complexity in the operating room, there is potential in the longer term for these findings to influence the use of human factors in the larger complex context of digital health as a whole [5, 11, 13].

4 PRE-WORKSHOP PLANS

4.1 Recruitment

We will broadly advertise the workshop to different communities of researchers and practitioners. This will include posting announcements to distribution lists as CHI-ANNOUNCEMENTS and social media, such as Twitter and Facebook. We will send targeted email invitations to leading researchers across different academic institutions inviting them to participate and distribute the announcement within their organisations. Our website will host our Call for participation, information about the workshop's organisers, news and announcements, and paper submission instructions.

4.2 Paper Submission and Review Procedure

Submissions to this workshop will take the form of position papers (4 to 8 pages, in ACM CHI Publication Formats) and are made through EasyChair. These submissions are expected to address at least one of the key topic(s) of this workshop and must present original material. They should also include a statement on the potential goals of their research and the problems it aims to address. Ultimately, the length is based on the weight of the contribution. Shorter, more focused papers are highly encouraged.

Following submission, the position papers will be divided for review among the workshop organisers and invited reviewers. Reviews will be based on quality and relevance to the themes of the workshop. After discussion of all submissions, successful submissions will be invited to the workshop. At this point participants will be asked to express any accessibility concerns which might affect their participation so that we can accommodate them accordingly.

Beyond the quality and relevance of submissions, we will aim to ensure an interdisciplinary and balanced group of researchers in this field. We will solicit widely and internationally for contributions to the workshop. This will both support the interactivity of the networking activities and also reflect the growing relevance and potential of interdisciplinary research across a range of HCI subdisciplines.

4.3 Two Weeks Before the Workshop

This workshop aims to foster effective interdisciplinary collaboration around surgical technology collaboration: bringing together challenges and methodologies that might not otherwise come into contact with one another. As such, our one-day workshop will focus on meetings and interactions between the participants, including the panel, while also allowing researchers a brief time to present their own work.

To support this, while avoiding video-call burnout, we will combine asynchronous with the synchronous aspects described below. To help participants familiarise themselves with one-anothers' work and interests ahead of the workshop, participants will prepare a short (c 1.5-2 min) presentation and record it in time to upload to (e.g. YouTube) two weeks before the workshop. Links to these will be shared among all participants, alongside submitted papers to allow them to familiarise themselves with the other participants' work. We will use the Miro platform to share the video links and the papers. Simultaneously, we will send out a well-designed survey to worldwide surgical stakeholders to gather their perceptions on the challenges and expected solutions. This survey serves as a wake-up call to the workshop and an ice-breaking move to engage interactions on the Miro platform. A Slack or Discord group for the workshop will open at the same time, to allow participants to discuss each others' papers and interests, ask questions and self-select discussion groups for activities at the workshop. We will provide a system for this group selection (to be determined).

5 WORKSHOP STRUCTURE - ON THE DAY

The workshop will be held on Zoom, using an organiser's institutional account, and will make use of captioning for hard-of-hearing users. The workshop has been scheduled to minimise disruption across a range of time-zones, supporting broad participation across North and south America, Europe, Africa, Asia, Australia, and to fall within normal working hours for the conference's host location. Presentations in the second half of the conference will be recorded, to allow tired participants in US time zones to review later. When combined with post-workshop discussion activities on our Slack or Miro, we hope this will allow good participation for as many as possible. Introductions and sessions will each be chaired by different members of the organising committee to provide different perspectives. The second half of the conference (Group Presentations and Panel Talk) will be streamed on YouTube to support wider participation and questions.

Below is a preliminary schedule - to be taken as an example, and subject to change.

30 mins: Introduction - A brief introduction outline the workshop's schedule, its goals, and introduce the panel. Followed by an overview of the collaborative tools we will be using, along with an introduction to some material to guide discussion.

60 mins: Group Discussion within 4-5 small groups, created in pre-workshop activities. This will focus on defining key challenges and opportunities around research collaboration between surgical practitioners and HCI researchers. The discussion will be supported

by a collaborative sketching tool such as Google Jamboard, and groups will create posters for presentation after the lunch break.

15 mins: 15 minute break.

60 mins: Group Presentations of posters, presenting the issues and ideas which arose from the group discussions with 10 minutes for presentations and five minutes Q&A per group.

15 mins: 15 minute Break.

75 mins: Panel Discussion from invited panel members who will give brief five minute presentations, then conduct a discussion on issues around the inclusive collaboration framework, addressing themes that arose in the group presentations.

5 mins: Announcements and close.

6 POST WORKSHOP PLANS

The results of the workshop will be summarised and published on the workshop's website. The posters and framework developed by participants during the workshop, and the panel-discussion will be linked on the project website and via social media to provoke further discussion in the community. Participants will also be invited to revise, develop, and submit extended versions of their position papers, based on their discussions at the workshop. We are currently in the process of identifying potential HCI journals (*e.g.*, TOCHI, IJHCS, and Journal of HCI) who would be interested in a special issue based on the topic of our workshop. In addition, the discussions and findings from the workshop will be refined into a "manifesto" on the challenges and opportunities on human factors in surgical technologies and collaboration. This manifesto will provide the basis for a special issue of a journal, where participants with an excellent contribution to the workshop will be invited to submit an extended version of their position paper.

With the organisers' strong links in the relevant research communities, it can be expected that beyond concrete plans the workshop contributes to further follow-up activities such as iterations of this workshop in future conferences. To facilitate such activities the workshop's website will continue to be regularly updated. Furthermore, we plan to foster a community of researchers focused on surgical technology research and innovation researchers through the Slack channel created for this workshop. This group will be maintained after the event to allow future collaborations and sharing of datasets, code, and best practices, and to act as a focus for a seminar group on human factor and surgical technology research.

7 ORGANISERS

The workshop has a broad international group of organisers, including established researchers, and younger perspectives; with interests in HCI, surgical research, surgical technology, healthcare intervention. (In alphabetic order:)

Roman Bednarik is an associate professor at the University of Eastern Finland. Since 2010 he has been conducting human-factors studies in surgical and operator environments. He and his team developed eye tracking applications for microsurgical settings, investigated human factors such as eye-hand coordination, and developed skill assessment methods.

Ann Blandford is a Professor of Human-Computer Interaction in the Department of Computer Science at UCL, and a member of UCL Interaction Centre. She was Director of the UCL Institute of Digital Health (2015-2019), and subsequently (2019-2020) Deputy Director (Digital) of the Institute of Healthcare Engineering. Her funded work is on evaluating complex systems "in the wild", with a focus on Digital Health. She takes a pragmatic approach to developing and applying theory in practice, recognising and working with the inherent "messiness" of the real world. She has been leading projects on HCI/digital health funded by EPSRC and NIHR.

Feng Feng is a Postdoctoral researcher at University of Eastern Finland and Microsurgery centre in Kuopio University Hospital. She has a background in both Cognitive Science and Industrial Design. Her interests include embodied cognition and interaction, multi-sensory perception, Human-Computer-Interaction and Human-Robot-Interaction, and the development of multi-sensory technologies.

Antti Huotarinen is a neurosurgeon, MD, PhD, working in Kuopio University Hospital and University of Eastern Finland. His clinical work focuses on intra-axial brain tumors, decompressive spine and functional neurosurgery. He has a special interest in training future neurosurgeons, developing easy-to-produce physical training models and scientific study of surgical skill. He has large experience in collaborating with technologists on a range of surgical training research projects.

Matti Iso-Mustajärvi is the Manager of the Microsurgery Center at Kuopio University Hospital. He is a PhD and Ear, nose and throat diseases specialist. He has extensive clinical experience in ear surgery, research on the safety of ear implants and the evaluation of medical devices. His current main role is testing services for surgical technique and cochlear implant research and leading the Microsurgery centre.

Ahreum Lee is a Postdoctoral Researcher at University of Eastern Finland. She has a background in Human-computer interaction and Industrial engineering. Her current research explores how technologies can be better designed to support communities and group interaction. Particularly, she currently investigates how new surgical technologies reconfigure team dynamics the OR by understanding surgical nurses' perspectives.

Federico Nicolosi is an Italian neurosurgeon (Milan). He founded UpSurgeOn S.r.l. in 2017, a company specialized in surgical simulation technologies which received a EU grant in 2019 (Horizon 2020 program). He is responsible for training programs in the Young Neurosurgeons Forum of the WFNS (World Federation of Neurosurgical Societies), and member of the the ISNTii (International Society for Neurosurgical Technology and Instrument Invention). He is co-author in several scientific papers and books.

Jeremy Opie is a Postdoctoral research fellow at the UCL Interaction Center and a member of the Wellcome/ESPRC Centre for Interventional and Surgical Sciences (WEISS). He has a background in robotic engineering and his research focuses on using qualitative methods to understand user needs in surgical settings and ensuring new medical technology is designed for the user in the right context.

Soojeong Yoo is a Research Fellow at the UCL Interaction Centre and a member of the Wellcome/EPSRC Centre for Interventional and Surgical Sciences (WEISS) Her research interests include augmenting workplaces with novel technologies such as virtual reality (VR) and augmented reality (AR) within the context of physical

activity, on-body interaction, personalised dashboards and human-adapted HCI.

Bin Zheng is an Associate Professor in Surgery at the University of Alberta, and a long time surgical technology innovator and educator. Currently, Dr. Zheng is the Endowed Research Chair in Surgical Simulation, supervising the program of applying HCI principles to surgical education in the University of Alberta.

8 CALL FOR PARTICIPATION

This workshop intends to work towards more integrated collaboration among the various disciplines of surgical stakeholders in this research: including human-computer interaction researchers and practitioners, surgical practitioners, and surgical technologists. The workshop has three goals. The first goal is to build mutual understandings on current challenges and limitations in research collaboration among HCI and other surgical stakeholders around the design, development and evaluation of technology. Second, we will discuss strategies and best practices to address limitations in surgical technology research collaboration; and forging a pragmatic framework which allow stakeholders to contribute effectively at all stages of the development life cycle. Third, we will construct a platform for collaboration which is compatible with surgical practitioners' routines, accommodates diverse research paradigms and supports longitudinal evaluation and iteration. Potential participants should submit 4 to 8 page long position papers (in ACM CHI Publication Formats), that addresses at least one of the key topic(s) of the workshop and must present original material. The paper should also include a statement on the potential goals of their research and the problem(s) it aims to address. Submissions will be via EasyChair. For more information visit (website TBD) or contact collaboratehealth.chi2022@gmail.com.

We will select papers based on relevance, quality, and diversity. At least one author of each accepted position paper must attend the workshop, and all participants must register for both the workshop and for at least one day of the conference.

8.1 Key Topics

- Understand different research cultures, traditions, paradigms and working routines in HCI and medical research for pragmatic practice.
- How to effectively organise research activities that accommodate different research focuses, investigation approaches and working routines? How to coordinate research collaboration in a way that surgical routines can broaden research opportunities?
- Regarding surgical technology development, how to afford surgical stakeholders the full access to contribute to the complete life circle of technology development? How can and in what way coordinate surgical stakeholders and research resources to support longitudinal evaluations on surgical technology?
- What practical guideline or framework can facilitate integrated interdisciplinary collaboration? What could be the components of this guideline/framework? How can this guideline/framework be constructed to support the collaboration and accommodate diverse investigation methods? How can this guideline/framework be constructed to facilitate communications across disciplines?
- How do new surgical technology interventions reconfigure individual and collective experience (e.g. in the operating room or other user contexts)? What can research methodologies be used to minimise the potential tensions raised by new surgical interventions?
- What would be the strategies to address complexity in the operation room, or more broadly, in the surgical environment? How can human factor methods play a role in analysing and evaluating complexity in surgical technology use?
- Regarding ethical policy-making, what potential ethical issues may arise when facilitating interdisciplinary collaborations? What suggestions and recommended solutions should we make to unleash restrictions on research efforts, which will eventually reduce human error and improve patient safety?

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