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LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE
FALL/L'AUTOMNE 2019

BULLETIN

SPECIAL ISSUE ON

Artificial Intelligence and Robotics

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CONTENT

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TRACK TESTING WITH THE AUTONOMOOSE / UNIVERSITY OF WATERLOO

Editor's Letter

ARTIFICIAL INTELLIGENCE (AI) IS ONE OF **THE** fastest-growing areas of research and development which has reached both the conventional and emerging fields of mechanical engineering. You can see the footprints of AI in design, manufacturing, automation, fault diagnosis, robotics and so on. Therefore, we have dedicated the fall 2019 issue of the *CSME Bulletin* to AI and Robotics and highlighted the research of Canadian mechanical engineers in this field.

We invite you to read the featured articles by Dr. **J. McPhee** on the integration of machine learning with dynamics and control in automotive and biomechatronics applications, Dr. **G. Zhu** on AI and robotics for active removal of space debris, and Dr. **Ramirez** and co-workers on integrated fault recognition and robotics-based repair processes in manufacturing. In the N*ew Faculty Spotlight* section, we are highlighting the research programs of Dr. **H. Rouhani** on wearable rehabilitation technologies as well as Dr. **Khoshdarregi** and Dr. **Ahmad** on digital and smart manufacturing, all benefiting from AI, machine learning and/or robotics.

We are very happy to announce that Dr. **R. Willing** from Western University has joined the CSME Bulletin team at a Technical Editor. You can enjoy reading the ME News section, written by Dr. Willing, nicely aligned with the theme of this issue. This section highlights the research of Dr. **C. Menon** at Simon Fraser University on robotic orthotic braces to reduce arm tremor, and Dr. **A. Arami** at the University of Waterloo on machine-learning based feature extraction from wearable sensors to prevent freezing of gait.

The next CSME Congress will be held at the University of Prince Edward Island (UPEI). We are delighted to have an article from Dean **N. Krouglicof** introducing us to the city of Charlottetown and the fast-growing Faculty of Sustainable Design Engineering at UPEI. You can also read a brief report by Dr. **K. Siddiqui** about the 2019 CSME-CFDSC Congress that was held at Western University in June 2019. We invite you to submit your papers to CSME Congress 2020 and we look forward to seeing you in Charlottetown.

Starting from this issue, we will include short reports from CSME Technical Committee (TC) chairs and the Editor of *Transactions of the CSME*, Dr. **Paraschivoiu**, in order to keep CSME members informed of new developments in their particular discipline. *Transactions of the CSME* is steadily increasing the number of articles received and its impact factor. Updates from the *CSME Student Chapters & Young Professionals* committee are provided by Dr. **M. Freire-Gormaly**.

This issue is the first written under the newly established editorial guidelines for the *CSME Bulletin* which, hopefully, will help us and future editorial board members enhance the quality of the *CSME Bulletin*. As part of the new guidelines, *Feature Articles* and *Faculty Spotlight* sections are now contributed by readers like you that responded to our call for articles. If you are working in an exciting topic in mechanical engineering, and you would like to share your results with the CSME community, please consider contributing an article in the future.

Our next issue will focus on the subject of Heat Transfer. Please consider contributing to the next issue by providing either a *Feature* or a *Faculty Spotlight* article. You will receive our call for contributions in January 2020. Alternatively, you can also contact us directly if you are interested in contributing to the next issue. We will be delighted to receive your contributions and comments about the *CSME Bulletin* as well as your ideas to improve it in the future.

We hope you enjoy reading this issue,

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PHOTO (REZAI): COURTESY OF THE LASSONDE SCHOOL OF ENGINEERING, YORK UNIVERSITY / PHOTO (GALLART): TABITHA GILLMAN

President's Message

Dear CSME Colleagues,

WHILE THE NEW ACADEMIC YEAR IS ALREADY WELL ADVANCED, I WOULD LIKE TO USE THIS opportunity to wish you a very happy and productive year. The 2019 International CSME Congress has been successfully completed and we need to thank our colleagues from Western University for its efficient organization and splendid execution. I enjoyed meeting many of you during this Congress and I am looking forward to meeting with you again during the 2020 Congress. This Congress will take place in Prince Edward Island and its organization is already well underway. I understand that colleagues there promised to have a special banquet with lobster, which is a Prince Edward Island specialty.

We were focused over the last six months on improving the efficiency of operations of the CSME Board of Directors, the Technical Committees and the membership services. The Technical Committees form the backbone to professional societies likes ours, so we need to carefully review their operations. Communications technology has changed significantly since when the current structure of the Board of Directors was established, so we need to determine what adjustments, if any, are required. I would welcome any suggestions on how to improve the operations of our Society. The Society is operated by volunteers and we would appreciate any help that you could offer.

We have nearly 3000 student members, which means that we can facilitate interactions between our members and industrial partners looking for good employees. We are looking for the proper organizational structure required for an efficient delivery of this service.

I am pleased to inform you that the CSME applied for membership to the International Association for Computational Mechanics (IACM, iacm.info). The IACM Board approved our application in its August meeting. The CSME Technical Committee for Computational Mechanics assumes all duties associated with the CSME representation in IACM.

Best,

MACIEJ FLORYAN, Ph.D., P.Eng. FCSME, FAPS, FASME, FCAI, FEIC
CSME *President*
Professor, Western University
Department of Mechanical and Materials Engineering

Message du président

Chers collègues,

Alors que la nouvelle année scolaire est déjà bien entamée, je profite de cette occasion pour vous souhaiter une année très heureuse et productive. Le Congrès international de la SCGM 2019 s'est achevé avec succès et nous devons remercier nos collègues de l'Université Western pour son organisation efficace et sa splendide exécution. J'ai eu le plaisir de rencontrer beaucoup d'entre vous lors de ce congrès et j'ai hâte de vous revoir lors du congrès 2020. Ce congrès aura lieu à l'Université de l'Île-du-Prince-Édouard et son organisation est déjà bien avancée. Je crois comprendre que nos collègues ont organisé un banquet spécial avec du homard, une spécialité de l'Île-du-Prince-Édouard.

Au cours des six derniers mois, nous nous sommes concentrés sur l'amélioration de l'efficacité des activités du conseil d'administration de la SCGM, des comités techniques et des services aux membres. Les comités techniques constituent l'épine dorsale des sociétés professionnelles comme la nôtre. Nous devons donc plaifier attentivement leurs activités. La technologie des communications a considérablement évolué depuis la création de la structure actuelle du conseil d'administration. Nous devons déterminer quels ajustements, le cas échéant, sont nécessaires. J'apprécierais toutes suggestions concernant la manière d'améliorer les opérations de notre société. La Société est gérée par des bénévoles et nous vous saurions gré de toute aide que vous pourriez offrir.

Nous avons près de 3000 membres étudiants, ce qui signifie que nous pouvons faciliter les interactions entre nos membres et les partenaires industriels à la recherche de bons employés. Nous recherchons la structure organisationnelle appropriée pour une prestation efficace de ce service.

J'ai le plaisir de vous informer que la SCGM a postulé à devenir membre de l'Association internationale de mécanique computationnelle (IACM, iacm.info). Le conseil d'administration de l'IACM a approuvé notre candidature lors de sa réunion du mois d'août. Le comité technique de la SCGM pour la mécanique computationnelle assumera toutes les tâches liées à la représentation de notre société dans l'IACM.

Cordialement,

Welcome New CSME members
1 May 2019 to 30 September 2019

Prof. **Mohsen Akbari**, University of Victoria
Dr. **Jubayer Chowdhury**, WindEEE Research Institute
Prof. **Marina Freire-Gormaly**, York University
Dr. **Stephen Andrew Gadsden**, University of Guelph
Mr. **Greg MacDougall**, CAVU Designwerks
Dr. **Faizul Mohee**, TMBN Extrados Inc
Dr. **Seyed Alireza Rohani**, Western University
Dr. **Ting Zou**, Memorial University

CSME-CFDSC Congress 2019

Kamran Siddiqui, Chris DeGroot, Chao Zhang (Congress Co-Chairs)

THE 2019 CSME INTERNATIONAL CONGRESS and the 27th Annual Conference of the CFD Society of Canada were jointly held at the picturesque campus of the Western University in London, Ontario from June 2nd to June 5th, 2019. The Congress was hosted by the Department of Mechanical and Materials Engineering at the Western University. This joint Congress provided a unique opportunity to bring researchers and students whose interests align with both societies to a common platform that facilitated the dissemination of results from cutting-edge research as well as networking opportunities among academia, government agencies, and industry.

This two and a half-day Congress had an extensive technical program featuring plenary lectures from internationally-recognized and distinguished speakers as well as activities like technical symposia, CSME Student Paper Competition, CSME Student Design Competition, CFDSC Undergraduate Poster Competition and NSERC Workshop on grants and scholarships. Annual General Meetings of CSME and CFDSC and meetings of various Technical Committees of CSME were also held during the Congress. Tours of various state-of-the-art research facilities were organized that included the Fraunhofer Project Centre, the WindEEE Dome, the Boundary Layer Wind Tunnel and NRC. Much of the event was hosted within the newly-opened Amit Chakma Engineering Building, which is pursuing LEED® Platinum Certification for its sustainable design.

There were five plenary lectures. CSME sponsored three plenary lectures covering a broad range of mechanical engineering topics.

Dr. **Peter Walker**, Professor at the New York University in the area of Biomechanics, spoke about the recent advancements in artificial knees. Dr. **Andy Sun**, Professor at Western University in the area of nano-materials, talked about novel applications of nano-materials for energy storage. Dr. **Ruxu Du**, Professor at the South China University of Technology in the area of Advanced Manufacturing, talked about a new idea of resilient manufacturing. CFDSC sponsored two plenary lectures covering different domains of CFD. Dr. **Leigh Orf**, Atmospheric Scientist at the University of Wisconsin, presented his work involving petascale simulations of supercell thunderstorms and discussed his latest hypothesis for tornado formation and their maintenance. Dr. **Marcelo de Lemos**, Professor at Instituto Tecnológico de Aeronáutica, Brazil, talked about recent advances that have been made by his research group in numerical modeling of flow, heat, and mass transfer in heterogeneous media.

The CSME Congress had 17 technical symposia covering all key areas in the mechanical

engineering discipline. These symposia were comprised of 282 technical presentations including eight Keynote presentations, all ran in 10 parallel sessions. The CFDSC technical program included 12 symposia with a total of 83 technical presentations including six Keynote presentations, ran in three parallel sessions. A featured aspect of the Congress was the heavy participation of graduate students. Out of 394 registered participants, 286 (~73%) participants were graduate students or postdocs.

About one-third of CSME-CFDSC Congress participants also attended the co-located Industry 4.0 Symposium. This symposium provided an opportunity to learn about new trends in Industry 4.0 and meeting and network with relevant academic and industry people.

Sponsorships for the Congress were provided by the Faculty of Engineering, Western University, High Speed Imaging, FLIR, Delta Photonics, Bombardier and Canadian Science Publishing.

DR. NICK KROUGLICOF, PhD, P.Eng..
Dean, Faculty of Sustainable Design Engineering

WE ARE EXCITED TO ANNOUNCE THAT THE 2020 CSME Congress will take place on June 21–24, 2020, at the new Faculty of Sustainable Design Engineering, University of Prince Edward Island (UPEI).

Established in 1969 as the provincial university, UPEI is located in the city of Charlottetown (population: 36,000), the vibrant capital of Prince Edward Island (PEI). The University is the province's only degree-granting postsecondary institution. PEI may be Canada's smallest province, but what it lacks in size it makes up for in heart! PEI is known for its red sandy coastline, its green rolling hills, and its reputation as a culinary and cultural destination.

UPEI offers programs in Arts, Science, Engineering, Education, Nursing, Business, and Veterinary Medicine, including a growing number of graduate programs. The Atlantic Veterinary College offers a high-quality doctor of veterinary medicine education and features the only veterinary teaching and referral hospital east of Montreal and north of Boston.

Home to over 4,600 students and approximately 250 full-time faculty members, UPEI is friendly and safe, and it's within walking distance of downtown. Students cite small class sizes and easy access to professors as top reasons for choosing UPEI. UPEI is also proud of its growing international student population: The campus welcomes and supports over 1,200 international students who come to UPEI from 90 countries, making up 26 percent of the student population.

The Faculty of Sustainable Design Engineering, where CSME 2020 will take place, has led the way in new, innovative programs focusing on experiential education. The Faculty has grown rapidly following the 2013 decision to offer UPEI's first accredited engineering degree program, a BSc in Sustainable Design Engineering. A big focus of our program is solving real-world problems: about 25 per cent of the program is design projects where students work with outside community or industry clients. Students work on these projects every single semester, not just in the fourth year. We have three focus areas (groups of electives in third and fourth year): Mechatronics, Bioresources, and Sustainable Energy.

Our undergraduate students have access to state-of-the-art design and lab facilities in our new building, which opened in August 2016. The building was designed with the program in mind, and houses five high bay research centres focused on Robotics and Industrial Automation; Sustainable Energy; Bioresources; Sensors, Optics and Imaging; and Advanced Manufacturing. Fifteen faculty members and 12 technical staff—engineers and technologists hired from industry—support the students in a program that emphasizes hands-on learning through design projects and labs.

Since 2017 the Faculty has also offered an MSc in Sustainable Design Engineering, which currently has around 30 students; this growth was facilitated by a huge increase in research funding starting in 2016 when many new faculty joined with strong industry research experience. In 2018, UPEI also began offering our undergraduate program at the Universities of Canada in Egypt.

We are incredibly excited about the opportunity to welcome CSME 2020 attendees to our Faculty!

For more information visit,
www.csme2020.com

Integration of Machine Learning with Dynamics and Control: From Autonomous Cars to Biomechatronics

DR. JOHN McPHEE, FCSME, FCAE, FASME, FEIC

Professor J. McPhee is the Canada Research Chair in System Dynamics at the University of Waterloo, which he joined in 1992. Prior to that, he held fellowships at Queen's University, and the Université de Liège, Belgium.

He pioneered the use of linear graph theory and symbolic computing to create real-time models and model-based controllers for multi-domain dynamic systems, with applications ranging from autonomous vehicles to rehabilitation robots and sports engineering. His research algorithms are a core component of the widely-used MapleSim modelling software, and his work appears in over 130 journal publications.

Prof. McPhee is the past Chair of the International Association for Multibody System Dynamics, a co-founder of two international journals and three technical committees, a member of the Golf Digest Technical Panel, and an Associate Editor for five journals. He is a Fellow of the Canadian Society of Mechanical Engineers, the Canadian Academy of Engineering, the American Society of Mechanical Engineers, and the Engineering Institute of Canada. He has received eight Best Paper Awards, the prestigious NSERC Synergy Award from the Governor General of Canada, and the PEO Engineering Excellence Medal in 2019.

IMAGES COURESTY OF THE RESEARCHER / UNIVERSITY OF WATERLOO

RESEARCHERS AT THE UNIVERSITY OF WATERLOO are strategically combining artificial intelligence (AI) methods with dynamics and model-based control approaches, to solve real-world problems that are too difficult or computationally intensive to tackle with either AI or conventional methods on their own. Our goal is to combine the best features of machine learning and model-based control theories, in contrast to computer scientists that are seeking purely AI solutions to dynamics and control problems. This article presents our recent work towards this goal, with an emphasis on two very active research applications: Autonomous Cars and Biomechatronics.

Autonomous Cars

To engage the CSME reader, we start with our autonomous car, the Autonomoose (Figure 1). From rolling dyno and track testing at Waterloo, we developed a physics-based model of the vehicle and tires. However, the details of the powertrain control were proprietary and unknown to us. Data collection from the on-board CAN bus allowed us to train a double-layer perceptron neural network representation of the powertrain, which was easily integrated with the vehicle and tire models using symbolic computing. By combining the physics-based and AI-based models into a single hybrid representation, we could create a model-predictive controller (MPC) for longitudinal speed that was both accurate and computationally efficient; further speedup was obtained by differentiating the symbolic model to obtain exact expressions for the gradients needed by the optimizer[1]. The MPC was deployed on the Autonomoose as a ROS (Robot Operating System) node, and preliminary track testing has demonstrated the improved performance of this hybrid controller in comparison to previous PI-based approaches.

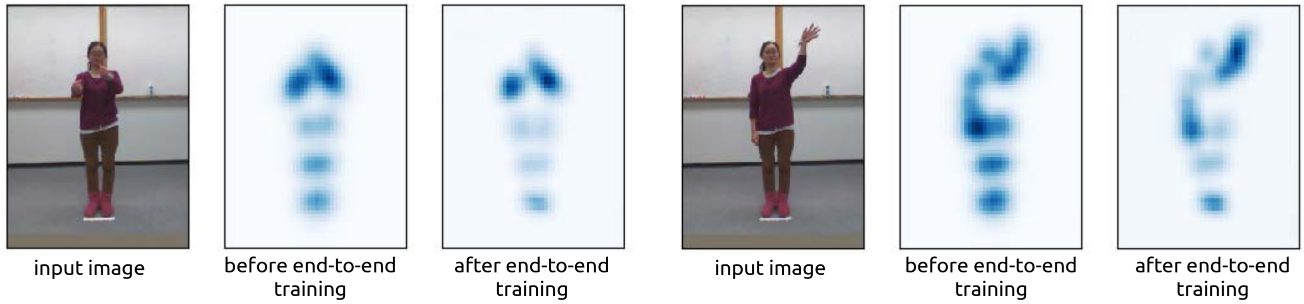
A challenging control task for automated driving is lane merging. Previous research utilized rule-based or optimal control approaches to solve the merging problem[2], but there is an increasing interest in using learning-based methods to train an automated merging policy[3], partly due to the super-human intelligence displayed by deep reinforcement learning (DRL) in playing board games[4]. DRL algorithms use deep (multi-layer) neural nets as the policy representation and, once trained, do not require the computing power of model-predictive control[5]. In our research, we examined decentralized decision making and control for on-ramp merging using DRL. The goal was to merge autonomously from an on-ramp to a highway while avoiding stops and collisions. The on-ramp automated vehicle obtained the states of other vehicles with its own sensors; there was no centralized control from roadside units. We used the states of the automated (merging) and highway vehicles as the input to the DRL training framework, and the acceleration command for the automated vehicle as the output. After training convergence, the learned policy enabled the automated vehicle to decelerate to merge behind (or accelerate to merge ahead) of a highway vehicle, much like human driving. We tested the learned policy with 16,975 merging episodes and observed 0 stops and only 1 collision, which is better performance for highway merging than that achieved by humans[6].

Biomechatronics

The strong performance of reinforcement learning in the previous project motivated us to use DRL in our end-effector-based stroke rehabilitation robot, for which we have developed a model-predictive controller. For effective rehabilitation, the weights of the controller should be tuned for each individual patient. Manually tuning for different patients is time-consuming and will not lead to the best performance. Inspired by[7], we are designing an adaptive controller with a DRL-based automatic tuner. Our goal is to develop a subject-specific controller, using measurements of the position and force at the robot end-effector, which will adapt to different patient movement and strength characteristics.

The rehabilitation robot measurement data can be augmented with the motion of the user. Currently, this information is extracted from markers or wearable technologies that are cumbersome and have high setup time. This is the motivation for a related project that is using deep convolutional neural networks (CNNs)

FIG. 2: POSE ACTIVATIONS BEFORE AND AFTER TRAINING THE POSE ESTIMATION LAYERS FOR HUMAN ACTION RECOGNITION.



to simultaneously recognize actions and perform markerless tracking of human motion[8]. In this project, a custom CNN architecture was designed to circumvent some of the challenges associated with training the complex neural network architectures commonly used for action recognition by exploiting the spatial information in pre-trained human pose estimation layers. More specifically, the generated pose data is re-projected using a stack of 3D convolutions in a seamless network architecture that integrates human pose with action recognition. The advantage of this framework is that action predictions are based on pose information rather than appearance, which is advantageous in single-environment applications where the variation in human movement is critical. On Multimodal Human Action Dataset (UTD-MHAD)[9], a 27-class multi-modal action recognition dataset, the proposed method – requiring only an RGB camera – outperformed several methods using richer data streams from depth cameras and inertial sensors. Interestingly, it was found that the spatial activations produced by the pose layers changed after training the model for action recognition. Figure 2 demonstrates that the activations for the joints that contributed most to the action, such as the wrists and ankles, were greatly accentuated after end-to-end training. Conversely, the non-moving joints such as the knees and hips were attenuated. This interesting phenomenon can be leveraged to gain new insights into discovering the key defining characteristics for specific human actions.

Vision-based artificial intelligence has also advanced our exoskeleton rehabilitation robotics research. While many robotic vision applications have focused on autonomous navigation, recent research has considered energy savings from environment sensing. For instance, autonomous and connected vehicles use future environment information to achieve energy-efficient driving through optimal power management. Environment recognition can likewise improve the energy-efficient control of lower-limb biomechatronic devices (e.g., exoskeletons and prostheses) that assist seniors and rehabilitation patients with walking[10]. The implementation of such energy-efficient controllers, however, remains fundamentally contingent upon their ability to accurately predict oncoming environments. Therefore, our research has focused on developing an accurate environment recognition system with robotic vision and deep learning (Figure 3)[11]. Using a wearable RGB camera, approximately 2 million images were collected while walking through unknown outdoor and indoor environments; the labelled images were uploaded to IEEE DataPort. A 10-layer deep CNN was developed and trained using five-fold cross-validation to automatically recognize three different oncoming environments: level-ground, incline staircases, and decline staircases. The environment recognition system achieved 95% overall image classification accuracy. Extending these preliminary findings, our next-generation system focuses on 1) improving image classification accuracy by using larger and more diverse training datasets, and 2) minimizing onboard computational and memory storage requirements using efficient deep CNNs designed for mobile and embedded vision applications. By developing more accurate and efficient prediction of future walking environments, we can achieve more energy-efficient control of robotic lower-limb exoskeletons and prostheses.

Conclusion

We are currently witnessing an explosion of research into the application of artificial intelligence to engineering problems. In the Motion Research Group at the University of Waterloo, we are combining AI tools with dynamic modeling and control theories. This hybrid approach has increased the efficiency, accuracy, and real-time practicality of our engineering solutions, and fostered exciting new projects in the fields of Autonomous Cars and Biomechatronics. We are optimistic that the rapidly-evolving progress in deep learning will further advance the frontiers of dynamics and control of future engineering systems. – *A. Hashemi, Y. Lin, W. McNally, B. Laschowski, B. Hosking, A. Wong, and J. McPhee*

References

[1]Hosking B, McPhee J. (2018). Powertrain Modeling and Model Predictive Longitudinal Dynamics Control for Hybrid Electric Vehicles. SAE Technical Paper 2018-01-0996, Detroit, United States.

[2]J. Rios-Torres and A. A. Malikopoulos, A survey on the coordination of connected and automated vehicles at intersections and merging at highway on-ramps, *IEEE Transactions on Intelligent Transportation Systems*, vol. 18, no. 5, pp. 1066–1077, 2016.

[3]Y. Hu, A. Nakhaei, M. Tomizuka, and K. Fujimura, Interaction-aware decision making with adaptive strategies under merging scenarios, arXiv preprint arXiv:1904.06025, 2019.

[4]D. Silver, A. Huang, C. J. Maddison, A. Guez, L. Sifre, G. Van Den Driessche, J. Schrittwieser, I. Antonoglou, V. Panneershelvam, M. Lanctot, et al., Mastering the game of go with deep neural networks and tree search, *Nature*, vol. 529, no. 7587, p. 484, 2016.

[5]T. P. Lillicrap, J. J. Hunt, A. Pritzel, N. Heess, T. Erez, Y. Tassa, D. Silver, and D. Wierstra, Continuous control with deep reinforcement learning, arXiv preprint arXiv:1509.02971, 2015.

[6]Y. Lin, J. McPhee, and N. L. Azad. Decision-Making and Control for Freeway On-Ramp Merging Using Deep Reinforcement Learning, arXiv preprint arXiv:1909.12967, 2019.

[7]M. Sedighizadeh, and A. Rezazadeh. Adaptive PID Controller Based on Reinforcement Learning for Wind Turbine Control. In *Proceedings of world academy of science, engineering and technology* (Vol. 27, pp. 257-262), 2008.

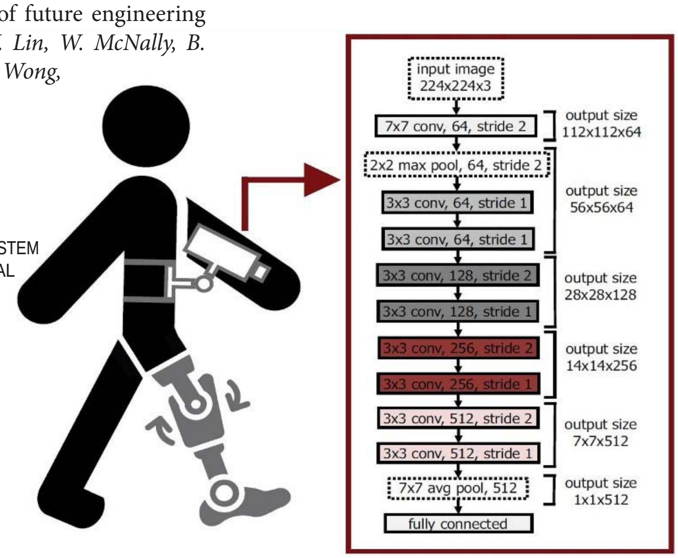
[8]W. McNally, A. Wong and J. McPhee, STAR-Net: Action Recognition using Spatio-Temporal Activation Reprojection, *16th Conference on Computer and Robot Vision* (CRV), Kingston, ON, Canada, 2019, pp. 49-56. doi: 10.1109/CRV.2019.00015

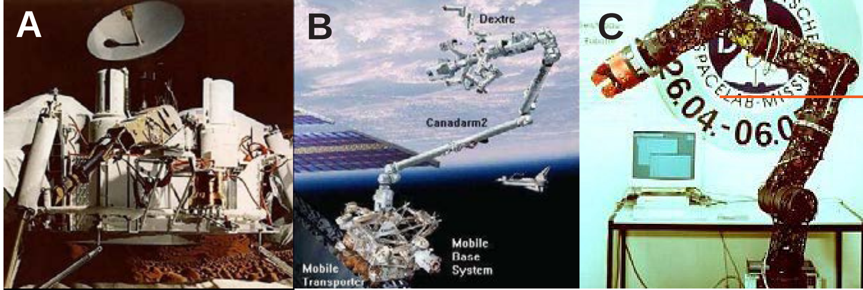
[9]C. Chen, R. Jafari and N. Kehtarnavaz, UTD-MHAD: A multimodal dataset for human action recognition utilizing a depth camera and a wearable inertial sensor, *IEEE International Conference on Image Processing* (ICIP), Quebec City, QC, 2015, pp. 168-172.

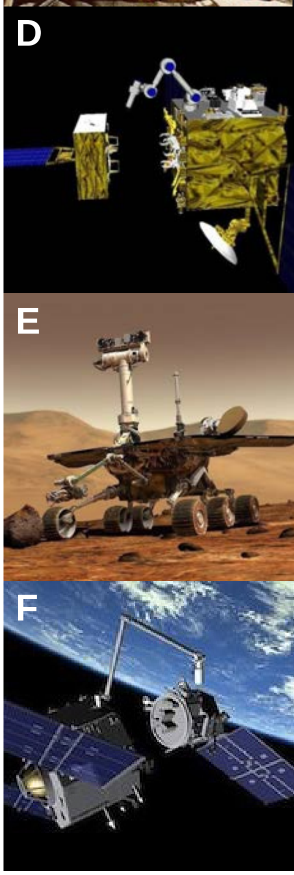
[10]Laschowski B, McPhee J, and Andrysek J. (2019). Lower-Limb Prostheses and Exoskeletons with Energy Regeneration: Mechatronic Design and Optimization Review, *ASME Journal of Mechanisms and Robotics*, 11(4), pp. 040801-040801-8. DOI: 10.1115/1.4043460.

[11]Laschowski B, McNally W, McPhee J, and Wong A. (2019). Preliminary Design of an Environment Recognition System for Controlling Robotic Lower-Limb Prostheses and Exoskeletons, *IEEE International Conference on Rehabilitation Robotics*, pp. 868-873. DOI: 10.1109/ICORR.2019.8779540.

FIG. 3: SCHEMATIC OF THE ENVIRONMENT RECOGNITION SYSTEM INCLUDING DEEP CONVOLUTIONAL NEURAL NETWORK.







On the Space Robotics for On-Orbit Service and Active Space Debris Removal

FIG. 1: SAMPLE OF SPACE ROBOTICS AND THEIR MISSONS: (A) LANDERS OF VIKING 1&11 (B) CANADARM; (C) ROTEX (D) ETS-VII, E) PHOENIX LANDER (F) ORBITAL EXPRESS

Dr. DR. ZHENGHONG (GEORGE) ZHU, PhD, P.Eng, MRSC, FEIG, FCSME, FASME, AFAIAA

Dr. Zhu is the Professor and Tier 1 York Research Chair in Space Technology in the Department of Mechanical Engineering at York University. He is also the inaugural Academic Director of Research Commons at Office of the Vice President Research & Innovation. He joined the Department of Earth and Space Science and Engineering at York in 2006 and then the Department of Mechanical Engineering in 2016. His r esearch interests include dynamics and control of tethered space system and space robot, space debris removal, satellite technology, and computational mechanics. He is the College Member of Royal Society of Canada, Fellow of Engineering Institute of Canada, CSME and ASME, and Associate Fellow of A/AA. Finally, he is the recipient of 2019 Ontario Professional Engineers Awards: Engineering Medal—Research and Development.

SINCE THE BEGINNING OF THE SPACE ERA in 1957 to 2018, over 8,378 satellites have been sent to space for navigation, communication, surveillance, and remote sensing. Among them, there are 4,987 satellites in Earth orbit. However, only 1,957 are operational. This means currently more than 60% of the satellites in orbit are 'dead' and can be labeled as space debris. The continuously growing population of space debris in orbit poses severe threats to the safety of operational satellites as well as the long-term sustainability of space activities. Although considerable efforts have been devoted to the reduction and removal of space debris over the past few decades, no instance of space debris removal has been performed yet. In order to remediate the risk of space debris, increasing attention is attracted by disposing the whole or remnants of 'dead' satellites in space as well as extending the lifespan of operational satellites via on-orbit servicing. These operations, including capture, installation, maintenance, and repair work on an orbital object, are the so-called on-orbit servicing (OOS), which is an emerging and promising key technique in the future of space exploration.

To satisfy the demands for safety, efficiency and automation during the capture of orbiting objects, robotic manipulators are adopted in OOS missions to perform dexterous operations mainly in four fields: International Space Station (ISS), Mars Exploration Rovers (MER), Orbital Docking System (ODS) and Pure Experimental System (PES). For instance, the Mobile Servicing System (MSS, or Canadarm2), Japanese Experiment Module Remote Manipulator System (JEMRMS) and European Robotic Arm (ERA) are typical examples of space robotic manipulators used on ISS. These robotic manipulators are either operated by astronauts or by pre-programmed scripts. Robotic manipulators of MER, such as those mounted on the landers of Viking 1 and 2, Spirits and Opportunity, Phoenix and Curiosity are pre-programmed to dig into the ground of the Mars surface, collect soil samples and/or position instruments on a target. Cameras mounted on these robotic manipulators are used to monitor the movements of the manipulators and take photographs of the surroundings. Robotic manipulators of ODS, such as the Shuttle Remote Manipulator System (SRMS, or Canadarm) mounted on the ISS, and the robotic manipulators mounted on Orbital Express, are used to perform grappling, docking, refueling, repairing and/or servicing of another orbiter. ROTEX and ETS-VII are PES, operations such as assembling, grasping, docking and other orbit-replaceable-unit exchanging operations were done to demonstrate the readiness and principles of ground control under time delay constraints. The FREND (Frontend Robotics Enabling Near-term Demonstration) successfully achieved autonomous docking and capture and serviced the target. The latest missions in OOS include the German's Deutsche Orbital Servicing Mission (DEOS) and US' Mission Extension Vehicle program (MEV-I&II). Both are targeting for in-space satellite refueling operation. The DEOS was planned to launch but was canceled and the MEV will be launched in 2020.

Generally, OOS involves nine steps:

1. Initial approach from far-range. This has been successfully executed in many space missions.

2. Fly-around and inspection of a target to assess target motion and find suitable contact points. Future research in this step is to execute the task autonomously using computer vision enhanced by artificial intelligence.

3. Final approach and rendezvous with the target. This stage has been successfully demonstrated by both ETS-VII and Orbital Express with known and cooperative targets. Research has been extended for non-cooperative and unknown target, where the target's motion must be precisely estimated.

4. Coarse manipulation. Here it is highly desired to control the robotic manipulator towards the target without disturbing the pose of the base spacecraft. Extensive research activities have been carried out in this area.

5. Visual-servo tracking and capture. The technology has been demonstrated on ETS-VII mission. More study is needed to optimize the attitude control of the base spacecraft and the contact force at capture.

6. Impact dampening and motion suppression to minimize contact forces and relative motion between the target and the robotic manipulator. This is especially important for capturing a tumbling target. More study in this area is needed.

7. Target berthing to dock the spacecraft with robotic manipulator. The technology has been demonstrated on ETS-VII successfully. However, the challenge is the suppression of residual vibration of manipulators.

8. Orbital unit exchange and refueling to replace components of and refuel the target spacecraft. It has been demonstrated by ETS-VII and

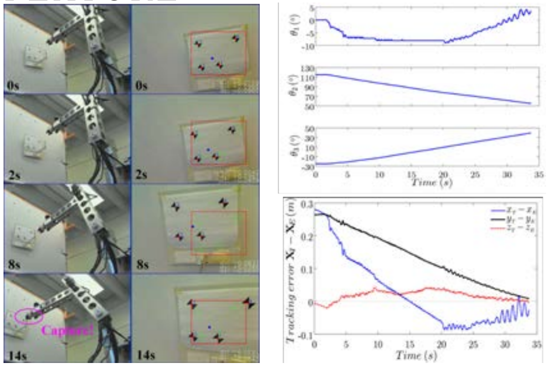


FIG 2: THE EXPERIMENT OF AUTONOMOUS CAPTURE OF A MOVING TARGET. LEFT, EXPERIMENT SNAP-SHOTS. RIGHT, TIME HISTORIES OF JOINT ANGLES AND TACKING ERRORS.

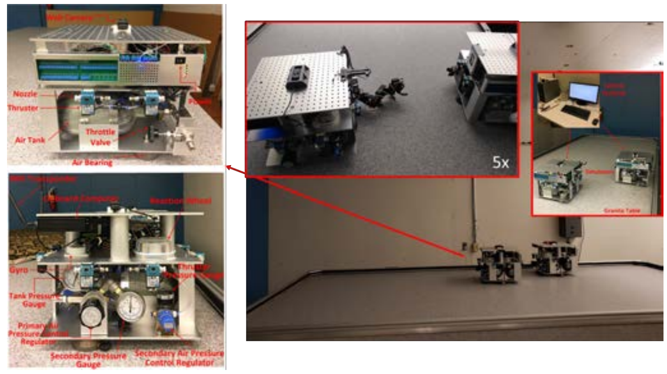


FIG 3: 3DOF ZERO-GRAVITY FREE-FLOATING SATELLITE SIMULATOR SYSTEM, WHERE THE ROBOTIC MANIPULATOR IS ALSO SUPPORTED BY AIR-BEARINGS TO ELIMINATE GRAVITY EFFECT ON ROBOT JOINTS.

Orbital Express with known and cooperative target. Research has been extended for unknown and non-cooperative tumbling targets.

9. More dexterous/skilled manipulation, for handling wires and connectors, for instance. ETS-VII mission demonstrated these simple tasks by teleoperation and pre-programmed scripts. Further studies are now focusing on autonomous operation with tactile robotics and artificial intelligence.

These tasks involve the dynamics of free-floating multi-body dynamics, soft contact dynamics, free-flying path planning and control, obstacle detection and avoidance, and artificial intelligence in computer vision for visual-servo.

The Space Engineering Design Lab at York University has been actively working on these challenges over the past 10 years. First, we developed a position-based visual servo control framework to detect, track and capture the free-floating target autonomously. Computer vision is used to detect and determine the relative pose and motion of the target the end-effector due to its non-contact and non-intrusive nature. Based on the relative pose and motion information, incremental inverse kinematics based visual servo is developed to eliminate the kinematic singularity in the joint space. With the consideration of joint speed limits, dynamic singularity is also avoided. This approach has been validated by extensive analytic analysis and numerical simulations, as well as experimental demonstration. Figure 2 shows the experimental capture process using a custom 6DOF robotic manipulator.

Second, we designed and built a 3DOF zero-gravity and free-floating satellite simulator testbed to investigate the soft contact problem in the autonomous visual servo control in capturing the free-floating target. Figure 3 shows the testing system. In this experiment, two satellite simulators supported by air-bearings are freely floating on a granite table. One satellite is equipped with a 6DOF robotic manipulator that is also supported by two air-bearings to eliminate gravity effect on joints. The satellite is also equipped with a camera to automatically estimate the pose and motion of another free-floating satellite. Figure 4 shows some experimental results where the path-planning was the simple waypoint approach.

Currently, we are building a 6DOF robotics-based hardware-in-the-loop (HIL) ground test facility for dynamics and control of capturing space target as shown in Figure 5 with a NSERC RTI grant. The system uses physical contact to produce contact force/torque, which is the hardest task in contact dynamics, to improve/correct existing mathematical model of soft-contact dynamics used in the computer simulation. Such a system is essential to overcome the physical barrier that hinders our effort in understanding soft contact dynamics in capturing a free-floating target, and dynamic response of the robot-target combination to control input in the post-capture stabilization in microgravity. Once commissioned, it will be the only testing facility in Canada for full 6DOF soft contact dynamics of free-floating space system.

Finally, there are many legal, regulatory, and political challenges with the implementation of on-orbit servicing and active debris removal missions. No private company can perform OSS without licensing and supervision from the government. For instance, any optical device, which can take images of Earth in the mission even unintentionally will be required to have a license from the government in which the company resides. This is an important consideration in the mission planning stage because optical images are required in target detection, path-planning and final capture in the OOS missions. Although beyond the technical problems, the urgency of this issue cannot be underestimated and an cross-disciplinary approach is required to pave the way for any future OOS missions by private sector.

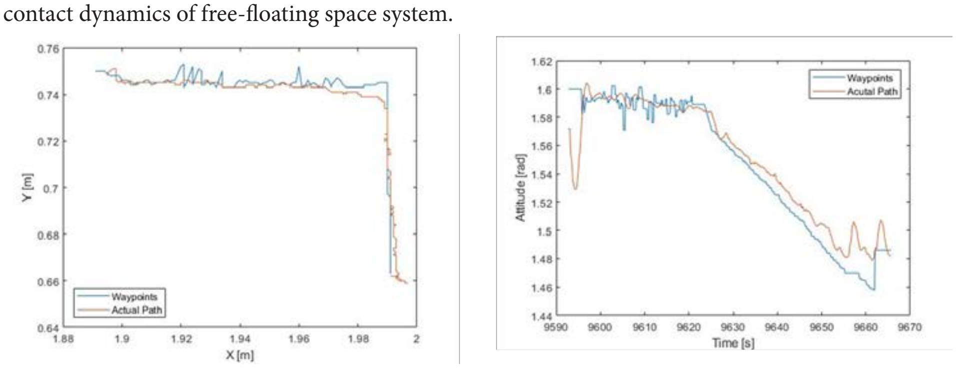


FIG 4: 3DOF ZERO-GRAVITY FREE-FLOATING SATELLITE SIMULATOR SYSTEM, WHERE THE ROBOTIC MANIPULATOR IS ALSO SUPPORTED BY AIR-BEARINGS TO ELIMINATE GRAVITY EFFECT ON ROBOT JOINTS.

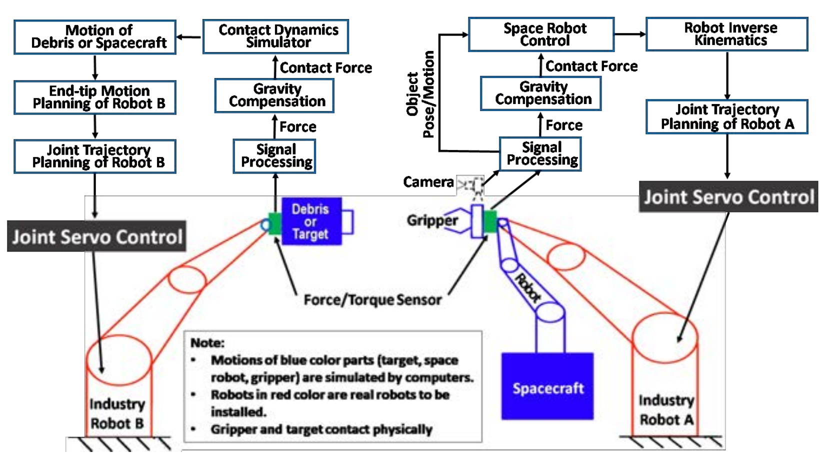


FIG. 5: THE 6DOF HIL ROBOTIC GROUND TESTING FACILITY FOR OOS – UNDER DEVELOPMENT.

IMAGES COURTESY OF THE RESEARCHER

FIG. 1: ZERO PROGRAMMING REPAIR PIPELINE PROCESS STRUCTURE, DEPICTING EACH OF THE STEPS NEEDED TO AUTOMATE THE REPAIRING PROCEDURE WITH SUCCESS.

Zero Programming Repair Strategy using Laser Metal Deposition

Dr. DANIEL RAMIREZ *is a postdoctoral fellow at the University of Alberta at the Chemical and Materials Engineering Department with a Mechatronics degree and a PhD in Artificial Intelligence in Robotic Systems for control purposes. His research experience extends overseas to the UK and Sweden and his working experience to Tenaris.*

SYED ALAM *is a MSc student in Welding Engineering at the University of Alberta. After completing his bachelors in Chemical Engineering he worked as a research engineer at Group Six Technologies, a laser cladding facility. His current research interests involve welding process automation and additive manufacturing.*

Dr. GOETZ DAPP *is Associate Director of the Canadian Centre for Welding and Joining (CCWJ) at the University of Alberta. He has an interdisciplinary background and extensive experience in developing and consulting for multimedia applications and technology, with a keen interest in 3D technology.*

HABIBA ZAHIR IMAM *is an MSc. student from the Laboratory of Intelligent Manufacturing, Design and Automation (LIMDA), Mechanical Engineering Department, University of Alberta. She received her BSc. in Mechanical Engineering from Eastern Mediterranean University in 2017. She is currently working on developing intelligent algorithms for automated industry 4.0-assisted repair technology.*

Prof. RAFIQ AHMAD *is an Assistant Professor in the Department of Mechanical Engineering, University of Alberta. Founder of the Laboratory of Intelligent Manufacturing, Design and Automation (LIMDA), he leads cutting-edge research on hybrid & smart systems for advanced manufacturing and repair to enable Industry 4.0 in Canada.*

Prof. PATRICIO F. MENDEZ *isWeldco/Industry Chair in Welding and Joining and Director of the CCWJ at the University of Alberta, and focuses on the physics and mathematics of welding and materials processing, including heat transfer, magnetohydrodynamics, arc plasma, thermodynamics, and kinetics. His patents include 6 of the original metal-based additive manufacturing patents.*

INDUSTRIAL ROBOTIC MANIPULATORS FOR manufacturing procedures have found good use in industries requiring to lift heavy loads, do monotonous movements, precision pick and place operations, painting, welding, and other added value operations. The current implementations of robotics in repair processes, in contrast, are highly manual, inefficient, and human-intensive. Intelligent path planning based on automated 3D scanning, registration and repair volume can minimize human involvement and maximize efficiency in robot assisted repair processes. A considerable portion of manufacturing in Alberta consists of repairs of heavy components, which follow a different business and application model than, for instance, additive manufacturing applications in aerospace. Repairing worn components has significant economic and environmental advantages. One advantage is that it enables companies to operate under reduced profit margins compared to making new components, which is a current constraint in Alberta operators of natural resources. Companies in Alberta working in this area include Group Six Technologies and Apollo Cladding, who remanufacture industry components for reuse and better performance.

The proposed research aims at integrating a KUKA 6-axis robotic manipulator and 2-axis positioner, a Creaform 3D scanner, 9kW Laserline fiber-coupled diode laser system and Thermach powder feeder. The goal of this research is to bring new developments to additive manufacturing for repair purpose with intelligent path planning, intelligent controls and process modelling.

At the first stage, a coordinate-measuring optical 3D scanner is used to generate a 3D point cloud of the geometry to repair. Once the physical constraints and information are gathered, repair volume extraction and toolpath generation are performed. For the specific purpose of metal deposition in the generated toolpath, a 9 kW laser is used to melt the powders delivered by the powder feeder. A coaxial cladding head made by Precitec is mounted on the robot's flange, directs the powder flow, and points the fiber guided laser beam onto the object's surface. The six axis robotic manipulator is coupled with a two axis positioner for precision deposition. To achieve versatility and reproducibility with beam focus and powder flow, a coaxial head with adjustable beam focus is used. The laser spot is routinely profiled with a Primes beam profiler after focus adjustment to understand the changes in geometry and beam quality which directly affects the metal deposition. A pyrometer is also in place for adaptive laser power control. A block diagram of the system can be seen in Figure 1.

Modelling of the additive manufacturing process is also necessary in this project to capture the true essence of the automation process. Due to high correlation between the process variables, a non-linear control strategy for metal deposition is being developed based on existing models from our research centre. This involves modelling of the heat source, heat affected zones and thermal cycles, which dictates the necessary heat input, powder injection and robot dynamics for each specific material in use during the cladding process. An optimal additive manufacturing process requires not only control of the process variables, but it also requires sophisticated robot movements powered by intelligent feedback controls. These modelling parameters work in tandem to achieve an optimal build-up profile and microstructure.

Repair Volume Extraction and Tool-Path Generation

The repair process combines reverse engineering and laser cladding technologies. Reverse engineering is the digitization of the physical damaged model so that it can be easily manipulated for repair volume extraction. Repair volume extraction is the primary step towards an automated repair process. This is done by scanning the damaged surface with a laser scanner, e.g. MetraScan 750 3D. The point clouds obtained represents a 3-dimensional shape where our intelligent algorithms can detect cladding features. Contingent on the measuring strategies, these points can be distributed in regular or irregular sectional lines or randomly distributed. The second step is to segment the point clouds into damaged points and nominal points. Segmentation is classifying the point clouds into a cluster that share the same label. This process often poses problems as it can lead to over-segmentation. The nominal points obtained are used to carry out surface fitting. Surface fitting is an essential step in reverse engineering that fits the points onto either a primitive surface or a free-form surface. This can be achieved by surface fitting algorithms e.g. random sample consensus (RANSAC) and square distance minimization (SDM). In the case studies developed for this project, the damaged component a cylindrical part and the parameters are obtained via surface fitting. Using this data, the points are sampled, and the surface is off-set to a predefined distance value. The repair volume is then extracted with the off-set surface, worn surface and post-processing algorithm. The next stage is to generate an optimal tool-path for laser cladding. To avoid collision and tool gouging issues, a level-set function tool-path planning algorithm will be developed and implemented. The research aims to integrate real-time sensor information with the tool-path manipulation and control to achieve zero programming and Industry 4.0-based repair technology, as desired by the resource-based industry.

Cladding and Automation

In order to automate the deposition process, a SCADA system is implemented. The hardware for this purpose includes a Siemens S7-1500 PLC, and a Controllino PLC. In the software layer we are using Siemens TIA Portal, CAD and CAM software and Vx Elements to ensure the correct flow and format of all the data including the 3D model of the part, the robot programming and signal monitoring and analysis. Figure 2 shows an overview of the previously described equipment and the interactions between hardware.

Laser cladding hardware is implemented to rebuild mechanical components with precision laser heat input and powder injection to revive worn-out parts and put them back into service. Suitable metal powder with client-specific mechanical and material characteristics is deposited onto wear-prone areas which increases the service life of the repair parts. To achieve such characteristics, parameters like travel speed, powder flow, injection angle, energy input, laser beam shape and focus length, are adjusted during the repair process.

The dynamics of the metal deposition process is non-linear and multivariate. This phenomenon imposes much challenges in the repair application along with the added uncertainty from unique wear pattern. Given this scenario tools such as nonlinear control and parametric programming, seem reasonable techniques to tackle the problem and deliver an Industry ready setup.

Classic industrial robot programming utilizes a set of predefined positions in Cartesian coordinates or axis angles for motion planning. In order for this process to achieve flexibility and compensate for measurement differences and product variations sensors can be used for dynamic adaptation of positions. This approach is especially feasible in conjunction with high product quantities. However, for low volume / high mix components it is necessary to achieve lower changeover times and to utilize the flexibility of robotics for mass customization and the production of individualized products . Our approach focuses on the combination of graphical programming of parametric geometries with robotics, which makes possible parametric robot control and mass customization of these parts. This allows us to parametrically modify the robot program according to the actual geometry of the volume extraction and toolpath previously generated. This approach enables the system to solve the limited flexibility of industrial robotics for high variations in part designs and manufacture.

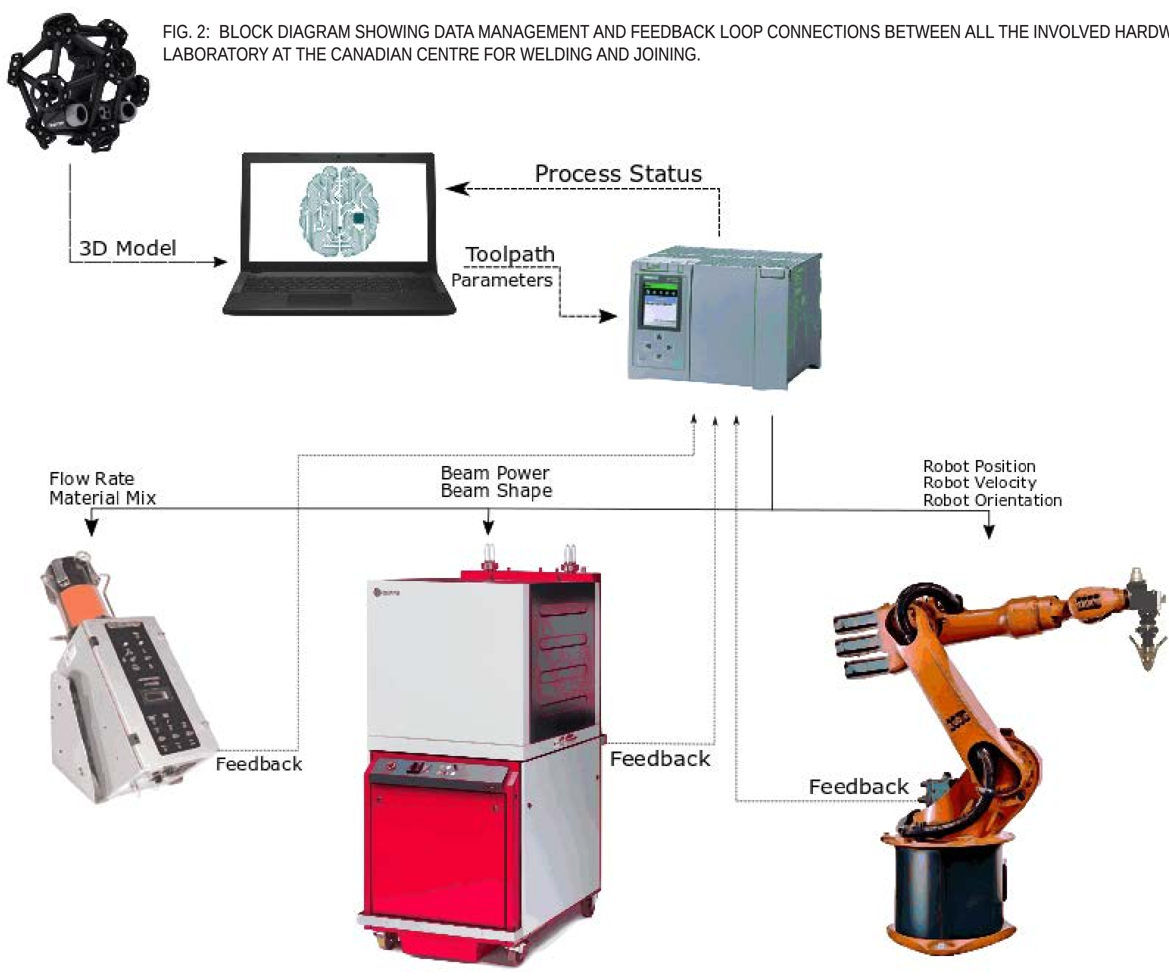


FIG. 2: BLOCK DIAGRAM SHOWING DATA MANAGEMENT AND FEEDBACK LOOP CONNECTIONS BETWEEN ALL THE INVOLVED HARDWARE PRESENT IN THE LABORATORY AT THE CANADIAN CENTRE FOR WELDING AND JOINING.

NEW FACULTY SPOTLIGHT SERIES:

FOCUS ON WESTERN CANADA

This series highlights new Canadian ME faculty members by region.
In this fall issue, research highlights from:

Dr. **Hossein Rouhani**, University of Alberta
Dr. **Matt Khoshdarregi**, University of Manitoba
and Dr. **Rafiq Ahmad**, University of Alberta

University of Alberta
Dr. Hossein Rouhani

Wearable Rehabilitative Technologies: Reverse Engineered Human to Enable Human

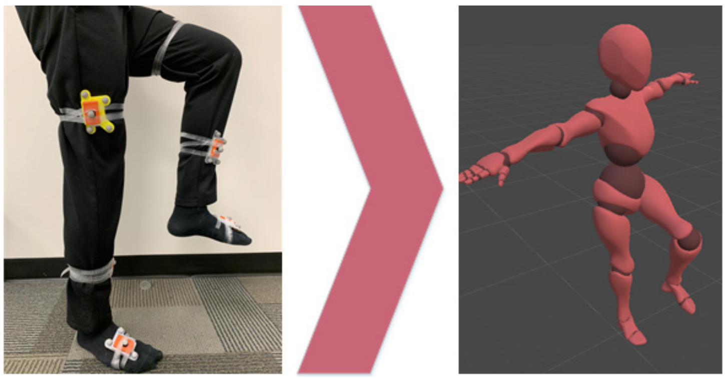


FIG. 1: BODY MOTION MEASUREMENT USING WEARABLE SENSORS.

Around four million adult Canadians suffer from physical disabilities that constrain their daily activity, independence and quality of life. Conditions such as traumatic brain injury, spinal cord injury, stroke, multiple sclerosis, amputation and arthritis can result in long-term disabilities, and consequently, the need for years of intensive healthcare services. At the same time, Canada's population growth and increasing life expectancy are resulting in an ageing population that challenges the healthcare system because of a shortage of caregivers and facilities and ever-increasing healthcare costs.

Canada's national health expenditure accounts for 11% of the national GDP. Since hospital spending accounts for the most substantial portion of the health expenditure, reducing hospital-related costs is essential to avoid a future healthcare crisis. To this end, community-based or at-home health monitoring and even intervention, using e-health and wearable technologies, can provide a solution. Such solutions are of special significance in Canada because of its geographical size and a lack of healthcare specialists in remote areas.

Despite the potential of these wearable solutions, most commercialized wearables are smartwatches, typically used for entertainment applications. There is a significant gap between commercialized wearables and approved biomedical devices. This gap is due to a lack of proven accuracy and reliability of the commercialized wearables for medical decision making and treatment. Dr. Rouhani's translational, inter-disciplinary research program aims at this gap.

Dr. Rouhani's solution to restore people's impaired motor function is to reverse engineer the human function, in a manner common in robotics. Human motion, such as walking, is controlled by the neuromuscular system, in which the sensory systems, such as vision, collect information about the body and environment. The central nervous system processes sensory information and controls the muscles in order to perform a targeted motion. Dr. Rouhani envisions wearable technologies, exoskeletons and neural prostheses that can restore normal function when this control loop is affected by trauma, disease, or ageing. His research program is focused on the following steps toward the development of wearable technologies, exoskeletons and neural prostheses. First, assessing body motion using wearable sensors. Second, using techniques such as machine learning to model the control mechanisms used by the neuromuscular system for the execution of motion. And finally, developing actuation mechanisms to move the upper or lower limbs in order to restore the impaired body motion.

Proposing innovative engineering solutions is the first stage in the development of biomedical technologies. Dr. Rouhani's research program in the Neuromuscular Control and Biomechanics Laboratory at the University of Alberta is built on three axes: knowledge/technology development; clinical validation and implementation; and technology transfer to Canadian industry. Within his translational research program, he has had several collaborative projects with the Glenrose Rehabilitation Hospital, the Toronto Rehabilitation Institute, the Institut de réadaptation Gingras-Lindsay-de-Montréal, and the University Hospital of Lausanne toward clinical evaluation and implementation of his developed technologies. His long-term goal is to see the impact of these technologies in clinical practice at numerous small Canadian clinics from coast to coast.

Dr. HOSSEIN ROUHANI, *PhD, P.Eng., MCSME*

Dr. Rouhani started as Assistant Professor in the Department of Mechanical Engineering at the University of Alberta in 2015. He earned his PhD in Biotechnology and Bioengineering from the Swiss Federal Institute of Technology (EPFL), followed by a postdoctoral fellowship at the University of Toronto. Dr. Rouhani's expertise is in the field of neuro-musculoskeletal biomechanics, biomedical instrumentation design and bio-mechatronics. He is a recipient of two postdoctoral fellowships from the Swiss National Science Foundation. He is an associate editor of the Canadian Journal of Electrical and Computer Engineering, and Frontiers in Sports and Active Living. He has had several collaborative research projects with hospitals in Canada and overseas, working towards the clinical implementation of novel rehabilitative technologies.

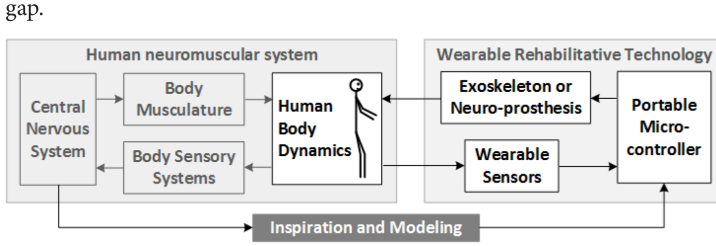


FIG. 2: WEARABLE REHAILITATUIVE TECHNOLOGIES: A DESIGN INSPIRED BY OF NEUROMUSCULAR SYSTEM

IMAGES COURTESY OF THE RESEARCHER

University of Manitoba
Dr. Matt Khoshdarregi

Intelligent Robotic Manufacturing Systems: Eliminating Manual Programming

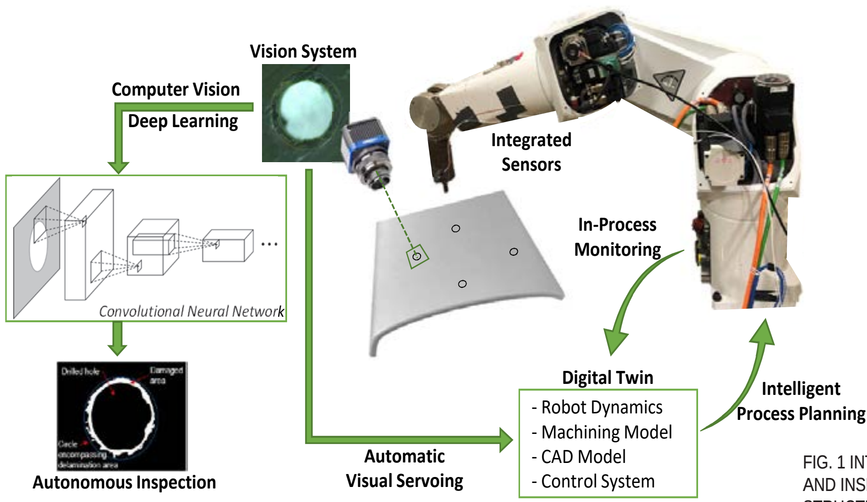


FIG. 1 INTELLIGENT PROCESS PLANNING, MONITORING, AND INSPECTION IN ROBOTIC DRILLING OF AEROSPACE STRUCTURES.

Dr. MATT KHOSHDARREGI, PhD, MCSME

Dr. Khoshdarregi is an Assistant Professor in the Department of Mechanical Engineering at the University of Manitoba. He received both his PhD and MASc degrees from the University of British Columbia, Vancouver, with a focus on machining dynamics and precision CNC design. At his current research laboratory, Intelligent Digital Manufacturing Lab (IDML), he works on integrating more intelligence into manufacturing machines by combining physics-based models, sensor fusion, computer vision and deep learning. His current focus is on autonomous process planning, in situ *monitoring, and inspection for robotic machining and hybrid additive-subtractive processes.*

IMAGES COURTESY OF THE RESEARCHER

In recent years, Artificial Intelligence (AI) has disrupted many industries including the manufacturing sector. While automation systems such as robots have long been integrated into production lines to replace human labor, the decision-making process has remained the responsibility of engineers and programmers who explicitly tell the system what to do and how to do it. However, in response to a constant demand for lower costs, faster delivery, and mass-customization, the manufacturing sector is currently undergoing a global transformation known as Industry 4.0 (the 4th industrial revolution). This new paradigm is powered by intelligent systems capable of making decisions autonomously with minimal programming and human intervention. Due to their versatility, efficiency and small footprint, industrial robots have been a centerpiece in the implementation of Industry 4.0.

At the Intelligent Digital Manufacturing Laboratory (IDML) at the University of Manitoba, Dr. Khoshdarregi and his team aim at developing manufacturing systems with autonomous decision-making capabilities. They achieve this goal by integrating physics-based virtual models (Digital Twins), sensor technology and communications (Internet of Things), and computer vision and deep learning techniques (Artificial Intelligence). Dr. Khoshdarregi's current research focuses on two main applications, namely robotic machining systems and hybrid additive-subtractive processes. His team develops AI-powered engines that allow manufacturing systems to autonomously "learn" the behavior of a process and optimize it accordingly. However, the main challenge is that machine learning techniques, e.g., deep convolutional neural networks (DCNN), require a large amount of training data, which is often impossible to collect in a manufacturing environment. To address this issue, Dr. Khoshdarregi combines scientific predictive models with real-world experimental data to train self-learning models.

As an example, his team is currently conducting research on fully autonomous robotic systems for drilling, countersinking and polishing of aerospace carbon-fiber composite panels. The goal is to develop a system that can automatically recognize a part, extract the required information from the corresponding computer-aided design (CAD) model and determine the location and orientation of the workpiece relative to the robot. The system will then determine the optimum strategy, e.g., robot pose, to achieve the highest accuracy and productivity. It will also use a fusion of sensory data to monitor the operation and make online corrective decisions. Finally, the robotic system will autonomously inspect the accuracy and quality of the final product without a need to transfer the part to a separate machine. Dr. Khoshdarregi and his team are also looking into developing a similar framework for hybrid additive-subtractive manufacturing of metal parts. In particular, their aim is to develop an intelligent framework for *in situ* process monitoring and closed loop control of additive processes using thermography, computer vision, and deep learning techniques.

University of Alberta
Dr. Rafiq Ahmad

Developing the Next Generation of Hybrid and Smart Manufacturing Systems and Production Technologies

The accelerated pace of global change and technological advancement in the manufacturing area is pushing the Canadian industry towards the digital era. The fourth industrial revolution brings unique opportunities to redefine target roadmaps based on advanced robotics, intelligent system design, smart processes and hybrid manufacturing solutions. The integration of these new technologies vows to increase productivity and efficiency, reduce greenhouse gas emissions, and increase flexibility to meet quality, cost, and customer demands.

Despite the potential benefits, industries in Canada, and particularly in Alberta, require solutions to bridge the technological gap. The Laboratory of Intelligent Manufacturing, Design and Automation (LIMDA), founded and led by Dr. Ahmad, was founded to support Canadian industry in such ventures. Aiming to provide Industry 4.0 systems and applications, the lab's research focus is the design of clean and green technologies, intelligent planning and production systems, smart Internet of Things (IoT) systems, and hybrid solutions for repair and remanufacturing.

An example of such solutions was provided for the repair and remanufacture of end-of-life parts, with the end goal of providing them with enhanced functionalities. Remanufacturing is a green technology that gives a new life to products; however, it becomes a challenging concept when damaged parts are used, as defects are often unpredictable in location and size. Thus, researchers at the LIMDA Lab developed a hybrid methodology based on automated reverse engineering, additive manufacturing and laser cladding to automate the remanufacturing process. Using data from a laser scanner, a model is reconstructed that accurately identifies the damaged areas. Then, repair areas are identified based on surface area and depth, and data-driven decisions on the repair methodology (additive or subtractive manufacturing) are made (Figure 1). This methodology was applied to the repair process of various primitive and freeform products, and its results were published in journals such as *Manufacturing Letters*, *Advanced Manufacturing Technology*, and *Computer-Aided Design*.

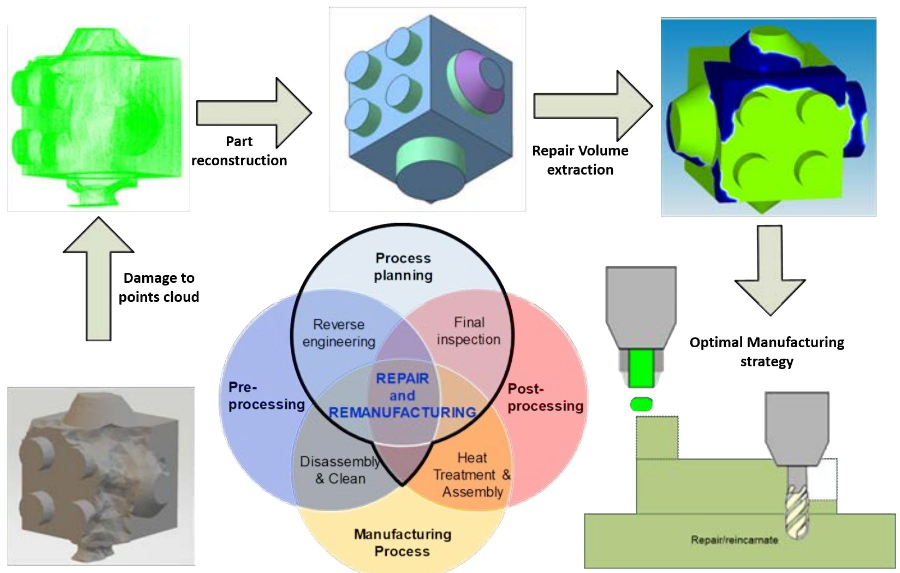


FIG. 1 LIMDA: LAB DEVELOPED A HYBRID METHODOLOGY BASED ON AUTOMATED REVERSE ENGINEERING, ADDITIVE MANUFACTURING AND LASER CLADDING TO AUTOMATE THE REMANUFACTURING PROCESS.

LIMDA's main contribution is the design and development of smart and hybrid systems and machines to meet the technologies required by the industry. The most significant advantage of pursuing these ideas in Alberta is the unique low-volume high-customization industry where Industry 4.0 research is necessary. An example of such an industry includes the construction, food and manufacturing sector. Dr. Ahmad's lab has taken an active role in supporting the rise of Construction 4.0 and Farming 4.0 in the region: from machine vision algorithms for automatic quality inspection processes to collision avoidance systems for automatic manufacturing systems, as well as Lean 4.0 management models (Figure 2). Numerous contributions have been published in high impact journals of the field, such as *Automation in Construction*.

LIMDA's future research will incorporate research in two novel areas of green and smart production systems. Using the expertise gained in previous years, researchers will explore optimal path planning for robotic laser cladding of metal alloys and online inspection processes for green remanufacturing processes. Furthermore, Dr. Ahmad's lab will lead to the development of smart machinery and systems in the food and manufacturing industry, especially focusing on developing Industry 4.0 in the aquaponics sector.

For more information, visit the group at https://sites.ualberta.ca/~rafiq1.

FIG. 2: INDUSTRY 4.0 RESEARCH; RISE OF CONSTRUCTION 4.0 AND FARMING 4.0 AS WELL AS LEAN 4.0 MANAGEMENT MODELS

Dr. RAFIQ AHMAD, PhD

Dr. Ahmad is an Assistant Professor in the Department of Mechanical Engineering, University of Alberta. Founder and director of the Laboratory of Intelligent Manufacturing, Design and Automation (LIMDA), he leads cutting-edge research on hybrid & smart systems for intelligent manufacturing and remanufacturing to enable Industry 4.0 in Canada. Dr. Rafiq is has a PhD in advanced manufacturing from Ecole Centrale de Nantes, France and a Masters in design and manufacturing from Ecole Nationale Superieure d'Arts et Metiers, France. He holds a BSc in Mechanical Engineering from University of Engineering and Technology, Pakistan. Before joining the University of Alberta, he worked as a postdoctoral researcher at the University of Luxembourg for two years, working in advanced manufacturing and automation areas.

IMAGES COURTESY OF THE RESEARCHER

HIGHLIGHTS

New Orthosis to Reduce Arm Tremor

The prevalence of pathological tremor is reported to be as high as 10% in elderly populations and can cause disability in their activities of daily living. Because pharmaceutical, surgical and ultrasound treatments to reduce tremor have varying efficacies and risks associated with them, robotic orthotic braces are an attractive alternative solution. The Menrva Research Group, led by Prof. **Carlo Menon** at Simon Fraser University, recently reported on the efficacy of their elbow Tremor Suppression Orthosis (TSO) when used by nine study participants with either Essential Tremor or Parkinson's disease[1]. The TSO controls elbow flexion/extension motions, guided by flexion/extension torques applied by the user. Key to the success of this device is its ability to separate applied torques associated with voluntary arm movements from those occurring as a result of tremor, which are treated like noise and effectively filtered out. Their tests demonstrated a 94.4% reduction in tremor power, while only increasing voluntary position and tracking errors by about 1 deg and 0.02 rad/s, respectively. More importantly, participants noticed a favorable effect of tremor suppression and expressed an interest in such a device (once the size and weight are reduced). — *Technical Editor, Prof. Ryan Willing*

HERRNSTADT G, MCKEOWN MJ, MENON C. CONTROLLING A MOTORIZED ORTHOSIS TO FOLLOW ELBOW VOLITIONAL MOVEMENT: TESTS WITH INDIVIDUALS WITH PATHOLOGICAL TREMOR. *J NEUROENG REHABIL.* 2019 FEB 1;16(1):23. DOI: 10.1186/S12984-019-0484-1.

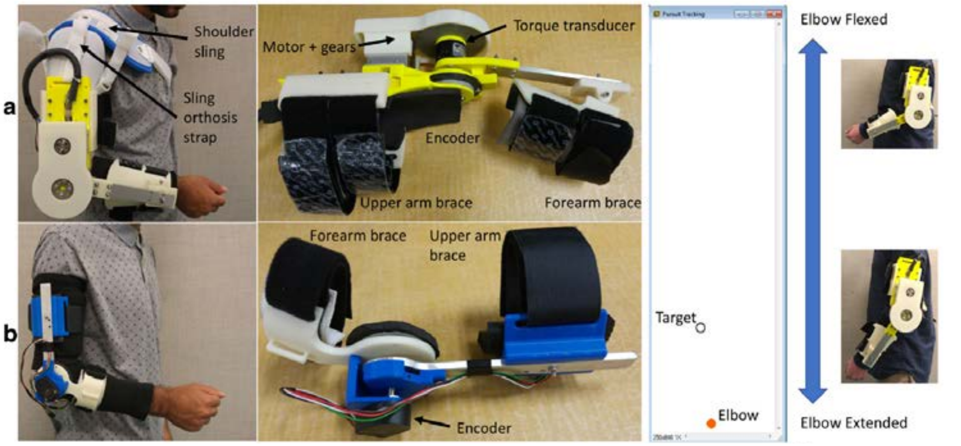


FIG. 1 ORTHOSES AND COMPUTER INTERFACE. A TSO COMPONENTS AND TSO DONNED. B MEASUREMENT-ORTHOSIS (MO) COMPONENTS AND MO DONNED. C PURSUIT TARGET GRAPHICAL INTERFACE SEEN BY THE STUDY PARTICIPANTS. CURSORS MOVED VERTICALLY. THE OUTLINED CIRCLE INDICATES THE POSITION OF THE TARGET ON THE SCREEN AND THE FILLED ORANGE CIRCLE INDICATES THE PARTICIPANT'S ELBOW CURSOR POSITION. FULLY EXTENDED ELBOW POSITION WAS CONSIDERED AS THE ZERO ANGLE AND CORRESPONDED TO THE CURSOR LOCATED AT THE BOTTOM OF THE GRAPHICAL INTERFACE WINDOW. FROM [1]. FIGURE REPRODUCED UNDER THE TERMS OF THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE (HTTP://CREATIVECOMMONS.ORG/LICENSES/BY/4.0).

Machine Learning to Improve Mobility of Patients with Parkinson's Disease

Parkinson's disease (PD) is a nervous system disorder that affects movement, with no known cure. While symptoms usually start gradually (e.g., a subtle tremor in one hand), they will typically worsen over time. Freezing of gait or "FOG" is a condition which can be experienced by advanced-stage PD patients, which they describe as feeling like their feet are glued to the ground. FOG can cause patients to fall and dramatically diminishes their quality of life. Although auditory, visual or vibrational cueing has potential for preventing FOG, it is important that such interventions only take place when needed (when FOG is about to occur), otherwise their effectiveness diminishes. Despite the challenge of predicting FOG events, an international team lead by Prof. **Arash Arami** at University of Waterloo has developed robust machine learning-based prediction techniques to potentially prevent FOG in patients[2]. By using features extracted from wearable 3D accelerometers, their subject-specific FOG prediction algorithm can predict FOG events with a sensitivity of 93% and a specificity of 91%. They anticipate that future work with more sophisticated inertial measurement units (IMUs) will improve prediction accuracy, allowing for more strategic use of cues to prevent FOG. The prediction algorithm will be implemented in the next step in a minimal wearable exoskeleton to assist step initiation when a FOG has been anticipated.— *Technical Editor, Prof. Ryan Willing*

ARAMI A, POULAKAKIS-DAKTYLIDIS A, TAI YF, BURDET E. PREDICTION OF GAIT FREEZING IN PARKINSONIAN PATIENTS: A BINARY CLASSIFICATION AUGMENTED WITH TIME SERIES PREDICTION. *IEEE TRANS NEURAL SYST REHABIL ENG.* 2019 SEP;27(9):1909-1919. DOI: 10.1109/TNSRE.2019.2933626.

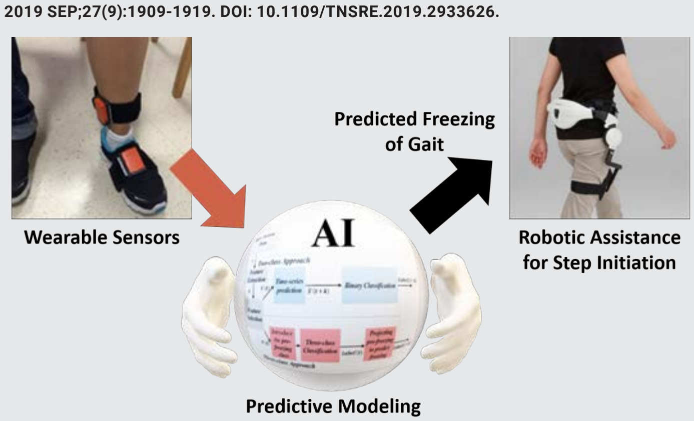


FIG. 2 PROPOSED WORKFLOW UTILIZING DATA PROVIDED BY WEARABLE SENSORS COMBINED WITH PREDICTIVE MODELLING TO PREDICT FREEZING OF GAIT (FOG). ONCE FOG CAN BE RELIABLY PREDICTED, THERE IS THE POTENTIAL TO UTILIZE ROBOTIC ASSISTANCE OR CUEING TO MAINTAIN OR RETURN TO NORMAL GAIT. FIGURE COURTESY OF PROF. ARASH ARAMI.

IMAGES COURTESY OF THE RESEARCHERS

CITY OF EDMONTON:
Camera helps identify sources of vibration complaints

ABOVE, CAMPBELL SCIENTIFIC CC5MPX CAMERA AND (TOP RIGHT) THE INSTANTEL VIBRATION MONITORING EQUIPMENT.

Each year, the City of Edmonton receives complaints and damage claims from the public concerning vibration in residential and commercial properties due to construction and traffic. The City of Edmonton takes a proactive approach to minimize and verify vibration complaints. Hundreds of ground vibration tests are conducted each year to identify sources of vibrations.

An Instantel Minimate Pro 6 vibration monitoring system is currently used to measure vibration levels for the City of Edmonton. It offers advanced monitoring technology with exceptional features and rugged design. Even though the logging system is highly accurate in identifying the time of the vibration event, it does not identify the source of the vibration which is extremely important if mitigation measures are to be implemented.

A joint effort was established between the City of Edmonton and Campbell Scientific Canada ("CSC") to better identify the source of the vibration at the exact time of the vibration event. CSC had to take into consideration that any potential equipment needed to be compatible with the Instantel vibration monitoring system, have the ability to capture the source of vibration as it occurred via a remote trigger, and be rugged enough to withstand the environmental factors of Edmonton's construction sites. CSC recommended the CC5MPX camera as the answer to our problem and now has further improved the quality and performance with the CCFC digital model. The cameras are similar with some changes: a larger built-in memory, an 18X automatic optical zoom lens, Wi-Fi capability and an easy to use web interface. Based on recent literature research, there is no available vibration system that incorporates a camera.

The City of Edmonton has vibration data and details on hundreds of construction equipment, the work processes they are involved in, and now, a more accurate identification of the vibration source. With this type of information the City of Edmonton can better address resident complaints with remedial measures that directly relate to the source of the vibration disturbances. *– Clarence Stuart, BSc QEP, Environmental Scientist, City of Edmonton (clarence.stuart@edmonton.ca)*

TOP PHOTO: INSTANTANEOUS PHOTO CAPTURE OF A TRIGGER VIBRATION EVENT. BOTTOM PHOTO: MONITORING VIBRATION LEVELS AT A CONSTRUCTION SITE WITH PHOTO CAPTURE.

Call for Nominations

Nominations of CSME peers are solicited for awards and honours of the Canadian Society for Mechanical Engineering (CSME) to be awarded in 2020. These aim to recognize and honour deserving mechanical engineering professionals who are members of the CSME. Note that members cannot nominate themselves.

At this stage, the CSME is pleased to call for nominations for these specific awards:

The Robert W. Angus Medal
Established in 1957 to recognize outstanding contributions to the management and practice of mechanical engineering.

The G.H. Duggan Medal
Established in 1935 to recognize the best paper dealing with the use of advanced materials for structural or mechanical purposes.

The C.N. Downing Award
Established in 1993 to recognize distinguished service to the CSME over many years.

The I.W. Smith Award
Established in 1977 to recognize outstanding achievement in creative mechanical engineering within 10 years of graduation.

Fellow of the CSME
A senior rank recognition awarded to members in good/uninterrupted standing in the society for at least 5 years, who have attained excellence in mechanical engineering and who have contributed actively to the progress of their profession and of society.

The nomination form is downloadable from the website (csme-scgm.ca/awards). Deadline for submission is 31 January 2020 for awards to be remitted at the banquet of the CSME Congress in Charlottetown, PE on 23 June 2020. Please do consider nominating your deserving CSME colleagues.

Transactions of the Canadian Society for Mechanical Engineering (TCSME)

I am happy to report on the 2018 and 2019 accomplishments of the *Transactions of the Canadian Society for Mechanical Engineering*, which is published by Canadian Science Publishing (CSP).

In 2018, four issues were published, and in 2019, three more issues have already been made available to date. A total of 90 papers have been published with CSP. In 2018, 295 manuscripts were submitted. This year we have already received 226 manuscripts. As of September 2019, the 90 papers published since 2018 were cited 41 times based on the Web of Science. Looking closely at the impact factor which calculates the ratio of 2019 citations of papers published in 2017 and 2018 to the total number of papers published in those two years, I am happy to report that *TCSME* is above 0.366 and will continue to increase during the fall. If *TCSME* receives 16 more citations of 2017 and 2018 papers by the end of the year, the impact factor should be above 0.500. Nevertheless, I expect a big increase in impact factor in 2020.

MARIUS PARASCHIVOIU, PhD, FCSME, FEIC
Editor-in-Chief , TCSME
Professor, Mechanical, Industrial and Aerospace Engineering
Concordia University

Heat Transfer Technical Committee

The Heat Transfer Technical Committee was happy to welcome Dr. **Sunny Li**, from UBC Okanagan, as the vice-chair of the TC. Work was also started on the TC web site (www.csme-scgm.ca/content/heat-transfer) where a list of CSME members with expertise in the heat transfer field was started; please contact the chair of the TC, Dr. **Dominic Groulx**, (dominic.groulx@dal.ca) to get your name, contact info and expertise added to the list.

In June, research papers were presented at the Heat Transfer Symposium held during the CSME-CFDSC Congress in London, Ontario. The community is again invited for next year's symposium and conference to be held in Charlottetown, Prince Edward Island.

Finally, through an electronic mailing list containing names of Canadian academic heat transfer researchers, the chair has also lead discussions on some important issues, for example: the disappearance of heat transfer textbook for undergraduate teaching, and specific heat transfer conferences. Looking ahead, we are studying the idea of submitting a proposal to host the 2030 International Heat Transfer Conference. Contact the chair if you would like to possibly participate. – *Dr. Dominic Groulx*

Biomechanics and Biomedical Engineering Technical Committee

The Biomechanics and Biomedical Engineering TC organized a successful Symposium at CSME 2019 with 42 papers presented in 7 technical sessions. The TC met during the 2019 Congress in London, ON, and discussed the mandate and scope of activities. The TC is planning to organize a successful Symposium at CSME 2020 in Charlottetown, PEI.

Current members of the Biomechanics and Biomedical Engineering TC includes **Ali Ahmadi** (University of Prince Edward Island), **Tohid Didar** (McMaster University), **Dana Grecov** (University of British Columbia), **Arman Hemmati** (University of Alberta), **Mohammad Pakanahad** (University of Toronto), **Pouya Rezai** (York University), **Dan Romanyk** (University of Alberta), **Hossein Rouhani** (University of Alberta) and **Ryan Willing** (Western University). – *Dr. Ali Ahmadi*

IN MEMORIAM
Dr. Allan Olson
(1930 - 2018)

Dr. Allan Olson, a retired faculty member (since 1996) from the Department of Mechanical and Materials Engineering at Western University died on January 13, 2018 at the age of 87. Allan was regarded as an all-around reserved, honest and dedicated teacher and faculty member by all his colleagues and students. Allan was also a proud husband, father and grandfather, and a keen golfer and accomplished snooker player. Allan will be sadly missed by all. – Dr. A.G. Straatman

CALL FOR PAPERS/ABSTRACTS:

The Canadian Society for Mechanical Engineering (CSME) invites you to submit a paper or an abstract to the 2020 CSME International Congress to be held at the University of Prince Edward Island in Charlottetown, Prince Edward Island, from June 21-24, 2020.

SYMPOSIUMS:

- Advanced Manufacturing
- Advanced Energy Systems
- Biomechanics and Biomedical Systems
- Computational Mechanics
- Engineering Design
- Environmental and Wind
- Fluid Mechanics
- Heat Transfer
- Machines and Mechanisms
- Materials Engineering
- Mechatronics, Robotics, Control and Automation
- Microtechnology and Nanotechnology
- Solid Mechanics
- Advanced Technologies for Road and Rail Vehicles

SPECIAL SYMPOSIUMS:

- Renewable Energy
- Agriculture and Machinery
- Fisheries and Ocean Technologies
- Biotechnology and Bioresources
- CubeSat
- Computational Heat and Fluid Flows: Algorithm Development and Non-standard Applications

ABSTRACT/PAPER SUBMISSION

The submissions to the Congress are in two formats:

- Abstract: 400-word maximum
- Full-length paper*: 6-page maximum

** Full-length paper submissions will be considered in the Student Paper Competition and/or Special Issue of Transactions of the Canadian Society for Mechanical Engineering.*

IMPORTANT DATES

- **January 15, 2020:** Submission of Abstract/Full Paper
- **February 28, 2020:** Notification of Acceptance to Authors
- **March 16, 2020:** Submission of Final Paper (where applicable)
- **April 15, 2020:** Early Bird Registration Deadline

For more information, visit ***www.csme2020.com*** or contact ***csme2020@upei.ca***

CSME STUDENT
& YOUNG PROFESSIONAL AFFAIRS
REPORT

THE CSME STUDENT & YOUNG PROFESSIONALS committee is supporting the CSME Student Chapters and new Chapters to gear-up for an exciting year of events, networking and outreach activities. In most recent news, there is a new CSME Student Chapter at the Chittagong University of Engineering Technology in Bangladesh. A new CSME chapter has also recently opened for Young Professionals and general CSME members in Edmonton . These new chapters and the existing CSME student chapters are planning to hold several outreach events such as volunteering in Science Fairs, industry networking events and research seminars.

During the CSME Congress at Western University in June 2019, the annual student paper competition was held. The papers presented in the Congress and written by students were evaluated and ranked on their scientific findings, creativity and communication in both their paper and presentation. Mina Hoorfar, PhD, P.Eng., Professor and Director of the School of Engineering at UBC Okanagan is the Chair of the 2019 CSME Student Paper Competition, she led the evaluation committee and judging of the papers and presentations.

1st Place *($1,000 prize)*
"Design of Passive Wind Tunnel Grids using a Prediction Model for Turbulence Intensity"
Dwaipayan Sarkar; **Eric Savory**, Western University

2nd Place *($750 prize)*
"Effect of Plastic Deformation on the Corrosion Behavior of 13Cr Stainless Steel"
Salar Salahi; **Mostafa Kazemipour**; **Ali Nasiri**, Memorial University

3rd Place *($500 prize)*
"Comparison of Commonly Used Atomization Models"
Jerry Siyu Chen; **Nasser Ashgriz**, University of Toronto

All CSME students and young professionals are encouraged to participate in the CSME congress this June in Prince Edward Island. We plan to have an industry/young professionals networking event and a workshop for the CSME student chapters. Come meet members of CSME chapters from across Canada. Keep an eye out for more details about the 2020 CSME Student Paper Competition and the 2020 National Design competition, too.

CSME STUDENT PAPER COMPETITION: SHORT-LISTED STUDENTS AT THE CSME CONGRESS IN JUNE 2019 AT WESTERN UNIVERSITY
FROM LEFT TO RIGHT: **JERRY SIYU CHEN (UNIVERSITY OF TORONTO, 3rd PLACE); RYAN BYERLAY (UNIVERSITY OF GUELPH); MEHRAN RAFIEAZAD (MEMORIAL UNIVERSITY); DWAIPAYAN SARKAR (WESTERN UNIVERSITY, 1st PLACE); YUNPENG WANG (WESTERN UNIVERSITY); MOSTAFA KAZEMIPOUR (MEMORIAL UNIVERSITY); SALAR SALAHI (MEMORIAL UNIVERSITY, 2nd PLACE).**

Please join as a CSME member, it is **FREE** for students (csme-scgm.ca/application). The Engineering Careers site (www.engineeringcareers.ca) also provides an opportunity to plan for your career. We are also looking forward to a CSME internship program for students to participate in industry.

Thank you to all the student chapter executives, volunteers and faculty mentors for your hard work! If you're interested in leading and founding a CSME student chapter at your campus, let us know. Contact us at marina.freire-gormaly@lassonde.yorku.ca or faizul.mohee@utoronto.ca or the CSME directly, we will walk you through the process. We're also looking to expand the CSME Student Affairs and Young Professionals Committee. If you're interested in helping lead activities locally or at the national level, please reach out. Do you have a great idea, story or proposal to improve the CSME student programming? Feel free to share your ideas with us!

DR. MARINA FREIRE-GORMALY, PhD, EIT, LEED GA
Chair of Student and Young Professional Affairs
Marina is an Assistant Professor at York University in the Department of Mechanical Engineering. She completed her PhD at the University of Toronto in the Department of Mechanical and Industrial Engineering. Marina's research team designs new technology for energy and water sustainability. Her research and teaching spans energy systems, nuclear, computational modelling and sustainability.

DR. FAIZUL M. MOHEE, PhD, P.Eng., PMP
Vice Chair of Student and Young Professional Affairs
Faizul is the lead structural and materials engineer at TMBN Extrados Inc. in Toronto and an adjunct professor at the University of Toronto. He completed his PhD at the University of Waterloo on mechanical anchors for composite materials and completed his master's at U of T. He has taught a machine learning, AI and big data for manufacturing course at York University and a materials science course at U of T. Faizul works in research and development for the energy, mining and nuclear industries and previously worked at Hatch, WSP and projects for OPG, Bruce Power, Terrestrial Energy, Baffinland, Stornoway, SaskPower and Emera. He is passionate about research, teaching and student engagement to build smart and sustainable infrastructure that is resilient and adaptive to climate change.

Gina Cody Research Chair in Mechanical, Industrial or Aerospace Engineering

Department of Mechanical, Industrial and Aerospace Engineering (18_C_MIAE_M)

The Department of Mechanical, Industrial and Aerospace Engineering invites applications for an outstanding candidate for the Gina Cody Research Chair at the rank of Associate or Full Professor. This call extends to all individuals with research interests related to a field in mechanical, industrial or aerospace engineering. The five year research chair is renewable and comes with an attractive research package.

Concordia University is strongly committed to building a diverse, equitable, and inclusive community, and recognizes the importance of inclusion in achieving excellence in teaching and research. Commensurate with their rank, candidates will be assessed on their demonstrated potential to attract diverse students and collaborators to Concordia University, conduct internationally-recognized research, secure research funds, as well as teach and drive curricular development within their respective area.

More information on the Department is available at: www.concordia.ca/miae. For more information on the School, please visit: www.concordia.ca/ginacody.

Qualifications
Candidates should possess Bachelor's and PhD degrees in mechanical, industrial, aerospace engineering or similar engineering disciplines. She/he shall be internationally recognized as a leader in their field, with an excellent track record in leading major research initiatives, attracting strong external funding, supervising graduate students and post-doctoral fellows and committed to excellence in teaching at both the graduate and undergraduate levels. She/he will conduct independent scholarly research, and demonstrate industrial application of their research activities. As this is a senior research chair appointment, the incumbent is expected to provide leadership in their research area through initiatives that may include large team-based grants etc. Membership or eligibility for membership in a Canadian professional engineering association, preferably in the Province of Quebec is required. The language of instruction at Concordia is English; however, knowledge of French is an asset.

How to Apply
Applications must include a cover letter clearly identifying the title and position code (18_C_MIAE_M), detailed curriculum vitae, teaching and research statements, and names of at least four referees. Electronic applications should be submitted by **January 15, 2020** and will be reviewed on an ongoing basis until a suitable candidate has been identified. Only short-listed applicants are notified. The appointment is expected to commence in July 2020 or shortly thereafter.

Concordia strives to be an inclusive institution that is welcoming of diverse backgrounds and experiences in order to improve learning, advance research, inspire creativity, and drive productivity. We define diversity broadly to include both ethnic and sociocultural background and diversity of perspectives, ideologies and traditions.

As part of this commitment to providing our students with the dynamic, innovative, and inclusive educational environment of a Next Generation University, we require all applicants to articulate in their cover letter how their professional experiences and expertise have prepared them to conduct innovative research and to teach in ways that are relevant for a diverse, multicultural contemporary Canadian society.

These ongoing or anticipated examples can include but are not limited to:

– teaching about underrepresented populations
– mentoring students from underrepresented backgrounds
– conducting research with underrepresented and / or underserved communities
– committee work
– offering or organizing educational programming
– participation in training and workshops

All applicants will receive an email invitation to complete a short equity survey. Participation in the survey is voluntary and no identifying information about candidates will be shared with hiring committees. Candidates who wish to self-identify as a member of an underrepresented group to the hiring committee may do so in their cover letter or by writing directly to the contact person indicated in this posting.

Concordia University recognizes the potential impact that career interruptions can have on a candidate's record of research excellence and will take them into careful consideration in assessing applications and throughout the selection process. Kindly forward your electronic applications to: Ms Sophie Merineau (assistant-to-chair@mie.concordia.ca). Applicants who anticipate requiring accommodations throughout any stage of the recruitment process may contact, in confidence, Nadia Hardy, Interim Deputy Provost and Vice-Provost, Faculty Development and Inclusion at vpfdi@concordia.ca or by phone at 514.848.2424 extension 4323.

Employment Equity
Concordia University is strongly committed to employment equity within its community, and to recruiting a diverse faculty and staff. The University encourages applications from all qualified individuals, including women, members of visible minorities, Indigenous persons, members of sexual minorities, persons with disabilities, and others who may contribute to diversification; candidates are invited to self-identify in their applications.

All qualified candidates are encouraged to apply; however, Canadians and Permanent Residents will be given priority. To comply with the Government of Canada's reporting requirements, the University is obliged to gather information about applicants' status as either Permanent Residents of Canada or Canadian citizens. Applicants need not identify their country of origin or current citizenship; however, all applications must include one of the following statements:
– Yes, I am a citizen or permanent resident of Canada
– No, I am not a citizen or permanent resident of Canada

Territorial acknowledgement
Concordia University is located on unceded Indigenous lands. The Kanien'kehá:ka Nation is recognized as the custodians of the lands and waters on which we gather today. Tiohtiá:ke/ Montreal is historically known as a gathering place for many First Nations. Today, it is home to a diverse population of Indigenous and other peoples. We respect the continued connections with the past, present and future in our ongoing relationships with Indigenous and other peoples within the Montreal community.

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