

INTRODUCTION TO DEEP LEARNING AND NEURAL NETWORKS

- 1) Deep learning and neural networks are techniques used in computer science to analyze data. They are especially useful in pattern and image recognition.
- 2) Neural networks use software to mimic the function of the many neurons in the human brain. These functions can be tuned over time; this means man-made neural networks can learn.
- 3) 3Deep learning refers to the use of multiple layers of neural networks.
- 4) Consumers benefit from these technologies every day when they read curated news headlines, research renting a room online or converse with a chatbot.
- 5) Although the emerging artificial intelligence (AI) market is estimated at just \$400 million this year, it can potentially enhance adjacent markets such as medicine, consumer electronics, robotics, and most importantly, autonomous cars.
- 6) Many global industrial and technology companies are pursuing autonomous cars.
- 7) Venture capitalists and technology companies are aggressively investing in and acquiring AI startups.

DEBORAH WEINSWIG

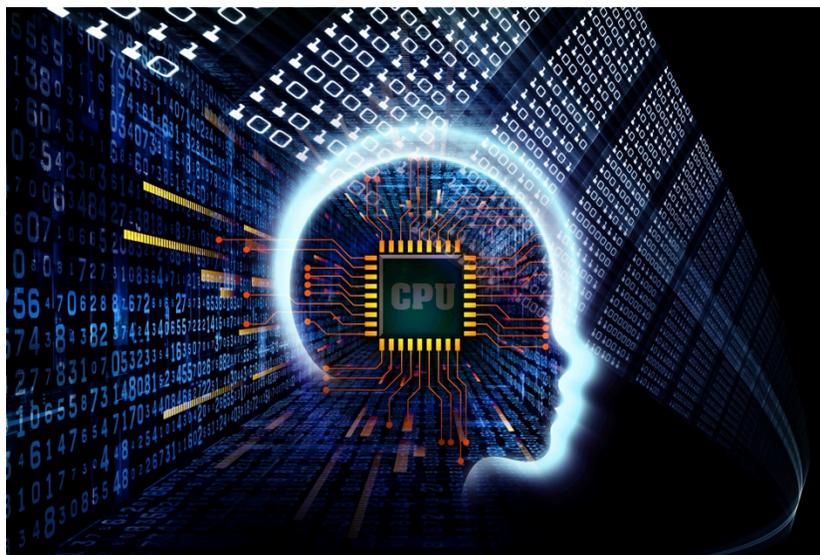
MANAGING DIRECTOR,
FUNG GLOBAL RETAIL & TECHNOLOGY
DEBORAHWEINSWIG@FUNG1937.COM
US: 646.839.7017
HK: 852.6119.1779
CHN: 86.186.1420.3016

EXECUTIVE SUMMARY

AI is presently causing a great deal of excitement in technology and financial circles. Decades of research into AI and neural networks have finally created breakthroughs that can be used in systems that can analyze data and make predictions. These breakthroughs have resulted in stunning amounts being paid to acquire AI companies and invest in startups. At the same time, the excitement over AI has created buzzwords such as “deep learning” and “neural networks,” but they are really just ways to analyze and identify data within the realm of computer science.

To develop these approaches, scientists and programmers have turned to the mysterious human brain and the trillion neurons inside it that transmit and process information, as the model for analyzing data. They have developed networks of cells that mimic the function of neurons. Although this approach has gained and lost favor over time among computer scientists it is currently considered the best approach to accurately and productively identify patterns. Patterns are extremely important in AI; images of handwritten objects or obstacles in the path of a moving autonomous vehicle are patterns that need to be identified and handled.

Although the AI industry is estimated at a mere \$400 million in its current infant state, the market could encompass tens of billions of dollars as adjacent industries such as autonomous cars, robots, military, medicine and consumer electronics embrace the technology.



Source: Shutterstock

The human brain is comprised of 1 quadrillion neurons that communicate with each other.

Although the AI industry is estimated at a mere \$400 million in its current infant state, the market could encompass tens of billions of dollars as adjacent industries such as autonomous cars, robots, military, medicine and consumer electronics embrace the technology. As mentioned above, technology that can identify obstacles in the road is extremely important to firms who offer and guarantee a safe ride in an autonomous vehicle. Industrial and technology companies around the globe are aggressively pursuing this potentially important and huge market. The recent advances in AI combined with the potentially large markets that could be enhanced by the technology, are the likely reason for the avalanche in funding of AI startups and the bidding wars that have occurred to acquire them.

The good news for us humans is neural nets and deep learning have the potential to improve our lives. We already use them every day when we

read a BuzzFeed article or look up a room on Airbnb. These two technologies are purely methods for analyzing data and do not appear to lead to computers that become autonomous and self-aware, the stuff of many frightening science-fiction stories.

INTRODUCTION

Neural nets are tools that can be created with electronics or software to emulate some of the function of a neuron, which comprise the human brain.

The human brain is comprised of 1 quadrillion neurons that communicate with each other. As in the human brain, many artificial neurons can be combined in a network to communicate with each other. Deep learning refers to the use of multiple layers of neural networks in order to increase accuracy and productivity.

Deep learning refers to the use of multiple layers of neural networks in order to increase accuracy and productivity.



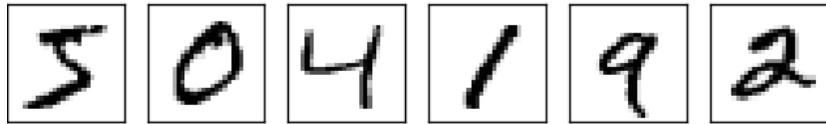
Source: Shutterstock

The parameters contained within these neurons can be changed or tuned to make the pattern identification more accurate, the network “learns” to identify those images.

Specifically, neural nets are good at identifying patterns—in images, speech, data, or even stock prices. The neurons contain programmable elements that are used to evaluate their inputs, and since the parameters contained within these neurons can be changed or tuned to make the pattern identification more accurate, the network “learns” to identify those images.

One application of neural nets is handwriting recognition. In this case, a neural net is fed a sequence of handwritten digits, and the weights are tuned until the network can recognize the digits with acceptable accuracy. The Mixed National Institute of Standards and Technology (MNIST) established a database of 60,000 training digits and 10,000 testing images for tuning and testing handwriting recognition systems. Some of the MNIST digits are included in the figure below.

Figure 1. MNIST Testing/Training Digits



Source: neuralnetworksanddeeplearning.com

Neural nets date back to the 1940s, when neurophysiologist Warren McCulloch and mathematician Walter Pitts published a paper that described how electrical circuits could be used to create a neural network.

Neural nets date back to the 1940s, when neurophysiologist Warren McCulloch and mathematician Walter Pitts published a paper that described how electrical circuits could be used to create a neural network. In the 1960s, the interest of computer scientists turned to von Neumann architectures that are based on a CPU, logic and memory, and interest in neural nets waned. However, in the 1980s, some groundbreaking developments in neural nets reinvigorated interest, which continues through the present day. Many researchers consider deep learning “the most accurate and productive technique in AI research today,” according to CB Insights.

There are deep learning and machine learning in products and services we consume and use every day, including:

- Product recommendations from Amazon
- Headlines from BuzzFeed
- Prices on the Airbnb website
- Facebook’s M assistant

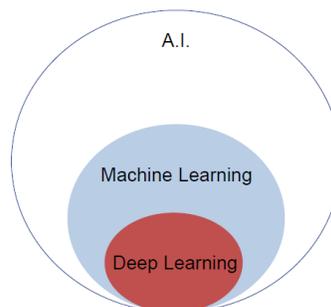
Google has integrated a deep-learning machine with its Street View platform to enable the identification of nearly every location, and the company is also using its own DeepMind AI technology to reduce the energy used to cool its data center by 40%.

AI AND NEURAL NETWORKS

AI refers to the branch of computer science that uses computers to apply human intelligence to solve problems. Within AI, machine learning refers to the techniques used to perform cognitive functions. Deep learning refers to the use of multiple layers of neural networks. The relationship among the three is shown in the Venn diagram below.

AI refers to the branch of computer science that uses computers to apply human intelligence to solve problems. Within AI, machine learning refers to the techniques used to perform cognitive functions. Deep learning refers to the use of multiple layers of neural networks.

Figure 2. Hierarchy and Interaction of AI Approaches



Source: CB Insights

Deep learning is just one way to create machine learning. Others include:

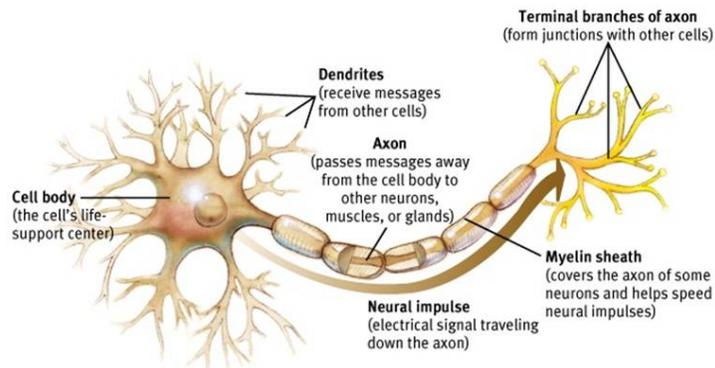
- Association Rule
- Bayesian
- Clustering
- Decision Trees
- Dimensionality Reduction
- Ensemble
- Instance-based
- Others
- Regression
- Regularization

NEURAL NETWORKS

The human brain is composed of about 100 billion brain cells, or neurons, and each neuron can connect to 10,000 other neurons. Thus, a human brain can contain 1 quadrillion, i.e., 1,000 trillion, synaptic connections. A neuron is illustrated below.

The human brain is composed of about 100 billion brain cells, or neurons, and each neuron can connect to 10,000 other neurons. Thus, a human brain can contain 1 quadrillion, i.e., 1,000 trillion, synaptic connections.

Figure 3. Illustration of a Neuron



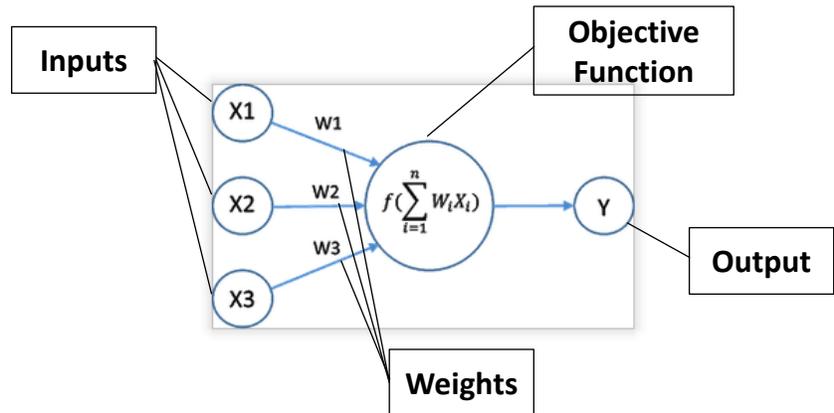
Source: appsychology.com

An artificial neuron, or perceptron, works much the same way as a human neuron, with inputs and outputs.

An artificial neuron, or perceptron, works much the same way as a human neuron, with inputs and outputs, and its functional diagram appears similar to a neuron. Several inputs connect to a neuron, which can be implemented in electronics or in software. The electronic device or software contains an algorithm that uses a mathematical function to create a result, which is sent to the output.

The figure below illustrates an artificial neuron in which the output is the sum of each of the inputs, multiplied by a weighting factor via the objective function. The result is considered a one or zero, depending on whether the output exceeds a certain threshold value. Neurons can also use nonlinear and more complex mathematical functions.

Figure 4. Diagram of an Artificial Neuron



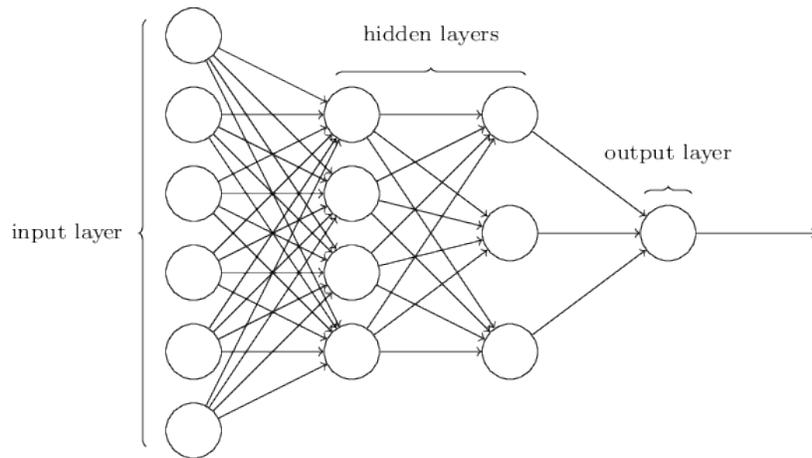
Source: *Infinitemusings.com/Fung Global Retail & Technology*

DEEP-LEARNING NEURAL NETWORKS

Deep learning is not a machine-learning approach in itself, but rather refers to the use of multiple layers of processing. Deep neural networks have two or more hidden layers, as depicted in the figure below.

Deep learning is not a machine-learning approach in itself, but rather refers to the use of multiple layers of processing. Deep neural networks have two or more hidden layers.

Figure 5. Deep Neural Network



Source: *neuralnetworksanddeeplearning.com*

APPLICATIONS

Applications for neural nets and deep learning center on image recognition and processing, however the networks can be applied to any data or information that contains patterns. Examples include:

- Computer vision
- Data mining
- Image processing/compression
- Natural-language processing
- Character/pattern recognition

- Robotics
- Stock-market prediction

Other applications continue to be discovered, such as in medicine, identifying odors, security and law enforcement and loan qualification.

Image processing and identification is a very hot topic these days, since many companies in the industrial, automotive and technology sectors are racing to develop autonomous vehicles, i.e., self-driving cars, that can identify and avoid typical and unforeseen obstacles on the road.

APPLICATION IN AUTONOMOUS VEHICLES/SELF-DRIVING CARS

Self-driving cars need advanced image-processing and identification platforms in order to navigate around and avoid objects and impediments on the road.

Self-driving cars need advanced image-processing and identification platforms in order to navigate around and avoid objects and impediments on the road.



In addition to the work of Tesla and major automobile manufacturers, many global industrial, technology and software companies are pursuing the development of self-driving cars and researching deep learning.

- There are numerous reports that detail **Apple's** research and efforts to develop an autonomous vehicle.
- **Google** is developing autonomous vehicles and is documenting on its blog the tests it is running near its Silicon Valley headquarters.
- Chip companies such as **NVIDIA** and **Qualcomm** are developing machine-vision chips for use in autonomous vehicles.

Chinese technology giants are also aggressively pursuing the introduction of self-driving cars.

Chinese technology giants are also aggressively pursuing the introduction of self-driving cars:

- Online marketplace **Alibaba** launched a venture with Chinese carmaker SAIC to develop Internet-enabled cars. Management commented they can quickly develop self-driving cars from the platform.
- Chinese web portal **Baidu** has tested a self-driving car on the roads of Beijing.

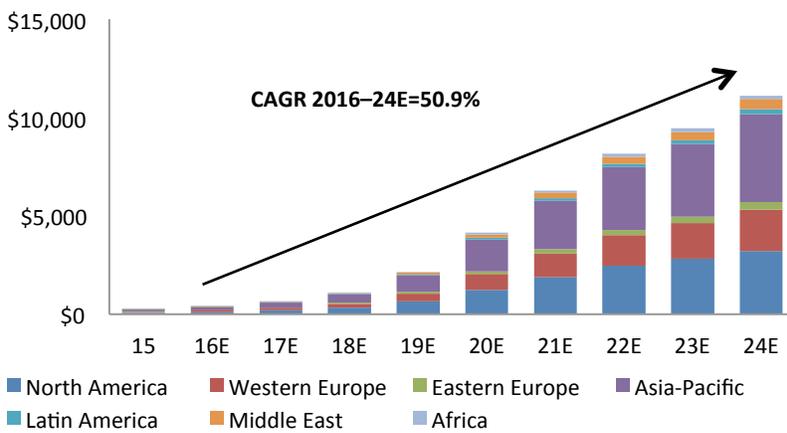
- **Tencent** announced a partnership with Taiwan’s Foxconn and a Chinese luxury auto dealer to explore opportunities in developing smart electric vehicles.
- Carmaker **Chongqing Changan Automobile Co.** launched a self-driving car that uses cameras and radar. The vehicle completed a 1,200-mile trip in April 2016.

MARKETS

Although the market for AI is estimated to be fairly small this year, just \$400 million, market researchers expect revenues to grow at a healthy 50%+ rate, and surpass \$10 billion in 2024, as illustrated in the graph below.

Although the market for AI is estimated to be fairly small this year, just \$400 million, market researchers expect revenues to grow at a healthy 50%+ rate, and surpass \$10 billion in 2024.

Figure 6. AI Revenue (USD Mil.)



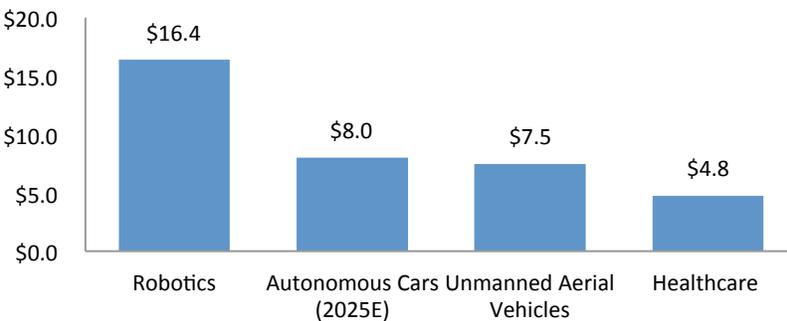
Source: Tractica

In the above graph, we see the Asia-Pacific region is forecast to pass North America in market size in 2019.

There are several adjacent markets that can benefit from AI, including robotics, autonomous cars, unmanned aerial vehicles and healthcare, as depicted in the figure below.

There are several adjacent markets that can benefit from AI, including robotics, autonomous cars, unmanned aerial vehicles and healthcare.

Figure 7. Selected Related AI Markets in 2020 (USD Bil.)



Source: Boston Consulting Group/Company reports/euRobotics/Frost & Sullivan/IHS Automotive/International Federation of Robotics/Japan Robot Association/Ministry of Economy, Trade and Industry/Teal Group/Fung Global Retail & Technology



STARTUPS, ACQUISITIONS AND VENTURE-CAPITAL FUNDING

Startups

The potential and power of deep learning has created several startups that develop applications. During the past five years, large technology companies have aggressively acquired them. At the same time, venture-capital financing has flooded into the industry at a rapid rate.

Several innovative private companies are outlined in the table below.

The potential and power of deep learning has created several startups that develop applications. During the past five years, large technology companies have aggressively acquired them. At the same time, venture-capital financing has flooded into the industry at a rapid rate.

Figure 8. Selected Private Machine-Learning Companies (USD Mil.)

Company	Description	Location	Total Funding
Sentient	Uses advanced AI technology to solve complex business problems	San Francisco, CA	\$136
Ayasdi	Machine intelligence platform that helps organizations benefit from big data	Menlo Park, CA	\$106
Digital Reasoning	Cognitive Computing for enterprises	Franklin, TN	\$74
Vicarious	A visual perception system that interprets photographs and videos	San Francisco, CA	\$72
DataRobot	Machine learning platform for building accurate predictive models	Boston, MA	\$57

Source: CB Insights/Companies

Acquisitions

There has been an explosion in the acquisition of machine-learning and deep-learning companies by large companies, totaling 31 acquisitions since 2011, according to CB Insights. The table below lists selected acquisitions from that list.

There has been an explosion in the acquisition of machine-learning and deep-learning companies by large companies, totaling 31 acquisitions since 2011.

Figure 9. Recent Machine Learning Acquisitions

Company	Business	Acquirer	Date
Turi	Machine learning and AI	Apple	Aug. 2016
Magic Pony	Machine learning and visual processing technology	Twitter	Jun. 2016
Itseez	Computer vision and pattern recognition	Intel	May 2016
Emotient	Emotion-detection technology	Apple	Jan. 2016
Vocal IQ	Speech-processing for improved human-machine interaction	Apple	Oct. 2015
Saffron	Cognitive computing platform	Intel	Oct. 2015



Company	Business	Acquirer	Date
Whetlab	Technology to make machine learning better and faster	Twitter	Jun. 2015
Madbits	Deep learning-based visual intelligence platform to identify image content	Twitter	Jul. 2014
DeepMind	Self-learning algorithms	Google	Jan. 2014
Indisys	Natural-language processing	Intel	Sep. 2013
DNNResearch	Deep learning and neural networks for image search	Google	Mar. 2013
IQ Engines	Image-recognition software	Yahoo	Aug. 2013
LookFlow	API for image recognition and categorization	Yahoo	Oct. 2013
SkyPhrase	Natural-language processing technology	Yahoo	Dec. 2013
Dark Blue Labs	Deep learning-based technology for understanding natural language	Google	Oct. 2014
Vision Factory	Object and text-recognition using deep learning	Google	Oct. 2014

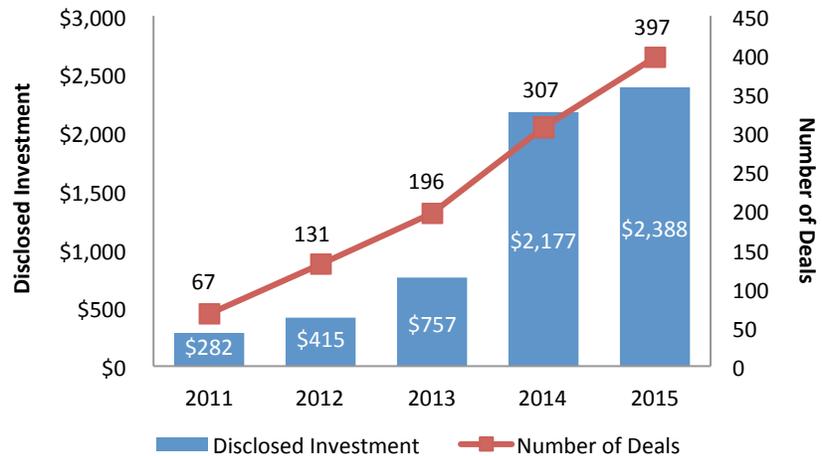
Source: CB Insights/Companies

Venture-Capital Funding

Venture-capital funding of AI nearly doubled in 2013 and nearly tripled in 2014, according to CB Insights. The amount of funds raised and deals completed increased further in 2015, as depicted in the figure below.

Venture-capital funding of AI nearly doubled in 2013 and nearly tripled in 2014, according to CB Insights. The amount of funds raised and deals completed increased further in 2015

Figure 10. Global AI VC Financing (USD Mil.)



Source: CB Insights



CONCLUSION

Although deep learning and neural networks are technology buzzwords today, they comprise real products and services we use on a daily basis. Deep learning and neural networks use software to mimic how neurons function in the human brain. They are particularly good at pattern recognition and image processing because they learn when their function is modified. These technologies will likely enable many global markets, particularly autonomous cars. Many global industrial and technology giants are aggressively researching AI, and this coincides with an investment and acquisition boom in AI startups.



Deborah Weinswig, CPA

Managing Director
Fung Global Retail & Technology
New York: 917.655.6790
Hong Kong: 852.6119.1779
China: 86.186.1420.3016
deborahweinswig@fung1937.com

John Harmon, CFA
Senior Analyst

HONG KONG:

8th Floor, LiFung Tower
888 Cheung Sha Wan Road, Kowloon
Hong Kong
Tel: 852 2300 4406

LONDON:

242-246 Marylebone Road
London, NW1 6JQ
United Kingdom
Tel: 44 (0)20 7616 8988

NEW YORK:

1359 Broadway, 9th Floor
New York, NY 10018
Tel: 646 839 7017

FBICGROUP.COM