ANNUAL REPORT
2013/2014
LEADING THE WAY IN HEALTH IT RESEARCH
AEHRC Staff in Brisbane (above)
and Perth (right)
CONTENTS

The Australian e-Health Research Centre 1
Foreword by the Chairman and CEO 2
Board of Directors 3
Research and Investment Advisory Committee (RIAC) 6
2014 Annual Colloquium 7
Management and Research Leadership 9
News and Awards 10
Research Program 12
  • Tele- and Mobile Health 13
  • Health Informatics 25
  • Biomedical Imaging 37
AEHRC Publications 2013-14 55
AEHRC Staff - Formal Affiliations 62
AEHRC Staff, Students and Visitors 63
Digitally-Enabled Health System 65
Special Purpose Financial Report 66
THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

A Partnership between CSIRO and the Queensland Government, The Australian e-Health Research Centre (AEHRC) is the leading national research facility applying information and communication technology to improve health services and clinical treatment for Australians. The Centre is an unincorporated joint venture between CSIRO and the Queensland Government.

Established in 2003 with initial funding from the Department of State Development and CSIRO, the partnership was extended in 2007 for a further 5 years with funding from CSIRO, Queensland Health and the Department of Employment, Economic Development and Innovation. The partnership was extended again in 2012 for a further 5 years with an additional contribution of $15 million from CSIRO and Queensland Health, supplemented by in-kind contributions from the partners, as well as funding from grant, consultancy and commercialisation outcomes.

From its Brisbane headquarters, the AEHRC combines CSIRO’s capabilities in information and communication technology and health, with Queensland’s extensive health research and clinical expertise. In 2009-10, the reach of the Centre was extended, with the establishment through CSIRO in-kind contributions of a group in Western Australia. The initial focus of this activity is on telemedicine and ocular imaging technologies for detection and diagnosis of eye conditions and systemic diseases. With ongoing research activities in New South Wales, Victoria and South Australia, the Centre has a strong national reach.

Through its research program, the AEHRC develops and deploys leading edge information and communication technology innovations in healthcare to:

- improve service delivery in the Queensland and Australian health systems
- generate commercialisation revenue, and
- increase the pool of world-class e-health expertise in Australia

The AEHRC’s multi-disciplinary team includes internationally prominent researchers, software engineers and doctoral students, dedicated to serving the needs of patients, clinicians and health agencies. Our scientists and engineers are experts across Health and Biomedical Informatics and Health Services research. The AEHRC health informatics team has expertise in health data management and statistical analysis, semantic interoperability of health and clinical data, database and data integration technology and natural language processing of medical records. The biomedical informatics team are leaders in analysis and manipulation of biomedical images, surgical simulation and biostatistics. The Health Services team currently does world leading research into mobile health and tele-medicine.
The Australian e-Health Research Centre has had an excellent 12 months in delivering e-Health impacts and scientific excellence to our unincorporated joint venture partners, CSIRO and Queensland Health, as well as other key stakeholders.

Scientifically, the AEHRC has published more than 50 journal papers over the past 12 months. Highlights include the results of our trial of the mobile phone-based cardiac rehabilitation program being published recently in the BMJ journal, Heart, whilst our researchers were invited to publish a review of retinal screening in the high impact journal, Progress in Retinal and Eye Research.

Our science has also been recognised at national and international conferences. At the recent International Alzheimer’s Disease Conference in Copenhagen, Shaun Frost’s work on diagnosing Alzheimer’s disease from retinal images was highlighted. At the same conference, our medical imaging team released a new cloud-based image analysis system that provides clinical reports, initially for monitoring the progression of Alzheimer’s disease. The AEHRC contributed papers internationally at, amongst others, the IEEE Engineering in Medicine and Biology conference in Japan; the International Health Terminology Standards Development Organisation meeting in Washington and the International Society for Quality in Healthcare (ISQua) conference in Edinburgh.

AEHRC researchers have now developed a range of new trials and initiatives with Queensland Health. Our mobile health team has been working with clinicians at the Princess Alexandra Hospital developing a new mobile phone-based model for insulin stabilization for new diabetes patients. Stephen Rose, our medical imaging Science Leader, has been appointed as the Interim Director of the Herston Imaging Research Facility, with the AEHRC partnering in many imaging projects at RBWH and the University of Queensland. Our Medtex platform for processing medical narratives is now processing histopathology reports nightly to provide cancer notification information to the Queensland Cancer Control and Analysis Team.

The AEHRC has contributed to national initiatives and delivered national scale trials over the past 12 months. Our clinical terminology team has worked with the National e-Health Transition Authority to develop a new version of the Australian Medicines Terminology (AMT). AMT v3 was recently released for integration into clinical systems in Australia, with the AEHRC Minnow browser as the only browser to support the new version which will be used in the Personally Controlled Electronic Health Record.

Internationally, the AEHRC biomedical imaging team’s software to assess the health of cartilage tissue has been incorporated into Siemens ‘ChondralHealth’ demonstrator for trial in New York and Harvard Medical School, while our surgical simulation team has delivered the next version of the colonoscopy simulator to our Swedish-based commercialisation partner. Michael Lawley has also seen his proposal for a Unique Resource Identifier standard for SNOMED CT adopted internationally.

The AEHRC has once again been a key contributor to the national e-health community. The e-Health Research Colloquium was a great success with over 300 people hearing about a range of e-health initiatives in Australia and internationally. The AEHRC continues to contribute through other community and scientific events, such as the Health Informatics Conference (HIC) 2014. The AEHRC also won the Qld iAward for Health for the sixth year in a row, with the MoTER Mobile Health platform. Vacation scholar, Hamish Thorburn (UQ) won the best student paper prize at the HIC2014 conference.

The AEHRC continues to support the next generation of Health IT researchers. Five AEHRC students finished their PhDs over the past 12 months - Shaun Frost, Kerstin Pannek, Aleš Neubert, Bevan Koopman and Marlien Varnfield. Congratulations to all of them!

Queensland and Australian e-health initiatives are maturing and the AEHRC is starting on various new initiatives. After a great year in 2013/14, the next 12 months looks equally promising.
BOARD OF DIRECTORS

PROF BRUCE BARRACLOUGH AO
Chairman, the Australian e-Health Research Centre

Prof Bruce Barraclough AO has a distinguished career in medicine with a particular focus on breast and endocrine surgery.

Amongst many professional activities, Prof Barraclough has served as the President of The International Society for Quality in Health Care, Chair of the Board of the NSW Clinical Excellence Commission, Chair of the Australian Council for Safety and Quality in Health Care, Medical Director of the Australian Cancer Network, a member of the NSW Health Care Advisory Council and Associate Dean (Clinical Strategy), University of Western Sydney Medical School.

Prof Barraclough is a Fellow of the Royal Australasian College of Surgeons, a Fellow of the American College of Surgeons and an Honorary Fellow, Royal College of Surgeons of England. He was formerly Dean of Education, Royal Australasian College of Surgeons.

In 2003, Bruce Barraclough was created an Officer in the Order of Australia for services to medicine as a surgeon, to medical education, particularly the development of high-level surgical training facilities, and to the community through fostering improvements in the delivery of safe, quality healthcare in Australia.

DR RICHARD ASHY
Chief Executive, Metro South Hospital and Health Service

Dr Richard Ashby is the Chief Executive, Metro South Health and previously held the positions of Executive Director and Director of Medical Services at the Princess Alexandra Hospital in Brisbane.

Dr Ashby is a former CIO of Queensland Health and is currently Chair of that organisation’s Clinical Informatics Steering Committee. Dr Ashby has a long history in e-Health in Queensland and nationally, having sponsored or managed the implementation of several large systems including the Clinicians Knowledge Network.

He has previously represented the Australian Medical Association on Standards Australia IT14.
MR RAY BROWN
Chief Information Officer, Queensland Health

Ray has worked in the ICT field for 35 years and in 2001 commenced with the Department of Corrective Services as the Chief Information Officer (CIO). In 2003, Ray joined the Queensland Police Service and in 2006 became the Acting CIO. During this period, Ray was involved in the successful implementation of the integrated new police operational system, QPRIME.

Ray was permanently appointed to the role of CIO in August 2009 having commenced with Queensland Health as an Executive Director in June 2008.

Ray’s goal is to support Queensland Health’s direction focusing on the successful implementation of eHealth within Queensland supported by a new infrastructure strategy providing a more flexible and collaborative technical environment that supports health service delivery.

PROFESSOR LYNNE COBIAC
Science Director, CSIRO Food and Nutrition Flagship

Professor Lynne Cobiac has recently been appointed as Science Director of the CSIRO Food and Nutrition Flagship, a multidisciplinary science portfolio that focuses on the distinctive nexus of food, nutrition and lifestyle as major drivers of human health and wellness.

The Flagship brings together science and technical staff with skills in genomics and molecular sciences, food structure, chemistry, process engineering and food safety, nutrition and metabolic health, clinical assessment and behavioural science, as well as environmental biotechnology. Professor Cobiac has a background in nutritional biochemistry and research coupled with an Advanced Masters of Business Administration (MBA) and business management experience.
BOARD OF DIRECTORS (continued)

DR IAN OPPERMANN
Director, CSIRO Digital Productivity and Services Flagship (left 30 April 2014)

Dr Ian Oppermann is with Australia’s national science agency, CSIRO, as Director of the newly established Digital Productivity and Services Flagship. Flagships are CSIRO’s response to National Challenges and the focus of this Flagship is frontier service creation in the Digital Economy.

Until July 2012, Ian was Director of CSIRO’s ICT Centre. The ICT Centre was a business unit within CSIRO addressing major scientific challenges in Wireless Communications, Robotics, Information Theory, environmental sensing and eHealth.

Prior to CSIRO, Ian headed Sales Partnering for Nokia Siemens Networks’ software business, and was Director of Radio Access Performance Business at Nokia. Prior to joining Nokia, Ian was director of the Centre for Wireless Communications, a research centre in Finland.

Ian has contributed to 6 books as editor or chapter author, authored or co-authored approximately 30 journal and 90 conference papers. Ian has a Doctor of Philosophy in electrical engineering from Sydney University and an MBA from the University of London. Ian is a Fellow of the Institute of Engineers Australia, a Fellow of the IEEE, a Senior Member of the Australian Computer Society, and a member of the Australian Institute of Company Directors.

MR GREG MCCALLUM
Minutes Secretary

Greg McCallum is a CPA and a Fellow of the Australian Institute of Management. A previous Managing Director of the Queensland Government GBE CITEC, he currently operates as a sole trader providing business management consulting and services, and also is a Commissioner of the Queensland Gaming Commission. He has held Directorships in various companies since 1995.

MEETINGS

Board Meetings for 2013-2014 were held as follows:

• 25 November 2013 (Strategy Planning Day)
• 17 March 2014
• 23 June 2014

The following persons attended Board of Directors meetings as Alternate Directors, Observers or Executives for their respective organisations:

• Dr David Hansen, CEO, The Australian e-Health Research Centre
• Dr Bronwyn Harch, Director, CSIRO Computational Informatics
• Dr Michael Brüning, A/Director, CSIRO Computational Informatics
• Ms Nga Do, Finance Manager, CSIRO Computational Informatics
RESEARCH AND INVESTMENT ADVISORY COMMITTEE (RIAC)

Reporting to the Board of the Australian e-Health Research Centre, the Research and Investment Advisory Committee performs an advisory function for the Centre’s research activities, and assists the Board to carry out the functions of the Australian e-Health Research Centre.

MEMBERSHIP
The following persons were members of the Research and Investment Advisory Committee throughout 2013-2014:

CHAIR
• Dr Michael Steyn, Director Department of Anaesthesia & Perioperative Medicine, Royal Brisbane & Women's Hospital

MEMBERS
• Professor Bruce Abernethy, Deputy Executive Dean, Faculty of Health Sciences, The University of Queensland
• Dr Michael Bainbridge, Adjunct Professor Clinical Informatics, University of British Columbia, Canada
• Dr John W Bennett, University Health Service, The University of Queensland
• Mr Paul Carroll, Senior Director, Health Services Information Agency, Queensland Health
• Mr Paul Carroll, Senior Director, Health Services Information Agency, Queensland Health
• Professor Lynne Cobiac, Director, CSIRO Preventative Health Flagship
• Professor Lyn Griffiths, Executive Dean, Faculty of Health, Queensland University of Technology
• Dr Mukesh Haikerwal AO, National Clinical Lead, National E-Health Transition Authority
• Dr David Hansen, CEO, the Australian e-Health Research Centre
• Dr Liisa Laakso, Griffith Institute for Health and Medical Research, Griffith University
• Dr James Lind, Director, Emergency Medicine Training, Gold Coast Hospital Emergency Department
• Mr Tamati (Tam) Shepherd, General Manager, Future Service Design Division, Department of Human Services
• Professor Ross Young, Executive Dean, Faculty of Health, Queensland University of Technology

MINUTES SECRETARY
• Mr Greg McCallum, Director, Daedalus Enterprises

MEETINGS
The following AEHRC staff members attended Research and Investment Advisory Committee meetings during 2013-2014 as guest presenters:

30 JULY 2013
• Dr Anthony Nguyen – Big Data in Healthcare
• Dr Sankalp Khanna – Big Data Analytics
• Mr Bevan Koopman - Big Data Analytics – Inference Under Uncertainty
• Mr Simon McBride – Delta Motus Project
• Dr Qing Zhang – Big Data Capture - Smarter Safer Homes

6 NOVEMBER 2013
• Dr Justin Boyle– Remote-I to Torres Strait
• Dr Michael Lawley – Implementation of SNOMED CT in Neurology
• Dr Qing Zhang – Smarter Safer Homes
• Dr Mohan Karunanithi – COPD Mobile Health Trial Outcomes
The Australian e-Health Research Centre was once again a proud host of the 10th Annual e-Health Research Colloquium held in Brisbane on 1 April 2014.

The theme of the colloquium this year was “Meaningful use of health data: the next e-Health challenge” and we had yet another very exciting line-up of speakers from around Australia and the USA. The first session provided thought provoking talks on digital technology and the health system with two keynote talks. Dr Ian Oppermann, Director of the CSIRO Digital Productivity and Services Flagship, described how a connected world is opening new possibilities as to how services are delivered. Dr Jeffrey Braithwaite, Director of the Australian Institute of Health Innovation at the University of NSW, then challenged us on the barriers and opportunities for digital technologies to change the healthcare system.

We then had the opportunity to hear from speakers on how digital technologies are changing the healthcare system, with Fiona Webster talking about acute care innovations at the Austin Hospital in Melbourne; Dr Qing Zhang explaining an AEHRC trial of technology to enable older Australians to stay in their home longer and Ghislaine Wharton from Torres Strait describing how our tele-ophthalmology services can reduce the incidence of eye disease in remote Australia.

Our international keynote speaker was Dr Bern Shen, who described how his Silicon Valley Start up, HealthCrowd, is using data analytics to understand and influence human behaviour.

The final session gave an opportunity for AEHRC scientists and collaborators to highlight science and projects over the past 12 months. Dr Margie Wright, from the Queensland Institute for Medical Research highlighted how our biomedical imaging team is helping to discover risk genes for brain diseases. Our clinical imaging team leader, Dr Jurgen Fripp, described how MR Imaging can be predictive of osteoarthritis. Two of our researchers from our mobile health team, Marlien Varnfield and Dr David Ireland, described different tele-health trials that AEHRC is currently leading. To round out a great day, one of our recently completely PhD students, Bevan Koopman, described new technology for searching clinical documents, while Dion McMurtrie from the National e-Health Transition Authority discussed how AEHRC technology is helping develop the Australian Medicines Terminology.
DR DAVID HANSEN

David Hansen is CEO of the Australian e-Health Research Centre, part of the CSIRO Digital Productivity and Services Flagship. David leads an e-Health research portfolio developing information and communication technologies for the healthcare system. These include projects for resource planning, biomedical imaging, mobile and tele-health and technologies that will underpin the e-health architecture in Australia.

Prior to joining CSIRO, David worked for LION bioscience Ltd in the UK, developing genomic data and tool integration software that was used to publish the first human genome and is now used at over 200 pharmaceutical and biotechnology companies and research institutes worldwide.

PROFESSOR YOGESAN KANAGASINGAM

Prof Yogesan has developed and commercialised many medical technologies. He is a NHMRC Research Translation Faculty and an Adjunct Professor at the School of Medicine, University of Notre Dame. Prof Yogesan is also a Board Director of the International Society for Telemedicine and eHealth. In addition to his vision to use technologies to prevent needless blindness, his research interests include diagnosis and early detection of systemic diseases from the eye.

DR SARAH DODS

Dr Sarah Dods is the Research Director of the Digital Economy group within CSIRO’s Digital Productivity and Services Flagship. Sarah has over 20 years’ experience in multidisciplinary innovation, including mining R&D, high-tech startups, academia, and public research. She is passionate about translating digital technologies and data science into value for Australians in their everyday lives.

DR LANCE MACAULAY

Dr Lance Macaulay’s research team aims to understand mechanisms that prevent or control age onset diseases such as vascular disease, type II diabetes and Alzheimer’s disease.

He leads CSIRO’s activities in two major Australian studies - the Australian Imaging, Biomarkers & Lifestyle (AIBL) Flagship Study of Ageing and the START stroke consortium (www.START.csiro.au).
NEWS AND AWARDS

Hans de Visser (left) wins the SimHealth 2014 Simulation Achievement Award for significant contribution to the advancement of modelling and simulation in Australia or New Zealand. The CSIRO Image Guided Surgery team also won the SimHealth 2014 Research Award for Best Technology Innovation for “A new locally developed Virtual Reality Colonoscopy Simulator” (Hans de Visser, David Conlan, Josh Passenger, Cedric Dumas and Olivier Salvado).
TEAM AEHRC WINS 2ND PRIZE IN THE HISA APP CHALLENGE 2013 FOR "DIABETEZE"

CHANNEL 9 - REVOLUTIONARY APP FOR PARKINSON SUFFERERS
https://www.youtube.com/watch?feature=player_detailpage&v=jYbrkmg69jY
TELE- AND MOBILE HEALTH

Our tele-health and mobile health teams are leading the world in the clinical validation of healthcare services using remote communication technologies. Taking a holistic approach and partnering with key clinicians, the research programs combine the use of new communication technologies with clinical science and the study of human behaviour. This capability is now contributing to international programs in the development of care models in the community.

HEALTH INFORMATICS

The AEHRC health informatics capability has expertise in database technologies, data modelling, data integration, semantic interoperability and description logics and data analysis and includes the use of artificial intelligence techniques to extract meaning from data. These capabilities have delivered tools which are used across Australia as well as internationally. Many of the projects address the key challenges of the health system, including patient flow through a complex health system, adoption of clinical terminology in electronic health records and pathology reporting and the use of standard technologies in the collection and use of clinical trial data.

BIOMEDICAL IMAGING

The AEHRC biomedical imaging capability has expertise in medical image analysis and surgical simulation and planning. These capabilities are delivering new ways of extracting clinically useful information from MRI images and new ways of modelling soft tissues for use in surgical simulation. This capability is now being used in projects around Australia and has been recognised nationally through awards, and internationally by invited presentations at major conferences.
TELE- AND MOBILE HEALTH

The AEHRC Tele- and Mobile Health group works on innovative remote diagnostic (tele-health) and mobile health solutions to enable access to specialist care for all and self-management of disease. Two of the example projects are mobile phone-based cardiac rehabilitation and NBN Satellite-based tele-eye care delivery to remote communities.

PROF YOGESAN KANAGASINGAM
Research Director

Prof Yogesan has developed and commercialised many medical technologies. He is a NHMRC Translation Faculty and an Adjunct Professor at the School of Medicine, University of Notre Dame. He is also a Board Director of the International Society for Telemedicine and e-Health. In addition to his vision to use technologies to prevent needless blindness, his research interests include diagnosis and early detection of systemic diseases from the eye.

DR MOHANRAJ KARUNANITHI
Team Leader, Mobile-Health

Mohanraj Karunanithi has a doctorate in Biomedical Engineering, University of New South Wales. He has over 10 years of experience in cardiac research and 5 years of medical industries’ experience. At AEHRC, Mohan manages and coordinates research in ICT application in healthcare management and delivery of chronic diseases and aged care.
Australia’s aging population, like other developed countries, is disadvantaged by the limited placements in and increased cost of residential care. More importantly, older people prefer to live on their own homes. It is widely recognised that enabling older Australians to live in their own homes longer is a key priority because current aged care services are not always equipped to provide the necessary services.

To address this, the AEHRC in association with the Australian Center for Broadband Innovation (ACBI), has developed the Smarter Safer Homes (SSH) platform. The SSH platform will enable new innovative support services for aged people living alone in their own homes. Using low-cost, non-invasive sensors, the SSH platform provides a measure of functional independence, through information on Activities of Daily Living (ADLs) to a service provider or family member. The information can be used to determine the services required to support the older person living alone, and is aligned towards improving the Quality of Life (QoL) of older people and the Family Quality of Life (FQoL) for the adult children supporting their aged parent(s).

In collaboration with the University of New England and an aged care facility, a 12 month pilot trial of the SSH platform began in September 2013. The SSH platform was implemented in 14 independent living homes of older people. The families of the older people, often living 1000s of kilometers away, were engaged in the trial. The trial is due for completion in September 2014.
The results of the Care Assessment Platform (CAP) randomised control trial were recently published in the leading cardiac journal, Heart, as the first to clinically validated mobile health delivery of Cardiac Rehabilitation (CR). The results of the trial demonstrated improvement in CR use by more than 30% compared to the traditional CR program. The CAP trial also demonstrated equal health improvements and better quality of life than that of the traditional CR programs.

Over the past 12 months, the Mobile Health team have developed the Mobile Technology Enabled Rehabilitation (MoTER) platform. The MoTER platform has been developed to provide a platform for the delivery of Cardiac Rehabilitation for Metro North and other Queensland Health and Hospital Services and to support the development of care delivery models for other chronic disease management. Already the MoTER platform is being used to develop mobile phone based care delivery models for diabetes and chronic obstructive pulmonary disease (COPD). The MoTER project will also develop an extended ambulatory care model to incorporate post-CR medical review by cardiology specialists.

The new MoTER android app for Cardiac Rehabilitation.
The success of the randomised controlled trial of the mobile health delivery of CR has led the AEHRC to be included in a trial of tele-monitoring for the management of heart failure. The AEHRC will contribute to the design and oversee the implementation of a clinical trial of tele-monitoring of home care delivery of heart failure for MedTech Global. MedTech Global is a Victorian based tele-monitoring technology provider.

The AEHRC was a partner with MedTech Global and Peninsula Health Services in an initial feasibility study funded through the Victorian Government Health Market Validation program. The success of the feasibility study has led to the funding of the trial to which the AEHRC will contribute.
DELTA MOTUS

PROJECT DESCRIPTION

The DeltaMotus project is a collaboration with the UQ CCR’s Asia-Pacific Centre for Neuromodulation (APCN, http://www.uqccr.uq.edu.au/apcn) investigating the impact of Parkinson’s disease on a variety of patient clinical measures and community life.

The project uses smartphone technology to quantify the extent of and change in symptoms experienced by patients, which is expected to help both the patient and their care team better understand changes in symptoms and the effects of medications and surgical interventions such as Deep Brain Stimulation (DBS).

Recent work has seen proof-of-concept studies to evaluate different measures of communication, movement, symptoms, activities and wellbeing. We also continue to develop measures of “Lifespace” (the area in which a person lives and carries out their activities) to understand how the disease influences the community life of patients and their caregivers.

PROJECT HIGHLIGHTS FOR 2013/2014

• Publication of our work on the Michael J Fox Foundation Data Challenge in leading journals and multiple conferences
• Commencement of four proof-of-concept studies evaluating objective measures of movement, communication, wellbeing and daily activities
• Multiple media stories and articles, including Channel 9 Brisbane and the Michael J Fox Foundation web site

AIMS FOR 2014/15

• Investigate the extent to which Parkinson’s disease models of care can be enhanced to cost effectively improve patient quality of life and health service delivery through more timely, clinically-useful, objective measures of symptoms

An example of patient-reported quality of life metrics supplied during proof-of-concept studies.
This project involves collaboration with an interdisciplinary team of scientists, engineers and clinicians drawn from AEHRC and APCN to develop smartphone-based systems for the acquisition of objective measures that quantify function and mood of people with Parkinson’s disease.

Proof-of-concept studies are currently being undertaken with APCN to discover the most useful set of measures and the subsequent signal processing for automated assessment of the patient’s experience of the disease. Measures such as voice, gait, stride and community movement are being evaluated. A particularly novel but challenging example of this work is the development of new measures of voice patterns during naturalistic conversations, which may lead to new speech pathology interventions.

Another novel aspect of our partnership with APCN is the opportunity to further knowledge of the impact of the surgical intervention Deep Brain Stimulation (DBS). Our remote monitoring platform will provide patients, their care team and PD researchers with unprecedented levels of detail on the impact of the procedure.
Researchers from AEHRC in Perth are trialing an eye test in collaboration with a US based company, Neurovision Imaging as a screening tool for Alzheimer’s disease. The project is part of the Australian Imaging and Biomarkers Lifestyle Study of Ageing (AIBL), which has 1000 volunteers who are making a valuable contribution to Alzheimer’s research.

The goal of the trial is to see if a non-invasive and inexpensive test for early detection of Alzheimer’s disease. The trial involves two visits by volunteers to the McCusker Alzheimer’s Research Foundation, where they will have their retinal imaging taken using a fluorescence fundus photography. Between appointments, volunteers take a curcumin supplement. Curcumin is a natural ingredient used in cooking; it also gives the spice, turmeric, its fluorescent yellow colour. We use curcumin to light up the amyloid-beta plaques in people’s retinas. If what we see from the eye tests correlates with what is occurring in their brains, then we will have the makings of a screening tool for early detection of Alzheimer’s. It may enable us to identify people very early in the development of the disease, which could enhance our ability to intervene and stop or delay disease progression.

Quantitative analysis of Aβ plaque number, area (µm²) and distribution is performed from retinal images to create retinal amyloid index (RAI). Blood testing is utilised to determine Curcumin uptake. Preliminary results (n=40) indicate that RAI is highly correlated with brain plaque burden from PET scans (R=0.762, p<0.0001), supporting the hypothesis of hallmark AD pathology in the retina and providing the basis of an ocular screening test for AD. The retinal amyloid test could also differentiate between AD and non-AD with 100% sensitivity and 80.6% specificity. The full study (n=200) is expected to be completed in late-2014.
This project investigates changes to the eye in Alzheimer's disease (AD) that might help detect the disease earlier and monitor the response to treatments. Early detection of AD is essential for intervention as subclinical brain changes occur well before the onset of clinical symptoms. An accurate, early diagnostic test for AD would enable current and future treatments to be more clinically effective, in addition to accelerating the development of new treatments.

The research for this thesis has involved collection and analysis of retinal photographs and pupil flash response parameters from participants at the McCusker Alzheimer’s Disease Research Foundation in Perth, Australia. The results demonstrate relationships between ocular abnormalities, neocortical plaque burden and AD. The eye testing demonstrates potential for early, non-invasive, cost-effective detection of AD as well as monitoring response to treatment.
In 2013, CSIRO received funding from the competitive Broadband-enabled Telehealth Pilots Program administered by the federal Department of Health.

The project piloted CSIRO’s award winning ‘Remote-I’ tele-eye care solution over the Broadband Satellite service, connecting metropolitan-based ophthalmologists to patients with eye conditions in rural and remote WA and Queensland. The project achieved its aim of closing the gap in access to eye care services for indigenous and older Australians living in under-served rural and remote areas, preventing needless blindness.

The main eye condition targeted through this project was diabetic retinopathy, which remains the leading cause of preventable blindness in working-aged people. It is identified in a third of people with diabetes and associated with increased risk of life-threatening systemic vascular complications, including stroke, coronary heart disease, and heart failure. One of the major issues the public health system faces to overcome this problem is the increasing waiting list for ophthalmology consultations. Tele-ophthalmology programs like this one offer new opportunities to improve access and quality of care for people with diabetic retinopathy.

The project was delivered via new partnerships between researchers from CSIRO, Western Australia Country Health Service (WACHS), The Australian Society of Ophthalmologists through its Indigenous Remote Eye Service (IRIS) and Queensland Health.

The sites for undertaking remote screening was chosen based on their limited internet connectivity; consequently a satellite dish was installed at each site and internet service plans established (formerly referred to as the National Broadband Network). Retinal cameras, servers and laptops were procured and connected at all sites to satellite broadband enabling the secure upload of patient records and images to CSIRO’s Remote-I system.

To date, there have been screening records from over 1000 patients uploaded to Remote-I and diagnosed by ophthalmologists, exceeding the project target of 900. Analysis of diagnosis data indicates 82 cases of diabetic retinopathy (DR) were picked up (31 in WA and 51 in Queensland). Critically, four patients were diagnosed with sight-threatening eye condition (31 in WA, 37 in Queensland). The majority of participants screened had no eye problems, which enables the removal of these patients from the queues of overwhelmed specialist lists, improving service efficiency.

Collaborators
- Western Australia Country Health Service
- The Australian Society of Ophthalmologists through its Indigenous Remote Eye Service (IRIS)
- Queensland Health – Torres Strait-Northern Peninsula Hospital & Health Service

Project Highlights for 2013/14
- More than 1000 patients were screened in WA and QLD (Torres Strait Islands)
- Almost 10% of the patients needed referrals for further examination by a specialist ophthalmologist
- 8 patients had sight threatening eye condition

Aims for 2014/2015
- Conclude the project and write articles to high impact journals in the field
- Explore opportunities to roll out the service to other regions and States
- Explore opportunities to implement the service delivery on an ongoing basis in collaboration with WA Health and QLD Health
This project aims to detect early stage age-related macular degeneration (AMD), a leading cause of vision loss in people over the age of 50 years in developed countries. Patients usually come to the ophthalmologist during the later stage of vision problems. Identifying people with early signs of the disease, therefore, and then determining their risk based upon their fundus characteristics is important, considering both the social and economic impact of AMD.

In this project, we aim to investigate an early AMD screening system and prevent vision loss through developing a system for detecting AMD pathologies from retinal colour fundus imaging. The system will utilize cutting edge image processing and computer vision algorithms, and machine learning based intelligent model to classify AMD pathologies and determine AMD stage or severity. This system will be integrated with Remote-I telemedicine system to screen and refer patients in a timely manner by nurses and primary care providers.

Daniel is working on the final version of his thesis. He is expected to submit it early 2015. Daniel Ting’s PhD is about the evaluation of a New Diagnostic Device and Diagnostic Technique (retinal video recording) for Diabetic Retinopathy Screening. There is a need for new ways to perform more efficient diabetic retinopathy screening and image reading. The retinal video recording is one of such methods where the screeners could capture a short video of the retina that will give multiple views and also allow the ophthalmologist to make a more comprehensive diagnosis. Daniel has also explored the effect of image compression and screen resolution on image reading for diabetic retinopathy when using telemedicine based diagnosis.
TELE- AND MOBILE HEALTH

TELEMEDICINE DELIVERY TO THE UNDER SERVED: REMOTE-I

PROJECT DESCRIPTION

CSIRO, in collaboration with WA Health, developing several telemedicine systems for use in Western Australia. One of them is an Emergency Telehealth system with electronic dash board. This system is being tested at WA Country Health Services.

We have also developed a tele-dentistry system for a pilot study to evaluate the use of mobile phones for remote examination of school children in WA and Queensland.

CSIRO researchers have developed these system based on their telemedicine platform called Remote-I. Remote-I includes the following features:

- A web-based mobile system that captures images from any imaging device and sends them to a centralized cloud centre
- An offline system for data capturing in areas with no immediate Internet connection
- An automated system to analyse captured images and support decision making by screening staff and medical specialists
- Security and encryption techniques for transmission of patient data

Remote-I is a hybrid telemedicine system, supporting both video conferencing and store-and-forward (asynchronous) consultations. After conducting a wide scale study in Pilbara, we are now scaling the reach of Remote-I across Australia and internationally. Our service saves patients (who are without any disease complications) time, money and effort and enhances their lifestyle by eliminating unnecessary travel.

COLLABORATORS

- Western Australia (WA) Department of Health
- Western Australia Country Health Services
- Royal Perth Hospital
- Zhongshan Ophthalmic Centre, Guangzhou, China

PROJECT HIGHLIGHTS FOR 2013/14

- Development of advanced clinical decision and automated disease grading for diabetic retinopathy and glaucoma
- Remote-I is installed at Zhongshan Ophthalmic Centre and 10 of the remote hospitals each cater for 3-5 million people in Guangdong, China
- WAiTTA iAwards 2013, for Age related Macular Degeneration automation system
- Two patent applications have been submitted around Remote-I and Age Related Macular Degeneration

AIMS FOR 2014/2015

- Clinical validation of the new technologies and algorithms
- Implementation and rollout throughout Australia
- Include modules for new applications such as Wound care and ENT
Scheduling system for video conferencing with dermatologists.

TELE-DERMATOLOGY PROJECT WITH THE AUSTRALIAN COLLEGE OF RURAL AND REMOTE MEDICINE (ACCRM)

PROJECT DESCRIPTION

The collaboration with the Australian College of Rural and Remote Medicine (ACCRM) is aimed at providing some of the advanced functionality in the Remote-I system within ACCRM’s tele-dermatology system. It is envisaged that the hybrid store-and-forward and video conferencing consultation services of Remote-I will provide interoperability between General Practitioners and specialists and compliance with secure messaging standards.

We have implemented many functionalities such as,

1. Linking with the existing ACCRM system;
2. Scheduling system for booking real-time video conferencing appointments with available specialists listed on the directory;
3. Calendar system for the convenience of appointment scheduling;
4. WebRTC based video conferencing module for practitioner and specialist video consultation with low cost;
5. Email and SMS functions for reminding scheduled appointments for practitioners, specialists and patients.

Currently, the clinical working group from ACCRM is testing the system.

COLLABORATORS

- Australian College of Rural and Remote Medicine

PROJECT HIGHLIGHTS FOR 2013/14

- Developed a fully functional system for trial at ACCRM

AIMS FOR 2014/2015

- Clinical validation of the current system by ACCRM members
- Secure additional funding for further trials and development
- Identify opportunities for smart algorithms to automate the decision support offered by specialists
The Health Informatics group is concerned with the capture, storage and analysis of health data across health administration, clinical treatment and health service and medical research. We address these issues by developing tools that help in the management and analysis of this data, whether the data is captured in an administrative database, electronic health record, coded in a clinical information system or captured as a medical narrative. New statistical algorithms and visualisation techniques that form part of our research enable the analysis and display of the data for clinicians, researchers and patients.

ANTHONY NGUYEN, PhD
Stream Leader, Intelligent Health Information
Project Leader, Clinical Information Processing and Reporting
Dr Nguyen received a BEng with first class honours and a PhD degree at the Queensland University of Technology. His research interests are in the area of medical text analysis of electronic health records using natural language processing, machine learning and clinical terminology. Anthony’s research team won the Health category of the Qld iAwards in 2013 for their medical text analysis platform (Medtex).

MICHAEL LAWLEY, PhD
Group Leader, Health Data and Semantics
Project Leader, Health Information Environment (HIE)
Dr Lawley received a BSc(Hons) from The University of Melbourne and a PhD from Griffith University. His research interests involve the interactions between symbolic models (based on first order logic) and statistical models (from machine learning). His work aims to enable semantically interoperable health data, and improve the precision and quality of longitudinal health records. Technology he has developed is used to produce each new version of SNOMED CT and AMT.

SIMON McBRIEDE
Research Consultant
Project Leader, Clinical Research Information Systems, DeltaMotus and Clinictivity
Simon leads e-health research projects for CSIRO’s Preventative Health Flagship. He has been working in IT-related research and start-up environments for more than 15 years. Simon holds a BAppSci(Computing) and an MBA(Entrepreneurship and Finance). Simon leads data management activities for CSIRO-sponsored clinical studies such as the Australian Imaging, Biomarkers & Lifestyle (AIBL) Study of Ageing.

JUSTIN BOYLE, PhD
Project Leader, Patient Flow Analysis
Dr Boyle (BEng, PhD) has research interests in hospital patient flow analysis, including predicting bed demand and investigating hospital capacity and demand interaction to provide information for efficient running of acute health services. He is also a key member of the NBN Enabled Indigenous Tele-Eye Care project, funded by the Department of Health and Ageing (DoHA).

ANTHONY NGUYEN, PhD
Stream Leader, Intelligent Health Information
Project Leader, Clinical Information Processing and Reporting
Dr Nguyen received a BEng with first class honours and a PhD degree at the Queensland University of Technology. His research interests are in the area of medical text analysis of electronic health records using natural language processing, machine learning and clinical terminology. Anthony’s research team won the Health category of the Qld iAwards in 2013 for their medical text analysis platform (Medtex).
PROJECTS

HEALTH INFORMATION ENVIRONMENT

Minnow with AMT V3, powered by the terminology server Ontoserver incorporating Snorocket.

PROJECT DESCRIPTION

The Health Information Environment project’s goals are to enable improved patient safety and outcomes through realising the value of a high-quality integrated health-data ecosystem.

Successful adoption of standard terminologies such as SNOMED CT and the Australian Medicines Terminology (AMT) is vital for the success of enabling patient data to move between clinical systems – and the new Personally Controlled Electronic Health Record (PCEHR) system – in a safe way. Many systems across health organisations such as Queensland Health will be required to migrate from other code sets to SNOMED CT. Our tools will help with this migration and deal with complexities such as the level of detail in each code and gaps in the codes while still ensuring that high-quality data is captured.

We have developed significant national and international impact through our tools: the free SNOMED CT and AMT browser, Minnow; the terminology mapping and subsetting tool, Snapper; the cloud-based terminology server, Ontoserver; and the reasoning engine, Snorocket.
HEALTH INFORMATICS

HEALTH INFORMATION ENVIRONMENT (continued)

COLLABORATORS

• Queensland Health – Health Services Information Agency (HSIA)
• The National E-Health Transition Authority (NEHTA)
• The International Health Terminologies Standards Development Organisation (IHTSDO)
• Royal Australasian College of Surgeons (RACS)
• U.S. Department of Veterans Affairs, Veterans Health Administration (VHA)
• Apelon
• HealthCare Software, Tasmania
• UK Medicines and Healthcare Products Regulatory Agency (MHRA)

PROJECT HIGHLIGHTS FOR 2013/2014

• Minnow updated to support AMT V3 and released as the official browser for AMT
• A new open source version of Snorocket, extended to support reasoning with numbers (concrete domains) was funded by the US VHA and is now used to produce the Australian Medicines Terminology (AMT) V3
• Consultancies with RACS and UK MHRA to map existing termsets to SNOMED CT
• NEHTA’s successful release of the first production version of AMT V3 which involved contributions from AEHRC towards tooling, testing and refining of the underlying model
• Formal adoption of the AEHRC-developed SNOMED CT URI Specification by the IHTSDO, as well as early use by HL7’s emerging FHIR Standard
• A new scalable version of Ontoserver with multi-version support developed and deployed for use across CSIRO and as a backend to support Minnow

AIMS FOR 2014/2015

• Official adoption of Concrete Domains (working with numeric values) in the international SNOMED CT standard by the IHTSDO
• Multiple commercial licences of Ontoserver to provide native SNOMED CT and AMT capability to third party health information systems
• Further develop our algorithms for searching, querying and analysing data using multiple versions of SNOMED CT
• Evaluate and continue to develop our techniques for combining symbolic and statistical representations of meaning for use with free text and coded data
The Australian Medicines Terminology is an extension of SNOMED CT that attempts to formally define medicines using the lightweight EL++ profile of description logics. AMT has introduced concrete domains, which are entities that can be used to define new concepts by specifying restrictions on the values of attributes with literal values, to model concepts that include numeric information in its definition. The availability of this information enables interesting applications based on formal reasoning, such as decision support systems.

The main focus of this project is to extend our ontology reasoner, Snorocket, to enable it to reason properly with these new constructs. Adding these features is challenging because most concrete domains constructs are excluded from the EL++ profile because theoretical work has shown that certain combinations lead to intractability. The hypothesis is that an efficient, sound and complete algorithm can be developed to support most of these features. The properties of the algorithm will be analysed formally and the implementation will be evaluated empirically.

Health data comes in many forms, including patient medical records, laboratory test results, pharmaceuticals and medical literature. Searching and interpreting this data involves bridging the ‘semantic gap’ aligning the meaning behind the words found in queries and documents. It goes beyond a traditional information retrieval approach in which keywords are matched between a query and document representation. The problem fundamentally turns on precisely matching concepts (i.e., determining when two concepts basically have similar meaning).

The focus of this project is the theory and application of using semantic space representations of words to enrich the symbolic definitional knowledge in (biomedical) ontologies such as SNOMED CT. The hypothesis is that semantic space representations of words can underpin more expressive conceptual representations and thereby allow matching of concepts to be enhanced. The semantic space approach will be evaluated with respect to the ability to effectively answer advanced information retrieval tasks in health data, such as the matching of clinical trials to patient records.

This research program involves the theory and application of Description Logic, the formal underpinnings of SNOMED CT. In particular, it will develop automated techniques to characterise, identify and extract self-contained modules to aid in the aforementioned tasks.
PROJECT HIGHLIGHTS FOR 2013/14

- Delivered three releases of the AIBL integrated data set to researchers
- Delivered a beta release of the Visual Analytics for Clinical Trials (VACT) web application
- Delivered updates to electronic data capture systems for START sub-trials, EXTEND-START/PrePARE, EXTEND-IA and STOP-AUST
- Assisted in trial infrastructure planning and delivered an electronic data capture system release for AusFAP and the Blood-based Biomarker for Colorectal Cancer study

AIMS FOR 2014/15

- Continue to provide support for AIBL, START, AusFAP and Blood-based Biomarker for Colorectal Cancer clinical studies
- Demonstrate the use of data semantics in analysis and visualisation of clinical study data, focusing on medications data

PROJECT DESCRIPTION

The Clinical Research Information Systems project provides data management services to CSIRO-sponsored clinical studies whilst pursuing research topics that enable novel analysis of clinical study data.

The project’s support activities provide data modelling and quality assurance services and hosts electronic data capture and data warehousing systems. During 2014 we continued to support a number of Preventative Health Flagship-sponsored studies including: the Australian Imaging, Biomarkers and Lifestyle (AIBL) Study of Ageing http://aibl.csiro.au; the STroke imAging pRevention and Treatment family of studies (START) http://start.csiro.au; and the Australian butyrate evaluation in Familial Adenomatous Polyposis adenoma prevention study (AusFAP) http://ausfap.csiro.au and the Blood-based Biomarker for Colorectal Cancer study.

Our research activities investigated semantic enrichment and visualisation of clinical study data via a prototype Visual Analysis of Clinical Trials (VACT) web application. VACT provides data visualisation features that make clinical study data more accessible and was made available to AIBL researchers. We also pursued a semantic web-based framework for publishing clinical study data, namely the Linked Clinical Data Cube (LCDC). The LCDC is an extension of the W3C’s Linked Data Cube concept and will enable ontology-based integration of open data sets such as Australian Medicines Terminology (AMT), SNOMED CT, and DrugBank.

Linked Australian Medication Data Set developed during an investigation involving interlinking AIBL medications with LinkedData.org data.
CLINICAL INFORMATION PROCESSING AND REPORTING (CIPAR)

The Clinical Information Processing and Reporting project is developing medical free-text analysis capabilities to support systems for quality control, decision support, and management and planning. This will automate the collation, analysis, summarisation and classification of relevant clinical data from electronic health records. Improving the current manual processes would provide significant benefits to healthcare service providers, administrators and patients.

The project aims to develop semantic text analysis services to unlock information in unstructured and semi-structured medical free-text. This is achieved by extracting clinically relevant information/patterns from the medical free-text using Natural Language Processing (NLP) and Clinical Terminologies. Novel tools and algorithms are developed to bridge the semantic gap between raw patient data and the way a clinician interprets the data.

Through the use of these services, seamless and reliable information extraction and reasoning can be achieved to improve clinical decision support.

In collaboration with Cancer Registries and clinical partners, the semantic medical text analysis service is being developed and evaluated for automating Cancer Registry tasks, expediting the coding and review of death certificates, and the checking of radiology reports to prevent missed fractures. These services allow for the near real-time fast tracking and retrieval of clinical cases that are not currently possible with current clinical workflows.

The Medex platform processes narrative reports and generates structured data for clinical decision support, reporting, analytics and search tasks.
CLINICAL INFORMATION PROCESSING AND REPORTING (CIPAR) (continued)

COLLABORATORS
• Queensland Cancer Control Analysis Team (QCCAT), Queensland Health
• Department of Emergency Medicine, Royal Brisbane and Women’s Hospital
• Department of Emergency Medicine, Gold Coast Hospital
• Cancer Institute NSW
• NSW Ministry of Health
• Peter MacCallum Cancer Centre, Victoria
• Royal College of Pathologists of Australasia

PROJECT HIGHLIGHTS FOR 2013/2014
• Medtex won the 2013 Queensland iAwards and was a finalist in the National iAwards in the Health category
• Streaming medical text analytic service developed for high throughput and parallel processing of large-scale electronic health records
• Medtex platform is operational on the production servers within Queensland Health, processing and analysing live pathology feeds across the State of Queensland for the identification of cancer notifiable reports. In addition, Medtex extracts additional synoptic/structured information from the free text records about the patients. This has the potential to provide indicative cancer information about the patients in real-time as opposed to the multi-year delay as currently achieved in Cancer Registries
• Medtex platform deployed within Cancer Institute NSW operating environment to process death certificates and to automatically code the underlying cancer cause of deaths. Currently there is a multi-year delay in collecting cause of death codes. As a result of deploying Medtex, real-time up-to-date mortality information is available for monitoring, planning and evaluating the management of conditions of high public health importance
• Medtex adapted to classify limb abnormalities from radiology (X-ray) reports. The findings from the analysis of the radiology reports are linked with patients’ disposition as recorded in an emergency department information system to provide decision support to the clinical review process

AIMS FOR 2014/2015
• Continue application of Medtex and improve technology across a breadth of health domains and report types including its adoption with clinical partners
• New techniques and algorithms to combine symbolic and statistical representations of meaning for improved medical named entity recognition
• Development of clinical decision support services for clinical interaction with Medtex

Semantic reasoning and inference within the international clinical terminology standard (SNOMED CT) for the checking of radiology reports to prevent missed fractures.
The majority of health data is recorded in free-text unstructured documents, such as clinical examination reports, nursing notes, discharge summaries, death certificates, etc. This data contains information that is valuable for secondary use, such as for population health monitoring and reporting. However, its clinical importance and large volume hinders manual analysis of such data. As a consequence, the analysis of clinical data is often performed retrospectively with delays that potentially undermine effective population health monitoring and reporting.

There has been a growing interest in using Electronic Medical Record (EMR) systems to improve the quality of health care through decision support, evidence based medicine and disease surveillance. The huge amount of textual clinical data that constitutes the majority of the patient record has to be consolidated in order to make full use of the information contained in EMRs.

In this research, natural language processing, machine learning and text mining approaches have been developed to deliver effective automated health monitoring and reporting solutions. These approaches scale to large amounts of unstructured data and have been integrated within a highly distributed computational framework. The approaches have been successfully applied to the analysis of:

1. pathology reports and death certificates to timely assess the incidence of cancer and the associated mortality rates, and
2. radiology reports to support the reconciliation of radiology findings with emergency department discharge records.

Current challenges include improved meaningful interpretation of clinical free-text and coping with rare diseases for which only few samples are available for computational learning.

The proposed research aims to develop focused relevance feedback technologies that are applicable to a broad range of data sources including clinical text. The research will be evaluated with respect to the ability to retrieve specific information from textual records.
The vast majority of information about patient care in electronic health records exists as unstructured free-text, such as regular health care professionals’ notes and radiology reports. Recognising key clinical information from these natural language generated free-texts and representing them as structured machine understandable data is essential for effective clinical decision support system developments as well as for secondary data use. The generalisation of clinical information extraction systems to all types of clinical data regardless of locality and healthcare applications remain a significant challenge.

With the increase in publication of biomedical papers and the challenging task of identifying information from within these publications, most traditional search engines are unable to identify artefacts such as hypothesis, observations, interventions, etc.

The aim of this research is to design and build a knowledge base of key scientific statements in the domain of evidence based medicine (e.g. background, intervention, population, and outcome), using scholarly publications as the main input.

Machine learning approaches such as supervised learning methods can train powerful statistical models to effectively extract information, but they must be trained on a large human annotated corpus to achieve best performances. However, within the healthcare domain, such annotations require the participation of domain experts, which incurs significant costs.

This project aims to investigate and develop effective machine learning approaches in the form of a hybrid framework (semi-supervised and active learning) by considering all the challenges and requirements for information extraction within the healthcare domain. Different machine learning methods will be investigated and applied in a cooperative manner for a diverse range of clinical information tasks (e.g. personal health information, medical concept identification, and medication extraction). A hybrid framework will be developed with the aim to considerably reduce the cost of learning while maintaining a high level of accuracy.

To achieve this goal, the project aims to:

1. create a model to capture the semiotic nature of this knowledge;
2. use machine learning techniques to recognise the target statements within publications;
3. use compositional distributional semantics to consolidate the resulting scientific artefacts according to their underlying class, and hence instantiate the intrinsic semiotic model; and
4. link the artefacts (i.e. create relations between artefacts of different classes) to provide a comprehensive knowledge network of the underlying domain.
PATIENT FLOW ANALYSIS

PROJECT DESCRIPTION

As State health systems in Australia are being pushed to perform better, our work assists state government partners by improving the capacity to plan and manage their resources. The health statistics team is helping hospitals by performing system evaluations to help meet patient flow performance targets, whilst solving the challenge of overcrowding and system bottlenecks.

The team has undertaken patient flow modelling research with our partner hospitals, where analytics, optimisation and operational decision support tools have helped hospitals obtain a better understanding of what they could do to meet flow-related performance targets. These activities have included:

- Improved bed demand prediction – developing and validating a web-based application (The Patient Admission Prediction Tool) to predict ED presentations and subsequent hospital admissions and discharges across time of day, and day of the year
- Patient flow and Hospital Occupancy – identifying stages of decline in patient flow system performance (‘choke points’) as a function of hospital occupancy and analysing the efficacy of hospital processes such as capacity alerts in managing high occupancy
- Linking ambulance, ED and admissions data - developing a data integration tool to produce linked datasets of clinical and administrative data, without identifying information such as names and addresses
- Disease surveillance - using a variety of models (e.g. adaptive cumulative sum plans, internet search data, Twitter) to identify disease outbreaks as early as possible
- ED Length of Stay performance – reviewing historical LOS performance to help improve compliance to the National Emergency Access Target (NEAT)
- Patient flow visualisation – creating a user-friendly support tool for bed administrators, to support their decision-making through viewing and analysing routinely collected hospital data
- Bed configuration – developing simulation models for patients admitted to inpatient beds from ED to assess how changing the numbers of beds in different specialities affects the waiting times for inpatient beds
- Adverse event analysis - examining the relationship between daily hospital occupancy rates and the occurrence of reported adverse events
- Early discharge strategies - investigating the effects of varying inpatient discharge timing on ED length of stay and hospital occupancy, to determine the ‘whole of hospital’ response to discharge timing
- Readmission prediction – developing models that use patient data to understand the characteristics of ‘frequent flyers’ and how they utilise the health system. This model can be used to identify inpatients pending discharge who have high risk of readmission to hospital
- Operating Room optimisation - statistical analysis of operating theatre datasets for discovery of new insights and system triggers to improve elective surgery scheduling, and predictive modelling to improve procedure duration estimation

Further information about the work can be found online: www.csiro.au/patientflow
PATIENT FLOW ANALYSIS (continued)

Hamish Thorburn from AEHRC wins award for Best Student Paper at HIC2014.

The AEHRC develops strategies for improving efficiency across our health sector.
As the hospital’s largest cost and revenue center, the operating theatre has a major impact on the performance of the hospital as a whole. Managing the operating theatre is difficult, however, due to the scarcity of costly resources and the increasing pressures imposed by the ageing population. Moreover, health service managers have to balance competing demands for elective and emergency surgical services, whilst complying with operational constraints and quality measures like the National Elective Surgery Targets (NEST). These factors clearly stress the need for optimal efficiency and necessitate the development of adequate planning and scheduling procedures. On the other side, the uncertainty associated with different activities, along with conflicting priorities and preferences of the stakeholders, adds additional layers of complexity to the OR scheduling problem, making this one of the most challenging real world scheduling domains.

In collaboration with the Gold Coast Hospital, this research project is aimed at developing prediction-guided algorithms for optimal scheduling of elective surgery. For this purpose we proposed an intelligent two stage methodology that integrates predicted information and historical utilization data with optimization techniques to improve current state of the art of real world dynamic scheduling problems. The proposed framework will employ a novel integration of machine learning and stochastic programming to address the underlying uncertainty in operating room scheduling problem. The resulting scheduling algorithms will help optimize NEST compliance, reduce resource contention, and ultimately improve patient outcomes.
BIOMEDICAL IMAGING

THE AEHRC Biomedical Imaging group develops innovative medical technologies based on medical imaging to improve screening and diagnosis of diseases, and provides clinicians with better imaging systems for treatment and intervention. The team of scientists has expertise in several imaging modalities including MRI, CT, X-ray, Ultrasound, PET, SPECT and Endoscopy. The main applications are oncology, neurodegeneration, musculoskeletal diseases, trauma, surgical planning and endoscopy based surgery. Our goal is to improve treatment outcomes and increase healthcare productivity.

OLIVIER SALVADO, PhD
Group Leader, Biomedical Imaging

Dr Salvado leads the Biomedical Imaging Group, which focuses on medical image analysis, computer simulation and planning of surgical interventions. By integrating cutting edge image processing techniques and numerical models, several national health challenges are addressed, allowing smarter and more efficient diagnosis and intervention.

A/PROF STEPHEN ROSE, PhD
Science Leader, AEHRC
Team Leader, Translational Research and Oncology

This team focuses on translational medical imaging research to improve cancer diagnosis, treatment delivery, toxicity outcomes and clinical productivity. Novel imaging technologies include advanced MRI techniques (diffusion, arterial spin labeling) and PET markers (inflammation, hypoxia). The team also has expertise with radiation therapy treatment planning, dynamic imaging, physiological models, and organ tracking from cineMRI.

JURGEN FRIPP, PhD
Team Leader, Image Analysis
Project Leader, Musculoskeletal Imaging

The aim of this team is to develop software for characterising diseases from medical images, and for training and planning of computer-assisted interventions. The main approach is to embed into image processing algorithms expert knowledge from physiology, biology, pathology and the physics of the imaging acquisition. Novel approaches based on machine learning are being investigated.

CÉDRIC DUMAS, PhD
Team Leader, Image Guided Surgery
Project Leader, Bronchoscopy Simulation

The team investigates novel technologies for image guided intervention. Examples include advanced visual and haptic rendering for surgical simulations, real-time assistance during examination and remote mentoring of medical procedures. The team has expertise in real-time computer graphics, virtual reality, and computer vision.
MEDICAL IMAGE ANALYTICS ON THE CLOUD

PROJECT DESCRIPTION

Advances in Medical Imaging technologies such as new PET tracers and MR Imaging machines, together with cloud technology, provide the opportunity for new imaging services to transform diagnosis and treatment options. We are developing technologies to automatically perform the quantification of medical images scans remotely using a cloud platform. The AEHRC has currently provided an evaluation version of clinical reports at http://milxcloud.csiro.au/

The first clinical report available performs PET-only quantification, as MR images are not always available. PET images are uploaded to a cloud-based platform where they are spatially normalised to a standard template and quantified. A report is then automatically generated and emailed to the user, containing localised as well as global quantification, and a surface projection of the PET marker concentration. The method has been validated against MR-based PET quantification and was shown to have less than 3% error. It covers five common PET markers for Amyloid and glucose metabolism.

Innovative methods are also being developed to quantify other imaging modalities and produce similar clinician-friendly reports. Anatomical MRI scans for brain atrophy, white matter hyper-intensities from MRI FLAIR sequences, and microbleeds from MRI-SWI are examples in our technology pipeline.

Novel findings about brain connectivity have been published in the last period revealing that some brain circuitry and anatomy are inherited and genetically driven.

Example of clinical report for PET analysis that can be computed automatically on the cloud and sent by email.
This research is a part of the START PrePARE program to study the post-stroke behavioural-functional correlates of ischemic stroke patients.

Jhimli is currently developing an automated method for the segmentation of stroke and white matter lesions in stroke patients. Previous approaches on stroke lesion segmentation are entirely intensity-based (dependant on T1W or FLAIR MRI scans), and rely more on heuristic decisions (thresholds) and their performances that significantly differ across datasets due to intensity heterogeneities.

A new two-stage pattern classification approach has been developed that involves Bayesian-Markov random field (MRF) classification and discriminative classifiers like random forest. The initial Bayesian-MRF classification (probabilistic) relies on FLAIR hyperintensities; thereafter context-rich features extracted from the multimodal MRI (T1W, T2W, FLAIR and ADC maps) are used to train the random forest classifier. The probabilistic classifications from the two classifiers are then combined in a strategic manner to obtain a binary classification of the stroke and white matter hyperintensities.

KAIKAI SHEN, PhD
John Stocker Postdoctoral fellow in collaboration with the Queensland Institute of Medical Research (QIMR)

GENETIC INFLUENCES ON BRAIN FUNCTIONAL AND STRUCTURAL CONNECTIVITY

The genes involved in the developmental pathways for adult brain structure and functions are still largely unknown. Dr Shen is applying advanced image analysis on the ongoing research in imaging of monozygotic (MZ: identical) and dizygotic (DZ: non-identical) twins conducted at the QIMR. The imaging data comprise the best technologies available, and in particular, the MRI imaging protocol includes novel advanced types of scans such as Diffusion imaging (DWI) allowing to image the diffusion of water in the white matter and infer the anatomical brain connections. This project builds upon one of the world’s first multimodal imaging study of twins led by the QIMR, and will identify how genes influence brain connectivity. Neural connectivity is a basic feature of brain organization and increasingly we are realising the importance of connectivity data to unravel the mystery of the mind. Differences in brain connectivity result in variation in behaviour as well as risk for disease affecting the brain. During this period, Dr Shen published novel findings showing that some neuronal circuits are inherited, that is driven in part by our genes.
Insights into how the brain is connected. This brain section shows the axonal pathways that are driven by genetic influence at more than 45%.

The link between cerebral blood flow, beta-amyloid protein deposition and cerebral microbleed remained unexplored in Alzheimer’s disease (AD) and dementia. Amyloid, which accumulates in the brain of AD patients, is thought to lead to impairment and damage to blood vessel functions. This project aims to investigate the role of cerebral blood flow and haemorrhages using advanced MR imaging (SWI and ASL) and explore their relationship with other biomarkers of AD such as beta-amyloid.

This project involves the creation of a tool that can assist clinicians in the classification of cerebral palsy (CP). Currently, manual identification of CP from MR brain scans is a time-consuming task, and is subject to variability. It is hoped that such a tool will provide a repeatable output that can assist clinicians, and save time on manual labour.

The first stage of this project is to develop the image processing algorithms that can incorporate expert physiological knowledge to automatically detect regions of abnormality associated with CP. These techniques aim to establish an understanding for natural (healthy) variability in the anatomy of the brain using a database of normative scans. Utilising this information, it is possible to then identify which variability in a specific scan is due to pathology. These key physiological signs of CP that must be detected include peri-ventricular white matter injury, white and grey matter lesions and cortical malformations. Based on the detected abnormalities, a score can then be generated that can incorporate knowledge of “sensitive” regions of the brain, that correlates with clinical scores for motor function. This output score can be used by clinicians as a guide for effective patient-specific therapy.

**PhD STUDENTS**

**AMIR FAZLOLLAH**

*Joint collaboration of The Australian e-Health Research Centre and Université de Bourgogne*

**CHARACTERIZATION OF CEREBRAL BLOOD FLOW AND MICRO-HAEMORRHAGES IN ALZHEIMER’S DISEASE**

**ALEX PAGNOZZI**

*The Australian e-Health Research Centre PhD Scholarship*

*The University of Queensland*

**NORMATIVE ATLASES FOR USE IN AUTOMATED DETECTION OF ABNORMALITIES**

Insights into how the brain is connected. This brain section shows the axonal pathways that are driven by genetic influence at more than 45%.
Premature birth constitutes a significant health burden and occurs in approximately 8% of live births in Australia. Long term sequelae of premature birth include cerebral palsy, mild motor dysfunction, cognitive deficits and educational difficulties. To understand the underlying causes of these deficits, non-invasive techniques which can probe their neural correlates are required.

Cerebral palsy (CP) and acquired brain injuries (ABIs) are debilitating forms of brain injury that can result in motor disturbances in paediatric populations. The ‘Move it to Improve it’ (Mitii) clinical trial is aimed at assessing whether a virtual-reality form of rehabilitative therapy can improve motor performance in children with unilateral CP or unilateral ABI.

Measuring brain plasticity in children with CP and ABI using advanced imaging techniques presents several significant challenges. Firstly, brain lesions limit the use of standard anatomical atlases to measure grey matter and white matter changes within the actual sensorimotor areas. Another challenge is the interpretation of functional MRI or diffusion MRI to characterise brain reorganisation. The heterogeneity of brain injury in these cohorts adds a further layer of complexity to such analyses.

This multimodal imaging study will utilise fMRI-guided dMRI connectivity and sMRI analyses to measure brain changes which occur during Mitii therapy and provide an in-depth investigation into cortical plasticity.
Understanding how healthy anatomy changes over time may provide insight into detecting the start of pathological processes. The aim of this research is to develop statistical models that will capture both longitudinal and cross-sectional variation in shape of populations using statistical methods like expectation-maximisation mixture models with mixed effects that allow for co-dependence of covariates. This can be used to model changes due to aging and assess neurodegenerative diseases (e.g. Alzheimer’s). In addition, they can be used to predict adverse outcomes in the neurodevelopment of preterm and newborn babies (e.g. cerebral palsy). In addition, MRI of preterm brain often suffers significant imaging artefacts that affect measurement accuracy. The use of these population constrained statistical methods may allow improved measurement accuracy and subsequent modelling.

**AMY CHAN**  
The Australian e-Health Research Centre, PhD Scholarship (APA and CSIRO top up)  
The University of Queensland

**STATISTICAL METHODS IN BIOMEDICAL IMAGE PROCESSING**

Detection of AD in its early stages, prior to clinical symptoms, is crucial in order to deliver effective interventions.

There is currently over 200,000 people with dementia in Australia, most of which is caused by Alzheimer’s disease (AD). The total AD population is estimated to grow to over 700,000 by 2040 and this poses significant economic and social challenges. Detection of AD in its early stages, prior to clinical symptoms, is crucial in order to deliver effective interventions.

This project will analyse and combine a large array of longitudinal measures including cognitive performance, lifestyle factors, blood based biomarkers and neuroimaging data to derive mathematical and statistical models which will characterise the nature of brain morphological changes that are associated with deterioration on an Alzheimer’s type dementia pathway, as compared to deterioration seen in healthy aging.
This work aims to mine large amounts of data contained by medical images in a way that gives clinicians the most relevant information for the decisions they need to make. This can reduce the time needed for reporting and enable better decision making, thereby helping to contain the currently unsustainable increases in health costs. The project is pursuing several avenues to achieve its aim, working closely with clinical collaborators in the departments of nuclear medicine, radiology, surgery, and radiation therapy at the Royal Brisbane and Women’s Hospital, the University of Queensland and the University of Adelaide.

COLLABORATORS
- University of Queensland
- University of Queensland Centre for Clinical Research
- Department of Radiation Oncology, Royal Brisbane and Women’s Hospital
- Specialised PET Services Queensland, Royal Brisbane and Women’s Hospital
- Department of Medical Imaging, Royal Brisbane and Women’s Hospital
- Department of Neurosurgery, Royal Brisbane and Women’s Hospital
- Department of Vascular Surgery, University of Adelaide

AIMS FOR 2014/2015
- To use intra-tumour analysis tools and kinetic analysis to elucidate the patterns of treatment failure in tumours and what role hypoxia plays in this to identify better treatment strategies
- Generalise the physiologically informed model to organs other than the liver
- Improve our approaches for de-multiplexing PET tracers to consider pairs of tracers with different half-lives and by using a more sophisticated model

PROJECT HIGHLIGHTS FOR 2013/2014
- A new method for analysing dynamic PET images which is more accurate and two orders of magnitude faster than existing approaches has been developed and patented
- With collaborators in Queensland Health, we have published our work demonstrating the correlation between changes in focal FDOPA uptake and patient survival time. This research will help clinicians identify the physiological reasons for local treatment failures, and hence has implications for the way the treatment of cancer is planned
- In collaboration with the University of Adelaide, we have been examining how the curvature of vessels correlates with patient outcome after endovascular aneurysm repair, a surgical procedure to place a stent in the aorta. A key outcome of this work is the demonstration that anatomical scale is important when assessing tortuosity for surgical planning, and this result has been published in the European Journal of Vascular and Endovascular surgery
- Christopher Bell has published his work in Physics Medicine and Biology showing how scanning protocols can be optimised when using more than one tracer during a PET scanner, and that the use of two tracers simultaneously is feasible in the clinic. This result opens the door for clinicians to better characterise tumours and to hence better treat them, without increasing the existing logistical load on hospitals
- Charles Baker’s work to develop a physiologically informed model for high blood perfusion organs won the 2014 Canon Extreme Imaging Competition (see page 10)
PET is a versatile imaging method that reveals the underlying activity of cells, which is an important complement to the anatomical images provided by CT and MRI. For cancer, several pieces of biological information are pertinent, especially when planning treatments; however, it is not generally practical to perform multiple PET scans of patients. PET images are intrinsically dynamic and contain a great deal of data that is currently underused. Kinetic modelling can extract relevant information from the data, but only if the model is appropriate to the tissue being examined.

In this project, Dr Charles Baker is developing new kinetic models that better describe the local physiology in the tissues of interest, with a particular focus on high blood perfusion organs. These methods provide parameters that are easily interpreted and hence can assist clinicians when reporting on images. This work, which won the Canon Extreme Imaging Competition in 2014, has already been applied in the clinic to help Nuclear Medicine Physicians reporting on the extent of cancer within a patient’s liver. This work has the potential to reduce the number of futile surgeries. A publication is forthcoming.

Imaging biomarkers such as FDOPA reveal the location of infiltrating tumour cells and hence prognosis at an earlier stage than structural images.

**VISITING SCIENTIST**

**DR CHARLES BAKER**
The Australian e-Health Research Centre PhD Scholarship
The University of Queensland

**PHYSIOLOGICALLY CORRECT MODELLING OF HIGH BLOOD PERFUSION ORGANS**

PET images are intrinsically dynamic and contain a great deal of data that is currently underused. Kinetic modelling can extract relevant information from the data, but only if the model appropriate to the tissue being examined.

In this project, Dr Charles Baker is developing new kinetic models that better describe the local physiology in the tissues of interest, with a particular focus on high blood perfusion organs. These methods provide parameters that are easily interpreted and hence can assist clinicians when reporting on images. This work, which won the Canon Extreme Imaging Competition in 2014, has already been applied in the clinic to help Nuclear Medicine Physicians reporting on the extent of cancer within a patient’s liver. This work has the potential to reduce the number of futile surgeries. A publication is forthcoming.

**PhD STUDENT**

**CHRISTOPHER BELL**
The Australian e-Health Research Centre PhD Scholarship
The University of Queensland

**(DE-)MULTIPLYING PET: ALLOWING CLINICIANS TO BETTER UNDERSTAND AND BETTER TREAT CANCER**

PET is a versatile imaging method that reveals the underlying activity of cells, which is an important complement to the anatomical images provided by CT and MRI. For cancer, several pieces of biological information are pertinent, especially when planning treatments; however, it is not generally practical to perform multiple PET scans of patients. This project is looking at ways of simultaneously using pairs of PET tracers and subsequently separating (demultiplexing) them. However, for clinical use, it is important that the logistical impact of such approaches is minimised. Methods have been developed (and now published) to help clinicians to design protocols to best trade-off the use of PET scanners and to retain the image fidelity while minimising logistical impact. This work has the potential to greatly increase the utility of PET, because it enables clinicians to better characterise tumours and to hence better treat them.
More than 6.3 million Australians (31%) have arthritis or a musculoskeletal condition. Of these, around 1.2 million Australians (6.3%) reported having a disability due to these conditions. The effects of arthritis and musculoskeletal conditions can be reduced through early intervention and appropriate long term management.

Magnetic Resonance Imaging (MRI) provides excellent visualization of articular cartilage along with other joint structures and this has generated extensive clinical interest in the development of MR technologies to provide quantitative analyses of joint structures to facilitate early stage diagnostic and management options.

In collaboration with the University of Queensland and Siemens Medical (ARC Linkage Grant), the Australian e-Health Research Centre is developing a quantitative joint analysis system that is being integrated into the Siemens MR scanner to allow clinically-based morphometric (volume, thickness) and biochemical analyses of cartilage, bone and intra-articular tissues of joints within the upper and lower limb, as well as the spine.

The significance of this project lies in its enormous capacity to provide ground-breaking MRI orientated technologies for automated segmentation and quantitative analyses of articular cartilage, bone and other joint structures designed to facilitate diagnostic and management options for osteoarthritis and other disabling joint pathologies.

Example slice of the hip acquired at the Steadman Philippon Research Institute (left) with segmentation of acetabulum [red] and femoral [green] cartilage and (middle): Biochemical MR overlayed. The biochemical MR can be used to quantify collagen damage inside the cartilage tissue. (right) 3D rendering of cartilage segmentation.

Decrease in intervertebral disc height measured at (Left) baseline, (Middle) pre-exercise, and (Right) postexercise using our informatics software for the spine.
In Australia, around one third of the population has arthritis or a musculoskeletal condition. This project develops methods for robust computerized analyses of magnetic resonance (MR) images to fully automatically localize the bones and cartilages without the need of musculoskeletal experts. This drastically reduces time lost in patient care (in the order of hours) due to manual measurements being required to be done these experts.

The methods developed utilize state-of-the-art robust machine learning and image processing techniques to automatically segment anatomical structures in these scans to facilitate faster and less skill-intensive Osteoarthritis assessment. These include learning anatomical shape and appearance of bones and cartilage in the presence of partial/missing imaging data and to accommodate the presence of pathologies present within the scans due to underlying conditions related to arthritis.

Novel techniques developed also include recovering missing imaging data, automated T2 analysis and anatomical-based region-specific machine learning for more accurate shape and appearance quantification, with the eventual goal of rolling out these algorithms onto Siemens MR Scanners.

COLLABORATORS
• The University of Queensland
• Siemens Healthcare, Germany
• Steadman Philippon Research Institute

PROJECT HIGHLIGHTS FOR 2013/2014
• MR scanning completed, algorithms developed and validation for knee, hip, shoulder and spine
• Pilot clinical validation of the automated detection of disc degeneration in the spine
• Pilot clinical validation for knee and hip completed with the Steadman Philippon Research Institute
• Knee, Hip and shoulder joint quantitative analysis software prototype delivered to Siemens for clinical evaluation

AIMS FOR 2014/2015
• Development of analysis methods for ultra high field and biochemical quantification
• Extend and improve the robustness and accuracy (in a clinical setting) of our joint quantitative analysis software
• Evaluate reproducibility of various MR quantification methods using different image acquisitions
• Extend the techniques for ligaments, muscles and pathologies for use in clinical decision support
Identifying the biomechanical factors contributing to musculoskeletal degenerations can provide clinicians with useful insights into the potential causes of joint pain, disorders, injuries, or abnormal movement patterns. Real-time dynamic MRI has increasingly been used in clinical research to perform subject-specific kinematic analysis, but it currently requires the manual and time-consuming intervention of expert clinicians.

The aim of this research is to develop a set of tools allowing the non-invasive, automatic, accurate, and reproducible kinematic analysis of dynamic MRI of the knee joint. Quantitative measurements describing the MSK motion will be extracted from dynamic MRI using advanced techniques such as deformable model-based segmentation, spatio-temporal MRI sequence registration, structure tracking, finite element modelling, and feature-based parameter extraction.
The development of osteoarthritis (OA) in the hip is normally associated with bone and cartilage morphological and biomechanical changes, which cause pain, stiffness, deformation of the joint and decreased motion. To quantitatively analyse this disease, an image analysis system can be developed to automatically and accurately extract the target structure from the magnetic resonance (MR) image of the hip joint for morphological assessment. MR imaging has been shown to be an ideal imaging modality providing direct and non-invasive visualization of joint structure with no ionizing radiation. The aim of this project is to develop an automated image processing system for effective and accurate segmentation of the target structure from the hip joint to a new case, and provide qualitative data about the damage of bones, cartilages and other tissues for early detection of hip OA, which allows the prediction of its subsequent progression and in-time therapeutic treatments before permanent damage has developed and surgeries like arthroplasty are required.

YING XIA
The Australian e-Health Research Centre, International PhD Student
The University of Queensland

MRI-BASED AUTOMATED SEGMENTATION AND QUANTITATIVE ANALYSIS OF THE HIP JOINT

Top: Segmentation of the knee bones from real-time MRI. Bottom: Estimation of bone 3D transforms across flexion and propagation to bone structures reconstructed from 3D MRI automated segmentations.

Estimation of cartilage contact areas (CA) from automatic segmentation marching-cubes. CA → area whose distance to the closest cartilage surface is lower than a given threshold T (with T obtained from clinical literature).

3D rendering of the femur bone extracted from an MRI of the hip. The coloured region shows an abnormal shaped area that was automatically detected and is indicative of femoral acetabulum impingement.
Prostate and cervical cancers are two of the most commonly diagnosed cancers worldwide. External beam radiation therapy is a front-line treatment for these cancers and involves high-energy x-ray beams being sent from multiple directions to deliver a radiation dose to destroy cancerous cells.

Currently, a week before a patient starts treatment they will have a CT scan. The main organs are manually marked out on this scan and the treatment dose plan is generated. There are two key problems with this approach. Firstly, the boundaries of soft tissue organs like the rectum, prostate and cervix cannot be easily identified from CT and, secondly, these organs can move and change shape daily. Usually there is only one CT scan for 37 dose treatments over 7 weeks.

This project addresses these issues by developing methods using high contrast MRI scans for treatment planning, and for automatically identifying the organs’ locations from these scans. These methods can improve treatment accuracy (reducing side effects), improve treatment workflows (for example by reducing the amount of time clinicians spend manually defining the organs), and enable new treatment methods (MRI guided adaptive radiation therapy).

Comparison of MRI-generated substitute CT (sCT) and (co-registered) planning CT for one of the prostate cancer study patients. (Radiotherapy and Oncology 2014; 111(1):145). The accurate conversion from MRI enables MRI-alone radiation therapy with excellent soft tissue visualisation for improved radiation targeting.

Comparison of an actual CT based dose plan (left) and an MRI-based substitute CT plan (right) for a localised prostate cancer patient in our current study.
COLLABORATORS
• Calvary Mater Newcastle Hospital, Newcastle
• School of Mathematical and Physical Sciences, University of Newcastle
• Cancer Care Services, Royal Brisbane and Women’s Hospital
• Liverpool Cancer Service, Liverpool Hospital
• Department of Medical Physics, Wollongong University
• Peter MacCallum Cancer Centre, Melbourne
• Sir Charles Gairdner Hospital, Perth
• Radiation Department, Centre Eugène Marquis, Rennes, France
• Wesley Hospital, Brisbane
• Sydney Medical School, University of Sydney
• Radiation Medicine Program, Princess Margaret Hospital/University Health Network, Toronto, Canada

PROJECT HIGHLIGHTS FOR 2013/2014
• Retrospective clinical trial (40 patients with localised prostate cancer, eight weeks of MRI scans) near completion at Calvary Mater Newcastle (320 MRI scans)
• New method developed for generation of substitute CT generation from MRI. The dose calculations from our more accurate MRI-based method are now less than 1% different from traditional CT based plans
• Seven journal papers published, including Radiotherapy and Oncology [IF 4.5] and Medical Image Analysis [IF 3.7]
• Dr Soumya Ghose selected for a European Union Erasmus Mundus scholarship for a fully funded invited research stay at the University of Bourgogne, Le Creusot, France (focus on prostate cancer imaging)
• The first papers describing the integration of medical image analysis software and commercial treatment planning systems using open source libraries have been published and received 17,907 paper downloads and 4,605 source code downloads at 07 August 2014

AIMS FOR 2014/2015
• Complete clinical validation and quantification of productivity benefits of MRI-based prostate cancer treatment at the Calvary Mater Newcastle Hospital, NSW
• Conduct a prospective clinical trial demonstrating feasibility and benefits of the MRI-alone technology for prostate
• Collection of further cervical cancer CT and weekly MRI scans from the Liverpool Hospital and development of MRI-alone planning methods for cervical and head and neck cancer treatment
• Investigation of wider adoption of MRI-based treatment planning to other radiation oncology departments nationally
Mr-Guided Genitourinary Cancer Radiation Therapy
(continued)

Postdoctoral Research Fellow

David Rivest-Hénault, PhD

MRI-Alone Radiation Therapy Treatment Planning for Prostate Cancer

Prostate cancer is the second most common cancer in Australian men, and radiation therapy is indicated in about 50% percent of those cases. The success of the procedure strongly depends on an accurate radiation dose delivery plan computed from a 3D scan depicting the anatomy of a patient.

The objective of David’s research is to define methods allowing substituting the current CT imaging with superior MRI in radiation therapy planning. His main focus is currently on increasing the precision of CT-MRI registrations for the creation of a special atlas used to estimate attenuation maps from MRI. He recently proposed a robust inverse-consistent multimodal rigid/affine registration algorithm, which benefits from a symmetric mathematical formulation that involves resampling the pair of input images into a middle space before estimating an unbiased registration transform. In addition, he also defined a structure-guided non-rigid registration technique, which helps overcome large anatomical discrepancies.

David Rivest-Hénault, PhD

MRI-Alone Radiation Therapy Treatment Planning for Prostate Cancer

Postdoctoral Research Fellow

Soumya Ghose, PhD

Cervical Cancer Treatment by MRI Alone Radiation Therapy

Radiotherapy is one of the most common treatments available for cervical cancer treatment. Segmentation of the cervix, bladder and rectum in magnetic resonance images (MRI), with superior soft tissue contrast will improve the effectiveness of radiotherapy in an adaptive radiotherapy model.

The objective of Soumya’s research is accurate segmentation of the organs in the female pelvis for adaptive radiotherapy planning. He is using a hybrid model of multi-atlas based segmentation and statistical shape model for segmentation of the organs. Affine registration followed by non-rigid registration between the test dataset and all the training dataset generates the corresponding labels for the test dataset. The resulting labels are ranked based on mutual information, and the most similar labels are fused to achieve a probabilistic segmentation. The most similar labels are further used to generate a statistical shape model of the organ to improve on segmentation accuracies.

Soumya Ghose, PhD

Cervical Cancer Treatment by MRI Alone Radiation Therapy

Postdoctoral Research Fellow

Biomedical Imaging
IMAGE GUIDED SURGERY

PROJECT DESCRIPTION

Endoscopy techniques are widespread in the hospital, and the rate of procedures increases more than 10% per year due to the success of minimally invasive procedures and the medical technology improvements:

- Colonoscopy is considered the gold standard for detection and treatment of early stage colorectal cancer, the third most common form of cancer and the second leading cause of cancer-related death in the western-world
- More than 400,000 colonoscopies are performed each year in Australia
- Bronchoscopy is used to perform lung biopsy, among other procedures, to help detect early stages of lung cancer, the leading cause of cancer-related death in the world
- More than 40,000 bronchoscopies are performed each year in Australia by thoracic doctors and similar techniques are used to explore the airways in critical care medicine, emergency and intensive care units, anaesthesiology, ENT, and Oral Pathology

The Image Guided Surgery team aims to improve productivity and efficiency of medical intervention relying on endoscopic imaging. Unlike traditional imaging techniques (MRI, CT, US) that require a lot of processing and benefit from a large number of filters and analysis tools to help for diagnostic, endoscopic imaging is its infancy and has a tremendous potential to provide more assistance to clinicians.

To improve clinical productivity, increase patient safety and thus reduce the number of medical errors during endoscopy procedures, there are two possibilities: training and automation. The Image Guided Surgery team addresses both these possibilities with recent success in training as well as the commencement of a new, exciting, strategic project, ARENA, providing real time assistance to clinical staff in the operating room.

Digital video from the endoscope
1. Detect folds
2. Detect camera motion
3. Extract the colon surface
Generate colon map showing missed areas

ARENA provides to the physician a full map of what has not been seen during the procedure (right image) in 3 steps from the endoscope video: unobserved areas (step 1) hidden behind folds are marked in green and areas outside of the camera’s field of view (steps 2 & 3) are marked in blue.
## CURRENT COLLABORATORS

- Clinical Skills Development Service, Queensland Health
- Thoracic Medicine Department, Royal Brisbane and Women’s Hospital
- Gastroenterology Department, Royal Brisbane and Women’s Hospital
- Department of Colorectal Medicine and Genetics, The Royal Melbourne Hospital
- Computer Science Department, University of Canberra
- School of Psychology, The University of Queensland
- School of Allied Health Sciences, Griffith University
- Surgical Science, Sweden
- Vestech, Australia
- Medtronic, USA

## HIGHLIGHTS IN TRAINING

- The colonoscopy simulator was used in July 2013 during the Colonoscopy training programme of the World Gastroenterology Organisation and GESA for the Pacific islands region
- Between September 2013 and January 2014, the Bronchoscopy simulation has been used in four training courses performed by RBWH specialists, for groups of 12 to 25 thoracic doctors
- In December 2013, the Colonoscopy Simulator model was improved further and is the first colonoscopy simulator able to provide realistic un-looping skills training of the colon
- A new licence agreement with Surgical Science was signed in June 2014

## HIGHLIGHTS IN IMAGE ASSISTANCE

- A contract has been signed with VesTech (Australian medical devices company) to provide to Medtronic, a real-time CT visualisation tool in the operating room
- A new and original approach of endoscopic video analysis has been developed, and a patent has been filed in July 2014 to protect two technologies

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The bronchoscopy simulator used by thoracic doctors to learn bronchus anatomy (Brisbane, December 2013).

The team of Fijian doctors with Hans de Visser, CSIRO research scientist, in Suva.
POSTDOCTORAL RESEARCH FELLOW

TIMOTHY COLES (completed February 2014)
The Australian e-Health Research Centre, OCE postdoctoral fellow

BRONCHOSCOPY SIMULATION

Timothy has designed and developed a number of part task trainers for Bronchoscopy training. Based on a new parametric model of the lung, he has experimented with a number of new concepts such as the Outside Observer for posture tracking of trainees and an Anatomy Checklist to train and remind thoracic doctors of the bronchus anatomy for standard bronchoscopy procedure. The bronchoscopy simulator was evaluated during four training courses in 2012, 2013 and 2014 at the Queensland Health Skills Development Centre.

PhD STUDENTS

ALI ARMIN
The Australian e-Health Research Centre, PhD Scholarship
University of Canberra

CAMERA MOTION DETECTION IN ENDOSCOPIC VIDEOS – ARENA PROJECT

Ali’s main objective is focused on evaluating endoscopy videos and detecting camera position and orientation in each frame, using different motion estimation algorithms. A new algorithm will be produce to get the best camera position based on the constraints of the endoscope motion.

LAVNEET SINGH (December 2012 – November 2013)
The Australian e-Health Research Centre, PhD Top-up
University of Canberra

3D SEGMENTATION OF ENDOSCOPIC VIDEOS – ARENA PROJECT

Lavneet’s main objective was to derive the 3-D structure of the colon from the colonoscopy video. Once the colon geometry and the endoscope camera position and orientation are known, missed areas can then be detected.


BOOK CHAPTERS


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<td>Ms Surabhi Gupta</td>
<td>Curtin University</td>
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<tr>
<td>Mr Guranth Iyer</td>
<td>The University of Queensland</td>
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<tr>
<td>Mr Enda McCauley</td>
<td>University of Western Australia</td>
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<tr>
<td>Mr Nenad Srbinovski</td>
<td>The University of Queensland</td>
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<tr>
<td>Mr Hamish Thorburn</td>
<td>The University of Queensland</td>
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### Visitors

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
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<tr>
<td>Dr Charles Baker</td>
<td>The University of Queensland</td>
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<tr>
<td>Prof Caroline Cao</td>
<td>Wright State University, Ohio, USA</td>
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<tr>
<td>Mr Dylan Cook</td>
<td>University of Wollongong</td>
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<tr>
<td>Ms Angel Kennedy</td>
<td>Sir Charles Gairdner Hospital, WA</td>
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<tr>
<td>Mr Devin Luu</td>
<td>University of British Columbia, Vancouver, Canada</td>
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<tr>
<td>Prof Jinping Qi</td>
<td>Donghua University, Shanghai, China</td>
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<td>Ms Amaza Reitmeier</td>
<td>Medtronic</td>
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<tr>
<td>Dr Hayley Reynolds</td>
<td>Peter MacCallum Cancer Centre</td>
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<tr>
<td>Dr Richard Speight</td>
<td>University of Leeds</td>
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<tr>
<td>Ms Amy Walker</td>
<td>University of Wollongong</td>
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AEHRC contributed to the CSIRO white paper 'A Digitally-Enabled Health System'.

SPECIAL PURPOSE
FINANCIAL REPORT

30 JUNE 2014

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE
(An unincorporated joint venture)

Detailed financial information from pages 68-76 have been deliberately omitted from this report.
The directors have determined that the unincorporated joint venture is not a reporting entity and that this special purpose financial report should be prepared in accordance with the terms of the joint venture agreement and the accounting policies outlined in Note 1 to the financial statements.

The directors declare that the accompanying Statement of Comprehensive Income, Statement of Financial Position, Statement of Cash Flows, Statement of Changes in Joint Venture Funds and Notes to the Financial Statements present fairly the unincorporated joint venture’s financial position as at 30 June 2014 and its performance for the year ended on that date in accordance with the terms of the joint venture agreement and the accounting policies described in Note 1 to the financial statements.

This declaration is made in accordance with a resolution of the Board.

**Director**

_Brisbane_

Date:

**Director**

_Brisbane_

Date:

**Director**

_Brisbane_

Date:

**Director**

_Brisbane_

Date:
INDEPENDENT AUDITOR'S REPORT
TO THE DIRECTORS OF THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

We have audited the accompanying special purpose financial report of The Australian E-Health Research Centre ("the unincorporated joint venture"), which comprises the statement of financial position as at 30 June 2014, and the statement of comprehensive income, statement of changes in joint venture funds and statement of cash flows for the year then ended, notes comprising a summary of significant accounting policies, other explanatory information and the directors’ declaration.

Directors' Responsibility for the Financial Report
The directors of the unincorporated joint venture are responsible for the preparation and fair presentation of the financial report in accordance with the joint venture agreement and the accounting policies described in Note 1 to the financial report. The directors are also responsible for such internal control as they determine is necessary to enable the preparation and fair presentation of the financial report that is free from material misstatement, whether due to fraud or error.

Auditor's Responsibility
Our responsibility is to express an opinion on the financial report based on our audit. We conducted our audit in accordance with Australian Auditing Standards. Those standards require that we comply with relevant ethical requirements relating to audit engagements and plan and perform the audit to obtain reasonable assurance about whether the financial report is free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial report. The procedures selected depend on our judgment, including the assessment of the risks of material misstatement of the financial report, whether due to fraud or error. In making those risk assessments, we consider internal controls relevant to the entity's preparation and fair presentation of the financial report in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the entity's internal controls. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of accounting estimates made by the directors, as well as evaluating the overall presentation of the financial report.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Independence
In conducting our audit we have complied with the independence requirements of the Australian professional accounting bodies.

Opinion
In our opinion, the financial report presents fairly, in all material respects, the financial position of The Australian E-Health Research Centre as at 30 June 2014 and its financial performance and its cash flows for the year then ended in accordance with the accounting policies described in Note 1 to the financial statements.

Basis of Accounting and Restriction on Distribution
Without modifying our opinion, we draw attention to Note 1 to the financial statements which describes the basis of accounting. The financial report has been prepared to assist The Australian E-Health Research Centre to meet the requirements of the Joint Venture Agreement with Commonwealth Scientific and Industrial Research Organisation and the State Government of Queensland. As a result the financial report may not be suitable for another purpose.

Trumans
Peter Bray
Partner
Chatswood
Dated: __________________ 2014