Telestration in Mobile Telementoring

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Abstract—**The paper analyses the domain of modern video conferencing-based mentoring systems applied in surgery. We aim to introduce mobility to telementoring, accompanied with telestration as an obligatory feature for telementoring systems. A detailed outlook to the domain resulted in encountering the camera movement problem, reported in the paper. As no direct solution was identified, a set of ideas towards the resolution of the problem is presented for further discussion and research.**

Keywords-telementoring, telestration, annotation, camera movement

I.   INTRODUCTION

Telemedicine is defined as a set of medical practices, without direct physician-patient interaction, via interactive audio-video communication channel [1]. The advances of Information Communication Technologies (ICT) created a fertile ground for rapid development of software and hardware systems for telemedical purposes. Reported shortage of general practice surgeons with even higher deficit predicted for the future [2] is the main reason for the expansion of the domain of telemedicine. Advances and spread of the technology may be the way for mitigating the consequences of the lack of specialists in this field.

The research explores the field of telementoring. The initial purpose of telementoring is to provide assistance for a less experienced specialist (in our case - a surgeon), when a local expert is unavailable. This traditional approach offers high benefits concerning improved outcome of the procedure, lower time expenditures and reduced cost regarding the relocation of an expert. Moreover, the educational side of telementoring is also of high importance, since the remote expert acts as a personal tutor for the surgeon performing the operation.

The paper is structured as follows: after a brief introduction and motivation for the expanding domain of telemedicine, the reader is provided with an overview of current telementoring systems and challenges they are facing. Moreover, ideas of mobility in the domain are introduced. Together with the new features, new challenges are presented. Section III explores the camera movement problem in detail, while possible solutions and questions for further research are formulated in Section IV.

II.   AN OVERVIEW OF CURRENT TELEMENTORING SYSTEMS

Video conferencing based tools are no longer a novel technology in medicine. Reviews by Augestad et al. [3] [4] summarize the benefits of using video conferencing in surgery during the past decade, highlighting the improvements in clinical and educational outcomes. When it comes to telementoring, the solutions are repeatedly demonstrated for laparoscopic surgery [5] [6] due to the simplicity of adopting this technological approach. However, current researches still limits telementoring to PCs/Laptops [7] at predefined "stations" or sites. We identified a general lack of studies exploring surgical telementoring from the mobile perspective. The limitations associated with mobile environments are gradually decreasing and disappearing due to rapid technological advances. Moreover, the fact that remote medical experts who are on call are likely to be moving around and almost always have their mobile phone (or a tablet computer) within reach, provides enough impetus for further exploration of mobile platforms. We believe that introducing mobility to the field of telementoring has potential waiting to be explored.

The use of mobile platform as a medium for telementoring systems introduces new challenges to be considered. As the mentor becomes mobile, dealing with possibly unreliable wireless Internet connectivity, varying bandwidth and limited battery power are the cases that require extra attention [8] [9]. However, limited computational power, available on mobile devices, is the most important constraint, as we are dealing with computationally intensive data processing. The mentioned hazards form a different angle for the analysis of current telementoring systems and telestration techniques towards possible adaptation and reusability.

Telestration (a technique, enabling drawing of freehand annotations over a still image or video) is not a very new approach to medical domain [9]. We argue that the telestration feature is an obligatory functionality of telementoring systems due to the increased accuracy of pointing actions. However, no analysis of the impacts of this feature to the workflow of the procedure was identified. This fact draws the guidelines for further research.

III. CAMERA MOVEMENT PROBLEM

As mentioned before, we are focusing on telementoring for minimally invasive (laparoscopic) procedures. The selection was made due to technological aspects: as only camera-based representation of the operative field is available for onsite surgeon, sharing it with the remote expert is highly feasible.

After an analysis of a set of laparoscopic videos (N = 10 laparoscopic sigmoidectomy procedures) and discussions with domain experts (experienced surgeons from University Hospital of Northern Norway having previous experience in telementoring), we came to a conclusion, that movement of the camera is an integral part of the procedure. However, it may lead to the decreased accuracy of mentoring. Looking from the point of telestration, camera movement results in repositioning of annotations, which are supposed to be fixed on a particular anatomical landmark. As camera movement cannot be omitted, a technological solution towards maintaining constant position of the annotations should be identified. It has to be resistant to homogenous tissue representation, reflections, catheterization smoke and accidental emergence of body liquids. The complexity of this task requires a detailed research towards determining an appropriate solution, especially having the limitations of mobile platforms in mind [10].

IV. DISCUSSION: IDEAS FOR SOLVING THE CAMERA MOVEMENT PROBLEM

In this section some ideas for solving the camera movement problem are presented. The main focus is to analyse the problem by looking from the software perspective in order to use computational techniques towards the solution.

A. Combination of video and still images

Notwithstanding the moving camera, the operative field is also in motion. The deformation of soft tissues responding to the changing pressure inside the cavity and moving surgical tools contributes to the complexity of the representation. A set of stable reference points are needed not only for fixing the annotations, but even for ensuring the required accuracy of mentor's commands. The tissues should not be moving at least while the annotations are made by the mentor and observed by the mentee. This claim transforms the moving operative field into a still image for a discussion.

The described situation offers a direct work-around instead of solving the camera movement problem – combination of laparoscopic video stream and still images at the point when the advices from the remote mentor (including telestration) are necessary. The increased accuracy of annotations should be sufficient impetus for supporting this idea. Moreover, relatively simple implementation and low demand of computational resources are advantages looking from the mobile mentor's perspective. However, the image based representation loses the interactive component, meaning that the actual operative field may change while the surgeons are discussing the still scene. Notwithstanding this disadvantage, the solution offers an improvement to conventional telementoring systems (audio and video conferencing) supporting the mobile mentor approach.

B. 3D models for laparoscopic surgery

3D modelling techniques are one more direction for improvement. Su et al. presented a novel approach of combining Computed Tomography (CT) or magnetic resonance (MR) images and laparoscopic video. It resulted in live 3D model representing not only the surface of a particular organ, but also its inner structure [11].

The described approach becomes handy when solving the camera movement problem. The CT/MR based 3D model is aligned according to the reference points tracked on the surface of a tissue (organ) to ensure accuracy in case of deformations. This step establishes sufficient number of reference points which can be continuously reidentified and used as anchors for fixing the annotations. Moreover, the elements of 3D model also represent stable structures which may be used towards the solution. We see this solution as a long term goal for laparoscopic surgery and telementoring due to extremely high demand of computational power and complexity of the algorithms. Further research is required towards simplifying the computations towards applications in current mobile environments.

C. Other approaches

The core of the problem we are solving is continuous reidentification of fixed reference points in order to maintain constant position of the annotations. Computer vision techniques may also be used for tracking anatomical landmarks, for instance blood vessels [12] [13] [14]. Unfortunately, all studies dealing with blood vessel tracking use still images as an input. However, we hypothesize about extending the functionality of the algorithms for analysing video content. Of course, the techniques have a high demand of computational power, therefore, further research is needed to ascertain the feasibility processing live video stream and the use of a mobile device on the client side.

Researches on soft tissue deformation tracking also offer a solid basis for fixing the annotations [15]. The approaches focus on capturing the reference points on the surface of the tissue in order to create an accurate representation. As the captured reference points are sufficient for solving the camera movement problem, the solution looks promising. Nevertheless, the algorithms are computationally intensive, positive results in processing live video stream were presented [15] [16]. Of course, the sufficient computational resources are not provided by mobile devices yet, but it is only a matter of time until the required improvement of ICT will be ensured.

V. CONCLUSION AND FUTURE WORKS

The work presented in the paper is in progress towards improving surgical telementoring. Most of the researchers in this field looked at the problems and future tendencies from the stationary point of view (stationary hardware and working position of the mentor). A new mobile approach introduces the challenges that were not considered before. However, we believe, that the potential of mobile platforms and its application in medical domain is still to be revealed. The new perspective leads to encountering the problems that have no direct solution yet. Our case reports the camera movement problem, preventing from maintaining constant position of the annotations and ensuring the required accuracy of mentoring. Ideas for possible solutions were directed towards further discussion and research.

Looking at the presented solutions, we hypothesize that 3D modeling approach (Section IV.B) has the most potential to become the overall direction for laparoscopic surgery and telementoring. The possibilities of advances in 3D modeling are close to unlimited. For instance, it allows having an accurate model of a particular organ, containing its inner structure which would make the surgeon aware of the internal elements of the tissue (blood vessels, nerves, etc.) before the cut is made. If we add live tracking of laparoscopic tools to the model [17], the system may grow to surgical action advice system, alerting the surgeon before the particular move which could harm an element of the inner structure (for example a cut of a blood vessel). In this case, the model of the particular tissue should be extended to the model of the entire operative field, including the surgical tools and the internal structure of the surrounding tissues.

It is not possible to solve the problems we are facing by looking at them from the theoretical point of view only. Therefore, to result in a prototypical implementation a design phase for mobile mentoring software is in progress. It will provide a more solid support for the claims made in the paper. However, to generate sound results, impact measurement scale should be established. It also requires a separate study, followed by trials and data collection.

Looking at all the presented solutions, the main obstacle for the mobile telementoring is the limited computational power provided by mobile devices. Fortunately, the technology moves forward, making this limitation to gradually decrease and disappear. It is only a matter of time until advances in mobile technology ensure the required characteristics for data processing. However, together with technological advances, the expectations of potential users evolve, creating new challenges and directions for further research.

VI. REFERENCES

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