Image Analysis

Image analysis with its closely related research areas of image processing and computer vision, have been associated with various applications including medical imaging, remote sensing, industrial automation, medical jurisprudence, telemedicine, proteomics, genomics, pattern recognition, robotics and content-based image retrieval.

A crucial step, along with image representation, in a wide range of image processing, image analysis and computer vision methods is image segmentation, which refers to partitioning an image to different regions that are homogeneous with respect to intensity, color or texture. The most representative class of image segmentation applications is in medical image analysis, for the detection of the boundaries of anatomical structures of interest. However, the inhomogeneity of medical images, as well as the existence of sampling artefacts, distortion and noise, make the boundaries of the anatomical structures fuzzy and disconnected, complicating the segmentation task. The early low-level image processing methods, which utilize local intensity information, are susceptible to the existence of noise and inhomogeneity. This fact imposes manual interventions so as to correct the end result. The research challenge lies in the utilization of region-based information, so as to facilitate the automated and precise detection of the boundaries of anatomical structures of interest and the extraction of malignancy risk indicators.

Active Contours guided by Textural Information

RTS Image lab introduced novel image segmentation methods, which are based on the active contour approach and utilize textural as well as intensity information. An optimization framework based on genetic algorithms has been developed for the automatic adjustment of active contour parameters. The proposed methods have been applied on standard image sets (VisTex, Brodatz, Berkeley), as well as on sets of thyroid ultrasound (US) images for the delineation of thyroid nodules, leading to higher quality segmentations than state-of-the-art segmentation methods. Moreover, they are applicable on US images provided from different US imaging devices or the same device with varying settings. It should be noticed that this work was the first on image segmentation of thyroid US images.

Thyroid Nodule Malignancy Risk Assessment based on Boundary Descriptors

RTS Image lab has introduced a novel computer-based approach for malignancy risk assessment of thyroid nodules in ultrasound images. The proposed approach is based on boundary features and is motivated by the correlation which has been addressed in medical literature between nodule boundary irregularity and malignancy risk. In addition, local echogenicity variance is utilized so as to incorporate information associated with local echogenicity distribution within nodule boundary neighborhood. Such information is valuable for the discrimination of high-risk nodules with blurred boundaries from medium risk nodules with regular boundaries. The classification results have been evaluated with the use of the receiver operating characteristic. It has been derived that the proposed approach is capable of discriminating between medium-risk and high-risk nodules.

Fuzzy Binary Patterns

RTS Image lab has proposed a generic, uncertainty-aware methodology for the derivation of Fuzzy BP (FBP) texture models, which assumes that a local neighborhood can be partially characterized by more than one binary pattern. The texture discrimination capability of four representative FBP-based approaches has been evaluated on the basis of comprehensive classification and on unsupervised segmentation experiments. The results reveal that the FBP-based approaches lead to consistent improvement in texture classification and segmentation as compared with the original BP-based approaches for various types and levels of additive noise on different reference datasets.

Fuzzy-based Texture Representation of Thyroid US for Nodule Discrimination

Another lab contribution involves thyroid ultrasound pattern representation. Considering that texture and echogenicity are correlated with thyroid malignancy, the proposed fusion approach encodes ultrasound texture by fuzzy local binary patterns and echogenicity by fuzzy intensity histograms. This approach has been experimentally investigated on real ultrasound images for the discrimination of nodules from normal thyroid parenchyma. The results demonstrate that the proposed fusion scheme outperforms previous approaches proposed in the literature.

TND-Thyroid Nodule Detector

RTS Image lab has developed an original scheme for the detection of nodular thyroid tissue in longitudinal ultrasound images, which has been presented and implemented as a prototype software system, named TND (Thyroid Nodule Detector). This system involves a novel algorithm, for automatic detection of the boundaries of the thyroid gland, and the extraction of noise resilient textural and echogenicity image features.

Color Wavelet Features for Tumor Detection in Endoscopic Video

RTS Image lab has investigated methods for processing and analysis of endoscopic imaging data. A computational approach for tumor detection in colonoscopic video has been proposed. It is based on a new color feature extraction scheme to represent the different regions in the frame sequence. The scheme is built on the wavelet decomposition. The features named as color wavelet covariance (CWC) are based on the covariances of second-order textural measures and an optimum subset of them is proposed after the application of a selection algorithm. The proposed approach is supported by a linear discriminant analysis (LDA) procedure for the characterization of the image regions along the video frames. The whole methodology has been applied on real data sets of color colonoscopic videos. The performance in the detection of abnormal colonic regions corresponding to adenomatous polyps has been estimated high, reaching 97% specificity and 90% sensitivity.

CoLD-Colorectal Lesions Detector

RTS Image lab has introduced CoLD, an innovative detection system to support colorectal cancer diagnosis and detection of pre-cancerous polyps, by processing endoscopy images or video frame sequences acquired during colonoscopy. It utilizes second-order statistical features that are calculated on the wavelet transformation of each image to discriminate amongst regions of normal or abnormal tissue. An artificial neural network performs the feature classification. CoLD integrates the feature extraction and classification algorithms under a graphical user interface, which allows both novice and expert users to utilize effectively all system's functions. It has been developed in close cooperation with gastroenterology specialists and has been tested on various colonoscopy videos. The detection accuracy of the proposed system has been estimated to be more than 95%. COLD can be used as a supplementary diagnostic tool for colorectal lesions.

Texture Feature Extraction from Images and Video in Hardware

A major drawback of feature extraction based on second-order statistical features is its high computational complexity, which is prohibiting for real-time video texture analysis in software. For this reason, we opted to overcome the limitations imposed by software by using dedicated hardware based on Field Programmable Gate Arrays (FPGAs), which are low cost and high density gate arrays capable of performing many complex computations in parallel while hosted by conventional computer hardware. The system developed by the RTS Image lab is capable of calculating a total of 64 second-order features in parallel. It is implemented on a single FPGA core that performs the calculation of both the co-occurrence matrices, which are needed for the calculation of the features, as well as the features themselves. The architecture exploits the symmetry and sparseness of the co-occurrence matrices and uses exclusively integer and fixed point arithmetic to increase performance, achieving real time operation.

Efficient Calculation of the Logarithm in Hardware

Motivated by the use of the logarithm function in the entropy feature, the RTS Image lab has introduced an algorithm for efficient approximation of the logarithm in hardware. It is based on a piecewise linear approximation methodology, implemented so that an arbitrary number of linear segments approximate the logarithm function. The achieved accuracy depends on the number of segments used, which also affects the size of a ROM used for storing the parameters that control the computation. The implementation of the ROM using an FPGA BlockRAM allows the parameters to be updated without reconfiguration of the FPGA core, while providing the considerable advantage of data set adaptability to the proposed architecture over the other relevant architectures, i.e. the parameters can be easily updated to minimize the approximation error for different data sets. The implementation results show that the proposed method adapts well to all data sets used and requires significantly less FPGA slices than the CORDIC architecture to achieve the same or higher approximation accuracy. Moreover, it provides a throughput of one result per cycle and up to four times lower latency than the CORDIC core.

Automatic Gridding of DNA Microarray Images

Another significant research contribution by the RTS-Image research group is the determination of the spot grid on complementary DNA (cDNA) microarray images. Complementary DNA microarrays are a well established technology for studying gene expression. A microarray image is obtained by laser scanning a hybridized cDNA microarray, which consists of thousands of spots, arranged in a two-dimensional array. The separation of the spots into distinct cells is widely known as microarray image gridding. The grey level intensity of each spot signifies the degree of hybridization of a cDNA sample to known DNA sequences, thereby indicating the expression levels of a specific gene. The reliable quantification of the gene expression requires a gridding algorithm, which should be able to grid images that include spots of various shapes, sizes and intensities, while being robust to noise and artefacts introduced at a microarray preparation stage, as well as rotation due to slight misalignments of the scanning robot coordinate system to the image coordinate system. Furthermore, it is desirable that the gridding be automatically performed, without any user intervention that would possibly affect the microarray experiment, as well as limit the processing throughput of large amounts of microarray images. The existing commercial software depends on user input for the determination of the grid. So, a novel methodology for automatic cDNA microarray gridding has been developed, which is based on the maximization of the margin between the consecutive rows and columns of the microarray spots. It is implemented by training a linear maximum

margin classifier with an automatically detected subset of spots on the microarray image. The classifier determines the optimal positioning of each grid line, whereas the use of a soft-margin variant provides robustness to outliers. This methodology is supported by a non-parametric Radon-based rotation estimator of general applicability for cDNA microarray images. The proposed method achieves successful automatic gridding of cDNA microarray images in the presence of irregular spots, noise and artefacts, as well as image rotation, whereas the experimental results on reference DNA microarray images containing more than two million spots demonstrate that it outperforms the most accurate state of the art methods, achieving perfect gridding for more than 98% the spots.

Hardware implementation of a disparity estimation scheme for real-time compression in 3D imaging applications

The RTS-Image research group has also contributed to the field of 3D imaging, more specifically by designing and implementing a novel hardware architecture of a disparity estimation scheme targeted to real-time Integral Photography (IP) image and video sequence compression. The software developed for IP image compression achieves high quality ratios over classic methodologies by exploiting the inherent redundancy that is present in IP images. However, there are certain time constraints to the software approach that must be confronted in order to address real-time applications. The main effort has been to achieve real-time performance by implementing in hardware the most time-consuming parts of the compression algorithm. The proposed novel digital architecture features minimized memory read operations and extensive simultaneous processing, while taking into concern the memory and data bandwidth limitations of a single FPGA implementation. The results demonstrate that the implemented hardware system can successfully process high resolution IP video sequences in real-time, addressing a vast range of applications, from mobile systems to demanding desktop displays.