NSF/ASME Student Design Essay Competition 2018
Undergraduate Category

Adaptive Products through Artificial Intelligence

A look into the future of product design and manufacturing

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Abstract

The novel time of design and manufacturing in 2035 will be characterized by enterprises that incorporates artificial intelligence to produce innovative, personalized products and to enable flexible manufacturing methodologies. Companies will be faced with the increasing demand of convenience and personalization of products and services. An enterprise that is able to successfully collect big data (through sensors, trend analysis, social media, and the internet of things) and apply the information to product personalization will be successful; I predict this will be done through the integration of machine learning into product design. With personalization, manufacturing techniques will need to satisfy a wide range of product parameters, and a lucrative enterprise will need to establish novel methods of flexible manufacturing through intelligent robotic systems. The ideas set forth in this paper present the fundamental idiosyncrasies and research challenges of a successful enterprise in 2035.

Introduction

To remain competitive, since the conceptualization of laissez faire economics and even prior to its definition, the continual development of technology has been essential for an enterprise's success. Now, technological development has reached a point which some refer to as a "hybrid age," where technology assists humans in novel areas of decision making and thought – what is human's most distinguishing asset is now being challenged by artificial intelligence [1].

Artificial intelligence has been a subject of the public's fascination since the conceptualization of computers, and perhaps even prior to that; we see this in fictional apocalyptic movies, and in real events such as IBM's Deep Blue defeating chess grandmaster Gary Kasparov. We live in a time now where AI's application is continually realized: in the development of self-driving cars, recommender services in Spotify or Pandora playlists, and many indirect examples such as post office address recognition [2].

Much of AI's practical application comes from new consumer trends, enabled by technological advancement. Consumers are now demanding more conveniences and personalized experiences. A study from Accenture found that 37% of consumers are willing to trade personal data for financial reward, 26% would use sensor based services to take care of needs without human intervention, and 47% would use personalized replenishment of household items [3]. The integration of all three aforementioned characteristics into product design will be essential for a competitive design and manufacturing enterprise in the year 2035.

The increasing supply of big data, usability of intelligence by machine learning, and consumer demand of personalization will ultimately lead to the integration of artificial intelligence in-to product design and real time usage. A successful design and manufacturing enterprise will need to develop, understand, and integrate artificial intelligence into their product design and services; however, they face challenges of technological limitations in sensors and computing power. Enterprises will face ethical dilemmas in data security and use, and changing political regulations. They will face complex issues of characterizing and understanding human psychology and behavior, and will face challenges understanding the optimal ways to collaborate man and machine. A company that can recognize and develop support technologies, that factors in ethical and political dynamics, and that can comprehend and empower the human in the human-AI relationship will be the most successful.

Defining Characteristics

Adaptive Products

Currently, products are typically designed to serve the purpose of a single function. The future of consumer products will incorporate physically adaptive technologies that can perform a multitude of tasks with the assistance of artificial intelligence. Areas where real-time adjustable, multi-function smart products will be useful will be in area of changing environments and conditions. Such areas could include adaptable prosthetics for different tasks and adaptive treads and maneuvering mechanisms on vehicles. Products will also be able to assist users in real-time high stakes decision making such as in space applications, military, rescue operations, surgery, home healthcare, and safety [4]. Machine learning capabilities will collaboratively work with users to assist in large searches of information, pattern recognition and situation prediction for decision making and design.

Data Collection

To create these adaptive products, sensor integration and constant feedback will be key. These sensors can range from simple force detection to complex vision systems. Sensors might include radar detection, relative location tracking, infrared, etc. Artificial intelligence functions well with big data for training sets. Enterprises will need to understand how to integrate sensors to collect data in products. Currently, data is readily collected with ease through the internet of things, but collection will be a much more complex challenge with physical systems.

Personalization

Successful enterprises will consider the increasing demand for personalization of products. Integral in the ability to personalize products is both the understanding of product design parameters based on individual psychological constructs and what I will call "flexible manufacturing." Flexible manufacturing will occur through manufacturing tools which are adept in multiple functions; they will be characterized by advanced robotics, including precision nanoscale manufacturing, and will incorporate artificial intelligence in production. Flexible manufacturing will enable a broad spectrum of design and manufacture options. Intelligent automation of manufacturing will also introduce higher levels of safety using predictive maintenance [5]. The concept of a robot fixing another robot will be feasible and economical. Personalization of products will also result in the decentralization of manufacturing sites, as they require less large scale, exact processes. 2035 could potentially see the manufacture of products on demand, in homes and at localized sites (realized through flexible manufacturing). A mechanic in a remote location in Alaska will be able to produce specific parts on demand with stock of raw material and flexible manufacturing equipment. Soon shirt sizes will no longer be small, medium, large, etc.; rather, they will be personalized to your fit and comfort.

Communication

Artificial intelligence systems must be able to readily input, interpret, and relay data and decisions – especially if involved in time sensitive applications. Therefore, computing power and rapid communication with individualized products, equipment, and services must be a key characteristic of the design and manufacturing company. The enterprise must have a widespread, reliable, and secure data storage system with backup measures for sensitive data; safety measures will be realized through block-chain structures and/or a cloud based system throughout the organization. The rapid transmittal of big data must be developed through new communication systems such as (LI-FI) light fidelity [6]. Furthermore, development of quantum, high speed computing technology will exponentially decrease processing time, further enabling AI capability.

In order to execute this vision, there are a number of research challenges that academia, government, and private industry will have to collaborate on.

Research Challenges

Characterization of Human Psychology

A major issue in understanding what design parameters to personalize is due to the lack of understanding on human psychology. Reverse-engineering the brain is one of the current engineering grand challenges; having some understanding of the human decision making process in product design will be essential for a company that wishes to personalize products in 2035. Recently, Ghosh utilized a cyber-empathic design process to understand latent psychological constructs, which will help define what product parameters are of principal importance (see Figure 1); sensors are embedded in products that give information to be used in structural equation modeling and help determine product perception and important parameters [7]. Extracting and processing big data from these sensors will likely be assisted by artificial intelligence algorithms, as they excel in pattern recognition.

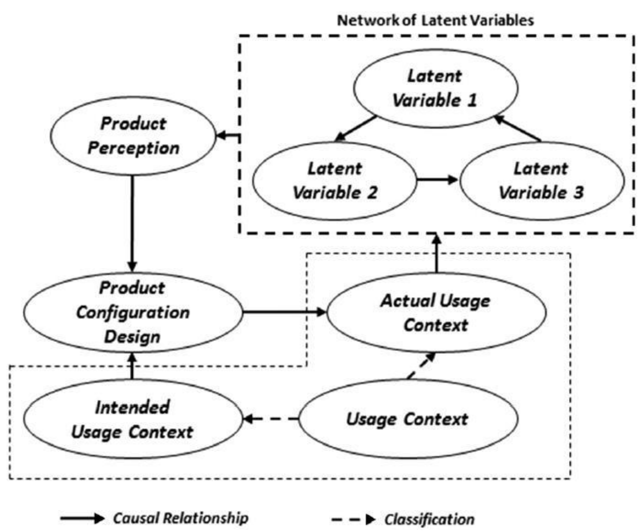

Figure 1: Relationship of usage context with product preference [7]

Sensor Technology and Communication

In order to integrate sensors into physical products such as shoes, the sensors themselves face challenges of cumbersome size and aesthetic degradation, power sources, and communication of information. Nanotechnology research is a future solution; Jean-Pierre Sauvage and J. Fraser Stodart won the Nobel Prize only two years ago for constructing an

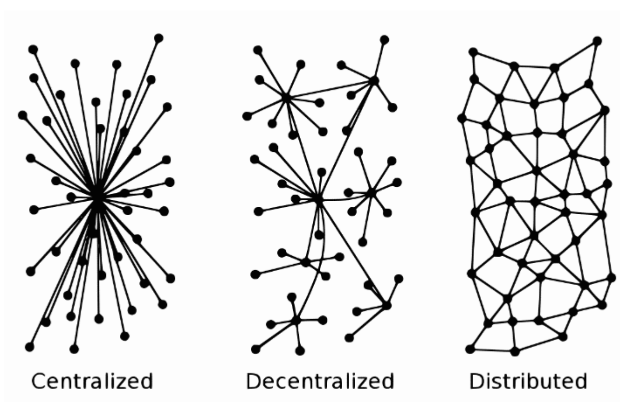

Figure 2: Types of Blockchain Networks [10]

electrically driven nanocar [8]. Piezo-electric research will also be essential for providing energy to the product sensors. Communication of information from these sensors will take new forms, and include research in harnessing new electromagnetic wavelengths such as visible light [9]. For artificial intelligence to readily access sensor data across a network of products and ensure proper, safe real-time action, investment must be made into incorporating block-chain research. Figure 2 refers to three major types of blockchain networks, each with their own advantages and disadvantages in terms of security, cost, and computation energy. When communicating with products such as vehicles, block-chain could provide a potential solution for security and fidelity of information [10].

Unsupervised Machine Learning

The research challenge integral to the function of this new enterprise is research in artificial intelligence. Developing methods for unsupervised machine learning will be key for applying models to work for other tasks, such as new product design and personalization, as well as flexible manufacturing. An example of current research in unsupervised learning can be seen in Figure 3; Convolutional neural networks (CNN) have been adopted in supervised learning, but only recently have been applied to unsupervised learning with strong performance demonstrated by Radford, Metz, and Chintala using deep convolutional generative adversarial networks (DCGAN) [11]. Supervised machine learning models currently allow better encoding of dataset characteristics, but supervised learning is detrimental when applied to other tasks. Therefore, unsupervised machine learning methods such as auto-encoders, convolutional clustering, and generative models must be heavily researched for integration and useful application.

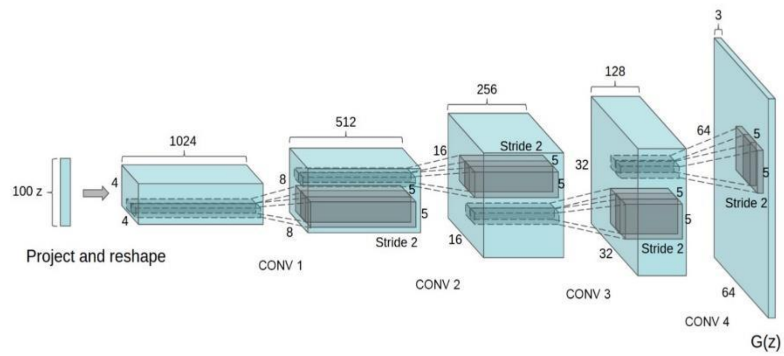

Figure 3: DCGAN, generator network model [11]

Adaptive Mechanics

The redesign of our traditional manufacturing machines must be researched to accommodate for the wide breadth of ability granted by artificial intelligence control systems. Manufacturing machines will no longer be designed for one role; instead, they will act as a “Swiss army knife” and have multiple abilities. Research into smart robotics will need to be conducted to develop manufacturing equipment with the maximum amount of functions and highest efficiency for AI manufacturing. Moreover, reconsidering manufacturing processes and procedures will need to be researched – instead of linear operating procedures and lines, networks of tasks within a manufacturing plant of smart robots can be optimized and developed with the aid of machine learning.

Political and Ethical Issues

Already we have seen the controversy of personal data usage, and of what type of data is legal and ethical to retrieve. Facebook recently encountered scandal in data-mining for political campaign usage, with its CEO testifying before congress [12]. Ethical issues also arise in the development of the artificial intelligence algorithms; a classic modern day example includes the self-driving car dilemma: a car has to decide whether or not to strike pedestrians or sacrifice its occupant [13]. Enterprise in 2035 will face challenges in programming legal and ethical decisions into artificial intelligence. Finally, perhaps the largest political challenge is the fear of job replacement. Workers will fear losing jobs and economic opportunities, and lobbying for restrictive legislation on such technologies could occur. Therefore, it is essential for the enterprise to research proper transition methods of effectively meshing artificial intelligence and modern technology to workers; likely, this will involve a need for increased education and training provided by the company.

To meet these research goals and to most effectively maintain the aforementioned novel defining characteristics, a unique mode of operation must be defined.

Mode of Operation

The company will operate in a large network of subsidiaries to offer services to a wide range of geographic locations; it will be decentralized. Transportation costs will be cut, and supply chain will be redefined; subsidiary sites will maintain volumes of raw material and need less manufacturing equipment with flexible manufacturing implemented. Finished product will be produced and transported shorter distances from numerous small manufacturing sites, rather than one large centralized location. The large number of locations will offer franchising opportunities, and allow the company to bridge into remote locations and typically inaccessible markets. The smaller sites will each be partially defined by the communities in which they exist; this will include employment, services, and outreach. Public image will be essential to companies that utilize private data, and trust will be prime importance.

The enterprise must be characterized by an environment of continued education for all levels of workers, as well as a heavy reinvestment of revenue into research, development, and community outreach. This will foster growth of employees, new innovative products, and better public image and trust.

Figure 4: Circular Economic Model [14]

Environmental consideration will be a fundamental factor in product design and manufacturing in 2035. Understanding the availability of finite resources and incorporating a circular economic model (see Figure 4) in contrast to a linear model, will allow the business to produce sustainable products. Circular economic models will include designing products with more limited lifespans, and involves a high emphasis on re-use, repair, and recycling of materials [14].

Establishing an effective mode of operation and business model will undoubtedly involve partnerships and cooperation with other organizations within the academic and private sector, as well as individual customers.

Partnerships

Academia

Partnership with academic institutions will be essential for producing the high level of research in machine learning, sensor technology, human psychology, smart robotics, and even geopolitical factors. Linking academia and industry provides institutions with opportunities in application, and creates a diverse feedback network of ideas. Partnering with academia will also lighten the amount of research reinvestment by the enterprise.

Companies

The enterprise will need to partner with well-established and secure big data organizations for the storage and accessibility of customer data (used in product personalization). Companies that develop novel storage systems such as cloud based RAM could also be beneficial to the enterprise in product design [15]. Partnering with marketing firms will be important in understanding and predicting trends and conceptualizing new markets that benefit from product personalization and adaptivity. Partnerships will be formed with sensor development industries and companies that specialize in battery and energy technologies.

Consumers

Feedback from consumers will come not only in the form of embedded product sensors, but also from direct feedback. A greater amount of individuals giving feedback typically results in convergence on a significant issue with the product, or a novel solution: crowdsourcing [16]. With the assistance of artificial intelligence, direct partnership with consumers can be established; rewards such as gift cards, discounts, or free products can be given as incentives for feedback. This can help the enterprise target areas of product redesign, and areas where product personalization is important.

To supplement the company's aggressive emphasis on research and novel mode of operation, state of the art support technology will be crucial.

Support Technology

Fundamental support technology to the company would include state of the art computing power to support the artificial intelligence speed and scope. State of the art devices will include graphics processing units, digital signal processing units, and field-programmable gate arrays for adaptive products and flexible manufacturing. Additionally, top computer vision and sensor technology will be essential in data collection for AI interpretation. Novel robotics technology and materials science will be critical for flexible and decentralized manufacturing plants. Access to the internet of things will enable crowdsourcing and feedback systems to supplement sensor data, and improved communication methods through light fidelity will be fundamental support technologies.

Conclusion

AI in manufacturing alone has an expected value of $4,882.9 million by 2023. With a predicted compound annual growth rate of 52.42%, the industry is forecasted to be worth $767.68 B in 2035 [17]. To harness this value, enterprise must incorporate machine learning into their design and manufacturing processes. The envisioned world of 2035 will involve a mass of available data that allows us to understand consumer behavior at a personalized level. Flexible manufacturing solutions and product design methods that incorporate artificial intelligence have the potential to control a new market, and transform the design landscape. The enterprise will face several research barriers before establishing its place of dominance in the new consumer environment: characterizing human psychology, improving sensor technology and communication, applying unsupervised machine learning, incorporating adaptive mechanics, and considering political and ethical obligations. Through research collaborations in academia, industry, and even with consumers, an enterprise will overcome these challenges and realize its full potential in the 2035 design and manufacturing environment.

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