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SYMPOSIUM
Proceedings

November 8-10, 2021
Virtual Conference

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Cybersecurity Program

November 8, 2021

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Exoskeleton Preface

Now in its fourth year of the User-Centered Design format for technology development, ErgoX 2021 held a common theme across all three of its tracks, which was that of Artificial Intelligence (AI) influence. While, AI itself is not new as a technology, it's convergence with other forms of technology are becoming ever more present. Examples can be seen in utilization of this capability for gathering insights trends, and even commands from Big Data and learning to interface with people through natural language processing (NLP) platforms such as Amazon's Alexa, Apple's Siri, Google Assistant, or Microsoft's Cortana platforms (Springboard). Now having those platforms in mind, how would you like to mix such capabilities with that of Cybersecurity, Robotics, and Exoskeletons as technology tracks? Envisioning the possibilities yet? What AI brings to the table for each of these tracks or technology capabilities is both the imagined and the unimagined, potentially creating new capabilities that have yet to be seen.

With this AI theme in tow, the 2021 ErgoX Exoskeleton Symposium Track kicked off the daylong event with Moderator, Dr. Christopher Reid (Boeing Company) and Keynote speaker Dr. Jose "Pepe" Contreras-Vidal, Director of the National Science Foundation's Industry-University Cooperative Research Center Building Reliable Advances and Innovation in Neurotechnology (IUCRC BRAIN). His talk, labeled as "Neuroengineering Pediatric Medical Exoskeletons with Diagnostic, Assistive, and Therapeutical Functions" spoke to the current capabilities brought to us from advanced powered exoskeletons used for medical patients with neurological disorders, such as spinal cord injuries or strokes that affect their physical capabilities. These exosystems are being used to bring a level of mobility back to these patients where otherwise, they would never have. Dr. Contreras-Vidal, intrigued attendees with the normative capabilities that these systems raised, and then dazzled us with potentials that they could continue to bring…such as patient lifelong exoskeleton utilization from childhood to adulthood to enable a more normal standard of living.

Sponsor Talks

This year's program had four sponsor talks of the five event sponsors. This was divided over three sessions with Gold Sponsor Liberty Mutual's Dr. Jesse Jacobs giving his talk on "Practical Considerations about Industrial Exoskeletons" which was followed by Catherine Hayes, our Silver Sponsor from South Carolina Research Authority (SCRA). Our third and fourth Silver Sponsors were from Jason Jones of Ekso Bionics and Ashley Stack of Ottobock. The sponsor talks were moderated by Drs. Christopher Reid (Boeing Company) and Donald Peterson (Northern Illinois University).

Research methods 1 – Research to Standards

The Exoskeleton Track program consisted of three technical sessions, known as Research Methods 1 through 3. The first of these was the Research to Standards session. This session heard from speakers whose research was funded by the ASTM International's Exo Technology Center of Excellence. Dr. William Billotte was the session Moderator and hosted Dr. Leia Stirling from the University of Michigan who spoke on "Designing a Standard Practice for Evaluating Exoskeletons on Transitions in the Environment". Our second speaker was Dr. Pei-Chun Kao of University of Massachusetts – Lowell speaking on "Exoskeleton Test Methods for Mobility on Variable Terrains". The final speaker for the

session was Dr. HeeSun Choi from Texas Tech University presenting on “Research to Standards for Evaluating the Exoskeleton Wearer’s Cognitive Performance”.

Research methods 2 – AI & Exoskeletons

Research Methods 2 was specific to the 2021 theme of Artificial Intelligence’s (AI) influence on exoskeletons. Moderated by Dr. Bill Marras (Ohio State University), it consisted of speakers Dr. Brockoslaw “Brock” Laschowski (University of Waterloo) talking on “Learning from Environment-Adaptive Control of Robotic Exoskeletons”, Dr. Luke Mooney from Dephy, who spoke on “Rapid Prototyping at a Wearable Robotics Startup”, and then Dr. Ignacio Galiana (Verve Motion), speaking to “Augmenting and Protecting our Workforce with Next Generation Wearable Technology”.

Research Methods 3 – Emerging Topics

Research Methods 3 was moderated by Dr. Don Peterson (Northern Illinois University) and spoke to Emerging Topics of interest for exoskeletons. These topics included talks by speakers Dr. Karl Zelik (Vanderbilt University) on “Assessing the Effect of Back Exoskeletons and Exosuits on Injury Risk”, Dr. Carisa Harris-Adamson (University of California – San Francisco) for “Assessing the Potential of Passive Exoskeletons in Construction”, and Dr. Simon Kudernatsch from Northern Illinois University speaking to “Ergonomic Observational Assessment to Identify Potential Applicability of Occupational Exoskeletons at Work Sites”.

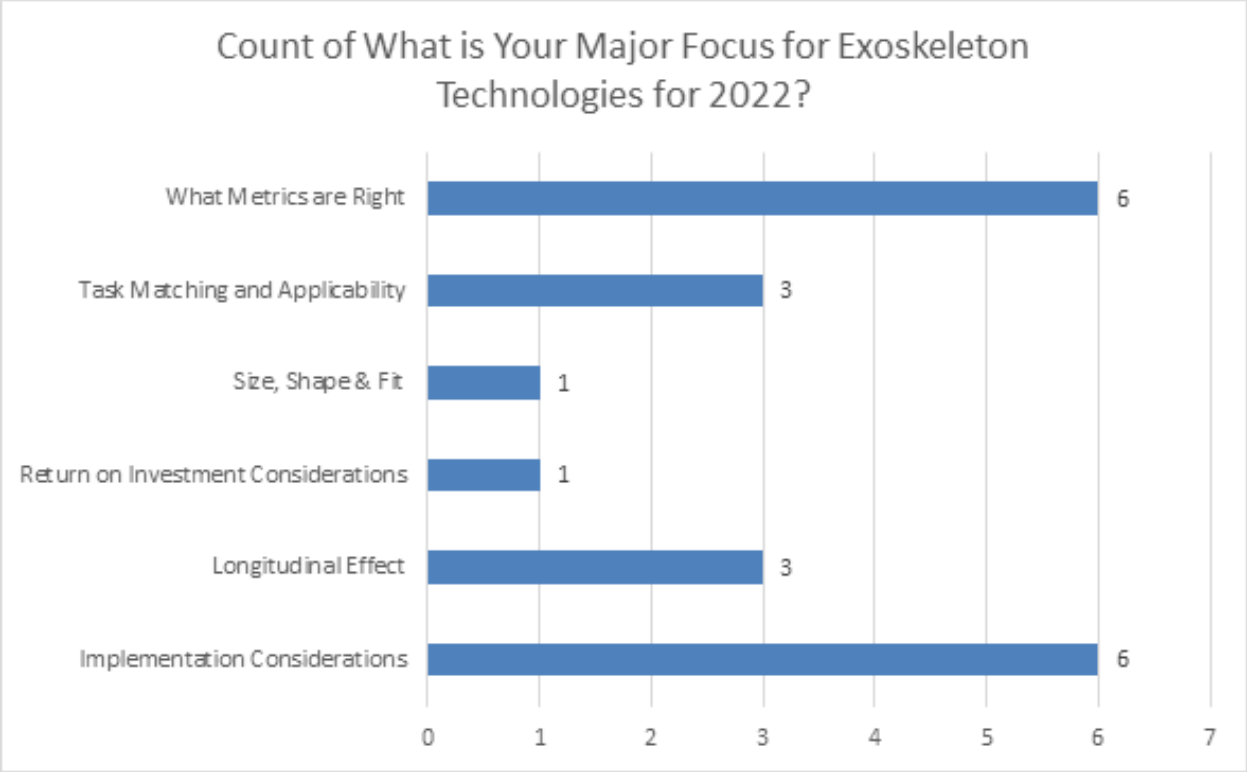
Closing Remarks

Dr. Hongwei Hsiao (National Institute for Occupational Safety & Health) led the closing talks with his track Co-Chairs, Drs. Peterson, Marras and Reid, acknowledging lessons learned and talking points of the day.

Thoughts that came out of the discussion included:

- “People are messy” - Dr. Marras spoke to the need to balance personalization aspects with individual tailoring of exoskeletons to physical and cognitive traits on the unique person inside, with that of mass producibility for improving manufacturing and accessibility to these devices.
- AI brings the opportunity to improve the human systems integration element – Deep Learning, adoption, and potentially symbiosis with users are all potentials of where the AI element can enhance the infrastructure of the exoskeleton itself for the people inside. However, the caveat at the moment is around the limitations of that said infrastructure and the technology capabilities (materials, motors, power source, weight, heat, etc.) that the AI will need to interact with.
- Translating between laboratory to field and back…unknowns still remain – The evolution of exoskeletons has to bring with it elements of usefulness, usability, and desirability in order to make it successfully beyond the technology hype into the adopted consumer communities they are designed to aid. This includes navigating barriers to accessibility, reducing evaluation time for exoskeleton assessment and usage application, access to practical proving ground scenarios to increase practicality of the designs, and design compatibility with tools and other personal protective equipment worn in the fields that they’d be used in.

The day ended with the great hope for where exoskeletons can possibly lead us into the future with intentional human augmentation for bettering performance and safety. The day's poll on "What is Your Major Focus for Exoskeleton Technologies for 2022" showed that many are still contemplating which metrics are appropriate to their needs as well as advances needed for successful field implementation (Figure 1). So this points us now to 2022's next ErgoX event that will be held in Atlanta, Georgia October 14-15, 2022 where the conversation can continue with how exoskeleton designers can utilize the science of human factors, ergonomics, user experience (UX), and designing for people to balance these technological capabilities or limitations.



Christopher R. Reid, Ph.D.
President, Human Factors & Ergonomics Society
ErgoX Symposium Chair
ErgoX Exoskeleton Track Symposium Chair

Donald R. Peterson, Ph.D., MS, FAIMBE
ErgoX Exoskeleton Track Symposium Co-Chair

William S. Marras, Ph.D., CPE
ErgoX Exoskeleton Track Symposium Co-Chair

Hongwei Hsiao, Ph.D.
ErgoX Exoskeleton Track Symposium Co-Chair
ErgoX Robotics Track Symposium Chair

Exoskeleton Program

November 9, 2021

Session	Speakers
Keynote Lecture: Neuroengineering Pediatric Medical Exoskeletons with Diagnostic, Assistive, and Therapeutical Functions	Jose 'Pepe' Contreras-Vidal, Ph.D., FIEEE, FAIMBE; Director, NSF IUCRC BRAIN, University of Houston
Sponsored Session - Practical Considerations About Industrial Exoskeletons	Liberty Mutual, Jesse Jacobs, PhD
Research Methods 1: Research to Standards	Moderator: William Billotte Leia Stirling, University of Michigan Pei-Chun Kao, University of Massachusetts Lowell HeeSun Choi, Texas Tech University
Research Methods 2: AI & Exoskeletons	Moderator: William Marras, Ohio State University Brockoslaw Laschowski, University of Waterloo Luke Mooney, Dephy Ignacio Galiana, Verve
Sponsored Session	Jason Jones, Ekso Bionics
Sponsored Session - Paexo Shoulder Exoskeleton by Ottobock	Ashley Stack, Ottobock
Research Methods 3: Emerging Topics	Moderator: Don Peterson Karl Zelik, Vanderbilt University Carisa Harris-Adamson, University of California - San Francisco Simon Kudernatsch, Northern Illinois University

Exoskeleton Sessions

November 9, 2021

Keynote Lecture: Neuroengineering Pediatric Medical Exoskeletons with Diagnostic, Assistive, and Therapeutical Functions

Jose 'Pepe' Contreras-Vidal, Ph.D., FIEEE, FAIMBE; Director, NSF IUCRC BRAIN, *University of Houston*
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Powered exoskeletons promise to improve the quality of life and independence of people with lower-limb disabilities. These complex human-machine systems have now reached clinical populations with spinal cord injury and stroke. In 2014, the FDA classified powered exoskeletons as Class 2 devices with special controls and several devices are currently marketed in the US and abroad. On the other hand, the regulatory science of powered exoskeletons is still developing. The type and extent of probable risks of these devices are yet to be understood, industry standards are yet to be developed, and shared control algorithms based on automated intent detection and fall prevention approaches are under-developed. Moreover, these systems are yet to reach pediatric populations. In this talk, I will review the challenges and opportunities for user-centered design of smart, AI-enabled, wearable powered exoskeletons with assist-as-needed and shared control capabilities via noninvasive brain-machine interfaces. I will conclude my talk with an outlook for the next generation of smart powered exoskeletons for medical and nonmedical applications.

Sponsored Session - Practical Considerations About Industrial Exoskeletons

Liberty Mutual, Jesse Jacobs, PhD

Research Methods 1: Research to Standards

Designing a Standard Practice for Evaluating Exoskeletons on Transitions in the Environment
Leia Stirling, *University of Michigan*
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Exoskeleton Test Methods for Mobility on Variable Terrains
Pei-Chun Kao, *University of Massachusetts Lowell*
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Research to Standards for Evaluating the Exoskeleton Wearer's Cognitive Performance
HeeSun Choi, *Texas Tech University*

Research Methods 2: AI & Exoskeletons

Computer Vision and Deep Learning for Environment-Adaptive Control of Robotic Exoskeletons

Brockoslaw Laschowski, *University of Waterloo*
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Robotic exoskeletons can provide powered locomotor assistance to older adults and/or persons with physical disabilities. However, the current locomotion mode recognition systems being developed for high-level control rely on mechanical, inertial, and/or neuromuscular sensors, which inherently have limited prediction horizons (i.e., analogous to walking blindfolded). Inspired by the human vision-locomotor control system, our research lab at the University of Waterloo has been developing intelligent environment classification systems powered by computer vision and deep learning to predict real-world walking environments prior to physical interactions, therein allowing for more accurate and robust high-level control decisions. To support this initiative, we recently developed the "ExoNet" database – the largest and most diverse open-source dataset of wearable camera images of indoor and outdoor walking environments, which were annotated using a novel hierarchical labelling architecture. To date, we have trained and tested over a dozen state-of-the-art deep convolutional neural networks (CNNs) on ExoNet for image classification and automatic feature engineering, including: EfficientNetB0, InceptionV3, MobileNet, MobileNetV2, VGG16, VGG19, Xception, ResNet50, ResNet101, ResNet152, DenseNet121, DenseNet169, and DenseNet201. We quantitatively evaluated and compared the benchmarked CNN architectures and their environment classification predictions using an operational metric called "NetScore", which balances the image classification accuracy with the architectural and computational complexities (i.e., important for onboard real-time inference with mobile computing devices). Our recent comparative analysis showed that the EfficientNetB0 network achieves the highest test accuracy; VGG16 the fastest inference time; and MobileNetV2 the best NetScore and least number of parameters and computing operations, which can inform the optimal architecture design or selection depending on the desired performance. Overall, this research initiative provides a large-scale benchmark and reference for next-generation environment classification systems for robotic exoskeleton control.

Rapid Prototyping at a Wearable Robotics Startup

Luke Mooney, *Dephy*

Augmenting and Protecting Our Workforce with Next Generation Wearable Technology

Ignacio Galiana, *Verve*

Sponsored Session, Ekso Bionics

Jason Jones, *Ekso Bionics*

Sponsored Session - Paexo Shoulder Exoskeleton by Ottobock

Ashley Stack, *Ottobock*

Research Methods 3: Emerging Topics

Assessing the Effect of Back Exoskeletons and Exosuits on Injury Risk
Karl Zelik, *Vanderbilt University*

Assessing the Potential of Passive Exoskeletons in Construction
Carisa Harris-Adamson, *University of California - San Francisco*

Observational Assessment to Identify Potential Applicability of Occupational Exoskeletons at Work Sites
Simon Kudernatsch, *Northern Illinois University*
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Robotics Preface

Robots have been a significant part of the workplace and our daily living for decades, and their development and application are growing rapidly in various industries. The International Federation of Robotics (IFR, 2020) reported that the total worldwide stock of operational industrial robots in 2019 had reached 2.7 million units, which is 2.7 times the number in 2009. Worker/user safety and health may be improved through increased use of robots for work that can be hazardous to humans, including repetitive tasks and manual handling which are risky for musculoskeletal health, in environments where pathogens are transmitted, and work performed in dangerous environments, such as work at heights, under water, and in confined spaces. However, there also are concerns for human worker safety arising from the rapid advances of robotics technologies, potential for unforeseen hazards and unanticipated consequences, and lack of experience working closely with emerging types of robots in varied work environments.

In responding to the need for focused discussions on human factors aspect of robotics, the ErgoX expanded its scope to have a 3-day Robotics symposium in 2020. Industries, standards development entities, professional organizations, academia, and government agencies presented their works and strategic goals with an emphasis on worker safety and health and business efficacy. This year (2021), we focused on the intersection of artificial intelligence (AI) and robotics to reflect the advancement of emerging technologies.

The symposium began with a keynote address on Deep Space Smart Habitats – Humans, Robots, and Autonomy by Dr. Stephen Robinson of the University of California (UC) Davis. Dr. Robinson brought his 37 years of experience at NASA and his directorship of the UC Davis Center for Spaceflight Research to the platform with very enlightening information on human/automation/robotic integration.

We had two critical and timely themes for the Research Sessions which followed the keynote presentation. The first Research Session focused on Trustworthiness of AI in Robotics. Ms. Shelly Bagchi (National Institute of Standards and Technology), Professor Sang Choi (University of Wisconsin - Whitewater), Professor Lucio Soibelman (University of Southern California), and Dr. Satyandra Gupta (University of Southern California) presented their works on trustworthiness of AI in robotics at workplace. Dr. Christopher Reid (Boeing Company) chaired the Session. The second Research Session emphasized human factors issues in AI and Robotics applications in various sectors. Dr. Sascha Wischniewski (German Federal Institute for Occupational Safety and Health), Dr. Eugen Solowjow (Siemens Corp. Technology), Dr. Luigi Monica (Italian Workers' Compensation Authority), and Professor Juan Wachs (Purdue University and NSF) discussed their robotics research and applications in manufacturing, general industry, warehousing, and healthcare settings. Professor Robert Radwin (University of Wisconsin – Madison) chaired the section.

The symposium concluded with a closing panel discussion on Human Factors in Robotics in the Age of AI. Four specialists on robotics shared with us their thoughts and views on challenges and opportunities for Human Factors in Robotics in the Age of AI: Ms. Nia Jetter (Amazon Technology), Ms. Megan Zimmerman (National Institute of Standards and Technology), Professor Peter Hancock (University of Central Florida), and Dr. Edward Chow (NASA Jet Propulsion Laboratory). The panel discussion hosts were Dr. Hongwei Hsiao (National Institute

for Occupational Safety and Health - NIOSH), Professor Robert Radwin (University of Wisconsin), and Dr. Christopher Reid (Boeing Company). Questions that were discussed included:

- Should AI robots be human tools, companions, partners, consultants, or supervisors? Your thoughts and why?
- With advancements in sensing, mapping, and communication capacities of robots, what are the most significant opportunities for human factors professionals to contribute to the 4th wave of AI and robotics, especially on the aspects of human safety and well-being and business growth?
- There has been significant progress on robots perceiving and navigating their environments. Many people anticipate that future robots will be able to operate in environments that are unmapped or unfamiliar to robots and humans. We however have seen fatalities and injury cases of self-driving vehicles and construction robots. What is the responsibility of the robot vs the human?
- The COVID pandemic has changed our living and work lives dramatically. During the past year, robots have been introduced for workplace disinfection, patient tele-care, and mask production. What are other potential robotics applications for current pandemic state?
- In terms of industrial robotics for manufacturing or warehousing industries, what do you see as the current challenges for integration within these types of work environments full of people? How do we balance safety and productivity?

With the great discussion, we ran out of time very quickly. We believe that some of the discussed questions could lend well to research topics. We hope to continue additional panel discussions at future symposia. Some of the questions for further discussion include:

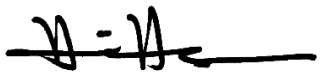
- Bias typically surfaces when unfair judgments are made about members of a group. What are the potential biases of robots toward certain human workers of varying sizes/shapes, ethnicities, races, or genders? How do we reduce the risk?
- Humans are social beings by nature. Industrial and social robots still have limited capability for interpreting or rendering social behavior. Do you see a need for robots to grow in social capacity for improved human-robot collaboration? What are the biggest challenges of building this capacity?
- How do you see robotics and AI/Machine Learning shifting the educational system for learning and training requirements for those currently in school? How should we best prepare our next generation to be ready for this evolving technology, particularly with regards to designing for human interactions?
- Cultural acceptance can be a challenge and typically takes good communication continuously over time. In your experiences, what have worker or public perceptions been for the continuing expansion of automation and robotics in the workplace? Is it currently seen as useful, usable, and acceptable?
- Using AI or robots in unethical ways can be a concern for public and workplace safety. What are current control measures? Are standards/guidelines needed to ensure ethics in the use of robotics?
- What are the top two research needs on robotics in the aspect of Human Factors you would recommend industry and federal agencies support?

- Multiple federal agencies have initiated Future of Work Initiatives. Robotics and AI are highly relevant to the Future of Work programs. In the future of work, under what circumstances should humans be replaced by robots and under what circumstances should robots augment humans?
- Health Equity is an important national initiative. Do you have any observations on how robotics can be used to identify, examine, and reduce the inequitable distribution of work-related risk and benefits due to demographic characteristics?
- Communication and interaction among human workers and robot swarms can be tricky because workers and robots need to sense not only the environment, but also each person or each robot in the swarm and then act both independently and collaboratively. What are the priorities the human factors community can do to advance human-robot communication?

The organizing committee members for the symposium are:

- Hongwei Hsiao, Ph.D., ErgoX Robotics Track Symposium Chair; retired Chief of the Protective Technology Branch and Coordinator for Center for Occupational Robotics Research, National Institute for Occupational Safety and Health (NIOSH). He is currently Professor & Rogelio "Roger" Benavides Memorial Chair at Texas A&M University – Corpus Christi.
- Robert Radwin Ph.D., ErgoX Robotics Track Symposium Co-Chair; Duane H. and Dorothy M. Blumke Professor in industrial and systems engineering and biomedical engineering at the University of Wisconsin-Madison; Discovery Fellow at the Wisconsin Institute for Discovery.
- Christopher R. Reid, Ph.D., ErgoX Robotics Track Symposium Co-Chair; Human Factors & Ergonomics (HFE) Technical Fellow for Boeing's Environment, Health & Safety (EHS) organization. President, Human Factors & Ergonomics Society 2022.
- Craig Schlenoff, Ph.D., ErgoX Robotics Track Symposium Co-Chair; Group Leader of the Cognition and Collaboration Systems Group and Program Manager of the Measurement Science for Manufacturing Robotics Program in the Intelligent Systems Division at the National Institute of Standards and Technology.

The organizing committee sincerely thank our participants, speakers, sponsors, and the Human Factors and Ergonomics Society staff for their contributions to this successful symposium.



Hongwei Hsiao, Ph.D.

Robotics Program

November 10, 2021

Session	Speakers
Keynote Lecture: Deep Space Smart Habitats – Humans, Robots, and Autonomy	Stephen K. Robinson, University of California Davis
Trustworthiness of AI in Robotics at the Workplace	Shelly Bagchi, National Institute of Standards and Technology Sang Choi, University of Wisconsin-Whitewater Lucio Soibelman, University of Southern California Satyandra Kumar Gupta, University of Southern California
AI and Robotics Applications in Various Sectors - Human Factors Issues	Sascha Wischniewski, Federal Institute for Occupational Safety and Health, Germany Eugen Solowjow, Siemens Corp. Luigi Monica, National Institute for Insurance against Accidents at Work Juan P. Wachs, NSF and Purdue University
Closing Panel Discussion: Human Factors in Robotics in the Age of AI - Challenges & Opportunities	Nia Jetter, Amazon Megan Zimmerman, National Institute of Standards and Technology Peter Hancock, University of Central Florida Edward Chow, NASA Jet Propulsion Laboratory

Robotics Sessions

November 10, 2021

Keynote: Deep Space Smart Habitats – Humans, Robots, and Autonomy

Stephen K. Robinson, University of California Davis

Trustworthiness of AI in Robotics at the Workplace

Metrics for Increased Trust in Human-Robot Collaborations

Shelly Bagchi, M.S., Electrical Engineer, *National Institute of Standards and Technology*

In order for systems to be considered trustworthy, they must be extensively tested before being ready for public consumption. In the case of collaborative robot systems, where there is a human component involved, user studies must be done to validate new methods and obtain user feedback that can be incorporated into the system. However, many academic studies use subjective questionnaires custom-designed for their systems, which leads to difficulties comparing results with those of other researchers, and thus slows progress in future research. In this talk, I will review some statistics from the current state of HRI research, and provide an overview of some widely-used validated surveys that can increase trust in human-robot interaction research.

Trustworthiness of AI/Robotics: Bridging the Gaps between Humans and Robots in Construction Safety

Sang Choi, Ph.D., Professor and Construction Program Coordinator, *University of Wisconsin – Whitewater*
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Impact of VR-based training on Human-Robot Interaction in Construction Robotics Teleoperation

Lucio Soibelman, Professor and former Chair of the Sonny Astani Department of Civil and Environmental Engineering, *University of Southern California*
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Abstract (Dr. Choi and Dr. Soibelman)
There has been an increased interest in automation and the expanded deployment of robots in the construction industry during the past decade. Robots are presented as a solution to address the significant challenges of the construction industry, such as safety concerns, labor shortages, and low productivity rates. However, the emergence of robots has produced an urgent and vast need for construction workers to reskill and upskill to interact with these new technologies safely and effectively. Workers interact with robots in the dynamic and unstructured nature of construction sites; therefore, human-related factors (e.g., self-efficacy, mental workload,

situational awareness) are critical in the Human-Robot Interaction (HRI). Additionally, building trust in robots among workers is critical in producing an increased sense of safety and an inclination to accept and work with robots in the future. In comparison to existing training methods (hands-on, lecture-based, apprenticeship training), Virtual Reality (VR)-based training is proposed as a training method to provide construction workers the opportunity to learn and practice with robots in hazardous virtual situations without imposing actual safety risks, equipment costs, and disturbance of construction sites. We predicted that VR-based training could improve construction workers' knowledge acquisition, safety behavior, operational skills, trust in the robot, self-efficacy, situational awareness, and mental workload in teleoperation of construction robots. We measured these factors on fifty construction workers randomly assigned to either VR-based training or traditional hands-on training led by an expert trainer. Our results indicate that VR-based training could significantly improve the aforementioned factors (except mental workload) compared to traditional in-person training. The findings suggest that VR-based training not only provides a viable, consistent, and effective option for future training programs but represents a safe and accessible format for construction robotics safety and skill training. The accurate simulation and visualization of the robot allowed workers to teleoperate it in dangerous scenarios to get a reliable understanding of the robot on construction sites, which has substantial implications for improving HRI using VR, especially in the construction industry.

Building Trustworthy Robotic Assistants

Satyandra Kumar Gupta, Ph.D., Smith International Professor, Department of Aerospace and Mechanical Engineering and Department of Computer Science, *Viterbi School of Engineering. University of Southern California*

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The use of collaborative robots can significantly improve human productivity and eliminate the need for human involvement in tasks that pose risks to human safety. Many emerging robotics applications require the use of multiple collaborating robots to operate under human supervision. To be useful in such applications, collaborative robots will need to (1) program themselves, (2) efficiently learn from the observed performance, (3) safely operate in the presence of uncertainty, (4) appropriately call for help during the execution of challenging tasks, and (5) effectively communicate with humans. This presentation will begin with an overview of the advances in physics-aware artificial intelligence that are being used to enable robots to automatically make decisions to meet aforementioned requirements. Building trust in robotic systems requires designing processes that enable potential users to safety use the new system, collect data, and make informed decisions regarding how much trust to place in the system. On-line learning raises major concerns from the trust point of view. Building trust requires human users to be able to understand the decision-making rationale of the system to better understand how the system "thinks". The second part of the presentation will describe computational methods for endowing robots with introspective capabilities so that they can seek help from humans on challenging tasks and explain their decision making. This allows robots to assess risk and prevent expensive failures. This also enables robots to elicit human guidance during the decision-making process and build trust. Robotic sanding task will be used as illustrative examples to show how smart collaborative robots can be used in high mix manufacturing applications.

AI and Robotics Applications in Various Sectors - Human Factors Issues

Advanced Robotic Systems in Industrial Settings - What do Users Expect?

Sascha Wischniewski, Ph.D., Head, “Human Factors, Ergonomics," *German Federal Institute for Occupational Safety and Health*

New robotic systems allow safe coexistence, cooperation, and collaboration with humans in hybrid work systems. Many of these systems can nowadays be found in industrial settings with the automotive sector being one of the key industries. A human-centered development approach always requires a participatory design, especially when it comes to innovative technologies. There is no exception for human-robot collaboration. The talk will cover several field studies on user expectations using known dialogue principles. It highlights commonalities and differences among users from different companies and demonstrates their expectations towards advanced robotic systems. Furthermore, occupational safety and health impacts in implementing interactive robotic systems will be discussed based on the findings from a European survey of enterprises.

Autonomous Machines and Human Factors in the Future of Manufacturing

Eugen Solowjow, Ph.D., Head of Research Group, *Siemens’ Central R&D Division*, Berkeley, CA.

A dominant trend in manufacturing is the move toward small production volumes and high product variability. It is thus anticipated that future manufacturing automation systems will be characterized by a high degree of autonomy, and must be able to learn new behaviors without explicit programming. The question arises how an increased level of machine autonomy will influence human factors to ensure safety and increased production efficiency in mixed human-robot scenarios. This talk introduces the Siemens research at the intersection of autonomous machines, human factors, and production efficiency.

Occupational Exoskeletons: Challenges and Opportunities for Human Factors, Ergonomics, and Safety Disciplines in the Workplace of the Future

Luigi Monica, Ph.D., Lead of the “Technical Assessments” of the *Italian Workers’ Compensation Authority (INAIL).*

The growing interest in exoskeletons indicates that wearable robotic devices will represent one of the next changes in many occupational scenarios and new challenge for human factors, ergonomics, and safety disciplines. Despite the high interest in exoskeletons with an occupational application to prevent work-related musculoskeletal disorders (WRMSDs), large-scale implementation of this type of exoskeletons has still a long way to go, mainly because there is little knowledge of these wearable service robot devices and their real preventive effects on WRMSDs, and because of some technical and user acceptability issues.

The objective of the work is to represent the opportunities of occupational exoskeletons and to illustrate the new challenges for ergonomics and safety disciplines. So, the work provides same

needs must be met and what requirements this typology of exoskeleton must possess, in order to maximize the user benefits and minimize potential negative impacts, using a human-centered design (HCD) and presents results of a joint project on collaborative exoskeletons developed by INAIL (Italian Workers' Compensation Authority) and /IIT (Advanced Robotics, Italian Institute of Technology.

Immersive Robotics and the Curse of Sterility

Juan P. Wachs, Ph.D., Professor and Faculty Scholar, Industrial Engineering School, *Purdue University*
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Robots can already solve sophisticated problems ranging from playing games, autonomous driving, and dancing—given enough observational of data for training. The core of such success resides in efficient algorithms, compliant hardware and robust computing, all implemented using carefully curated data collected before the training phase. Thus, robots learn in a "sterile" domain, under clean, controlled and to some extent supervised environments. As the target domain changes, however, moving to more quotidian scenarios, robots struggle to perform well. To address this hurdle, my work in the area of robotics and autonomous systems focuses on transferring skills and knowledge from controlled settings to the wild. In this talk, I emphasize strategies and techniques to address fundamental challenges in immersive learning. Specifically, I will discuss work related to surgical assistants, telesurgery, and skill augmentation. While medicine is the main domain of the research discussed, the outcomes and findings are applicable to the range of field robotics. Progress in these directions will contribute to the public purpose of creating the knowledge for developing robots that are more accessible, effective and sensitive to social needs.

Closing Panel Discussion: Human Factors in Robotics in the Age of AI - Challenges & Opportunities

Nia Jetter, Amazon; Megan Zimmerman, *National Institute of Standards and Technology*; Peter Hancock, *University of Central Florida*; Edward Chow, *NASA Jet Propulsion Laboratory*

Cybersecurity Speakers

Dr. Sunny Fugate is the Senior Scientific and Technical Manager for Cyber Warfare at the Naval Information Warfare Center, Pacific. Dr. Fugate earned his PhD from the University of New Mexico in 2012 with a focus on adaptive threat detection and has supported the Naval Information Warfare Center, Pacific since 2002 where he leads research efforts for protecting computing systems and networks from attack and to better incorporate human factors and human cognition into our systems and defenses. During his career Dr. Fugate has supported the Defense Advanced Research Projects Agency, the Office of Naval Research, the National Security Agency, Defense Threat Reduction Agency, Marine Forces Cyber Command, and US Cyber Command. Dr. Fugate's research efforts have included AI and expert- system based network intrusion detection, network traffic analysis and visualization, the development of cyber common operational picture displays and implementing cyber symbology, moving target defenses, game theory of cyber defenses and cyber operations, understanding attacker cognition and undermining attacker cognition using the theory of oppositional human factors, and constructing and testing systems to perform defensive cyber deception. Dr. Fugate is also a founding member of the Cybersecurity Technical Group of the Human Factors and Ergonomics Society, a board member and volunteer science educator for the League of Extraordinary Scientists and Engineers, a ComicCon Panelist, and father of two boys.

Robert S. Gutzwiller
After receiving his PhD in Cognitive Psychology from Colorado State University in 2014, Dr. Robert S. Gutzwiller accumulated extensive research and management experience working for the United States Navy. He transitioned to a tenure-track faculty position in Human Systems Engineering at Arizona State University in 2018. Robert now leads and directs the Applied Attention Research lab (@aarlab1 on Twitter) at ASU and studies the application of human attention in the context of a broader human systems engineering perspective. In particular, his research focuses on human-automation interactions; building models of task switching choice for multitasking environments; and recently, Robert is pioneering application of human factors psychology to cyberspace operations. Dr. Gutzwiller has been funded by the Army, Secretary of Defense, DARPA, NASA and ONR, among others. He is the author of over 45 peer-reviewed papers, has received the Human Factors Society's *Jerome H. Ely* award for the most outstanding journal article, and *Marc Resnick* best paper award. He was also awarded by the Navy for exceptional leadership, and exemplary achievement in multi-disciplinary engineering projects.

Dr. Megan Nyre-Yu received her doctorate in Human Factors from Purdue University in 2019 and joined Sandia National Laboratories shortly thereafter. Her graduate work explored human-machine teaming and automation development, especially in cybersecurity settings. At Sandia she conducts applied and operational research across different applications in cybersecurity, such as incident response, digital forensics, and ICS security. Her activities focus particularly on automation selection, design, and technology transfer.

Dr. Celeste Lyn Paul is a cybersecurity subject matter expert and technical leader at the National Security Agency. There, she prevents and eradicates cybersecurity threats to critical national systems by understanding the human role in defensive cybersecurity operations. Dr. Paul has over 10 years of service in the Intelligence Community where she has conducted mission-driven research across a range of emerging technologies. Prior to government service, she spent 10 years in industry and open source software working at the intersection of humans and technology. Dr. Paul earned her Ph.D. in Human-Centered Computing from the University of Maryland Baltimore County. In her spare time she enjoys cooking and flying small aircraft.

Colonel (Retired) Stoney Trent, Ph.D. is a Research Professor at Virginia Tech and is the founder and president of The Bulls Run Group, LLC, a company that specializes in delivering human-centered technologies to high-risk work groups. Dr. Trent is a Cognitive Engineer and Military Intelligence and Cyber Warfare veteran, who specializes in leading new interdisciplinary initiatives. At Virginia Tech, he led the planning of a University Institute for National Security, serves as Fellow for the Acquisition Innovation Research Center, and leads cross-departmental strategic initiatives. While on active duty, Stoney designed and secured over $350M to stand up the Joint Artificial Intelligence Center (JAIC) for the Department of Defense. As the Chief of Missions in the JAIC, Stoney established product lines to deliver human-centered AI to improve warfighting and business functions in the world's largest bureaucracy. Previously, he established and directed U.S. Cyber Command's $50M applied research lab, which develops and assesses products for the Cyber Mission Force. Stoney has served as a Strategic Policy Research Fellow with the RAND Arroyo Center and is a former Assistant Professor in the Department of Behavioral Science and Leadership at the United States Military Academy. He has served in combat and stability operations in Iraq, Kosovo, Germany, and Korea. Stoney is a graduate of the Army War College and former Cyber Fellow at the National Security Agency.

Exoskeleton Speakers

Carisa Harris Adamson, PhD, CPE is an Associate Professor in the Department of Medicine at the University of California at San Francisco (UCSF). She is the Director of the Northern California Center of Occupational & Environmental Health at the University of California at Berkeley and the Director of the UCSF/UCB Ergonomics Research & Graduate Training Program. Dr. Harris and her team performs research in a variety of areas focused on understanding and preventing work related injuries and improving human performance, productivity, and health. Her epidemiological research assesses and adjusts for healthy worker survivor bias in the assessment of physical, personal and work psychosocial factors associated with musculoskeletal disorders and subsequent work disability. Additionally, her team is developing and/or testing a variety of exposure assessment devices (wearables) for primary and secondary prevention purposes and performs various intervention studies on occupational tasks with high risk of musculoskeletal injuries, such as the implementation of passive exoskeletons in construction work.

Dr. William "Bill" Billotte is the Director of Global Exo Technology Programs and Executive Director of the Exo Technology Center of Excellence at ASTM International. Bill leads a dynamic team that pursues a vision of people of all ages free to pursue high-quality life and participate fully in work and society thanks to safe and reliable exo technologies. He serves as an advisor to the Automotive Exoskeleton Group (AExG) and is a member of several standards committees including F48 on Exoskeletons and Exosuits.

Prior to joining ASTM, Bill spent the past 17 years providing scientific and technical advice to federal agencies, first responders, and international organizations on topics including exoskeletons, critical infrastructure protection, CBRNE detection, and first responder equipment. His scientific curiosity and passion for helping others has led him to work on a host of diverse projects. Bill advocated and aided the establishment of the ASTM F48 committee and is working on their long term strategy and research agendas. He spent a year abroad as a visiting scientist on the European Union's critical infrastructure protection team at the Joint Research Centre in Italy, where he provided technical assistance to their working groups to help inform EU policies and international standards. He sponsored a forum through the National Academy of Sciences to convene experts from the federal, private, international, and non-government sectors to exchange information and ideas to improve preparedness and capabilities for disasters that involve accidental or intentional contamination with CBRN agents. He coordinated programs that produced over 50 homeland security focused national standards and over 100 reports on first responder equipment.

Bill has received several awards including the US Department of Commerce's Gold Medal Award for Heroism. Bill holds a Ph.D. in Biology from the University of Dayton, a Master in Science in Engineering from Wright State University, and a Bachelor of Mechanical Engineering from The Georgia Institute of Technology.

Dr. HeeSun Choi is an assistant professor in the Department of Psychological Sciences at Texas Tech University. She is primarily interested in attentional and cognitive declines and failures and their implications for safety-related outcomes, particularly among older adults and industry workers. Her current research focuses on the effects of human assistive and augmenting technology such as VR/AR and exoskeletons on the user's cognitive performance and safety behaviors. Dr. Choi's current research on cognitive performance while wearing an exoskeleton is funded by the ASTM International Exo Technology Center of Excellence. Dr. Choi received her PhD in human factors and applied cognition from North Carolina State University in 2016 and previously worked for the National Institute for Occupational Safety and Health (NIOSH) as a research fellow.

Dr. Jose 'Pepe' L. Contreras-Vidal's primary research areas are neuroengineering, brain-machine interfaces (BMI), rehabilitation engineering and understanding the brain in action from pediatric to adult populations in health and disease. He was elected a Fellow of the IEEE and AIMBE for his research on BMI and powered exoskeletons for rehabilitation and restoration of walking. As Director of the NSF Research Center for Building Reliable Advances and Innovations in Neurotechnology (IUCRC BRAIN) at the University of Houston, a member of the BRAIN Initiative, he leads faculty, undergraduate, graduate and postdoctoral students, and industrial partners in the design of neurotechnologies to improve the quality of life of people with disabilities. As Director of the NSF-funded Research Experiences for Undergraduate (REU) Site "NEUROTECHNOLOGIES TO HELP THE BODY MOVE, HEAL AND FEEL AGAIN", he oversees a national training program that prepares students to become socially responsible leaders and innovators in the development of neurotechnologies for clinical applications and fundamental research. His work at the nexus of art, science and AI is opening new windows to study the neural basis of human creativity in children and adults while informing neural interfaces. He is Co-Chair of the Industry Connections group of the IEEE Standards Association working on Standards and Interoperability of Brain-Machine Interfaces. His published research, funded by NIH, NSF, industry, and foundations, has been highlighted by The Economist, Science, Wall Street Journal, NPR, Nature and others. His career development in biomedical engineering was highlighted in Science. He has been appointed Adjunct Professor of Physical Medicine and Rehabilitation, University of Texas Health Science Center. He is also a Member of the National Institute of Health (NIH)'s National Advisory Board on Medical Rehabilitation Research (NABMRR).

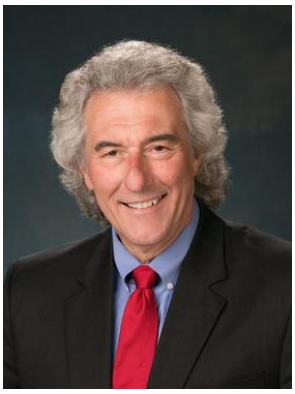
Ignacio Galiana is the co-founder and CEO of Verve Motion, a company commercializing the next generation connected wearable technology for the millions of workers that power our economy and society. Verve launched in 2020 out of Harvard University with a mission to improve the limits of human performance and safety by pioneering the integration of robotics into functional apparel. Prior to Verve, Dr. Galiana was a Program Manager at the Wyss Institute at Harvard University where he led the soft exosuit projects in the Walsh Biodesign Lab. While at Harvard, he was the technical lead for the Harvard team under the DARPA Warrior Web program developing soft exosuits to enhance human walking performance.

Galiana received his Ph.D. in Automation and Control from Universidad Politécnica de Madrid in 2013. During his Ph.D. he received multiple awards including the “best Ph.D. thesis in Europe on haptics” for his contributions to the design and control of haptic devices for VR and Telerobotics.

Pei-Chun Kao is an Assistant Professor in Physical Therapy & Kinesiology at the University of Massachusetts Lowell. She received the physical therapy degree from the National Taiwan University, Taipei, Taiwan, and the M.S. and Ph.D. degrees in Biomechanics from the University of Michigan, Ann Arbor. Her research interests include neuromechanical control of human walking, cognitive-motor interference, and robotic exoskeletons.

Dr. Simon Kudernatsch with a M.S. and Ph.D in Biomedical Engineering, has over nine years of experience in occupational and whole-body biomechanics. His expertise is in the design and execution of biomechanical experiments, hand-arm vibration exposures, biomechanical measurement modalities, and product design and evaluation including medical and wearable devices. Dr. Kudernatsch’s current research focuses on design and development of occupational exoskeletons, development of exoskeleton performance testing methodologies, and exoskeleton intervention.

Brokoslaw Laschowski is a PhD candidate at the University of Waterloo and the Waterloo Artificial Intelligence Institute in Canada. He specializes in using mathematical, computational, and machine learning methods to optimize the design and control of humans interacting with wearable robotic systems and technologies. Applications of his research include rehabilitation robotics, human-machine interfaces, biomechatronics, and wearable assistive technologies (i.e., exoskeletons and robotic prostheses). He received his MASc in mechanical engineering from the University of Waterloo and an MSc in kinesiology, with a specialization in biomechanics, from Western University. Brokoslaw has published in many top-tier scientific journals and conferences, including the IEEE Transactions on Medical Robotics and Bionics, the Frontiers in Robotics and AI, and the IEEE International Conference on Biomedical Robotics and Biomechatronics. He recently served on the executive committee of the Canadian Society for Biomechanics and worked at the Holland Bloorview Kids Rehabilitation Hospital and as a biomechanics professor at Humber College. To date, Brokoslaw has earned over $234,000 in scholarships and awards (e.g., the Natural Sciences and Engineering Research Council of Canada) and co-authored grant proposals that received over $197,000 in research and infrastructure funding (e.g., the Canada Foundation for Innovation). He has presented at many national and international conferences and was recently a Best Paper Award finalist at the 2019 IEEE International Conference on Rehabilitation Robotics. His award-winning research has been featured on media networks like BBC News, CBC, and Maclean's Magazine, in addition to the recent GTC keynote address by the founder and CEO of NVIDIA.



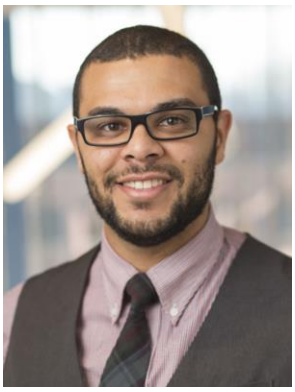
William S. Marras holds the Honda Chair in Integrated Systems Engineering at the Ohio State University and serves as the Director of the Spine Research Institute at the Ohio State University where he leads NIH, NSF, DoD and privately funded research efforts. Dr. Marras holds joint academic appointments in the Department of Orthopaedic Surgery, the Department of Neurosurgery, and the Department of Physical Medicine & Rehabilitation. His research is centered on understanding multidimensional causal pathways for spine disorders through quantitative epidemiologic evaluations, laboratory biomechanical studies, personalized mathematical modeling, and clinical studies of the lumbar and cervical spine. His findings have been published in over 300 peer-reviewed journal articles, hundereds of refereed proceedings, and numerous books and book chapters including a book entitled The Working Back: A Systems View. Professor Marras has been active in the National Research Council (NRC) having served on over a dozen boards and committees and has served as Chair of the Board on Human Systems Integration for multiple terms. He has also served as Editor-in-Chief of Human Factors and is currently Deputy Editor of Spine. Dr. Marras holds Fellow status in six professional societies and is an elected member of the National Academy of Engineering (the National Academy of Science, Engineering and Medicine), recorded a TEDx talk entitled "Back Pain and your Brain" and has been featured on NPR's All Things Considered.

Luke Mooney, PhD is Cofounder and CEO of Dephy. Throughout his professional and academic career, he has focused on the development and commercialization of wearable robotics. With the founding of Dephy in 2015, Dr. Mooney has built a world-class team and led them in the successful execution of Army contracts that developed, evaluated and ruggedized an autonomous ankle exoskeleton, the ExoBoot. Designed for maximizing walking augmentation, the ExoBoot has demonstrated breakthrough performance with applicability in multiple user applications. As an academic researcher, Dr Mooney has published fourteen peer-reviewed articles focusing on the design and evaluation of robotic prostheses, exoskeletons, and wearable sensors, including the first autonomous exoskeleton to reduce the metabolic cost of walking. Along with the mechanical design of these devices, he has designed and implemented control algorithms that leverage both the human and device strengths to enable effective cooperation.

Dr. Donald R. Peterson is a Professor of Mechanical Engineering and serves as the Dean of the College of Engineering and Engineering Technology at Northern Illinois University. He is also an affiliated professor in the Department of Biomedical Engineering at Texas A&M University and a Fellow of the American Institute for Medical and Biological Engineering (AIMBE). Dr. Peterson is a graduate of Worcester Polytechnic Institute, earning degrees in Aerospace Engineering (BS) and Biomechanical Engineering (BS) and a graduate of the University of Connecticut, earning degrees in Mechanical Engineering (MS) and Biomedical Engineering (PhD). Dr. Peterson's experience in biomechanical engineering and medical research has been focused on measuring and modeling injury biomechanics and human, organ, and cell performance, including exposures to various physical stimuli and the subsequent biological or physiological responses. His research has involved the investigation of injury mechanisms and human–device interaction and has led to the generation of new technologies and systems, such as personal protection technologies, occupational exoskeleton systems, robotic exoskeleton assist devices for hemiplegic rehabilitation, long-duration biosensor monitoring and reporting systems, novel surgical and dental devices and instruments, smart medical devices for home patient care, and biotechnology systems. Dr. Peterson currently serves as the Chair of the ASTM International Committee F48 on Exoskeletons and Exosuits and as a US delegate on the International Standards Organization Technical Committee (ISO/TC) 108/SC4 on Human Exposure to Mechanical Vibration and Shock. Dr. Peterson has published over 130 peer-reviewed scholarly works and is the Editor-in-Chief for "The Biomedical Engineering Handbook", published by CRC Press.

Dr. Chris Reid is a Human Factors & Ergonomics (HFE) Associate Technical Fellow for Boeing's Environment, Health & Safety (EHS) organization in Charleston, SC. He is the EHS portfolio manager of wearable technology (e.g., exoskeletons, mixed reality, and wearable sensing and computing systems). Prior to Boeing, Dr. Reid worked for Lockheed Martin on astronaut spacesuit assessment as a Human Factors & Ergonomics Discipline Lead at NASA and as a Human Factors Engineer for the US Army assessing Warfighter personal protective equipment. Outside of Boeing, he is a member of the Human Factors & Ergonomics Society Executive Council as the 2020 President-Elect, advises on ergonomics as a Delegates Committee member for the National Safety Council's Board of Directors, sits on the Editorial Boards for the Augmented Human Research and Theoretical Issues in Ergonomics Sciences Journals, is a 2019-2020 Special Issue Editor for the Human Factors Journal, Chair of the Annual ErgoX International Symposium, and Chair of the HFE Subcommittee for ASTM F48 standards on Exoskeletons. He is a recipient of both the 2018 Rising Star Award from the National Safety Council and the 2020 Black Engineer of the Year Award. He graduated from the University of Central Florida, with degrees in Electrical Engineering Technology (BS) and Industrial Engineering (MS and PhD).

Leia Stirling is an Associate Professor in Industrial and Operations Engineering at the University of Michigan, a Core Faculty in the Center for Ergonomics, a Core Faculty in the Robotics Institute, and the University of Michigan Center for Occupational Health and Safety Engineering (COHSE) Director of Occupational Safety Engineering and Ergonomics. She received her B.S. (2003) and M.S. (2005) in Aeronautical and Astronautical Engineering from the University of Illinois at Urbana-Champaign, and her Ph.D. (2008) in Aeronautics and Astronautics from MIT. She was a postdoctoral researcher at Boston Children's Hospital and Harvard Medical School (2008-2009), on the Advanced Technology Team at the Wyss Institute for Biologically Inspired Engineering (2009-2012), then an Assistant Professor at MIT (2013 – 2019). She joined the faculty at the University of Michigan in 2019. Her research quantifies human performance and human-machine fluency to assess performance augmentation, advance exoskeleton control algorithms, mitigate injury risk, and provide relevant feedback to subject matter experts across domains.



Karl Zelik is an engineering professor at Vanderbilt University where he co-directs the Center for Rehabilitation Engineering and Assistive Technology. He is also Co-Founder and Chief Scientific Officer of HeroWear, which develops occupational exosuits that reduce fatigue and physical strain on workers. Zelik strives to reduce physical disabilities in society, and enhance human performance and well-being through advances in biomechanical science and wearable assistive technology. He is an advocate for science communication, outreach, and inclusion. He received the International Society of Biomechanics Promising Scientist Award and the American Society of Biomechanics Young Scientist Award in 2017, a Nashville Emerging Leader Award in 2018, and a Nashville Business Journal 40 Under 40 Award in 2021.

Robotics Speakers

Shelly Bagchi is an Electrical Engineer at the National Institute of Standards and Technology in Gaithersburg, Maryland. She received her Masters in Electrical Engineering from the Georgia Institute of Technology in 2015, and her Bachelors in Computer Engineering from the George Washington University in 2013. Her research interests are in human-robot interaction, situational awareness, and augmented reality. She previously co-taught the introductory Artificial Intelligence class in Georgia Tech's Online Masters in Computer Science program, a program which has enrolled over 10,000 students. She participates in the ASTM Standards Committee E57 on 3D Imaging Systems and the IEEE Study Group on Metrology for Human-Robot Interaction. Shelly also serves as an organizer for the 'Test Methods and Metrics for HRI' Workshop, which occurs annually at the ACM/IEEE International Conference on Human-Robot Interaction, as well as the 'Artificial Intelligence for Human-Robot Interaction' Symposium, part of the annual AAAI Fall Symposium Series.

Professor Sang D. Choi, PhD, MPH(c), MS, CPE, CSP is a Full Professor and Construction Program Coordinator in the Department of Occupational & Environmental Safety & Health (OESH) at the University of Wisconsin – Whitewater, Wisconsin. Dr. Choi also served as adjunct and the visiting professor in the Department of I & Sys (Human Factors) Engineering (Interactive ICT & VR/AR Training) at Korea Advanced Institute of Science and Technology (KAIST). Dr. Choi was the President (2018-2019) of the International Society for Occupational Ergonomics and Safety. He has worked in the ANSI/ASSP A10.100-2018 Technical Report (TR) – Prevention through Design (PtD) for Construction Safety and Health committee, and also serves in the CDC National Occupational Research Agenda (NORA) Construction Sector Council. Professor Choi's research interests are Human Factors & Ergonomics Engineering, Human-Computer Interaction, Human-Robot Interface, PtD (Autonomous/Automation), Human-Systems Integration, and SMART Safety Risk Assessment/Management. Dr. Choi has successfully led applied safety research projects associated with the CDC/NIOSH, DOT/WI-BOTS, ASSP, and UWW Research Development Grants. Dr. Choi is currently an OSH specialist/assignee of the CDC/NIOSH Intergovernmental Personnel Act Mobility Program. Dr. Choi has produced over 160-refereed high-quality publications and has being invited numerous times to be as the keynote/session speaker at prestigious national and international conferences. Professor Choi was a Guest Editor for special issue "Occupational Ergonomics, Human Factors and Safety: Theory, Application and Practice" in the International Journal of Environmental Research and Public Health. Dr. Choi is a Board-Certified Safety Professional (CSP #21433) and a Board-Certified Professional Ergonomist (CPE #1179).

Dr. Edward Chow is the Manager of the Civil Program Office at the NASA Jet Propulsion Laboratory (JPL). He also served as the project manager/principal investigator/investigator for a number Artificial Intelligent (AI), advanced networking, and cybersecurity projects such as the Real-time Automated Insight Engine for Data to Decision (RAID) Project funded by OSD T&E S&T C4T to develop the next generation AI technologies to enable human-like automated data analytics for testing of complex system such as the F-35 Joint Strike Fighter; A cloud-based AI agent called AUDREY for the Department of Homeland Security (DHS) Next Generation First Responder Program where, for each first responder, there is an AI agent constantly monitoring in-situ and body worn Internet of Things sensors and collaborate with other AI agents to protect the safety of first responders; A high performance 5G edge computing project for DHS; and A zero-day exploit detection project. He is also supporting the team that is developing the Trusted and exPlainable Artificial Intelligence for Saving Lives (TruePAL) project for the National Highway Traffic Safety Administration to reduce the traffic accidents for first responder vehicles. Dr. Chow received his Ph.D. in Electrical Engineering from University of Southern California in 1988. Dr. Chow is the recipient of the prestigious NASA Exceptional Engineering Achievement Medal and the JPL Lew Allen Award.

Dr. Satyandra K. Gupta is Smith International Professor in the Department of Aerospace and Mechanical Engineering and Department of Computer Science in Viterbi School of Engineering at the University of Southern California. He serves as the Director of the Center for Advanced Manufacturing. He served as a program director for the National Robotics Initiative at the National Science Foundation from September 2012 to September 2014. Dr. Gupta's interests are in the area of physics-aware decision making to facilitate and advance the state of automation. He has published more than four hundred technical articles. He is a fellow of the American Society of Mechanical Engineers (ASME), Institute of Electrical and Electronics Engineers (IEEE), and Society of Manufacturing Engineers (SME). He serves as the editor of the ASME Journal of Computing and Information Science in Engineering. Dr. Gupta has received numerous honors and awards for his scholarly contributions. Representative examples include a Young Investigator Award from the Office of Naval Research in 2000, Robert W. Galvin Outstanding Young Manufacturing Engineer Award from the Society of Manufacturing Engineers in 2001, CAREER Award from the National Science Foundation in 2001, Presidential Early Career Award for Scientists and Engineers in 2001, Invention of the Year Award at the University of Maryland in 2007, Kos Ishii-Toshiba Award from ASME in 2011, Excellence in Research Award from ASME Computers and Information in Engineering Division in 2013, and Distinguished Alumnus Award from Indian Institute of Technology, Roorkee in 2014. He was named “the 20 most influential professors in smart manufacturing” by Smart Manufacturing Magazine in June 2020. He has also received ten best paper awards at international conferences.

P.A. Hancock, D.Sc., Ph.D. is Provost Distinguished Research Professor in the Department of Psychology and the IST, School for Modeling, Simulation and Training at the University of Central Florida (UCF), where he also holds courtesy appointments in the Department of Civil and Environmental Engineering and the Department of Industrial Engineering and Management Systems At UCF he was named the 16th ever University Pegasus Professor (the Institution's highest honor), and in 2012 was named 6th ever University Trustee Chair, a competitive appointment for which he has been approved for two additional five year terms. He is also an affiliated scientist of the Humans and Automation Laboratory at Duke University, a Research Associate of the University of Michigan Transport Research Institute, and a Senior Research Associate at the Institute for Human and Machine Cognition in Pensacola, Florida. Professor Hancock is the author of over a thousand refereed scientific articles and publications as well as writing and editing twenty-five books including: Human Performance and Ergonomics in Academic Press' Handbook of Perception and Cognition series. To date, he has secured over $21 Million in externally funded research during his career and has been continuously funded by external sources across the span of his forty-year career. He has delivered, or been author on, over 1,000 scientific presentations. In 200, he was the Keynote Speaker for the combined meeting of the International Ergonomics Association and the Human Factors and Ergonomics Society in San Diego which was the largest professional meeting of the discipline. In 2006, he won the Norbert Wiener Award of the Systems, Man and Cybernetics Society of the Institute of Electrical and Electronic Engineers (IEEE), being the highest award that Society gives for scientific attainment. In 2008, he received the Otto Edholm Award of the Ergonomics Society. That same year he won the Andrew P. Sage Award of the Systems, Man and Cybernetics Society of the Institute of Electrical and Electronic Engineers (IEEE) for the best published work in the Journals of the Society which numbered over three-hundred papers for the year. In 2012, he was named winner of the Oliver Keith Hansen Award of the Human Factors and Ergonomics Society for achievement in outreach activities and was also named Fellow of the Aerospace Medical Association. He is a Fellow and current President of the Human Factors and Ergonomics Society and is only the second individual to have been elected President twice. He is also a Fellow and past President of the Society of Engineering Psychologists as well as being a former Chair of the Board of the Society for Human Performance in Extreme Environments. Notably, in 2015, he was elected only the 13th Honorary Member of the American Society of Heating, Radiation, and Air Conditioning Engineers (ASHRAE) since 1896, joining a list of twelve prior selectees including a past-President of the United States. Recently, he has been elected a Fellow of the Royal Aeronautical Society (RAeS) and in late 2016 he was named the 30th Honorary Member of the Institute of Industrial and Systems Engineers. Before the recent re-organization, he was the only scientist serving concurrently on the USAF Science and Innovation Advisory Board and the Science Board of the US Army.

Dr. Hongwei Hsiao serves as Chief of the Protective Technology Branch and Coordinator for the Center for Occupational Robotics Research at the National Institute for Occupational Safety and Health (NIOSH). He received his degrees from Cornell University and the University of Michigan and has held engineering and management positions in both the manufacturing industry and the U.S. Government. He also has taught human factors engineering in academia. Dr. Hsiao has headed numerous programs and projects in safety research. He also coordinates development of strategic goals for the NIOSH robotics center and manages center resources and seminars. The Center addresses worker safety and integration with caged robots, collaborative robots, mobile robots, exoskeletons, autonomous equipment, drones, and artificial intelligence. His research covers human-robot interface, statistics and big data, anthropometry and biometrics, biomedical engineering, construction safety, and health protection. He manages several laboratories for NIOSH, including the Virtual Reality, Anthropometry Research, High Bay, Vehicle Safety, Digital Modeling, Human Factors, Robotics Research, and Sensor Development Laboratories. An editorial board member for eight scientific journals, Dr. Hsiao has written or contributed over 170 publications and patents in human factors and engineering innovation for injury control. He was credentialed as a Silvio O. Conte Senior Biomedical Research Service Fellow by the Government Executive Resources Board in 2003.

Nia Jetter is passionate about changing the world through innovation, technology planning, teaching, mentoring, and solving tough problems in Autonomy and AI that can be applied across different platforms. She has a dedicated focus on helping people who may not have easy access to educational materials to understand topics like artificial intelligence. Nia is enthusiastic about working the human-AI interface as artificial intelligence is further integrated into our society.

Nia has 20 years of experience in the Aerospace Industry and has supported a variety of programs across the product-lifecycle from design and development to mission and anomaly resolution and through customer delivery and support. In January 2021, Nia left the Aerospace Industry as a Technical Fellow to join Amazon as a Senior Principal Technologist for Robotics AI. In this role she is a leader in technical development for autonomy as well as strategic planning for robotics and other autonomous applications.

Nia has a bachelor's degree in Math with Computer Science and a minor in Earth Atmospheric and Planetary Sciences from MIT as well as a Master's Degree in Aeronautical and Astronautical Engineering from Stanford. Nia enjoys reading (especially science fiction), astronomy, baking, travelling, dancing, and creating short videos that break down complex topics like AI and explains them simply for her YouTube channel (Thinque Bytes). For more information, please see her website: www.niajetter.com.

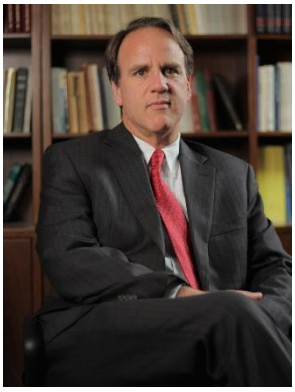
Luigi Monica is a technologist. He is responsible for the technical-scientific section “Technical Assessments” of the Italian Workers’ Compensation Authority (INAIL) - Department of Technological Innovation and Safety of Plants, Products and Anthropic settlements. He coordinates conformity assessment activities of machines, plants, appliances and products to the safety requirements prescribed by the provision applicable laws (Machinery Directive, PED Directive, etc.) in support of the Authorities market surveillance. He received his doctoral degree in Mechanical Engineering with a focus on Production Systems and Industrial Plants. His research expands from risk assessment methodologies, machine and equipment safety of work and production plants, to risk management and technological innovation.

Professor Robert Radwin is the Duane H. and Dorothy M. Blumke Professor in industrial and systems engineering and biomedical engineering at the University of Wisconsin-Madison. He investigates new ways to measure and quantify physical stress in the workplace, utilizing signal processing, computer vision and machine learning. His expertise is sought after as a consultant to industry and government for ergonomics in manufacturing and product design. Professor Radwin has received numerous awards as an innovator and researcher, is a fellow of five professional societies, has served on prestigious national committees, and is the reviews track editor for the journal Human Factors and associate editor for the journal IISE Transactions on Occupational Ergonomics and Human Factors. He is founding chair of the University of Wisconsin-Madison Department of Biomedical Engineering and is a Discovery Fellow at the Wisconsin Institute for Discovery.

Dr. Stephen K. Robinson spent 37 years at NASA, where he worked as a machinist, lab technician, engineer, research scientist, branch chief, safety representative, and astronaut, before joining the faculty at the University of California, Davis in 2012. Robinson is now a tenured professor in the UC Davis Mechanical and Aerospace Engineering Department. He has recently been appointed Director of the UC Davis Center for Spaceflight Research. Dr. Robinson also directs the UC Davis human/Robotic/Vehicle Integration and performance Lab, where graduate and undergraduate students pursue research in human spaceflight, spacecraft design for human health and safety, aviation safety, human/automation/robotic integration, human performance, automation and control, and CubeSat and UAV design. During his 17 years as a NASA Astronaut, Dr. Robinson flew on four space shuttle missions, including three spacewalks, visited the ISS twice, trained in Star City, Russia, and has extensive expertise in spacecraft systems, human/systems integration, operational safety, space robotics, aerodynamics, and fluid physics. Dr. Robinson has received numerous awards, including NASA’s highest honor - the NASA Distinguished Service Medal, and UC Davis’ highest honor – the UC Davis Medal. Robinson is a UC Davis alumnus in Mechanical and Aeronautical Engineering (double B.S., 1978) and received his M.S. and Ph.D. in

turbulence physics from Stanford University in Mechanical and Aero/Astro Engineering (1986, 1990). Dr. Robinson is an active pilot, an artist, and a multi-instrument musician– he currently plays with the mostly astronaut folk-music band Bandella, and the all-astronaut rock band Max Q.

Craig Schlenoff is the Group Leader of the Cognition and Collaboration Systems Group and the Program Manager of the Robotic Systems for Smart Manufacturing Program in the Intelligent Systems Division at the National Institute of Standards and Technology. He leads the Agility Performance of Robotic Systems project and co-leads the Embodied AI and Data Generation for Manufacturing Robotics project. His research interests include knowledge representation/ontologies, intention recognition, and performance evaluation techniques applied to manufacturing robotic systems. He has led multiple million-dollar projects, dealing with performance evaluation of advanced military technologies and agility performance of manufacturing robotic systems. He has published over 150 journal and conference papers, guest edited three journals, and written three book chapters. He is currently the Associate Vice President for Standardization within the IEEE Robotics and Automation Society and the vice chair of the IEEE Robot Task Representation Working Group. He previously served as the program manager for the Process Engineering Program at NIST and the Director of Ontologies at VerticalNet. He received his Bachelor's degree from the University of Maryland and his Master's degree from Rensselaer Polytechnic Institute, both in mechanical engineering, and his PhD from the University of Burgundy, France in computer science.



Professor Soibelman obtained his BS and MS Degrees from the Civil Engineering Department of the Universidade Federal do Rio Grande do Sul, Brazil. He worked as a construction manager for 10 years before moving in 1993 to the US where he obtained in 1998 his PhD in Civil Engineering Systems from the Civil and Environmental Engineering Department at the Massachusetts Institute of Technology (MIT).

In 1998 he started as an Assistant Professor at the University of Illinois at Urbana Champaign. In 2004 he moved as an Associate Professor to the Civil and Environmental Engineering Department at Carnegie Mellon University (CMU) and in 2008 was promoted to Professor. In January 2012 he joined the University of Southern California as the Chair of the Sonny Astani Department of Civil and Environmental Engineering. In June 2021 he stepped down as the Astani Department Chair.

During the last 25 years he focused his research on advanced data acquisition, management, visualization, and mining for construction and operations of advanced infrastructure systems. He published over 200 books, books chapters, journal papers, conference articles, and reports and performed research with funding from NSF (NSF career award and several other NSF grants), NASA, DOE, US Army, NIST, IBM, Bosch, IDOT, RedZone Robotics among many others funding agencies. He is the former chief

editor of the American Society of Civil Engineers Computing in Civil Engineering Journal. In 2010 he received the ASCE Computing in Civil Engineering Award, in 2012 received the 2011 FIATECH Outstanding Researcher Celebration of Engineering & Technology Innovation, or CETI, Award, in 2016 he received the ASCE Richard R. Torrens Award, in 2017 he received the ASCE Construction Institute Construction Management award, in 2013 he was elected an ASCE fellow, in 2016 he was appointed as Viterbi Dean Professor at USC and was appointed as a Distinguished 1,000 talent Professor at Tsinghua University, in 2019 was elected to the National Academy of Construction, and in 2020 he was appointed as the Fred Champion Estate Chair in Engineering Professor at USC and in 2021 was elected as an ASCE Distinguished Member.

His areas of interest are: Use of information technology for economic development, information technology support for construction management, process integration during the development of large-scale engineering systems, information logistics, artificial intelligence, data mining, knowledge discovery, image reasoning, text mining, machine learning, advanced infrastructure systems, sensors, streaming data, construction robotics, and Multi-reasoning Mechanisms.

Dr. Eugen Solowjow is Head of Research Group at Siemens' central R&D division, located in Berkeley, CA, USA. His research interests are in the areas of Machine Autonomy, Robotics, and Artificial Intelligence with applications to factory automation. Eugen holds a Ph.D. (Dr.-Ing.) from Hamburg University of Technology (TUHH), Germany and was a visiting scholar at the University of California, Berkeley.

Dr. Juan Wachs is a Professor and Faculty Scholar in the Industrial Engineering School at Purdue University, Professor of Biomedical Engineering (by courtesy) and an Adjunct Associate Professor of Surgery at IU School of Medicine. He is the director of the Intelligent Systems and Assistive Technologies (ISAT) Lab at Purdue, and he is affiliated with the Regenstrief Center for Healthcare Engineering. He completed postdoctoral training at the Naval Postgraduate School's MOVES Institute under a National Research Council Fellowship from the National Academies of Sciences. Dr. Wachs received his B.Ed.Tech in Electrical Education in ORT Academic College, at the Hebrew University of Jerusalem campus. He received his M.Sc. and Ph.D. in Industrial Engineering and Management from the Ben-Gurion University of the Negev, Israel. He is the recipient of the 2013 Air Force Young Investigator Award, and the 2015 Helmsley Senior Scientist Fellow, and 2016 Fulbright U.S. Scholar, the James A. and Sharon M. Tompkins Rising Star Associate Professor, 2017, ACM Distinguished Speaker 2018, and 2020 Faculty Scholar. He is the AI-Medic CEO, a company using AI to assist in telesurgery. He is also the Associate Editor of IEEE Transactions in Human-Machine Systems, Frontiers in Robotics and AI. Currently Wachs serves as a Program Director at the National Science Foundation (NSF) for the Robust Intelligence,

National Robotics Initiative (NRI and Foundational Robotics Research (FRR), and Fairness in AI (FAI) programs.

Dr. Sascha Wischniewski is head of the unit "Human Factors, Ergonomics" at the German Federal Institute for Occupational Safety and Health (BAuA). His fields of expertise are anthropometry and digital human modelling, ergonomics of smart in-formation and communication technologies and human factors in robotics. Sascha is a graduate engineer in Mechanical Engineering from and holds a doctoral degree in Industrial Engineering. His work focuses on human-technology interaction in the working world with special emphasis on innovative technologies for physical and cognitive work assistance. He is active in standardization and currently chair of the Technical Committee Human Factors in Robotics of the International Ergonomics Association.

Megan Zimmerman is a research scientist at the National Institute of Standards and Technology (NIST) whose work centers enabling technologies for collaborative robotics within manufacturing applications. Megan joined NIST in 2016 and has been active within both the human-robot-interaction (HRI) and Artificial Intelligence (AI) communities since 2014. Megan's primary fields of expertise include human robot interaction, Artificial Intelligence, and alternative robot control interfaces, including Virtual Reality and Tangible User Interfaces. Megan is currently leading efforts at NIST to generate public datasets for generalizable assembly tasks and action recognition and comprehension within humans, human teams, and human robot teams.