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Preface

The 1999 international conference on Information Processing in Medical Imaging (IPMI '99) was the sixteenth in the series of biennial meetings and followed the successful meeting in Poultney, Vermont, in 1997. This year, for the first time, the conference was held in central Europe, in the historical Hungarian town of Visegrád, one of the most beautiful spots not only on the Danube Bend but in all Hungary. The place has many historical connections, both national and international. The castle was once a royal palace of King Matthias. In the middle ages, the Hungarian, Czech, and Polish kings met here. Recently, after the summit meeting of reestablished democracies in the area, it became a symbol for the cooperation between central European countries as they approached the European Union. It was thus also symbolic to bring IPMI, in the year of the 30th anniversary of its foundation, to this place, and organize the meeting with the close cooperation of local and traditional western organizers.

It also provided a good opportunity to summarize briefly a history of IPMI for those who were new to the IPMI conference.

This year we received 82 full paper submissions from all over the world. Of these, 24 were accepted as oral presentations. These were divided into 6 sessions. In spite of our efforts, it was found to be impossible to make these sessions fully balanced and homogeneous. Therefore, the session titles express the leading themes of the respective sessions rather than provide a thorough description of all papers included in each of them.

The first session (traditionally) dealt with new imaging techniques. The topics here span from an analytical study of bioelasticity using ultrasound, to multipolar MEG, binary tomography, and navigated surgery. The second session concerned image processing in three-dimensional ultrasonography and dynamic PET. The third and the fifth sessions presented classic IPMI topics about image segmentation and registration. The papers on segmentation brought new ideas about hybrid geometric snake pedals, geodesic active contours, adaptive fuzzy segmentation, and segmentation of evolving processes in three dimensions. Papers on registration expanded both linear and non-linear approaches to elastic transformations and introduced hierarchical deformation models for 4-D cardiac SPECT data. The fourth session included a mixture of papers on segmentation and registration as applied to analysis of images of the brain cortex. The final (sixth) session dealt with feature detection and modelling. It included detection of masses in mammography, physiologically oriented models for functional MRI, comparison of MR and x-ray angiography, and a unified framework for atlas matching based on active appearance models. It was an explicite requirement of the IPMI Board, as well as the conviction of the organizers, to insist on a demonstration of medical applicability of all the image processing methods presented. We believe that all the selected papers fulfill this difficult but crucial criterion. The time alloted to oral presentations was 20 minutes plus 30 minutes for a (scheduled) discussion which, however, by IPMI tradition is virtually unlimited and depends on the importance of the problem, the clarity of the paper and the interest of the audience. In the proceedings, the space alloted to each oral presentation is 14 pages. It is a compromise between a need to provide the readers with sufficient details of the presentation and a requirement to keep the extent of the book to within 500 pages. The organizers regret that they could not accept the often justified requests of many authors to expand the space for their papers.

An additional 28 submissions were accepted as poster presentations. Ample time was given to the audience to meet the authors in front of their posters and to discuss the presentations in depth. In addition to short oral presentations, each of two poster sessions was concluded by a plenary discussion. In the proceedings, the space alloted to each poster presentation is 6 pages.

The poster presentations were divided into 2 sessions. The first dealt with various methods of cardiovascular image analysis, modelling and analysis of shapes, and with the segmentation and detection of specific image structures. The second concerned reconstruction, measurement in medical images, registration, and image modelling. Although oral papers and plenary discussions form the traditional basis of the IPMI meeting, the introduction of poster sessions further enlarged the space permitted for additional topics, for considering more specific applications, and for extended informal discussions.

The uniqueness of the IPMI meeting has been emphasized from various personal viewpoints in the forewords of previous proceedings. It consists in a magic mixture of an interdisciplinary approach, informal communication, thorough discussions, high scientific standards, the promotion of young researchers, and a friendly atmosphere. It is a great responsibility for the organizers to cultivate the IPMI tradition and sustain all its many flavours for the future. We sincerely wish IPMI many happy returns for its 30th birthday and wish it well, long into the 21th century.

March 1999

Attila Kuba
Martin Šámal
Andrew Todd-Pokropek

A brief history of the universe, the IPMI phenomenon (IPMI 1969-1999)

The big bang from the point of view of IPMI took place in late 1969. Some 20 odd (some of them very odd) researchers gathered together in Brussels for an ad hoc meeting on the use of computers in nuclear medicine, sponsored by a grant from Euroatom, obtained by our first 'president', François Erbsmann. The meeting was originally given the name Information Processing in Scintigraphy, and only Europeans participated. It is worth noting that at that time a computer with 4K of memory was considered respectable. By 1971, the expansion of this Universe had reached Hannover, under our second president, Eberhard Jahns, and by this time some grit from across the Atlantic had also been incorporated. From these first few seconds of the expanding IPMI universe, little (written) trace remains of the white heat of invention. The first meeting produced no written record, and the second proceedings only exist (but do exist) as an unpublished manuscript. One of the pieces of grit, present at the 2nd meeting, agreed to run the 3rd meeting in Boston (Cambridge), and so Steve Pizer (aided by Charlie Metz) permitted continuing expansion to North America. As a result of this, IPMI has been established of an oscillating universe with a period of 2 years with, at this interval, the centre of gravity switching between Europe and North America. We have considered further expansion to the far east, Australia, or South America, but have been prevented from doing so by the strong force effect (lack of money). A rare photograph exists of some of the participants at the Boston meeting, lounging on a lawn, not wearing very much, and observing attractive students go by. Ah, the universe was young then! By now, the ratio of North American contributions had reached 50%, a value which has been maintained. Although scintigraphy (nuclear medicine) was still the target application, tomographic reconstruction was considered important and a number of general image processing papers foreshadow a slow drift towards computer vision applications.

Two years later, in 1975, the meeting switched to Paris (Orsay) which I ran. The meeting was now scheduled for a total of 5 days, with one free afternoon, and another long lasting phenomenon was discovered, that of the IPMI football (soccer) match. Despite unwarranted complaints about bias in refereeing, this match has always been won by the European team, and it is hoped and anticipated that this strange effect will be preserved. We have also always had a few female scientists present at the IPMI meetings, but regrettably their charm has only been present in limited numbers. In Paris the IPMI universe reached the number of 100 participants, and a major aim of the meeting has been to try to limit total numbers to this order. IPMI has always permitted long presentations with effectively unlimited time for ensuing questions, and it has been a second major aim of IPMI to try to remove limits in total time to permit this disorder.

In 1977 we arrived in Nashville under the leadership of Randy Brill, and the title of the meeting now changed officially to Information Processing in Medical Imaging (IPMI). Many other clinical applications were now included, such as angiography, ultrasound, and CT, with a significant component of tomographic reconstruction. In 1979 we returned to (central) Paris, under the direction of Robert Di Paola, the first paper being about a relatively novel technique, magnetic resonance. The spin doctors have increased their influence at each successive meeting. The proceedings were published by INSERM. In 1981 we were laid back in California, activated by the acerbic wit of Michael Goris, but mainly thinking about nuclear medicine and ultrasound (and Californian fruit and wine). A major theme of the meeting was applications in cardiology

In 1983 we returned to Brussels, led by Frank Deconinck, and the first publication of the proceeding by a regular publisher was produced. All subsequent proceedings have been published, by Martinus Nijhoff, Plenum, Wiley, Kluwer, and for the majority, Springer. Papers such as 'Image analysis– topological methods' indicated new directions in scale space, and more substantial mathematical presentations. While evaluation continued to be an important topic, the meeting welcomed novel acquisition methods, here Impedance Tomography. In 1985 we passed to Washington and Steve Bacharach. While the scientific highlights of the meeting were significant, a couple of our Scottish participants yet again remain fondly in our memories as being those most responsible for the excellent social interactions always a feature of IPMI (here the infamous fire alarm incident).

We were received in The Netherlands in 1987 by Max Viergever and now bathed in the more abstract universe of general image processing (meta-models, multiresolution shape) whilst retaining our interest in reconstruction. One of our present chairmen gave his first paper expressing his deep angst with the title 'The reality and meaning of physiological factors'. As usual, the bar near our student accommodation remained open late in the night as the deeper notions of Information Processing were explored.

As a result of the tragic death of our first chairman, it was here that the François Erbsmann prize was established in recognition of his original intention, to aim the meeting towards promoting the work of young scientists (even if some of the lengthy questions and answer sessions do not always seem to reflect this). I should also sadly point out that we have also lost our 2nd chairman, Eberhard Jahns, as a result of a car accident. However, I am pleased to report that as far as we are aware, all the rest have so far survived (despite the ravages of time and of our Scottish colleagues).

Two years later we returned to California (1989), now as Berkeley ageing hippies (or at least some of us). MRI was now considered to warrant a whole session, segmentation even more, but image reconstruction was the major topic here. The quality of the papers had now reached a level where the competition to be included was such that then (and we hope now) authors reserved their best papers for this meeting, and braced themselves for the Spanish inquisition of the questions following their presentations. The final decade of the 20th century dawned for the IPMI universe in Wye in England, organised by Alan Colchester and Dave Hawkes (1991). The quality of the meeting seemed to have been maintained, as were the traditions. Multi-modality approaches appeared, MR was the dominant image type, and computer vision methods were emphasised. Posters were first introduced, but not published, at this meeting. A highlight was probably the sometimes violent philosophical discussions about whether an edge could actually exist. On the final day, after the football match, Nico Karssemeijer was obliged to present his paper in plaster, having had his leg broken, illustrating yet again our tremendous dedication to science. From the embrace of the elegant pubs in Kent, 2 years later we stormed the mountains of Arizona, to be precise, Flagstaff, under the leadership of Harry Barrett (1993). The meeting continued its traditions, ranging from discussions of higher order differential structures to optical tomography. The arguments about segmentation continued, we were somewhat on edge and tetchy (a skeleton in our cupboard?), but the high point was reached by those climbing to the top of the nearby Humphrey's peak (3850m). The highlight of our next meeting, in Brest directed by Yves Bizais, was certainly the student celebration of their end of term where a group of them promenaded with loud drumming throughout the night. Fortunately, this did not worry everyone, as the student bar rarely closed before dawn. More posters were presented and now included in the proceedings. This excellent meeting was followed by that organised by Jim Duncan in Poultney, Vermont. The scientific quality was again considered to be excellent, and the surroundings beautiful. Neuroscience here clearly dominated other clinical applications. Despite this increasing interest in brains, somehow (again!) the Europeans won the football match. During the outing to a ski-resort a number of participants found refuge from the plague of insects, against instructions, by skiing down an icy ski-run (exceptionally open in June in a heat wave!). Jim Duncan as (to date) our last chairman has said how much he appreciated the cooperation and respect given to him by the enthusiastic participants at an IPMI meeting. At least he did not have to rescue any from jail as I have had to in the past.

I do not know what will be the highlights of the current meeting for which these proceedings represent the written trace. I hope that the scientific expansion of the meeting will continue, and that in the social context, we will also continue in the long tradition of IPMI to enjoy ourselves, have fun, and make many new friends. The proceedings of this meeting only reflects a small part of the value of the IPMI experience. The length of time allocated for questions and answers after presentations is an important part of the IPMI experiment, but unfortunately is not recorded (perhaps fortunately in some cases). A new 'Special Prize for Brilliance' has been suggested. The ability to discover and discuss new approaches in depth is just as important, which has always been the justification for limiting the total number of participants.

This brief and certainly biased history of the IPMI universe has not mentioned the first presentations of some very significant results, nor included the names of all the co-chairmen of the meetings, and especially the names of all the participants without whom the meetings could never have happened or been successful. Let us hope that the strange charm of the meeting will persist (where you can find a GUT in a TOE), with its ups and downs, strung together in theory, without loss of colourful traditions. Can this be maintained? This question is perhaps the big crunch (or is that the result of the next football match)?

March 1999 Andrew Todd-Pokropek

François Erbsmann Prize winners 1987–1997

1987 10th IPMI, Utrecht, NL:
John M. Gauch
Dept. of Computer Science, University of North Carolina, Chapel Hill, NC, USA
Gauch, J.M., Oliver, WR, Pizer, SM: Multiresolution shape descriptions and their applications in medical imaging. In Information Processing in Medical Imaging. Eds. de Graaf, CN, Viergever, MA, Plenum, New York (1988) 131-149

1989 11th IPMI, Berkeley, CA, USA:
Arthur F. Gmitro
Dept. of Radiology, University of Arizona, Tucson, AZ, USA
Gmitro, A.F., Tresp, V., Chen, Y., Snell, R., Gindi, G.R.: Video-rate reconstruction of CT and MR images. In Information Processing in Medical Imaging. Eds. D.A. Ortendahl, J. Llacer., Wiley-Liss. New York (1991) 197-210

1991 12th IPMI, Wye (Kent), UK:
H. Isil Bozma
Dept. of Electrical Engineering, Yale University, New Haven, CT, USA
Bozma, H.I., Duncan, J.S.: Model-based recognition of multiple deformable objects using a game-theoretic framework. In Information Processing in Medical Imaging. Eds. Colchester, A.C.F., Hawkes, D.J., Springer, Berlin (1991) 358-372

1993 13th IPMI, Flagstaff, AZ, USA:
Jeffrey A. Fessler
Division of Nuclear Medicine, University of Michigan, Ann Arbor, MI, USA
Fessler, J.A.: Tomographic reconstruction using information-weighted spline smoothing. In Information Processing in Medical Imaging. Eds. Barrett, H.H., Gmitro, A.F., Springer, Berlin (1993) 372-386

1995 14th IPMI, Brest, France:
Maurits K. Konings
Dept. of Radiology and Nuclear Medicine, University Hospital Utrecht, Utrecht, The Netherlands
Konings, M.K., Mali, W.P.T.M., Viergever, M.A.: Design of a robust strategy to measure intravascular electrical impedance. In Information Processing in Medical Imaging. Eds. Bizais, Y., Barillot, C., Di Paola, R., Kluwer Academic, Dordrecht (1995) 1-12

1997 15th IPMI, Poultney, VT, USA:
David Atkinson
UMDS, Radiological Sciences, Guy's Hospital, London, United Kingdom
Atkinson, D., Hill, D.L.G., Stoyle, P.N.R., Summers, P.E., Keevil, S.F.: An autofocus algorithm for the automatic correction of motion artifacts in MR images. In Information Processing in Medical Imaging. Eds. Duncan, J., Gindi, G.. Springer, Berlin (1997) 341-354

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We thank all the researchers who submitted full-length manuscripts for consideration. Their work and interest is essential to permit the unique IPMI tradition to continue in the future. Almost all of the submitted papers were of very high quality and we regret that we had to turn down a significant number due to lack of space.

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Czech Society of Nuclear Medicine, Czech Medical Association J.E. Purkyně,

Leapfrog Technology Ltd, London, UK.

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Cardiovascular Image Analysis

Shape Modeling and Analysis

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Poster Session II

Measurement and Quantitative Image Analysis

Analysis of Image Sequences and Functional Imaging

Analytical Study of Bioelasticity Ultrasound Systems

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Abstract. A framework is presented for designing and evaluating bioelasticity imaging systems.

1 Introduction

Manual palpation has been an essential technique for diagnosing disease since the time of the ancient Greeks. They found that by compressing the surface of the skin a stress field is created inside the elastic tissues of the body that can be sensed by the fingertips. Regions atop stiff objects like cancerous lesions produce a greater restoring force at the skin surface than do adjacent regions. Hence, abnormalities may be detected and, in some cases, identified and sized based on their elasticity. The clinical success of manual palpation is based on the high elasticity contrast that exists for many pathologies – orders of magnitude for some cancers [1] – producing intense stress fields that make it easy to detect surface lesions. Unfortunately those stress fields decay rapidly with distance from the lesion, so it is difficult to sense objects deep in the body.

Elasticity imaging is palpation by remote sensing. It is the name for a class of techniques used to visualize tissue stiffness with a sensitivity and spatial resolution much greater than manual palpation. Often local elastic properties are imaged using ultrasonic or magnetic resonance signals to track local movements in mechanically stimulated tissues [2,3,4,5]. We use ultrasound to track the motion produced during static compression [6,7,8]. Two sets of radio-frequency echo signals are recorded from a region in the body before and after applying a small compressive force. The two echo fields are compared using a series of correlation techniques to register the data and thereby estimate displacement in one, two, or three dimensions depending on the boundary conditions for motion and the dimensionality of the echo fields. Spatial derivatives of the displacement field are combined to estimate strain tensor components that we call *strain images*. If the stress field is approximately uniform, then strain is inversely proportional to elasticity, and strain images describe tissue stiffness directly. The key to elasticity imaging is precise displacement estimation at high spatial resolution.

Ostensibly the procedure for creating strain images is straightforward, but in practice achieving high-quality images requires great attention to detail. We must seek a careful balance between three experimental conditions: *high waveform coherence* and *accurate displacement estimation* are required for low noise

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and superior spatial resolution, and a *large applied compression* yields high strain contrast. Conditions resulting in high strain contrast often produce severe decorrelation noise, i.e. strain noise caused by the inability of the image formation algorithm to track motion when there is low coherence between pre- and post-compression echo fields. A balance is achieved by carefully selecting the applied stress, boundary conditions, ultrasonic system parameters, and signal processing, none of which are independent. Thus far, the designs of most elasticity imaging experiments are empirical. Comprehensive analyses provided by the time-delay estimation literature [9] are of limited value because, unlike most radar and sonar applications, ultrasound echo signals are stochastic and the spatially-spread scatterers move in three dimensions when tissue is deformed.

This paper briefly summarizes a maximum-likelihood (ML) strategy for ultrasonic strain image formation and outlines a new approach for evaluating experimental designs. The evaluation is based on the *Fourier crosstalk matrix* concept originated by Barrett and Gifford [10] for designing medical imaging systems. We describe two mathematical models of ultrasonic waveforms recorded from a deformed object. A continuous model leads to the ML approach to strain imaging. A discrete model leads to the crosstalk matrix. The paper concludes with applications of the crosstalk matrix to the evaluation of system design.

2 Continuous Waveform Model

Biological tissues are modeled as incompressible, viscoelastic materials containing randomly positioned point scatterers. The object function that describes the spatial distribution of scatterers is the acoustic impedance field, $z(\mathbf{x})$, a zero-mean, Gaussian random process. The three-space coordinate vector is $\mathbf{x} = (x_1, x_2, x_3)^t$, where $\mathbf{x}^t$ is the transpose of $\mathbf{x}$. A shift-invariant sensitivity function[1] $h(\mathbf{x})$ maps the object function $z(\mathbf{x})$ into the echo data $r(\mathbf{x})$ over a region of support S according to the convolution equation

$$\begin{aligned} r(\mathbf{x}) &= \left[\int_S d\mathbf{x}'\, h(\mathbf{x}-\mathbf{x}')\, z(\mathbf{x}')\right] \; + \; n_0(\mathbf{x}) \\ &= \bar{r}(\mathbf{x}) \; + \; n_0(\mathbf{x}) \; . \end{aligned} \tag{1}$$

The additive noise process $n_0(\mathbf{x})$ is signal independent, zero-mean, band-pass white, and Gaussian with power spectral density G_n, i.e.,

$$E\{n_0^*(\mathbf{x})\, z(\mathbf{x})\} = 0 \,, \qquad E\{n_0(\mathbf{x})\} = 0 \,, \qquad E\{n_0^*(\mathbf{x})\, n_0(\mathbf{x}')\} = G_n\, \delta(\mathbf{x}-\mathbf{x}') \;,$$

where $E\{fg\}$ is the expected value taken over all f and g. We assume a 2-D echo field from a linear array transducer. An echo field is a collection of waveforms

[1] Sensitivity functions combine the pulse-echo system response with two frequency-dependent functions that describe scattering and absorption in the medium. If the system response function is Gaussian, the Fourier transform of the sensitivity function, (6), is approximately Gaussian [11].