SUMMARY
Over-arching goal(s) of your research

In 2013, Dr. Boulanger was awarded the CISCO chair in healthcare solution, a $2M, 10-year investment by CISCO Systems in the development of new IT technologies for healthcare in Canada.

The use of information technology is already contributing in significant ways to the enhancement of healthcare delivery and improvement in 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 in the improvement of quality and cost-effectiveness of healthcare. There are great opportunities ahead for computing research 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 is focusing of 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;
- To commercialize the outcome of the research.

RESEARCH PROGRESS
Activities over the past year (2018-19)

Medicine for All

MedROAD: The aim of this project, started in 2013 is to increase the access of basic medical diagnostic tests to patients in remote regions of the world. Our research group has developed a portable medical diagnostic kit which 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 potable medical grade instruments such as a fully automated blood chemistry analyzer capable of measuring up to 100 metabolites (see Figure 1a). All devices transmit geo-located data wirelessly via a smartphone which relays the encrypted data in HL7 to a remote secure 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 to the patient history using machine learning algorithms. Following this 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. In 2018-19, we continue the re-engineering of MedROAD. New functionalities include the ability to do teleconferencing with patients and healthcare providers using CISCO Spark technology, the addition of more monitoring sensors, and the development of advanced machine learning algorithms to add automated data analysis capabilities. One can see in Figure 1b an illustration of the web-portal used during a test performed in collaboration with AHS Critical Care Hub in Calgary.

From Medical Imaging to Virtual Treatment Planning and Training
In the past years, imaging procedures have fundamentally changed medical practice to the points that not only are they indispensable, but it is impossible to imagine medical practice without them. Starting with the familiar X-ray, a whole host of imaging procedures has been developed: CT, MRI/MRA, ultrasound, angiography, and nuclear medicine are well-known modalities. By fusing various imaging modalities and physiological data (like the one produced by MedROAD), the physician can create a patient-specific model that can be used in surgical planning, discussion of options with the patient, and even allow surgeons to map out the surgical route before the actual procedure takes place. With the help of AHS, the SERVIER Virtual Cardiac Centre (SVCC), Alberta Cardiovascular and Stroke Research Centre (ABACUS), Centre for the Advancement of Minimally Invasive Surgery (CAMIS), AHS Surgical Simulation Chair (SCC), and CISCO Systems, we are exploring various aspects of these complex technologies and their potential impact on the medical community.

Multiview Ultrasound: In 2016, we were awarded a large NSERC/CIHR Collaborative Health Research Project grant of $900K to explore the use of a newly patented ultrasound multi-view fusion technology developed in our group which can create 3D models of a beating heart at low cost (see Figure 2). In our system, we use optical tracking to align multiple ultrasound scans. A set of markers attached to the ultrasound transducer are tracked in 3D space by a multi-camera optical tracking system. Another set of markers are placed on the chest and abdominal area of the subjects to estimate the respiratory motion and cycle. The transformations correspond to the alignment of multiple ultrasound scans are computed based on the positions of markers. In addition to the FOV improvement, the fusion of multiple images has also been shown to improve the image quality and information such as contrast, contrast-to-noise ratio, signal-to-noise ratio, and anatomic features. In our algorithm, we use a wavelet-based fusion technique to compute the fused image intensity values for the overlapping regions. The project is currently in its final phase of development and is currently being tested by clinicians at the Mazankowski heart institute. A US patent have been awarded in 2019.

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

VRSurgical: The importance of information acquisition is not simply 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 SVCC, we developed last year the first version of a new immersive visualization/communication solution for surgical planning. VRSurgical 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, radiologist and surgeons can visualized in 3D patient information and plan for various options and communicate more accurately with each other (see Figure 3).

**Figure 3:** VRSurgical System a Virtual Meeting Place for Surgical Planning and Review

**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. Emerging strategies for improving cardiac rehabilitation and overcoming these barriers based on gaming technologies. Between 2017-19, we developed a virtual reality based remote exercise-based CR system called MedBIKE which allows patients to perform a controlled exercise program in the comfort of their own home using a virtual reality gaming experience while being monitored by a remote CR clinician. Using MedBIKE, a cardiac patient can exercise in safety in a virtual world where he is continuously tele-monitored by a clinician (see Figure 4) checking for the evolution of his/her vital signs as well as making sure the patient follow the level of exercised prescribed by his/her cardiologist to improve his/her heart condition. A new version of MedBIKE for pediatric cardiac rehabilitation was developed this year and recently delivered to the department of pediatrics at the University of Alberta. A clinical study of the applicability of the system is currently being performed across Alberta.

**Figure 4:** MedBIKE Cardiac Rehabilitation System

**Virtual Spin-Class:** With the great ability of Unity 3D to develop rapidly various game scenarios, a third application of MedBike was developed for encouraging exercise for mild cardiac disease and others who would benefit from exercise participation. Using the multi-player capability of Unity 3D, a spin-class version of the system was developed. The game consists of numerous bikes (currently max 6 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 measured by wireless ECG sensors. Each participant is represented by an avatar that can be personalized at the beginning of the game. The virtual landscape is an island
where participants must discover special targets that if collided with will cumulate points. The spin-class instructor can change the island level of difficulties by increasing the programmable bike resistance. The winner of the game will be the participant with the most points and with the best physical condition as measured by the 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 and to detect from the ECG any abnormal condition that should be reported to the spin-class instructor and the participants.

**ADDITIONAL ACCOMPLISHMENTS AND ACHIEVEMENTS**

Research grants, awards, recognitions, publications, patents, and conference presentations (past year only), and the trainees working under your supervision. The most significant achievements from previous years may be included (please note: this information may be condensed or excluded due to space constraints)

Dr. Boulanger’s research work is recognized around the world. He has published more than 344 scientific papers and 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. In addition to the CISCO chair, Dr. Boulanger was able to get financing from numerous granting agencies including: CIHR, NSERC, CFN, Royal Alexandra Hospital, Alberta Innovate, and the Ward of the 21 Century.

He is on the editorial board of three major academic computer science journals and reviewer for medical journals on imaging. Dr. Boulanger was also the general chair of the AI/GI/CRV 2017 conference the premier Canadian conference in artificial intelligence, computer graphics, and computer vision.

Dr. Boulanger is also the president of PROTEUS Consulting Inc. a Canadian-based consulting firm specialized in visual simulation applications. He is also the CTO of MedROAD Inc. dedicated to use 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 2018-19**

An overview of your anticipated research activities for 2019-20 and an explanation of how funding will be used.

**Medicine for all**

**MedROAD-at-Home:** Following the results of the 2016 pilot project with Whitehorn home care and AHS it became clear that the primary market for the MedROAD technology is aged care monitoring. Canada’s aging population is exploding with over nine million baby boomers retiring in the next decade, and a current demographic of more people over the age of 65 than under the age of 15. To help the elderly population to stay at home, we will need to develop new monitoring systems that will be able to measure not only vital signs but also lifestyle which include fall detection as well as exercise level, diet, and living conditions. Using this monitoring system, families, private aged care services, and government will be able to take better care of their aging parents, reduce hospitalization, and the need to go to aged care facilities. The focus of this project is to use our new version of MedROAD to develop services to reduce the need for seniors to be hospitalized given their increased risk of complications, morbidity, and mortality in hospital (see Figure 5).

MedROAD-at-Home is based on the re-engineered version of MedROAD V2.0 with additional functionalities that we tested in collaboration with AHS Critical Care Hub. Last year analysis was very informative on what modifications MedROAD should undergoes in order to reach MedROAD-at-Home specifications. Once these new
functionalities are implemented in MedROAD, MedROAD-at-Home will be tested for usability in a one-year pilot project with the help of the Ward of the 21st Century and two aged care facilities in Edmonton and Calgary.

Continuous Patient Monitoring: We are in the process of integrating into MedROAD a new wearable technology vest developed for the Canadian Space Agency by Hexoskin Inc. of Montreal called Astroskin. 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 is to integrate the sensed data into the MedROAD system and then to develop new machine learning algorithms to measure frailty conditions of acute patients (see Figure 6).

From Medical Imaging to Virtual Treatment Planning and Training

Multiview Ultrasound: The Multiview project started in 2016 is coming to an end with a clinical trial. The next step for this project is to replace optical tracking by mounting the ultrasound probe on a robot arm that will allow to reduce stress injuries for scenographers and the ability to semi-automate the acquisition process. In 2019, we were able to secure a NSERC RTI grant to pay for the medical grade robot. We are now in the process of applying for an CIHR CHRP grant to pay for the grad students to implement this new robotic based Multiview system. If successful, the project should start in April 2020.

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

Virtual Spin-Class between Canada and Brazil: This summer (2019), we are planning to demonstrate our system remote 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. Our goal is to study the usability of the system when MedBIKES are located at long distances between each other allowing us to study the effects of bandwidth and network delays on usability. We are also planning to test the Virtual Spin-Class concept at the Faculty of sports medicine and at the YMCA.

**VRSurgical:** Following the initial success of the VRSurgical system, this year is dedicated to perform usability studies with SVCC in order to test in typical real-world cases its usability and its limitations.

*Optimal word count for this report is 1200-1400 words.*