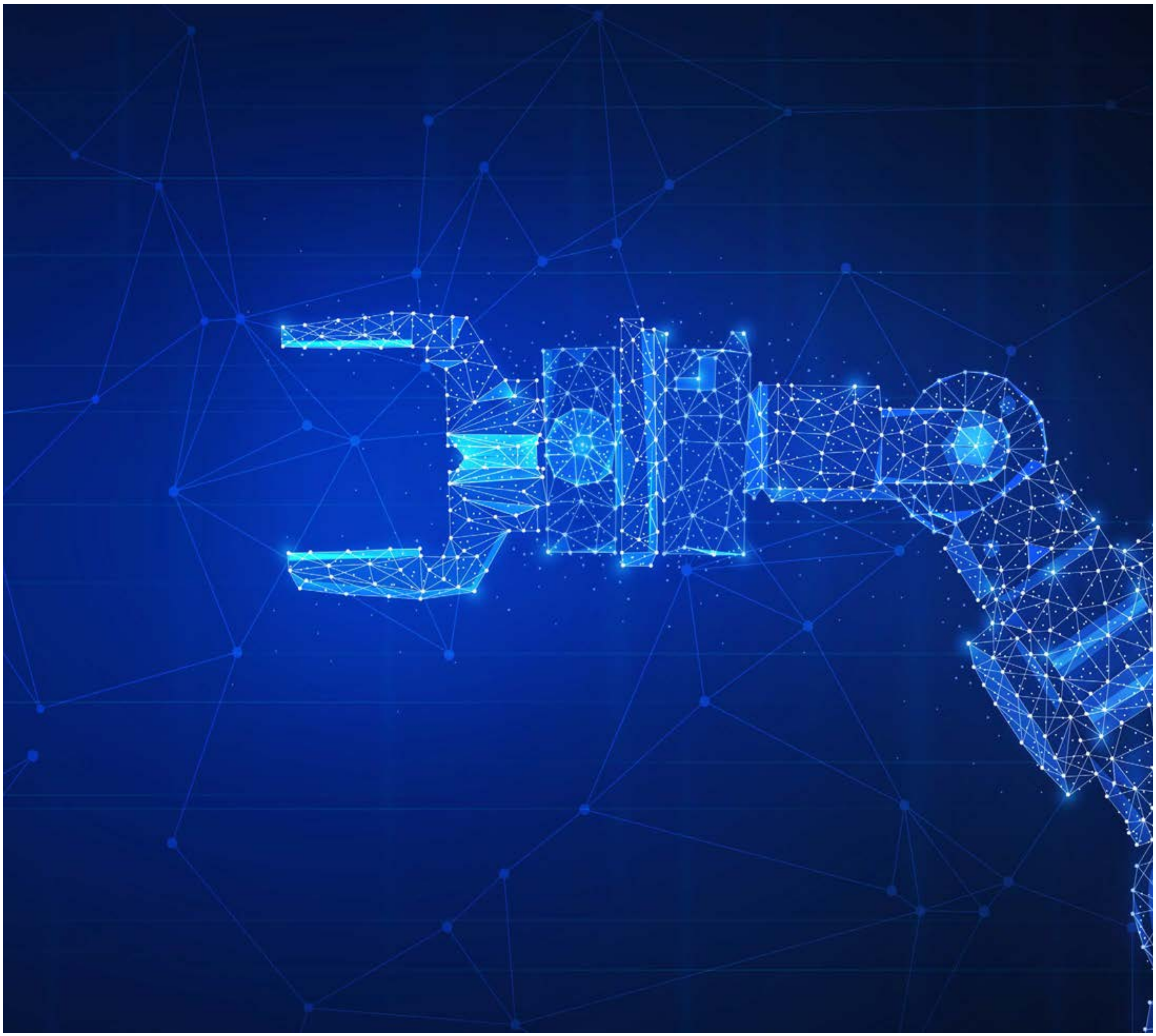
THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE
FALL/L'AUTOMNE 2022

BULLETIN



SPECIAL ISSUE ON

The Future of Robotics and Manufacturing

CONTENT

FALL/L'AUTOMNE 2022

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Guest Editor's Letter

WE WELCOME YOU TO THE FALL ISSUE OF the CSME *Bulletin*, this time dedicated to research in Robotics and Manufacturing, two topics of special interest given the current rise in prices due to disruptions in supply chains. This issue is co-edited with the CSME Technical Committees in Mechatronics, Robotics and Controls, represented by Dr. **Ehsan Hashemi**, and Manufacturing, represented by Dr. F**arbod Khameneifar**. We hope you enjoy the issue.

The main *feature article* by Dr. **Melek** provides us with a glimpse to the new generation of collaborative robots (cobots). Robots that will be able to work alongside humans by virtue of their artificial intelligence and ease of programming. Cobots are set to play an essential role for more advanced adoption of automation in different industry sectors with safe and frequent interactions with workers in a human-centric environment. Meanwhile, the *Q&A* section with Dr. **Jamshidifar** shows us how automation in warehouses will be reducing the final cost of various products, thus living costs for everyone, by minimizing the delivery/pickup time in multi-delivery tasks. In this regard, the various safety and optimality advantages of robotic solutions make them sustainable for the soaring demands in the market of warehouse automation. None of these advances would have happened without the strong mechatronics program in Canada, which the CSME history section highlights. Finally, the *ME News* section highlights exciting research on manufacturing and robotic actuators at Canadian universities.

A new generation of faculty members in Canada are also focusing on increasing automation and improving manufacturing tools. We highlight five of them: Drs. **Leyla Amiri**, **Oguzhan Tuysuz**, **Behrooz Yousefzadeh**, **Cuiying Jian** and **Ehsan Hashemi**. Dr. Amiri discusses their research on the development of advanced energy technologies for heating and cooling purposes to support sustainability requirements and address energy challenges. Dr. Tuysuz presents their research on digital machining and its impact on reducing manufacturing costs and sustainability. Dr. Yousefzadeh explains their research on novel metamaterials and devices with advanced wave-steering functionalities. Dr. Jian presents their research on upgrading heavy carbonaceous materials (HCMs) into functional materials i. Dr. Hashemi discusses their research on shared control with physical interaction between the autonomous system and human, and autonomous navigation in unstructured environments with human presence. Faculty members were once students, and we would like to encourage graduate and undergraduate students to join the CMSE student chapter. If you are interested, reach out to our new student affairs committee chair, Dr. **Romanyk**, who shares some of their exciting new plans for the committee in this issue.

Last CSME 2022 Congress was held at the University of Alberta. We have asked Dr. **Hossein Rouhani** and Dr. **Andre McDonald**, co-chairs of the event, to provide us with the main highlights of the event. We also take the opportunity to let all members know that the CSME 2023 Congress will be held at Université de Sherbrooke, Sherbrooke, Québec. Please consider attending and contributing an article to the conference. Also, consider submitting articles to the CSME *Transactions* which, as you will see in the issue, is continuing to have a strong impact factor, to the *Technical Committees*; and, of course, to the CSME *Bulletin*. A call for contributions to the CSME *Bulletin* will be made in December.

The next CSME *Bulletin* issue will discuss the **Future of Transportation** and will be led by the Transportation Systems and Eng Analysis & Design Technical Committees. Please let the CSME editors know your suggestions for future issues.

We hope you enjoy this issue of the CSME *Bulletin*.

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

President's Message

Message du présidente

PHOTO: LASSONDE SCHOOL OF ENGINEERING

Dear CSME Members,

This is my first letter as President of the Canadian Society for Mechanical Engineering (CSME). I hope everyone has had a good summer, with the opportunity to take some time off to enjoy the longer daylight hours and rest from a very different and challenging year of remote, hybrid, asynchronous, synchronous experiences for all of us. I can imagine each of us has all sorts of plans for a return "back to normalcy" while still weathering the post-pandemic challenges.

In June 2022, I took presidential responsibility. This is an exciting time to be a part of mechanical engineering as a whole and CSME in particular. Our membership base has grown to over 4000 through the recruitment of many student members. Presently we have 34 mechanical departments/schools on board with CSME across Canada.

I am happy to inform you that the next senior vice-president of CSME is Prof. Ali Ahmadi, a long-term volunteer of CSME and Congress Chair. I would like to thank the Past President, Prof. Mina Hoorfar and several past Board Members for their contributions and dedication. At the same time, I am confident that our existing CSME leaders will continue taking our organization to new heights. I can feel the new energy and vigour in society and countless volunteers who are putting a huge amount of their time into ensuring a stronger and brighter future for society.

The 2022 CSME Congress was organized by colleagues from the University of Alberta, attracting over 300 participants. The 2023 CSME Congress is organized by colleagues from Université de Sherbrooke – and it will take place on 28-31 May 2023. I expect our professional network to continue to grow. I will be happy to see many of our members attending our flagship event in the beautiful city of Sherbrooke and learn how you would like to shape the next years of our amazing technical organization.

Sincerely,

ALEKSANDER CZEKANSKI, PhD, MBA, P.Eng., FCSME, FEIC, FCEEA
CSME *President*
Associate Professor, Mechanical Engineering
Lassonde School of Engineering, York University

Welcome new CSME / SCGM members

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Mr. Osama Elnahrawi, *Rabigh Power Plant* (Saudi Arabia)
Mr. Hasan Ghaddar, *Team Pro* (Lebanon)
Prof. Liying Jiang, *Western University*
Prof. Kui Jiao, *Tianjin University* (China)
Prof. *Mohammad Khondoker,* University of Regina
Mr. Elias Kuruvila Sunny, *Polar Sapphire Ltd.*Prof. Haoxiang Lang, *Ontario Tech University*
Mr. Alexander Vladimisky, *Buhler Versatile Industries Inc.*

Chers membres de la SCGM,

Ceci est ma première lettre en tant que président de la Société canadienne de génie mécanique (SCGM). J'espère que tout le monde a passé un bon été, avec la possibilité de prendre du temps pour profiter des heures de clarté plus longues et se reposer d'une année très différente et stimulante d'expériences à distance, hybrides, asynchrones et synchrones pour nous tous. Je peux imaginer que chacun de nous a toutes sortes de plans pour un retour « à la normale » tout en continuant à surmonter les défis post-pandémiques.

En juin 2022, j'ai pris la responsabilité présidentielle. C'est une période passionnante pour faire partie de l'ingénierie mécanique dans son ensemble et de la SCGM en particulier. Notre base de membres est passée à plus de 4000 grâce au recrutement de nombreux membres étudiants. Actuellement, nous avons 34 départements/écoles de mécanique en tant que membres supporteurs à travers le Canada.

Je suis heureux de vous informer que le nouveau vice-président sénior de la SCGM est le professeur Ali Ahmadi, un bénévole de longue date de la société et président du Congrès 2021. Je tiens à remercier la présidente sortante, la professeure Mina Hoorfar et plusieurs anciens membres du conseil d'administration pour leurs contributions et leur dévouement. Dans le même temps, je suis convaincu que nos dirigeants actuels de la SCGM continueront d'amener notre organisation vers de nouveaux sommets. Je peux sentir la nouvelle énergie et la vigueur de la société et les innombrables bénévoles qui consacrent énormément de leur temps à assurer un avenir plus fort et plus brillant pour la société.

Le Congrès 2022 de la société a été organisé par des collègues de l'Université de l'Alberta, attirant plus de 300 participants. Le Congrès 2023 est organisé par des collègues de l'Université de Sherbrooke – et il aura lieu du 28 au 31 mai 2023. Je m'attends à ce que notre réseau professionnel continue de croître. Je serai heureux de voir plusieurs de nos membres assister à notre événement phare dans la belle ville de Sherbrooke et d'apprendre comment vous aimeriez façonner les prochaines années de notre incroyable organisation technique.

Cordialement,

Aleksander Czekanski, PhD, MBA, PEng, FCSME, FEIC, FCEEA
Président de la SCGM
Professeur agrégé, Génie mécanique
Université York

Message from the Congress Chair and Co-Chair

DR. HOSSEIN ROUHANI, PhD, P.Eng.
CSME2022 Congress Chair

DR. ANDRÉ McDONALD, PhD, BS LAW, P.Eng., CEng, PE, FASM, FIMMM, FIMECHE
CSME 2022 Congress Co-Chair

PHOTOS COURTESY OF THE CONGRESS CHAIR AND CO-CHAIR

THE 2022 CSME INTERNATIONAL CONGRESS was held on June 5 – 8, 2022, at the Faculty of Engineering of the University of Alberta in Edmonton, AB. This Congress was composed of five plenary lectures, 14 keynote lectures, four workshops, and 280 podium presentations in 68 technical sessions within 16 symposiums. In addition, social events were organized every evening along with tours of various research facilities. The Congress took place in accessible facilities of the Engineering Teaching and Learning Complex (ETLC) and the Electrical and Computer Engineering Research Facility (ECERF).

The Congress started on Sunday, June 5, 2022, with four workshops offered in the morning and afternoon, followed by a social event in the evening. Monday, June 6 started with the opening ceremony, followed by two plenary lectures and 30 technical sessions. Then, a presentation was offered on NSERC grant programs by NSERC program officers. Finally, the reception ceremony was held in Dinwoodie Lounge, where we hosted the award reception ceremonies for the CSME Fellowships, CSME Student Paper Awards, and CSME National Student Design Awards. On Tuesday, June 7, we organized one plenary lecture and 25 technical sessions. Then, the banquet ceremony was held at the beautiful Fairmont Hotel Macdonald along with other award reception ceremonies. On Wednesday, June 8, there were two plenary lectures and 25 technical sessions, followed by the closing ceremony after lunch.

We were proud to organize a Congress program that included activities on Equity, Diversity, Inclusion and Decolonization (EDID). This included four sessions on EDID in Engineering Education & Research Symposium with 14 invited speakers and panellists, a 'power hour' on "Breaking Barriers in Recruitment, Mentorship, and Career Planning" with four invited panelists, and a workshop focused on the "30 by 30" Initiative.

We published the presented research studies in the ***Progress in Canadian Mechanical Engineering Volume 5*** series. These Proceedings were published by the University of Alberta library and each paper received a unique DOI number.

We would like to thank the CSME community, especially the CSME Board of Directors, for providing us with the opportunity to host this Congress, the CSME Congress Committee for supporting us with their advice and experience from previous CSME Congresses, and the CSME 2022 Scientific Committee for supporting us through review of manuscript submissions and serving as Symposium Chairs/co-Chairs. We would also like to thank our colleagues at the University of Alberta, especially the Dean of Engineering, Dr. Simaan Abourizk, the staff of the Dean's Office, the Department of Mechanical Engineering, the Student Organizing Committee and all volunteers for their gracious support.

We express our sincerest gratitude to our sponsors and supporters, particularly the Faculty of Engineering at the University of Alberta for their Platinum sponsorship and HADLAND Imaging for their Gold Level sponsorship of the CSME 2022 Congress.

2023 joint CSME / CFDCanada International Congress

May 28-31, 2022 (www.csmecongress.org)

Université de Sherbrooke, Sherbrooke, Québec

Symposia:

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- Biomechanics and Biomedical Engineering
- Computational Mechanics
- Engineering Analysis & Design
- Environmental Engineering
- Fluid Mechanics
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- Materials Technology
- Mechatronics, Robotics & Controls
- Microtechnology and Nanotechnology
- Solid Mechanics
- Transportation Systems
- EDI initiatives in higher education and research
- Energy efficiency in Nordic greenhouses
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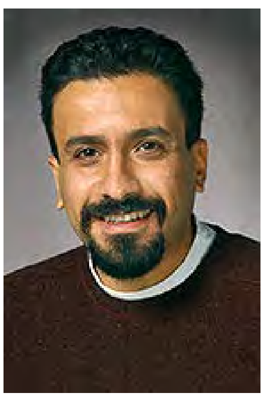
* 6-page papers can be considered in the Student Paper Competition and/or in Special Journal Issues

COLLABORATIVE ROBOTICS, CAPABILITIES AND APPLICATIONS

FIG 1: EXAMPLES OF COLLABORATIVE ROBOTICS SYSTEMS IN THE ROBOHUB (UNIVERSITY OF WATERLOO): A) HUMANOID ROBOT AND B) COLLABORATIVE ROBOTIC ARMS WITH THREE FINGER GRIPPERS.



DR. WILLIAM W. MELEK , PhD

William W. Melek (SMIEEE) is a professor, University Research Chair and director of RoboHub at the University of Waterloo. He is and an expert on robotics, artificial intelligence, sensing, and state estimation. He earned his doctorate in mechanical engineering from the University of Toronto in 2002, and then led the Artificial Intelligence Division of Alpha Laboratories Inc. He founded University of Waterloo Laboratory of Computational Intelligence and Automation in 2004 and was awarded the Young Engineer Medal of Professional Engineers Ontario in 2006. He is the past President of the North American Fuzzy Information Processing Society (NAFIPS), and a senior member of the Institute for Electrical and Electronics Engineers (IEEE). Dr. Melek developed Canada's first industry-ready modular reconfigurable robot (MMR); the state-of-the-art open architecture system is now used in the automotive sector. He has also led the way in designing practical, intelligent and adaptive control architectures for MMRs based on neural networks. Conceptual prototypes have been developed for the nuclear industry in the United States. He holds twelve Canadian and U.S. patents, and his contributions to the manufacturing industry have been featured in the National Post, The Globe and Mail *and CBC television.*

IMAGES COURTESY OF THE RESEARCHER

INTRODUCTION

A robot is a machine which can be programmed to complete a task, while the term robotics describes the field of engineering concerned with developing robots and automation. Each robot has a different level of autonomy. These levels range from human-controlled robots that carry out tasks to fully-autonomous robots that perform tasks without any external intervention.

Robotics adoption in different industry sectors is growing as we begin to drop restrictions associated with the COVID-19 pandemic, which disrupted several industries for a good part of two calendar years, and efforts to recover the global economy continue. According to a recent report by the international federation of robotics[1], we are seeing strong order intakes for industrial robotics systems in the third quarter of 2022 which is expected to carry over to 2023. Also, we are seeing strong Government incentives in developed countries to support the adoption of automation, which is a key pillar of Industry 4.0, i.e., NextGenerationEU[2]. Moreover, there is continued demand from the electronics industry to produce higher throughout electronic products and components. Other drivers for increased adoption of robotics and automation in the manufacturing and other industry sectors include the growing demand for steel and metal products. Advances in adjacent technologies such as Cloud computing, 5G networks (and sub- 6G), new machine vision, and artificial intelligence expanded the range of applications which can benefit from robotics and automation.

In terms of sustainability, robots are crucial for cost-efficient production of green technology, e.g., solar panels. Modern robots use less energy due to: 1) lightweight construction of moving robot components, 2) use of intelligent power-management systems for these robots, e.g., smart parking positions, and 3) new, energy-optimized end-of-arm tools such as grippers with almost no energy consumption.

SERVICE ROBOTICS

The two main classes of robots based on area of application are: 1) industrial robots, and 2) service robots. These robots can further be classified into one of two categories in terms of level of interaction with humans and ability to perceive their environments and plan their tasks accordingly. These categories are: a) traditional robots which are often physically separated from humans through fencing or can co-exist with humans who cannot enter the robot workplace, and b) collaborative robots which can interact with humans to perform tasks in a cooperative or collaborative manner. In specific terms:

- **(A)** *Traditional Robots* seen in industry are usually fixed installations which perform repeatable tasks that are rarely changed. The interaction with worker happens only during programming. They are profitable to industry only with medium to large lot size. Industrial robots come in different sizes, degrees of freedom and payload carrying capacity depending on the task and application requirements. They can often operate at very high speeds and require physical segregation from the human operators while performing the programmed task(s). Examples of these robots include the Fanuc M-900 articulated arm used by manufacturing and automotive industry in heavy assembly, welding and loading tasks.
- **(B)** *Collaborative Robots*, on the other hand, allow for flexible relocation of the robotic setup and frequent task changes. With minimal training, they are easy to use and program. They offer safe and frequent interaction with workers and can be profitable even at single lot production. They are usually small and slower than their traditional industrial counterparts. Examples of some of the classes of collaborative robots can be seen in *Figure 1*.

Many service robots nowadays have built in controls and intelligence to be categorized as collaborative robots. Service robots are seeing growth in terms of the range of sectors which started exploring their adoption[3]. Some of the applications of service robots include: 1) delivery robots; 2) cleaning and disinfecting robots such as Roomba cleaning robots[3]; 3) medical and rehabilitation robotics; 4) social robots telepresence; and, 5) automated restaurant robots which are used for staff support as well as to reduce personal/contact with food.

COLLABORATIVE ROBOTICS

The next generation of industry will require flexible and adaptable manufacturing environments. Industry 4.0 architecture can provide customizable and reconfigurable services to enable a highly integrated human-machine collaborative system. Typical traditional industrial robots are replaced by a more intelligent system; collaborative robots, a.k.a, "cobots". A cobot is often viewed as a machine that humans can touch and interact with. Cobots have features that can enable various levels of human-machine interaction (HMI) in industrial applications. At present, collaborative applications are very limited in production facilities. Currently, human workers and robots primarily work alongside each other in a form of coexistence. A new generation of cobots has the potential for a more responsive collaboration while maintaining the advantages industrial robots possess in terms of sensing and payload carrying capacity.

Cobots have started to make an impact on the largest sector for industrial robots: The automotive industry. Forecasts for the annual revenues of cobots suggest global revenues of $7.6B by 2027[3]. Even more optimistic revenues of $9.2 B by 2025 are predicted. Climate change, shrinking workforces, and aging population are going to increase the already rapid technological development within the manufacturing industry.

Human workers and cobots can safely share the same workspace. Using cobots, companies can save on costly feed systems and production space. When people and robots work together, conventional safety measures to ensure separation between human and machine can be relaxed. In the event of unexpected contact, for example, collaborating robots reduce their speed and thus also their kinetic energy. By removing fencing and restriction on accessible space for working, highly efficient and far more flexible tasks can be realized: from industrial work assistants to service robots in public spaces, and from personal assistance robots in clinical environments to robotic systems at home which can support independent living.

Cobots are set to play a paramount role in shaping the response to global trends which call for more advanced adoption of automation in different industry sectors. One of the most important developments directly linked to the improvement in collaborative robots in manufacturing is 5G technology. In flexible manufacturing environments where a group of cobots can be utilized at different workstations to perform a variety of tasks in a human-centric environment, it is essential to ensure to deploy a network connectivity solution that can support a fleet of continuously communicating robotic systems as well as maintain a low latency under circumstances where these robots need to share information about the workspace or receive real-time commands from the human. Therefore, the need for a dedicated private and powerful 5G network able to cope with the demands of advanced manufacturing is something OEMs are beginning to examine for increased productivity in flexible and agile production environments.

TASK ASSIGNMENT FOR COLLABORATIVE ROBOTS

Many developed countries are experiencing accelerating demographic shifts, with an aging population and a decrease in how many people are able and/or willing to perform the often dull, difficult, or dangerous jobs. Robots, particularly those that are collaborative, communicative, and interactive, are a leading contender for reducing and/or eliminating the demands of these tasks to make work and jobs more rewarding and productive, and support shifting requirements to facilitate remote work. The current advances in human-robot interaction (HRI) and engineering techniques have demonstrated the feasibility of collaborative robotics as effective task-completion tools. Physical tasks assigned to collaborative robots are defined in terms: 1) Automation: the robot relieves a person from having to do simple, repetitive tasks; 2) Teleoperation: the robot carries out physical actions in a remote location from an operator; and 3) Augmentation: the robot enhances a person's physical capabilities (e.g., speed and strength).

Ensuring these physical tasks can be carried out by robots in a manner that is safe, reliable, and predictable requires the development of advanced software and hardware, which must be incorporated into the robot and its interface. Cobots perform their tasks through interaction with workers, but how can we ensure efficient and ergonomic interaction? To enable HRI, we need a computational framework for intuitive human-robot teaching and interaction scenarios that: 1) communicate effectively the context and the state of the robot, including its current state, goals, confidence, abilities and 2) inform the worker of any information that the robot is lacking to achieve its goal safely and reliably. However, the main challenges associated with bringing cobots to technological readiness include the need for:

a) ensuring worker safety and comfort,
b) generating robust and reactive robot motions adapted to unstructured environments,
c) maintaining reliable communication between worker and robot, especially for teleoperation applications where the connection may be unreliable, and
d) allowing robot re-programming by people with different levels of expertise.

As mentioned earlier, one of the main advantages of collaborative robots is the ability of a worker to easily program it with little prior programming experience. These systems require development of an accessible two-layer user interface. The first layer will allow a worker to intuitively interact with the robot and adjust its tasks, e.g., learning from demonstration, while the second layer provides direct access for engineers and technicians to program the robot. An example of an intelligent-based motion planning approach for collaborative robotic arms can be seen in *Figure 2*.

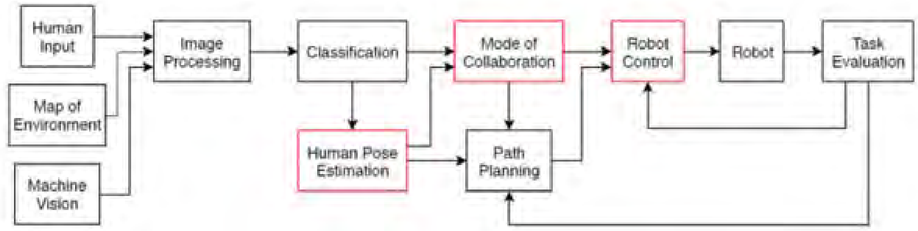


FIG 2: AN EXAMPLE OF AN INTELLIGENT-BASED MOTION PLANNING APPROACH FOR COLLABORATIVE ROBOTIC ARMS. CLASSIFICATION IS PERFORMED THROUGH MACHINE LEARNING TO IDENTIFY OBJECTS OF INTEREST IN THE ENVIRONMENT SUCH AS HUMAN, ROBOT, WORKBENCH AND OBJECT(S) TO BE MANIPULATED. MODE OF COLLABORATION CAN BE: 1) HUMAN ALONE, 2) ROBOT ALONE OR 3) HUMAN AND ROBOT COLLABORATION.

SUMMARY

Collaborative robots will play a key role in Industry 4.0. However, a factory staffed by robots alone is not something we can expect to see anytime in the near future, even in the advent of smart factories. Human workers will remain the central focus while robots will play a bigger role in relieving and supporting human workers especially when dealing with dull, dirty and repetitive tasks. In this collaborative, and human-centric environment, people will be able to go about their work more efficiently and, above all, more ergonomically. This aspect is becoming increasingly important, especially in light of the accelerating demographic shifts and the aging population. An ever-smaller number of people being employed means that we still have to ensure that we can generate the entire productive output for the social systems. This poses a challenge that can only be overcome by employing the available workforce more productively than ever before.

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HIGHLIGHTS

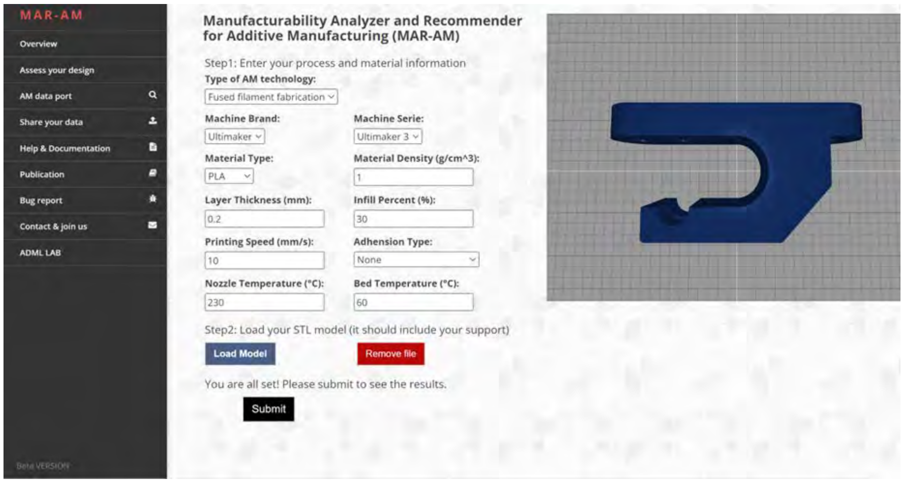

FIG. 1: A SCREENSHOT OF THE MANUFACTURABILITY ANALYZER AND RECOMMENDER FOR ADDITIVE MANUFACTURING (MAR-AM) WEBSITE, DEMONSTRATING THE TYPES OF MATERIALS AND PROCESS INFORMATION THAT, ALONG WITH PART GEOMETRY, IS USED TO PREDICT PART MANUFACTURABILITY.

WEBSITE SCREENSHOT USED WITH RESEARCHER PERMISSION

Web-Based Tool for Predicting and Improving Manufacturability of 3D Printed Parts

Additive manufacturing (AM) using 3D printers is increasing in popularity as the costs of consumer-level and industrial 3D printers decreases and more free-to-use 3D design tools are being developed. These manufacturing technologies can lower the costs associated with goods by allowing on-demand and distributed manufacturing, reduced setup time, and easy sharing of designs. One barrier to more widespread use of these manufacturing technologies is the amount of intuition needed when designing parts for manufacturability. While rules and checklists have been developed to assess the likelihood that a part can be successfully manufactured using a 3D printer, these are not suited to novice users and do not provide feedback to the user on how to improve manufacturability. Recent work by **Ying Zhang** and **Yaoyao Fiona Zhao** at McGill University aims to lower the bar to entry into the world of 3D printing by developing a web-based tool for analyzing and recommending strategies to improve the manufacturability of part designs[1]. The beta version of their automated manufacturability analyzer and recommender for additive manufacturing (MAR-AM) is accessible online (http://mar-am.com/mar, *Figure 1*) and employs a hybrid machine learning (ML) model. Their tool will consider the part geometry, materials and print machine settings to determine manufacturability, which for the time being refers to the ability of the part to be created without aesthetic defects. Furthermore, if the print job is predicted to fail, their tool will analyze alternative printing strategies and return suggestions which, based on ML predictions, should succeed. While still under development, the beta version of MAR-AM performed well at predicting failure and suggesting viable solutions to enable manufacture for a case study of 11 different parts. As tools like this develop, they will be capable of considering a wider variety of AM techniques, more design and process parameters, and more nuanced metrics of success. This will shorten the development cycle of additively manufactured parts and expand the usability of AM technologies to a wider audience; an important step towards democratizing manufacturing. — *Technical Editor, Prof. Ryan Willing, MCSME*

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Novel Low-Cost Actuators that are Recyclable, Reconfigurable and Recoverable

While most industrial robotic systems are built for rigidity, soft fluidic actuators typically consist of elastomeric materials with embedded flexible materials. These types of actuators are easily customized, lightweight, and low cost. Inexpensive silicone rubbers are usually the materials of choice for these actuators, which are fabricated using a multi-step molding process, although alternative thermoplastic elastomers have been seeing increased usage as they can be fabricated using 3D printers. Unfortunately, these are not common commodity materials that can be disposed of through typical recycling waste streams. **Dan Sameoto** and his team at University of Alberta have been considering polypropylene as an alternative due to its ubiquity within many consumer goods and, therefore, established recycling facilities. In their recent article[2], his team describes recyclable, reconfigurable and recoverable vacuum actuated muscle-inspired pneumatic structures (R3VAMPs), made from polypropylene and polypropylene co-polymers. Their design incorporates a 3D printed polypropylene patterned infill structures contained within a thin polypropylene sleeve. The infill materials can be reconfigured in a variety of manners, such that when a vacuum is created within the sleeve, it will cause the actuator to either contract, stiffen or bend; all these modes are described with example experimental results in their article. Most impressive, the raw materials for an actuator cost as little as $0.25 and are recyclable. They propose that systems like these could become building blocks for wearable, collaborative or disposable robotics as each can be reconfigured and repurposed for a desired function, lowering costs for end users. — *Technical Editor, Prof. Ryan Willing, MCSME*

Advanced Energy Systems

– *Dr. Xili Duan*, FCSME

The main activities of the AES TC over the past six months include:

- Supported the CSME International Congress 2022 held at the University of Alberta, by organizing the Symposium on Advanced and Future Energy Systems.
- Participated in the preparation for the CSME International Congress 2023 to be held at the Université de Sherbrooke.
- Supported the CSME *Transactions* published through the Canadian Science Publishing (CSP) by handling the review of submissions in the field of energy systems.
- Organized two online seminars (in June and September 2022) of the CSME Heat Transfer and Energy Systems Seminar Series jointly with the Heat Transfer Technical Committee.

Engineering Analysis and Design

– *Dr. Aman Usmani*, FCSME

- The TC Chair, Vice Chair and members are in place.
- TC Chair Aman Usmani and Vice Chair Hamid Akbarzadeh held a meeting to discuss and plan for the TC activities such as topical seminars and the 2023 Symposium
- A Zoom meeting of the full TC is being planned in November
- Attempt is underway to identify and nominate the Symposium vice chair. Local candidate from the University of Sherbrooke has not been possible yet.

Thanks to Professor Sabastien Poncet, the call for Symposium 2023 has been prepared with the following Schedule/deadlines:

- **January 15, 2023**: Submission of Abstract/Full Paper
- **March 6, 2023**: Notification of Acceptance to Authors
- **March 20, 2023**: Submission of Final Paper (where applicable)
- **April 6, 2023**: Early Bird Registration Deadline

More information, can be found on www.csmecongress.org

- As with Aman Usmani's past participation in the Canadian Nuclear Society (CNS), various CNS conferences are being planned including as deputy chair of the Structural Mechanics in Reactor Technology (SMiRT) 28th International Conference in August 2025 in Toronto.

Materials Technology

– *Mamoun Medraj*, MCSME

The activities for the Materials TC for this year are as follows:

1. The materials technology symposium that will be chaired by Ali Niasiri.
2. Committee membership: Invite professors from the universities not on the list. We looked at the current membership in our committee and noticed that we are missing reps from many universities.
3. Lecture series: we plan to start this activity and invite one professor from each Canadian university that has materials research or teaching activities within the Mechanical Engineering Dept. to inform our community about the various materials related research done in our mechanical engineering departments.

Manufacturing Technical Committee (TC) Report

– *Farbod Khameneifar*, MCSME

Dr. Khameneifar has been the TC chair since June 2022 (after the 2022 CSME Congress). Current activities:

1. The TC chair has launched and organized the first-ever CSME webinar series on Manufacturing since September 2022. Prof. Lihui Wang (professor and chairholder at KTH, Sweden, and the editor-in-chief of Robotics and Computer-Integrated Manufacturing and Journal of Manufacturing Systems) gave a talk on September 22, 2022, as the first invited speaker of the webinar series.
2. Acting as an associate editor of the *Transactions of the Canadian Society for Mechanical Engineering* (TCSME).
3. Acting as a co-guest editor for the CSME *Bulletin* to be published in November 2022.

Future activities:

1. Organizing the Manufacturing symposium at the 2023 CSME Congress at the Université de Sherbrooke.
2. Continuing the CSME webinar series on Manufacturing with international and national invited speakers.

Transportation Systems

– *Dr. Yuping He*, FCSME

CSME 2023 Congress

n October 17, the online TC meeting was held to discuss the themes of the Symposium on Transportation & Automotive Engineering at 2023 CSME Congress at University of Sherbrooke, QC, Canada, May 28-31, 2023.

ii. *TCSME*

- An associate editor

iii. Plans for the next 6 Months

- Dr. Yuping He (TC chair) and Dr. Bruce Minaker (TC vice chair) will be guest editors for the spring 2023 issue of the CSME *Bulletin*.

SPOTLIGHT ON NEW FACULTY

RESEARCH HIGHLIGHTS FROM ACROSS CANADA

Interested in being featured? Contact the editors: secanell@ualberta.ca & prezai@yorku.ca

Université de Sherbrooke
Dr. Leyla Amiri

Rock thermal energy storage: A novel sustainable energy solution for a net-zero emission society

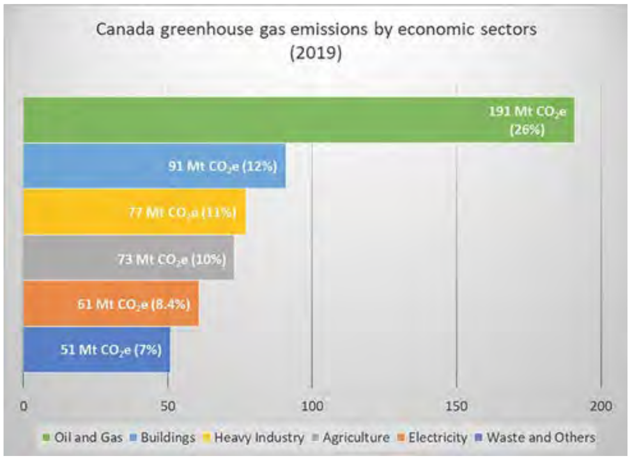

FIG. 1: CANADA GREENHOUSE GAS (GHG) EMISSIONS

LEYLA AMIRI, PhD

Dr. Leyla Amiri is an Assistant Professor in the Department of Mechanical Engineering at Université de Sherbrooke. She obtained her PhD in Mining Engineering from McGill University in 2019. In 2020, she received the prestigious Izaak Walton Killam Post-Doctoral Fellowship at Dalhousie University. In 2021, she joined Université de Sherbrooke as the inaugural recipient of the Claire-Deschênes Postdoctoral Fellowship. The focus of her research is on the development of advanced energy technologies for heating and cooling purposes.

PROBLEM STATEMENT

Canadian residential buildings account for 17% of national energy consumption, 19% of which is consumed for water heating and 61% for space heating[1]. Canada's nationally determined contribution (NDC) aims to reduce greenhouse gas emissions by 40% below 2005 levels by 2030[2]. The total Canada greenhouse gas (GHG) emission in 2019 equalled 730 Mt CO_2 (*Figure 1*)[2]. The expectation is that upcoming environmental and regulatory factors will require buildings to adopt more sustainable heating and cooling systems imminently.

Investing in energy efficiency and renewable and alternative energy sources in the building sect or will result in immediate benefits and will go toward a net-zero carbon emission society. Buildings face technical, economical, and environmental challenges in their respective energy sectors, which need to be addressed to guarantee sustainable sector growth.

OBJECTIVES

The integration of renewable energy sources has been explored in numerous studies as a promising option for meeting heating and cooling energy demands in different sectors[3,4]. However, challenges in applying renewable energy technologies are associated with the intermittent availability of renewable energies. Thus, thermal energy storage (TES) systems are a critical technology in enabling the deployment of renewable energies to minimize mismatches between energy supply and demand. Among different types of TES systems, rock thermal energy storage (RockTES) is the most effectively applied technology for long-term energy storage due to its ability to hold large amounts of energy at significantly high temperatures and relatively low costs[5]. Therefore, the main objective focuses on the fundamental and applied aspect of thermal energy extraction and storage using sensible heat (e.g., limestone as a storage material) for renewable heating and cooling systems. The fundamental coupling of flow and heat transfer in RockTES is evaluated at various scales by developing an advanced numerical model to accurately predict heat flow between air and the rocks. Dr. Amiri's laboratory aims to develop technologies that can support the sustainability of Canadian society in challenging environments and address the associated energy challenges particularly for building sectors.

METHODOLOGY

Numerical and experimental research is undertaken to investigate the characteristics of RockTES coupled with renewable sources available at a remote Canadian community located in British Columbia, Canada by means of packed rock beds for building heating purposes in cold-climate regions (*Figure 2*). Such a task is initially achieved by employing a 3D model, by which fluid flow and heat transfer inside the packed rock bed can be modelled. RockTES systems are investigated in-depth with a mathematical model. To validate the simulation results, a physical packed bed in the lab scale is designed and manufactured, using 3D printing. To summarize, the experimentally measured fluid flow and heat transfer behaviour inside a packed rock bed will be compared with the numerically calculated one as well as existing analytical and empirical models.

The results of the proposed research offer useful information for the design and performance evaluation of RockTES systems. The proper range of packed bed properties could lead to considerable energy savings for establishments in remote, cold climates, both commercially and non-commercially for heating, cooling and ventilation applications.

References page 20

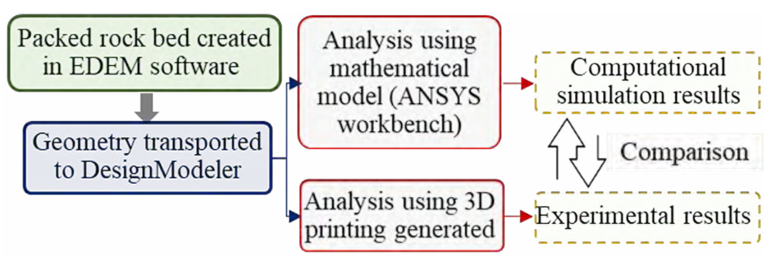

FIG. 2: METHODOLOGY FLOWCHART

Polytechnique Montréal
Dr. Oguzhan Tuysuz

Digital Modeling and Simulation of Machining Processes

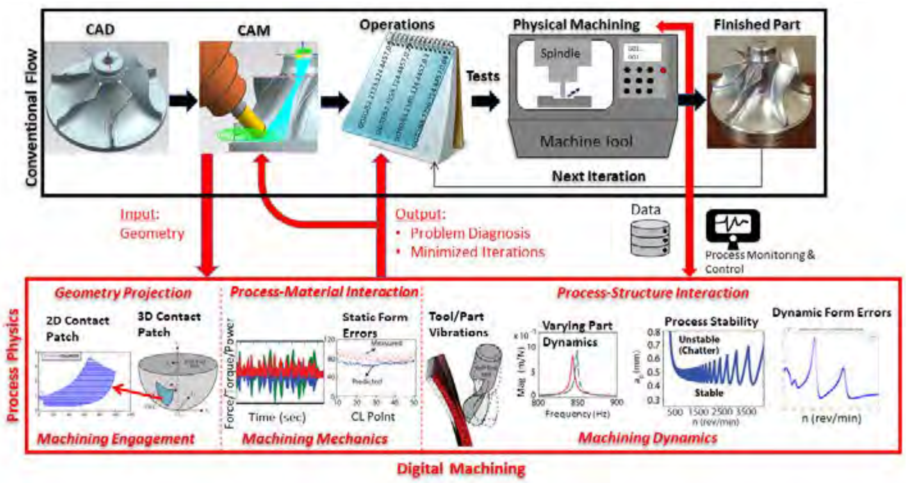

FIG. 1: COMPARISON OF (A) CONVENTIONAL, AND (B) DIGITAL/VIRTUAL MACHINING

Dr. OGUZHAN TUYSUZ, PhD

Dr. Tuysuz received his Master of Applied Science (MASc) and doctoral (PhD) degrees in Mechanical Engineering from the University of British Columbia (UBC) in 2012 and 2018, respectively. Upon completing his PhD, he had worked at Pratt & Whitney Canada (P&WC) as Machining Technologies Development Specialist until November 2021. Dr. Tuysuz's research interests are centered on machine tool dynamics and modeling the mechanics, dynamics, chatter stability, dimensional form errors and their compensation in machining processes. Application fields of his research are aerospace, automotive, and energy industries. His interdisciplinary, physics-based manufacturing process modeling research integrates analytical, numerical, and experimental approaches to digitize manufacturing and to minimize the physical iterations in the process development. He has authored several journal articles and conference proceedings in machining process modeling and is the recipient of Reviewer of the Year Award from ASME-Journal of Manufacturing Science and Engineering *in 2019. Dr. Tuysuz is currently an Assistant Professor of Mechanical Engineering at Polytechnique Montréal since November 2021 and a member of Product Development and Manufacturing Research Group and Virtual Manufacturing Research Laboratory.*

Increased functionality requirements from components in aerospace, automotive, and energy industries have led to tightly-toleranced components that are fabricated with subtractive manufacturing (machining). The main goal of Dr. Tuysuz's manufacturing research is to mathematically model, simulate, and optimize machining operations. It includes theoretical development, experimental validation, and industrial applications, and is centered on two main pillars: i) physics-based, and ii) data-based, virtual/digital modeling of machining processes and machine behavior.

In the traditional process flow (*Fig. 1a*), machining operations are generated for a designed part using Computer Aided Design/Manufacturing with purely geometry-based methods. The toolpaths are then iteratively tested until the desired surface and dimensional qualities are achieved on Computer Numerical Control (CNC) machines.

However, it is imperative to integrate the machining process physics into *Fig. 1a* through digital/virtual modeling to innovate in the functions critical to manufacturing such as productivity, part quality, cost, and material waste. Dr. Tuysuz's digital machining research (*Fig. 1b*) starts with calculating the 3-dimensional (3D) contact geometry between the cutting tool and the part along complex toolpaths. The 3D contact is converted to a 2D representation to be used in the machining process mechanics and dynamics models. Modeling of machining mechanics aims at predicting the cutting forces, power, and torque to check violations of cutting tools and machines limits. The cutting forces are then used to predict the static deflections of the flexible tools and parts, and the associated dimensional form errors. These errors are compensated in the virtual environment to ensure the dimensional compliance of the parts by minimizing the physical tests.

Then, machining dynamics is modeled to avoid vibrations, and the associated form errors and surface marks by focusing on the interaction between the process mechanics and the structural dynamics of CNC machines/flexible parts. Process forces excite the vibration modes of machines and parts, which result in either stable vibrations causing dynamic dimensional errors or unstable (chatter) vibrations causing poor surface quality, violation of part dimensions, and in turn scrapped parts. Process stability is thus assessed, and the stability diagrams are predicted to obtain chatter-free machining parameters. As an application example, Dr. Tuysuz developed the mathematical model of the entire process chain to simulate machining mechanics and dynamics of thin airfoils in the digital environment during his PhD under the supervision of Dr. Altintas at UBC.

Dr. Tuysuz and his team are currently working on expanding the virtual machining process research to data-driven modeling with machine learning to connect the physical and virtual manufacturing by correlating the manufacturing data with the process and machine variables within Industry 4.0 concept. Though the virtual process models minimize the physical trials by predicting the machining process states, they do not consider uncertainties and progressive changes in the process. Hence, the objective is to develop physics-guided machine learning models to automatically predict, monitor, and control the machining states using the in-process manufacturing data.

The ultimate goal of Dr. Tuysuz's research is to develop digital twins of challenging, advanced machining processes. The developed general methods are applicable to different industries such as aerospace, automotive, and energy. The main impacts of his research are: i) reduced costs through minimized corrective post-machining operations and machine failures, ii) environmentally sustainable manufacturing due to reduced material waste through minimized scraps, and iii) scientifically advanced theory for intelligent, self-adjusting machines.

Concordia University
Dr. Behrooz Yousefzadeh

Advanced Materials and Devices for Asymmetric Propagation of Elastic Waves

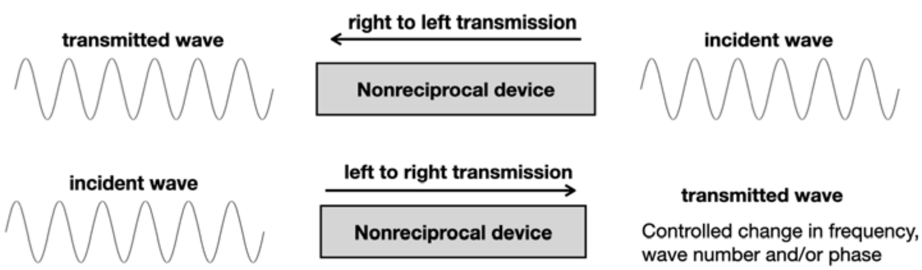

FIG. 1: NONRECIPROCAL DEVICES CAN PROVIDE NEW FUNCTIONALITIES FOR CONTROLLING AND STEERING OF ELASTIC WAVES.

We learn at a very young age that if we see someone in the mirror, they too can see us. This happens because when light finds a path from someone's eye(s) to ours, then it can equally travel in the opposite direction. At a much later stage in our lives, we can learn to describe this observation in terms of symmetries of transmission channels for electromagnetic waves. This invariance property is called reciprocity.

The same symmetry holds for elastic and acoustic waves. These waves propagate reciprocally through a medium: their left-to-right transmission characteristics between two points (frequency, amplitude and phase) are identical to their right-to-left characteristics. Reciprocity has been a guiding principle in vibration and noise control over the past 150 years. It has improved our measurement techniques and helped develop new methods of analysis.

Despite its incredible effectiveness, reciprocity may also be regarded as a hindrance. For example, reciprocity makes it impossible to create a device that supports asymmetric wave propagation along opposite directions; think of one-way mirrors and diodes, but for elastic waves instead of light. In photonics and electronics, nonreciprocal devices are established ingredients in many sensing, communication and signal processing applications. But can we extend these concepts to elastic waves?

The research team at Concordia's Wave and Vibration Engineering (WAVE) Lab works on the design and implementation of devices and materials that support asymmetric (nonreciprocal) propagation of elastic waves along opposite directions (*Figure 1*). Despite being compatible with the laws of physics, such extreme wave functionalities do not naturally occur in ordinary materials. The engineered materials and devices that exhibit such characteristics are called metamaterials.

The WAVE Lab have recently focused on two strategies for achieving elastic nonreciprocity in (meta)materials: (i) nonlinearity and (ii) time-dependent constitutive properties. The first strategy relies on embedding carefully designed nonlinear components within a material to leverage the nonlinear dynamic response in a controlled fashion. This approach employs the lab's expertise in the analysis of nonlinear wave phenomena. A recent contribution developed a specialized numerical technique for classification of various regimes of nonreciprocal dynamics in nonlinear systems. It is now possible to implement nonreciprocal phase shifts in coupled mechanical waveguides.

The second strategy relies on materials with constitutive properties that vary periodically in time and space in response to an external bias. Modulation of the material properties can prevent the propagation of an incident wave at certain frequencies, therefore leading to unidirectional (one-way) transmission of waves. It is barely five years since this phenomenon was observed in experiments on a mechanical system (*Figure 2*). The current efforts at the WAVE Lab focus on developing realistic design guidelines for implementing nonreciprocity caused by modulations in mechanical devices and metamaterials.

Nonreciprocal devices can facilitate innovations in shielding and absorbing layers for shock and vibration mitigation, and in wave focusing and storage devices for energy harvesting. Beyond nonreciprocity, the research at the WAVE Lab aims to utilize nonlinear wave phenomena for developing devices that possess novel wave functionalities for controlling and steering of elastic waves.

Dr. BEHROOZ YOUSEFZADEH, PhD, MCSME

Dr. Yousefzadeh is an assistant professor in the Department of Mechanical, Industrial and Aerospace Engineering at Concordia University, and a member of Quebec's Centre de Recherches Mathématiques. Before joining Concordia, he worked at California Institute of Technology as a postdoctoral scholar. He obtained his PhD and MASc in Mechanical Engineering from UBC, Vancouver.

Dr. Yousefzadeh's research team, Wave and Vibration Engineering (WAVE) Lab, works on the development of novel materials and devices with advanced wave-steering functionalities. The team's recent publications appeared in Nature Reviews Materials *and* Journal of the Mechanics and Physics of Solids.

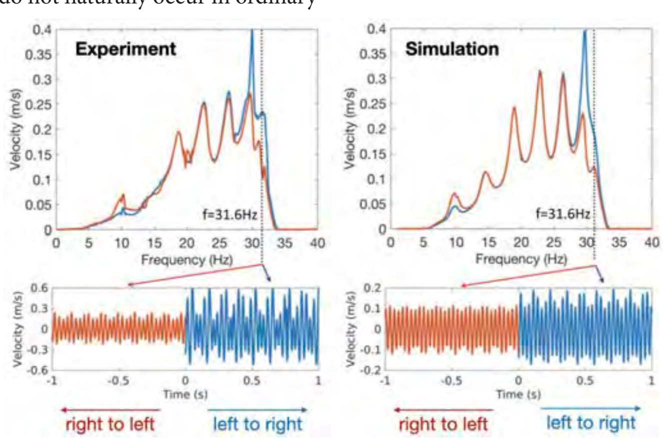

FIG. 2: AN EXAMPLE OF NONRECIPROCAL DYNAMICS CAUSED BY MODULATIONS. [HTTPS://DOI.ORG/10.1103/PHYSREVLETT.121.194301]

York University
Dr. Cuiying Jian

Manufacturing Carbons for a Sustainable Future

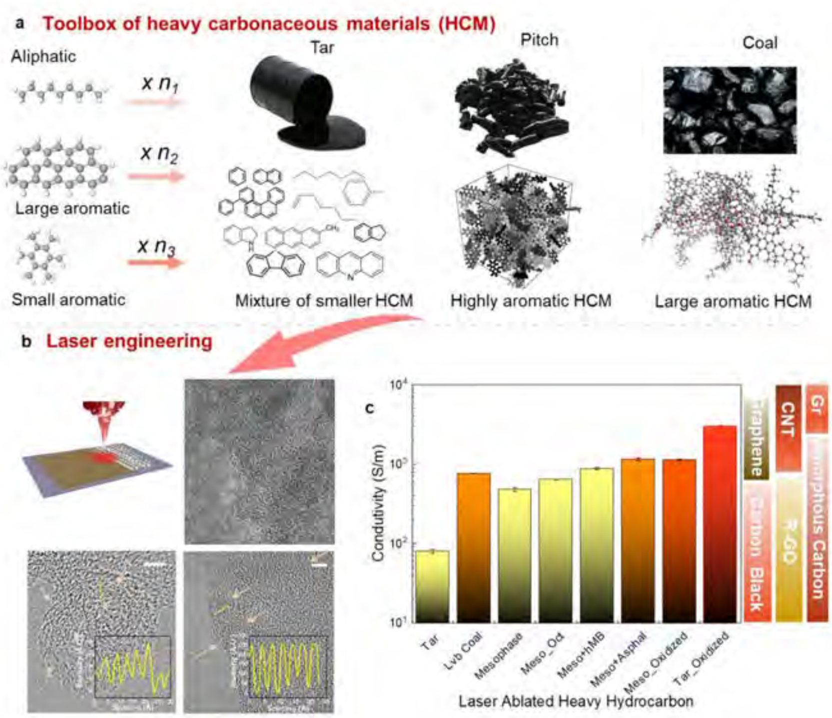

FIG. 1: LASER INDUCED CHEMICAL EVOLUTIONS OF HCMS. (A) COMPOSITIONS OF THREE TYPICAL HCMS (TAR, PITCH, AND COAL) THAT ARE MIXTURES OF ALIPHATICS, AROMATICS, AND HETEROATOMS. (B) SCHEMATIC OF LASER ABLATION, AND NANOSCALE STRUCTURES OF LASER-ABLATED HCMS RESOLVED BY HIGH-RESOLUTION TRANSMISSION ELECTRON MICROSCOPY. (C) CONDUCTIVITY OF LASER-ABLATED HCM THIN FILMS COMPARED TO THE CONDUCTIVITIES OF SYNTHETIC CARBON MATERIALS. COPYRIGHT ©2020, AAAS.

PHOTO (JIAN): COURTESY OF THE LASSONDE SCHOOL OF ENGINEERING, YORK UNIVERSITY

Dr. CUIYING JIAN, PhD, P.Eng.
Dr. Cuiying Jian is an Assistant Professor of Mechanical Engineering at York University. She received her PhD in Mechanical Engineering from the University of Alberta, and obtained her M.S. in Mechatronics Engineering and BSc in Mechanical Engineering from Harbin Institute of Technology. Prior to joining York, Dr. Jian worked as a postdoctoral fellow at Massachusetts Institute of Technology. Dr. Jian is an emerging leader in processing heavy carbonaceous materials. Her research is dedicated to exploring behaviors and properties of carbon-based materials for green, profitable applications in electronics, composites, and wastewater management.

The global challenge of achieving a net-zero carbon emission economy has increased society's interests in developing green, non-combustive applications of traditional carbon-intensive materials, such as coal, pitch, and steam-cracked tar. The Jian lab at York University focuses on upgrading these heavy carbonaceous materials (HCMs) into functional materials, and further employ these as-upgraded/produced functional materials in electronics, composites, and wastewater management.

Untapped HCMs are combinations of polycyclic aromatics, alkanes, and heteroatoms such as oxygen and metal, and as a result no single molecular structure can represent the broad chemical and structural heterogeneity in HCMs. Intuitively speaking, the aforementioned complexities demand comprehensive materials characterization to fully reveal their compositions and properties. However, the framework developed in the alternative photovoltaic technology scheme by Prof. Vladimir Bulović in 2015 (for details, please see Energy Environ. Sci., 2015, 8, 1200-1219.) suggests that, from application-oriented perspectives, materials complexity is not equivalent to processing complexity. Specifically, Prof. Vladimir Bulović proposed the following correlations between materials complexity and fabrication complexity: Simple materials (e.g., single-element silicon) generally require complex fabrications to achieve flexible tunability needed in the final application (e.g. controlling doping levels in semiconductors), while complex materials (e.g. organics and quantum dots) require potentially simpler fabrications to achieve the same scope of functionality and tunability. Inspired by this, we exploited the built-in diversities in HCMs, and produced a wide range of value-added materials via one-step processing. Below, we will illustrate our approach using materials conductivity as an example.

To obtain functional materials of different conductivities from HCMs, we employed the laser ablation/annealing method, given its rapid heating and enhanced controls. During laser-assisted additive manufacturing, HCMs are investigated as a collection of organic fragments as shown in *Figure 1a*. Here, three HCM samples, i.e., tar, pitch, and coal, are chosen as precursors given their wide-ranging aromatic contents (pitch > coal > tar) and molecular weights (coal > pitch > tar). After laser ablation, materials with distinct structures and morphologies are obtained (F*igure 1b*), depending on precursors' aromatic contents and molecular weights. Laser-ablated coal shows the largest graphitic fringes and domains with a few layers of stacking, while laser-processed pitch forms small fragments without evident stacking. On the other hand, laser-ablated tar shows para-crystalline nanoscale graphitic sheets mediated with amorphous carbons. By further tuning HCM internal chemistries and molecular compositions, broadly distributed conductivities were obtained for laser-ablated HCM thin films (*Figure 1c*). These conductivities obtained span over three orders of magnitudes, comparable to those of carbon nanotubes, carbon black, amorphous carbon, and graphitic carbon. A variety of applications can be readily foreseen. For instance, these materials can be used as either low-cost conductive additives (carbon black), or to fabricate transparent conductors and field effect transistors (graphene), as well as photovoltaic devices and pressure sensors (amorphous carbon). ***...continued page 20***

University of Alberta
Dr. Ehsan Hashemi

Learning-Aided Cooperative Control and Sensing for Safe Autonomy

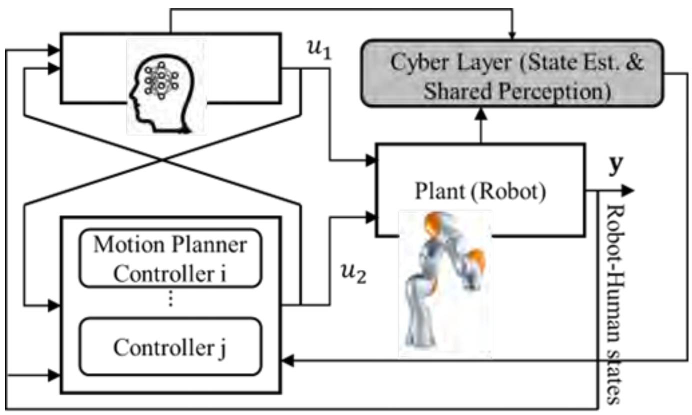

FIG. 1: SAFE RL AND SHARED PERCEPTION FOR SAFE HUMAN-ROBOT INTERACTION

Dr. EHSAN HASHEMI, PhD, MCSME

Dr. Hashemi is an Assistant Professor in the Department of Mechanical Engineering at the University of Alberta (since 2021) with an adjunct appointment in the Department of Mechanical and Mechatronics Engineering at the University of Waterloo. He earned his PhD in Mechanical and Mechatronics Engineering from the University of Waterloo, followed by a postdoctoral fellowship at the University of Waterloo and a research fellowship at Karlsruhe Institute of Technology (Germany). Dr. Hashemi was a Research Assistant Professor at the University of Waterloo and a Visiting Professor at the school of Electrical Engineering and Computer Science, KTH Royal Institute of Technology (Sweden). Dr. Hashemi is an IEEE senior member and his expertise is in control theory, distributed estimation, human-robot physical interaction, and cyber-physical systems.

RESEARCH PROGRAMS AND SUMMARY

Autonomous systems are expected to perform tasks which are more complex in increasingly dynamic environments in close proximity or in cooperation with humans. However, perception, scene understanding and safe decision making for autonomy, while interacting with humans, is still extremely challenging due to computational and processing constraints, uncertainties in the environment, and safety concerns. Dr. Hashemi's translational research aims at enhancing reliability and computational efficiency of perception, decision making, and motion planning for shared control in robotic and cyber-physical systems. This is to enable autonomy for reliable operation in non-trivial scenarios, to enhance their resilience to disturbances in dynamic environments, and to identify human objectives for cooperative tasks. His research program focuses on fundamental and practical aspects of a new learning-aided cooperative control and sensing paradigm for safe autonomy.

Dr. Hashemi and his team at the Networked Optimization, Diagnosis, and Estimation (NODE) lab are primarily interested in enhancing the reliability of robot perception by using physics-informed Machine Learning, which integrates underlying physics of the system into the learning process to address computationally-challenging cases in dynamic scenes and corner cases. His group is exploring observable human states from human-autonomy interaction to develop statistical predictive models for shared control in safety-critical situations, e.g., in Automated Driving Systems (ADS).

The knowledge gained from this work is then used for modeling, motion planning and control, considering contextual/semantic information of the environment and robust to bounded model uncertainties, for cooperative systems and personalized assistive technologies (e.g., lower-limb exoskeletons). For the shared control with physical interaction between the autonomous system and human, Dr. Hashemi's team is developing novel inverse optimal control methods and safe Reinforcement Learning (RL) to identify the user's objective for a cooperative control framework considering safety constraints and preferences (*Figure 1*). For autonomous navigation in unstructured environments with human presence, his group at the NODE lab is developing statistical models for semantic mapping and static scene segmentation to run onboard (in real-time) with direct applications in autonomous mobile robots and ADS. In order to enhance the reliability of perception and decision making, communication between different autonomous agents are leveraged for remote state estimation, indirect sensing, and distributed controls for various projects on networked robots and connected ADS (*Figure 2*).

Dr. Hashemi's research programs funded by NSERC Alliance and Alberta Innovates, as well as industry partners (e.g. General Motors, Rogers, Avidbots), include fundamental research, knowledge development, and technology transfer to Canadian assistive, robotic and intelligent transportation industries. He has large- and small-scale projects with Canadian industry partners on autonomous navigation and connected ADS with several technology transfers and patents. Dr. Hashemi's team has the long-term goal of safe decision making and motion planning for shared human-autonomy control

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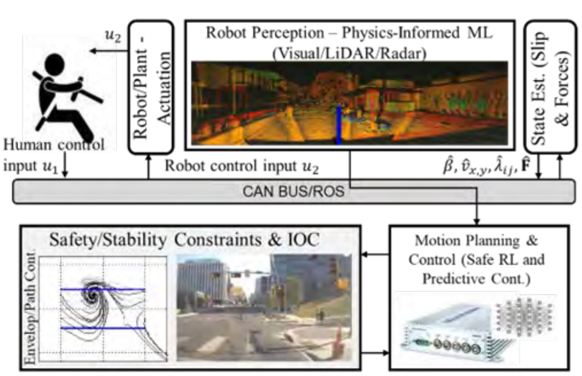

FIG. 2: SHARED CONTROL AND NAVIGATION IN SAFETY-CRITICAL SITUATIONS FOR AUTOMATED DRIVING SYSTEMS

ALL IMAGES COURTESY OF THE RESEARCHER

What are the most interesting advances in automation in the past few years?

One of the most interesting advances in automation in recent years is the applications of robotic systems in fully automated warehouses. The explosion of e-commerce and online shopping, especially during the pandemic era, has increased the requirement for more warehouses for the storage of goods and probably decreased the requirement for physical storefronts. The increasing demands for warehouses provide substantial opportunities for fully automated warehouses which, compared to the traditional warehouse, can be significantly beneficial. Based on a study conducted by eMarketer and reported by Shopify[1], the global e-commerce market is expected to total $5.55 trillion in 2022. Considering such a huge market and the predicted future growth in the coming years, the various advantages of a robotic solution make them a sustainable and optimal solution for the soaring demands in the market of warehouse automation.

Can you describe how automation and collaboration with humans/users will enhance safety and accessibility to everyone.

Most traditional warehouses rely on humans and lift trucks. The warehouse shelves are installed at a considerable distance from one another to allow for the different maneuvers of a lift truck, where a human controls the lift truck to pick up/deliver various items from/to the shelves. To keep the environment in a standard temperature range for the lift truck drivers, the considerable empty space in the warehouse required to let the lift truck maneuver needs to be kept at the same temperature as the rest of the whole warehouse. In addition, by relying on human operated lift truck systems, the time and energy needed to pick up/deliver items is not optimal. More items need to be kept on their shelves at the desired temperature range waiting for the human operated lift truck to do their tasks in a long pickup queue. In such systems, only single tasks with one lift truck could be handled and there is no option for multi-item delivery/pickup.

When compared with traditional warehouse approaches, automation of warehouse with various robotic systems could provide a much more optimal solution for the soaring demand fed by the explosion of e-commerce.

How can your research in automation reduce the cost of living?

The time and effort of holding the goods to be delivered to the costumer are two key factors in determining their final cost. Minimizing the time and effort for holding the objects in the warehouse will reduce the final cost.

Effective usage of the warehouse volume is one of the key aspects of fully automated warehouses. With such solutions, the required free distance between the shelves is governed by the totes/pallet sizes, keeping the warehouse much more compact. Accordingly, less volume needs to be kept in the same temperature of the whole warehouse resulting in less greenhouse gas emissions.

In such systems, the motion of the robot could be optimized to minimize the delivery/pickup time. In addition, multiple loaders may be used on each robot to handle multi-delivery/pickup tasks. The order of such delivery/pickup tasks could be optimized to minimize the required total time of multi-motion tasks. In addition to the direct benefit of such time optimality, the waiting time of other items on the delivery/pickup queue will be minimized leading to less storage time. Based on the frequency of calls, the placement of highly demanded items on the shelves/storage locations could be optimized to minimize the required time and energy to pickup/deliver such items. Moreover, power optimization of the robotic systems could be considered as another aspect to minimize the electricity consumption. Ultimately, the reduction of the final cost of various products will result in a reduction of living costs for everyone.

Can you give our readers some examples of the most trending automation technologies used in the warehouses at the moment?

There are multiple examples of warehouse automation technologies. One of the most famous ones is using autonomous mobile robots such as the lift-robots Amazon is using in its fulfillment centres[2]. In such centres, a considerable number of lift-robots are used to move and park numerous pods over a vast area. Depending on the costumer order, a pod is moved to a station where an employee picks and packages it. High-rise warehouse automation solutions are another example, where a huge planar robot is used to deliver/pick parcels to/from high-rise shelves[3]. Such systems are befitting from a much larger volume for pallet storage thanks to the capability of robots to reach considerable heights on 2-dimensional shelves[4]. Using robotic systems for storing pallets in 3-dimentional shelve is the third example which provides a much denser storage capability. This, however, adds considerable complexity to the robot's motion algorithms.

Who is doing this right, in your opinion? Is there a certain area, industry or company that is really exemplifying how this type of automation can be leveraged?

In my opinion, there is no right or wrong answer. The better way to assess each approach is to see the situation and the company requirements. For example, if a company does not care about the footprint of the warehouse, the approach of Amazon may be easier to implement. If a company cares about the footprint, using high-rise warehouse automation solutions could be a better option.

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Dr. HAMED JAMSHIDIFAR *is a Senior Advanced Systems Engineer in Honeywell Aerospace, Mississauga, Ontario. Before joining Honeywell, Dr. Jamshidifar was a postdoctoral fellow at the University of Waterloo where he received his PhD degree in Mechanical and Mechatronics Engineering in 2018. Mr. Jamshidifar research experience has focused on novel Cable-Driven Robots from micro-size to macro-size scaling from lab-scale prototypes to fully developed industrial robots. In the macro scale, his research includes the invention, design, analysis, modeling, optimization, fabrication, motion-planning and control of Cable-Driven Parallel Robots (CDPRs) for various large-workspace applications including fully automated warehouses. In the micro scale, his research includes design, modeling, fabrication and control of Cable-Driven Surgical Robotics (CDSRs). Mr. Jamshidifar also worked at Intuitive Surgical, where he worked on novel instruments for the da-Vinci Xi RS System. So far, the results of his research studies have been published in multiple US patents and patent applications, as well as journal papers published in IEEE Transactions on Robotics, IEEE/ASME Transactions on Mechatronics and IEEE Transactions on Medical Robotics and Bionics.*

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A constituent society of the Engineering Institute of Canada

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NEWS COMMUNIQUÉ

Office of the President

November 2022

The Canadian Society for Mechanical Engineering (CSME), founded in 1970, is pleased to announce the winning recipients of its 2023 technical awards. These awards may be bestowed biannually to members of the society for their outstanding contributions to specific areas of mechanical engineering in Canada.

The following three exceptional engineers will be presented with their medals on 30 May at the 2023 CSME International Congress to be held from 28-31 May at the Faculty of Engineering, University of Sherbrooke, QC. Each winner will be presenting a plenary lecture at the Congress.

Please consider attending the 2023 CSME International Congress to congratulate these exceptional winners and attend their lectures: www.csmecongress.org.

Emerging Technologies Medal
For "exceptional research and innovation contributions to the field of thermal plasma in Canada"

Javad Mostaghimi, PhD, FCSME
Professor, Mechanical & Industrial Engineering Department, University of Toronto, ON

Jules Stachiewicz Heat Transfer Medal
For "exceptional research and innovation contributions to the field of heat transfer in Canada"

J. Maciej Floryan, PhD, FCSME
Mechanical and Materials Engineering, Western University, ON

Mechatronics Medal
For "exceptional research and innovation contributions to the field of mechatronics in Canada"

Yang Shi, PhD, FCSME
Department of Mechanical Engineering, University of Victoria BC

Call for Nominations – 2023 CSME Awards
Nominations of CSME peers are currently solicited for three of the society's regular 2023 awards, including society fellowships. Note that members cannot nominate themselves – worthy candidates from the diverse CSME community must be nominated by CSME Fellows. The nomination deadline is **31 January 2023** and the nomination form is available on the CSME website: csme-scgm.ca/awards

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Dr. Javad Mostaghimi

A Mechanical & Industrial Engineering professor at the University of Toronto, Dr. Javad Mostaghimi is also founding director of the Centre for Advanced Coating Technologies. He received his BSc degree from Sharif University, Iran and MSc and PhD degrees in mechanical engineering from the University of Minnesota in 1978 and 1982, respectively. Before joining the University of Toronto, he held positions at Pratt & Whitney Canada and the University of Sherbrooke.

His main research interests are in plasma processing and thermal spray coating. Professor Mostaghimi is a fellow of the Royal Society of Canada and seven other societies and the recipient of many awards, including the NSERC Brockhouse Canada Prize and the Heat Transfer Memorial Award of the ASME. He is an inductee of the ASM Thermal Spray Hall of Fame. He is a member of the editorial board of P*lasma Chemistry and Plasma Processing* and the International Review Board of the J*ournal of Thermal Spray*.

Dr. J. Maciej Floryan

Jerzy M. Floryan, Professor at the Department of Mechanical and Materials Engineering, Western University, is a world-leading expert in heat transfer. He is a fellow of APS, ASME, CSME, CASI, JSPS, EIC, CAE, Erskine, Lady Davis, NATO, STA, and Humboldt. He received Humboldt Research Prize, McCurdy Award, Robert W. Angus Medal, and the Canadian Pacific Railway Engineering Medal. He has held visiting positions at Technion, City University of Hong Kong, Darmstadt Technical University, Tokyo Metropolitan University, Beijing Institute of Technology, University of Canterbury, National University of Singapore, Stuttgart University, French Aerospace Research Institute, National Aeronautical Laboratory (Japan) and Los Alamos National Laboratory. He is credited with numerous fundamental contributions to heat transfer, including the creation of the concept of patterned convection, the discovery of the pattern interaction effect and thermal drift, the identification of energy-efficient chaotic mixing, and the elucidation of fundamentals of rupture of non-isothermal interfaces.

Dr. Yang Shi

Dr. Yang Shi, a Professor in the Department of Mechanical Engineering, University of Victoria, is an internationally renowned expert in control systems and mechatronics with successful applications in industrial automation, autonomous flying and underwater vehicles, and cyber-physical systems. He has published three monographs and over 220 papers in premiere journals; his publications have received 17,080 citations with an h-index of 71 (Google Scholar).

Recognizing his pioneering work, Clarivate Analytics has named him a worldwide Highly Cited Researcher based on his exceptionally high research impact during 2014-2022. Dr. Shi has significantly contributed to CSME, ASME and IEEE technical committees and conferences; he serves as Co-Editor-in-Chief of two premium IEEE journals and as general chairs of several flagship conferences. He has received two university teaching awards and trained over 160 next-generation engineers/researchers. He is a Fellow of IEEE, CSME, ASME, and the EIC.

Transactions of the Canadian Society for Mechanical Engineering (TCSME)

I am happy to update the Mechanical Engineering community on the continued progress of the *Transactions of the Canadian Society for Mechanical Engineering*. In the prior 12 months TCSME has received 177 manuscripts which lead to 47 accepted papers. This translates to an acceptance rate of 26%. The average number of days from submission to first decision is also very respectable at 39 days.

The two-year impact factor for *Transactions of the Canadian Society for Mechanical Engineering* (TCSME) has maintained its value, which is now 1.324. Recall that last year it was 1.450 (2020).

I want to acknowledge the current editorial board for their hard work:

- Dr. Martin Agelin-Chaab, *Ontario Tech University*
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Please support the journal by downloading and/or submitting articles to the TCSME. The journal can be accessed at the link: www.nrcresearchpress.com/journal/tcsme.

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

FACULTY SPOTLIGHT *continued . . .*

Dr. Amiri, Rock thermal energy storage (pg. 12) references:

1. Natural Resources Canada. *Canada Energy Fact Book* 2020–2021.
2. Canada's Next Steps for Clean Air and a Strong Economy. *Emissions Reduction Plan 2023 Environment and Climate Change*, Canada.
3. Pokhrel, Sajjan, et al. "Renewable heating solutions for buildings; a techno-economic comparative study of sewage heat recovery and Solar Borehole Thermal Energy Storage System." *Energy and Buildings* 259 (2022): 111892.
4. Ghoreishi-Madiseh, Seyed Ali, et al. "Performance evaluation of large scale rock-pit seasonal thermal energy storage for application in underground mine ventilation." *Applied Energy* 185 (2017): 1940-1947.

Dr. Jian, Manufacturing Carbons for a Sustainable Future (pg. 15) continued:

Built on the above, three major directions are under exploration in the Jian lab at York University, towards upscaling the upgrading/manufacturing of HCMs with desired properties beyond applications in electronics. First of all, fundamental understanding of collective functionalities of HCMs and additives are necessary to provide guidelines to precisely tune the morphology and structure of as-annealed products. In this regard, HCM conversion mechanisms under laser processing can be probed by computational approaches, including all-atom reactive molecular dynamics, ab initio quantum mechanics, and time-dependent density functional theories. Secondly, as mentioned in the beginning of this article, HCMs are inherently complex mixtures with built-in chemical and structural diversities. Machine learning methods can help to accelerate reactive computations and screen the vast parameter spaces of HCMs, and provide a viable way to systematically scrutinize both precursor properties and manufacturing parameters. Thirdly, for commercialization, a fully integrated continuous manufacturing process is desired, which can transform precursors into solid continuous films and enable large-scale production and/or device fabrications. With the insights from materials understanding, laser-assisted manufacturing can be customized by computer-aided design to integrate raw materials, additives, laser ablation/annealing, packing facilities, and device fabrications into an automated production line. Along with our efforts in these directions, we welcome all kinds of collaborations, inquiries, and discussions. Please feel free to drop a line to Dr. Cuiying Jian at Cuiying.Jian@lassonde.yorku.ca.

Dr. Hashemi, Learning-Aided Cooperative Control and Sensing for Safe Autonomy (pg. 16) continued:

in unstructured environments through fundamental research in safe RL, human attention for computationally-efficient shared perception, and physics-informed machine learning. Within his translational and interdisciplinary research program, Dr. Hashemi has had several national and international collaborative projects with the University of Waterloo, McGill University, University of Toronto, University of Michigan (Ann Arbor), KTH Royal Institute of Technology (Sweden), Karlsruhe Institute of Technology and University of Stuttgart (Germany), and Schlegel Villages long-term care homes.

MECHATRONICS EDUCATION IN CANADA

IN 2001, 2003, AND 2005, THE CSME BIENNIAL forums on "Mechatronics Education in Canada" looked at the "Past Experience and Future Directions" of an emerging field. Two decades later, significant changes in current Mechatronics curricula are required to keep up with technology.

At that time, Canada appeared far ahead of the U.S. in promoting Mechatronics undergraduate teaching. Furthermore, most Canadian Mechatronics programs had their roots in Mechanical Engineering, focusing more on Mechanical design aspects. Universities led by UBC and Waterloo and later by Simon Fraser, Western, and McMaster had started full-fledged Mechatronics degree programs. In addition, other universities such as Victoria, Calgary, Sherbrooke, and the University of Toronto created options in this area.

As technology evolves, educational institutions must update and modernize their programs. For example, with the emergence of Industry 4.0 and the Internet of Things (IoT), there has been a demand for more computer software and hardware content while providing better hands-on training experiences. Notably, there is a need for better coverage of digital logic, embedded systems, programmable logic controllers, and data structures and algorithms.

McMaster was one of the first programs to embrace a more comprehensive software coverage focusing on embedded systems design. Other programs, such as Waterloo, have revised (or are in the process of revising) their curriculums to include more open-ended design and computer-related content. However, with the struggle to balance all required areas for accreditation, curriculum revision seems an arduous task. The critical challenge is how to include more innovative content, in a 4-5 year program, without sacrificing fundamentals.

As the Chair of the CSME History Committee, I would like to continue this effort by documenting the history of Mechatronics Education in Canada, particularly since 2005. I welcome your contributions, comments, or any feedback that you may have on this initiative.

Mainly, I look forward to increased membership in our committee. If anyone is interested, please get in touch with me.

Farid Golnaraghi, PhD, FCSME
Chair, CSME History Committee
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Sources:

1. www.eng.mcmaster.ca/cas/programs/degree-options/bengmanagement/mechatronics
2. uwaterloo.ca/mechanical-mechatronics-engineering

STUDENT AFFAIRS CSME REPORT

I WOULD LIKE TO START BY EXPRESSING HOW excited I am to be serving as the new Chair of the CSME Student Affairs Committee, and would like to thank the outgoing Chair, Dr. **Marina Freire-Gormaly**, for all her support as I take on this new role. I completed my BSc and PhD at the University of Alberta in Mechanical Engineering, and have served as Faculty in the same department since 2018. My research primarily surrounds the mechanical characterization of natural and synthetic biomaterials involved in the craniofacial environment, especially surrounding dental interventions or those involving cranial sutures. On the side of teaching, most of the courses I teach are focused on engineering design, mechanics, and simulation.

With respect to the CSME Student Affairs Committee, my primary goals in the short term will surround increasing activity for local CSME Student Chapters and increasing involvement in the National Design Competition. It's no secret that COVID-19 has had a large impact on many aspects of networking and related events, and the activity of local Student Chapters has been no exception. Over the coming year, I will be taking steps to promote more activity of CSME Student Chapters through connecting those that are active and helping to increase the national network. In areas where local CSME Student Chapters are not formed, I will be trying to work with interested people in the area in forming these initiatives. Along with the newly appointed chair of the National Design Competition, Dr. *Grant McSorley*, University of Prince Edward Island, our interests regarding the National Design Competition surround further promotion of the event and working to have it as a major component in the Annual CSME Congress. We firmly believe that student networking and involvement in the CSME Congress is critical to its continued success, and see the National Design Competition as a way to increase such activity.

Overall, I have a strong passion for increasing student activity in the CSME and facilitating the expansion of student networks. I am very open to discussing matters with those who have suggestions surrounding student matters, or those who simply want to know more about how they can get involved. Please feel free to contact me (dromanyk@ualberta.ca) to discuss such matters further. I look forward to working with you all over the coming years to promote student activities and involvement in the CSME.
— Dan Romanyk, PhD, P.Eng., MCSME

CALL FOR SUBMISSIONS >>

The Future of Transportation

Guest editors of the May 2023 issue will be the co-chairs of the *CMSE Transportation Systems Technical Committee*, Professors **Yuping He** and **Bruce Minaker**, and the co-chairs of the *CSME Engineering Analysis and Design Technical Committee*, Dr. **Aman Usmani** and Professor **Hamid Akbarzadeh**.

To contribute articles to the next CSME *Bulletin*

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