Proceedings of the 2023 International Conference on Mechatronics and Smart Systems
DOI: 10.54254/2755-2721/12/20230299

Capsule endoscopy robotics and SLAM technology

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Abstract. Gastrointestinal diseases are a relatively common disease, and the advent of endoscopic technology is important for the early detection and treatment of this disease. In order to adapt to current medical conditions, endoscopic robots that can move autonomously are known to be the trend of development. Most of the current capsule endoscopic robots use simultaneous localization and mapping SLAM technology to localize the capsule robot and create a map of the intestinal tract. his paper summarizes the classification of capsule endoscopy robots by referring to several articles on capsule endoscopy robots. Their working methods, advantages and disadvantages are analyzed by comparing the various types of capsule endoscopy robots horizontally. This paper also analyses the application of SLAM technology to capsule endoscopy robots. The future development of capsule endoscopy robot is prospected by combining the mainstream SLAM software and hardware technologies today. This provides the development direction for the future development of capsule endoscopy robot.

Keywords: SLAM, endoscopy robots, intestinal endoscopy.

1. Introduction

With the accelerated pace of modern life, people have irregular diets, resulting in abnormal gastrointestinal work and a high incidence of gastrointestinal diseases. Compared with traditional intestinal endoscopy, capsule endoscopy robot has the advantages of capsule endoscopy with easy examination, no trauma, no lead, no pain, no cross infection, and does not affect the normal work of patients. However, after the capsule endoscope enters the body, its location is difficult to determine, which is not conducive to the doctor's judgment that the picture transmitted by the endoscope belongs to that location of the stomach and intestines [2]. At this point, how to let the doctor know where the capsule endoscope is located is the key to the problem. Therefore, SLAM technology was invoked for the intestinal capsule endoscopic robot to construct up-to-model maps to assist the physician in determining the exact location of the capsule robot in the human body with the help of monocular vision technology. SLAM technology is a technology that enables a robot to prevent itself from moving in an unfamiliar environment, to recognize the environment and to process data so that it can gradually map the unfamiliar environment. The SLAM technique was proposed by Smith Self and Cheeseman in 1986. During the development process it was divided into traditional era, algorithmic analysis era and robustness-predictability era. In the traditional era by using Kalman filtering, particle filtering relic maximum likelihood estimation; algorithmic analysis era by observability, convergence, and consistency; robustness-predictive by working with robustness and view perception. Visual SLAM technology is when the mainstream of brother ah SLAM technology, through the depth camera, infrared camera and other means to perceive the impact of the environment and obtain information. SLAM technology is divided into a front-end image collection part and a back-end image and keyframe part of the capsule robot. In the front section collection part is divided into monocular SLAM technology, binocular SLAM technology and Light detection and ranging (LIDAR) SLAM technology . In this investigation, the application of monocular SLAM technology in on endoscopy is studied, endoscopic localization and construction of gastrointestinal feature maps with monocular SLAM are investigated, and the future development of SLAM technology applied to capsule endoscopic robots is also discussed. The back-end technology mainly focuses on closed-loop detection, which is performed several times to improve the recognition of key frames and to improve the accuracy of SLAM technology detection.

2. Classification of intestinal capsule robots

Intestinal capsule robots can be classified as bionic robots, internal force-driven robots, and external magnetic field-driven robots. Bionic robots mostly mimic earthworm-like multi-sectional robots and legged robots. Internal force-driven robots propel the capsule movement by friction or electrical stimulation with advocacy, while external magnetic field-driven robots drive the capsule by magnetic levitation, magnetic rotation, or magnetic field mixing [3].

2.1. Bionic robots

The bionic capsule robots are divided into peristaltic autonomous endoscopic robots and hovering motion endoscopic robots [4]. Peristaltic autonomous endoscopic robots allow themselves to move through the gastrointestinal tract by mimicking the peristaltic movements of a multi-segmented organism and allowing themselves to rub against the gastrointestinal tract, with the consequence or making the patient feel uncomfortable during the examination. The movement of the peristaltic capsule endoscopy robot in the gastrointestinal is influenced by the peristaltic pressure of the stomach and intestines [5]. The motion of a peristaltic autonomous endoscopic robot is inefficient and prolongs the examination time when it is limited to the low efficiency of frictional work. The hovering endoscopic robot moves by its own device or by rotation, etc., and has a higher efficiency of movement compared to the peristaltic endoscopic robot.

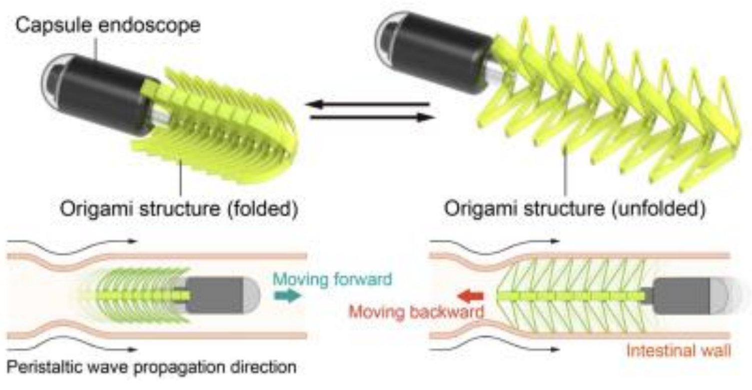

Figure 1. The capsule endoscope is moved through the gastrointestinal tract by folding and unfolding the multi-sectional structure [5].

2.2. Internal force-driven robots

Internal force-driven robots are divided into two categories: friction-driven and electrical stimulation-driven [3]. Friction drive is like peristaltic autonomous endoscopic robots in that both move by friction

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with or of the stomach and intestines. The electrical stimulation robot, on the other hand, stimulates gastrointestinal peristalsis by applying electric shocks to the patient's stomach and intestines, and the peristalsis of the stomach and intestines drives the movement of the robot. Compared to the friction robot, the electrical stimulation robot can not only achieve mooring in the gastrointestinal, but also achieve control of the gastrointestinal through electric shock, thus achieving bidirectional movement in the gastrointestinal, which in turn allows the doctor to observe the patient's pathological location back and forth to reduce the false positive rate in the examination. The electrostimulation-driven capsule endoscopy robot can be based on an electrostimulation module with additional electrostimulation therapy functions, enabling it to have both diagnostic and therapeutic functions. However, the duration of use is reduced due to the use of electric power [6].

2.3. External magnetic field-driven robots

There are three types of external magnetic field driven robots: magnetically levitated robots, magnetically rotating robots, and magnetic field hybrid drives [3]. Magnetically levitated robots are propelled through the stomach and intestines by the interaction between permanent magnets. Maglev robots are propelled through the stomach and intestines by the interaction between permanent magnets. The magnetic levitation robot has stability and reliability, but the current positioning accuracy is still slightly lacking due to errors in magnetic positioning, and the closed loop detection in the human body does not allow it to follow the intended path of travel [7]. The magnetic rotating robot moves in a rotating manner through the patient's gastrointestinal tract by applying an external magnetic field to the robot. The magnetic rotating capsule endoscope robot has a low measurement accuracy due to its own speed when rotating itself [8]. Hybrid magnetic field driven robots are driven by magnetic fields in conjunction with other forces. Compared with other ways of robots, robots driven by external magnetic fields have the advantages of multi-directional and multi-angle movement, low energy consumption, long time detection, no harm to humans and easy to swallow [9].

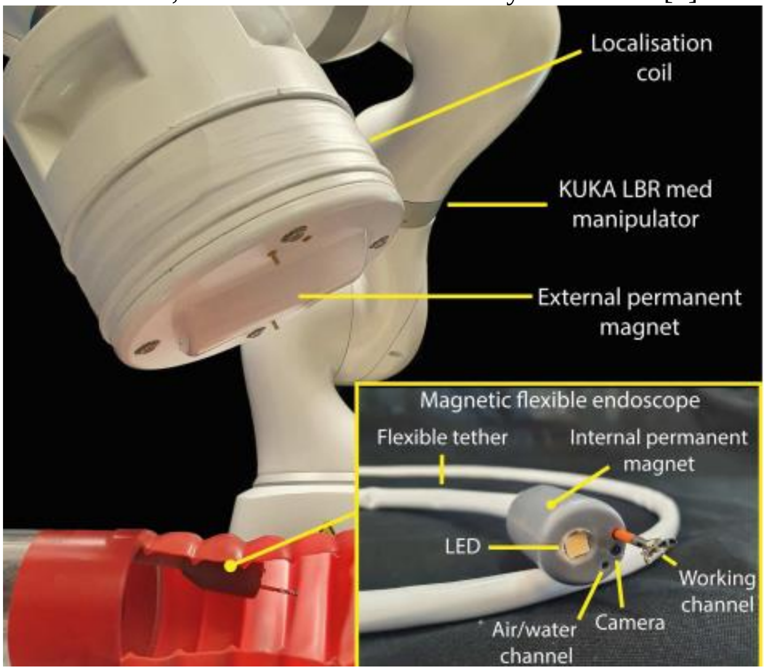

Figure 2. Description of the parts of the magnetic flexible endoscope system. The magnetic endoscope contains LEDs and a working channel for inflatable perfusion under the endoscope. A KUKA LBR Med robotic arm [10].

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3. SLAM technology on capsule robot

Recent years saw a breakthrough in the field of 3D localization using inputs as simple as a video feed. Real-time 3D mapping of a scene captured by a camera is possible because to a family of algorithms known as SLAM, which can also pinpoint the exact location of the camera in an image with great precision. The algorithm functions as follows: first, it determines the main focal points of interest in the images it receives from a video stream. Using techniques like SIFT or ORB on specific areas of the image with distinguishing qualities, these crucial locations may be found. The algorithm then tries to compare each of the newly identified key points to the key points that had already been identified for each new frame. After enough key points have been identified and matched, the algorithm attempts to identify what arrangement of cameras and key point placements in a 3D environment would allow each matched key point to appear in the correct location in each frame it was viewed in. Some implementations of the algorithm can turn the cloud of key points into a 3D mesh that accurately depicts the scene the video stream is presenting once sufficient key points have been added to the 3D model. Once the scene has been set up, we may triangulate where a new frame should be placed by using the key points from new frames. Once the action has begun, the key points from new frames can be utilized to triangulate the position of the new frame within the scene. Some alternatives use a pre-processed image instead of the original, such as a black-and-white version, a single channel (in endoscopy, typically the red one since you can see the veins more clearly), or any pre-process that would help the feature detector locate important features more effectively. These algorithms have many benefits when used in endoscopy. One can use the map generated by the algorithms coupled with the location of the device, for example, to help surgeons navigate and help them get oriented in the patient's body. A use case for the 3D model that doesn't involve localization may be estimating the size of any item that is sufficiently recorded from various angles.

Furthermore, monocular Slam technology is also widely used in capsule robotics, in the medical field, by putting into the applicable capsule robot for gastrointestinal tract related testing, what is a capsule robot, is a capsule-sized gastrointestinal tract endoscopic robot, after being taken, through the role of external magnets and permanent magnets inside the capsule mutual attraction and repulsion [1], drive the capsule movement and steering, to achieve the movement in the digestive tract The capsule is then moved through the esophagus, stomach and intestines, and finally eliminated by the body. During this process, the computer can display the relevant monitoring data of the intestinal tract simultaneously, so that the doctor can have a basis to complete the task. It may sound simple, however, the capsule robot must improve dense terrain reconstruction and posture estimation algorithms through deep learning techniques, as well as detection and recognition capabilities through SLAM vision technology before it can be put into use.

4. Conclusion

Based on the problems of the bionic capsule robot and the internal force-driven robot, this paper argues that the magnetically powered capsule endoscopic robot is the one that can minimize the patient's discomfort in performing endoscopy at present. The application of monocular vision SLAM technology to capsule endoscopy robots still has some errors in the complex modelling of the human digestive system, including but not limited to the scale shift caused by monocular vision, which requires multiple loopback inspections to reduce errors and improve accuracy. In view of the current problems of capsule robots, this paper argues that the future development direction of capsule endoscopy robots will be based on mentioning the accuracy of monocular vision SLAM technology and fusing binocular vision SLAM technology with capsule endoscopy capsule robots or to LIDAR SLAM technology which is dominated by reducing the cost of LIDAR. If we fuse LIDAR SLAM technology with capsule endoscopy, we will get a high precision capsule endoscopy robot. If this capsule endoscopic robot can be envisioned to be applied in the detection of patients by doctors, this will greatly reduce the chance of false positives in the diagnosis in patients' conditions.

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