**Autonomy in Surgical Robotics**

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## Summary

The paper addresses the readiness of robots for “consumer” application in modern medicine at different stages of autonomy. The amount of autonomy granted to the robot to perform its tasks is divided into five levels beginning with level 0. At each level the authors include tasks or technologies that are in use or need to be implemented for commonplace acceptance based on existing literature. It serves as a reference for where the field is at progressing towards completely robotic surgical intervention rather than a review of any individual papers. It then ends with an assessment of the concerns surrounding autonomous medicine legally and morally, and then addresses how far the field has to come before seeing acceptance.

## Strengths

The paper succeeds in its division and analysis of the respective subtasks and developments at each level of autonomy. By providing a short description of the problem for context and then addressing what work has been done towards that end makes the information very digestible. Particularly as a reader who is not knowledgeable about much of the medical practices involved it clarifies a lot of the technical as well as health issues involved in each step or procedure. This couples well with the paper structure to make the otherwise very dense read much more manageable. The short subsections allow the reader to quickly find tasks of note and see what has been done on the relevant work that they are interested in.

The imagery (while sparse) is well used to provide both repetition and a secondary methodology for understanding the content of the paper. The flowchart depicting each level of autonomy allows you to quickly compare the steps involved in each level and understand intuitively the difference. The summative table at the beginning of the paper also serves as a succinct snapshot of the paper that condenses a lot of the larger concepts into a single page. Both of these visualizations provide a simple reference to look at to quickly understand the topics that are more user friendly than the large paragraph descriptions.

## Weaknesses

The major criticism of this paper is that I found the lines between the levels of autonomy to be fairly blurry. It seems that the amount of control a robot has is more of a gradient rather than a series of steps. For the purposes of the paper, it seems fine to have some arbitrary distinctions in order to make the discussion more structured, but with the variety of tasks involved in healthcare I found the distinctions to be more gray than black and white. While the idea comes from self-driving cars, it seems out of place since cars only do one thing. Regardless of size or shape, a car spins some wheels, whereas medical robots can perform any number of different tasks, from taking images to removing pieces of a brain.

A more minor criticism is that the sub-headings (while extremely useful for reference) don’t always seem to have a logical separation. All of the elements that follow the “Enabling technologies” subheading are things that have been developed or are being developed that would allow for robots to reach the given level of autonomy. However, after that subheading there are some really broad sections with no direction or organization that discuss seemingly random aspects that vaguely fit into the current level of autonomy. I would have liked to see these elements potentially discussed altogether afterwards as examples of each level.

## Novelty

While this is more of a review than a new paper there are still several key takeaways or additions from this paper. The most obvious is the classification of autonomy levels that could be used for legal or ethical distinctions. It is important to be able to divide the rapidly growing field into effective distinctions for either discussion or regulation purposes. This paper proposes the measurement of autonomy as that division. The author’s discussions on the concerns in the field as well as the general state are also both keen takeaways. They address the legal and ethical problems with developing medical technology (briefly) and speculate on ways to minimize the risk or improve the reception of new technology. They look at other fields that see highly divisive autonomy and propose learning from the regulatory processes they have seen, namely AI development and self-driving cars. Lastly, the paper serves as a snapshot of where the field is now and discusses the level of development that is needed to bring biomedical robotics into the mainstream. The necessity of patience and clear demonstrations of consistent success means that while the technology may develop quickly it will likely not see use for quite some time. Particularly for new researchers in the field this is an important reminder.