The HELICoiD project: A comprehensive framework for real-time detection of human brain tumours using hyperspectral images

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ABSTRACT

Hyperspectral images allow obtaining large amounts of information about the surface of the scene that is captured by the sensor. Using this information and a set of complex classification algorithms is possible to determine which material or substance is located in each pixel. The HELICoiD (HypErspectraL Imaging Cancer Detection) project is a European FET project that has the goal to develop a demonstrator capable to discriminate, with high precision, between normal and tumour tissues, operating in real-time, during neurosurgical operations. This demonstrator could help the neurosurgeons in the process of brain tumour resection, avoiding the excessive extraction of normal tissue and the accidental leaving of small tumour tissues. The precise delimitation of the tumour boundaries will improve the results of the brain surgeries. The HELICoiD demonstrator is composed by two hyperspectral cameras from Headwall manufacturer, the first one in the spectral range from 400 to 1000 nm (visible and near infrared - VNIR) and the second one in the spectral range from 900 to 1700 nm (near infrared - NIR). The demonstrator also includes an illumination system that covers the spectral range from 400 nm to 2200 nm. A data processing unit is in charge of managing all the parts of the demonstrator, and a high performance platform aims to accelerate the hyperspectral image classification process. Each one of these elements is installed in a customized structure specially designed for surgical environments.

Brain tumours are among the commonest tumours worldwide with estimated incidences of approximately 3.4 per 100,000. Tumour removal can be a cure for some low grade tumours and can prolong life in more aggressive tumours. However, because brain tumours infiltrate and diffuse into the surrounding normal brain tissue, the surgeon's naked eye is often unable to distinguish between the tumour and normal brain. Consequently, tumour tissue can unintentionally be left behind during surgery which can later recur. On the other hand, if too much of the tissue is taken out, normal brain is damaged which can lead to permanent disability.

Current techniques such as intra-operative Image Guided Stereotactic (IGS) neuronavigation has improved tumour resections but is rendered inaccurate due to brain shift and changes in tumour volume that occur during operation. Intra-operative Magnetic Resonance Imaging (iMRI) was developed as a solution to intra-operative brain shift, however it has been found to have poor spatial resolution, is very time consuming and prohibitively expensive. Recently developed fluorescent tumour markers such as 5-aminolevulinic acid (5-ALA) can identify tumours but require pre-operative administration, do not identify low grade tumours and are poor at defining tumour margins mainly due to the diffuse nature of brain tumours. Therefore, there is an on-going need for a system capable of accurately identifying tumours and tumour boundaries.

Hyperspectral imaging has been used in diverse medical studies, showing that this technique is able to capture images of a large area of tissue and has exhibited great potential in the diagnosis of cancer in cervix, breast, colon, gastrointestine, skin, ovary, urothelial carcinoma, prostate, oesophagus, trachea, oral tissue, tongue and lymph node. However, hyperspectral imaging systems are not standardised, as different technologies have been used in these studies.

HELICoiD is a European collaborative project funded by the Research Executive Agency, under Grant Agreement 618080, through the Future and Emerging Technologies (FET-Open) programme, under the 7th Framework Programme of the European Union. HELICoiD is a collaborative project between four universities, three industrial partners and two hospitals. The main goal of the project is to use hyperspectral imaging to generalize a methodology to discriminate between normal and malignant tissues in real-time during surgical procedures. This information will be provided to the surgeon in real-time via different display devices, and in particular by overlaying the conventional images with a simulated colour map which indicates the normal tissues and the tissues affected by tumour cells. The integration of hyperspectral imaging and intraoperative imaged guided surgery systems should have a direct impact on patient outcomes. Potential benefits include: allowing confirmation of complete resection during the surgical procedure, avoiding complications due to "brain shift", and providing confidence that the goals of the surgery have been achieved.

The project has developed a complete system that allows to capture hyperspectral images of the in-vivo brain surface during neurosurgical operations. This HELICoiD demonstrator is capable to acquire two hyperspectral datacubes, one in the VNIR range (covering from 400 nm to 1000 nm) and another one in the NIR range (covering from 900 nm to 1700 nm). Using this demonstrator, a database of 33 hyperspectral images of both spectral ranges from 22 different patients has been generated. From this hypercubes, two different datasets (VNIR and NIR) have been created with pixels labelled as tumour and normal tissue. A classification framework based on a supervised classifier employed to distinguish between the different classes of the labelled samples has been developed. Three different pixel-wise classifiers (SVM, ANN and RF) have been compared using the same classification framework. Preliminary results of the classification algorithms offer high accuracy (over 95%) in the discrimination between normal and tumour tissues. Additionally, classification maps of the whole brain surface hyperspectral image have been generated to indicate the precise localization of the labelled classes. These classification maps have been assessed by the neurosurgeons that carried out the surgical procedures and they consider that this technique to detect the tumour areas in the brain surface is accurate and offers promising results.