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ETPL BM - 001	A Multi-Classifier System for Automatic Mitosis Detection in Breast Histopathology Images Using Deep Belief Networks

Mitotic count is an important diagnostic factor in breast cancer grading and prognosis. Detection of mitosis in breast histopathology images is very challenging mainly due to diffused intensities along object boundary and shape variation in different stages of mitosis. This paper demonstrates an accurate technique for detecting the mitotic cells in Hematoxyline and Eosin stained images by step by step refinement of segmentation and classification stages. Krill Herd Algorithm-based localized active contour model precisely segments cell nuclei from background stroma. A deep belief network based multi-classifier system classifies the labeled cells into mitotic and nonmitotic groups. The proposed method has been evaluated on MITOS data set provided for MITOS-ATYPIA contest 2014 and also on clinical images obtained from Regional Cancer Centre (RCC), Thiruvananthapuram, which is a pioneer institute specifically for cancer diagnosis and research in India. The algorithm provides improved performance compared with other state-of-the-art techniques with average F-score of 84.29% for the MITOS data set and 75% for the clinical data set from RCC

ETPL BM - 002	Weighted Level Set Evolution Based on Local Edge Features for Medical Image

Level set methods have been widely used to implement active contours for image segmentation applications due to their good boundary detection accuracy. In the context of medical image segmentation, weak edges and in homogeneities remain important issues that may hinder the accuracy of any segmentation method based on active contours implemented using level set methods. This paper proposes a method based on active contours implemented using level set methods for segmentation of such medical images. The proposed method uses a level set evolution that is based on the minimization of an objective energy functional whose energy terms are weighted according to their relative importance in detecting boundaries. This relative importance is computed based on local edge features collected from the adjacent region located inside and outside of the evolving contour. The local edge features employed are the edge intensity and the degree of alignment between the image's gradient vector flow field and the evolving contour's normal. We evaluate the proposed method for segmentation of various regions in real MRI and CT slices, X-ray images, and ultra sound images. Evaluation results confirm the advantage of weighting energy forces using local edge features to reduce leakage. These results also show that the proposed method leads to more accurate boundary detection results than the state-of-the-art edge-based level set segmentation methods, particularly around weak edges

ETPL BM - 003	High-quality parallel-ray X-Ray CT back projection using optimized interpolation

We propose a new, cost-efficient method for computing back projections in parallel-ray X-ray CT. Forward and back projections are the basis of almost all X-ray CT reconstruction methods, but computing these accurately is costly. In the special case of parallel-ray geometry, it turns out that reconstruction requires back projection only. One approach to accelerate the back projection is through interpolation: fit a continuous representation to samples of the desired signal, then sample it at the required locations. Instead, we propose applying a prefilter that has the effect of orthogonally projecting the underlying signal onto the space spanned by the interpolator, which can significantly improve the quality of the interpolation. We then build on this idea by using oblique projection, which simplifies the computation while giving effectively the same improvement in quality. Our experiments on analytical phantoms show that this refinement can improve the reconstruction quality for both filtered back projection and iterative reconstruction in the high-quality regime, i.e., with low noise and many measurements

ETPL BM - 004	Melanoma Is Skin Deep A 3D Reconstruction Technique for Computerized Dermoscopic Skin Lesion Classification

Melanoma mortality rates are the highest amongst skin cancer patients. Melanoma is life threating when it grows beyond the dermis of the skin. Hence, depth is an important factor to diagnose melanoma. This paper introduces a non-invasive computerized dermoscopy system that considers the estimated depth of skin lesions for diagnosis. A 3-D skin lesion reconstruction technique using the estimated depth obtained from regular dermoscopic images is presented. On basis of the 3-D reconstruction, depth and 3-D shape features are extracted. In addition to 3-D features, regular color, texture, and 2-D shape features are also extracted. Feature extraction is critical to achieve accurate results. Apart from melanoma, in-situ melanoma the proposed system is designed to diagnose basal cell carcinoma, blue nevus, dermatofibroma, haemangioma, seborrhoeic keratosis, and normal mole lesions. For experimental evaluations, the PH2, ISIC: Melanoma Project, and ATLAS dermoscopy data sets is considered. Different feature set combinations is considered and performance is evaluated. Significant performance improvement is reported the post inclusion of estimated depth and 3-D features. The good classification scores of sensitivity = 96%, specificity = 97% on PH2 data set and sensitivity = 98%, specificity = 99% on the ATLAS data set is achieved. Experiments conducted to estimate tumor depth from 3-D lesion reconstruction is presented. Experimental results achieved prove that the proposed computerized dermoscopy system is efficient and can be used to diagnose varied skin lesion dermoscopy images

ETPL BM - 005	Multi-Grained Random Fields for Mitosis Identification in Time-Lapse Phase Contrast Microscopy Image Sequences

This paper proposes a multi-grained random fields (MGRFs) model for mitosis identification. To deal with the difficulty in hidden state discovery and sequential structure modeling in mitosis sequences only containing gradual visual pattern changes, we design the graphical structure to transform individual sequence into a set of coarse-to-fine grained sequences conveying diverse temporal dynamics. Furthermore, we propose the corresponding probabilistic model for joint temporal learning and feature learning. To deal with the non-convex formulation of MGRF, we decompose model training into two sub-tasks, layer-wise sequential learning of both temporal dynamics and visual feature and new layer generation by graph-based sequential grouping, and optimize the model by alternating between them iteratively. The proposed method is validated on very challenging mitosis data set of C3H10T1/2 and C2C12 stem cells. Extensive comparison experiments demonstrate its superiority to the state of the arts

ETPL BM - 006	A Study of Distinctiveness of Skin Texture for Forensic Applications through Comparison with Blood Vessels

Skin texture without obvious features is different from other hard biometrics on the skin, such as fingerprints and palmprints. Skin texture gives an impression that it is not distinctive like other soft biometric traits. It was proposed for personal identification a decade ago but did not draw attention from the biometric community, partially due to the success of other biometric technologies for commercial applications. However, in some forensic cases, e.g., identifying masked terrorists in images, skin texture may be the only option. Faces, tattoos, and skin marks are not always available for identification. To address these forensic needs, researchers have recently attempted to visualize blood vessels hidden in color images. Their performance is highly sensitive to image quality. Skin texture that is easily captured even in low-resolution images, such as that of the forearm skin, is suitable for these forensic applications. To study the distinctiveness of low-resolution skin texture, in this paper, an algorithm composed of a positive sample generation scheme, dynamic and directional grids, a large feature set generation scheme, and partial least squares regression has been proposed. More than 6300 inner forearm and thigh images collected from a laboratory environment and from the internet with large pose, viewpoint, and illumination variations were employed in this paper. The proposed algorithm was compared with the state-of-the-art texture recognition methods, and skin texture was compared with blood vessels, a hard biometric trait, extracted from color and infrared images. The results showed that the proposed algorithm performed significantly better than did the texture recognition methods, and skin texture outperformed blood vessels in all of the experiments, achieving encouraging performance

ETPL BM - 007	Detecting Cardiovascular Disease from Mammograms with Deep Learning

Coronary artery disease is a major cause of death in women. Breast arterial calcifications (BACs), detected in mammograms, can be useful risk markers associated with the disease. We investigate the feasibility of automated and accurate detection of BACs in mammograms for risk assessment of coronary artery disease. We develop a 12-layer convolutional neural network to discriminate BAC from non-BAC and apply a pixelwise, patch-based procedure for BAC detection. To assess the performance of the system, we conduct a reader study to provide ground-truth information using the consensus of human expert radiologists. We evaluate the performance using a set of 840 full-field digital mammograms from 210 cases, using both free-response receiver operating characteristic (FROC) analysis and calcium mass quantification analysis. The FROC analysis shows that the deep learning approach achieves a level of detection similar to the human experts. The calcium mass quantification analysis shows that the inferred calcium mass is close to the ground truth, with a linear regression between them yielding a coefficient of determination of 96.24%. Taken together, these results suggest that deep learning can be used effectively to develop an automated system for BAC detection in mammograms to help identify and assess patients with cardiovascular risks

ETPL BM - 008	Automatic Image Processing Based Dental Image Analysis Using Automatic Gaussian Fitting Energy and Level Sets

Computational methods play an important role in enhancing the diagnosis of the skin cancer. Melanoma is the most fatal type of skin cancers that causes significant number of deaths in recent years. In this paper, novel boundary features are introduced based on the color variation of the skin lesion images, acquired with standard cameras. Furthermore, to reach higher performance in melanoma detection, a set of textural and morphological features are associated with proposed features. Multilayer perceptron neural network is used as classifier in this work. Results analysis indicate that proposed feature set has the highest mean accuracy (87.80%), sensitivity (87.92%), specificity (87.65%) and precision (90.39%) in comparison with the previous works in Dermatology Information System (IS) and DermQuest datasets

ETPL BM - 009	Skin lesion images classification using new color pigmented boundary descriptors

Computational methods play an important role in enhancing the diagnosis of the skin cancer. Melanoma is the most fatal type of skin cancers that causes significant number of deaths in recent years. In this paper, novel boundary features are introduced based on the color variation of the skin lesion images, acquired with standard cameras. Furthermore, to reach higher performance in melanoma detection, a set of textural and morphological features are associated with proposed features. Multilayer perceptron neural network is used as classifier in this work. Results analysis indicate that proposed feature set has the highest mean accuracy (87.80%), sensitivity (87.92%), specificity (87.65%) and precision (90.39%) in comparison with the previous works in Dermatology Information System (IS) and DermQuest datasets.

ETPL BM - 010	Automatic micro aneurysm detection of diabetic retinopathy in fundus images

Regular eye screening is essential for the early detection and treatment of the diabetic retinopathy. This paper presents a novel automatic screening system for diabetic retinopathy that focuses on the detection of the earliest visible signs of retinopathy, which are microaneurysms. Microaneurysms are small dots on the retina, formed by ballooning out of a weak part of the capillary wall. The detection of the microaneurysms at an early stage is vital, and it is the first step in preventing the diabetic retinopathy. The paper first explores the existing systems and applications related to diabetic retinopathy screening, with a focus on the microaneurysm detection methods. The proposed decision support system consists of an automatic acquisition, screening and classification of diabetic retinopathy colour fundus images, which could assist in the detection and management of the diabetic retinopathy. Several feature extraction methods and the circular Hough transform have been employed in the proposed microaneurysm detection system, alongside the fuzzy histogram equalisation method. The latter method has been applied in the preprocessing stage of the diabetic retinopathy eye fundus images and provided improved results for detecting the microaneurysms

ETPL BM - 011	Computer-aided Diagnosis of Focal Liver Lesions Using Contrast-Enhanced Ultrasonography with Perflubutane Micro bubbles

This paper proposes an automatic classification method based on machine learning in contrast-enhanced ultrasonography (CEUS) of focal liver lesions using the contrast agent Sonazoid. This method yields spatial and temporal features in the arterial phase, portal phase, and post-vascular phase, as well as max-hold images. The lesions are classified as benign or malignant and again as benign, hepatocellular carcinoma (HCC), or metastatic liver tumor using support vector machines (SVM) with a combination of selected optimal features. Experimental results using 98 subjects indicated that the benign and malignant classification has 94.0% sensitivity, 87.1% specificity, and 91.8% accuracy, and the accuracy of the benign, HCC, and metastatic liver tumor classifications are 84.4%, 87.7%, and 85.7%, respectively. The selected features in the SVM indicate that combining features from the three phases are important for classifying FLLs, especially, for the benign and malignant classifications. The experimental results are consistent with CEUS guidelines for diagnosing FLLs. This research can be considered to be a validation study that confirms the importance of using features from these phases of the examination in a quantitative manner. In addition, the experimental results indicate that for the benign and malignant classifications, the specificity without the post-vascular phase features is significantly lower than the specificity with the post-vascular phase features. We also conducted an experiment on the operator dependency of setting regions of interest and observed that the intra-operator and inter-operator kappa coefficients were 0.45 and 0.77, respectively

ETPL BM – 012	Joint Segmentation of Retinal Layers and Focal Lesions in 3-D OCT Data of Topologically Disrupted Retinas

Accurate quantification of retinal structures in 3-D optical coherence tomography data of eyes with pathologies provides clinically relevant information. We present an approach to jointly segment retinal layers and lesions in eyes with topology-disrupting retinal diseases by a loosely coupled level set framework. In the new approach, lesions are modeled as an additional space-variant layer delineated by auxiliary interfaces. Furthermore, the segmentation of interfaces is steered by local differences in the signal between adjacent retinal layers, thereby allowing the approach to handle local intensity variations. The accuracy of the proposed method of both layer and lesion segmentation has been evaluated on eyes affected by central serous retinopathy and age-related macular degeneration. In addition, layer segmentation of the proposed approach was evaluated on eyes without topology-disrupting retinal diseases. Good agreement between the segmentation performed manually by a medical doctor and results obtained from the automatic segmentation was found for all data types. The mean unsigned error for all interfaces varied between 2.3 and 11.9 µm (0.6-3.1 pixels). Furthermore, lesion segmentation showed a Dice coefficient of 0.68 for drusen and 0.89 for fluid pockets. Overall, the method provides a flexible and accurate solution to jointly segment lesions and retinal layers

ETPL BM - 013	Melanoma Is Skin Deep: A 3D Reconstruction Technique for Computerized Dermoscopic Skin Lesion Classification

Melanoma mortality rates are the highest amongst skin cancer patients. Melanoma is life threating when it grows beyond the dermis of the skin. Hence, depth is an important factor to diagnose melanoma. This paper introduces a non-invasive computerized dermoscopy system that considers the estimated depth of skin lesions for diagnosis. A 3-D skin lesion reconstruction technique using the estimated depth obtained from regular dermoscopic images is presented. On basis of the 3-D reconstruction, depth and 3-D shape features are extracted. In addition to 3-D features, regular color, texture, and 2-D shape features are also extracted. Feature extraction is critical to achieve accurate results. Apart from melanoma, in-situ melanoma the proposed system is designed to diagnose basal cell carcinoma, blue nevus, dermatofibroma, haemangioma, seborrhoeic keratosis, and normal mole lesions. For experimental evaluations, the PH2, ISIC: Melanoma Project, and ATLAS dermoscopy data sets is considered. Different feature set combinations is considered and performance is evaluated. Significant performance improvement is reported the post inclusion of estimated depth and 3-D features. The good classification scores of sensitivity = 96%, specificity = 97% on PH2 data set and sensitivity = 98%, specificity = 99% on the ATLAS data set is achieved. Experiments conducted to estimate tumor depth from 3-D lesion reconstruction is presented. Experimental results achieved prove that the proposed computerized dermoscopy system is efficient and can be used to diagnose varied skin lesion dermoscopy images

ETPL BM - 014	Fundamental Storage-Latency Trade-off in Cache-Aided MIMO Interference Networks

Caching is an effective technique to improve user perceived experience for content delivery in wireless networks. Wireless caching differs from traditional web caching in that it can exploit the broadcast nature of wireless medium and hence opportunistically change the network topologies. This paper studies a cache-aided MIMO interference network with 3 transmitters each equipped with M antennas and 3 receivers each with N antennas. With caching at both the transmitter and receiver sides, the network is changed to hybrid forms of MIMO broadcast channel, MIMO X channel, and MIMO multicast channels. We analyze the degrees of freedom (DoF) of these new channel models using practical interference management schemes. Based on the collective use of these DoF results, we then obtain an achievable normalized delivery time (NDT) of the network, an information-theoretic metric that evaluates the worst-case delivery time at given cache sizes. The obtained NDT is for arbitrary M, N and any feasible cache sizes. It is shown to be optimal in certain cases and within a multiplicative gap of 3 from the optimum in other cases. The extension to the network with arbitrary

ETPL BM - 015	Joint Fronthaul Multicast Beamforming and User-Centric Clustering in Downlink C-RANs"

The cloud radio access network (C-RAN) is deemed as a cost-effective architecture to exploit the capacity benefit of densely deployed radio access points. The low-latency fronthaul data transmission from the central processor to small-cell base stations (SBSs) is a key requirement in C-RANs, for which conventional wired fronthaul links will be cost-prohibitive and also inconvenient. Therefore, scalable and low-cost wireless fronthaul solutions have drawn much attention in both industry and academia. In this paper, we propose to adopt the multicast beamforming strategy over fronthaul links to deliver each user's message to a cluster of SBSs selected according to the user-centric clustering scheme, which then adopts the joint beamforming technique to cooperatively transmit the signal to the target users. Some approximate techniques are applied to obtain a tractable formulation for this mixed integer nonlinear programming (MINLP) problem, and an iterative algorithm based on the block coordinate update method is proposed accordingly. Then, a binary search based algorithm is developed to preserve the sparsity of beamformers due to the relaxation of the discrete clustering function with the continuous exponential function. Extensive simulation results are provided to show the performance of the proposed algorithms in terms of convergence, power consumption and weighted sum rate

ETPL BM - 016	Angle and Delay Estimation for 3D Massive MIMO/FD-MIMO Systems Based on Parametric Channel Modeling

In order to meet the challenge of increasing data-rate demand as well as the form factor limitation of the base station, 3D massive MIMO (Multiple-Input Multiple-Output) technology has been introduced as one of the enabling technologies for the fifth generation (5G) mobile cellular systems. In 3D massive MIMO systems, a base station (BS) will rely on the uplink sounding signals from mobile stations to figure out the spatial information for downlink MIMO operations. Accordingly, multidimensional parameter estimation of a MIMO channel becomes crucial for such systems to realize the predicted capacity gains.

ETPL BM - 017	Millimeter-Wave Channel Estimation Based on Two-Dimensional Beamspace MUSIC Method

Due to the spatial sparsity caused by the severe propagation loss, the millimeter-wave (mm-wave) channel estimation can be performed by estimating the directions and gains of the paths that have significant power. In this paper, we apply the beamspace two-dimensional multiple signal classification (MUSIC) method to estimate the path directions (the angles of departure and arrival) and use the least-squares method to estimate the path gains. Different from its element-space counterpart, the beamspace MUSIC method may exhibit spectrum ambiguity caused by the beamformers. In this paper, we therefore analyze the sufficient conditions on the beamformers under which the MUSIC spectrum has no ambiguity which also leads to the maximum number of resolvable path directions. Moreover, based on the uniform linear array with half-wavelength spacing, we show that the discrete Fourier transform (DFT) beamformers, which are naturally analog and often employed in the mm-wave communication systems with hybrid precoding structure, can avoid the spectrum ambiguity and maximize the number of resolvable path directions. Simulation results demonstrate that the proposed two-dimensional beamspace MUSIC mm-wave channel estimator significantly outperforms existing estimators that are based on beam training and sparse recovery; and in the meantime, it requires much less training slots than these existing methods

ETPL BM - 018	Cross-Layer Performance of Downlink Dynamic Cell Selection with Random Packet Scheduling and Partial CQI Feedback in Wireless Networks with Cell Sleeping

In this paper, we consider a coordinated multipoint (CoMP) dynamic cell selection (DCS) transmission scheme for serving sleeping cell user equipments (UEs). According to this DCS scheme, packets of UEs in a sleeping cell are randomly forwarded to the potential active base stations (BSs) by the packet serving gateway (PSG) and UEs in the sleeping cell dynamically select their serving BS from these active BSs. We model the system as a fork/join (F/J) queuing system and develop a cross-layer analytical model that considers the time varying nature of the channels, channel scheduling mechanism, partial channel quality information (CQI) feedback, cell selection mechanism, bursty packet arrivals and packet scheduling mechanism. The developed analytical model can be used to measure various packet level performance parameters such as packet loss probability (PLP) and queuing delay while accounting for out-of-sequence packet delivery. We validate the accuracy of the developed analytical model via simulations and we compare the performance of the DCS scheme under consideration with the conventional fixed cell selection scheme and with the state-of-the-art DCD scheme. Presented numerical results show that the DCS scheme under consideration significantly improves the PLP performance. Queuing delay performance, on the other hand, depends on the system and operating parameters

ETPL BM - 019	An Experimental Evaluation of Switched Combining Based Macro-Diversity for Wearable Communications Operating in an Outdoor Environment

This paper investigates the potential improvement in signal reliability for outdoor wearable communications channels operating at 868 MHz using switched combining based macro-diversity. In this study, a number of different macro-diversity configurations consisting of two and four base stations were considered to help mitigate the impact of body shadowing upon a wearable node which was located on the central chest region of an adult male. During the field measurements, five different walking movements were performed and then analyzed to investigate the efficacy of using macro-diversity. It was found that all of the considered switched combining schemes including switch-and-stay combining (SSC), switch-and-examine combining (SEC) and SEC with post-examining selection (SECps) provided a worthwhile signal improvement when an appropriate switching threshold was adopted. The maximum diversity gain obtained in this study was found to be 19.5 dB when using four-base station SECps. The diversity gain, the number of path examinations and the number of path switches between base stations for the switched combiner output varied according to the determined switching threshold, highlighting the importance of the selection of an appropriate threshold level. Furthermore, the performance/complexity trade off is demonstrated. Finally, the fading behavior at the output of the switched diversity combiners was then characterized using the diversity specific equations developed under the assumption of independent and non-identically distributed Nakagami- m fading channels. Over all of the measurement scenarios considered in this study, the theoretical models provided an adequate fit to the fading observed at the output of the virtual switched combiner

ETPL BM - 020	Ergodic Fading MIMO Dirty Paper and Broadcast Channels: Capacity Bounds and Lattice Strategies

A multiple-input multiple-output (MIMO) version of the dirty paper channel is studied, where the channel input and the dirt experience the same fading process with channel state information at the receiver (CSIR). This represents settings where signal and interference sources are co-located, such as in the broadcast channel. First, a variant of Costa's dirty paper coding (DPC) is presented, whose achievable rates are within a constant gap to capacity for all signal and dirt powers. Additionally, a lattice coding and decoding scheme is proposed, whose decision regions are independent of the channel realizations. Under Rayleigh fading, the gap to capacity of the lattice coding scheme vanishes with the number of receive antennas, even at finite SNR. Thus, although the capacity of the fading dirty paper channel remains unknown, this work shows it is not far from its dirt-free counterpart. The insights from the dirty paper channel directly lead to transmission strategies for the two-user MIMO broadcast channel (BC), where the transmitter emits a superposition of desired and undesired (dirt) signals with respect to each receiver. The performance of the lattice coding scheme is analyzed under different fading dynamics for the two users, showing that high-dimensional lattices achieve rates close to capacity

ETPL BM - 021	A Novel Mirror-Aided Non-imaging Receiver for Indoor 2×2 MIMO Visible Light Communication Systems

Indoor visible light communication (VLC) systems are now possible because of advances in light emitting diode and laser diode technologies. These lighting technologies provide the foundation for multiple-input multiple-output (MIMO) data transmission through visible light. However, the channel matrix can be strongly correlated in indoor MIMO-VLC systems, preventing parallel data streams from being decoded. Here, in 2×2 MIMO-VLC systems, we describe a mirror diversity receiver (MDR) design that reduces the channel correlation by both blocking the reception of light from one specific direction and improving the channel gain from light from another direction by utilizing a double-sided mirror deployed between the receiver's photodetectors. We report on the channel capacity of the MDR system and the optimal height of its mirrors in terms of maximum channel capacity. We also derived analytic results on the effect of rotation on MDR's performance. Based on numerical and experimental results, we show that the double-sided mirror has both constructive and destructive effects on the channel matrix. Our design can be used with previously described non-imaging systems to improve the performance of indoor VLC systems

ETPL BM - 022	Detecting Anatomical Landmarks from Limited Medical Imaging Data Using Two-Stage Task-Oriented Deep Neural Networks

One of the major challenges in anatomical landmark detection, based on deep neural networks, is the limited availability of medical imaging data for network learning. To address this problem, we present a two-stage task-oriented deep learning method to detect large-scale anatomical landmarks simultaneously in real time, using limited training data. Specifically, our method consists of two deep convolutional neural networks (CNN), with each focusing on one specific task. Specifically, to alleviate the problem of limited training data, in the first stage, we propose a CNN based regression model using millions of image patches as input, aiming to learn inherent associations between local image patches and target anatomical landmarks. To further model the correlations among image patches, in the second stage, we develop another CNN model, which includes a) a fully convolutional network that shares the same architecture and network weights as the CNN used in the first stage and also b) several extra layers to jointly predict coordinates of multiple anatomical landmarks. Importantly, our method can jointly detect large-scale (e.g., thousands of) landmarks in real time. We have conducted various experiments for detecting 1200 brain landmarks from the 3D T1-weighted magnetic resonance images of 700 subjects, and also 7 prostate landmarks from the 3D computed tomography images of 73 subjects. The experimental results show the effectiveness of our method regarding both accuracy and efficiency in the anatomical landmark detection

ETPL BM - 023	Multi-Parameter Ensemble Learning for Automated Vertebral Body Segmentation in Heterogeneously Acquired Clinical MR Images

The development of quantitative imaging biomarkers in medicine requires automatic delineation of relevant anatomical structures using available imaging data. However, this task is complicated in clinical medicine due to the variation in scanning parameters and protocols, even within a single medical center. Existing literature on automatic image segmentation using MR data is based on the analysis of highly homogenous images obtained using a fixed set of pulse sequence parameters (TR/TE). Unfortunately, algorithms that operate on fixed scanning parameters do not avail themselves to real-world daily clinical use due to the existing variation in scanning parameters and protocols. Thus, it is necessary to develop algorithmic techniques that can address the challenge of MR image segmentation using real clinical data. Toward this goal, we developed a multi-parametric ensemble learning technique to automatically detect and segment lumbar vertebral bodies using MR images of the spine. We use spine imaging data to illustrate our techniques since low back pain is an extremely common condition and a typical spine clinic evaluates patients that have been referred with a wide range of scanning parameters. This method was designed with special emphasis on robustness so that it can perform well despite the inherent variation in scanning protocols. Specifically, we show how a single multi-parameter ensemble model trained with manually labeled T2 scans can autonomously segment vertebral bodies on scans with echo times varying between 24 and 147 ms and relaxation times varying between 1500 and 7810 ms. Furthermore, even though the model was trained using T2-MR imaging data, it can accurately segment vertebral bodies on T1-MR and CT, further demonstrating the robustness and versatility of our methodology. We believe that robust segmentation techniques, such as the one presented here, are necessary for translating computer assisted diagnosis into everyday clinical practice

ETPL BM - 024	Experimental Evaluation of Impulsive Ultrasonic Intra-Body Communications for Implantable Biomedical Devices

Biomedical systems of miniaturized implantable sensors and actuators interconnected in an intra-body area network could enable revolutionary clinical applications. Given the well-understood limitations of radio frequency (RF) propagation in the human body, in our previous work we investigated the use of ultrasonic waves as an alternative physical carrier of information, and proposed Ultrasonic WideBand (UsWB), an ultrasonic multipath-resilient integrated physical and medium access control (MAC) layer protocol. In this paper, we discuss the design and implementation of a software-defined testbed architecture for ultrasonic intra-body area networks, and propose the first experimental demonstration of the feasibility of ultrasonic communications in tissue mimicking materials. We first discuss in detail our FPGA-based prototype implementation of UsWB. We then demonstrate how the prototype can flexibly trade performance off for power consumption, and achieve, for bit error rates (BER) no higher than 10-6, either (i) high-data rate transmissions up to 700 kbit/s at a transmit power of -14 dBm (˜ 40 µW), or (ii) low-data rate and lower-power transmissions down to -21 dBm (˜ 8 µW) at 70 kbit/s. We demonstrate that the UsWB MAC protocol allows multiple transmitter-receiver pairs to coexist and dynamically adapt the transmission rate according to channel and interference conditions to maximize throughput while satisfying predefined reliability constraints. We also show how UsWB can be used to enable a video monitoring medical application for implantable devices.

ETPL BM - 025	Biomedical Sensing With Conductively Coupled Terahertz Metamaterial Resonators

Metamaterials that can support ultrasharp resonances using conductively coupled split ring resonators are potential candidates for designing label-free biomedical sensors. The sharp spectral response, as well as the ability to confine the field, increases the interaction between the electromagnetic field and unidentified analytes. A sensitivity level of 3 × 104 nm/RIU/unit-volume is achieved when the whole area of the sensor is covered with the analyte. More interestingly, we demonstrate that the sensitivity can be significantly enhanced by a factor of 19 reaching a value of 5.7 × 105 nm/RIU/unit-volume when selected spots are covered with the analyte. These results will pave the way for designing practical biomedical sensors in the terahertz frequency range

ETPL BM - 026	A Multiband Antenna Associating Wireless Monitoring and Nonleaky Wireless Power Transfer System for Biomedical Implants

This paper presents a multiband conformal antenna for implantable as well as ingestible devices. The proposed antenna has the following three bands: medical implanted communication service (MICS: 402-405 MHz), the midfield band (1.45-1.6 GHz), and the industrial, scientific, and medical band (ISM: 2.4-2.45 GHz) for telemetry or wireless monitoring, wireless power transfer (WPT), and power conservation, respectively. A T-shaped ground slot is used to tune the antenna, and this antenna is wrapped inside a printed 3-D capsule prototype to demonstrate its applicability in different biomedical devices. Initially, the performance of the proposed antenna was measured in an American Society for Testing and Materials phantom containing a porcine heart in the MICS band for an implantable case. Furthermore, to stretch the scope of the suggested antenna to ingestible devices, the antenna performance was simulated and measured using a minced pork muscle in the ISM band. A modified version of the midfield power transfer method was incorporated to replicate the idea of WPT within the implantable 3-D printed capsule. Moreover, a near-field plate (NFP) was employed to control the leakage of power from the WPT transmitter. From the simulation and measurements, we found that use of a ground slot in the implantable antenna can improve antenna performance and can also reduce the specific absorption rate. Furthermore, by including the NFP with the midfield WPT transmitter system, unidirectional wireless power can be obtained and WPT efficiency can be increased

ETPL BM - 027	Efficient Sequential Compression of Multichannel Biomedical Signals

This paper proposes lossless and near-lossless compression algorithms for multichannel biomedical signals. The algorithms are sequential and efficient, which makes them suitable for low-latency and low-power signal transmission applications. We make use of information theory and signal processing tools (such as universal coding, universal prediction, and fast online implementations of multivariate recursive least squares), combined with simple methods to exploit spatial as well as temporal redundancies typically present in biomedical signals. The algorithms are tested with publicly available electroencephalogram and electrocardiogram databases, surpassing in all cases the current state of the art in near-lossless and lossless compression ratios

ETPL BM - 028	Multi-Polarization Reconfigurable Antenna for Wireless Biomedical System

This paper presents a multi-polarization reconfigurable antenna with four dipole radiators for biomedical applications in body-centric wireless communication system (BWCS). The proposed multi-dipole antenna with switchable 0°, +45°, 90° and -45° linear polarizations is able to overcome the polarization mismatching and multi-path distortion in complex wireless channels as in BWCS. To realize this reconfigurable feature for the first time among all the reported antenna designs, we assembled four dipoles together with 45° rotated sequential arrangements. These dipoles are excited by the same feeding source provided by a ground tapered Balun. A metallic reflector is placed below the dipoles to generate a broadside radiation. By introducing eight PIN diodes as RF switches between the excitation source and the four dipoles, we can control a specific dipole to operate. As the results, 0°, +45°, 90° and -45° linear polarizations can be switched correspondingly to different operating dipoles. Experimental results agree with the simulation and show that the proposed antenna well works in all polarization modes with desirable electrical characteristics. The antenna has a wide impedance bandwidth of 34% from 2.2 to 3.1 GHz (for the reflection coefficient = -10 dB) and exhibits a stable cardioid-shaped radiation pattern across the operating bandwidth with a peak gain of 5.2 dBi. To validate the effectiveness of the multi-dipole antenna for biomedical applications, we also designed a meandered PIFA as the implantable antenna. Finally, the communication link measurement shows that our proposed antenna is able to minimize the polarization mismatching and maintains the optimal communication link thanks to its polarization reconfigurability

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Thank you!