Technical Project Report: Visualizing endoscopic tools inside the patient.

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1 Introduction

Minimally Invasive Surgery (MIS) is a relatively emergent alternative to open surgery that has become risingly popular because of its benefits, such as: decreased overall expenses, lower complication rates, decreased post-operative pain, shorter hospital stays, etc. [1]. These, among other reasons is why the MIS market is expected to grow up to $44.4 billion in 2030 making it an attractive field. [2]

MIS also started to take over **open** pancreatic cancer surgery, mostly because its low survival rate at 47% one-year survival rate and 12% five-year survival rate for early pancreatic cancer in the UK; caused in its majority by mayor complications such as: pancreatic fistula, delayed gastric emptying, postoperative bleeding, hepatic infarction. [3] Furthermore, its minimally invasive alternative: The Minimally Invasive Distal Pancreatectomy (MIDP), not only being the most performed pancreatic resection technique, has also proved to have advantages with respect to open surgery such as: Shorter hospital stay, decreased blood loss, fewer overall complications, faster recovery and being cost effective. [4]

In spite of the advantages given by the MIDP it is still one of the most challenging fields in general surgery because of the deep position of the pancreas inside the abdominal cavity and some important vasculature near the organ of interest. [4] One of the main technical issues with this type of surgeries is the inability to guide the instruments properly inside the patient without any additional context from the outside, hence, any type of ”see-trough” vision or adding visual context of the spatial position of the organs inside the patient proves to be helpful to the whole surgical procedure.

The goal of this project is to visually and auditively **augment** some important aspects inside and outside the patient to ease the MIDP procedure. And for this augmentation to be useful inside and outside the operation room (OR) by using some techniques learned throughout the course.

2 Related Work

One of the pioneers of visualization in MIS such as laparoscopic surgery is Henry Fuchs. He augmented the procedure giving ”see-trough” vision of the surgical site as well as the virtual extension of the trajectory and physical form of the laparoscope inside the patient with a Video see through head-mounted display. [5]

A more current approach to this type of augmentation was given by John Hopkins University with ARAMIS: Augmented Reality Assistance for Minimally Invasive Surgery using Head-Mounted Display. Having promising results in improved intuitiveness, hand-eye coordination and depth perception. [6]

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3 Methods

In this project we used different techniques learned in the lecture for visualization purposes and surgery support inside the OR, such as:

- Focus and context visualization for enhancing depth perception of augmented objects inside the patient.
- Context sonification to simulate a real surgery environment.
- Adding visual cues to guide the surgeon inside the patient using shaders and textures.
- Augmenting the laparoscope's vision by rendering its **augmented** field of view (FOV) into a virtual monitor to further support the surgeon.

For the implementation of all the desired interactions mentioned above we used Unity as our engine of choice, it is to note that for compatibility with Hololens v1 we used the 2019.· version of Unity, where we imported some 3D Models from Narvis Lab. We also used C# as the programming language to implement all the scripts which will be mentioned in their respective subsections.

In addition we used some 3D printed objects to resemble the tools used in a real surgery, they were tracked using Vuforia engine and Vuforia image targets pasted to the 3D objects.

3.1 Visualizing the Pancreas Inside the Patient

We want to provide more information from the organ of interest from inside the patient to enhance the visual spatial information given to the surgeon.

In order to render the pancreas above other objects we used shaders, since the rendering sprite component was not compatible with the mesh given by the 3D Models. For this project we choose the ”GUI/TextShader” and set the render queue to 3000 to ensure that the object is rendered above all else. As seen in 1. See figs. 1 to 3

3.2 Changing the color of the pancreas by distance

We want to provide visual navigation cues to give the surgeon a sense on how close we are to the organ of interest, supporting the difficulty that is to navigate inside the patient when the tools are not seen from outside.

For this we used the ColorLerp function of Unity to interpolate between the normal color of the pancreas to a more *”red-ish”* color using the square magnitude of the distance between the pancreas and the surgery tool. The pseudoalgorithm is given in 1, where $T_{Pancreas}, T_{SurgeryTool}$ are the transforms of the objects. See figs. 1 to 3

3.3 Visualizing the surgery Tool inside the patient.

For the surgeon to have a better spatial notion on where the surgery tool is we want to augment the surgery tool inside the patient, for this we change the shader with the render queue when we detect that the surgery tool collides with the skin by using the box collider feature in Unity and using the OnTriggerEnter, OnTriggerExit functionalities. We change the color to blue when the tool is inside the patient and to default when it exits. The algorithm is given in 2. See figs. 1 to 3

Algorithm 1 Color change by Distance

Require: $T_{Pancreas}, T_{SurgeryTool}, distanceMax, distanceMin$
  $distance \leftarrow squareDistance(T_{Pancreas}, T_{SurgeryTool})$
  while App Running **do**
    $Color(T_{Pancreas}) \leftarrow defaultColor$
    if distance<distanceMin **then**
      $Color(T_{Pancreas}) \leftarrow red$
    else if distance < distanceMax **then**
      $Color(T_{Pancreas}) \leftarrow ColorLerp$
    end if
  end while

Algorithm 2 Render Tool Inside Patient

Require: $Shader_{Standard}, Shader_{GUITextShader}$
  while App Running **do**
    if Entering Collision **then**
      if Object=skin **then**
        $Shader \leftarrow Shader_{GUITextShader}$
        $Color \leftarrow Blue$
      end if
    else if Exit Collision **then**
      if Object=skin **then**
        $Shader \leftarrow Shader_{Standard}$
        $Color \leftarrow default$
      end if
    end if
  end while

3.4 Changing skin Transparency

To add Focus and Context Visualization to further correct and improve the depth perception and occlusion of the pancreas we change the skin transparency when we enter the patient using the surgery tool. Similar to 2 the algorithm checks if the two objects collide using the box collider and used the OnTriggerEnter and OnTriggerExit to implement the functionalities. See figs. 1 to 3

4 Discussion

From figs. 1 to 3 we can see how the different visualization techniques work in conjunction. The results seem to be promising, with functionality as expected and clear and intuitive visualizations for the surgeon. There are some issues with the accuracy of the Vuforia tracking, some line of sight problems with the optical tracking because the Hololens cameras have a small FOV and an inconvenient orientation and the speed of the rendering inside the Hololens is sometimes insufficient. This could be addressed using a better tracking system e.g. double cameras, fiducials, and also upgrading the Hololens computing power.

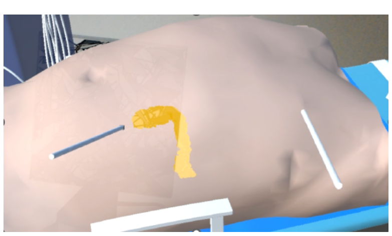

Figure 1: The patient from the outside. The pancreas is its normal color and its visualized outside the patient.

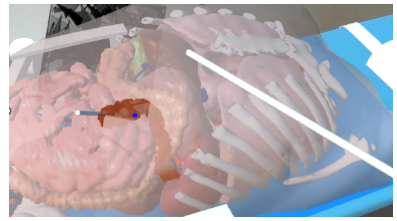

Figure 2: The surgery tool is inside the patient, we can see the blue dot of the tip of the tool rendered over the patient and the skin transparency going up to add context.

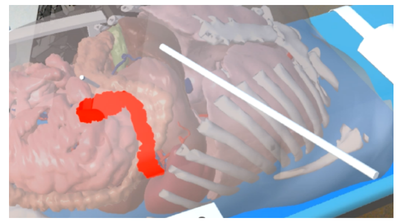

Figure 3: The pancreas turns red if we are extremely close to the organ.

5 Conclusion

In this project we created different visual augmentations that can successfully support the surgeon giving intuitive visual cues to navigate effectively inside the patient up to some accuracy and lag. We are convinced that applying minor changes to the computing power of the head mounted display and adding better optical tracking mechanisms will make this application suitable for supporting surgeons inside the operation room facilitating the surgery through visual augmentation of the patient and providing visual cues to ease navigation during the procedure. Moreover, the app could also potentially be used for training and education.

Acknowledgments

For the purpose of this report I focused on the main aspects where I mainly contributed to the project. But it is to note that everything done in this project was shared effort and work.

References

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