UNIVERSITY OF ALBERTA

Cisco Systems Research Chair in Healthcare Solutions

Professor Pierre Boulanger | 2022 Chair Report
Faculty of Science | Department of Computing Science

A special thank you

“I and my team would like to thank CISCO Systems for their generous financial and in-kind donations since the Chair’s inception in 2013. CISCO’s vision and generosity has profoundly impacted patient care and will continue to do so for decades. Without CISCO Systems’ investment, none of the research programs supported by the Chair would have been possible.”

Professor Pierre Boulanger

The Centennial Centre for Interdisciplinary Science (CCIS), north campus, University of Alberta

Overview

MAIN GOALS OF THE CHAIR

The use of information technology is already contributing significantly to the enhancement of healthcare delivery and improvement in the quality of life for Canadians. However, the deployment of information technology has only scratched the surface of possibility regarding new computer technologies and information science. Computer technologies could significantly accelerate our understanding of how to sense and collect valuable health and wellness data and indicators—if we avail ourselves of the opportunities to analyze and use that information for evidence-based healthcare; stabilize physiology; modify risky behaviours; design and field "snap" clinical procedures; and care for people with health challenges. The main emphasis of this Chair is on transformative changes and new directions that information technology can bring to the healthcare system from an end-to-end perspective. More specifically, the Chair's primary objectives have been:

- To develop technologies to improve access to medical services primarily in remote regions
- To develop new medical imaging tools for diagnostics and surgical planning
- To collaborate closely with the medical community to address their needs and validate the technology's usefulness by performing clinical trails
- To commercialize the technology

SIGNIFICANT ACHIEVEMENTS TO DATE

Since the Chair's inception, many objectives evolved as opportunities became available. The Chair allowed us to finance more than 20 interdisciplinary projects since 2013. The Chair was also successful from a scientific point of view, resulting in 110 publications and three U.S. patents. From a highly-qualified personnel perspective, we trained three Postdocs, 22 PhDs, and 22 Master's students. Over the years, we consciously focused on the medical community's needs—how our research impacted patients' outcomes by performing numerous clinical trials and ensuring the technology was sufficiently developed to be commercialized. During the latter period of the Chair's tenure, we focused our efforts on transforming MedROAD from a proof-of-concept to a genuine commercial product. MedROAD is now commercialized by Naiad Lab Inc., a start-up company that was able to secure investment from private venture capital and identify customers to use the system.

$3M

In total research grants

110

Publications from 2013-22

3

U.S. and Canadian patents developed

Impact + Outcomes

The CISCO Chair's most successful projects and resulting contributions to state-of-the-art include:

MEDROAD

This project, started in 2014, aims to increase access to necessary medical diagnostic tests for patients in remote regions worldwide. Our goal was to develop a portable medical diagnostic kit that enables remote medical testing and assessment. Our devices can send medical information wirelessly to a secure server, where remote physicians can access and analyze the data and provide clinical decisions. The MedROAD acquisition system consists of numerous portable medical-grade instruments. All devices transmit geo-located data wirelessly via a smartphone, relaying the encrypted data in HL7 to a secure remote server using an internet connection through LTE wireless or satellite connections. The patient's data is automatically analyzed and compared to known pathologies and patient history using machine learning algorithms. Following data analysis, alarms are generated to warn the remote physician to look at a specific patient file to develop treatment strategies.

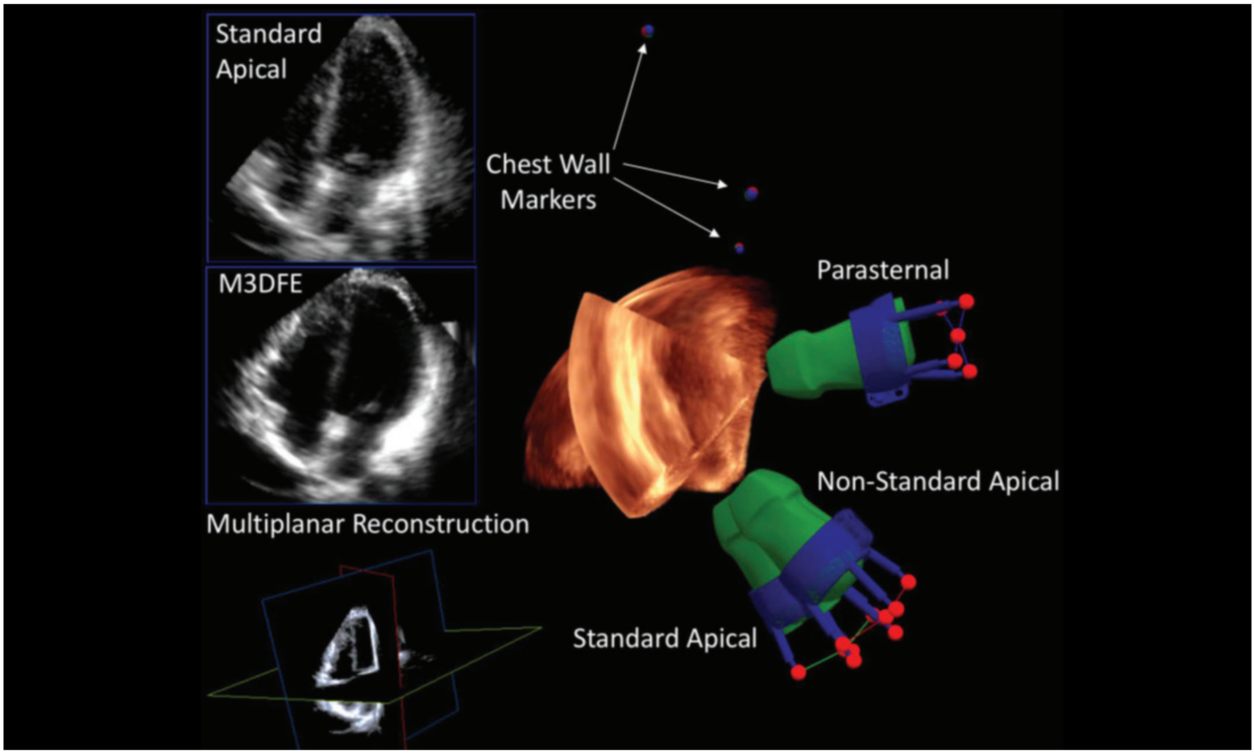

Figure 1a: Multiview Fusion of 3D Ultrasound Using Optical Tracking

From 2016 to 2020, we did numerous pilot projects with seniors' care facilities and medical clinics to test and optimize the concept of MedROAD. Following an extra investment of $50K from CISCO Systems, we ran a pivotal pilot study with the Associate Clinic in Pincher Creek from November 2020 to April 2021. A total of 27 patients registered for continuous use, and ten patients registered as irregular users. MedROAD has two primary ways of providing care: 1) Virtual clinic hub/room in the clinic and 2) At-home monitoring of chronic conditions. In this pilot study, MedROAD was used for home monitoring of patients suffering from chronic hypertension, diabetes, and COVID-19. The results indicated that MedROAD can reduce clinic visits for hypertension and diabetic patients by 75%, resulting in significant savings of time and money for the patient and the healthcare system.

Based on the lessons learned during these pilot studies, a new commercial version of MedROAD was re-engineered. From March 2021 to the end of the Chair in February 2022, a professional team of programmers was hired to focus on improving usability and refactoring the software core to industry standards. The team was in direct contact with clinicians to help improve usability and add new functionalities to fit their needs. The latest version of MedROAD is now being

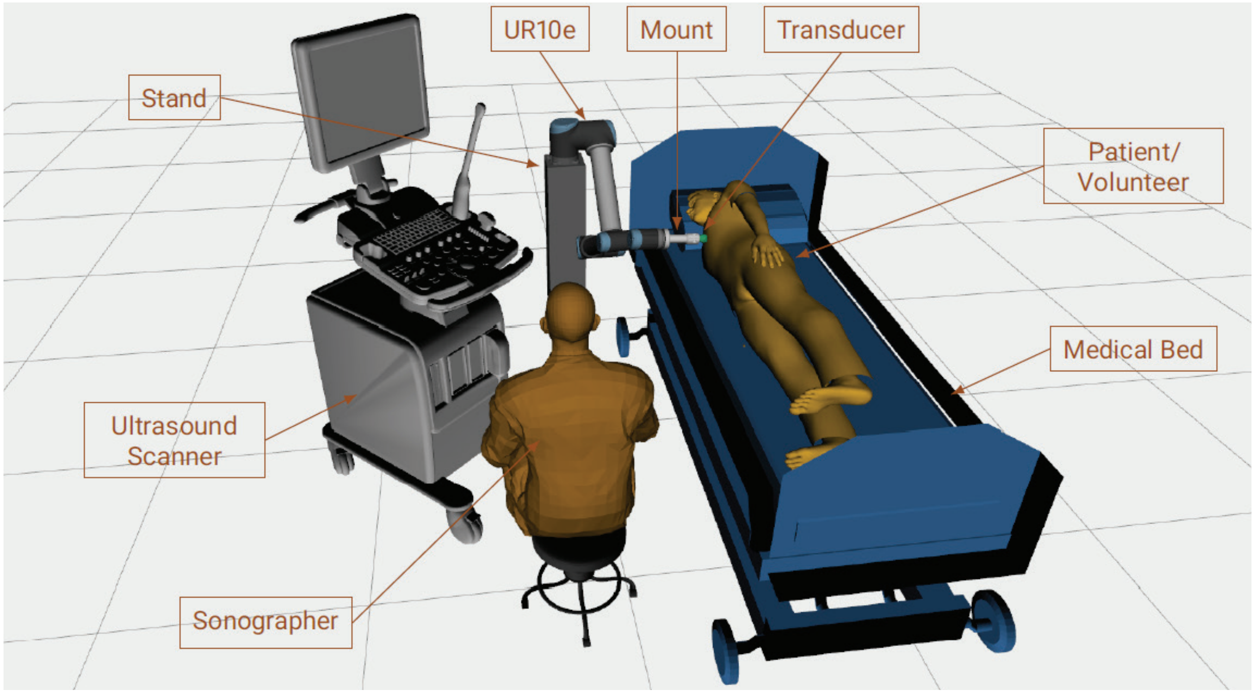

Figure 1b: Overall arrangement of the new robotic multiview echocardiography system under development at ABACUS Cardiovascular Research Centre

deployed and evaluated by Naiad clients. To date, MedROAD is the only software that allows a physician to communicate with their patients remotely using CISCO Webex and at the same time measure patient's blood work, vital signs, and symptoms using medical-grade biosensors.

MULTIVIEW ULTRASOUND

In 2016, we secured a three-year NSERC/CIHR Collaborative Health Research Project to explore how ultrasound images can be fused from multiple viewpoints to improve the field of view and image quality and contrast. As illustrated in Figure 1a (above), a set of markers attached to the ultrasound probe was used to track the device in 3D space using a commercial multi-camera Optitrack system. The 3D transformations measured by the tracking system were then used to align and register the multiple ultrasound scans. Dr. Becher's team at the Mazankowski Heart Institute successfully demonstrated the advantages of the Multiview approach for imaging the heart. From the clinical study, it became clear that the optical tracking approach suffers from occlusion problems, which interfere with the free movement of the sonographer.

To solve this problem, we decided that the ultrasound probe should be tracked mechanically using a robotic arm (see

67

Graduate students who worked on the research team

37

Seniors in MedROAD'S Pilot

Figure 1b on previous page). The main advantage of a robotic arm is that it can be used to automate some of the digitizing functions. For example, the robotic arm could allow the sonographer to place the ultrasound probe at a location that needs to be scanned without the constraint of gravity. The sonographer could then remotely control the robot arm using a haptic device and apply the desired pressure on the probe to perform semi-automated measurements. Once operational, this system could relieve the sonographer's physical burden, reducing fatigue and repetitive stress injuries. In addition, with this system, a sonographer could perform remote imaging of COVID-19 patients without danger of contamination. The system is now being implemented clinically at the ABACUS Cardiovascular Research Centre, financed by a large grant from Alberta Innovate and NSERC.

CONTINUOUS ECG MONITORING TO REMOTELY DETECT CARDIAC ANOMALIES

Cardiovascular diseases (CVD) are the leading cause of death worldwide, with nearly 17.9 million deaths per year. CVD continues its decades-long rise in low-income and middle-income countries. Even in high-income countries with accessible healthcare systems, the age-standardized rate of CVD has begun to rise. There is thus an urgent need to focus on implementing cost-effective policies and technological solutions to improve this situation by emphasizing early CVD detection, which can be lifesaving, especially in the younger population. This project aims to develop an ambulatory cardiac monitoring system that automatically detects cardiac anomalies over long periods during daily activities. One of the critical problems that needs to be solved is the ability to deal with motion artifacts that corrupt the ECG signal. Using an advanced adaptive filter algorithm that fuses accelerometer and ECG data, we were able to reduce motion artifacts sufficiently to allow ECG analysis to be performed in real-time. A novel neural network algorithm was then developed to recognize 17 different cardiac abnormalities with an accuracy of 99%. An alarm is triggered once an anomaly is detected, suggesting that the individual should seek medical assistance. A clinician can then visualize the ECG or decide to perform a more accurate clinical 12 leads ECG analysis. This unique technology offers an excellent opportunity to expand our recent development into a commercial system that clinicians can use in Canada and worldwide. The work is now being commercialized to Naiad's clients and clinically tested in Dr. Becker's ABACUS clinic.

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MEDBIKE

Exercise-based cardiac rehabilitation (CR) is the physical activity component of a multi-disciplinary cardiac rehabilitation program and is an integral step in caring for patients with acute or chronic cardiac diseases. However, despite evidence for improved outcomes and event reduction, most patients do not participate in exercise-based CR. Between 2016 and 2019, we developed a virtual reality-based remote exercise-based CR system called MedBIKE. MedBIKE allows patients to perform a controlled exercise program in the comfort of their own home, using virtual reality gaming to improve adherence to the exercise program while being monitored by a remote CR clinician. Using MedBIKE, the clinician can ensure the patient follows the level of exercise prescribed by their cardiologist to improve their heart condition. In 2020, a new version of MedBIKE for pediatric cardiac rehabilitation was developed and delivered to Dr. Michael Khoury at the University of Alberta's Department of Cardiac Rehabilitation. It was then planned that this new version of MedBIKE would undergo a two-year clinical trial in autumn 2020, but because of COVID-19, this activity was rescheduled to start in July 2022. In 2021, a Heart and Stroke Foundation grant was secured to allow us to upgrade the MedBIKE software and design a new exercise program to the latest specifications of the medical team. Once the software is updated, ten bikes will be deployed into private homes, where pediatric patients will undergo remote cardiac rehabilitation securely.

UWB MICROWAVE TOMOGRAPHIC IMAGING FOR BREAST CANCER DETECTION

Microwave Tomographic Imaging (MTI) is an emerging imaging modality for biomedical applications to study functional and pathological conditions of soft tissues. Microwave imaging works best for high dielectric contrast regions such as bones and fatty areas compared with soft tissue. Recent progress in ultra-wideband (UWB) radar technology and tomographic reconstruction algorithms has allowed us to develop a new imaging modality capable of detecting breast cancer at high accuracy. Unlike the current clinical tomographic imaging methods such as X-ray mammography and computed tomography (CT), MTI offers a safe, portable, cost-effective, real-time imaging supplement for the non-invasive detection of breast cancer. A recent study performed in our lab has shown that the technology compares favourably to MRI imaging at a much lower cost. In addition, safety is an essential feature of MTI. This modality uses non-ionizing microwave pulses at average power levels comparable to the microwave fields of a cell phone. Because of its safety, one can now perform safe breast examinations for patients under 40 years old, which are currently not recommended using X-ray technologies. This work resulted from a collaboration with Dr. Karumudi from the Department of Electrical Engineering.

Other medical projects financed by the CISCO Chair include:

- Prediction of clinical outcomes in acute ischemic stroke using machine learning (Dr. Buck, Division of Neurology)
- Automated personalized exposure therapy based on physiological measures using experience-driven procedural content generation (Dr. Loucks, Faculty of Rehabilitation Medicine)
- Appendectomy training system in virtual reality using proxy haptic: an advanced human perception study (Dr. White, Division of Surgery)
- Deep learning using pre-brachytherapy MRI to automatically predict applicator induced complex uterine deformation (Dr. Menon, Division of Medical Physics)
- Enabling remote and advanced digital pulmonary sounds analysis for respiratory diseases (Dr. Ferrara, Respiratory Disease Department)
- Improving cranial vault remodeling for unilateral coronal craniosynostosis – introducing automated surgical planning (Drs. Louie and Robertson, Division of Plastic Surgery)
- Real-time tumour tracking for adaptive radiation therapy machines (Dr. Fallone, Medical Physics Group)

> “The CISCO Chair allowed us to secure grants totaling $3M to complement its research objectives. These grants were from CIHR, NSERC, Stollery Hospital Foundation, and Alberta Innovates.”
>
> **Professor Pierre Boulanger**

Additional Accomplishments + Achievements

The CISCO Chair allowed us to secure grants totaling $3M to complement its research objectives. These grants were from CIHR, NSERC, Stollery Hospital Foundation, and Alberta Innovates. During my ten years as Chair, we published 110 scientific papers in top-tier journals and conferences and were able to secure three U.S. and Canadian patents on various aspects of the technology developed. The team necessary to create these technologies was composed of three Postdocs, 22 PhDs, and 22 Master’s students. We also received assistance from 20 course-based master’s students in the Multimedia Master thesis program. In addition, four programmers were hired to help with student projects and develop professional software that is now being commercialized.

What’s Next?

Additional funding for 2022-23 would allow for expansion of three main projects:

- Finance a PhD student who would extend the machine learning capabilities of MedROAD, automatically analyzing patients’ conditions to detect heart and lung dysfunctions during their daily activities. This would allow us to

$30,000

Grant for automated detection of lung pathologies

$600,000

Grant for advancing cardiac disease diagnosis

complement the current projects in collaboration with Dr. Becher (Mazankowski Heart Institute), Dr. Ferrara (Respiratory Disease Department in Medicine), and Naiad Lab's clients.

- Hire a programmer to add new MedBIKE functionalities, re-engineer the software towards commercialization, and create new training programs. This would allow us to complement the current projects by collaborating with Dr. Khoury and D. Nee from the UofA Pediatric Cardiology Department.
- Finally, add extra human resources (two grad students) to the Multiview ultrasound project exploring haptic robot telemanipulation and automated imaging of the heart ventricles. This project resulted from collaborating with Dr. Punithakumar's team at the SERVIER Virtual Cardiac Centre.

As of time of writing, Dr. Punithakumar and I secured the following grants:

- July 2022 – June 2023: Mitacs BSI, $30,000, Automated detection of lung pathologies using ultrasound imaging
- March 2021 – March 2024: Alberta Innovates AICE Concepts, $600,000, Co-Investigator Advancing cardiac disease diagnosis with robotic multiview echocardiography fusion and machine learning

Based on the success of the CISCO Chair, I have applied to the Faculty of Science to create a new CRC Chair Tier I, focusing on Healthcare Informatics. This new Chair would aim to expand the reach of information technology into the medical field, contribute to numerous precision health strategic initiatives across the country, and create a new Canadian center of excellence in medical imaging and remote diagnostics.

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