SUMMARY

The use of information technology is already contributing in significant ways 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 possibilities that new computer technologies and information science have to offer. There are great opportunities ahead for computer technologies to accelerate our understanding of how to sense and collect valuable health and wellness data and indicators, to analyze and use that information for evidence-based healthcare, to stabilize physiology, to modify risky behaviors, to design and field “snap” clinical procedures, and to 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 has been focusing the past years on the following research objectives:

- Medicine for all: The MedROAD project;
- From Medical Imaging to Virtual Treatment Planning and Training;
- Networked Collaborative Systems for Consultation, Surgical Planning, Postoperative Evaluation, and Education;
- Commercialization of research outcomes.

Since the start of the Chair, many of these projects have evolved, and many of them have been deployed for real clinical applications. As a result of this development, in January 2020, Dr. Boulanger and two other business partners created a new start-up company called Naiad Lab Inc to market the MedROAD and MedBIKE products.

RESEARCH PROGRESS

Medicine for all

MedROAD: This project, started in 2014, aims to increase the access to necessary medical diagnostic tests to patients in remote regions of the world. Our research group has developed a portable medical diagnostic kit that allows remote medical testing and assessment. Our devices have the capability of sending medical information wirelessly to a secure server where remote emergency and specialist physicians can access and analyze the data and provide a clinical decision. The MedROAD acquisition system consists of numerous portable medical-grade instruments, such as a fully automated blood chemistry analyzer capable of measuring up to 100 metabolites. All devices transmit geo-located data wirelessly via a smartphone, which relays the encrypted data in HL7 to a secure remote server using an internet connection through LTE wireless or satellite connections. At the server location, the new data is then automatically analyzed by the server computers and compared to known pathologies and the patient history using machine learning algorithms. Following data analysis, alarms are generated to warn the remote specialist physician to take a closer look at a specific patient data point, allowing for faster treatment strategies.

From 2016 to 2019, we did numerous pilot projects with aged care facilities and medical clinics to test and optimize the concept of MedROAD. Over the years, MedROAD evolved to be a large software that needed to be re-engineered to reach a sufficient level of maturity that will allow us to go beyond proof-of-concept to real deployments at medical facilities. In 2019-20, we started this re-engineering process. As with most large software,
this was quite an endeavor and required the hiring of two more programmers. During this period, we did numerous stress tests on the system to verify the overall robustness and its ability to scale. We also documented the software professionally and used industry-standard software engineering tools to test and manage configurations. We also deployed the MedROAD server on Amazon Web Services (AWS) cloud computing facilities to move the current server outside the non-secure university environment to a more secure and scalable environment. We now have a stable and well-documented version of the software ready to be deployed in 2020-21 to real-world clinical applications.

From Medical Imaging to Virtual Treatment Planning and Training

**Multiview Ultrasound:** In 2016, we were able to secure a three-year NSERC/CIHR Collaborative Health Research Project grant of $480K to explore the use of a newly patented ultrasound multi-view fusion technology (see Figure 1a). In the current system, we use optical tracking to align multiple ultrasound scans. A set of markers attached to the ultrasound probe is used to track the device in 3D space using a commercial multi-camera Optitrack system. Chest and abdominal respiratory motion and cycle are also measured using other markers placed on the patient. The 3D transformations measured by the tracking system is then used to align and register the multiple ultrasound scans. In addition to field-of-view improvement, the fusion of multiple ultrasound images also improves image quality and contrast. As planned, the 2019 activities consisted mainly of performing clinical testing of the Multiview system with patients from the Mazankowski Heart Institute. These clinical tests were successful at demonstrating the advantages of the Multiview approach for imaging, but it became clear that the optical tracking approach suffers from occlusion problems, which interfere with the free movement of the sonographer. We concluded that solving this occlusion problem would require that the ultrasound probe tracking should be measured mechanically using a robotic arm (see Figure 1b). With the robotic arm, there would be no optical occlusion problems, and the programmable aspect of the robotic arm could be used to automate some of the digitizing functions. The robotic version of the system 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.

This level of interaction, we believe, could relieve the sonographer's physical burden, hence reducing fatigue and repetitive stress injuries. With this system, the sonographer could perform remote imaging of COVID-19 patients without danger of contamination. In 2019, we were able to secure an NSERC RTI grant to pay for the medical-grade robot necessary for this project. We now have all the required equipment (haptic interface and robot) to deploy the system in 2020.

**Networked Collaborative Systems for Consultation, Surgical Planning, Postoperative Evaluation, and Education**

**VRSurgical:** The importance of information acquisition is not merely to acquire data at an increased speed and spatial precision, but also to make patient-specific models quickly available to, and usable by, many specialists who may be
at different locations in the operating room, the hospital, or even across the country. In collaboration with Servier Virtual Cardiac Centre, last year we developed the first version of a new immersive visualization and communication solution for surgical planning. VR Surgical can deal with most patient data and the limitations in network latency, bandwidth, and processing power in remote locations (rural Alberta, airports, and other countries). Using this immersive system, radiologists and surgeons can visualize patient information in 3D to plan for various options and communicate more accurately with each other (see Figure 2).

![Edmonton and Calgary](image)

Figure 2: VR Surgical System a virtual meeting place for surgical planning and review

In 2019, we performed a usability study to demonstrate how the system can help with a collaborative medical meeting between radiologists at the Servier Virtual Cardiac Center. The results were not conclusive, and it became clear that further development of the system is necessary to deal with some of the issues discovered during the study.

**MedBIKE:** Exercise-based cardiac rehabilitation (CR) is the physical activity component of a multi-disciplinary cardiac rehabilitation program and is an integral step in the care of patients with acute or chronic cardiac disease. However, most patients do not participate in exercise-based CR despite evidence for improved outcomes and event reduction. Between 2016 and 2018, 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 make sure the patient follows the level of exercise prescribed by his/her cardiologist to improve his/her heart condition. In 2019, a new version of MedBIKE for pediatric cardiac rehabilitation was developed and delivered to Dr. Nee at the University of Alberta Department of Cardiac Rehabilitation and has now undergone a two-year clinical trial.

**Virtual Spin-Class:** With the great ability of Unity 3D to rapidly develop various game scenarios, a third application of MedBike was developed for encouraging exercise for people with mild cardiac disease and others who would benefit from exercise participation. Using the multiplayer capability of Unity 3D, a spin-class version of the system was developed. The game consists of numerous bikes (currently limited to six bikes) to be connected via the internet to a central cloud-based game engine that allows registered participants to chase moving targets or each other and to score points depending on their physical performance as measured by wireless pulse and SPO2 sensors. In this version, there is no clinician online. Instead, the sensor data is automatically analyzed by an advanced machine learning algorithm to determine exercise level performance. In November 2019, we were able to demonstrate our remote system capability by performing the world's first virtual spin class session between the University of Alberta in Edmonton and the Federal University of Paraíba in Brazil using a standard internet connection. Our collaborators in Brazil also did a usability study of the system. The study reveals that there were no noticeable lags between participants from Brazil and Canada that interfere with their actions in the virtual world. The study also showed that the application was considered enjoyable. The test participants pointed out that they would seek out virtual spin exercise classes and would enjoy spinning with people from other countries.

**ADDITIONAL ACCOMPLISHMENTS AND ACHIEVEMENTS**
Dr. Boulanger's research work is recognized around the world. He has published more than 450 scientific papers. He has patented (12) new concepts like the Multiview ultrasound probe, which may revolutionize the field of medical imaging by replacing expensive imaging sensors like CT and MRI during cardiac procedures. For 2019-20, he published 12 papers in peer review journals and conferences. In 2019, he was awarded $104K from NSERC RTI, $28K from NSERC Discovery, $75K from MITACS, $25K from the SMART Network, and an extra $50K from CISCO Systems to deploy MedROAD VC at two private clinics managed by Dr. Cathy Scrimshaw from the Alberta College of Family Physicians (ACFP).

He is currently supervising 5 Ph.D. students and 3 Master students to work on the various projects related to this Chair.

Dr. Boulanger is also the CTO and founding member of Naiad Lab Inc., a company dedicated to using advanced technology solutions to enhance the health and quality of life of our clientele worldwide and to commercialize the CISCO Chair IP.

**OVERVIEW OF RESEARCH PLANS FOR 2020-21**

**Deployment of MedROAD Virtual Clinic:** Starting August 1, 2020, we will initiate the deployment of the new re-engineered version of MedROAD Virtual Clinic at two sites. The first project is to deploy MedROAD VC at two private clinics managed by Dr. Cathy Scrimshaw from the Alberta College of Family Physicians (ACFP). We aim to demonstrate that MedROAD can provide a safe and effective way to deliver high-quality care to patients, lower the cost and risk associated with on-site clinical activities, and to promote seamless delivery of care during COVID-19. The partnership with Dr. Scrimshaw provides a unique opportunity to explore how virtual clinics can lead to a better quality of care in urban and remote communities, improving health outcomes, and introducing a preventative healthcare model. Furthermore, this deployment presents an incentive to explore educational and policy-making opportunities concerning virtual care and/or telehealth during a pandemic and a post-pandemic environment. To encourage this initiative, CISCO invested $50K to help us defray the cost of this deployment. This 5-month project will run six months ending on December 31, 2020. The project will be under the guidance of Dr. Boulanger’s CISCO Chair but will be executed by Naiad Lab Inc. under a subcontract.

**MedROAD for COVID-19:** Ever since the start of the COVID-19 pandemic (Feb. 2020), we were asked by our medical partners to find new ways to retarget MedROAD functionalities to deal with healthcare system needs. Possible new features include the ability to do teleconferencing with patients and healthcare providers using CISCO WebEx technology instead of WebRTC, the addition of low-cost sensors to monitor the evolution of COVID-19 remotely, and the development of advanced machine learning algorithms for the automated data analysis of possible infection. One can see in Figure 3a how MedROAD could be retargeted to track COVID-19 infection during the mandatory 14 days quarantine using a low-cost sensor measuring SPO2, pulse, and temperature. A second potential application of MedROAD is to detect possible COVID-19 infection of employees at work using an inexpensive instrumented watch that can measure blood pressure, SPO2, temperature, and pulse. In both cases, advanced machine learning algorithms using Bayesian Networks are now being implemented by two graduate students, and a pilot study of the functionality of both systems will be performed by the end of 2020.
Continuous Monitoring of Acute Cardiac During COVID-19: We are continuing the integration (into MedROAD) of a new wearable technology vest developed for the Canadian Space Agency by Carre Technologies Inc. of Montreal called Astroskin (Figure 4a). This new vest tested by the Canadian astronaut David Saint-Jacques in June 2019 during a mission at the international space station, combines numerous sensing devices into one wireless, easy-to-use garment that records vital sign data in real-time. This vest measures pulse and electrical activity of the heart, blood pressure, breathing rate and volume, skin temperature, blood oxygen saturation, physical activity levels. Our goal this year is to start the implementation of new machine learning algorithms to measure frailty conditions of these acute patients, especially in the context of COVID-19 (see Figure 4b). One Ph.D. student will be working on detecting anomalies on long ECG measurements (48 hours) that will then be integrated into the Bayesian network to evaluate the overall condition of the patient automatically. The project is in collaboration with Dr. Becher at the Mazankowski Heart Institute, Naiad Lab Inc, and the R&D team of Carre Technologies.

From Medical Imaging to Virtual Treatment Planning and Training

Multiview Ultrasound: By using the robot and the haptic interface paid by the NSERC RTI grant, we will focus our research on the following objectives: (1) development of new semi-autonomous multi-view fusion algorithms, (2) new techniques to reduce sonographer fatigue using human-robot cooperation, (3) new configuration to protect sonographer from COVID-19 infection. In 2020 we are planning to start the development of the essential infrastructure of the system at the Maznakowski Heart Institute with the help of Prof. Tavakoli from the Department of Electrical Engineering who already managed to control a similar robotic arm with a haptic device. We will also be working with Prof. Becher at the Mazankowski Heart Institute to deal with the medical aspect of the new system and to help us design its functionality.
Networked Collaborative Systems for Consultation, Surgical Planning, Postoperative Evaluation, and Education

**VRSurgical:** The results of last year's usability study will allow us to define new functionalities that are necessary to make VRSurgical a useful tool. The new features will be implemented and tested in 2020 with the team at the UofA Radiology Department and two graduate students from the Master in the multimedia program.

**MedBIKE:** This new pediatric MedBIKE is currently being used for two years in a clinical study by Dr. Nee at the Department of Cardiac Rehabilitation. Our team is maintaining the software and fixing bugs.

**MedGLAD:** In 2020, we are planning to study how we can retarget MedBIKE functionalities (remote sensing, gaming, video conferencing) to be applied to the remote treatment of acute or chronic musculoskeletal disease at home or in remote clinical centers. This project will be financed by the Smart Network in collaboration with the robotic group at the Faculty of Rehab Medicine. In addition to necessary vital signs measurements (provided by a low-cost sensing watch), the new system will add the ability to transmit and display Kinetisense motion sensing to the remote clinician. As opposed to MedBIKE, this future version renamed MedGLAD will not use an instrumented bicycle but instead a low-cost force-sensing floor or shoe inserts. Such cheap force sensors could detect walking/running direction, cadence, and impact forces exerted by the patient. This information will complement the Kinetisense motion capture capability to fully characterize the progress of the patient to follow his exercise program, help the clinician to adapt the exercise program to the patient's abilities, and use the information to control the actions in the virtual world.

**Virtual Spin-Class:** More usability studies and testing will be performed in 2020 in collaboration with the group in Brazil. Naiad Lab is now looking for eventual customers and is planning to deploy the system in Edmonton in 2021.

**STATEMENT TO THE CHAIR DONOR/FUNDING ORGANIZATION**

Dr. Boulanger and his team would like to thank CISCO Systems for their generous financial and in-kind donations since the start of the Chair in 2013. Without CISCO Systems' investment, none of the research programs supported by the Chair would have been possible. This is especially true during this COVID-19 pandemic, where, because of CISCO's collaboration, we can develop new medical practices that will help reduce the challenges that all societies in the world are facing today.