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Reconstruction of biliary structure in 2D MRCP images using multi-scale analysis

Rajasvaran Logeswaran[a,b,*]

[a]BK Digital Media Division, Department of Media (HCI Lab), College of Information Technology, Soongsil University, 1-1, Sangdo-Dong, Dongjak-Gu, Seoul 156-743, South Korea

[b]Faculty of Engineering, Multimedia University, 63100 Cyberjaya, Malaysia

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Abstract

Magnetic resonance cholangio pancreatography (MRCP) has become a reference technique for biliary tree analysis. Typical MRCP images, however, suffer from difficulty in distinguishing the structure of the biliary tree in order to identify abnormalities, for clinical diagnosis. For efficiency in analysing MRCP image series, the need arises for the use of semi-automated image processing techniques. A segment-based multi-scale approach is described, incorporated with image selection, enhancement and watershed segmentation, to identify and reconstruct the hierarchical biliary tree structure in 2D MRCP images. The results achieved may be further extended to higher dimensional images.

Keywords: Medical image processing; Magnetic resonance cholangio pancreatography; Biliary tree structure detection; Multi-scale analysis; Watershed segmentation

1. Introduction

MRCP or magnetic resonance cholangio pancreatography [1] has become an accepted technique for diagnosis of pancreaticobiliary diseases. This technique has the merits of being non-invasive, as compared with the "Gold standard" ERCP (endoscopic retrograde cholangio pancreatography) [2] or PTC (percutaneous transhepatic cholangiogram) gives a much better resolution than US (Ultrasound) [1], and is non-ionising. MRCP images reveal a mapping of the biliary system and pancreatic ducts (tree-like structure of bile ducts, see Fig. 1), generally without the need for contrast medium, sedation, hospitalisation or antibiotic prophylaxis, and minimises over-distension of the ducts (may occur in ERCP due to injection of contrast medium [3]). In addition, the equipment may be used without much dependence on the operator's skill and there is generally good inter-observer agreement in the interpretation of the images [4].

There are several weaknesses in MRCP images, mainly, the appearance of artefacts, acquisition noise and partial-volume effect (due to the thickness of slices, e.g. series of 8 mm thin slices and 50 mm thick slab images acquired from the patient records of the collaborating medical institution), making identification of the actual biliary tree difficult. In addition, the angle of capture may hinder accurate identification of the biliary pathways due to non-ideal rotation, faint branches, etc., which encumbers clinical diagnosis. Furthermore, MRCP images are generally captured as a series of 2D slice images to represent a 3D volume [4–6]; thus manual identification of the tree structure in each 2D image can be time consuming and tedious. Such identification allows reconstruction of the biliary tree to provide for better interactive visualisation, rotation and manipulation in order to aid clinical diagnosis by radiologists.

This paper describes a technique of using a multi-scale approach, along with several pre-processing algorithms, image segmentation using the watershed algorithm [7–9], and some post-processing, to identify and reconstruct the hierarchical structure of the biliary tree in MRCP images. Multi-scale or scale-space analysis [10–12] is employed for detecting the significance of each part of the biliary tree. Possible applications

* Corresponding author at: Faculty of Engineering, Multimedia University, 63100 Cyberjaya, Malaysia. Tel.: +60 3 8312 5396; fax: +60 3 8318 3029.
E-mail address: loges@ieee.org.

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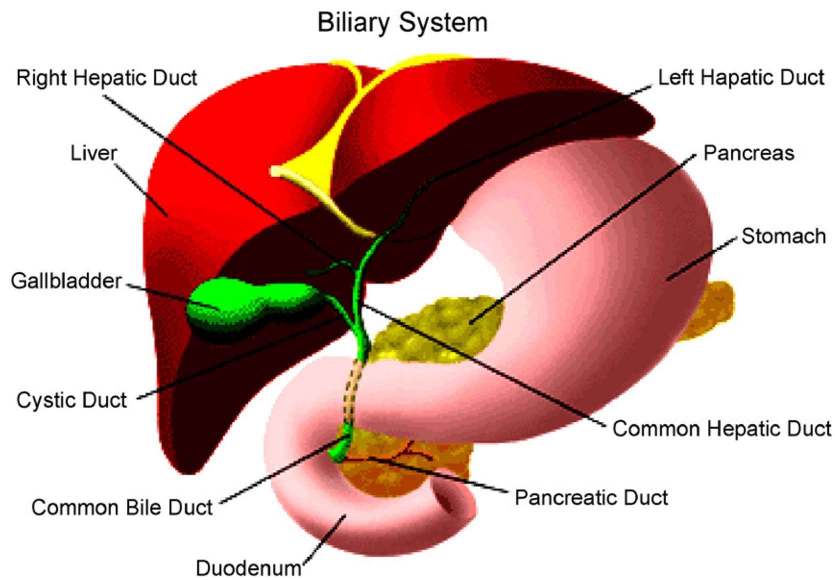

Fig. 1. Biliary ducts anatomy in the abdomen (taken from http://www.uabhealth.org/14738/).

of the findings include applications related to reconstruction of the biliary tree structure in series of slice images and in analysis of the tree structure for various pancreatobiliary diseases. Results achieved show promising results with a range of 2D MRCP images and may be extended for viable higher dimensional modelling of the biliary tree and similar structures.

2. Algorithm

Several steps are required in extracting the biliary tree from MRCP images. In the interest of practicality, this paper concentrates on identifying the distended biliary structures in single 2D MRCP thick slab images, targeting disease detection applications. Healthy biliary structures are usually of less interest to the medical practitioner, whereas the thin slice MRCP images are usually more appropriate for reconstruction and analysis in 3D, as the individual images of 8 mm thickness or less are noisy (low signal strength) and contain too little depth information for adequate structure hierarchy identification. The proposed algorithm is summarised by the flowchart in Fig. 2 and described below.

2.1. Region of interest (ROI)

MRCP images (e.g. Fig. 3(a)) are usually acquired as a series of square images of resolutions 128 × 128, 256 × 256 or 512 × 512, covering a region larger than the section under diagnosis and including orientation and location sequences. Parts of other organs, tissue or artefacts present become a hindrance to diagnosis and, as such, the first pre-processing stage incorporates the removal of non-liver non-biliary tree components in the images. The resulting "clean" trimmed image has the additional benefit of reduced size, which facilitates less intensive and faster processing, reduced storage (including intermediate representations) and improved transmission size and speed.

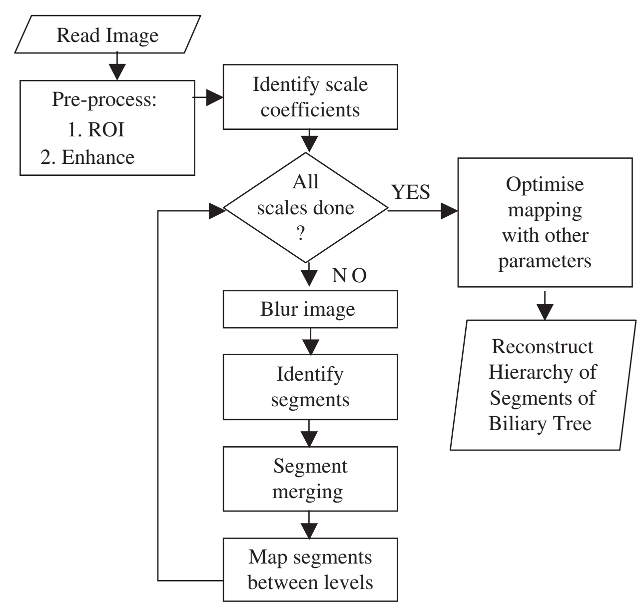

Fig. 2. Flowchart of the segment-based multi-resolution technique for identification of the biliary tree structure.

Automated detection tools, utilising PDM (Point Distribution Model) [13], splines [14] and snakes [15], are under development, but manual and simple semi-automated ROI identification (through rectangular or freehand area selection) suffices for this stage (see Fig. 3(b)).

2.2. Image enhancement

MRCP images are very susceptible to the acquisition parameters and settings. By the nature of various visualisation requirements of MRCP image series, parameter value changes are frequently necessary, even on pre-defined MR imaging sequences. These changes in values affect the intensity of the