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Investigation of Innovation Dynamics along the Life Cycle of Deep Learning

HM Adnan Zami

Faculty of Engineering North South University, Department of Electrical and Computer Engineering, Dhaka, Bangladesh.
hm.zami@northsouth.edu

Abstract. Evolution of artificial intelligence over the years has given birth to specialized subfields, one of which is deep learning. This paper aims to investigate the dynamic life cycle of deep learning from its conceptualization and investigate the impact of the underlying technologies. Innovation of new products and their evolution over the course of the dynamic changes in deep learning technologies are studied to evaluate the processes of reinvention and renovation. Moreover, the disruptive effect of deep learning in overtaking or consuming creative destruction has also been investigated. Finally, the strategies, policies and regulatory roles and its impact on employment firms and economic growth were studied to understand the impact of deep learning and its future role in our society.

Keywords. Deep learning, natural language processing, engineering technology management, artificial intelligence, face recognition.

1 Introduction

Advent of artificial intelligence-based inventions, especially in the field of deep learning, has given life to a spectrum of innovations that are shaping our daily lives. These innovations are a result of advancement in high-performance computing and devices. Much of the concepts defined in the early stages of deep learning development introduced around 1940s have only recently started gaining momentum. Over the course of its life cycle, underlying technology cores for deep learning were reinvented. Businesses that adopted these new technology cores rode along the waves of creative destruction. Others fell victim to disrupted waves of innovation causing products to migrate along industries and even countries. Techno-human cognitive nature of deep learning technology promises to reshape jobs, firms and economic growth. This brings along the need to regulate roles and create strategic policies that would protect human interest in surviving as a society. Impact of deep learning in shaping products, businesses and human roles will be studies and examined to understand the dynamics of the development life-cycle in this paper.

1.1 Investigation Scope of Innovation Dynamics of Deep Learning

This paper will present the complete life cycle of deep learning from its birth till today. Each critical advancement of deep learning algorithms and core technology will be studied to observe the trend of development. Following that, application of such technology in inventing and innovating products along those line of development will be analyzed. Since deep learning technology has been popular for natural language processing and image recognition mostly, products pertaining to these fields were identified and studied. Additionally, businesses that played major roles in implementing

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these technologies successfully to create innovation were highlighted. Results were compared between competing businesses that failed to migrate to give an overview of how deep learning has shaped various industries. Progression of deep learning technologies mentioned in impacting job roles and quality of products are also examined by comparing relevant businesses.

1.2 Impact and Importance of Deep Learning based Innovation

Deep learning opened up exciting possibilities for economic development as much of its application is used for mass automation. Deep learning has provided image-based product searches – Ebay, Etsy– and efficient ways to inspect products on the assembly line. The first supports consumer convenience, while the second is an example of business productivity. Advanced systems for all kinds of industries such as medical, automotive, finance and others are greatly impacted by products such as pattern recognition in disease diagnosis, autonomous driving, fraud detection and more. Capability of predicting trends and improving efficiency has labeled deep learning a significant contributor in the economy. PricewaterhouseCoopers Company, and Analysis Group (funded by Facebook) foresee large gains in quality and productivity for companies. PricewaterhouseCoopers has flagged AI's possible $15.7 trillion contribution to the global economy by 2030 making Ai the biggest commercial opportunity in today's fast paced economy [1].

2 Technology Invention and Growth Forming Life Cycle

Ambition to create better quality products with lesser resources has driven humans to invent technology to get jobs done better. This led to the act of technology management which has driven the human race into finding ways to replace their work activities with machines. Management of technology ensures formation, growth and exploitation of technology possibilities to large-scale economic value creation out of ideas. With the introduction of such ideas, technology became a tool for driving innovation. The key to understanding how these technologies develop and impact businesses and our lives is to understand the growth forming lifecycle.

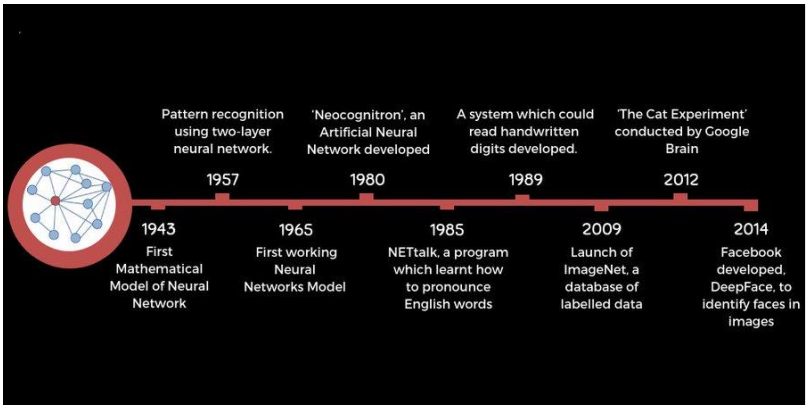


Fig. 1. Deep learning technology core growth forming life cycle

History of deep learning or specifically, neural networks, dates back to 1943. The first mathematical model of neural network was designed by Warren McCulloch and Walter Pitts. In their paper, McCulloch and Walter mentioned about creating nets that behave specifically under an assumption. When these nets are combined, a network of neurons can then behave in a way that logically reasons through a situation [3]. This was the first instance of neural network which didn't receive much attention until John Von Neumann, Norbert Wiener and others implemented these ideas.

2.1 Intelligent Machines and Early Deep Learning Applications

First intelligent machine was introduced by Samuel Arthur in 1949 by popularizing the term machine learning in his paper [4]. He created a checker playing algorithm that use rote learning and in 1962 it beat checker master Robert Nealey. This one of the earliest applications of machine learning that shed light on the possibilities of machines overcoming humans. Moreover, artificial intelligence concepts began early in the 1900's, the term was first coined in 1956 by John McCarthy.

Deep learning is a more specialized field of machine learning and artificial intelligence that mimics the human mind via neurons. In 1960, Henry J. Kelly developed Back Propagation Model [5]. In 1962, Stuart Dreyfus developed a simpler version based on chain rules. However, the concept of backpropagation was still clumsy and inefficient. Few years later in 1965, Alexey Grigoryevich Ivakhnenko and Valentin Grigor′evich Lapa created earliest deep learning algorithm with polynomial activation functions. The best statistically chosen features were forwarded to the next layer from each layer.

During the 1970s, the AI winter resulted from a lack of funding for DL and AI research. Despite limited funding, individual researches carried on their work which resulted in the introduction of the first convolutional neural network [6]. Fukushima developed a neural network with multiple pooling and convolutional layers in 1979. His model was known as Neoconitron which was trained to understand visual patterns. Fukushima's design allowed important features like adjusting increasing "weight" of certain outcomes.

2.2 Breakthrough in AI and Deep Learning

Moving forward, Yann LeCun performed the first practical demonstration of backpropagation by combining neural network with backpropagation on handwritten digits. This model was later used to read handwritten checks. Moreover, the 2nd AI winter from 1985-90s improved research for NN and deep learning. In 1995, Dana Cortes and Vladimir Vapnik developed support vector machine and Sepp Hocchreiter and Juergen Schmidhuber developed LSTM (long short-term memory) for recurrent neural network in 1997.

The real break though came after 1999 when computers and GPUs got significantly more powerful. At this time, neural network started competing with support vector machine and offered better results. However, vanishing gradient problem became an issue which was later resolved by layer-by-layer pre-training and development of

LSTM. This was a time when Big Data was starting to rise. In 2009, Fei-Fei Li of Stanford launched ImageNet which was a free database with more than 14 million labeled images.

With increasing computing speed and massive set of training database, AlexNet, a convolutional neural network became one of the most popular deep learning model that achieved great success in recognizing images. Smilarly, in 2012 Google Brain released The Cat Experiment which showed that a neuron in the model was capable of detecting cat images and another detecting human faces. This was another breakthrough in training unsupervised neural networks for image recognition.

3 Innovation Dynamics of Deep Learning

Along the lines of technological development, Already, AI applications are increasingly being utilized in a range of industry sectors, from health care, finance, and information technology to consumer sales, marketing, transportation and fulfillment, and national security. Deep learning is a game changing development as it models using it offers to learn and improve itself from existing data. These high performing models have equipped businesses with the latest deep learning tools to innovate products and policies to maintain business principles.

3.1 Innovation of New Products

Top performing tech companies of this decade have one way or another implement deep learning models. Following the technological life cycle of deep learning, businesses have been quite skeptical about adopting these models because of inefficient performance and premature models. However, as computing power enabled Deep Learning models to outperform conventional methods for image recognition and natural language processing, companies have moved to create their own products.

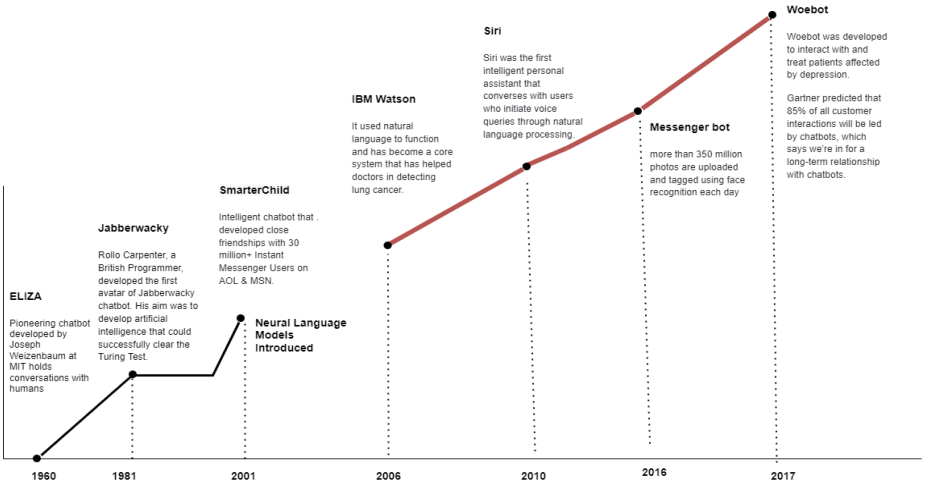


Fig. 2. Natural language processing innovation timeline

Earliest chatbot dates back to 1964 when ELIZA, pioneering chatbot developed by Joseph Weizenbaum was introduced at MIT. It demonstrated simple conversation with humans. Fast forward to 2011 and the first modern virtual assistant Siri was introduced by Apple. Siri uses deep learning algorithms to create natural sounding voices that allows Siris personality to shine through. Various other voice assistants based on NLP were developed such as Cortana, Alexa, Google Assistant, Baidu, Bixby etc. all of which were created thanks to the development of NLP due to deep learning algorithms.

Chatbots are another category of products that rely on deep learning algorithms to understand conversations. These products analyze the lexical structure of sentences to provide support especially for online customers. Ecommerce website face millions of transactions a day where thousands of customers may want to reach customers service. Chatbots have become an exceptionally easy way to handle basic queries that do not need to take up a customer service executives time which saves great resources for companies.

Emerging application of deep learning products include self-driving cars which use computer vision. A prime example is Tesla. Moreover, image recognition has gained popularity in medical imaging, object detection in satellite image and even traffic control systems.

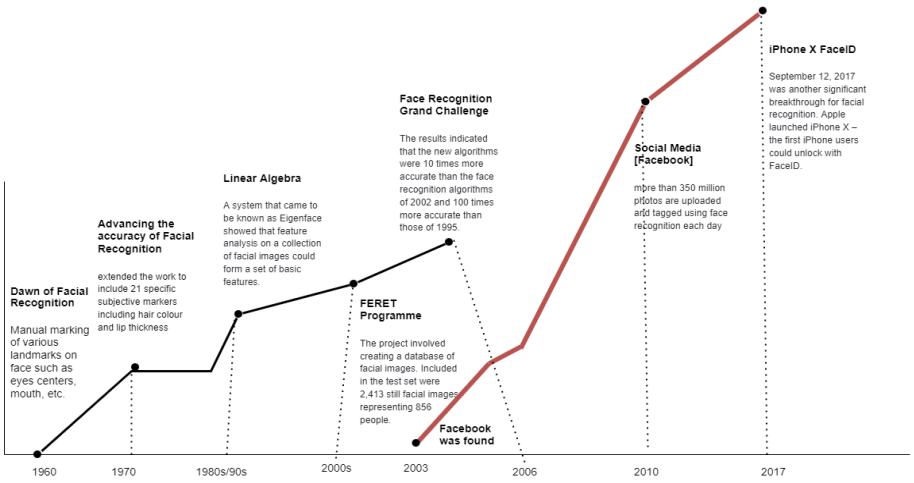


Fig. 3. Face recognition technology development timeline

3.2 Incremental Advancement of Products and Sustaining Innovation Effects

Although innovation using deep learning technology core resulted in a myriad of innovations, not all of them are here to last. Throughout the course of deep learning technology core development, newer versions of products have been released which has affected the ability of deep learning technology to sustain innovation effects. Much of the products that started during the early stages have been replaced by better models. The success of e ach product depends on how it diffuses through different customers.

It was not until Alexey Grigoryevich Ivakhnenko's creation of first neural network in 1965 that people started implementing neural network models. However, it was not until the 1990s technology boost that allowed businesses to implement neural network in mass consumer products. Yann LeCun's application of using CNN to read handwritten digits was one of the first practical use of neural networks. By early 2000s, 10% to 20% of all checks written in the US were being processed by this technology. This is an example of deep learning has introduced new methods of processing checks and it still sustains today.

Looking into voice recognition products like Siri which was launched in 2011, other voice assistants like Cortana launched in2014, Google Assistant launched in 2016 and Bixby launched in 2017 followed along. The products using these technologies were mostly mobile phones or personal computers. These products gained a boost as deep learning technology sustained their use in the world today. Because of these voice assistant technologies, customers are still purchasing mobile phones and laptops instead of moving to alternative products.

Similar to voice assistants, the growth of chatbots since the birth of the internet in 1983, has increased. Eliza was the first chatbot in 1964 which was capable of only having personal conversations. With the growth of smartphones in 2000s and 2010s, chatbots remerged with better technology core. In 2016, NLP tools with business-user friendly frontend interfaces were developed which made it easier for businesses and customers to interact using chatbots.

4 Reinvention and Re-innovation

The journey of reinvention and re-innovation unfolds winners and losers in the race for economic control. For deep learning technology, it has resulted in reinventing some of the most popular products in use today. Especially in the field of image recognition and natural language processing, products that implemented deep learning achieved far more success in fulfilling its objective. Since deep learning technology tries to replicate human mind, it is only natural that technologies using this core will emerge itself with human interactions.

4.1 Reinventing Face Recognition Technology to Re-innovate Smartphone Security

Dawn of facial recognition goes back to 1960 when manual markings were done on various landmarks of the face such as the eyes, mouth, ears, etc. A decade later this method was improved with 21 specific subjective markers including hair color and lip thickness. Although it improved face recognition, but the results were not as satisfactory especially under poor lighting. Later around 1980s, linear algebra was implemented in a system known as Eigenface that showed feature analysis on a collection of facial images. This system set basic features which were later analyzed using linear algebra. Later in 200s, FERET program was introduced which was a project involved in creating a database of facial images. It included 2413 still facial images of 856 people. Around the same time, Facebook was found which started their online journey. In 2006, Face Recognition Grand Challenge took place that resulted in finding new algorithms 10

times more accurate than the face recognition algorithms of 2002.

While face recognition technology was improving, one prime factor that enabled this was a large database of labeled images. Facebook started acquiring massive users and had more than 350 million photos uploaded and tagged by 2010. This gave them an upper hand in using deep learning tech to improve their services which they did. They started adding suggestions for friends when a person was tagged with another person in the same photo. Finally, in 2017, we see the first mobile phone iPhone X using FaceID to unlock their phones. If we look back at mobile phones from early 2000s, most of then used a standard pin to unlock. Afterwards lock screens were introduced with slide to unlock option. Moving on, fingerprint scanner was introduced by Pantech Gi100 in 2004. Then came iPhone X in 2017 which brought facial recognition to re-innovate smartphone security.

4.2 Reinventing Chatbots with Natural Language Processing

ELIZA was the pioneering chatbot that was designed using conventional architecture. In 1981, we saw the birth of Jabberwacky. Rollo Carpenter was a British Programmer who developed the first avatar of this chat bot. He aimed to develop AI models that could successfully clear the Turing Test. Then came SmarterChild which was an intelligent chatbot that developed close friendship with over 30million users on AOL and MSN. Finally, in 2001 Natural language processing models were introduced and things started to change. Afterwards. IBM created Watson in 2006 which used natural language processing to function and was a core technology that assisted doctors in detecting lung cancer. Then in 2010 Siri was introduced and Messenger bot came in 2016 followed by Woebot in 2017. Woebot was developed to interact with and treat patients affected by depression. Moreover, with online businesses on the rise, Gartner predicted that 85% of all customer interactions will be led by chatbots.

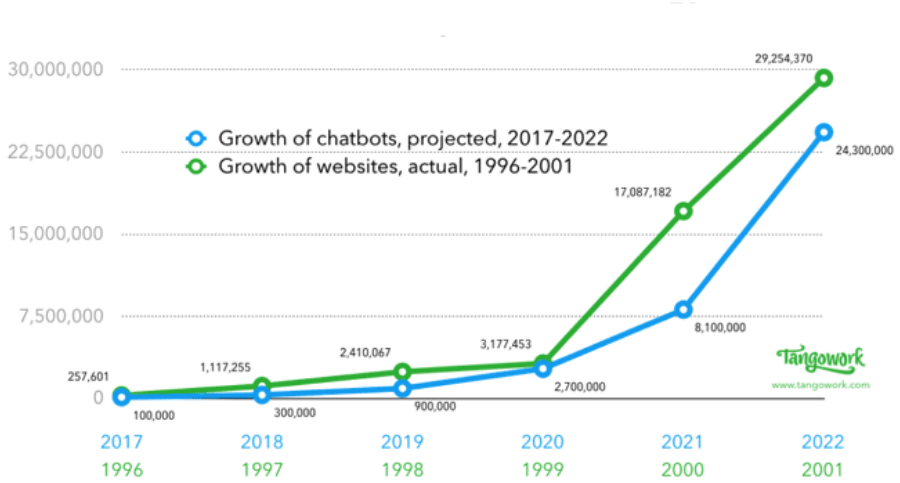


Fig. 4. Growth of chatbots and websites

5 Creative Destruction and Disruptive Innovation

The opportunity of AI is significant, but there is no doubt that its penetration might cause disruption. The productivity dividend of AI probably will not materialize immediately. Its impact is likely to build up at an accelerated pace over time; therefore, the benefits of initial investment might not be visible in the short term. Patience and long-term strategic thinking will be required. With the advancement of deep learning technology core, it is already evident that a massive wave of creative destruction will produce new innovations.

5.1 Creative Destruction using Deep Learning

In 2009, a company called WeChat in china created an advanced chatbot. This product quickly took off and in the last quarter of 2021, it had almost 1.27 billion monthly active users from a wide range of age groups. Through its platform, it has made it easy to create very simple chatbots. It became an example of the most favored ways for marketers and employers to reduce the work they do as they interact with customers online. Since the introduction on NLP in 2011, chatbots have grown from around 250,000 to almost 30 million. This has been the case in many sectors too. Acceptance of AI chatbots by customer and industry grew to 48% for online retail, 25% for telecom, 20% for financial advice, 27% for healthcare, 15% for insurance and 20% for banking. Prior to chatbots, these services were offered by customer service executives. The results show how deep learning innovated advanced chatbots that has been causing creative destruction to customer service industry.

Likewise, email services have been impacted by deep learning technology. Earliest email service providers included Yahoo Mail, Outlook Mail, AOL Mail and many others. However, the customer base for these products has changed over the years and some have even gone extinct. Outlook Mail started off with the highest customer usage but soon after 2005, Gmail took over. Reason being that Gmail introduced new smart compose and spam filter. With spam emails becoming a major concern, people shifted to Gmail with Gmail having 1.5 billion users by October 2019.

5.2 Disruptive Innovation Effects of Deep Learning

Internet and smartphones have increased social media usage. Th first social media platform was six degrees which let users connect by creating profiles, adding friends and school affiliations. Millions of users registered but due to inadequate internet architecture, it did not last. Following that, other platforms like Ryze, Friendster, MySpace, Orkut, Hi5 were introduced but they are not among the leading social media giants we know today.

Top social media platforms today all have one thing in common and that is the use of deep learning. Facebook uses NLP system built around neural networks to identify posts that are excessively promotional, spam or clickbait. LinkedIn created their own recruiter recommendation system which capitalizes deep learning algorithms with machine learning models. YouTube has used mannequin challenge to get videos to

create an AI model with ability to discern the dept of field in videos. All other social media platforms has changed companies due to disruptive innovation effects caused by the introduction of deep learning.

6 Effect of Deep Learning Products on Firms, Jobs and Policies

Businesses looking to innovate or expand their businesses by implementing deep learning technology core has greatly benefitted in recent times. Examples of Google, Amazon, Facebook, Netflix and numerous other platforms show just how much deep learning technology can impact businesses. With new technology comes a shift in roles of jobs as well as new policies.

6.1 Migration of Products along the Boundaries of Firms and Industries

In this age of digital connectivity, online businesses have expanded greatly all over the world. Marketing cap of leading large ecommerce companies of June 2021 shows how Amazon and Alibaba are bagging $1,734.95 and $614.83 billions. With such huge market, how is it that these two businesses have expanded so much when compared to others? Amazon began as an online bookstore but quickly grew. One of the prime reason for growth and retention of customers is that they use AI to understand the context and intent behind customers search queries. Moreover, Amazon created brick-and-mortar Amazon Go stores where customers can just walk-in, put items in their shopping bag and walk right out without need to use credit card or cash. This was possible because of facial recognition technology core and machine learning. Their implementation of such technology at the right time has retained their customer and helped them expand their business.

When it comes to user search, Google comes to mind. As the leading search engine, their leaders have always invested in the latest technology to implement with their product. They use deep learning for smart reply, photo sharing suggestions, offensive content detection in YouTube, Driving Mode, Smart Scheduling and way more. These systems do not require human intervention rather they are programmed to autonomously suggest the user to perform and action.

6.2 Implication on Jobs, Firms and Economic Growth

According to the World Economic Forum's "The Future of Jobs Report 2020", AI is expected to replace 85 million jobs worldwide by 2025. Though that sounds scary, the report goes on to say that it will also create 97 million new jobs in that same timeframe [8]. With deep learning technology at the heart of AI, companies that successfully transfer to deep learning innovations can expect great results.

Concerns rise however on the fact that deep learning technology might take over human roles as its sole purpose is to imitate human like behavior using neural networks. Previous examples pointed out how chatbots have taken over customer service executive jobs, although it cannot rule it out completely. McKinsey reckons that, depending upon various adoption scenarios, automation will displace between 400 and

800 million jobs by 2030, requiring as many as 375 million people to switch job categories entirely [10]. However, there will assuredly be an increasing number of jobs related to programming, robotics, engineering, etc. After all, these skills will be needed to improve and maintain the AI and automation being used around us.

6.3 Strategy, Policy and Regulatory Roles

New technology will bring in new policies and regulatory bodies to prevent its abuse. Social media platforms and companies that collect large amount of user data have seen backlash in the past because of weak regulations. Government of each country should play the primary role in establishing strict policies along with strategies to implement and regulate them. First, the diverse application of Ai must be understood at it can benefit education, medicine and finance. Deep learning technology can provide security by implementing autonomous offense and defense, cybersecurity and local law enforcement security. Computer vision that uses deep learning at its core can be installed on the streets to monitor crimes, absconding criminals or report theft. However, abuse of such systems can lead to massive security breaches. The risks must be understood before any deep learning-based innovation is implemented for use. Civilians must stay vigilante to protect their privacy and prevent firms from abusing their rights without their knowledge.

6 Conclusion

Deep learning technology core has immensely developed especially in the last decade which is the reason for drastic change in innovation. The dynamic life cycle of deep learning technology development has shown the critical times of its development. Adopting such technology core has helped companies grow exponentially in just a short amount of time. Waves of creative destruction and disruptive innovations swayed economic power between firms. Prime examples of these are social media platforms which despite of starting early, failed to capitalize by not adopting to deep learning technology. To ensure that the future brings greater good at limited amount of risk, government must take a stand to provide a safe environment for businesses and customers to use deep learning-based innovations.

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