# Analysis of the Pancreato-biliary System from MRCP

Kevin Robinson and Paul F. Whelan
*Vision Systems Laboratory, School of Electronic Engineering,*
*Dublin City University, Glasnevin, Dublin 9, Ireland*
*kevin.robinson@eeng.dcu.ie*

***Abstract***

*We present a preprocessing and segmentation scheme designed to address the particular difficulties encountered in the analysis of magnetic resonance cholangiopancreatography (MRCP) data, as a precursor to the application of computer assisted diagnosis (CAD) techniques. MRCP generates noisy, low resolution, non-isometric data which often exhibits significant greylevel inhomogeneities. This combination of characteristics results in data volumes in which reliable segmentation and analysis are difficult to achieve. In this paper we describe a data processing approach developed to overcome these difficulties and allow for the effective application of automated CAD procedures in the analysis of the biliary tree and pancreatic duct in MRCP examinations.*

## 1. Introduction

The pancreato-biliary system, consisting of the pancreatic duct and biliary tree (see Fig. 1), is routinely examined by radiologists using a set of MRI acquisition protocols collectively referred to as Magnetic Resonance Cholangiopancreatography or MRCP [1]. The data generated by this class of imaging protocol typically exhibits a number of undesirable qualities (poor signal to noise ratio, low spatial resolution, non-isometric voxels, and greylevel inhomogeneity) all of which mean that MRCP data is poorly suited to the direct application of standard automated CAD procedures.

In this paper we address the effective utilisation of MRCP for the automated and semiautomated screening and assessment of the pancreato-biliary system [2–4] through the application of novel and well focused image processing, segmentation, and visualisation techniques. The primary goal is to present a unified preprocessing pipeline designed to facilitate the subsequent robust application of CAD techniques to the analysis of MRCP data in the identification and flagging of features of potential interest to the examining radiologist. The most immediate and important aspect of that task lies in the rapid and consistent assessment of the gall bladder and common bile duct, and in the reliable recognition and localisation of stones located at these two sites. Such stones appear in the data as signal void in the otherwise high intensity regions representing the stationary fluids within the pancreato-biliary system.

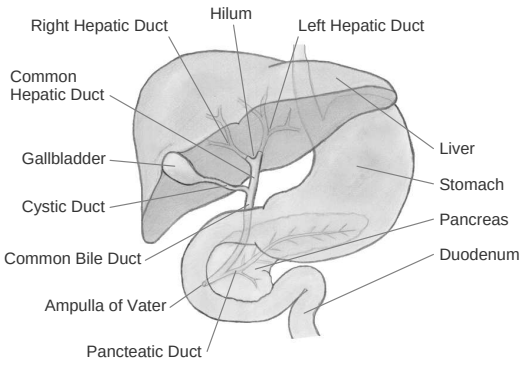
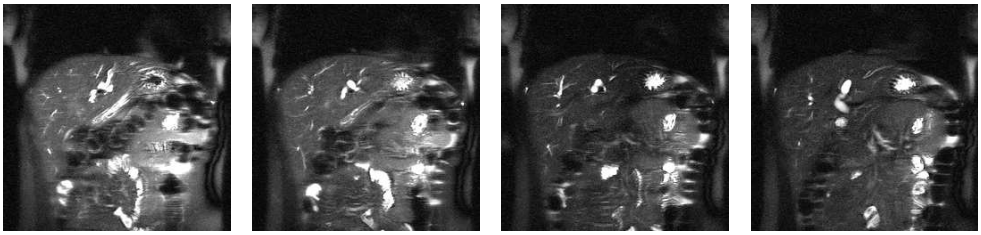



**Fig. 1:** The pancreato-biliary system.

## 2. Method

In order to achieve our goal we have implemented a four phase data processing procedure which takes raw MRCP data and generates a robust segmentation of the biliary tree suitable for further analysis and visualisation. This sequence of processing steps is specifically designed to overcome the difficulties associated with this particular segmentation task. First a greylevel homogenisation procedure is applied, matching the data histograms between successive slices in the data volume. This is followed by a gradient weighted adaptive Gaussian smoothing step designed to reduce noise while preserving semantically important boundaries in the data. Next a targeted signal suppression technique removes extraneous areas of high intensity signal from surrounding anatomical regions, and finally a watershed based segmentation procedure completes the operation, leading to the final segmentation results. Each of the four steps in this processing pipeline and the particular issues which they address are highlighted in the sections which follow.

1. *Intensity non-uniformity correction:* Due to the characteristics of the MRI acquisition protocols utilised in the collection of the MRCP data, intensity non-uniformities often appear, resulting in the first several coronal slices in the data volume being significantly brighter than subsequent slices (see below):



   Thus we have developed a data preparation procedure in the form of a histogram based intensity non-uniformity correction scheme [5] in order to minimise the effect of these greyscale inhomogeneities. The task is complicated by the need to preserve the integrity of the final volume histogram, as this is utilised for automatic threshold selection operations in later processing steps. Straightforward histogram scaling approaches result in the introduction of spikes and voids into the final histogram due to histogram bins merging and separating. In order to preserve the original histogram shape after scaling we model a continuous function passing through the discrete sample points represented by the original histogram bins. This allows us to apply an arbitrary scaling by resampling this continuous function at any desired set of intervals using cubic interpolation in order to determine the new bin sizes.

   To achieve the necessary histogram matching, the characteristic peaks representing the background and soft tissue signals are identified and aligned across all the slices in the volume. We then need to redistribute the voxels across the new set of histogram bins. A total ordering is defined for all the voxels in a slice based on each voxels original intensity level and the mean intensity in its near neighbourhood, and this ordering allows the appropriate number of voxels to be assigned to each intensity level in the final, matched slices.

2. *Adaptive Gaussian smoothing:* In the next phase of the process we aim to reduce the considerable noise present in the MRCP data, and to this end we have developed a three dimensional adaptive filtering scheme based on the Gaussian smoothing model [6]. This approach attenuates signal noise while at the same time preserving well the semantically important discontinuities present in the data. We utilise a smoothing kernel based on an oriented ellipsoid model, symmetrical in two axes, with a shortened third axis aligned parallel to the local

gradient vector. This provides smoothing oriented primarily along the local isosurface, thus preserving boundaries while at the same time attenuating background noise. The weighting function used to generate the filter masks weights at each neighbour point $q$ is given by:

$$wt(\vec{pq}, \nabla u) = e^{-((\frac{\|\vec{pq}\| \|\nabla u\|}{\lambda e^{\mu}})^2 + (\frac{\vec{pq} \cdot \nabla u}{\lambda})^2 \times (e^{2\mu} - e^{-2\mu}))}$$

where $\vec{pq}$ is the offset vector from the current point $p$ to the neighbour $q$, $\nabla u$ is the local greyscale gradient vector at $p$, $\lambda$ controls the smoothing strength, and $\mu$ specifies the degree of directionality to be applied. If $\mu = 0$ the second term in the power disappears and the filter becomes isotropic (the ellipsoid becomes a sphere). Negative $\mu$ would correspond to a boundary suppressing filter.

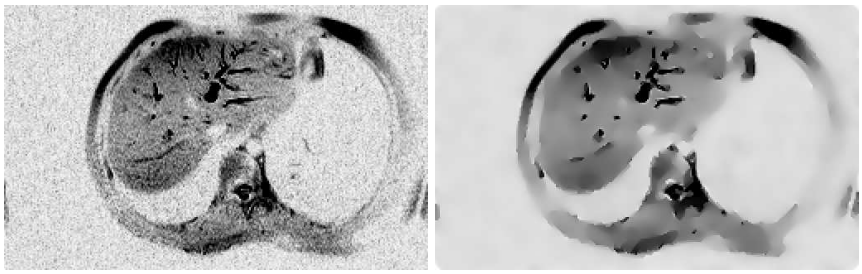


**Fig. 2:** An image unfiltered and after twenty iterations of the filter have been applied.

In Fig. 2 a single slice from an axially acquired MRCP volume is shown before and after filtering. The image intensities have been inverted for clarity. The aim of preserving the biliary tree (the dark features within the liver), while at the same time attenuating intra-regional noise has been achieved well, with most visible ductal segments displaying much improved contrast with the surrounding liver tissue.

3. *Greyscale reconstruction:* We apply a morphological reconstruction procedure to the data in order to suppress the signal originating from neighbouring structures in the scanned volume, while preserving the signal due to the tree structure which we wish to segment. This goal of retaining the narrow branch features during the morphological processing is addressed by a hybrid reconstruction approach as detailed in [7] where we describe a generalisation of the traditional reconstruction by dilation procedure [8, 9], in which we allow the degree of greylevel connectivity required to be specified during the reconstruction process.

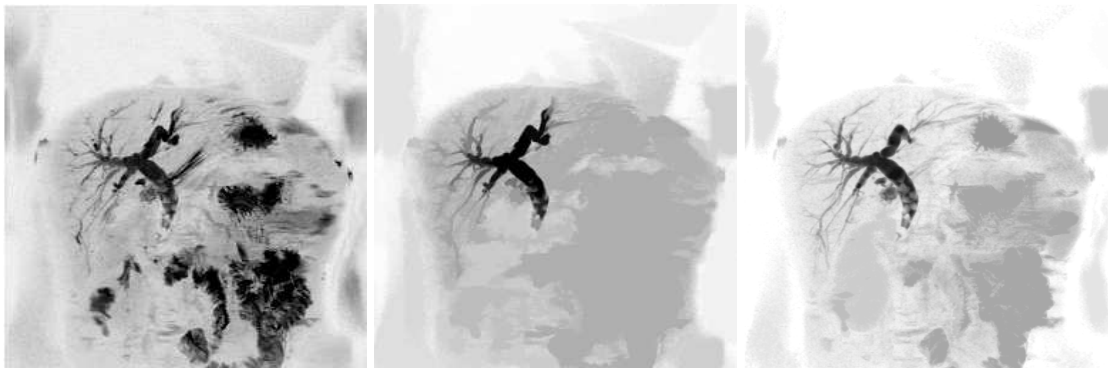


**Fig. 3:** Maximum intensity projections of one of the datasets from our study, preformed on the original, geodesic reconstructed, and hybrid reconstructed data volumes.

Notice in Fig. 3 that the traditional, geodesic reconstruction by dilation, while doing an excellent job in suppressing neighbouring regions, also severely compromises the detail resolvable in the finer branches of the biliary tree. Our hybrid reconstruction approach is effective in retaining this finer detail, while at the same time achieving good suppression of the surrounding structures. This is achieved through the use of a larger, anisotropic structuring element in the reconstruction process, allowing a non-geodesic reconstruction to be achieved.

4. *Biliary tree segmentation:* The final step in the processing pipeline is to segment the ductal system itself in order to arrive at a three dimensional representation of the tree suitable for further visualisation, interrogation, and analysis. The focused pre-segmentation processing which we have applied up to this point allows good segmentation results to be consistently achieved utilising a relatively straightforward segmentation approach. We have used a marker based watershed segmentation procedure [10] in order to achieve the segmentations illustrated in this paper.

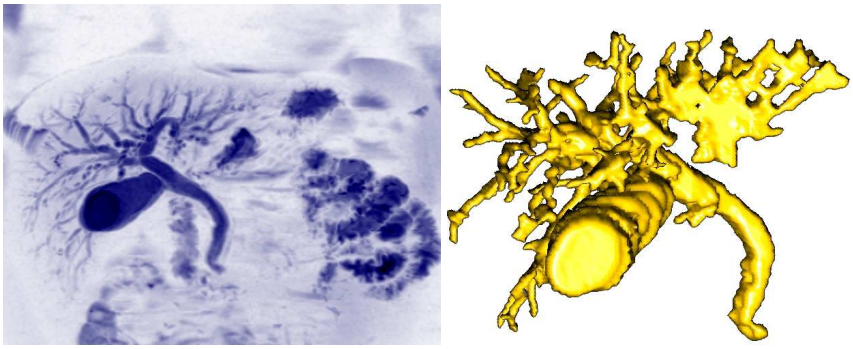


**Fig. 4:** A MIP rendering and the corresponding surface rendered watershed segmentation.

Fig. 4 shows the segmentation results achieved on one dataset. While on the whole satisfactory, notice the merging of a number of the smaller ducts in the top right hand portion of the segmented tree. This is due to the poor contrast of the ducts in this region and the resulting low gradient magnitudes present, which have failed to contain the watershed defined segmentation within the desired portions of the data.

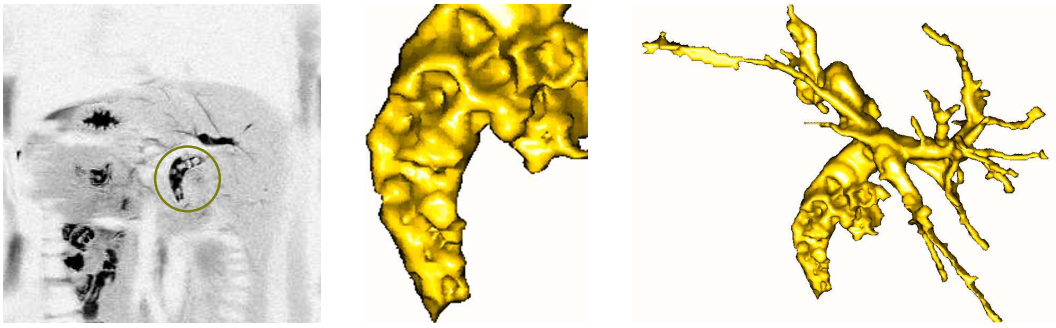


**Fig. 5:** Stones in the common bile duct (circled), as viewed from behind.

In Fig. 5 we illustrate the depiction of common bile duct stones, in coronal section (left), and in surface rendered review (right). The centre view shows a closeup of the common bile duct region from the full rendering to the right, and demonstrates more clearly the regions of signal void which correspond to the locations at which stones are present in the duct.

## 3. Results & Conclusion

We have developed and tested these techniques using a large database of MRCP studies covering a wide range of well and poorly visualised pancreato-biliary systems. Missing features often exist in the acquired datasets due to a lack of bile and pancreatic juice present in the ducts, as the protocols on which MRCP studies are based are designed to highlight stationary fluids in the scanned volume. The degree of visualisation of the finer branches in the tree is extremely variable, but where the acquired data demonstrates a reasonable representation of the pancreato-biliary system we have achieved good results in the segmentation process, as is demonstrated in the figures shown here. The robust identification and isolation of the finer branches in particular is much assisted by the preprocessing steps which we have described.

Once a segmentation has been achieved tools such as those illustrated in Figs. 6 and 7 can be used in order to visualise and interrogate the data further. The orthogonal sections viewer shown in Fig. 6 allows the user to browse the data in the axial, coronal, and sagittal planes, and to identify corresponding locations in these and the surface rendered image in the top righthand quadrant of the viewer. Interactive feedback can provide further details to the user as they select regions within the data, and selecting a location in one view can cause the same point to be shown in all views. In this way the maximum of useful information can be extracted from the acquired data.

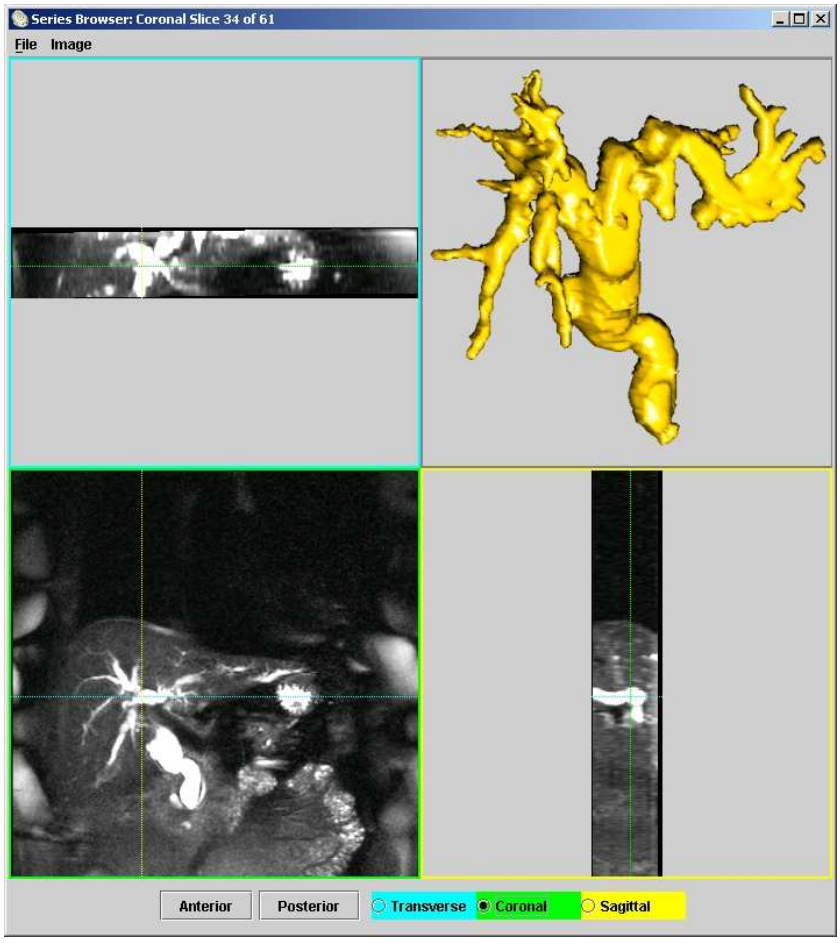



**Fig. 6:** Orthogonal sections review tool showing a typical MRCP dataset.

The volume visualisation tool illustrated in Fig. 7 provides the user with a versatile volume and surface rendering interface to allow for the generation of arbitrary three dimensional rendered views from any location and at any angle situated either outside of or within the segmented tree structure. This provides for the possibility of generating external and virtual endoscopic views, and simulated fly through image sequences, allowing the operator to gain a better appreciation of the condition of the various ducts under examination. At lower render qualities truly interactive performance can be achieved. Then once an informative point of view has been attained the rendering quality can be increased and the image can be zoomed and clipped so to provide the best possible visualisation results to the operator. A view can saved and archived at any point allowing a permanent record of the examination to be generated for future reference.

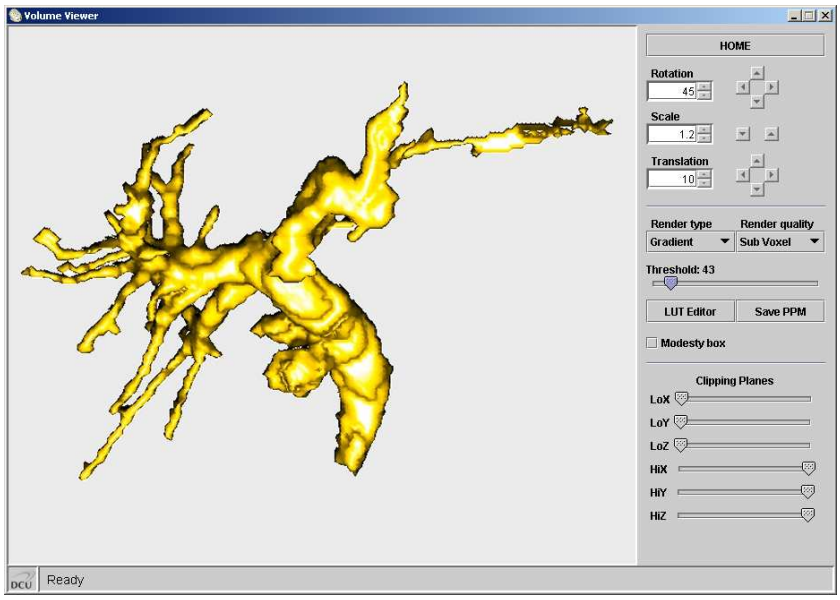



**Fig. 7:** Surface rendering tool showing a segmented biliary tree.

## References


[1] J. Sai and J. Ariyama. *MRCP: Early Diagnosis of Pancreatobiliary Diseases*. Springer-Verlag, 2000.

[2] E. Neri, P. Boraschi, G. Braccini, D. Caramella, G. Perri, and C. Bartolozzi. Mr virtual endoscopy of the pancreaticobiliary tract. *Magnetic Resonance Imaging*, 17(1):59–67, 1999.

[3] X. Lin, Y. Sun, J. Hu, C. Ko, C. Chen, and T. Wang. Three-dimensional reconstruction of the biliary tract from two-dimensional biliary images. *Endoscopy*, 27:400–403, 1995.

[4] Y. Chen and M. Wang. Mr cholangiography 3d biliary tree automatic reconstruction system. *Computerized Medical Imaging and Graphics*, 28:13–20, 2004.

[5] K. Robinson, O. Ghita, and P.F. Whelan. Intensity non-uniformity correction in multi-section whole body mri. In *SPIE OPTO-Ireland*, Dublin, Ireland, 2005.

[6] K. Robinson. Non-linear noise suppression strategies in medical image processing. In *RINCE Research Seminar Series*, Dublin, Ireland, 2004.

[7] K. Robinson and P.F. Whelan. Narrow branch preservation in morphological reconstruction. In *Irish Machine Vision and Image Processing Conference*, pages 42–49, Dublin, Ireland, 2004.

[8] L. Vincent. Morphological grayscale reconstruction in image analysis: Applications and efficient algorithms. *IEEE Transactions on Image Processing*, 2(2):176–201, 1993.

[9] K. Robinson and P.F. Whelan. Efficient morphological reconstruction: A downhill filter. *Pattern Recognition Letters*, 25(15):1759–1767, 2004.

[10] L. Vincent and P. Soille. Watersheds in digital space: An efficient algorithm based on immersion simulations. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 13(6):583–598, 1991.