Keynote – Speaker 1

Prof. J. Geoffrey Chase

Modeling, computers and the future of healthcare

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Overview

Healthcare costs rise on average 7-11% per year, and in the last two years, healthcare spending in the OECD has failed to keep up to even the 2.4% per year increases it had been maintaining. Thus, the cost of healthcare has grown from 2-3% of GDP 30+ years ago, to ~10% of GDP today in the OECD. Far more critically, the failure to keep up means the equity gap, the difference between what we can afford and the demand (in cost) for healthcare, is growing even, or is that ever?, more dramatically with significant growing social, political and, of course, economic impacts. Much of this issue is driven by interactions between uncontrollable demographics around aging, sedentary lifestyles and chronic diseases.

Within this toxic economic milieu, critical care, the delivery of health care in the intensive care unit treats less than 1% of hospital patients but comprises ~10% of healthcare costs, averaging around 1% of GDP in the OECD. Hence, the ICU, with its excessive use of technology, is a prime target for reducing cost and improving care simultaneously, through the use of modeling, computation and (traditional) automation mixed with (emerging) data management.

This research presents a technical and clinical overview of the research of my group, and associated eTIME consortia (engineering Technology and Innovation in MEdicine). In particular, it focuses on how we use engineering methods and modeling to create personalised, next-generation sensors, diagnostics and decision support to automate and guide (improved care). The works center on three core therapies of ICU medicine: glycemic control; cardiovascular monitoring and management; and mechanical ventilation.

Each area considered has its own less acute ward and outpatient chronic disease analog providing a route towards developing therapies in hospital for eventual dissemination to outpatient care for chronic disease in the home or community.

Overall, the use of computational models and methods in the monitoring, diagnosis and personalised treatment of high cost, high mortality conditions, as well as chronic disease, offers the opportunity to use automation. Simple connections to devices creates systems to automate large portions of care. This automation would bring the economic and productivity benefits found in many other industries and areas to medicine, where better productivity is the key to improving the cost and equity of access to care.

Keynote – Speaker 2

Prof. Merryn Tawhai

Patient-Specific Model-Based Assessment of Lungfunction in the Clinical Setting

M.Tawhai
University of Auckland, Bioengineering Institute, New Zealand

Overview

Mechanical ventilation (MV) is a primary therapy for intensive care unit (ICU) patients, providing external support to assist with breathing when the patient is at risk of airway or tissue closure or collapse, or when the drive to breathe is compromised. Up to ~60% of all ICU patients require MV, and this patient group stays 50-100% longer in the ICU. When MV-associated damage to the lung develops, this further increases the ICU stay, complicates patient management, and has long term consequences for patient quality of life.

Patient-specific characteristics and distribution of injury and/or underlying disease means that MV patient response to therapy is highly variable, and thus a "one size fits all" protocol to standardise care is not appropriate. Current clinical practice relies heavily on subjective assessment of the patient ("clinician experience"), and less on objective assessment of patient data. So, while therapy is specific to each patient, the care itself is not 'patient-specific' and often doesn't take account of the individual, transient needs of the patient, nor their respiratory status as it evolves in response to injury and treatment. What is needed is the ability to quantify and monitor the patient-specific state of the lung with regards to MV care, and the ability to do so at every breath so that the clinical team can be alerted to changes in patient response as soon as they occur.

We are developing and validating new patient-specific model-based technologies that are aimed at minimising lung damage in MV, identifying patients who are at risk of developing lung injury, and titrating ventilation protocols for individual patients to optimise desired clinical endpoints. To this end, we are integrating advanced biophysically-based computational models of patient-specific lung function with clinical decision-support software. This presentation will explain the role of these computational models in optimising MV therapy, as well as other areas of clinically-relevant application.

Programm

Donnerstag 15.03.2018, Campus Schwenningen, Gebäude E

8:00-9:00	**Anmeldung**	**Foyer, Gebäude E**

9:00-9:30	**Eröffnung** **Prof. Dr. Knut Möller** *(Leiter Institut für Technische Medizin, HFU)* **Prof. Dr. Ulrich Mescheder** *(Prorektor Forschung und Leiter Institut für Angewandte Forschung, HFU)* **Dr. Thomas Schauer** *(Sprecher Fachausschuss AUTOMED, TU Berlin)*	**Raum E0.02**

9:30-10:30	**Session 1: Therapie/Rehabilitation/Robotik**	**Raum E0.02** **Vorsitz: *Prof. Dr. R. Riener***
9:30-9:45	*Structural Health Monitoring of Breast Tissue Mechanics for Non-Invasive Diagnosis of Breast Cancer*	Cong Zhou et al./ Dept. of Mechanical Eng./ University of Canterbury, NZ
9:45-10:00	*Automatic real-time adaptation of electrode positions for grasping with FES during forearm movements*	Till Thomas et al./ Control Systems Group/ Technische Universität Berlin
10:00-10:15	*Pilot Study: Effects of Arm Weight Compensation with the Rehabilitation Robot ARMin*	Fabian Just et al./ Sensory-Motor Systems Lab/ University of Zurich, CH
10:15-10:30	*Entwicklung eines automatisierten Verfahrens zur Extraktion der perfundierten ex vivo Niere aus IR-Aufnahmen*	Susanne Kromnik et al./ Institut für Biomedizinische Technik/ Technische Universität Dresden
10:30-11:00	**Kaffeepause**	**Foyer, Gebäude E**

11:00-11:45	**Session 2: Optische Technologien**	**Raum E0.02 Vorsitz: *Prof. Dr. P. Belloni***
11:00-11:15	*Leistungsgesteuerte temperaturüberwachte Lasertherapie der Netzhaut mittels adaptiv robuster H_∞-Regelung*	Ole Thomsen et al./ Institut für Medizinische Elektrotechnik/ Universität zu Lübeck
11:15-11:30	*Optimizing Controlled Laser Cutting of Hard Tissue (Bone)*	Gabor Kosa et al./ BIROMED-Lab/ Dept. of Biomedical Eng./ University of Basel, CH
11:30-11:45	*The Impact of Human Tissue Reflectance on the Choice of Endoscopic Light Sources*	Alexander Gaertner et al./ Institut für Technische Medizin / Hochschule Furtwangen
11:45-12:15	**KEYNOTE**	**Raum E0.02**
	"Modeling, computers and the future of healthcare" Distinguished Prof. Geoffrey Chase, University of Canterbury, Dept. of Mechanical Engineering, Christchurch, New Zealand	
12:15-14:00	**Mittagspause**	**Foyer, Gebäude E**
14:00-15:00	**Session 3: Beatmungs- und Überwachungstechnik/ Intensivversorgung**	**Raum E0.02 Vorsitz: *Prof. Dr. O. Simanski***
14:00-14:15	*Automatic Control of Ventilation Therapy in Acute Respiratory Distress Syndrome Based on Open Lung Management*	Anake Pomprapa et al./ RWTH Aachen University
14:15-14:30	*Modellprädiktive Druckregelung für die kontinuierliche Überdrucktherapie*	Mathias Scheel et al./ HOFFRICHTER GmbH Schwerin/ Arbeitsbereich Automatisierungstechnik Mechatronik, Hochschule Wismar
14:30-14:45	*Robuste physiologische Herzunterstützung mit rotatorischen Blutpumpen*	Daniel Rüschen et al./ Philips Lehrstuhl für Medizinische Informationstechnik/ RWTH Aachen
14:45-15:00	*Sensorpositionierung bei einem Smart-Shirt zur Atemanalyse bei Spontanatmung*	Bernhard Laufer et al./ Institut für Technische Medizin/ Hochschule Furtwangen

15:00-15:30	**Kaffeepause**	**Foyer, Gebäude E**
15:30-16:30	**Session 4: Messtechnik und Sensorik**	**Raum E0.02 Vorsitz: *Prof. Dr. K. Möller***
15:30-15:45	*Sensormodul für sterilisierbare, medizinische Container*	Lukas Böhler et al./ Aesculap AG, Tuttlingen/ AGH University of Science and Technology, Krakow, PL
15:45-16:00	*Energy Harvesting Module for Intelligent Medical Containers*	Mateusz Daniol et al./ Aesculap AG, Tuttlingen/ AGH University of Science and Technology, Krakow, PL
16:00-16:15	*Laparoscopic Instrument Classification using a Loss-Sensitive Neural Network*	Tamer A. Alshirbaji et al./ Institut für Technische Medizin/ Hochschule Furtwangen
16:15-16:30	*The effect of Hierarchical Hidden Markov Model on Phase Recognition in Laparoscopic Videos*	Nour A. Jalal et al./ Institut für Technische Medizin/ Hochschule Furtwangen
17:30	**Abfahrt nach Villingen**	**Bahnhof, Schwenningen**
18:15	**Stadtführung**	**Altstadt Villingen**
ab 19:15	**Abendveranstaltung im Restaurant Zuma**	**Altstadt Villingen**

Freitag 16.03.2018, Gebäude E

9:00-9:30	**KEYNOTE** ***"Patient-Specific Model-Based Assessment of Lung Function in the Clinical Setting"*** Prof. Merryn Tawhai, University of Auckland, Auckland Bioengineering Institute, Auckland, New Zealand	**Raum E0.02**

9:30-10:30	**Session 5:** **Biosignal- und Bildverarbeitung**	**Raum E0.02** **Vorsitz: *Prof. Dr. T. Schanze***
9:30-9:45	*Compressing and denoising of multiple biomedical time series by SVD*	Thomas Schanze/ Institut für Biomedizinische Technik/ Technische Hochschule Mittelhessen, Gießen
9:45-10:00	*Quantitative Magnetresonanztomographie erlaubt einen Blick auf die Mikrostruktur des Gewebes*	Lukas R. Buschle et al./ Deutsches Krebsforschungszentrum/ Universitätsklinikum Heidelberg
10:00-10:15	*Correlation Based Spike Sorting*	Pavel Larionov et al./ Institut für Biomedizinische Technik/ Technische Hochschule Mittelhessen, Gießen
10:15-10:30	*Analyzing ECG Data with an R-Wave Classifier based on Circular Statistics and Vector Strength*	Jan-Dirk Janßen et al./ Institut für Biomedizinische Technik/ Technische Hochschule Mittelhessen, Gießen
10:30-11:00	**Kaffeepause**	**Foyer, Gebäude E**

11:00-12:00	**Session 6: Modellbildung, Simulation**	**Raum E0.02 Vorsitz: *Dr. T. Schauer***
11:00-11:15	*Causality in Time Series*	Niels Wessel et al./ Department of Physics, Cardiovascular Physics/ Humboldt-Universität zu Berlin
11:15-11:30	*Time Series Prediction of Surgical Progress using Logistic Regression Modelling*	Calum R. MacLellan et al./ Biomedical Engineering/ University of Glasgow/ Institut für Technische Medizin/ Hochschule Furtwangen
11:30-11:45	*Exploring the Behaviour of a Wound Healing Mathematical Model*	Alistair McQueen et al./ College of Science and Engineering/ University of Glasgow/ Institut für Technische Medizin/ Hochschule Furtwangen
11:45-12:00	*A Novel Time Series Model to Predict Critical Oxygen Desaturation Events in the Blood*	Hisham ElMoaqet et al./ Dept. of Mechatronics Eng./ German Jordanian University, Amman, JO
12:00-12:15	**Schlusswort und Verleihung "Best Paper Award"** **Prof. Dr. Knut Möller** *(Leiter Institut für Technische Medizin, HFU)*	**Raum E0.02**
12:15-13:30	**Mittagspause**	**Mensa, Campus Schwenningen**
13:30-16:00	**Exkursion zur Firma Karl Storz SE & Co. KG (Treffpunkt Foyer, Gebäude E)**	

Session 1: Therapie/Rehabilitation/ Robotik

Raum E0.02
Vorsitz: ***Prof. Dr. R. Riener***

Structural Health Monitoring of Breast Tissue Mechanics for Non-Invasive Diagnosis of Breast Cancer

Cong Zhou[1], Brent Hainsworth[1], Maxwell Sydney[1], Michael Lee[1], Zane Ormsby[2], Marcus Haggers[2] und J. Geoffrey Chase[1]

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Introduction

Structural health monitoring (SHM) encompasses a range of methods to translate measured vibration response into estimates of underlying mechanical properties, such as stiffness and damping [1-3]. However, mechanical propeties of tissues are also diagnostic parameters. In particular, breast cancer tumors are 4-10x stiffer than healthy tissues [4], and the breast can be mechanically excited to offer a measurable vibration response.

Digital image based elasto-tomography (DIET) is a non-invasive breast cancer diagnostic concept. It sinusoidally actuates the breast tissue at a range of frequencies and response is measured using non-contact digital imaging [5]. Measurements can be used in SHM methods to estimate underlying, regional tissue stiffness, where high values would indicate the presence of cancerous tumors.

To date, it has been validated for simple phantoms, but not with much more complex clinical data. This abstract presents initial clinical results for the hysteressis loop analysis (HLA) SHM methodm, previously only proven in nonlinear civil structures [6-8].

Methods and Materials

Patients

Two women recently diagnosed with breast cancer were recruited at Canterbury BreastCare (Christchurch, NZ) to undergo testing for both breasts (cancerous and healthy) with a prototype DIET system, as part of an ongoing larger clincal trial. Women ranged in age from 46-50 years, with cancer diagnosed by mammography.

Ethics approval for the experimental tests, data collection, and analysis of this data was granted by the NZ National Health and Disability Ethics Committee, South Island Regional Committee.

Hysteresis Loop Analysis (HLA)

The dynamic hysteretic behaviour of each reference point at the breast surface is represented using a single-degree-of-freedom (SDOF) model. Briefly, the dynamic hysteretic behaviour of each SDOF reference point at the breast surface is defined:

$$f_s\big(v(t), \dot{v}(t)\big)/m = k_e \cdot v(t) = -\ddot{v}(t) \quad (1)$$

where $f_s\big(v(t), \dot{v}(t)\big)/m$ is a mass normalized, generalized restoring force approximated by a nominal elastic stiffness, k_e, and actuated tissue displacement $v(t)$. $\ddot{v}(t)$ is the acceleration calculated from double differentiation of measured displacement. Gravity and vertical actuation force are ignored because only horizontal stiffness is identified. Finally, the hysteresis loop for each reference point on the breast surface can be reconstructed using $v(t)$ and $\ddot{v}(t)$.

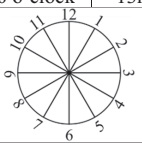
The HLA algorithm identifies the stiffness component of any reconstructed hysteresis loop or force-displacement relationship for each SDOF reference point using statistical methods. A standard least squares linear regression analysis can be implemented to calculate the regression coefficient for the estimation of the elastic nominal stiffness if the hysteresis loop is linear.

To preserve generality of the approach, a sup F type hypothesis test is employed to filter distorted hysteresis loops to obtain the underlying linear portion of the hysteresis loop and estimate the nominal elastic stiffness.

Analyses

One woman has cancer in one breast and the other one has cancer in both breast. Thus, there are 4 total breasts, with 1 healthy or clear breasts, and the other having a cancerous tumor. Approximate tumor size and location are known from mammography, as listed in Table 1. The 4 breasts are denoted P1L, P1R, P2L and P2R, respectively, as listed in Tab. 1.

Tab. 1: Summary of 4 clinical breasts with tumor size and location with schematic of location in the last row

Clinical subject		Tumor location	Tumor size
P1	Left (P1L)	1:00 o'clock	50mm
	Right (P1R)	Healthy	Healthy
P2	Left (P2L)	2:00 o'clock	11mm
	Right (P2R)	10:00 o'clock	13mm
Schematic of location			

The HLA method is run automatically for each breast, and knows only the data given to it, so it is blinded to the outcome and any other data. Results are compared to the actual diagnosed state. There are thus initial returns on the method's ability to find cancer, as well as its ability to find a negative result for healthy, clear breasts.

These are the first initial clinical results for this concept.

Results

Fig. 1 shows the diagnostic nominal stiffness map for P1L and P1R in plan view. It is clearly seen that a cancerous area (CA) is diagnosed at 12:00-2:00 o'clock in the left breast, matching the mammography tumor location at 1:00 o'clock in the left, while no cancerous area is identified in the right breast. Thus, the results indicate the robustness to false identification in the null case, which is critical in any method where false positives incur a cost and physical burden of biopsy.

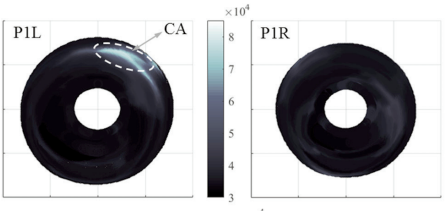


Fig. 1: Diagnostic result for clinical subject P1.

Similarly, Fig. 2 shows the diagnostic stiffness map for P2L and P2R under the actuation freqeuncy of 34Hz. Cancerous area is identified at 1:00-3:00 o'clock in the left breast P2L, where mammography detected the tumor at 2:00 o'clock in the left. In addition, cancerous area in the right breast is identifed at 9:00-10:30 o'clock, which also matches mammography tumor location at 10:00 o'clock in the right. This results indicate the HLA method is capble of identifying cancerous breast individually without using comparison between each pair for patients. In addition, the tumor sizes for P2L and P2R are 11-13mm, while the average detected tumor size with mammography is ~12-14mm [9]. Hence, the identification reuslts on P2 also validate the method's capability to today's average detection size.

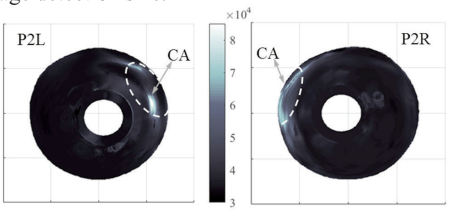


Fig. 2: Diagnostic result for clinical subject P2.

Discussion

Nominal elastic stiffness, k_e, and the threshold, k_t, are both automatically defined using a non-invasive and computationally efficient approach. It thus avoids requiring highly skilled operator such as mammography, magnetic resonance imaging and ultrosound, which thus reduce the potention cost of breast cancer diagnosis.

Density and stiffness vary with different layers in real human tissue, which thus caused a variation of identified stiffness for healthy breast in

the clinical trial. However, the stiffness for healthy tissue are clearly smaller than cancerous area tissue, as well as significantly lower than the defined threshold, k_t. Hence, the method shows good robustness to false positive detection, while false positive mammography are common due to low only 5~10% contrast in radio density between the healthy tissue and cancerous tissue [10].

Conclusions

The HLA method shows its potential given the initial mixed clinical results here, while the sensitivity of this specific SHM method might be affected by the variation of tumor size and stiffness contrast between healthy tissue and cancerous tissue. Therefore, more clinical trails are still needed to be tested to justify the robustness of the overall approach, particular for young women aging 30-40 years who generally have denser and stiffer breast tissue. Given the non-invasive nature of the DIET concept, its use in young women who are ineligible for mammography is of particular import.

Acknowledgements

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References

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