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Endoscopic scanning probe device for rapid screening of hollow organs dysplasia

Summary

A robotic optical-biopsy scanning framework termed EndoDrone is proposed to improve the sensitivity of gastrointestinal (GI) endoscopy by automated scanning and real-time classification of wide tissue areas based on optical data. A "hot-spot" map is generated to highlight dysplastic or cancerous lesions for further scrutiny or concurrent resection. The device works as an add-on accessory to any conventional endoscope and to our knowledge is the first of its kind. The current functional prototype, which uses hyperspectral (HS) optical biopsy, is compatible with the anatomical dimensions of the colon, is envisaged to allow the identification of flat and small precancerous lesions that are currently missed.

Features & benefits

- The device has been validated in vitro and is currently being validated on GI tissue.

- The device acquires spatially-registered HS data and reconstruct it as 2D and 3D images with sub-mm resolution.

- Single-point HS sensors obtain 0.6 mm-deep rich diagnostic optical biopsy data. With the device, full images can be generated by accurate actuation of a radial array of multiple single probes.

- Real-time automated image segmentation is achieved via machine learning classification of acquired HS data, allowing the generation of a "hot-spot" map.

- Current size is compatible with the anatomical dimensions of the colon and oesophagus, but further miniaturisation is possible.

- The mechatronic framework could be used with other optical and non-optical single-point probe modalities (Fluorescence, FLIM, Polarised, Confocal, Raman, OCT, US).

Applications

- Aims to improve the adenoma detection rate of endoscopy operators independently of their skills.

- Special focus on the automated detection of small flat dysplastic lesions (<5mm) which are often missed by conventional methods.

- The device works as an add-on overtube accessory to any conventional endoscope. Could be included as a fixed-feature in future endoscope designs.

- In principle, other non-GI hollow organs (upper airway, bronchi, bladder) could be scanned with miniaturised versions.

Dr Andrew Tingey
Director of Healthcare Licensing
e: andrew.tingey@imperialinnovations.co.uk
t: +44 (0)20 3053 8813
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Figure 1: Optical design of the DRS sensors (A). Front view of the device in a collapsed and deployed configuration (B).

Background

GI endoscopy is the gold-standard procedure for detection and treatment of dysplastic lesions and early stage cancers. Despite its proven effectiveness, its sensitivity remains suboptimal due to the subjective nature of the examination, which is substantially reliant on human-operator skills. For bowel cancer, colonoscopy can miss up to 22% of dysplastic lesions, with even higher miss rates for small (<5 mm diameter) and flat lesions.

Technology

A team at Imperial College London led by Dr George Mylonas and Prof Daniel Elson developed the EndoDrone. The proposed system seeks to improve the sensitivity of GI endoscopy by automated scanning and real-time classification of wide tissue areas based on their hyperspectral optical biopsy features. A "hot-spot" map is generated to highlight dysplastic or cancerous lesions for further scrutiny or concurrent resection. The device comprises a radial array of eight optical sensors that can be partially rotated and translated along the GI tract by using a conventional endoscope as a guide-rail, while acquiring optical data (see Figure 1, above).

The key features of this technology are:

- This is the first demonstration of 2D and 3D reconstruction of endoscopic HS optical biopsy data acquired via robotic scanning of a simulated colon by a radial array of contact single-point optical probes.

- Sub-millimetre optical resolution and automated HS image segmentation have been achieved, which could allow the identification of flat pre-cancerous lesions that are currently missed.

- In vitro studies showed that the smallest simulated flat pre-cancerous lesions resolved by the device are 0.75 mm in diameter.

- The size of the device is compatible with the anatomical dimensions of the colon.

- It does not make use of endoscope's working channels, avoiding workflow interference.

- Different optical and non-optical biopsy modalities can be easily integrated within the framework, including fluorescence spectroscopy, fluorescence lifetime spectroscopy, confocal, etc.

Market

The global endoscopy market is expected to expand at a compound annual growth rate (CAGR) of 6.9% and reach USD $9.7 billion by 2021. Colonoscopy is among the most promising areas of growth, where there has been significant focus on pipeline development due to increasing patient population and awareness.

Team

- Dr George Mylonas: George was the Deputy Director of the Hamlyn Centre for Robotic Surgery at Imperial College. More recently, he joined the Department of Surgery & Cancer at Imperial College London to concentrate on developing surgical technologies suitable for clinical translation. He is also a Senior Engineering Fellow with the HELIX Centre.

- Prof Daniel Elson: Daniel is a Professor of Surgical Imaging and Biophotonics in the Hamlyn Centre for Robotic Surgery, Institute of Global Health Innovation and Department of Surgery & Cancer at Imperial College London.

- Mr. Fernando B. Avila-Rencoret: Fernando is a PhD candidate at the Hamlyn Centre for Robotic Surgery and the Department of Surgery & Cancer at Imperial College London. Fernando is a medical doctor and holds an M.Res. in Medical Robotics. He was selected as an MIT Technology Review 'Innovator under 35', and a '<Google X> Pioneer' at "We solve for X".

Intellectual Property

The technology is protected by an International Patent Application (PCT/EP2015/054794; Probe Deployment Device).

Relevant publications

1. F. B. Avila-Rencoret, D. S. Elson, and G. Mylonas, "Towards a robotic-assisted cartography of the colon: A proof of concept," in 2015 IEEE International Conference on Robotics and Automation (ICRA), 2015, pp. 1757-1763

2. F.B. Avila-Rencoret, D.S. Elson, G. Mylonas; A Robotic Hyperspectral Scanning Framework for Endoscopy, Conference Paper September 2016, Conference: [BEST PAPER & PRESENTATION] 6th Workshop on Computer/Robot Assisted Surgery - CRAS, 2016, At Pisa, Italy

3. ICRA 2016 Video teaser: https://vimeo.com/favilar/endodrone (password: endodrone)