

# Screw-Propelled Endoscopic Robot

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**Abstract**— Modern endoscopes still require high levels of skill and precision to operate as they apply significant forces on small areas in order to move deeper into their environments. This often results in complications as those forces accumulate and begin to stretch, bruise, or even perforate the body. In this paper, we propose a novel design which utilizes a series of discrete propulsion modules which evenly distribute forces along the body. Each module is comprised of a screw-like shell that is driven to provide the propulsion as well as an IMU to obtain the orientation of each module. These segments can then be individually manipulated in order to control and visualize the shape of the overall robot. This allows the surgeon to derive valuable information such as the shape of the environment traversed and accurate localization of problematic areas, increasing the overall safety of the procedure.

## I. INTRODUCTION

Although colorectal cancer is the fourth-leading cause of cancer-related death in the world, stage I detection has a 5-year survival rate of over 90%[1]. It is thus vital for the general population to be screened regularly, and at-risk individuals to be evaluated even more. Traditional colonoscopies are performed using an endoscope which is propelled forward by a somewhat nonspecific manual force applied posteriorly to the endoscope, accompanied by twisting the endoscope, and pressure on the patient’s abdomen. These maneuvers increase the risk of patient injury. Progress is estimated by searching for landmarks, which can lead to ending the surgery prematurely if the final landmark is misidentified. We address these traditional endoscope issues with our novel screw-propelled endoscope design, which alleviates painful colonic wall stretching, enables accurate localization and tracking, and increases overall safety.

## II. DISTRIBUTED PROPULSION

In order to avoid the accumulation of forces when performing traditional colonoscopies, a series of propulsion modules are used to distribute force. Modules are connected with flexible linkages allowing the robot to conform to its environment. As shown in Fig. 1, each module consists of an inner housing for the motor, drive wheel, and electronics and an outer shell lined with external threads that is driven in order to produce motion. By alternating the direction of the threads, a net forward force propels the robot deeper into the colon. As the scope moves deeper, the flexible linkages allow it to naturally conform to the shape of its environment enabling the robot to easily traverse bends and corners.

The relatively simple mechanical design of the system also allows the robot to easily be adapted to its environment. The outer shell can easily be replaced with custom-sized threads for different conditions. In addition, since the drive mechanism does not require complex couplings, the limiting factor of the overall diameter of the endoscope is the size of the motor.

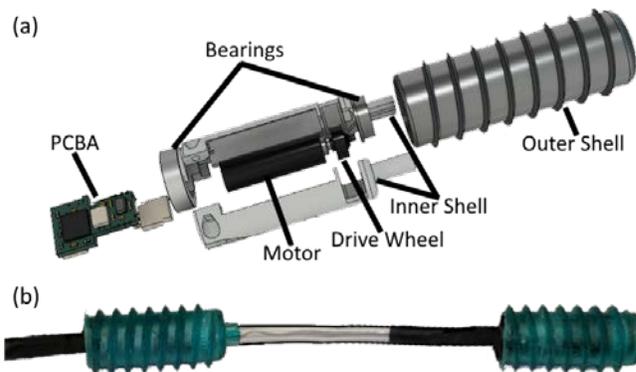


Fig. 1. (a) Propulsion module assembly in CAD  
(b) Physical prototype

## III. SHAPE VISUALIZATION

Each propulsion module also contains a motor controller and a 9 degrees of freedom IMU allowing for individual control and sensing. Using sensor fusion, an accurate heading of each module can be derived. These headings are then modeled as the tangents to a circle, producing an arc representing the shape formed from two modules. Chaining this model for each additional module produces an approximate shape for the entire robot. Then, by rotating propulsion modules at varying speeds, the shape of the robot is able to be manipulated as well. By sensing the shape of the environment through the robot, it becomes possible to actively manipulate the robot’s shape so that it is able to easily progress through a colon.

## IV. CONCLUSIONS AND FUTURE STEPS

The robotic endoscope proposed in this paper has the potential to address major issues which exist in colonoscopies today. With early and accurate detection of colorectal cancer being so essential to the patient’s survival, surgeons need a tool which can help complete surgeries with minimal risk. Our design proposes a low cost robotic solution which is able to help complete more detailed surgeries while significantly reducing patient risk.

Future work in the device’s development include developing a clinically ready model by reducing the robot’s size, hermetically sealing the device, and completing the user interface which allows shape visualization and video streaming from the device. Once this is done, we would be able to begin in-vitro and ex-vivo testing as well as pre-clinical trials in order to obtain approval for our new medical device.

## REFERENCES

- [1] Howlander N., et al. (Eds) “SEER Cancer Statistics Review, 1975-2013”, National Cancer Institute. Bethesda, MD, [http://seer.cancer.gov/csr/1975\\_2013/](http://seer.cancer.gov/csr/1975_2013/), based on November 2015 SEER data.