

ROBOTICS ACADEMY SUMMIT REPORT 2019

PROJECT SUMMARY

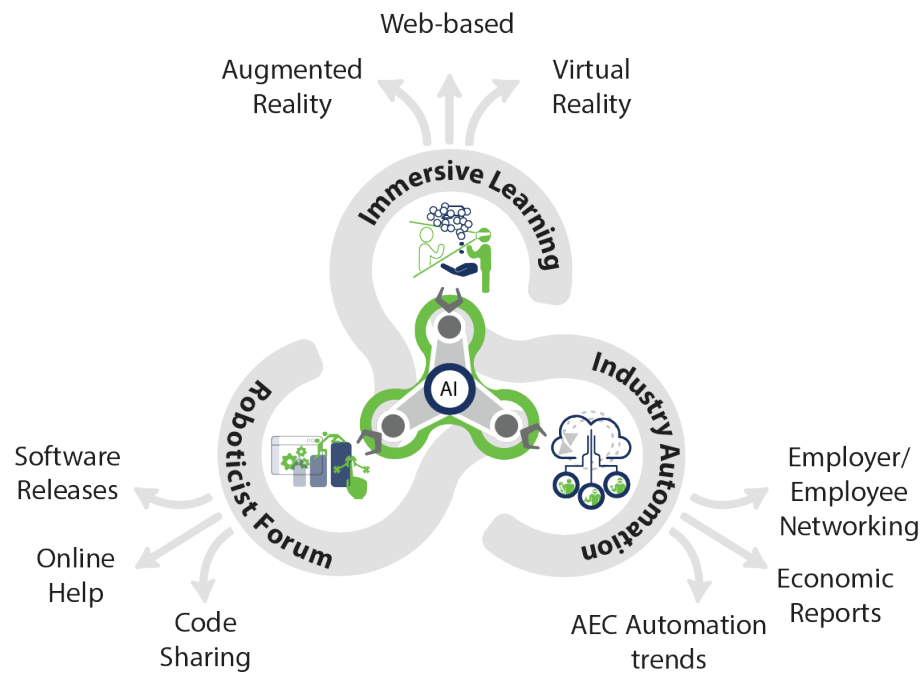
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A team of interdisciplinary researchers from Florida International University (FIU) have been awarded a one-million-dollar grant by the National Science Foundation (NSF) to research and propose a training program for the future workforce of the Architecture, Engineering, and Construction (AEC) industries. The funds will support researchers to assess the employment impacts of adopting automation and robotic technologies in the building industry, as well as evaluating how businesses can prepare for a robotic-driven future. The research findings will be utilized to develop the Robotics Academy, an AI-based immersive training platform which responds to the needs of the industry and its workforce. The first phase, which must be completed by May 2020, is focused on researching and planning this training program. If selected for a continuation grant of five million dollars, the team will deliver the Robotics Academy.

Today we are at the brink of the fourth industrial revolution due to advancements in the fields of Artificial Intelligence (AI), information technology, Virtual Reality (VR), Augmented Reality (AR), and robotic automation among others. The global economy is rapidly being reshaped by the use of sophisticated machines that enhance human dexterity, visual perception, speed, and strength. Automation and machine intelligence promise to fuel economic growth, produce new occupations, and free humans from dangerous and mundane jobs. However, it is also expected that these technologies will lead to job displacement, alter skill profiles for existing jobs, and change how people work. Therefore, addressing the impacts of robotic automation and mitigating its disruptive changes in the AEC clusters has overwhelmingly important consequences for the entire US economy. The AEC industries drive the design, construction, and operation of the built environment, activities that impact environmental health and influence nearly every industry, trade, labor, employment, and commodities market across the global economy.

It is reported that by 2030, nearly 40 percent of the jobs in the US could be displacement by robots. Although, these estimations are alarming, we believe that AEC professionals, business owners, and workers can be prepared to compete in a changing automated economy. **Our vision is to design, build, and launch the Robotics Academy, an AI and cloud-based set of resources to support AEC workers, educators, business owners, entrepreneurs, and economic development policy makers to drive the transition to an inclusive and prosperous automation economy.**

Leveraging the advances in AI, cloud computing, VR, AR, IoT, and big data, the Robotics Academy will be comprised of three components:



1) Immersive Learning: This component delivers multi-media training content for the AEC professionals and workers. This AI-powered learning environment considers a user's background, career aspiration, biometric reading, and learning style to deliver a customized sequence of lessons via VR, AR and other media applications. The content will be supported on personal computers, mobile devices, as well as Head-Mounted-Displays (HMDs) for both individual and group training.

The following areas describes our research and progress for developing an immersive learning environment for the Robotics Academy:

Curriculum: Based on literature reviews, interviews, and focus group studies, we have learned that the applications for robotics in the AEC industry are continuously expanding. However, one of the biggest hurdles throughout the adoption process is the lack of training resources. It is expected once the training limitations are overcome, the use case applications will expand even further. Thus, we are developing our curriculum to accommodate this expansion. We plan to achieve this by creating training modules that begin with robotic safety and operations and expand to teaching use cases and end of arm tooling integration. A modular training structure will allow the curriculum to continuously grow without the constant need to restructure.

Artificial Intelligence: To optimize lesson customization with AI, all modules will be divided into micro-lessons that will be sequenced to make up larger modules. This approach will allow the Machine Learning (ML) algorithms to evaluate the user performance and make recommendations for appropriate

lessons by stringing the micro-lessons into customized training. Our ML algorithms will be constantly trained by user decision-making and biometric feedback, ultimately informing the curriculum designers where the content needs to be altered and improved.

Delivery Method: In order to accommodate various learning styles and users' preferences, each lesson will have multiple methods of delivery. We will provide lessons in VR and AR in both narrating mode and sandbox mode. Each mode will be complemented with demonstration 360 videos, animation sequences, and interactive UI. As many users have expressed the desire to have face-to-face training, we are in the process of working with several robotics facilities across the country to provide standardized and intensive face-to face training.

Micro-credentialing: to provide a certification path, the Robotics Academy is developing a badge system. Badges are micro-credentials representing competency in specific content areas throughout the Robotics Academy training. These micro-credentials will be developed as stackable and portable badges. To ensure that they hold value for completing future training pathways, and are widely recognized by the AEC industry, we are building our program to meet our partners training needs and feedback in our development process.

2) Roboticist Forum: This component will create an open knowledge platform for an expert and user driven exchange to support the sharing and advancement of technology in the AEC robotics and software systems. This forum will use a combination of social media and GitHub features for audiovisual information exchange. It will also incorporate immersive teleporting assistance in VR and AR for more hands-on troubleshooting. This AI-based component will facilitate an efficient skill building environment with the community of adopters.

3) Automation Forum: This component is an open knowledge networking and information exchange platform providing crucial information to and between professionals, business leaders, and policy makers invested in implementing automated technology processes in the AEC industry cluster. A key component of the Automation Forum is several economic impact analyses conducted by our economic team. The Automation Forum will build upon similar ML profile matching algorithms conducted for the Immersive Learning and Roboticist Forum components.

SUMMIT REPORT

The Summit, which took place on November 8, 2019, featured discussions with and among five keynote speakers — industry leaders and noted analysts of the state of the future of automation and AI across the global economy. The Summit was attended by sixty representatives of the region's leading Architecture, Engineering and Construction firms, including two of the Nation's largest housing developers and builders.

The Summit featured presentations from each of the keynote speakers, and an extended focus group roundtable involving the invited business representatives, the Summit keynote speakers and the project team. The day-long agenda: 1) Examined the state of the field, industry, and automation application across the global economy; 2) Included presentations and discussions of new automation and AI opportunities and challenges in the AEC cluster; 3) Communicated the shared experience of the keynote speakers in their path to adoption and application of new automation and AI technologies; and 4) Facilitated an in-depth exchange between the industry partner invitees, who discussed their differing experiences, perspectives, and challenges faced by businesses in the face of new AI and advanced automation technologies.

INTRODUCTION

Kevin T. Greiner

Principal, UrbanCentric Analytics; Senior Fellow, FIU Jorge M. Perez Metropolitan Center

The Summit moderator, Kevin T. Greiner opened the Summit and presented his opening remarks. Mr. Greiner is leading the economics research component of the Robotics Academy Project.

Mr. Greiner detailed the industry structure of the AEC Cluster, noting that these industries have had much slower productivity growth compared to the rest of the national and global economy. The industry is primarily comprised of small businesses employing less than five employees, and therefore is extremely susceptible to disruption from AI and automation. Mr. Greiner also addressed the importance of national and economic competitiveness of the Project, and the looming transformative effects that AI and automation will have on the AEC Cluster. He argued that the successful adoption and transition to AI and automated construction, engineering and design will be one of the defining regional and national economic competitiveness issues of the next century.

Shahin Vassigh

**Professor of Architecture, FIU College of Communication, Architecture & the Arts;
Principal Investigator, *Preparing the Future Workforce of Architecture, Engineering,
and Construction for Automation and Robotic Processes Project***

Professor Vassigh is the Principal Investigator for the NSF Future Workforce Project.

Professor Vassigh detailed the scale of potential impacts that AI and automation will have on employment and industry. Some of the key points raised by Professor Vassigh included:

- Robotic Automation is going to be the largest employment disruption in world history;
- Research reports estimate that by 2030, 375 million workers world-wide will be forced to change occupations due to automation;
- in US this number translates to 40% of existing jobs;
- in the last five years, worldwide installation of industrial robots has increased by an average of 10 percent per year;
- In the US, adoption of AI and robotic technology is lagging behind many industrialized countries. South Korea has 3 times more installed robots per capita than the US.

Professor Vassigh detailed the scope of the multi-disciplinary project, and its innovative aspects.

- The project is supported by a grant from the National Science Foundation's **Convergence Accelerator Program, which is** a new capability within the National Science Foundation to: 1) Accelerate **use-inspired**, and **convergence research** in areas of national importance, 2) Encourage rapid advances through partnerships that include multiple stakeholders, and 3) Create entrepreneurial-centered research program;
- The Robotics Academy is an AI-powered immersive platform for training of professionals and workers in the Building Industry for the design, application, **and** use of robotic systems;
- The Project includes major industry collaborators including Magic Leap Inc., Gensler, Kuka Robotics, and Oppenheim Architecture among others;
- In the Phase I of the research program, the team has learned through interviews with industry leaders and practitioners that:

1) there are not enough trained people to work with robotic technologies in the US and they are being sought after in other countries; 2) training resources for robotic operations are scarce, and many learn by trial and error and extensive internet research; 3) robots are replacing the **3Ds — Dull, Dangerous and Dirty** tasks; 4) certificates and credentials lead to gaining confidence and job security; and 5) the adoption of robotics in the building industry is not eliminating jobs, but is creating **new jobs, new use cases, and entrepreneurship opportunities.**

Lastly, the project is focused on developing a series of certificate programs for AI, automated technology, and robotics. In appreciation for attending the Summit, all participants will get free access to all of the project's training and certificate programs.

KEYNOTES

Phillip G. Bernstein

Associate Dean and Lecturer in Professional Practice at the Yale School of Architecture

Professor Bernstein was formerly a Vice President at Autodesk, and a practicing architect at Pelli Clarke Pelli Architects. Mr. Bernstein's address focused on the process, workflow, and business model changes that will be required to fully move architecture, design, and construction to a future that fully takes advantage of AI and automated technologies. Mr. Bernstein addressed the following issues:

- The slow progress and rate of adoption of AI and automated design and construction within the industry;
- As an industry insider responsible for growing Autodesk's Building Information Modeling (BIM) systems, Mr. Bernstein commented on the long history and adoption of BIM across the AEC Cluster, but noted that despite the widespread use of BIM, it has not led to the greater automated, prefabrication, or construction efficiencies that it was expected to have;
- Professor Bernstein explained that the only way that real change leading to the wide spread adoption of automated and prefabricated construction would be for the industry to adopt a significantly different work processes and business models. He detailed his model for a new architecture and construction practice which features extremely close collaboration at the front end of design and construction projects, vertical integration of design and construction capabilities within a single firm, and a different construction contracting model which is collaborative, rather than adversarial, between client and construction manager.

Andrew Tsay Jacobs**Practicing Architect and Director, Perkins and Will Inc. Building Technology Lab**

Andrew Jacobs directs the Perkins & Will Building Technology Lab, where he explores the application of robotic construction technology for developing new solutions to address complex design and construction problems, as well as creating new building prototypes and technologies for commercial adoption.

Mr. Jacobs presented his thoughts on the state of the industry relative to robotics, and Perkins & Will's commitment to research and development of new production and construction solutions, as well as architectural scale use cases. Mr. Jacobs presented the firm's on-going collaboration with the Autodesk BUILD Space in Boston, focused on developing robotic technology platforms for processing and assembling wood and timber-built products and building systems.

Andrew presented his firm's portfolio of pre-fabricated building systems, including the robotically cut and fabricated structural timber wall system he designed as the building block of an 18-story office building. He also described multiple experimental wall systems cut and fabricated by the Lab's robotic arms as well as large-scale robotically produced timber pavilions that they will be installing in various locations in the US.

Matt Trimble**R&D | Product Development Director, Branch Technology**

Mr. Trimble, as R&D Director at Branch, specializes in the development of increasingly larger-scale 3-D printed structures. His Team at Branch currently uses a set of robotic arms he has designed to 3-D print with specialized carbon-fiber reinforced plastic compound to produce a wide range of experimental and practical structures. Matt's team currently holds the record for the world's largest 3-D printed structure, which is a pavilion in Memphis, Tennessee.

Matt presented his recent portfolio, and the evolution of his work in 3-D printed structures, including multiple pavilions, a hanging hydroponic garden installed at the Field Museum in Chicago, and his newest work developing housing systems using a 3-D printed structural components, clad with concrete.

Philip F. Yuan

Principal and Founder, Archi-Union; Professor and PhD Advisor of CAUP at Tongji University; Co-chair of Built Environment Technology Center, CAUP

In addition to his architectural practice, Mr. Yuan directs the Built Environment Technology Center at Tongji University, where he the development of robotically and 3-D printed experimental structures. Phillip highlighted his experimental work as well as his commissioned projects delivered by Archi-Union, which include light-weight 3-D printed pedestrian bridges, weight supporting pavilions, interior building systems, complete homes, and a 107,000 square foot convention center.

Mr. Yaun's presented his award-winning work which combines the use of experimental materials, 3-D printed and robotically constructed structural systems, conventional materials, thin-shell structures, robotically constructed brick walls, and timber systems for buildings. His projects combine robotically fabricated and assembled systems with conventional materials and construction trade labor.

While not completely pre-fabricated, Mr. Yuan's projects are both practical, beautifully designed, and increasingly larger in scale. His work has significantly driven industry thinking regarding the practical use and application of robotically fabricated building systems and complete buildings. In particular, he discussed:

- The significantly different rates of adoption for robotic systems and design software across the world. Specifically, Europe and Asia are leading the adoption and development of automated and robotic construction, and the US is lagging behind, with high rates of use concentrated in Michigan and California;
- The advantages of producing experimental work, and the more open acceptance and support for new construction techniques in China, which is fostering a rapidly growing culture of innovation and original invention;
- Process business model changes he has been using in practice to further the use and adoption of new construction and design techniques, including the use of software developed by his firm to more closely integrate the front-end design process with robotic fabrication and construction;
- His thoughts on the future of architecture and construction, emphasizing the opportunities for younger and new innovators to enter the industry, the increasing blurred line between formal design, fabrication, and end construction, and the role of Universities in the construction innovation process.

Michael A. Finney**President & CEO, The Miami-Dade Beacon Council Foundation**

The Miami-Dade Beacon Council serves as the official economic development organization for Miami-Dade County. Mr. Finney addressed his personal experience installing and developing automated and robotic manufacturing, especially in the Aerospace Industry. First, robotics allows precision manufacturing that is not capable with just human and traditional machine production. Second, that fully capturing the capabilities of AI and robotics will require process and business model changes to implement.

Michael also discussed his desire, as CEO of the Beacon Council, to foster innovation and help commercialize new technology in Miami-Dade County. The Beacon Council has the capability to assist businesses with funding, site selection, marketing, and industry contacts and expertise.



*Audience engaged in the Robotics Academy Summit's Focus Group Discussion



Keynote speakers of the Robotics Academy Summit

FOCUS GROUP DISCUSSION

The focus group discussion between the Summit participants and the Summit panelists addressed the state of the AEC industries relative to automation and AI implementation, the threat to industry structure, and how to move progress on building and construction efficiency forward. Summit participants focused on nine major issues.

ISSUE: How are members of the audience planning for change? Are you investing in R&D to move in new direction? Do you see AI and Robotics as a competitive challenge – now, or in the future? Is it something to worry about?

In a show of hands, only one member of the audience indicated that they were actively investing in or using AI or automation technology as part of their business. In general, the participants overwhelmingly do not see AI or automation as an immediate competitive issue (threat or opportunity). The consensus is that the active use of robotics in construction will evolve over the long term, and that the accepted, current construction process will remain in place.

Specific comments from the participants indicated investment in prefab construction, even large firms aren't seeing a "tidal wave" of technology, nor are they "afraid" of robotics right now. The most pertinent commenter indicated that construction is too complex to be modeled or replaced in large parts by automation or robotics, including scheduling, cost estimating, productivity, and labor relations.

ISSUE: Are we missing People-Centric issues in the design process? How do we solve issues of equity, livability, resilience as a functional component of AI and Automation?

The question was raised that while the technical accomplishments of the panelists are impressive, and will lead to further innovation, how can they be used to address the challenges of income inequality, resilience and improving the livability of the built environment?

The response from the panel was that collectively (we) need to be aware of the social impacts of new technology application at every step in the process. That this is a “special time” where technology isn’t just about solving technical questions, but provides a platform to address bigger, global impact issues in the design process.

The motivation in design is now centered on material efficiency and speed. There are other opportunities — technology opens up design and construction to new generations, younger workers and entrepreneurs. New construction methods and technology will create opportunities for younger workers, as many older workers move out of the workforce.

ISSUE: China, as leading adopter of automated tech, an example? Is there something to learn?

China built its economy on inexpensive labor, including the construction industry. However, that is changing rapidly. China’s economy is growing at 5-6% over last 10 years, while labor costs have been growing at 9% per year. The labor costs included in hi-rise buildings grew 33% alone. So China is going through some of the same issues as the west. China is demonstrating that technology doesn’t need to displace workers, but can be a platform on which existing trades can still apply their skills, and that new jobs in construction, especially for younger workers, as older workers retire, can grow.

ISSUE: Is the issue of slow adoption a knowledge question? Is knowing what's out there the problem?

The consensus from the participants is that yes, getting better and more timely information regarding the leading applications of new robotic construction technology would absolutely help, especially if it provides accurate costs and performance analytics.

ISSUE: How do we (Construction and Design) partner to improve process and adoption?

The issue of how designers and builders (construction managers - CMs) can partner to improve building performance, make use of the best aspects of new technology, including AI, robotics, and prefabrication, took up the bulk of the focus groups discussion.

The question asked by participants of the panelists was “We’re not anticipating the need to move to large-scale robotic or pre-fab construction right now – so the real question is how do we (construction industry) work with you (researchers) so you’re not working in a vacuum and are working on solutions that really add value to the industry?” Florida alone spends \$10B per year on construction, so what’s a better way for us to partner?

In terms of developing solutions or testing new technology, robotics needs to be built in at the beginning of the building process. CM’s don’t get excited unless they see that robotics can be translated into real processes that deliver real results.

We need a refactoring of the relationship between designers and builders – designers can become experts at robotics, but if they can’t translate that into construction, there’s no progress. Design has to be approached from a robotic process perspective.

Other industries have for some years been doing this integrated design-build process using automation and robotics. The Automotive and Aerospace industries have integrated design, construction, and fabrication by having sub-contractors work together at the beginning to cooperatively design, then build and deliver products. The Boeing 777 is one of the best models.

However, this model is a proxy for the supply chain. The Boeing model may not be the best model for the AEC cluster, as Boeing vertically controls the production process.

Also, risk management has to change.

There's an enormous disparity between the drawn building and how it's supposed to be built. Much of how it is to be built is just assumed. Optimization needs to happen using technology, but with closer work between design and construction at the beginning.

ISSUE: The question of who will lead the application of new technology, especially AI and Automation, is a major question to industry analysts. Who will be the next innovators?

The representative from KUKA robotics, one of the world's largest makers and distributors of industrial robots — answered. KUKA's biggest buyers in the US are the automotive industry in Michigan and the Southeast. In Florida, there has been a growth in many disruptive businesses — developing robotic systems for painting, milling, and the construction of pods — complete building rooms and bathrooms. Other businesses are starting to use robots to seal, sand and paint walls and drywall. Others are using robots for manual tasks — lifting heavy shower pans and cut and place large tiles. KUKA is also seeing the transfer of knowledge from one industry to another. Having an existing manufacturing base is helping to push the adoption of robotics in construction and will be a major competitive advantage.

ISSUE: We want to know more about how the business model can be changed to improve performance and make more effective use of technology.

What will it take to change the current design-construction business model to improve building performance and apply the new technology?

“We need to get past seduction — to get to really what technology-driven design and construction can do.” The profession was seduced in the 1990s by looks versus performance. We need to get back to building performance being main driver for new technology adoption.

“We need to rethink our age – the late 90’s was about cool form.” In the 21st century the wider adoption of other technologies – computers everywhere, has changed everything, it’s changed perspective of use of technology. Form is not the first thing anymore – it’s the relationship of humans to the built environment that is now the most important element. There are changes from country to country, and the growth of China has changed the business model. In Europe, design and construction has been traditionally top-down. China combines top-down, with real opportunity for small and micro-sized businesses, all integrated in the design and construction process.

ISSUE: BIM – since workers’ knowledge is shrinking, what is the future of BIM. Is it at its end?

“BIM will either grow into the organizing platform for design and construction, if augmented by AI and other technologies, or, will just continue to be a rendering and representation tool.” Right now BIM is a fancy drawing platform. So the real question: is there a real desire to take BIM further?

“We’re still building buildings like the Pyramids.” Vertical transportation is a simple, but crucial element to save time, money, materials, manpower. Understanding even simple, but cost consuming issues, like waiting for materials to arrive on a working floor of a building under construction, and how much money can be saved, are issues the industry can raise to drive better use of technology.

ISSUE: The Need to push progress:

“At Yale, we’ve had 3-D printers and robots for 20 years... There are plenty of architects who have been educated to use this technology, but there’s been no progress.” What’s finally going to change this?

“Money and profitability drive decision making, we need incentives to drive greater capital spending to use these technologies.” Many components of the building like interiors and partitions can be mass produced. Shells may always be site-built. Show us how to modularize building systems so that they can be made off-site and delivered for on-site assembly.

“In the end, we’re still not close to building anything that looks like a building using robotics.” However, in the UK, all public housing must now include pre-fabricated construction. Policy makes a difference.

NEXT STEPS

The Robotics Academy Summit concludes the Project's initial research phase. Input from the team's base research, interviews and the Summit has provided a wealth of information regarding the adoption, impact, and future application of AI and automated technologies to the design and construction process.

Moving forward, the Project team will complete 1) the development guidelines for the Robotics Academy web site, 2) software specifications for the development of the A/R training systems, 3) a preliminary economic impact model, forecasting employment, income, and secondary economic impacts of the adoption of automated design and construction technologies, and 4) a working prototype of the A/R training system.





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