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Procedia Computer Science 167 (2020) 2200–2210

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Computational Intelligence and Data Science (ICCIDS 2019)

Artificial Intelligence in Business: From Research and Innovation to Market Deployment

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Abstract

For the last few years, one can see the emergence of a large number of intelligent products and services, their commercial availability and the socioeconomic impact, this raises the question if the present emergence of AI is just hype or does it really have the capability of transforming the world. The paper investigates the wide range of implications of artificial intelligence (AI), and delves deeper into both positive and negative impacts on governments, communities, companies, and individuals. This paper investigates the overall impact of AI - from research and innovation to deployment. The paper addresses the influential academic achievements and innovations in the field of AI; their impact on the entrepreneurial activities and thus on the global market. The paper also contributes in investigating factors responsible for the advancement of AI. For the exploration of entrepreneurial activities towards AI, two lists of top 100 AI start-ups are considered. The inferences obtained from the research will provide an improved understanding of the innovations and the impact of AI on businesses and society in general. It will also provide a better understanding of how AI can transform the business operations and thus the global economy.

Peer-review under responsibility of the scientific committee of the International Conference on Computational Intelligence and Data Science (ICCIDS 2019).

Keywords: Artificial Intelligence; Fourth Industrial Revolution; Business Analytics; Machine Learning; Deep Learning; Business Intelligence

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10.1016/j.procs.2020.03.272

1. Introduction

Innovation has always been the main engine of an improved standard of living throughout history. However, the process of innovation can be highly disruptive as it makes conventional technologies obsolete. Cloud computing, Internet of things (IoT), big data, data science, artificial intelligence (AI), and blockchain are the rising technologies that may create winners as well as losers across the world. Some of these technologies are at least two and a half decades old 0-[3] but were neither in the mainstream nor were viable for commercial applications. However, in the last few years, the situation has changed dramatically, today, almost every field employs one or more of these technologies. There are many factors responsible for this, including advancements in computer technology (high-performance computing, grid, and cloud computing), increase in transparency through code sharing (services like GitHub, GitLab, BitBucket) and a large number of open source software. At present, the enormous uses of these technologies in every field including healthcare, automobiles, finance, gaming, environmental monitoring, agriculture, sports, energy management, security, etc are changing the way, human beings, live, work and amuse themselves. Further advancement of these technologies can contribute to develop hyper-automation and hyper-connectivity, which would bring us at the dawn of the Fourth Industrial Revolution or Industry 4.0 [4]-[7].

Primarily, the advancement in AI is the heart of the enhanced performance of all other technologies and the evolution of Industry 4.0. There are sufficient pieces of evidence available in the literature that proves that the AI technology offers new opportunities that can lead to notable transformation in businesses and the overall economic system [4], [6], [7]-[11]. At the business level, some of the benefits of AI are: the quick unveiling of patterns in big data, speedy visualization and analytics, improved product design, delivering meticulous insights, and many more. These benefits are expected to introduce new levels of service, increased profit, expansion of businesses, improved efficiency and cost structures [7], [10], [11]. In this paper, the new growth economics, Neo-Schumpeterian Economics, is used as a base model to analyze the impact of AI in business [12]. The three forces which drive the Neo-Schumpeterian Economics are innovation, knowledge, and entrepreneurship. In particular, the paper uses these forces as a foundation to explore the success of AI algorithms, investigate their deployment commercially, and investigate investors, the entrepreneurial actions, and thus the global market. For the exploration of entrepreneurial activities towards AI, the two lists of top 100 AI start-ups are considered. As per the knowledge of the authors, this novel methodology has not been used before; therefore a comparative analysis is not possible. The novel points of the paper are summarized below:

- Recognition of the factors which are resulting in today's AI exponential growth
- Identification of academic achievements in AI which are advancing the commercially available intelligent products.
- Determination of the top AI industries and investment trends in AI.
- Exploration of geographically strong AI locations.
- The data analysis done proves that AI is not hype.

The inferences obtained from the research will provide a better understanding of the innovations and the impact of AI on businesses and society in general. It will also provide a better understanding of how AI can transform the organization of research & development, business operations and the global economy. The results obtained can aid the countries to get prepare for the adoption of AI in near future.

The present work is organized as follows: Sect. 2 focuses on the research objectives and list of data sources, Sect. 3 provides the state-of-the-art (SOTA) research (datasets and algorithms) and innovative applications in AI; Sect. 4 illustrates the results obtained from the global market analysis of top AI start-ups, Sect. 5 provides some conclusions and directions for future research.

2. Research Objectives and Data Collection

The present age is possibly the most exciting period of human history where technological innovations are taking place at the rate of the blink of the eye. Robots working in industries, cars driving themselves, smart watches

monitoring patient's health, and AI playing games (e.g. Chess and Go) better than world champions are some of the technological innovations under AI.

2016 has been an amazing year for machine learning, deep learning, and AI. Almost every high tech CEO claimed to make their company an 'An AI company'. The question arises:

- Why is it so? Why does every company want to be an AI company or want to acquire AI companies? Are all other technologies slowly being augmented (or replaced) with AI?
- How does AI impacting all the lines of business across the world such that there is not even a single field left where its impact cannot be seen? Which countries are leading the race of AI?
- AI is 60-year-old technology yet was not able to show its impact until the present era. Then what are the factors which are resulting in today's AI exponential growth?

Through this paper, the intention is to answer the above questions. The research was initiated by scanning a number of business newsletters, AI magazines, journal papers, conference articles, machine learning posts, annual reports of the companies, press releases, stock market websites, online forums, and many other platforms to gather the data required to help us in the investigation. The answers to these questions will help the human society to get prepared for the future challenges. This will also aid in accepting the transformations occurring as a result of the infusion of AI in human life and business.

3. State-of-the-art of AI: Datasets, Algorithm, and Products

The "Artificial intelligence" [13] was founded as a field by John McCarthy, professor emeritus of computer science at Stanford University in 1956. He organized the famous Dartmouth conference at Dartmouth College, Hanover and started AI as a field. He had the belief that there will be systems which will evolve intelligence of human order. In 1973, Firschein and Coles [14] postulated a list of twenty-one hypothetical products that would result from the advances of AI by the 1990s. Some of the products which were predicted by them have become a reality today and are listed in Table 1. This table provides an insight into the advancement of AI in the last 48 years.

Table 1.AI technologies predicted in 1973 [14] with definitions and today's reality.

S. No.	Products postulated	Abilities proposed (Firschein 1973)	Today's Reality
1.	Automatic language translator	"Language translating device capable of high-quality translation of text in one foreign language to another. (Both technical and commercial material)."	Google Translator, Bing Microsoft Translator
2.	Automatic identification system	"System for automatically determining a person's identity by recognizing his voice, fingerprints, face, etc"	Apple Face ID, Mastercard Identity Check with NuData Security.
3.	Automatic diagnostician	"A system capable of interactive and/or automatic medical diagnosis based on querying the patient, an examination of biological tests, etc."	Qualcomm Tricorder, Medtronic Sugar.IQ Cognitive App in collaboration with IBM Watson.
4.	Industrial robots	"An autonomous industrial robot capable of product inspection and assembly in an automated factory, using both visual and manipulative skills."	Kiva warehouse robots, FANUC intelligent robots, Mitsubishi Robots
5.	Robot chauffeur	"Robot cars capable of operation on standard city streets and country highways, using visual sensors"	Google Waymo, Mercedes-Benz E-Class, Volvo XC60
6.	Universal game player	"A system capable of playing Chess, Checkers, Kalah, Go, Bridge, Scrabble, Monopoly, etc., at a controllable level of proficiency, from master level to novice."	AlphaGo, Deep Blue

The journey of AI has not been smooth; the period of hypes was followed by periods with reduced funding (also known as AI winters). However, despite these hindrances, today AI is back in limelight due to development of 'deep learning' neural networks with many hidden layers. This progression of AI is accredited to two main factors: the availability of a huge amount of data (big data), and hardware accelerators (graphics processing units (GPUs) and tensor processing units (TPUs)) [15]-[17].

Behind all the real-world applications (table 1), there is an intelligent agent (IA). It interacts with the environment in a repetitive cycle of sense-think-and-act. It explores the input data (big data) in order to learn correlations, extract features, detect similarities, and discover good depiction at multiple levels. Earlier, the unavailability of data and efficient hardware was hindering the progress of AI. However, in the last few years, the accessibility of low-cost and low-power sensors has resulted in the production of a huge amount of data. An investigation of a list of dataset providers is done to elucidate the amount, diversity and accessibility of datasets available on the web (Appendix A). The extensive list of dataset providers with their URLs and related information is given below as Appendix A.

Next, the exploration of input data requires AI or machine learning tools like support vector machines (SVM), decision trees, Bayesian algorithms, deep learning networks (DLN) and ensemble configurations. Among them, the DLNs have become the most popular approach in the last few years. These DLNs were in theory and practice since 1943 but insufficient processing speed and data was hindering their progress. The use of NVIDIA GPUs (graphics processing units) allowed researchers to program them conveniently and train their networks 10 or 20 times faster [19] than conventional computers. Some of the DLNs have reported surpassing human-level accuracy in certain tasks [15] - [35]. The successful AI applications are categorized under four broad areas viz. computer vision, speech recognition, text analysis, and computer games. Table 2 summarizes a brief description of each DL area, their successful applications and the DL algorithms preferred for each area.

Table 2 Broad areas of DL, their description, successful applications, and the DL algorithms preferred for each area.

Broad areas	Description	Applications	Deep learning algorithm
Computer Vision	This area deals in making machines capable of analyzing and understanding images or sequence of images.	Face recognition, Image restoration, Computer-aided diagnosis (CADx), People counting, Gesture recognition, Iris recognition, Product defect , detection	Convolutional Neural Networks (CNNs)
Text Analysis	The area focuses on deriving high-quality information from the text data.	Information extraction, Question answering (Q/A), Search engines, Query Processing, Recommendation/ Personalization, Sentiment analysis, Document summarization, Fraud detection, Demand forecasting, Product search ranking, Translation	Gated-Recurrent Neural Networks (RNNs) (both Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU))
Speech Recognition	The area deals in making machines capable of responding to vocal instructions.	Speech-to-text processing Voice search and dialing	CNNs, RNNs, and their combination
Game playing	The area deals in making machines capable of playing games against humans and other computer agents.	Go, Chess, Atari	Policy Gradient Reinforcement Learning, Deep Autoencoder, Deep Q-Networks.

The success and the hype generated by DLNs in the last few years have propelled many companies to become an AI company and have spawned a plethora of AI-based start-ups. In the next section, the top 200 AI start-ups are analyzed, the investors' and entrepreneurial actions are investigated in launching AI-based services in existing and new industries.

4. Global Market Analysis

In a knowledge-based society, start-ups are considered as the innovation and growth drivers of the economy; their analysis would help to gain valuable insights into the exploration of the transformational impact of AI on the businesses. Two lists of top 100 AI start-ups obtained with the help of the CB Insights' Mosaic algorithm† [36] are considered. The algorithm identifies the top AI start-ups by evaluating the factors like profile, mosaic score, financing history, investor quality, business model, funding history, etc. The lists were made available by investigating, 1650+ and 2000+ global start-ups, using the Mosaic algorithm. In the rest of the paper, the AI start-ups list for 2017 and 2018 is referred to as AI17 and AI18 respectively. A part of these results has been presented at an international conference DIGITS 2018 [22] jointly organized by University of Maryland and Birla Institute of Management and Technology. The extended version of the manuscript has been submitted to Journal of Business Research, Elsevier for consideration as a journal research article [23].

4.1. Sectors and Industries

AI start-ups initiated all over the world are categorized in 22 different fields including autonomous vehicles, business intelligence, healthcare, etc. Fig. 1. depicts the percentage of 200 AI start-ups (AI17 and AI18) in different lines of business which majorly covers all the fields where AI is showing its impact. It can be seen clearly that the spread of AI is all pervasive, from education to healthcare, from home to industry; there is no place where AI is not being used or explored.

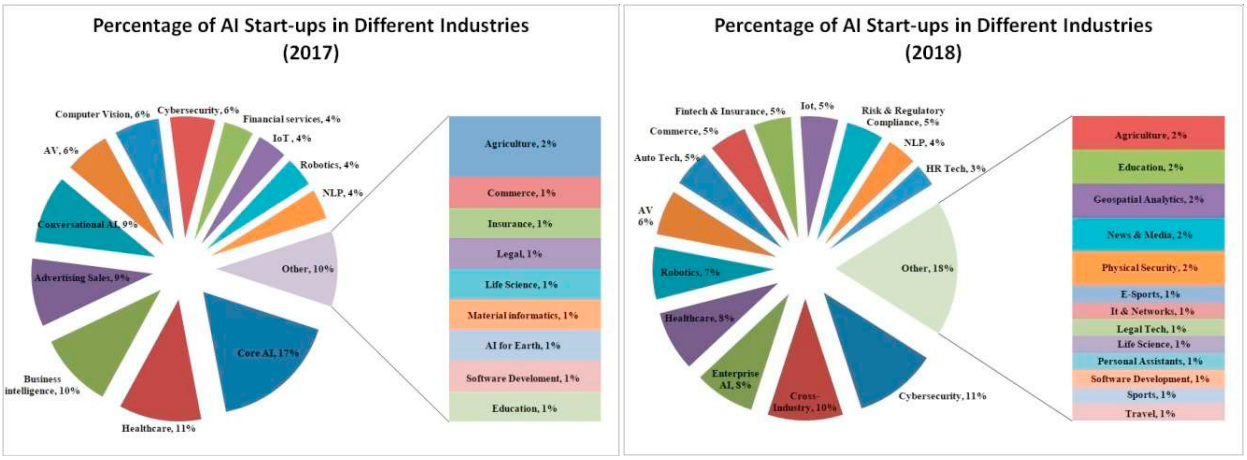

Fig. 1 Percentage of AI start-ups in different industries for (a) 2017 (b) 2018

Fig. 1. illustrates that in AI17, Core AI gained the maximum attention and in AI18, cybersecurity was maximally benefitted from the AI technology. The detailed analysis of the data uncovered the top six industrial sectors of AI17 and AI18 viz. cybersecurity, healthcare, business intelligence, enterprise AI, core AI, and cross-industry.

These pre-eminent AI start-ups are creating technological and process-oriented innovations that would generate efficiency gains and business opportunities in the near future. Some of the processes under the above top six industrial sectors that would be responsible for technological transformations in the global market are explored. The processes are viz. medical image analysis, drug discovery, robotic surgery, virtual nurses, health monitoring,

† Mosaic algorithm: It is a data- driven technology developed by CB Insights to measure the growth of private companies. The algorithm uses machine learning and advanced language processing techniques to understand these companies.

personalized product search and recommendation, sale and demand prediction, customer segmentation, cyber attacks prediction, and automated manufacturing.

4.2. Funding

In 2011 the total investment in these AI start-ups across the world was $25.88 million (in 7 start-ups) which increased exponentially to $1866.6 million (in 64 start-ups) in 6 years (2011 to 2016). Fig. 2. depicts a 71.13% increase in investment in these AI start-ups (AI17). Across the world, the U.S. is leading this revolution with maximum investment.

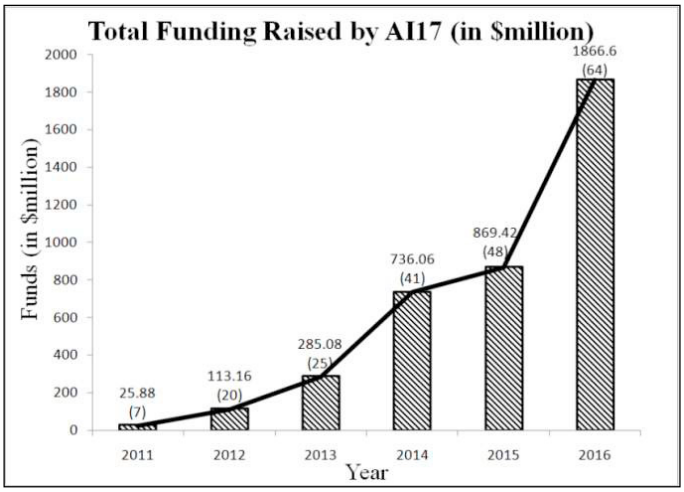

Fig. 2 Year-wise investment (in $ Million) in 100 AI start-ups

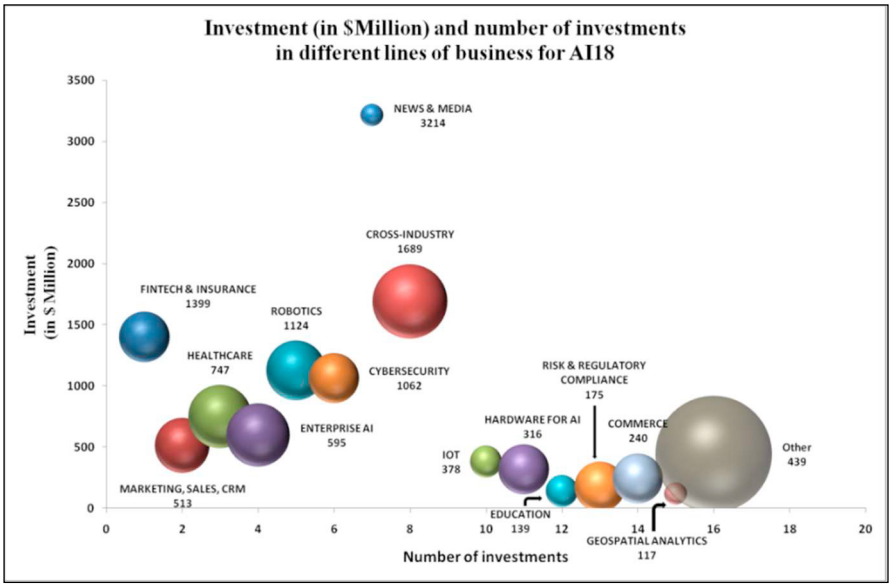

Fig. 3 Investment (in $ Million) in different lines of business in AI18. The size of the bubble indicates the number of start-ups working in each line of business

Furthermore, the total investment in AI18 is $12.74 billion i.e. 2.27 times incremented in comparison to the total investment in AI17 (2011 to 2016). This shows the rising interest of investors in AI. Fig. 3. shows the investment (in $million) made in different industries in AI18. The size of the bubble indicates the number of start-ups working in each line of business. An important observation that can be made from the chart is there are only 2% start-ups in news and media, but it has got the highest investment share of 25.22% of the total investment.

The two start-ups that received one-fourth of the global investment made in AI18 are California based SoundHound Inc. and Beijing based Bytedance. Both of them aim to make the human-machine interaction as simple as human-human interaction. California based SoundHound Inc. has millions of users, telling smartphones to accomplish tasks without even touching them. Hound and SoundHound are its two example products applying AI technology to speech (get weather information, make calls and send text, etc.) and music (find songs by singing or just by humming) respectively. On the other hand, Toutiao by Bytedance is China's largest mobile platform for personalized news recommendations with 120 million daily active users as of September 2017. Toutiao is featured to identify fake news by analyzing posts and comments with AI technologies.

From the above analysis, it can be estimated that there is special interest in the use of AI for personalized services, almost every company is thinking to implement AI in their respective sector with the common goal of making their products and services intelligent in order to grow their business.

4.3. Geographical Analysis

In this section important insights from the geographical distribution of AI17 and AI18 are inspected. Fig. 4 shows the area of AI17 and AI18 start-ups in different parts of the world. The data analysis revealed surprising results; top global AI start-ups are located in only 6.6% of the countries on the earth i.e. out of a total of 195 countries in the world, AI17 and AI18 are located only in 13 countries. The U.S. is leading this revolution with the headquarters of approximately three fourth of the total start-ups with the majority in California, Silicon Valley, the heart of AI.

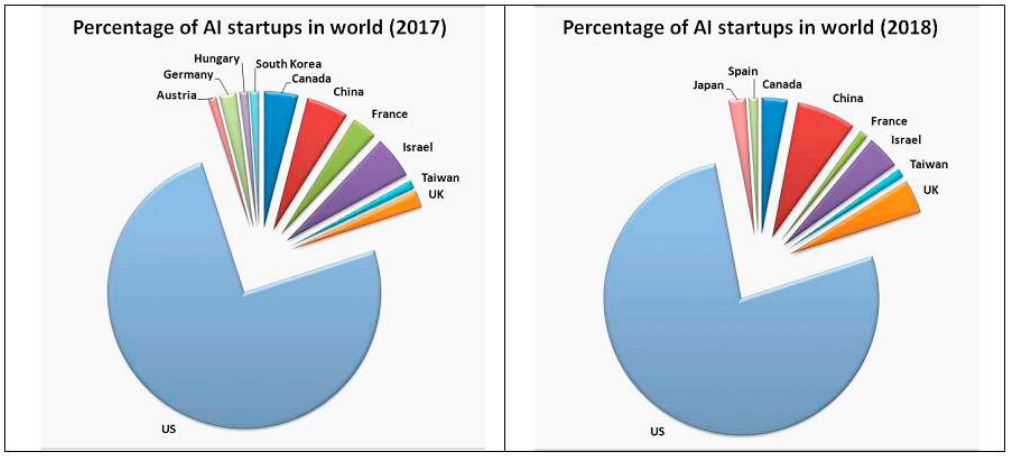

Fig. 4 Percentage of AI17 and AI18 in different parts of the world

5. Discussion and Conclusion

The present work illustrates the prominent achievements and influential technological innovations in the field of AI. The commercial availability of AI-driven products, proposed 48 years ago, proves that AI is not hype but has the ability of transforming the business and thus the global economy. This progressive growth and deployment of AI-driven system is attributed to two major factors: big data and fast processing units (GPUs and TPUs). The work identifies four broad areas of deep learning (computer vision, text analysis, speech recognition, and game playing); preferred DL algorithm for each of them and various successful applications which have surpassed human-level

accuracy. The work also explores an exclusive list of dataset providers and their URLs. The results summarized in tables can aid researchers and industries working in the field of AI.

The analysis of the top 200 AI start-ups explicitly shows the influence of advance research and innovation in AI on the global market. The study shows that the AI wave is on and an appetite for AI growth is exponential. The investment in AI is showing an upward trajectory in the last 6 years and should remain the same for the upcoming years. The study also uncovers the top AI industries that will generate more opportunities in near future viz. business intelligence, healthcare, core AI, cybersecurity, and marketing & sales. Some of the key advantages of automation, cognitive technologies, and data analysis using AI algorithms are an increase in productivity, time and cost efficiency, human error reduction, faster business decisions, customer preference prediction, and sales maximization.

However, the study shows that the AI technology is confined only in a few regions in the world. This is creating an "AI divide". This divide, like the digital divide, would strengthen the inequality in social, economic and cultural sectors; would create a chasm. Moreover, AI is software dominant and software is prone to vulnerabilities. Some of the deep learning algorithms/methods are the backbone of AI; these require passing through multiple factors to be used for real-time applications. Identifiable systemic failure modes, repeatability, transparency, explainable, path tracing, penetrability, etc. are some of the major factors established at the time of assessment of software; even after passing through these factors, there exist cases where DL algorithms have produced unreliable results. Apart from these, challenges like trust, ethics, bias, and shortage of AI talent also needs attention for commercial usage of AI applications.

Acknowledgements

One of the authors, Ms. Neha Soni, wants to thank Department of Science & Technology, Ministry of Science & Technology, New Delhi, India for sponsoring this work.

Appendix A. List of dataset providers, their URLs, data charges, API support, amount and type of data available.

S.No	Dataset Provider	URL	Free/ Paid	API Support	Number of datasets	Type of datasets
1	Kaggle	https://www.kaggle.com/datasets	Free	Yes	10,043	Food, Internet, Linguistics, Finance, Business, Demographics, Politics, World, Crime
2	NASA	https://data.nasa.gov/browse?limitTo=datasets#	Free	Yes	42,966	Aerospace, Applied Science, Earth Science, Space Science
3	University of California Machine Learning Repository (UCI ML)	https://archive.ics.uci.edu/ml/datasets.html	Free	Third party API support	440	Life Sciences, Physical Science, Engineering, Computer Science, Social Science, Game
4	UNICEF datasets	https://data.unicef.org/resources/resource-type/datasets/	Free	Third party API support	111	World data: Migration, Immunization, Education, Maternal mortality, Child marriage, child labor, sanitation and hygiene, gender and education, malnutrition
5	AWS Public Datasets	https://registry.opendata.aws/	Free	Yes	112	Satellite images of earth, Customer reviews, Trade data, Climate data
6	Quandl	https://www.quandl.com/search?query=	Both	Yes	187	Equities, Currencies, Interest rates and Fixed Income, Mutual Funds, Real-Estate, Energy, Economy and Society, Agriculture, Metals

7	Google Cloud Public Datasets	https://cloud.google.com/bigquery/public-data/	Free	Yes	39	Bike and Taxi Share Trips Data, Crime Data, Traffic Fatality, Air Quality, Police Report, Disease Data, Educational Statistics, Basketball Data
8	ProPublica Data Store	https://www.propublica.org/datastore/	Both	Yes	Not Applicable	Health, Environment, Criminal Justice, Transportation, Education, Politics, Business, Military
9	U.S. Government's open data	https://www.data.gov	Free	Yes	302614	Agriculture, Climate, Consumer, Ecosystem, Education, Energy, Finance
10	Indian Government's open data	https://data.gov.in/	Free	Yes	4281	Annual Budget of India, Crime Data, Water Irrigation Schemes, Traffic Statistics, Transport Statistics, Financial Statistics, Education, Health, Government Schemes
11	HealthData	https://healthdata.gov/	Free	Yes	3061	Assessment of Healthcare Providers and Systems, Restaurant Scores, Food Inspection, Mortality Rate, Management Reporting, Hospital Survey Reports from patients, Hospital Inspections
12	IMDb	https://www.imdb.com/	Free	Yes	Not Applicable	TV episodes information, Directors and Writers information, Movies rating and votes, TV series information, Cast and Crew in movies
13	Nasdaq	https://www.nasdaq.com/	Free	Yes	Not Applicable	Stock Data, Financial data, Revenue, EPS, Ownership Summary, Company News
14	StackExchange Data Explorer	https://data.stackexchange.com/	Free	Yes	Not Applicable	Questions, Answers, Comments, and Tags in various subjects.
15	GitHub	https://github.com/datasets https://github.com/awesomedata/awesome-public-datasets	Free	Yes	118	Natural Gas Prices, Gold Prices, Global Temperature, Language Codes, CO2 Emission
16	Gapminder	https://www.gapminder.org/data/	Free	Yes	519	Employment rate, agricultural land, alcohol consumption rate, Life expectancy, children per women, Foreign Direct Investment, Flood-deaths, Government Health Spending.
17	The World Bank	https://datacatalog.worldbank.org/	Free	Yes	3294	Climate Investment Funds, Demographic and Health Survey, Afrobarometer survey, Enterprise Survey
18	Datashop	https://www.datashop.biz/	Paid	Yes	55	Car, Economy, Finance, Linguistics, Geography, Postcodes, Media
19	Data & Sons	https://www.dataandsons.com/	Both	No	Not Applicable	Attorney E-mail List, Business Information and Financials, Earth Science, Education, Health and Medicine, Politics, Social Media Audience
20	AggData	https://www.aggdata.com/data	Both	Yes	4500	Arts and Entertainment, Clothing and Accessories, Computer and Electronics, Food and Dining
21	Socrata	https://opendata.socrata.com/browse?limitTo=datasets	Free	Yes	4796	Business, Education, Fun, Government, Public Safety

22	Academic Torrents	http://academictorrents.com/browse.php?cat=6	Free	Yes	392	News Articles, License Plates, Twitter Dataset.
23	Quantopian Data	http://academictorrents.com/browse.php?cat=6	Both	Yes	56	Sentdex Sentiment Analysis, Dividend, Stock Splits, Issue Equity, Earning Guidance
24	data.world	https://data.world/search?q=datasets	Both	Yes	5022	Agriculture, Geospatial, Country Codes, Ground Water Quality, Daily Weather, Ecosystem observation
25	Million Song Dataset	https://labrosa.ee.columbia.edu/millionsong/pages/additional-datasets	Free	Yes	4	Cover Songs, Lyrics, Last.fm, beat tunes.
26	Figure Eight	https://www.figure-eight.com/data-for-everyone/	Both	No	Not Applicable	Finance, Medical, Chatbots, Aerial Imagery, Autonomous Vehicles
27	YouTube-8M Dataset	https://research.google.com/youtube8m/index.html	Free	Yes	Not Applicable	6.1 Million (with 3 average labels) videos
28	BuzzFeedNews	https://github.com/BuzzFeedNews/everything	Free	Yes	Not Applicable	Live News Headlines, News Articles, Standalone Datasets
29	Entaroadun	https://gist.github.com/entaroadun/1653794	Free	No	Not Applicable	Movies, Music, Book, Food, Merchandise, Healthcare, Dating, Scholarly Paper Recommendation
30	Reddit-top-2.5-million	https://github.com/umbrae	Free	No	Not Applicable	1000 Posts on from 2500 subscribers on reddit.
31	Webscope Datasets	https://webscope.sandbox.yahoo.com/	Free	No	Not Applicable	Advertising and market data, Computing Systems Data, Language Data, Image, Graph, and Social Data.
32	ChemDB Chemoinformatics Portal	http://cdb.ics.uci.edu/cgibin/LearningDatasetsWeb.py	Free	No	32	Chemicals and isomers

Recently, Google has made available a search engine specifically for dataset.

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