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Research Challenges in Industrial Technology and Impediments to Adoption

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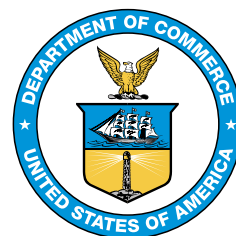
**Research Challenges in Industrial
Technology and Impediments to Adoption**

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Abstract

New technology understood and implemented by industry is responsible for many of the improvements to our daily lives. The creation of new technology is a non-linear cycle born of necessity and incremental progress. Industry creates its own new technology when needed only when the resources are available. Academia on the other hand creates new technology as a matter of course. When the needs of industry are clearly communicated to academia and the advancements of academia are implemented by industry a synergy is formed. This article presents the needs of industry from an industry perspective. Facilitated by industry engagements conducted by the National Institute of Standards and Technology, this article represents the perspectives and experience of Chuck Werner from the Michigan Manufacturing Technology Center who has worked with hundreds of manufacturers for more than 30 years. The challenges of industry are presented here to aid academics in justifying their research and clearly stating areas of needed research. The article also provides contextual understanding of the challenges to adopting new technology as well as the perspective of small to medium size manufacturers who would most benefit from academic research.

Keywords

Automation;Industry;Manufacturing;Robotics.

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Author Contributions

Werner C: Contained Information. **Harrison WS:** Writing and Structure. **Pilipchak P:** Supervision and structure.

1. Introduction

In the new world of hyper-global competitiveness, the need for technology adoption is accelerating, and new technical challenges arise as fast as new solutions are found. Manufacturers must adapt by adopting new technologies that keep them competitive. Academic research has the potential to address the technical challenges manufacturers face; however, applied research yielding tangible near-term benefits necessitates a precise understanding of the prevailing industrial challenges.

The flow of information from academia to industry is natural and straightforward.¹ It can, for example, occur through publications, students hired into industry, or research-derived startups; however, the reverse is less straightforward. Industry experts typically operate outside of academic spheres. Furthermore, they are disincentivised to share any facts about the challenges they face for fear of giving their competitors useful information. The National Institute of Standards and Technology (NIST) seeks to address this asymmetry by identifying technical challenges and communicating them through accessible channels for academics. To achieve this, NIST is publishing a series of articles in collaboration with industry experts, such as Chuck Werner, to bring these challenges to the attention of the larger academic community.

The following sections are meant to help technology creators like academics, understand not just where development is needed, but also some of the impediments to its progression and adoption. There is a slight emphasis here on Small to Medium Enterprises (SMEs) because they typically do not have the resources to participate in the research and development ecosystem directly.

Section 1 has a brief introduction followed by the background in Section 2. Next Section 3 covers the research that is needed. It is broken into two categories: specific technical challenges and aspirational automation challenges. Section 4 covers what new technology must have in order to make it to industry and Section 5 covers the challenges to the adoption of new technology. The perspective of the small to medium size enterprises is then given in section 6. Finally, section 7 covers how researchers can use the information presented here.

2. Background

This is not a literature review. Those doing research already have access to the literature, which is largely generated by academics. The industry perspective is lacking within the literature because manufacturers and business owners rarely publish in academic journals. This article is meant as an industry perspective given by Chuck Werner, who has extensive

¹Commercial equipment and materials may be identified to specify certain procedures. In no case does such identification imply recommendation or endorsement by NIST, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

interactions with industry, including hundreds of manufacturers. Mr. Werner has more than 30 years of manufacturing experience and has done more than 950 assessments of manufacturers in the Michigan area as a part of the Michigan Manufacturing Technology Center (MMTC).

Mr. Werner has direct experience helping manufacturers understand and implement new technology. His position is unique in that his organization (Michigan Manufacturing Technology Center) does not sell any technology, neither hardware nor software. It is considered critical to the MMTC to maintain a strictly agnostic approach to the suppliers thereof. There are no agreements, financial or otherwise, that might result in a preference toward one supplier of a technology over another. Instead, they assist in matchmaking, serving as the trusted advisor assisting a client in identifying and prioritizing a specific need for a technology, vetting the abilities of potential suppliers of those technologies, and then facilitating the introductions between customer and supplier. Vetted suppliers are contacted and allowed to present/compete to be the right fit for a client.

3. Needed Research and Development

The following sections will have a slight focus on SMEs. SMEs, by their very nature, have the least exposure to academia. They rarely have the resources for internal research and development, and they also rarely have excess capital to fund academic research. Even if an SME doesn't have the aforementioned challenges and takes part in research, they will often be hesitant to publish any results for fear of aiding their competitors. Conversely, SMEs are the most vulnerable to global shifts in the economy and technical landscape. For these reasons, this article will have a slight focus on their challenges.

High-mix-low-volume production is a defining characteristic of many small and SMEs and increasingly influences the operations of larger manufacturers. The ongoing evolution of manufacturing hinges, in part, on the ability to deliver highly customized products and services. However, customization and flexibility often conflict with traditional goals of automation and high throughput. Automated solutions tend to be cost-effective only at high production volumes, whereas manual approaches, though adaptable, introduce inefficiencies and variability.

Advancements that enable partial or full automation while maintaining flexibility for product variation are essential. Manufacturers must focus on reducing or automating variability-enabling processes to remain competitive in high-mix-low-volume environments. New technologies that support high-mix-low-volume production will benefit the manufacturing sector broadly, with particularly strong implications for SMEs.

The following sections highlight areas of needed research. Section [3.1](#) covers those that have a clear technical challenge and associated research area. Section [3.2](#) covers needed capabilities without a clear technical area of needed research.

3.1. Specific Technical Research Challenges

3.1.1. Machine Learning for Part Inspection

Part inspection often involves looking for defects and measuring part dimensions, and is an integral part of manufacturing; however, manual part inspection has issues with repeatability, and automated approaches like those that use machine learning are still not adequate to satisfy the need. Automated part inspection using scanning technologies is both slow and expensive. The challenge in automated defect detection is in determining the type of defect. Modern systems can successfully detect defects, but struggle to classify those defects in meaningful ways. Additionally, the defect detection and dimension measurement often require the precise placement of the part in very specific orientations which leads to an undesirably long process duration.

3.1.2. Stacking and Palletization Quality Detection

Automated palletizing and storing is a common task in the automation space. A method is needed to check the safety of both the stacked goods as well as the integrity of the platform on which things are being stacked. While current systems are relatively good at stacking, there is no current implementation to check the integrity of the structure holding the goods. Warehouse environments can store heavy objects many feet high and are starting to implement automated hi-los and forklifts. It is not unreasonable to assume large amounts of time may pass before these shelves and racks are inspected by human eyes.

3.1.3. Robust surface treatment

Here, surface treatment refers to any task that requires a robot to follow the geometry of a surface. Surface treatment could include sanding, grinding, painting, or powder coating. While there are solutions to automate these tasks, they either require meticulous path programming or rough programming with compliant end effectors. A method is needed to understand the geometry well enough to follow the contour of objects using relatively cheap optical cameras.

3.2. Aspirational Automation Challenges

3.2.1. Interfaces

Installation time has a negative impact on Return on Investment (ROI) and if perceived as too long may prohibit the new technology from ever being installed fully. Development is needed to help automation technologies take less time for implementation. This includes approaches that require little to no programming, interfaces that require little to no training, and sensors and cameras that see and understand the world in the same way as operators.

3.2.2. Mobile Robotics

SMEs often have to be creative with equipment given market changes and internal dynamics. For this reason, automation techniques that allow SMEs to move and repurpose their equipment are ideal. Mobile industrial robotics could be a solution, while flexible perception, or smaller robots with higher payloads, could also address the challenge.

3.2.3. Cheap Part Presentation Structure

Part presentation (how a part is presented to a robot) is a major source of peripheral costs² to robots and an area in need of further development. Ideally, the robot could pick up any part of any geometry, providing the end effector is capable. Even the capability of the end effector would increase if the robot was capable of more intelligent grasping. This would enable more flexible bin picking, which has historically been challenging for automation. Metal Inert Gas (MIG) welding defects, for example, are largely due to the inconsistencies associated with part placement during the part presentation phase, requiring a downstream welder to fix any defects. This increases the cost of the automation considerably.

3.2.4. Design to Manufacturing Automation

In most cases, design is not connected directly to manufacturing. Engineers must take designs and manually determine a methodology for manufacturing and part analysis. There are only a handful of examples in industry where the manufacturing process is automatically generated, but part analysis like finite element analysis must still be done manually. More development is needed in techniques that automate the design-to-manufacturing phase. This would help greatly in a high-mix-low-volume production environment.

3.2.5. Better Networking

Interconnectivity is a large source of cost in systems integration and oftentimes heavily sways purchasing decisions. System integrators are faced with devising ad hoc solutions to interconnectivity that can add quite a bit of time to deployment. A method where all of the components in a manufacturer's facility can communicate relevant information is needed. Here we do not refer to process control communication like Open Platform Communication (OPC), Ethernet Industrial Protocol (IP), or DeviceNet. A richer, more extensible means of communicating across a facility that includes all of the information a manufacturer may want for analysis and monitoring is needed.

²A peripheral cost is any expense for supplementary equipment or activities required to make primary automation equipment functional. The peripheral cost of an industrial robot might be part presentation equipment like dunnage, guarding/safety devices, or downstream testing due to inaccuracies and defects. Peripheral costs can often make a useful technology non-viable.

3.2.6. AMR Mapping

Autonomous Mobile Robots (AMRs) typically require mapping technology in order to operate, and often the mapping must be done by driving the AMR around the manufacturing floor manually. A faster, cheaper way is needed to map environments so that AMRs can function effectively without the manual step.

4. New Technology Must Make the right difference

The previously presented areas of research are important for both justifying current research, while also describing needed capabilities that may benefit from a yet unconnected area of study. Here we present some insights into the culture and challenges of technology adoption to further enhance the degree to which technology creators can impact industry. Understanding the culture of technological advancement may uncover new avenues for research and development the authors could not have foreseen.

4.1. The Manufacturers Perspective

From a manufacturer's perspective, technology must be monetarily useful. New technology must:

- Free up capital
- Help growth
- Make the manufacturer more appealing to customers

All new technology must do one of the listed items to an extent that the ROI is acceptable. A good rule of thumb for SMEs purchasing big equipment is that the equipment must pay for itself within one year, and for smaller investments, three to six months is a good range. The time scale can be longer for bigger businesses.

In addition to the ROI typically having a shorter time scale, SMEs have some slightly different requirements than larger manufacturers. New technology should, among other things, be:

- Movable from one area to another
- Easily programmed/utilized/installed
- Able to do a variety of things

Many SMEs function with a high mix low volume production, and thus do not have the need for inflexible technology. Additionally, training staff or acquiring new hires with a significantly new skill base is also a challenge.

5. Change is the Key and the Challenge

Those who seek to do impactful research and make useful developments can benefit from understanding how technology changes within industry, and the challenges to which it encounters.

One of the first challenges to the adoption of new technology is that implementers often do not have a clear systematic approach to change. New technology that requires changes to existing practices can present a challenge. This is compounded because the leadership of many SMEs are very well versed in the technical aspects of generating a product; however, oftentimes they are not well equipped to understand the intricacies of running a business or the adoption of new technology.

Technology adoption as a whole is understood on the macro scale, as far as how the technology transitions from early adopters to mainstream. The micro scale of adoption is less understood given that it is heavily influenced by company and regional culture/circumstances. This is not to say there are no accepted approaches to change and development. Approaches to defect removal and quality control like Six Sigma do exist, however, there is not a widely adopted approach for implementing change due to new technology adoption. This is a difficulty experienced by both small and large manufacturers.

5.1. Having been burned

Another impediment to the adoption of new technology is the “I’ve been burned” scenario. It arises from a business having implemented a new technology and not seeing any substantial benefit from it. This occurrence is shockingly common and is a major impediment to the adoption of new technology.

The first technology many manufacturers are exposed to is Enterprise Resource Planning (ERP) software. In theory ERPs can help manufacturers streamline many parts of their business as well as provide transparency to the operation. Anecdotally, Mr. Werner’s personal experience is that about 80% of the businesses in roughly 950 assessments in the Michigan area possess an ERP, though about 90% of those manufacturers do not like what they have. While that number may be exaggerated, a Capterra study in 2023 found that number to be 47%, which is still a considerable issue [1]. Often a manufacturer will adopt a new technology without understanding what their business needs most. Additionally, sales representatives interacting with business owners feel that their solution is a great fit even when it is not optimal. The result is a business adopting new technology that they might not need or don’t understand why it’s useful.

This is not limited to software, it is also the case for equipment such as robots. It is not uncommon for a robot to permanently be parked on a pallet because the circumstances for installation have never been met. After a manufacturer has experienced this, many feel “they have been burned” resulting in resistance to any new technology. At its root, the

challenge is that manufacturers are not made fully aware of the value of the technology they are adopting and so resistance to its implementation is the result.

5.2. Who is the technology for, SMEs?

New technology is often a better fit for large manufacturers because they are often the ones that fund its development and/or have the resources to participate in the research. This means that brand new technology is often unfit for SMEs, requiring large amounts of customization for them to fully utilize it. Because of their size and limited resources, heavy customization requirements mean SMEs will have difficulty adopting new technology.

6. What it is like to be an SME

The concept of a “Small to Medium Organization” presents a large window of any non-startup of a handful of people to any business with less than five hundred associates under roof. To provide contextualization regarding the importance for the adoption of automation and other technologies it is critical to understand that small to medium businesses represent around 99.9% of all businesses in America[2]. This percentage has been consistent throughout the last decade. These businesses employ almost 50% of all workers in the United States[3, 4]. These facts, combined with supply chain constraints due to offshoring and COVID-19, and adding ongoing challenges in finding a stable workforce leave these businesses without the human bandwidth to effectively run the business. This makes the adoption of technologies to close these gaps critical for sustaining the supply chain.

The identification, prioritization, and application of the correct technological opportunity for smaller businesses is often a challenge for a few reasons. One is that a fair number of small to mediums are or were family-owned businesses. This often results in an environment where the leadership team is extremely gifted at what the business does, but where the time to focus on other skills or educate themselves on other opportunities to improve the operation (like technology) is unavailable to them.

Another challenge is the large amount of variation in business models for SMEs. These differences have a significant impact on identifying the appropriate technology application with regards to ROI. The needs of a low mix/high volume manufacturer are very different than those of a project-based business which are similar, but not the same as a true prototyping or engineer-to-order business. Even the correct fit for an information system is different based on the business model. Unfortunately, sellers of technology are highly motivated to make their product be the “right fit” and may be biased in their presentation. It is critical for the decision-makers in the business to have an effective needs analysis, an understanding of their business model, and an effectively calculated ROI to be used in their decision-making process.

A final consideration is the availability of capital. SMEs must plan a year or more out to be able to have the funding available for technology investment. Even larger, higher rev-

enue companies cannot afford to invest money to learn about technology. Their selected investment must tie directly to solving a specific business problem and must have a quick payback period.

7. How researchers can use this information

It is our hope that researchers can use this document as a means to both select research areas as well as to validate the areas in which they are currently working. There are very few sources written by industry experts that exist in the academic literature and here we provide an industry perspective published in a medium where academics can find it. This document and future ones like it can help ensure that research directly benefits our society.

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