Sensors, Medical Images and Signal Processing:
The Growth of Clinicians' Expectations

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Summary
Objectives: To summarize excellent research in the field of medical sensor, signal and imaging informatics published in the year 2010.
Method: Synopsis of the articles selected for the IMIA (International Medical Informatics Association) Yearbook 2011.
Results: Current research in the field of sensors, signal, and imaging informatics is characterized by theoretically sound techniques and evaluations with focus in imaging informatics. When compared to research on sensors and signals, imaging research represent the majority of published papers in 2010. Research published in 2010 was characterized by an increased participation of the clinicians in the study design, implementation and validation of computerized diagnosis aid tools.
Conclusions: The best paper selection of articles on sensors, signal, and imaging informatics shows examples of excellent research on methods concerning theoretically sound original development in this field.

Keywords
Medical informatics, International Medical Informatics Association, yearbook, image processing, signal processing, medical sensors

Yearb Med Inform 2011: 92-5

Introduction

The content of MedLine/Pubmed containing articles from 2010 was interrogated while hunting for excellent research in the fields of sensors, signals and imaging. Two major observed trends appeared clearly from the query results:

- An increased interest and credibility of computerized diagnosis aid tools was observed with clinicians,
- Ambient assisted living and monitoring using smart garments, prostheses, and non-invasive diagnosis tools.

The research trends are discussed in the following sections and the associated six most representative papers listed in Table 1 are summarized in the appendix.

Regained Interest and Credibility of Computerized Diagnosis Aid: Clinicians Are Joining the Development Cycle

Research published in 2010 was characterized by an increased participation of the clinicians in the study design, implementation and validation of computerized diagnosis aid tools, which shows growing interests and expectations for computer-assisted analysis of signals and imaging data. The chicken and egg causality dilemma is raised as it is difficult to state whether credibility was gained because medical doctors joined to development loop, or they joined because their expectations in computer-aided diagnosis (CAD) systems have become more credible. Papers published in 2010 showed increased caution regarding validation schemes, where several large datasets are used and split for training, optimization and testing purposes to estimate reliably the performance that would be achieved at the time the system would be introduced into clinical practice [1,2]. Techniques alone are not sufficient anymore to significantly impact the scientific community and new policies are observed by international societies and journals to foster usefulness, usability and validation of the proposed methods. Contributions in user interfaces, clinical workflows and integration are increasingly recognized by the bioengineering community [3,4,5,6]. Moreover, it was observed that clinician's expectations are beyond traditional CAD schemes aiming at providing second opinions and documented information, and towards computer's abilities to detect what cannot be seen by the human eye. This was particularly observed in imaging modalities or organs where visualization is difficult (e.g., 4D imaging [7,8], 3D textures [9], long and complex videos [10], …).

Ambient Assisted Living

Several excellent contributions on sensors and signal processing for ambient

assisted living were found in 2010. Sensors integrated in smart garments enable seamless and continuous monitoring of various vital signs [11], stress indicators [12] and physical condition [13]. Integrated accurate control of prosthesis using physiological signals such as surface electromyogram for subjects with amputated hands was proposed [14]. Non-invasive, reliable indicators of diabetes, renal disease or airway inflammation are proposed by [2] using tailored electronic olfaction and automatic categorization of human breath.

Table 1 Best paper selection of articles for the IMIA Yearbook of Medical Informatics 2011 in the section 'Sensor, Signal and Imaging Informatics'. The articles are listed in alphabetical order of the first author's surname.

Section
Sensor, Signal and Imaging Informatics
▪ Bashar MK, Kitasaka T, Suenaga Y, Mekada Y, Mori K. Automatic detection of informative frames from wireless capsule endoscopy images. Med Image Anal 2010;14(3):449-70.
▪ Guo D, Zhang D, Li N, Zhang L, Yang J. A Novel Breath Analysis System Based on Electronic Olfaction. IEEE Trans Biomed Eng 2010;57(11):2753-63.
▪ Lee SH, Kim JH, Cho N, Park JS, Yang Z, Jung YS, Moon WK. Multilevel analysis of spatiotemporal association features for differentiation of tumor enhancement patterns in breast DCE-MRI. Med Phys 2010;37(8):3940-56.
▪ Naik GR, Kumar DK, Jayadeva. Twin SVM for gesture classification using the surface electromyogram. IEEE Trans Inf Technol Biomed 2010;14(2):301-8.
▪ Quellec G, Lamard M, Bekri L, Cazuguel G, Roux C, Cochener B. Medical case retrieval from a committee of decision trees. IEEE Trans Inf Technol Biomed 2010;14(5):1227-35.
▪ Zhang H, Wahle A, Johnson RK, Scholz TD, Sonka M. 4-D cardiac MR image analysis: left and right ventricular morphology and function. IEEE Trans Med Imaging 2010;29(2):350-64.

Conclusions and Outlook

The best paper selection for the Yearbook section 'signal, sensor, and imaging informatics' can by no means reflect the broadness of the field. A large number of papers were reviewed and even the initial selection of over 100 target articles was hard to make. Reducing this selection to only 20 for a detailed review was even harder. The final six articles selected represent well the current research trends of the domain of sensors, signals and imaging informatics with dominant research areas in image-based computer assisted diagnosis and ambient assisted living. Up-to-date information about current and future issues of the IMIA Yearbook is available at http://www.schattauer.de/de/magazine/uebersicht/zeitschriften-a-z/imia-yearbook/objectives-contents-formats.html.

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8. Zhang H, Wahle A, Johnson RK, Scholz TD, Sonka M. 4-D cardiac MR image analysis: left and right ventricular morphology and function. IEEE Trans Med Imaging 2010;29(2):350-64.
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Appendix: Content Summaries of Selected Best Papers for the IMIA Yearbook 2011, Section Sensors, Signal and Imaging Informatics*

Bashar MK, Kitasaka T, Suenaga Y, Mekada Y, Mori K

Automatic detection of informative frames from wireless capsule endoscopy images

Med Image Anal 2010;14(3):449-70

Wireless capsule endoscopy (WCE) enables accurate visualization of the entire gastro-intestinal tract. The length of the video resulting from the whole journey of the capsule is of eight hours on average and consist of approximately 50,000 frames. Consequently, excessive time is required for video diagnosis. In [15], WCE videos were mapped to a 2D image enabling an overview of the whole exam at a glance. Bashar et al. propose a two-step removal of unusable frames that are contaminated by turbid fluids, faecal materials and/or residual food that are characterized by colors (from brown to yellow) and texture (bubble-like). In a first step, non-bubbled contaminated frames are detected using a support vector machine classifier in a twin color representation based on local color moments in Ohta space and hue saturation value (HSV) color. Bubbled regions in remaining frames are detected using multi-scale Laguerre Gauss circular harmonic templates that look like clusters of bubbles for high orders. A threshold on the local absolute energies of the responses allows segmenting bubbled regions with significantly enhanced performance when compared to conventional Gabor-based and wavelet-based texture features. The two-step processing pipeline allowed a best detection rate of 86.42% with low false positive rates.

Guo D, Zhang D, Li N, Zhang L, Yang J

A Novel Breath Analysis System Based on Electronic Olfaction

IEEE Trans Biomed Eng 2010;57(11):2753-63

Non-invasive diagnosis tools are investigated by Guo et al. by using automated analysis of electronic olfaction of breath as indicators of diabetes, renal disease or airway inflammation. Starting from general-purpose electronic noses, the authors select chemical sensors that are sensitive to the biomarkers and compositions in the human breath. The sensors provide responses to gas particles in terms of measurable electronic signals that are then filtered, amplified, and digitized, and then post-processed for computerized classification of the breath. From the raw sampled signal, a pre-processing step removes signal baselines of the sensors and normalizes sample-to-sample variations. Then, principal component analysis is used to obtain a compact representation of the dynamic responses of the sensors, in which a k-nearest neighbour classifier maps breath instances to either healthy versus diabetes, healthy versus renal diseases or healthy versus airway inflammation. A validation of the system on a large database of human breath with proven diagnoses showed high sensitivity and specificity. They also show that the dynamic sensor responses are representative of the outcomes of the haemodialysis treatment of renal diseases.

Lee SH, Kim JH, Cho N, Park JS, Yang Z, Jung YS, Moon WK

Multilevel analysis of spatiotemporal association features for differentiation of tumor enhancement patterns in breast DCE-MRI

Med Phys 2010;37(8):3940-56

Dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) of the breast provides highly detailed 3D anatomical information together with information on dynamic absorption of contrast agent, which yields 4D data (3D plus time). The differences in tumor vascularity present varying contrast absorption patterns according to their malignancy. Human interpretation of DCE-MRI is a challenging task due to the high amount of data with limited visualization options and can be subjective. Lee et al. propose semi-automated analysis of DCE-MRI images while focusing on the dependency between spatial and kinetic features. A three-level post-processing pipeline classifies user-provided volumes of interest into malignant versus benign observed mass. The first level extracts seven pixelwise kinetic features characterizing the shapes of the contrast absorption curves. In a second level, spatial features consisting of mean intensity values and 3D moments being invariant to shifts, rotations and scales are extracted for each 3D image outputted from the seven kinetic features of step 1. Step 3 extracts five additional kinetic features corresponding to the kinetics of the spatial features (mean intensity values and 3D moments) computed for each time t on the original 4D data. A selection of features resulting from steps 2 and 3 is carried out using support vector machines (SVM)-recursive feature elimination, which is used to differentiate between benign and malignant tumors using a least-squares SVM classifier allowing an area under receiver operating curve (ROC) of 0.88.

Naik GR, Kumar DK, Jayadeva

Twin SVM for gesture classification using the surface electromyogram

IEEE Trans Inf Technol Biomed 2010;14(2):301-8

Reliable classification of gestures from surface electromyogram (sEMG) signals is required to efficiently control hand prostheses. Naik et al. propose to discriminate from seven common hand

* The complete papers can be accessed in the Yearbook's full electronic version, provided that permission has been granted by the copyright holder(s).

gestures using twin SVM classifiers in the hyperspace spanned by independent component analysis (ICA) of sEMG signals. Being proposed by the authors in [16], twin SVM classifiers address the problem of unbalanced cardinality of classes in one-versus-rest binary classification tasks. For each unbalanced binary classification, two separating hyperplanes are built, where each one has only constraints from one class. This has two advantages: first, it removes the assumption that the two classes come from similar distributions, which solves the problem of unbalanced cardinality. Second, it allows applying different kernels for each class. The methodology of twin SVMs is applicable to any multiclass categorization problem. Balanced class-specific sensitivity and specificity on the orders of 85% and 88% are obtained respectively, which would permit use of hand prostheses at least in low-risk applications.

Quellec G, Lamard M, Bekri L, Cazuguel G, Roux C, Cochener B

Medical case retrieval from a committee of decision trees

IEEE Trans Inf Technol Biomed 2010;14(5):1227-35

Content-based image retrieval (CBIR) was often proposed as a promising technology for diagnosis aid and visual information management [18]. One of the current limitations of CBIR in medical application is the lack of precision of the retrieved images when relying on visual information only. Quellec et al. propose a case-based retrieval system that fuses information from image content as well as nominal and continuous clinical attributes for diabetic retinopathy and mammography screening. The cornerstone of their approach is to use a committee of decision trees (DT) for indexing cases, which allows efficient management of missing attribute values. Visual information is included in DTs by defining groups with similar image signatures, and affiliations to each group are used as attributes in DTs. Image signatures are computed from a symmetric version of the Kullback-Leibler divergence between wavelet coefficient distributions in each subband, and groups with similar signatures are found using fuzzy c-means clustering of the signatures. The similarity between two cases is computed by comparing their assignment weights to each leaf of the tree. To balance the importance of each attribute, several DTs are built with randomized subsets of attributes and the final distance between cases is computed by aggregating assignment weights to each leaf of each tree. Excellent retrieval precision of 79% and 87% for the five first retrieved cases were obtained for diabetic retinopathy and mammography screening, respectively.

Zhang H, Wahle A, Johnson RK, Scholz TD, Sonka M

4-D cardiac MR image analysis: left and right ventricular morphology and function

IEEE Trans Med Imaging 2010;29(2):350-64

Tetralogy of Fallot (TOF) is a common heart disease characterized by anomalies in left and right ventricular dynamics. Consequently, 3D videos of the beating heart from 4D MR images are appropriate to characterize ventricular motions. Zhang et al. propose 4D modelling of the ventricles based on a combination of active shape models and active appearance models. First, 4D templates consisting of 16 3D templates from various samples of the cardiac cycle are created for each ventricle from manual tracing. Then, affine transforms of each template are used to map them to each subject, which provides 4D segmentations of the ventricles. From the segmented ventricles, features characterizing dynamics of the ventricles' shapes are used to differentiate between normal subjects and TOF. They consist of modal shape indices from the segmented ventricles [17] as well as full vectors of volume-time curves and their derivation (dV/dt). A linear discriminant classifier allows separating normal subjects versus TOF with 90 to 100% of sensitivity and specificity.