NEW YORK UNIVERSITY

UNIVERSITY OF DELAWARE

1st IEEE Workshop (Virtual)

RELIABLE AND RESILIENT DIGITAL MANUFACTURING

EXPERTS WITH INTERDISCIPLINARY BACKGROUNDS TO FACILITATE THE GROWTH OF THE NEW AREA OF DIGITAL MANUFACTURING

SEPTEMBER 16-17, 2021

https://r2dm-workshop.github.io/

NSF

IEEE

PREFACE

Welcome to the IEEE Workshop on Reliable and Resilient Manufacturing (R2DM). Implementation of Industry 4.0 has resulted in increased use of sensors and data driven technologies for achieving automation in every phase of manufacturing. Artificial intelligence and robotics are now increasingly being used in the design and manufacturing phases. The need for a platform that integrates design, manufacturing and qualification phases has resulted in increased connectivity and data sharing. However, the connectivity has also exposed the system to a variety of risks that are inherent to a cyber component of a cyber-physical system. The reliability and resilience of the connected manufacturing systems in the presence of these threats is a major concern. This workshop aspires to capture the present state of the art in implementing new manufacturing technologies such as additive manufacturing in the industry and the security risks related to intellectual property protection, sabotage and counterfeit detection. The workshop brings together experts from manufacturing and cybersecurity fields to develop a group that will address some of the pressing challenges in this area.

We are thankful to the National Science Foundation's Future manufacturing program to support this workshop and IEEE for agreeing to provide technical sponsorship of this event. We also thank all the speakers for enthusiastically agreeing to participate in the workshop. We hope that this workshop will continue in the future years to develop a community that bridges the gap between manufacturing and cybersecurity professions.

ORGANIZING COMMITTEE

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Workshop Program

September 16 (All times of US Eastern Times)

10:00 AM **Welcome - Nikhil Gupta (New York University)**
Manufacturing Security - The Necessity, Needs and Trends

10:30 AM **Keynote - Andrew Wells (National Science Foundation)**
NSF Support for Reliable and Resilient Digital Manufacturing

11:30 AM **Shuran Song (Columbia University)**
Adaptable and Scalable Robot Teleoperation for Human-in-the-Loop Assembly

12:00 AM **Don Jones (Carlisle & Co.)**
Balancing 3D Printing Opportunities and Security for Aftermarket Parts

12:30 AM **Break**

1:00 PM **Danny Huang (New York University)**
Toward Characterizing Behaviors of Open-source Contributors for Manufacturing Software to Identify Security Risks

1:30 PM **Mohammad Al-Faruqe (University of California - Irvine)**
Attacks and Defenses through Side-channels of Manufacturing Systems

2:00 PM **Jitesh Panchal (Purdue University)**
Design of Traceability and Anti-counterfeiting Schemes for Mechanical Parts

2:30 PM **Satish Bukkapatnam (Texas A&M University)**
Cybersecurity for Smart Manufacturing: From Industrial Quality and Integrity to Security Assurance

3:00 PM **Ferenc Pankotai (Solar Turbines)**
Additive Manufacturing as Technology Enabler at Solar Turbines

3:30 PM **Day 1 Closing**

Workshop Program

September 17 (All times of US Eastern Times)

10:00 AM **Welcome - Nektarios Tsoutsos (University of Delaware)**

10:30 AM **Keynote - Paul Huang (Office of Naval Research)**
Navy Manufacturing Technology (MR) Program

11:30 AM **Mark Yampolskiy (Auburn University)**
Security Threats in AM: Attacks within Cyber and Beyond

12:00 AM **Eric MacDonald (University of Texas - El Paso)**
AM of Elastomer, Ceramic and Metal Multi-functional Structures

12:30 AM **Break**

1:00 PM **Student Presentations**
Judges: Mihail Maniatakos (NYU-Abu Dhabi) and Yan Lu (NIST)

Dimitris Mouris: *Peak Your Frequency: Advanced Search of 3D CAD Files in the Fourier Domain*

Harsh Srivastava: *Determination of Volume Fraction of Fibre Reinforced Composite Materials using Image Processing Techniques*

Caleb Beckwith: *Threat Vector Analysis - Finding Fault in the Pile*

Lars Folkerts: *FSS: Fourier Silhouette Search*

Praveen Sreeramagiri: *Actor-Network Theory as a Tool to Analyze Cyber Threats in Manufacturing*

3:00 PM **Roundtable Discussion**

3:30 PM **Workshop Closing**

Dr. Andrew Wells
Program Director
National Science Foundation

Biosketch

Dr. Andy Wells has been a Program Director in the National Science Foundation's Advanced Manufacturing program since 2019, where he supports fundamental research to advance American manufacturing technologies. He is also the co-leader of the Future Manufacturing solicitation, which supports research and education that will enable new, potentially transformative, manufacturing approaches to eliminate scientific technological, educational, economic and social barriers that limit current manufacturing. He is an NSF representative to the National Science and Technology Council's (NSTC) Subcommittee on Advanced Manufacturing, and to the Manufacturing USA Interagency Working Group. Andy brings to the program over 25 years of experience developing and building precision equipment that enables manufacturers and researchers to visualize and transform materials at the micro- and nano-scale. Most recently, he was a technical program manager at Thermo Fisher Scientific and FEI Company, where he led development of scanning electron microscopes and ion-beam machining tools for semiconductor, materials science, and life science customers. Previously, he developed equipment for laser and mechanical micromachining at Electro Scientific Industries and was an adjunct professor at Portland State University. Andy received his PhD and MS degrees in mechanical engineering from Caltech, and his bachelor's degree from Dartmouth.

NSF Support for Reliable and Resilient Digital Manufacturing

The National Science Foundation accelerates advances in manufacturing technologies with emphasis on research that fundamentally alters and transforms manufacturing capabilities, methods and practices. Through its support of basic research, the NSF aims to revitalize American manufacturing to grow the national prosperity and workforce, and to reshape strategic industries. This presentation will share some of NSF's recent investments in reliable and resilient digital manufacturing, with examples of representative awards and highlights of some ongoing projects. Relevant programs and solicitations will be described, along with some guidelines for submitting proposals.

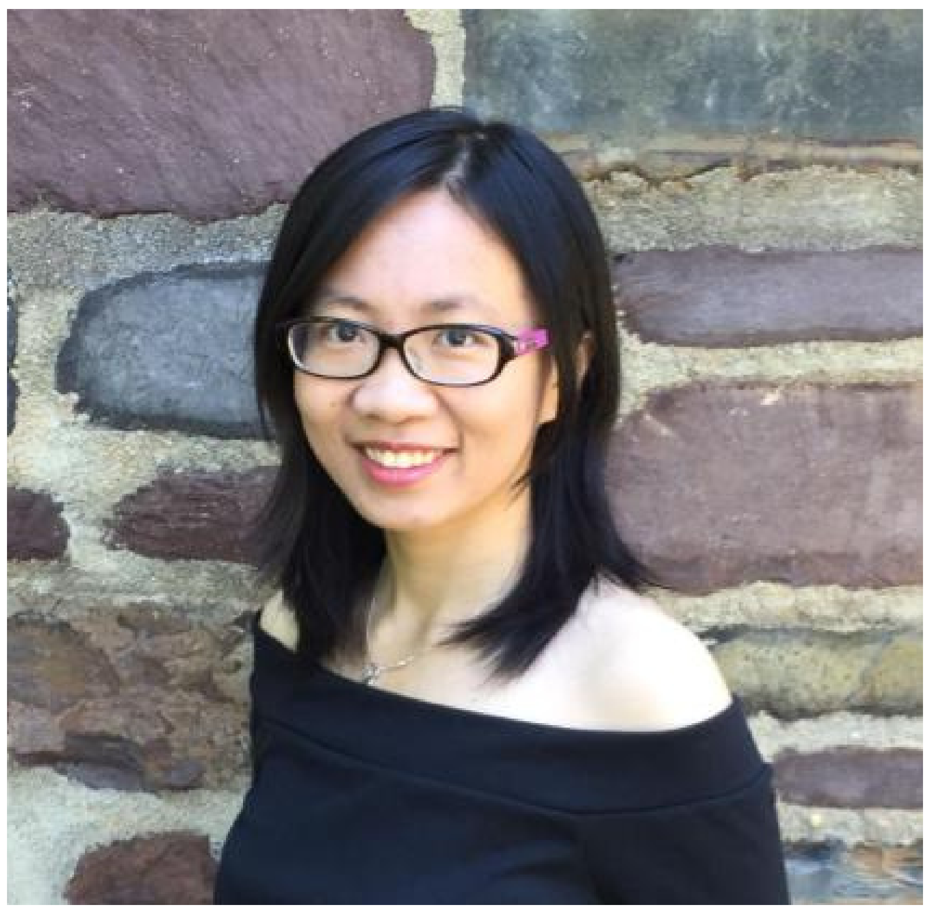
Biosketch

Mr. Paul Huang, Program Officer at Office of Naval Research responsible for Advance Manufacturing Enterprise and Sustainment thrust for Navy ManTech program. He is currently the Navy Primary to the Advance Manufacturing Enterprise (AME) subpanel of the Joint Defense Manufacturing Technology Panel. He also serves as the COR for the Naval Shipbuilding and Advance Manufacturing (NSAM) and Program Manager for the Institute for Manufacturing & Sustainment Technologies (iMAST) Center of Excellence. Also actively involved with various Manufacturing USA institutes in particular serves as the Navy representative on the Technical Advisory Committee (TAC) at the Manufacturing for Digital (MxD) and Advance Robotics for Manufacturing (ARM) Institutes. Also is a guest researcher at the National Institute of Standards and Technology (NIST) System Integration Division.

Paul Huang
Program Office
Office of Naval Research

Previously worked at the Army Research Laboratory where his research was in the areas of inorganic composite development, thermal barrier coatings for diesel engines, tribological coatings for bearings, and was past DoD Coordinator for MIL-HDBK-17 Metal Matrix and Ceramic Matrix Composites volumes.

Paul received a BS in Materials Science & Engineering, Virginia Tech, and MS in Mechanical Engineering, Northeastern University.



Biosketch

Shuran Song is an assistant professor in the Department of Computer Science at Columbia University. Before that, she received her Ph.D. in Computer Science at Princeton University. Her research interests lie at the intersection of computer vision and robotics. She is a recipient of several awards including the Best Paper Award at T-RO '20, Best Systems Paper Award at RSS '19, Best Manipulation Systems Paper Award from Amazon '18, and has been finalist for Best Paper Awards at conferences ICRA '20, CVPR'19, RSS '19, IROS '18. She has received TRI Young Faculty Researcher Award, Microsoft Research Faculty Fellowship, and Faculty Research Awards from Amazon and JP Morgan.

Shuran Song
Professor
Dept. of Computer Science
Columbia University

Adaptable and Scalable Robot Teleoperation for Human-in-the-Loop Assembly

The COVID-19 pandemic has accelerated the adoption of remote working in many industries. The ability for employees to work remotely, often from home, has become crucial to an organization's long-term resilience and growth potential. However, while advances in software and networking have made it possible for information workers to work remotely, most manufacturing workers cannot, because the infrastructure that is needed doesn't exist. This Future Manufacturing (FM) project will research an adaptable and scalable robot teleoperation system that allows factory workers to work remotely. The research will benefit both the manufacturing industry and the workforce by increasing access to manufacturing employment and improving working conditions and safety. By combining human-in-the-loop design with machine learning, this research can broaden the adoption of automation in manufacturing to new tasks. Beyond manufacturing, the research will also lower the entry barrier to using robotic systems for a wide range of real-world applications, such as assistive and service robots.

Don Jones
President
DJE Logistics, LLC

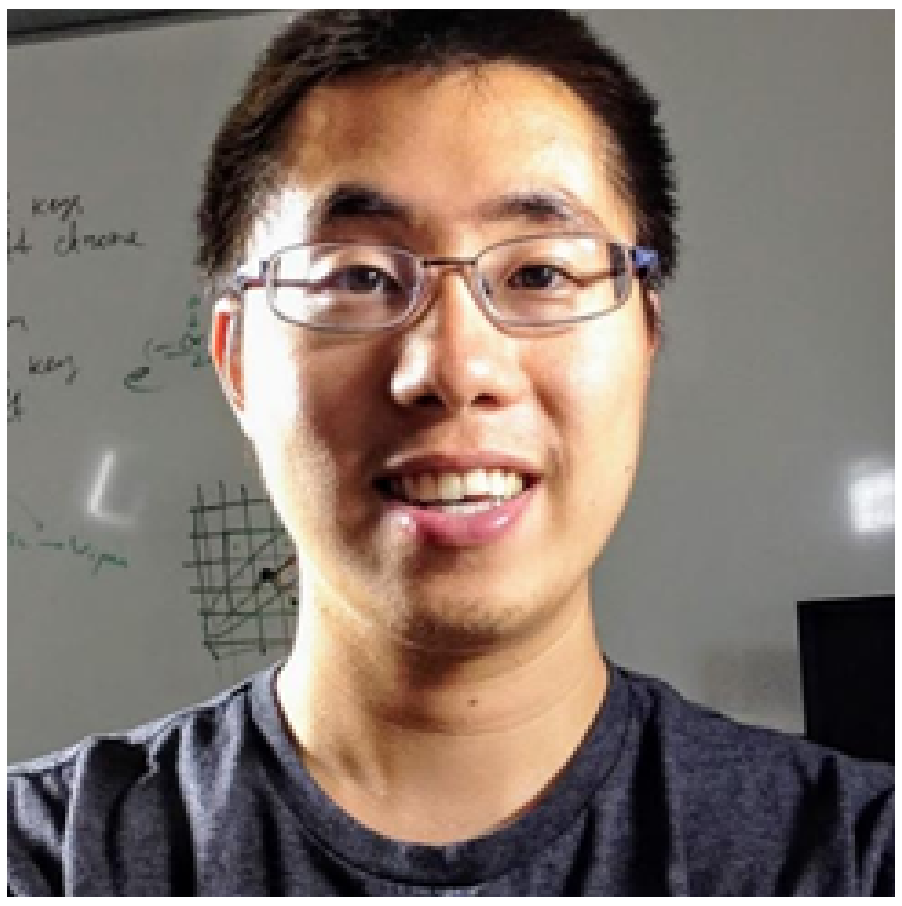
Biosketch

Don retired from Caterpillar in 2019 after a 29-year career in international logistics and information systems focused on aftermarket parts. Don has broad and deep global expertise in service parts logistics across supply chain management/optimization, inventory forecasting, distribution center operations, transportation, customs, quality management and packaging. He held positions with global leadership responsibilities within Caterpillar's own logistics operations, retiring as Director of Global Parts Strategy and Transformation. He was also a key member of the team that grew Cat Logistics' externally focused 3PL business to over 5,000 employees from 1992 until sold in 2012 with roles in information systems development/implementation, sales, and distribution center startups across numerous industries.

Don also has specialized expertise in 3D printing and impact on global parts logistics and led development and implementation of Caterpillar's additive programs in support of global aftermarket parts. He has published articles on application of 3D in the Wall Street Journal and Aggregate Research and spoken at several additive conferences, including keynote at RAPID/TCT and the Edison Awards. Don holds a BA in Management from the University of Illinois and a MS in International Logistics and Supply Chain Strategy from The Georgia Institute of Technology.

Balancing 3D Printing Opportunities and Security for Aftermarket Parts

Additive manufacturing has numerous applications for automotive, heavy equipment and aerospace OEM support of their aftermarket parts businesses, in addition to transforming part characteristics through design for 3D printing. Supporting global customer demand for slow moving parts without holding inventory, reducing cost by elimination of tooling, removing minimum order quantities, and drastically reducing lead times all support the OEM brand promise and drive higher margins. However, this environment also exposes OEMs to intellectual property loss and liability for counterfeit parts, and also removes barriers to entry of competitors. In this section Don will explore these areas in more depth and answer questions from the audience.



Biosketch

Danny Y. Huang is an Assistant Professor at New York University's Electrical and Computer Engineering Department. He is broadly interested in empirically understanding the security and privacy of emerging technologies, including Internet-of-Things. He completed his postdoc at Princeton University and obtained his PhD in Computer Science and Engineering from University of California, San Diego.

Danny Huang
Assistant Professor
Dept. of Electrical and
Computer Engineering
New York University

Toward Characterizing Behaviors Of Open-source Contributors For Manufacturing Software To Identify Security Risks

Increasingly, many software or firmware products for additive manufacturing are open source or rely on open-source components. However, open-source contributions could introduce security vulnerabilities. For example, the community of contributors may lack security expertise; or too many contributors could have the permission to merge new changes to the code without a robust process to check for security vulnerabilities. These examples highlight the supply chain risks that open-source contributors could introduce to the additive manufacturing process.

In this talk, we outline our first steps toward characterizing the behaviors of such open-source communities. In our preliminary investigation, we analyze hundreds of additive manufacturing related repositories on GitHub and examined thousands of pull requests and the comments included. We find examples of infrequent contributors that had the permission to merge pull requests, and of pull requests that were merged but which the community later criticized. We discuss plans to analyze security vulnerabilities based on these findings.

Mohammad Abdullah Al Faruque
Associate Professor
Dept. of Electrical Engineering and Computer Science
University of California Irvine

Biosketch

Mohammad Al Faruque is currently with the University of California Irvine (UCI), where he is an associate professor (with tenure) and directing the Cyber-Physical Systems Lab. Prof. Al Faruque is the recipient of the School of Engineering Mid-Career Faculty Award for Research 2019, the IEEE Technical Committee on Cyber-Physical Systems Early-Career Award 2018, and the IEEE CEDA Ernest S. Kuh Early Career Award 2016. He is also the recipient of the UCI Academic Senate Distinguished Early-Career Faculty Award for Research 2017 and the School of Engineering Early-Career Faculty Award for Research 2017. He served as an Emulex Career Development Chair from October 2012 till July 2015. Before, he was with Siemens Corporate Research and Technology in Princeton, NJ. Besides 150+ IEEE/ACM publications in the premier journals and conferences, Prof. Al Faruque holds 9 US patents. Prof. Al Faruque has published 2 books in the area of Embedded and Cyber-Physical Systems. Prof. Al Faruque is currently serving as the associate editors of the ACM Transactions on Design Automation on Electronics and Systems and the IEEE Design & Test

Attacks and Defenses through Side-channels of Manufacturing Systems

Today's manufacturing systems are cyber-physical systems due to the tight integration of the computational, communication, and physical components. Therefore, most of the information in the cyber-domain manifests in terms of physical actions (such as motion, temperature change, etc.). This leads to the system being prone to physical-to-cyber domain attacks that affect confidentiality. Physical activities are governed by energy flows that may be observed. Some of these observable energy flows unintentionally leak information about the cyber-domain and hence are known as the side-channels. Side channels such as acoustic, thermal, and power allow attackers to acquire the information without actually leveraging the vulnerability of the algorithms implemented in the system. During this presentation, Dr. Al Faruque will present examples of side-channel attacks in an additive manufacturing system. In the second part of the presentation, Dr. Al Faruque will demonstrate how these side-channels can be used for sabotage attack detection in an additive manufacturing system. Dr. Al Faruque will present how by utilizing multiple side-channels, we improve system state estimation significantly compared to uni-modal techniques.

Biosketch

Dr. Jitesh H. Panchal is a Professor of Mechanical Engineering at Purdue University. He received his BTech (2000) from Indian Institute of Technology (IIT) Guwahati, and MS (2003) and PhD (2005) in Mechanical Engineering from Georgia Institute of Technology. Dr. Panchal's research interests are in the science of systems engineering and design, with focus on decision making in decentralized socio-technical systems, secure design and manufacturing, and integrated products and materials design. He is a co-author of two books, and has co-edited one book. He is a recipient of CAREER award from the National Science Foundation (NSF), Young Engineer Award, and three best paper awards from ASME, and a university silver medal from IIT Guwahati. He is currently an Associate Editor of the ASME Journal of Mechanical Design.

Jitesh H. Panchal
Professor
Dept. of Mechanical Engineering
Purdue University

Design of Traceability and Anti-counterfeiting Schemes for Mechanical Parts

Modern supply chains provide opportunities for counterfeiters, saboteurs, or other attackers to infiltrate supply networks, resulting in a growing need to ensure the integrity of goods produced. In contrast to the significant progress in counterfeit prevention of electronic parts, research on counterfeit prevention of non-electronic hardware and materials, which are the bulk of automotive and aerospace systems, is still in its infancy. Existing methods for mechanical parts either require expensive modifications to manufacturing processes, or are only applicable during certain phases of a product's lifecycle. Thus, there is a need to develop techniques for achieving traceability throughout the product lifecycle, from manufacture to assembly to after-market maintenance and repair.

This talk will present an approach for mitigating this traceability problem: design of general traceability schemes built on context-specific identifying features. Such schemes are "general" in the sense that the process for developing a scheme should generalize across different use cases, given accessible product data. Such accessible product data may include physical quality assurance information, such as images of the product surface, profilometer data, or mechanical or electrical response characteristics. Unlike other traceability solutions, this approach gives control of the traceability scheme design to the stakeholders most directly involved with a product, as the scheme may be tuned to their unique data storage, data acquisition, and security requirements through exploration of the scheme design space.

Biosketch

Satish T. S. Bukkapatnam serves as Rockwell International Professor with the Wm Michael Barnes '64 Industrial and Systems Engineering department at Texas A&M University, and the Director of Texas A&M Engineering Experimentation Station (TEES) Institute for Manufacturing Systems. He is a fellow of IISE, and SME, has received Oklahoma State University regents distinguished research, and Fulbright-Tocqueville distinguished chair awards. He received his Ph.D. and M.S. degrees in industrial and manufacturing engineering from Penn State. The Society of Manufacturing Engineers (SME)'s magazine listed him among the top 20 most influential professors in Smart Manufacturing (inaugural class). His research has yielded 116 journal publications and 73 conference proceedings; one US patent (five pending); received over $7 million in grants and contracts as PI/Co-PI, with government and the private sector. He served as a mentor to 23 PhD students, 6 of whom are on the faculty in US Universities, 53 Master's and 100+ undergraduate students--16 of whom belong to underrepresented communities.

Satish T. S. Bukkapatnam
Professor
Dept. of Industrial and Systems Engineering
Texas A&M University

Cybersecurity For Smart Manufacturing: From Industrial Quality And Integrity To Security Assurance

During past two decades, the industry has made major progress in quality and integrity assurance in their processes based on fusing process physics with various data science principles. The data pipeline enabled in smart manufacturing opens interesting possibilities to advance these principles for cybsersecurity assurance, especially in the context of the emerging manufacturing-as-a-service (MaaS) paradigm. This talk presents two specific use cases: The first focuses on securing the digital thread based on embedding alternative signatures into products with specific performance guarantees. The second focuses on detecting cyberattacks in a sensor-integrated smart manufacturing environment with robotic material handlers.

Biosketch

Ferenc Pankotai holds a Masters in Mechanical Engineering Degree with specialization of Turbo Machinery and Aerospace from the Budapest University of Technology and Economics (Hungary), as well as, a Masters in Mechanical Design Engineering from the Rose-Hulman Institute of Technology (USA). He has more than 23 years of experience designing and managing gas turbine manufacturing globally. Ferenc has been with Solar Turbines, a Caterpillar company since 1998.

Ferenc currently is the Manager for Additive Manufacturing and Combustion Engineering. In this role, Ferenc is responsible for development, design, implementation and product life-cycle maintenance of gas turbine combustion systems and provides strategic leadership and direction for emission and fuel flexibility turbine product strategy. He is also responsible for development and deployment of Additive Manufacturing technologies for Solar Turbines.

Ferenc Pankotai
Manager, Combustion Engineering and Additive Manufacturing
Solar Turbines Incorporated

Additive Manufacturing as Technology Enabler at Solar Turbines

As part of our ongoing commitment to manufacturing excellence, Solar Turbines began utilizing Additive Manufacturing in 2013 with the introduction of Laser Powder Bed Fusion and Laser Metal Deposition. These innovative technologies have increased Solar's ability to develop and test new components faster, produce components at a lower cost with improved quality and performance, and remanufacture components at overhaul with increased yield and productivity. The early approach to candidate component selection was to prioritize components that can deliver immediate manufacturing cost savings and quality improvements, often as direct replacements for castings and forgings. Additive is now being used to solve complex design challenges and field issues to better serve Solar's customers. Additive manufacturing has become an integral part of Solar Turbines' product development process and cost reduction strategy.
As Solar continue to grow additive across the business, engineering organization is now well along in designing AM-optimized components that can take advantage of the design freedom enabled by additive to unlock performance enhancing product improvements that were previously impossible to produce.

Biosketch

Dr. Mark Yampolskiy is an Associate Professor at Auburn University, department of Computer Science and Software Engineering (CSSE). He is also an Affiliated Faculty with Auburn Cyber Research Center (ACRC) and National Center for Additive Manufacturing Excellence (NCAME). He was among the pioneers and is one of the leading experts in the field of Additive Manufacturing Security. His research interests include the cyber-physical means of attack and defense in AM.

Mark Yampolskiy
Associate Professor
Dept. of Computer Science
and Software Engineering
Auburn University

Security Threats in AM: Attacks within Cyber and Beyond

Additive Manufacturing (AM), often referred to as 3D printing, is increasingly used to manufacture functional parts, including components of safety critical systems. However, it is exposed to a variety of AM-specific Security Threats. This talk will explain origins of the threats, contrast the differences to Security Risks, and provide an overview of the broadly accepted threat categories and their interdependencies. For each of the threat categories, selected attacks will exemplify how threats can come to fruition. These examples demonstrate that, in AM, attacks within the Cyber domain as well as across the Cyber-Physical boundary are possible. The talk will conclude with an outline of few common misconceptions and an appeal to build multidisciplinary research teams.

Biosketch

Eric MacDonald, Ph.D. is a professor of mechanical engineering and Murchison Chair at the University of Texas at El Paso. He received his doctoral degree (2002) in Electrical and Computer Engineering from the University of Texas at Austin. He worked in industry for 12 years at IBM and Motorola and subsequently co-founded a start-up specializing in CAD software and the startup was acquired by a firm in Silicon Valley. Dr. MacDonald held faculty fellowships at NASA's Jet Propulsion Laboratory, US Navy Research and was awarded a US State Department Fulbright Fellowship in South America. He is a co-founding editor of the Elsevier journal Additive Manufacturing and also a member of ASME, ASEE, senior member of IEEE and a registered Professional Engineer in the USA state of Texas.

Eric MacDonald
Professor
Dept. of Mechanical Engineering
University of Texas at El Paso

Additive Manufacturing of Elastomer, Ceramic and Metal Multi-functional Structures

3D printing has been historically relegated to fabricating conceptual models and prototypes; however, increasingly, research is now focusing on fabricating functional end-use products. As patents for 3D printing expire, new low-cost desktop systems are being adopted more widely and this trend is leading to a diversity of new products, processes and available materials. However, currently the technology is generally confined to fabricating single material static structures. For additively manufactured products to be economically meaningful, additional functionalities are required to be incorporated in terms of electronic, electromechanical, electromagnetic, thermodynamic, chemical and optical content. By interrupting the 3D printing and employing complementary manufacturing processes, additional functional content can be included in mass-customized structures. This presentation will review work in multi-process 3D printing for creating structures with consumer-anatomy-specific wearable electronics, electromechanical actuation,
electromagnetics,propulsion, embedded sensors in soft tooling and including metal and ceramic structures. Other projects to be presented include stereovision process monitoring of powder bed fusion, 3D printed smart molds for sand casting, complex ceramic lattices for electromagnetic lenses, elastomeric lattices for the athletic gear, computational geometry and complexity theory for 3D printing, thermography stereovision for directed energy deposition.

Dimitris Mouris
PhD Researcher
Dept. of Electrical and
Computer Engineering
University of Delaware

Peak Your Frequency: Advanced Search of 3D CAD Files in the Fourier Domain

Dimitris Mouris[1], Charles Gouert[1], Nikhil Gupta[2], Nektarios Georgios Tsoutsos[1]

[1] University of Delaware, Newark, USA
[2] New York University Tandon School of Engineering, Brooklyn, USA

An ever-increasing number of industries are adopting additive manufacturing (AM), also known as 3D printing, to their production lifecycles for manufacturing parts. A computer aided design (CAD) model is used to manufacture the part. The capability for efficient search and retrieval of the CAD models from the database has become an essential need for designers and users. However, traditional search techniques perform poorly in the context of searching CAD designs. In this paper, we propose Fourier Fingerprint Search (FFS), a retrieval framework for 3D models that deduces and leverages critical shape characteristics for search. FFS introduces a novel search methodology that incorporates these characteristics and uses two advanced matching techniques that operate at different granularities and take into account unique patterns associated with each design. In addition, FFS supports both exact and partial matching in order to provide helpful and robust search results for any scenario. We investigate a diverse set of features and enhancements for search that allows for high adaptability in all situations, such as dividing shapes into smaller parts, surface interpolation, and two different types of rotation. We evaluate FFS using the FabWave CAD dataset with approximately 3000 manufacturing models with different configurations. Our experimental results demonstrate the efficiency and high accuracy of our approach for both exact and partial matching, rendering FFS a powerful framework for CAD model search.

Harsh Srivastava
Student
Dept. of Chemical Engineering
National Institute of
Technology, Warangal

Determination of Volume Fraction of Fibre Reinforced Composite Materials using Image Processing Techniques

Harsh Srivastava[1], Sukhpaul Sehmbi[2], Gary Mac[3], Hammond Pearce[3], Ramesh Karri[3], and Nikhil Gupta[3]

[1] National Institute of Technology Warangal, Telangana, India
[2] New York City College of Technology, Brooklyn, USA
[3] New York University Tandon School of Engineering, Brooklyn, USA

Fibre reinforced composites have recently garnered attention for their potential use in manufacturing of parts for automotive, drones, and high performance sports equipment due to their ability to mimic the strength of metal although, at a much lighter weight. Integration of continuous or short fibres in the matrix of the composites could be attributed to their enhanced mechanical properties such as high tensile strength, stiffness, wear and corrosion resistance, durability, low thermal expansion, and stability at high temperatures. Fibre volume fraction is one such parameter that could be used to determine the following mechanical properties and therefore, holds significant importance. Generally, the strength of the fibres decrease with increase in volume fraction due to ineffective stress transfer between the matrix and fiber. Therefore, it is necessary to determine to fibre volume fraction. Certain destructive techniques are available for determining the volume fraction such as removal of matrix by burn off or acid digestion. These methods are however, time consuming and require the disposal of toxic waste. Furthermore, using CT technology is nondestructive and efficient as it is able to penetrate the complex layers of composites in 360 - degree views. This paper proposes employing image processing techniques on CT scans of a 3D printed part to determine the volume fraction of the fibre reinforced composite material.

Caleb Beckwith
Student
Dept. of Mechanical Engineering
The City University of New York

Threat Vector Analysis - Finding Fault in the Pile

Caleb Beckwith[1], Harsh Naicker[2], Svara Mehta[3], Viba R. Udupa[4], Hammond Pierce[5], and Gary Mac[5]

[1] New York City College of Technology, Brooklyn, USA
[2] Vellore Institute of Technology, Vellore, India
[3] Indian Institute of Technology Goa, Goa, India
[4] National Institute of Technology Karnataka Surathkal, Mangalore, India
[5] New York University Tandon School of Engineering, Brooklyn, USA

In the additive manufacturing (AM) supply chain, there are numerous factors that may allow malicious third parties to negatively influence the specific outcomes of a given product. These factors are known as threat vectors, and commonly include avenues for counterfeiting, information leakage, and sabotage. To determine the specific risks within a given production line, product designers should perform risk analyses to study the likelihood of various attacks. These can be visualized as heat maps, which then allow for designers to address possible attackers and determine the likelihood and vector they may begin navigating. To that effect, a case study was examined in order to address possible sabotage attacks. Attackers seeking to sabotage may introduce malicious files into groups of benign files. For AM one such case where this applies is with G-Code files, and through the application of machine learning the malicious files can be detected through feature recognition in the code seeing how the altered ones deviate from the acceptable ones thus finding the fault(s) in the pile.

Lars Folkerts
PhD Researcher
Dept. of Electrical and Computer Engineering
University of Delaware

Fourier Silhouette Search: A 3D Search Engine for Versatile Inputs

Lars Folkerts[1], and Nicholas Kater[1]

[1] University of Delaware, Newark, USA

With the rapid growth of 3D printing, there is an increased need to find parts based on a different medium of inputs. Traditional search techniques rely extensively on text keywords. This makes it impossible to find real world parts based on the object's geometry. Even if a user can carefully craft a query in their natural language, text based methods alone cannot find poorly labeled parts. We propose a new method, Fourier Silhouette Search (FSS), that expands 3D model search to real world and post-synthesized parts. FSS uses silhouettes as input to a Fourier Fingerprint Search backend, allowing 3D CAD searches to be based on late-stage manufacturing GCode files and real world objects.

Praveen Sreeramagiri
PhD Researcher
Dept. of Mechanical Engineering
Lehigh University

Actor-Network Theory as a Tool to Analyze Cyber Threats in Manufacturing

Praveen Sreeramagiri[1], Gillian Andrews[1], Amanda K. Greene[1], Ganesh Balasubramanian[1]

[1] Lehigh University, Bethlehem, Pennsylvania

We propose Actor-Network Theory (ANT) as a tool to reveal unique challenges and consequences of cyber-attacks in manufacturing. As an approach, ANT rejects the dualism which often separates humans and non-humans, recognising the active role of both in affecting the world. The existing body of research focuses on analysing vulnerabilities in cyberspace instead of their ramifications in the material world. We suggest that two key ANT concepts in particular—depunctualization and translation—provide a vocabulary to discuss the consequences of attacks in manufacturing, such as viewing altered products as actants with agency to alter subsequent networks (e.g., when a manufactured part is integrated into an automotive vehicle). Numerous case studies have demonstrated that an attack-altered product going undetected is not as unlikely as we might like to believe. We argue that by tracing the movement of specific materials and products through networks, we can elucidate the effect of cyber-attacks not only on CPSs, but also on other broader impacts, potentially endangering physical safety, shaping public perception, and influencing economic markets. This analysis sheds new light on the need for sector-specific examinations and protections, and the value of interdisciplinary methods like ANT for conceptualizing cyberthreats in manufacturing.

WORKSHOP ORGANIZERS

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SPECIAL THANKS TO:
GARY MAC
SAI SAKETH GANGISETTY