Chapter 59
Insights into the Advancements of Artificial Intelligence and Machine Learning, the Present State of Art, and Future Prospects: Seven Decades of Digital Revolution

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Abstract The desire of human intelligence to surpass its potential has triggered the emergence of artificial intelligence and machine learning. Over the last seven decades, these terms have gained much prominence in the digital arena due to its wide adoption of techniques for designing affluent industry-enabled solutions. In this comprehensive survey on artificial intelligence, the authors provide insights from the evolution of machine learning and artificial intelligence to the present state of art and how the technology in future can be exploited to yield solutions to some of the challenging global problems. The discussion centers around successful deployment of diverse use cases for the present state of affairs. The rising interest among researchers and practitioners led to the unfolding of AI into many popular subfields as we know today. Through the course of this research article, the authors provide brief highlights about techniques for supervised as well as unsupervised learning. AI has paved the way to accomplish cutting-edge research in complex competitive domains ranging from autonomous driving, climate change, cyber-physical security systems, to healthcare diagnostics. The study concludes by depicting the growing share in market revenues from artificial intelligence-powered products and the forecasted billions of dollars worth of market shares ahead in the coming decade.

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59.1 Introduction

With an ultimate aim to surpass human capabilities, the technology is continuously evolving through the difficulties and has achieved greater milestones on their way [1]. Huge amounts of digital data and the need to keep abreast with the ever-evolving optimized versions of hardwares have fueled the rising interest of AI and ML [2]. Mainstream ML techniques such as classification, regression, dimensionality reduction, object recognition, and language processing are widely used in predictions, recommendations, detection, and many other similar applications. These technologies have already gained strong roots since the last decade and are expecting an exponential rise in the coming future [3].

The foreground of this in-depth analysis revolves around the past, present, and future of this entire paradigm with their current opportunities and future prospects. We continue with the present technologies under each type of ML and AI, their industrial applications and market trends followed by exhibition of the predictions and capabilities of the revenue market around their applications in the next decade, concluding the comprehensive study.

59.2 The Evolving Hype of AI/ML

This section highlights the history of evolution of AI, ML technologies, and their recent advancements by citing landmarks that led to the successful deployment of the wide applications this technology offers.

59.2.1 The Past

The term AI was first discussed in a context when a study was carried out jointly by three universities Dartmouth, Harvard, and Bell telephone laboratories which subsequently led to the birth of AI and soon followed the first programming language Lisp [4] for the AI researcher community. The machine learning paradigm was one of its kinds which learnt from experiences like a human and could solve problems by manipulating sentences in formal languages. The early 1960s witnessed the first-ever industrial robot 'Unimate' working in general motor's assembly lines. The mid-sixties gave birth to the chatbot 'ELIZA' [5] that facilitated dialogs between machines and humans (Fig. 59.1).

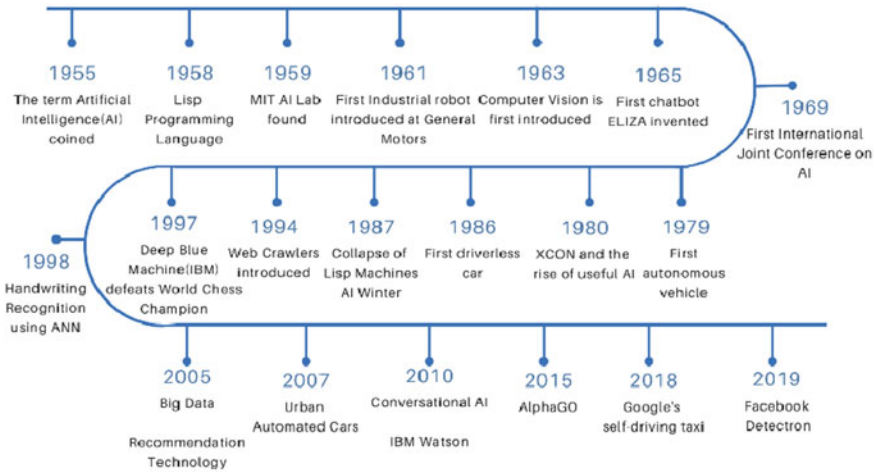

Fig. 59.1 Evolution of AI [6]

59.2.2 The Present

The late seventies led to the first autonomous vehicle 'Stanford cart' [7]. With the commencement of the 1980s, AI capacity at automation was explored with the Xcon program [8]. The mid-eighties saw the first Mercedes-Benz driverless car running on the empty streets of Munich. In the twenty-first century, the introduction of recommender systems designed to assist users in product selection choices based on their requirements led to the acceleration of the e-commerce market. IBM Watson [9], a real-time question–answer-based system was a technological revolutionary breakthrough in the last decade.

59.3 Subdomains of AI/ML

This section discusses the various emerging subdomains of AI and ML that are pioneers to the upcoming techniques in the field.

59.3.1 Artificial Neural Networks (ANN)

ANN [10] trains machines to solve problems in a way as a human brain does. The first neural network perceptron was developed by Frank Rosenblatt in the late nineteen-fifties. ANNs like convolutional neural networks, long short-term memory, recurrent neural networks, and auto-encoders gradually evolved over the years. These

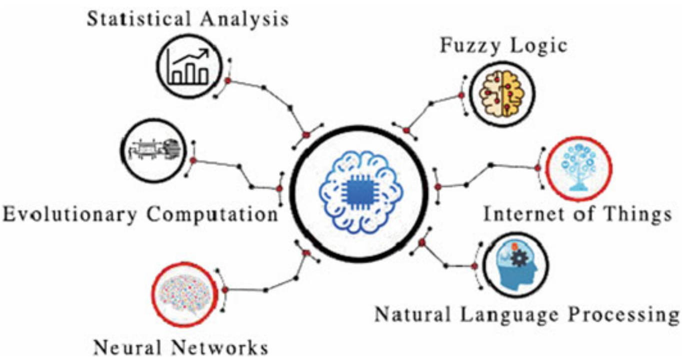

Fig. 59.2 Emerging subfields of AI and ML

techniques culminated into the first successful ANN-based handwriting recognition system in the mid-nineties. Applications of ANN include biometrics like iris, fingerprints, and face recognition systems which are now deployed across organizations that primarily require unique user authentication (Fig. 59.2).

59.3.2 Evolutionary Computation

A technique inspired by Darwinian evolutionary concepts of reproduction, mutation, recombination, and selection, introduced a new sub-domain in AI, known as evolutionary computation [11]. The underlying techniques like genetic programming and grammatical evolution [12] optimize solutions for enhancing computational efficiency.

59.3.3 Natural Language Processing (NLP)

Human–computer interaction through direct communication with devices like voice assistants and chatbots marked the NLP era [13]. Recent applications of NLP include answer sheet evaluation for examinations, text search and filtering, and lexical analysis.

59.3.4 Bayesian Networks and Fuzzy Logic

Statistical tools to incorporate cause-and-effect relationships in modeling complex systems came into being through the Bayesian networks [14]. They are impactful within the broader armamentarium of AI methods with a wide array of applications in pharmacogenomics and physiologically based pharmacokinetic modeling.

The challenge of modeling human reasoning in an environment without measurements, vagueness, and uncertainty brought about fuzzy logic into existence [15]. The logic can be embedded from microcontrollers to large networked or workstation-based systems.

59.3.5 Internet of Things (IoT)

The advent of IoT [16] following the World Wide Web (WWW) created the digitized interconnected virtual and the physical world we live in today. IoT frameworks spanning organizations and countries have made it possible to integrate data from diverse sources leading to the development of smart cities across the globe.

59.4 Popular AI Methods

This section provides a brief insight discussing all the algorithms along with their suitability with respect to creating AI models.

59.4.1 Supervised Learning

Linear, multiple, and logistic regression analyses are used for modeling the relationship between predictor and output variables. Ordinary least square regression (OLSR) is used for estimating unknown parameters. Multivariate adaptive regression splines (MARS) gives near optimal solutions by allowing automatic selection of variables, interaction between predictors, handling missing values, and avoids overfitting with self-tests. Locally estimated scatter plot smoothing (LOESS) and locally weighted scatter plot smoothing (LOWESS) regression are used to reveal trends and cycles in input data by automatically choosing a smoothing parameter for a smooth curve. Ridge regression deals with multicollinearity in multiple regression [17] (Fig. 59.3).

Dimensionality reduction transforms data from high-dimensional space to low-dimensional space, hence retaining meaningful information. Techniques supporting this include principal component analysis (PCA) for unsupervised learning, linear discriminant analysis (LDA) in linear space, and quadratic discriminant analysis (QDA) for quadratic space for supervised learning, whereas partial least squares regression (PLSR) and principal component regression (PCR) for regression analysis [18].

Ensemble methods combine various multiple learning algorithms to stabilize the variance of predicted solution and thus increase the accuracy. Bagging is based on the

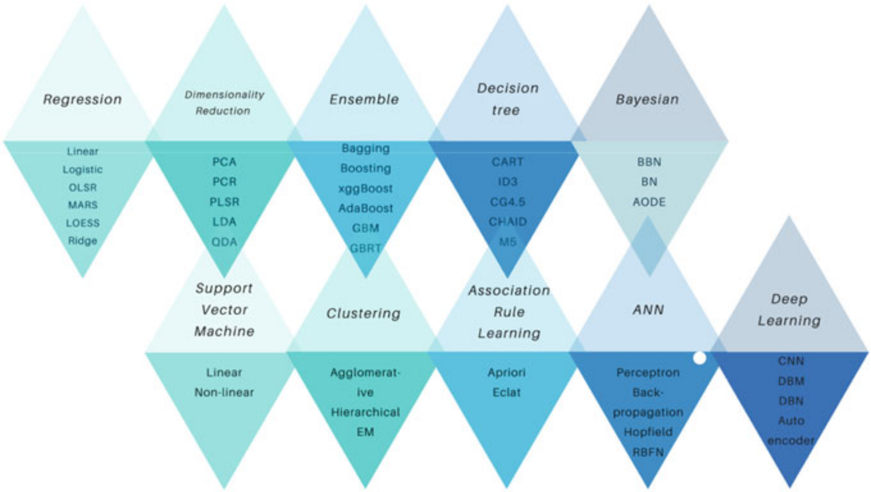

Fig. 59.3 Classification of machine learning algorithms based on similarity

bootstrap sampling method and works by adaptive learning of weaker data instances simultaneously to combine them for maximum accuracy. Random forest is a widely used bagging method that combines randomness and decision trees. Boosting works by learning new hypotheses with each phase of classification sequentially, improving weights of the weaker data instances, and boosts the accuracy. AdaBoost improvises weaker data instances by assigning higher weights to them, and gradient data boosting (GBM) learns with gradients of a loss function [19].

Decision tree, a form of supervised learning, follows a two-step process of growth and pruning of trees. Classification and regression trees (CART) is an algorithm for classifying data into binary labels. CHAID and M5 algorithms are advancements of the CART algorithm. The Iterative Dichotomiser 3 or ID3 algorithm uses information gain to decide the splitting attribute and builds the tree accordingly. C4.5 is an advancement of the ID3 algorithm [20–22].

Bayesian networks (BN) or Bayesian belief networks (BBN) are probabilistic models, and their graphical illustration is in the form of directed acyclic graphs. To overcome the inherent drawback of attribute independence in many real-world settings, averaged one dependence estimators (AODE) was introduced. They are popularly used for statistical validation of any machine learning model [23].

Support vector machines have found applications in real-world applications like face detection, text and hypertext categorization, classification of images, bioinformatics, and generalized predictive control for chaotic dynamics [24].

59.4.2 Unsupervised Learning

The clustering algorithms following under the above category and used widely for implementations include k-means clustering based on centroid approach, mean-shift clustering based on sliding window approach, density-based spatial clustering applications with noise (DBSCAN) based on neighborhood concept in relation to data points. Expectation maximization (EM) and clustering using Gaussian mixture models (GMM) are based on assumption of Gaussian distribution of data points and for finding the parameters of the Gaussian EM. The two variants to hierarchical clustering are agglomerative and divisive hierarchical clustering [25].

Prominently used in market-basket analysis, multimedia data mining, and video data mining, association rule mining has many implementation variants among which, a priori algorithm, frequent pattern (FP) growth remains the most widely used ones [26, 27].

Deep belief networks (DBN) and convolutional neural network (CNN) are extensively used for object detection, whereas the new breed ones yolov3, mask-regional convolutional neural networks (RCNN), and faster RCNN are used in multi-object detection. Auto-encoders are yet another form of neural networks used for dimensionality reduction. Back-propagation remains the backbone of neural network design and mainly used in the design of multi-layer perceptrons [28].

59.5 Market Trends with AI Applications

In this section, we touch upon the broadly used use cases of AI and ML and their diversity in domains. We also look at the region wise distribution of global AI markets. The products dominating the software market have been discussed.

59.5.1 AI Use Cases

AI applications range from healthcare analysis to product recommendations. In a survey by Tractica [29], Fig. 59.4 depicts the top ten predicted to be the highest revenue earning use cases of AI by 2025.

Figure 59.5 [30], on the other hand, illustrates the context for which industries apply ML algorithms and models. Popular reasons why companies incorporate AI include generating hidden insights, improving customer satisfaction, retaining customers by improving interaction, providing prompt query resolution, providing relevant recommendations, improving the customer's overall experience, and thereby reducing churn. Another major reason why companies invest in AI includes reducing costs by forecasting demands and gaining internal insights of the organization.

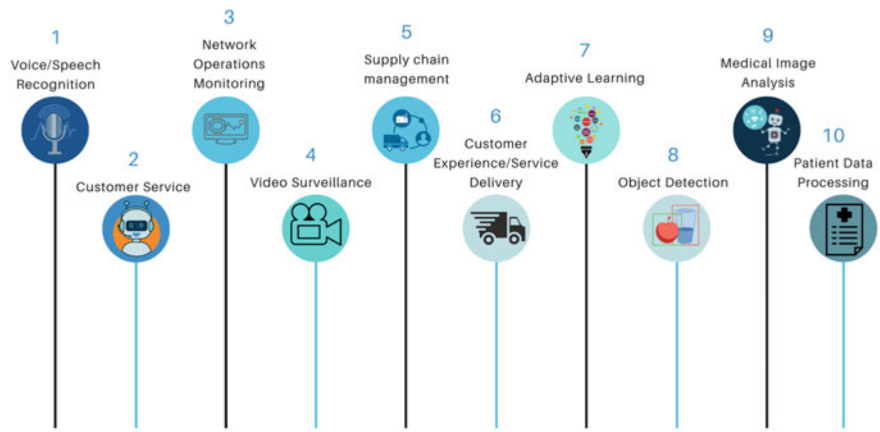

Fig. 59.4 Top ten use cases of AI and ML in software market

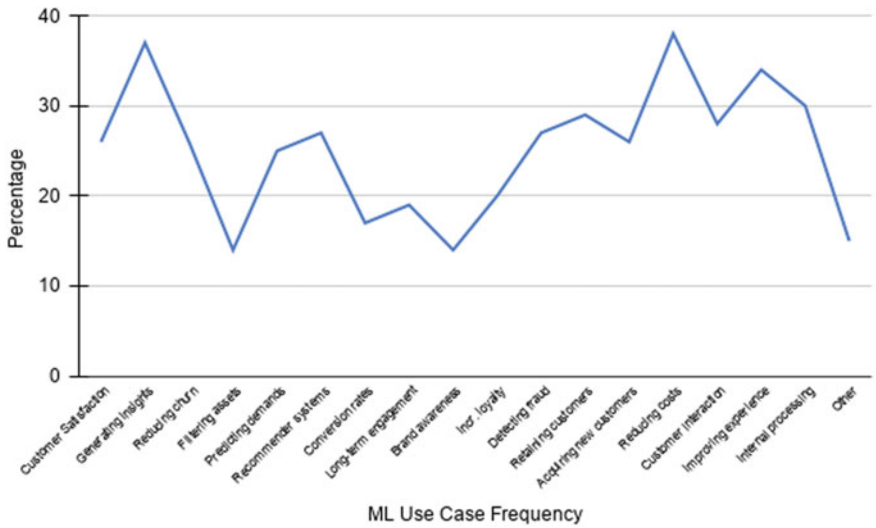

Fig. 59.5 ML use case frequency

Industries also increase loyalty and reduce fraud by imbibing appropriate security mechanisms.

59.5.2 Popular AI-Enabled Products

AI-enabled virtual assistance, delivery robots, and tele-health are some examples of how AI is helping people every day. Use of pseudo-intelligent digital personal assistance (Siri, etc.) to perform a task, ML to accurately detect cancer cells, or Alexa in home automation is definitely going to boost industrial and market demand for AI power products. Google Duplex, Deepmimd's Alpha Star, or AI algorithms providing product suggestions, and support systems in telemedicine are a few applications to which customers have become accustomed to. The personalized ad serving and AI-powered dynamic pricing is nothing less than any boon to various airlines' booking sites. Proliferation in connected devices, data, and usability is trending market growth. Internet dependencies and cloud-based applications in health care, banking financial services and insurance (BFSI), retail, automobiles, security surveillance, smart home devices, and tourism, etc., contain sensitive user information. Data coming from these sources are hence vulnerable to threats and cyber attacks, thus opening a wide scope for designing strong security systems using AI and ML algorithms. Utilizing data from user's wearable devices or smartphones through contact tracing applications for alerting citizens to nearby COVID-19 cases has demonstrated the significance of AI. According to [31], 59% of more people are likely to use tele-health services post-pandemic which was 25% during 2019, while 36% would switch their physician to a virtual one in the USA. This huge demand reports the telemedicine market size to witness \$175.5 billion by 2026 from \$45.5 billion in 2019 [32]. The wearable AI market alone is forecasted to reach \$180 billion by 2025 [33]. In 2019, the global market size for AI by component, technology, deployment, and industry was valued at \$27.23 billion and is expected to achieve \$266.92 billion by 2027 with 33.2% of compound annual growth rate (CAGR) during this period [34] while another survey [35] calculates a CAGR of 42.2%, with revenue forecast to be \$733.7 billion considering solution, technology, and end use.

59.6 Future with AI

Our study so far has highlighted the journey of AI to date. It is a fairly growing market with a lot of future scope. This section discusses the future of AI.

59.6.1 Emerging Trends for the Future

The goal of AI is to design 'general' intelligence for performing unpredictable tasks rather than 'specific' intelligence, which is able to perform only a single task outstripping human skills. The learnings through direct interaction of the object or the model

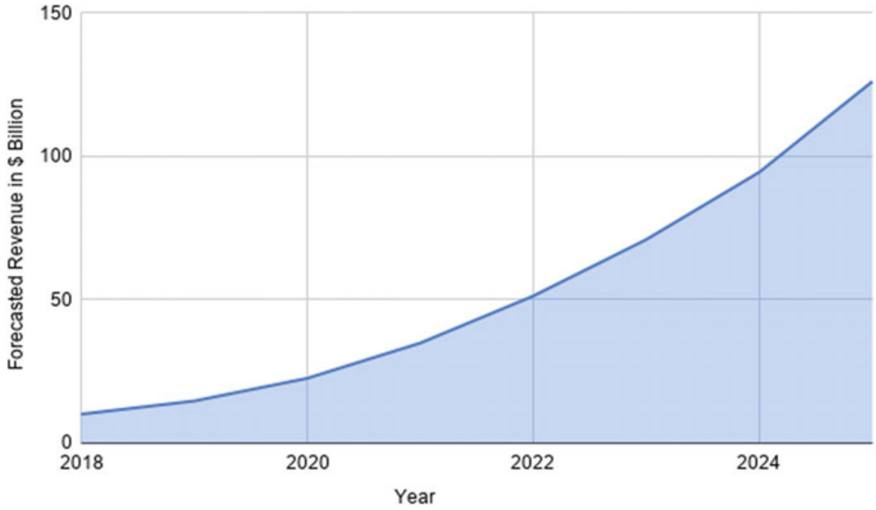

Fig. 59.6 Forecasted market revenue generation from AI software market

to the physical environment are important for domains like robotics and driverless cars for understanding the cause–effect behavior.

The upcoming AI models will be designed based on the pre-trained models and will be implemented on the energy-efficient hardwares [36].

With the vast opportunities and applications AI offers, it is predicted that the global revenue market for AI-driven services and products will drastically increase from 10.1 Billion Dollar in 2018 to 126 Billion Dollars in 2025 as illustrated in Fig. 59.6 [37].

Industries and markets are evolving with business strategies like reducing costs, automation, innovation, and managing risk factors with advanced analytics of AI. This estimates that the markets will grow in the coming few years. As represented in Fig. 59.7 [38], in 2017 in a survey by market research future, it was recorded that 44% of the global machine learning market was centered in North America, 29% in Asia Pacific, 21% in Europe, and 7% for the rest of the world on the basis of the vertical, organization size, and components of the industry.

59.7 Conclusions

Valuable insights into the future market trends and the plethora of opportunities available to the global AI community are focused through the course of this study. Since the nineties when AI first evolved, the field has been growing with dominance. Tools and algorithms are continuously progressing to accelerate hardware performance while optimizing computational resources. In the foreseeable future, AI techniques

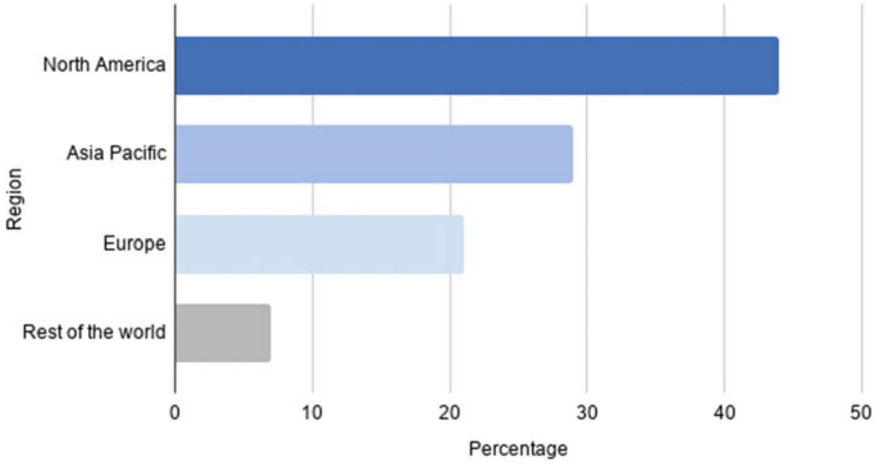

Fig. 59.7 Global machine learning market by region in year 2017

will encompass all unexplored domains such as climate change, clean energy, health care, and education addressing the world's challenging issues.

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