PREFACE

This special issue on “Biomedical Systems, Signal and Control” is a collection of related papers selected and extended from those presented at the 17 International Federation of Automatic Control (IFAC), World Congress held in Seoul, Korea, from 6-11 July 2008.

IFAC was founded in September 1957 and is a worldwide multinational federation of National Member Organizations (NMOs). Each NMO represents the engineering and scientific societies concerned with dynamic systems and control within its own country. The aims of the Federation are to promote the science and technology, both theory and application, of systems, signal and control in the broadest sense in all systems, whether, for example, biological, medical, engineering, physical, social or economic.

Technical excellence is a main concern of IFAC. In a world where rapid and widespread dissemination of information has become possible for everybody, maintaining the highest level of scientific excellence is the only way in which an organization like IFAC can prosper. Thus, IFAC prides itself on promoting consistent and rigorous peer review in all its publications.

IFAC organises Triennial World Congresses, with attendance varying between 1000 and 2000 delegates from both academia and industry alike. They are held in the home country of the President in office during the third year of his or her term of office. Locations and years of past Congresses include: 1st Congress, 1960: Moscow (USSR), 2nd Congress, 1963: Basle (CH), 3rd Congress, 1966: London (UK), 4th Congress, 1969: Warsaw (PL), 5th Congress, 1972: Paris (F), 6th Congress, 1975: Boston/Cambridge (USA), 7th Congress, 1978: Helsinki (SF), 8th Congress, 1981: Kyoto (J), 9th Congress, 1984: Budapest (H), 10th Congress, 1987: Munich (FRG), 11th Congress, 1990: Tallinn (USSR), 12th Congress, 1993: Sydney (AUS), 13th Congress, 1996: San Francisco (USA), 14th Congress, 1999: Beijing, P.R. China, 15th Congress, 2002: Barcelona, Spain, and 16th Congress, 2005: Prague, Czech Republic. A main goal of all these Congresses is the merging of both the applications and industry side of the field and the academic and scientific research aspects, from which potentially new and exciting science and technology can emerge.

The 17 IFAC World Congress held in Seoul, Korea in 2008 received 3713 submissions from 40 countries and regions. The IFAC Technical Committee on Biological and Medical Systems (TC 8.2) organised several technical, special and milestone sessions in the areas of biological and medical systems modelling and control. The selected papers presented in this world congress are all of a high quality, having undergone a 3-4 person peer-review process including revision. Based on a rigorous selection process, the authors of 10 papers were invited to produce extended versions to appear in this special issue of the journal. All of these extended papers have subsequently undergone further review by this journal's editorial staff. Taken together, we believe that these selected articles constitute a valuable source of information on the broad state of the art in Biomedical Systems, Signal and Control.

The following summary is broken into 4 main general topic areas. Specifically, there are sections on: Modeling, Control, Pattern Recognition and Imaging, and the Artificial Pancreas. These are each broad areas of endeavour within Biomedical Engineering and IFAC's areas of scientific and research interest. The Artificial Pancreas and related Glycemic Control represents a current major challenge problem for Biomedical Engineers interested in dynamic systems modeling and control, particularly with the epidemic growth in the social and economic costs of treating diabetes and its complications, both in hospital and in the general populace.

Dynamic Systems Modelling:

BSPC-D-08-00102

To develop strategies to decrease the impact of disease outbreak, Briat and Verriest present an epidemiological model for describing disease evolution through a system of nonlinear differential equations. The model is extended from standard epidemiological models with recovery rate of the population is expressed as a distributed-delay term modelling the time spent being sick by infected people. The model is validated by using real epidemic measurement reported in the literatures. In addition, an optimal pulse control with one pulse vaccination strategy is presented with a realistic example demonstrating the effect of the optimal pulse control.

BSPC-D-08-00096

Chapman and Evan focus on the implications of a structural identifiability analysis on a series of fundamental three-compartment epidemic model structures, derived from the general Susceptible-Infective-Recovered (SIR) framework. The models represent various forms of incomplete immunity acquired through natural infection, or from administration of a birth targeted vaccination programme. Theoretical analysis demonstrates that the addition of a vaccination campaign has a negative effect on the structural identifiability of all considered models.

This topic area and these papers in particular are particularly topical given the recent events related to the outbreak of the H1N1 ("swine") flu virus worldwide in early 2009, which occurred after this congress! The continuing evolution and global spread of viruses and disease in this modern age is a growing medical concern and our ability to better model and understand these events will be part of future solutions.

Control Systems:

BSPC-D-0800116

Schrempf and Habelsberger present a model-based approach for predicting individual training intensity of N-repetition maximum in strength rehabilitation. A biomechanical model is presented to describe muscle strengthening by modelling training device and the mechanics of the musculoskeletal system into a mechanical model with a physiological model to describe the generation of extensor muscle force and the associated muscle fatigue. The model-based approach allows predicting individual N-repetition maximum only from an isometric maximum voluntary contraction or sub-maximal voluntary contraction measurement. The predictive results show a good agreement with experimental data.

BSPC-D-08-00097

Miyaguch and colleagues address a control problem for suppressing extensive continuous passive motion (CPM) and reaction force in the physiotherapy for injured ulna collateral ligament (UCL) after orthopaedic surgery. Using the kinematics of the skeleton model for upper limbs, the upper limit of UCL extension specified by physiotherapist is approximated by the upper limit of pronation angle, which is used to generate the reference trajectory based on the measured trajectories of normal subjects. An impedance controller is also presented to control the pro-/supination of the patient according to the designed reference trajectory. The approach is tested by the experiments using simulated patient.

BSPC-D-08-00083

Cai and colleagues focus on the optimal control in the synchronization of the contrast bolus peak and CT imaging aperture for computed tomography angiography. They develop an adaptive optimal controller to track the contrast bolus peak in real time by instantaneously processing the bolus CT images, dynamically predicting the bolus peak position, and adaptively moving the CT table in the opposite direction of the blood flow. In addition, a dynamic

programming approach is presented to cover the lower limbs with asymmetric arterial flow. Simulation data of real patients and physical model are used in the validation.

This topic area and the first two of these papers relate to our growing demand, with aging populations, for physical rehabilitation. A growth area, physical rehabilitation and the associated biomechanics has recently been significantly improved in various studies through the use of specialised systems, methods and technologies that use feedback control to optimise patient recovery, thus minimising potential costs of long-term treatment, while maximising potential outcomes. The last paper crosses over into the next area, the always critical medical imaging arena, where control systems are being used in a variety of novel and emerging ways to provide ever better and more insightful medical images.

Pattern Recognition, Image Processing and Related Topics:

BSPC-D-08-00103

To address the problem of analysing and classifying P-wave morphology of medium/long duration ECG, Herreros and colleagues presented an approach combined with P-wave detection and morphology classification. An embedding phase-space method is developed for P-wave detection with the post-processing of signal extraction, rotation, and filtering, while the classification is developed using the K-mean clustering algorithm with an index to measure the degree of variability of P-wave morphology. ECG signals of patient and control subjects are used in the validation. Good results are demonstrated in P-wave detection and the classification detects different electrical activity of morphology.

BSPC-D-08-00098

Tahayori and colleagues present a theoretical solution to address the problem of designing the optimal excitation pattern for Magnetic Resonance Imaging instead of traditional pulse excitation. They introduce a class of on-resonance piece-wise continuous amplitude modulated signals and use Galerkin approximation method to achieve analytically tractable response of spin system. Signal contrast efficiency is introduced as performance measure to be optimized subject to dynamics expressed by the Bloch equation. The numerical results show the continuous wave excitation can generate improved signal intensity for a single tissue type and short periods of time pulses provide the maximum signal contrast efficiency.

These papers examine novel methods of signal processing and pattern recognition applied to improve and optimise medical imaging. As such, they therefore represent and clearly illustrate the increasingly inter-disciplinary nature of medical imaging and Biomedical Engineering in general.

Artificial Pancreas:

BSPC-D-0800110

Magni and colleagues address the issues of feedback control of glucose concentration using subcutaneous insulin delivery and subcutaneous continuous glucose monitoring for type I diabetic patients. A large-scale *in-silico* simulation model of glucose metabolism is used to generate sufficient data of virtual patients with inter-subject and intra-subject variability. They investigate the performance of a linear output feedback model predictive control, which is validated to achieve satisfactory results in the control glucose concentration with the robustness to sensor errors as well as errors in the meal announcement signal. The results are also used to investigate a nonlinear model predictive control scheme with the potential improvement in the feedback control.

BSPC-D-08-00107

Lee and Bequette present a strategy for developing and implementing key components of closed-loop glucose control for an artificial pancreas. The identification problem of suitable model is addressed by using a multisine input signal, followed by a developed constrained

model predictive control. The control incorporates additive output disturbance, state input disturbance with Kalman filtering, first-order reference trajectory, first-order control action, output constraint relaxation, and pump shut-off procedure, as well as meal detection and meal size estimation algorithms to improve meal glucose disturbance rejection. Simulation studies are used to evaluate the closed-loop performance with satisfactory control performance to handle announced and unannounced meal disturbances.

BSPC-D-08-00104

In the context of metabolic systems models in glycaemic control, Chase and colleagues introduce a new pharmacodynamic surface oriented approach for comparison and validation of models. The three-dimensional surface consists of plasma insulin, plasma glucose and resulting rate of change in endogenous glucose balance. Three clinically validated models and one model with an added saturation dynamic are used in the analysis. Clinical data is used to determine an optimal set of population parameters, while the trend prediction of the surface modelling is also tested. The approach of examining pharmacodynamic surface is validated to be effective means of analysing and validating a metabolic model's inherent dynamics and basic trend prediction on a population level.

Diabetes is growing exponentially in all its forms, creating a social and economic tidal wave that threatens to overwhelm health care systems worldwide. Already its effects are being felt in reduced quality and length of life for tens of millions of individuals worldwide. These papers are at the forefront of research bringing engineering methods to create better models and clinical methods of treating the disease to reduce the long term cost to both the patient and society.

In summary, health care costs and challenges are growing faster than the world's health care systems and current resources can keep up with. The scientific and technological expertise of IFAC research into these myriad of problems is regularly developing new avenues to reduce, manage, optimise, or even eliminate, some of these problems. These papers all embody the main goal of IFAC TC 8.2 on Biological and Medical Systems to integrate engineering, physiology, biology and clinical medicine to create new scientific and technological breakthroughs to improve our world.

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