THE IMPROVEMENT OF OBJECT DETECTION AND LOCALIZATION FOR AUTONOMOUS CAMERA MOVEMENT

(Technical Paper)

AN INVESTIGATION OF THE SOCIAL IMPLICATIONS OF MEDICAL ROBOTS

(STS Paper)

A **Thesis Prospectus Submitted to the**

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

By
Harshneet Bhatia
Spring 2020

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature *Harshneet Bhatia* Date 10/13/2020
Harshneet Bhatia

Approved ______________________ Date 10/14/2020
Homa Alemzadeh, Department of Electrical and Computer Engineering (Computer Science by Courtesy)

Approved ______________________ Date 10/20/2020
Toluwalogo B. Odumosu, Department of Engineering and Society

Technical Project Description

The presence of robots in the surgical field has been rapidly growing in procedures, such as minimally invasive surgery (MIS). The integration of robots into the surgical field allows for increased flexibility and precision, which could in turn lead to the automation of surgical subtasks. While the spike in robot-assisted procedures holds considerable promise for the future, this calls for better accuracy in the localization and detection of workspace tools, in order to effectively prevent the occurrence of accidents during surgery.

The RAVEN-II Surgical Robot, was first introduced to the Link Lab in early 2018. Professor Homa Alemzadeh and several of her undergraduate and graduate students have been working with the medical robot since then. The work surrounding this robot focuses on the safety and reliability of such technologies.

I began working on this project as an independent study in January 2019. This is my third consecutive semester working with Professor Homa and some of her graduate students. The first semester I was brought onto this project, I had little to no knowledge on machine learning and deep learning specifically. I used that time to gain my first real exposure to artificial intelligence, labelling datasets, training models, and such. My work dealt with detection and classification work previously done. In an ideal world, the RAVEN would be able to localize, detect, and classify the objects in its surgical workspace with ease. The RAVEN II's training is done through an MRCNN model that uses transfer learning. The four objects of interest are the "Right Grasper," "Left Grasper," "Red Block," and "Green Block." The way the model approaches this problem is by generating bounding boxes for each object present and then classifying and creating masks for each. Since our set of labelled images was limited in size, my goal for the semester was to fine-tune the hyperparameters of the model and to come up with optimal values.

After hyper-parameter tuning, the resulting losses suggested that a learning rate of 0.01 and the highest batch size the GPU could support would be optimal.

The following semester, I was paired with a graduate student to integrate the Perception component I had worked on into a larger scaled pipeline. Along with the Perception unit, we were adding a control unit that was essentially a ZED mini, which is a stereoscopic camera, that would adjust according to the locations of the objects of interest present. The ZED mini would zoom in/out, tilt up/down, and pan left/right. This was done by feeding the coordinates returned after the classification of the objects to the control algorithm. The control algorithm calculates the centroid of those coordinates and determines what movements would help achieve the desired field of view. I tried to improve upon the MRCNN model accuracies by artificially generating more images to train the network on. After performing image augmentation, we were able to see better accuracies. The model achieved a 61.21% overall accuracy for the detection and localization of graspers and multiple blocks in the drylab workspace.

However, further work was and is still required to yield better accuracies. One thing we had observed was that the dataset images did not provide much variety in the position and location of the objects. As a result, I am exploring other image augmentation techniques to diversify the location of the objects of interest with respect to their surroundings. A possibility we are considering is the cut and paste augmentation technique. What this does is basically take the identified objects and their masks and then place them somewhere else in the image, where the background image would most likely be of the workspace. The challenge with this is that the corresponding labels must also be artificially generated for each augmented image. This is important, since the problem of data scarcity is faced by many. The technical thesis will go into greater depth regarding the techniques used and the results obtained.

STS Project Details

Although the usage of robots in the medical field remains promising, it raises many questions from an STS standpoint. Medical robots, such as the RAVEN-II, can achieve decent accuracies, but there will always be room for error. The stakes are high, given that these technologies are used during surgery. This brings into question the parties that should be held responsible in the event that the robot was to malfunction or behave unexpectedly, the potential impact it could have on other surrounding domains, and the level of comfort patients have with these types of robot-assisted procedures. The aim of my STS research is to seek answers to these questions.

Currently, there are no clear guidelines as to whether the physician, the hospital, or the creators of the technology should be held responsible if an accident were to occur. From a legal perspective, this is quite concerning. It is important to consider how much we should trust these technologies. I believe that the best way to approach this would be to look at the socio-technical system as a whole. The system as a whole comprises of many parties that each play their own role. While the physicians are the ones actually using the technology, they are only as good as their training and the tools they use. The hospitals hire these physicians, but they also acquire the medical robots. Maybe they are the ones at fault. The engineers behind the robots could be another potential source of blame. However, there is always a gap between the creators of the technology and the users themselves. A holistic view of the system would provide a better answer to the question, instead of just placing all the blame on one group of individuals. A case review of Therac-25 will shed more light on this. Therac-25 was a radiation machine that offered treatment to cancerous patients. The machines were said to have plenty of safety mechanisms in place by its creators, but several patients ended up getting a larger dosage of radiation than their bodies could handle (Besnard and Baxter, 2003). The case study examines what led to the failure and how it was not limited to just one source.

If surgical robots were to become entirely autonomous, something equally important to take into consideration is effect patients and nonusers would have on these technologies. Patients' decisions regarding whether or not they would like to go under the needle with such robots would have a significant impact on the other parts of the socio-technical system. A SCOT framework analysis would be particularly useful for our purposes. The SCOT theory is built upon the idea that users are the ones that control the types of technologies that emerge. In addition to this, users determine which of those technologies are a success, while the others become a failure. A users vs nonusers approach will provide further insight on this, since nonusers indirectly influence the way such technologies are designed and used.

On the flip side, we must also analyze the social implications that the technology has on the users and nonusers, which SCOT does not address (Klein and Kleinman, 2002). This might include the type of repercussions this would have on hospitals, insurance companies, and patients. Some of the key factors include the shift in costs that this would imply for hospitals and insurance companies and if these procedures would become more accessible to certain groups/individuals. The social balance could very well lead to groups of "resistors," "rejectors," "excluded," and "expelled" being formed (Wyatt, 2003). That being said, this imbalance does not account for some of the other problems that would arise from medical robots. My research will address both the conclusions we are able to draw based on the SCOT approach, as well the shortcomings of this framework when applied to surgical robots.

The final question we will be trying to answer is why some patients remain skeptical of undergoing surgery with a robot involved. There are numerous external factors that could be swaying their decisions and causing this. We will delve deeper into this by taking a look at the guidelines surgeons must follow while disclosing information to a patient before a procedure, the marketing language that is used, and user studies.

Conclusion

Surgical robots have the potential to not only transform patients' experiences, but to also transform our healthcare system as we know it. This would create a domino effect on the rest of society and its structure. While the concept of completely autonomous surgery being performed by medical robots such as the RAVEN-II may seem far-fetched at this time, I would argue that we are not too far away from it. This provides the importance and motivation behind my STS research. These technologies do come with their own drawbacks, but it is ultimately up to us to determine what's to keep. It all comes down to the connotation that these robots would have with patients and physicians, as well as the societal changes it would bring.

References

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