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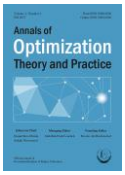

Machine learning approaches to mental stress detection: a review

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Abstract

Purpose of Review: Machine Learning has shown exponential growth in ingesting a huge amount of data and give accurate outcomes equivalent to the human level. It provides a glance at the future where complex data, analysis and analytical model together help innumerable people suffering from health issues. This paper reviews the current application of ML in the health sector, their limitation, predictive analysis, and areas that are hard-to- diagnose and need advance research.

New Findings: We have reviewed 30 papers on mental stress detection using ML that used Social networking sites, blogs, discussion forums, student's record, Questioner technique, clinical dataset, real-time data (video, driving task, audio), Bio-signal technology (ECG, EEG), a wireless device and suicidal tendency. Collectively, these studies show high accuracy and potential of ML algorithms in mental health, and which ML algorithm yields the best result.

Summary: With the advancement of ML, it has unfolded many areas like traditional clinical trials which are not sufficient to collect all the information about a person. Currently, define under DSM-V stage to detect these illnesses at the preliminary stage, diagnosing and treating before any mishap. It has re-defined the mental health practicing reducing cost and time, making it easier and convenient for patients to reach better health care whenever they need it.

Keywords Mental stress; Sentiment analysis; SVM; Naïve Bayesian classifier; Twitter; Depression; Machine learning

1. Introduction

Technology advancement helps to discover and develop new ways that have high potential in helping patients with complex situations. As technology improves patients are first to benefit from their outcome by probing the best treatment for them. All over

the world, health care organizations are growing to digitized and automated with new systems. ML can accumulate data and churn out many smart solutions that help in diagnosing and treating patient mentally and emotionally ill. The increasing population worldwide has made enormous pressure on the health sector for better treatment and health services. Big data and ML have the potential to make revenue of 100 billion dollars annually, According to McKinsey. ML has made path breaking advancement in the field of health care. Google has developed an ML algorithm that identifies cancerous tumors. Stanford University used deep learning to identify skin cancer. This article provides a review of Machine learning techniques in mental health, application of ML in various health sectors, literature survey, study and performance metrics, summary of studies, limitations, discussion on future research and recommendation, and area hard-to- diagnose in health sector.

ML in Mental Health

The word “Machine Learning” coined by Arthur Samuel in 1952. In medicine, the ML application is steadily increasing. ML gives the ability to machine to "learn" automatically and predict the outcomes without human intervention. Deep Learning is a subset of ML. It has been used widely in healthcare sectors helping patients and clinical practitioners. Areas such as oncology, radiology, cardiology, and pathology with complex datasets, identify patterns and help clinical to obtain better decisions by reviewing pictures of reports. According to the World Health Organization[1], 940 million people worldwide affected by mental health disorders, and anxiety is the most common mental health problem affecting 248 million people. Depression leads to suicide. It is estimated 8 million people (approximately 14.3%) deaths occur due to mental illness worldwide. If these stress symptoms recognized at an early stage whether it's long-term or short-term, it will prevent a person from suicidal thoughts. Similarly, the health sector also has a humongous amount of data. In several countries, electronic health record (EHR) software has started digitizing the personal health information of patients such as patient’s records, bills and prescription. World Health Organization (WHO) asserts, depression leads to mental disorder. Now for precise and timely prediction of a person's emotion, we want an intelligent system to detect symptoms and learn from the datasets.

ML Techniques for Big Data Analysis

ML is a constitutive part of the Artificial Intelligence (AI) application that automates the predictive analytical model. Machine Learning is efficient in analyzing big datasets generated from disparate sources. IDC predicts - "amount of data will grow by 50 to 5.2 ZB subject to data analysis" in 2025. ML is prediction-oriented whereas the traditional approach is interpretation-oriented. It is a system that learns from the data, recognizes patterns and makes business-oriented results. ML divides into three categories that are supervised, unsupervised and reinforcement learning. Deep learning is also a subset of ML. There are three types of machine learning supervised, unsupervised, and

[1] World Health Organization. Depression is a mental disorder. Available at: https://www.who.int/news-room/fact-sheets/detail/depression. Accessed Jan 30, 2021

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reinforcement learning.

Supervised Learning - In this type of learning, the dataset act as a teacher. It has a role to train the model and learns from observation. The trained model predicts when new data fed to the machine. Mathematically, the model contains the input as (X) and the output as (Y), and an algorithm needed to learn the mapping function: Y=f(X). ML algorithms widely used in the healthcare department that recognize patterns and make decisions help clinical practitioners. An example of SL is text classification used to detect sentiment from the textual feed posted by individuals. Diagnosis of Major depressive disorder (MDD) characterized as depressed and non-depressed post. It may be positive, negative, or neutral.

Unsupervised Learning - It contains unlabeled data. Unlike, SL there is no teacher and supervision. Mathematically, there is an input variable(X) but no output variable(Y). In this learning, the algorithm has to learn from observations and find out its structure for data. When the dataset is fed into the model, it finds patterns on the data make clusters and split the dataset into those clusters. USL uses clustering method (K-mean, hierarchical, KNN, principle component analysis) to sort, spilt and grouped into clusters. As an example, Genetics use to cluster DNA patterns to analyze evolution in biology also help in diagnosing class of cancer patients based on gene computation.

Reinforcement Learning - It is a learning based on the "hit and trial" method. Problems act as agents and use the experience from the environment and bring the best outcome. Reinforcement learning in healthcare is appealing, but there are some challenges in the real- world. Some examples of RL application are treatment of lung cancer, epilepsy, and bioinformatics.

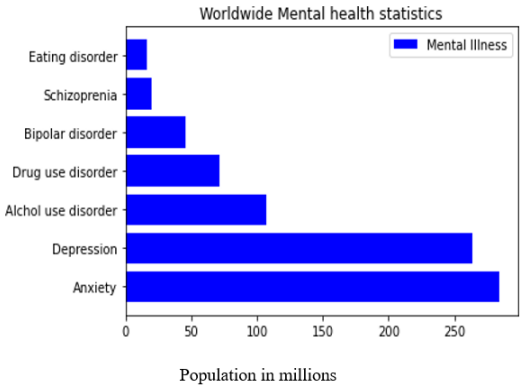
Deep Learning – Deep learning in healthcare has become amazingly efficacious for assisting medical professionals and transforming patient care. It can learn without human guidance, extract from unlabelled and unstructured data. Deep learning AI imitates the working of the human brain in identifying objects, speech recognition, translation, and decision making. Some DL applications in healthcare are chatbots, imaging solutions, identify particular types of cancer and rare diseases.

Health fields such as bioinformatics, ML show notable advances by analyzing complex data. Researchers are using ML techniques for diagnosing mental illness. In the mental health sector, majorly five conventional ML algorithms are used, Support Vector Machines (SVM), Random Forest(RF), K-Nearest Neighborhood(KNN), Gradient Boosting Machine(GBM), and Naive Bayesian(NB). Reviewing Literature Survey states that Support Vector Machines- SVM, Gradient Boosting Machine- GBM, Random Forest, and Naive Bayesian, used in mental health area Cho *et al*.,(2019). The purposes of Machine Learning techniques are to examine the datasets and retrieve vital information. Mainly, Supervised and Unsupervised learning is in the health sector. Reinforcement learning (RL) is also a another type of learning used for the analysis of data.

2. Background

In paper Aldarwish and Ahmad, (2017), the author uses user-generated content (UGC) on social networking sites like Facebook, Twitter and Instagram. Researchers believe SNS post of persons will help to predict mental health. It will include un-reported patients suffering from mood fluctuation, losing hope from life, stress, anxiety etc. According to WHO[2], suicide is the cause of deaths between 15-29 years old worldwide. Machine Learning benefits to various fields include medical diagnosing, speech recognition, image recognition, and NLP. Allows researchers to obtain valuable information from the dataset and built an intelligent system. Back Depression Inventory (BDI) and (CESD_R) Hussain *et al*., (2015) are questionnaire technique help in diagnosing patient's mental health.

For emotional identification Deshpande and Rao, (2017), Emotion artificial intelligence is ongoing research in the area of text analysis. With the growth of digital media, datasets are available in both text and images for sentiment analysis. Based on curated word-list person tweets are being classified as negative or neutral, which help to detect depression. Nowadays, people express their ideas, emotions, opinions, feelings and share content on a routine basis in social networking sites. Globally text messages widely used form of communication. For Emotion Artificial Intelligence, textual data is being used for data analysis and to detect sentiments using various ML techniques. Stress is a word compatible with worse life experiences or life occasions. It is a kind of mental agony. Statistics reports presents[3] worldwide mental disability affects our body with severe problems like panic attacks, anxiety, fear, depression, substance use disorder, Schizophrenia, eating disorders, post-traumatic disorders etc. (Fig. 1). Around 13% of the world population affected by mental health and substance use disorders. Sometimes everyone feels low in their lives, but when the feeling persists of might cause mental illness or depression.



[2] World Health Organization. Depression is a mental disorder. Available at: https://www.who.int/news-room/fact-sheets/detail/depression. Accessed Jan 30, 2021

[3] Marissa Walsh, Pharm.D., Mental health statistics 2021. Available at: https://www.singlecare.com/blog/news/mental-health-statistics/. Accessed Jan 21, 2021

Figure. 1 Worldwide Statistics of Mental Health and Substance use disorder (in millions)

3. Methods: Study Selection and Performance Measures

We have reviewed research papers for detecting mental illness using different ML techniques. Research paper has been collected from PubMed, Google Scholar, Science Direct, Conference Papers, and Journals. Keywords used to select paper diagnosing mental illness, sentiment analysis, depression, and machine learning. All these studies depict stress detection using Social media posts like Twitter, Facebook, clinical records, and Biosensors like HRV, ECG, EEG. Table 1 includes (detail of 30 studies) based on predictive analysis of ML techniques in mental health areas. The columns summarize the purpose of the study, dataset, accuracy, method, and ML algorithms. Most popular hash tags(in percentage) used worldwide in social networking sites(Facebook, Twitter) to express their thoughts in depression like #depression #anxiety #sadness(Fig. 2). Over the years, ML has made a remarkable breakthrough in the field of the health sector diagnosis, treatment, medical data collection, and helps clinics to make decisions. The rise of publication counts in the field of mental health to detect mental illness using the Machine Learning technique over the year 2011 to 2020 (Fig. 3). Mental stress detection on different datasets ML algorithms are applied accuracy is obtained according to the size and sample of data. Comparison chart depicts accuracy of SVM and Naïve Bayesian on different datasets combined SNS post (Facebook, twitter), Sentiment analysis on Twitter post, Facebook sentiments, Record of University students, and Biosensors (EEG) (Fig. 4)

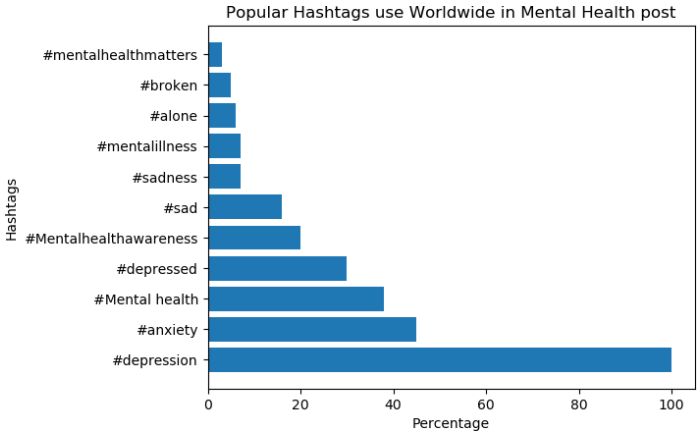


Figure. 2 Top Hashtags used in depression on Instagram, Twitter, and Facebook

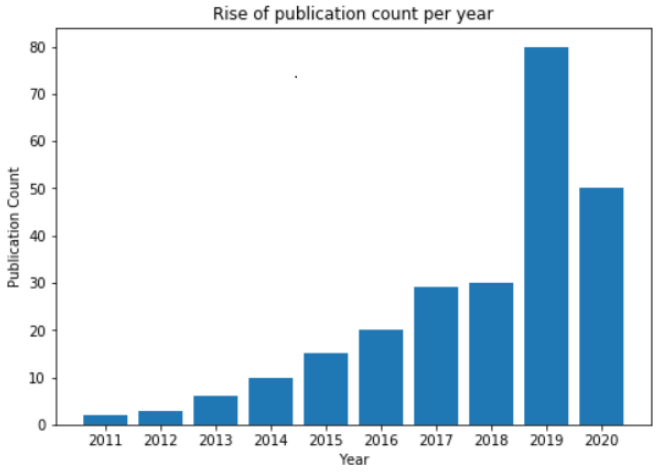


Figure. 3 Publication count increases from (2011-2020) in mental health using ML

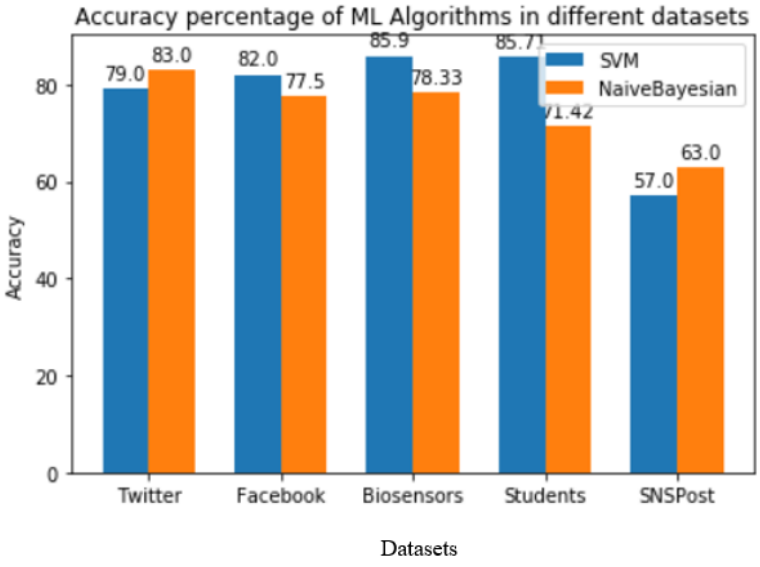


Figure. 4 Accuracy percentage of SVM and Naïve Bayesian classifier on different dataset

Table 1 Summary of ML Techniques used to detect Mental Stress, Dataset, Method and

Author	Method	Purpose of Study	Dataset	ML Techniques	Accuracy
Social Network Sites					
Maryam *et al.,* (2017)	Quantitative	Predicting stress from UGC- User Generated Content in Social media sites (Facebook, Twitter, Live Journal) classify on basis of mood and negativism and BDI-questionnaire.	6773 post, 2073 depressed,4700 non-depressed post (textual)	SVM Naïve-Bayesian	57% 63%
Gyeongcheol *et al.,* (2018)	Qualitatively	Analysis of ML Algorithms helps Diagnosing mental illness, properties and their limitations and how algorithms implemented	Not reported	SVM, GBM,KNN, Naïve Bayesian,K Nearest, Random Forest	75% (highest accuracy reported by SVM classifier due to its data sparsity)
Reshma *et al.,*(2019)	Quantitative	Detecting sentiment analysis on twitter using Tensi Strength framework From social media text. Lexicon approach to detect stress and relaxation	Large datasets divided into 100 record (textual)	SVM NB WSD and n-gram	65%(Precision True Positives over sum of TP and FP) 67% (Recall True Positive over the sum of TP and FN)
Jamil *et al.,* (2015)	Quantitative	Automatically classifies the MDD diagnosis from individuals Facebook profile in addition questionnaire technique BDI and CESD-R.	Facebook post	SVM KNN	Sadness - 53.66% Late night activity- 13.33% Confused-26.66%
Mandar *et al.,* (2017)	Quantitative	Detect depression using emotional analysis on Twitter feeds using NLP based on curated word-list(negative or neutral)	10,000 Tweet Using Twitter API	SVM F-1 Score Naïve Bayes NLP	79%(linear and non- linear) 83%(text classification)
Moha. *et al.,* (2018)	Mixed	Comparative analysis of different ML techniques and deep learning, and develop a hybrid model for sevtiment analysis	1,048,588 tweets (positive and negative classification)	Naive Bayes Random Forest Decision Tree CNN Hybrid Model	77.5% 73.8% 72.5% 79.6%(word to vector 83.6%)

Author	Method	Purpose of Study	Dataset	ML Techniques	Accuracy
Social Network Sites					
Chawre *et al.*, (2020)	Qualitative	Facebook posts used as token. Feature extraction from social interaction and classify as positive and negative.	Not reported	TSVM SVM Naïve Bayes Random forest Decision Tree Adaboosted D-Tree	84% (extract post) 82% (classify post) 77.5% 73.8% 72.5% 67%
Megha *et al.*, (2018)	Mixed	Analyze existing Sentiment analysis Techniques and to Improve the overall accuracy using hybrid sentiment classification model for tweets.	1,600,000 tweet, 1000 positive and 1000 Negative review 7086 sentences	SVM Adaboosted D-Tree Decision Tree	82% 67% 84%
Clinical Datasets					
Ravinder et al.,(2019)	Quantitative	Calculate stress of University students one week before their exams and usage of internet using ML technique	Record of 206 students (Jaypee Institute of Information Technology)	SVM Randm Forest Naïve Bayes KNN PSS	85.71% 83.33% 71.42% 55.55%
Christ. *et al.*,(2018)	Quantitative	Predicting persistent symptoms of depression in age more than 65	Data of (284 patients) based on demographic and physcometric for continuous 12 months	LR GB	69% 74%
Hugo *et al.*, (2017)	Quantitative	By evaluate the behavior (depression, stress,self-esteem) of an adolescent and detect the suicidal tendency. Propose a desktop tool.	Dataset of adolescent with suicidal tendency in Peru 10000 Instances 800 real record (suicide attempts)	JRIPalgorithm C4.5(decision tree family) Naïve Bayes	97.4% 98.4% 98.65%
Ashley *et al.*, (2020)	Quantitative	Predicting mental illness in adolescent	7,638 twins from child and adolescent Twin study	Random forest SVM	75% 75%

Physiological Sensors					
Chandrasekhar *et al*.,(2018)	Quantitative	A system to detect stress using biosensors EEG integrated with mobile development (ios device) using ML techniques	Electroencephalography (EEG)	SVM KNN Mobile Application	Not reported
Adnan *et al*., (2015)	Quantitative	Machine Learning-based Signal Processing Using Physiological Signals for Stress Detection	K-nearest neighbour(KNN), and support vector machine (SVM)	Respiration, GSR Hand, GSR Foot, Heart Rate and EMG	92.06% 98.41%

Summary of ML Studies and Mental Health

The research papers are analyzed in Table 1 on the basis of prediction values, method, technique and understanding of data. The analysis was done on social networking sites, clinical datasets, and Physiological sensors both qualitative and quantitative.

Detecting Mental Illness on Social Media

In (Aldarwish andAhmad, (2017);Chaware *et al*.,(2020);Reshma and Kinariwala,(2019)) Social Networking Sites(SNS) is a platform where users post their day to day activity, thoughts, emotions, choice of carrier. Facebook, Twitter, Instagram are social networking sites used to predict disorders in individual's behavior and find out the problems. By mining these social networking sites we can recognize the thoughts process of a person.

Troussas *et al*.,(2013) performed Sentiment analysis used to analyze Facebook post using the classifier Naïve Bayesian. 5000 positive and 5000 negative sentiments with (Precision=0.77), (Recall=0.68), and (F-score=0.72).

Reshma and Kinariwala,(2019) applied sentiment analysis on Twitter data using both lexicon (TensiStrengthframework) and ML algorithm. Large dataset divided into 100(a record). SVM and Naive Bayesian classifier are used. Word Sense Disambiguation (WSD) removes ambiguity. SVM with WSD and n-gram (Precision=65%) and (Recall=67%).

Hussain *et al*., (2015) developed a tool used to diagnose Major Depressive Disorder(MDD) of an individual from Facebook activities. It is used to track their day-to-day activities for some time. Questionnaire technique used by Psychiatrist to detect and diagnose mental illness, Beck Depression Inventory (BDI) and CESD-R. It depicts classification of posting based on different category 53.66% (sadness),13.33% (sleeping disorder), 26.66%(confused), and 6.66%(exhaustion).

Gyeongcheol *et al*., (2015) give analysis of different ML algorithms for diagnosing mental stress. Majorly, five ML algorithms Support Vector Machine(SVM), Naïve Bayes, GBM,

and K- Nearest Neighborhood (KNN), and Random Forest are used to detect mental illness. Researchers concluded SVM has the highest accuracy (AUC=75%).

Predicting Depression from Clinical Dataset

Ahuja *et al*.,(2019) predicted mental stress using dataset of 206 students (Jaypee Institute of Information Technology) using four classification methods. To enhance the accuracy and performance 10-Fold Cross-Validation is applied on small dataset. SVM acquire highest accuracy of (AUC=85.71%) followed by Random Forest (AUC=83.33%), Naïve Bayes (AUC =71.42%), and KNN (AUC =55.55%).

Hatton *et al*.,(2019) uses ML algorithm Logistic Regression(LR) with (AUC=0.67) and Gradient Boost with (AUC=0.72). The dataset for 361 participants (222 females and 139 males) of older adults aged above 65 years for continuous 12 months. 21% participants were missing after 12 months only 284 patients (100 males and 184 females) remained. Baseline demography (age, sex, education) and Psychometric Data Patients Health Questionnaire (PHQ-9) collected only (PHQ-9>10) depressive symptoms predicted by model. LR (AUC =0.67) and XGBoosting (AUC=0.74).

Hanai *et al*., (2018) performs an interaction between patient and agent by modeling audio and video sequence to detect the depressed symptom with minimal information. Three experiments are performed Context-free modeling interviews text performed better than video (F1-score=0.59 vs. 0.50), Weighted model question about subject audio performed better than text (F1- score=0.67 vs. 0.44), and in Sequence Modeling text performed better (F1-score=0.67).

Limitation of ML and Mental Health Studies

The studies above have shown several limitations of ML concerning clinical datasets and social media post validation and verification. To enhance the performance and accuracy of a model 10 Cross-Fold classification applied due to the small dataset. Iterative k-fold cross-validation used to remove the error Ahuja *et al*.,(2019). To remove the ambiguity WSD technique merges with the SVM to improve the result and accuracy Reshma and Kinariwala,(2019). Predicting stress through textual data supervised learning have certain limitation and cannot impart accuracy equivalent to human level. Medical professional commonly assumes diagnostic uniformity, such as Major Depressive Disorder (MDD) like lack of sleep, confusion, depression, lack of energy etc. But, now ML has to identify new subtypes of psychological disorders substance use, alcohol, illness trajectory Hussain *et al*. (2015). As noticed by the ML application, the size of the dataset limits the performance of the algorithm. Especially, ML studies have shown weak performance in large samples than small samples. The proper use of cross-validation classification and small data helps to reduce overestimation and variability.

4. Discussion: Future Research and Recommendation

The purpose of this study to shows the concept of ML algorithms used in mental stress detection their detailed application in a particular domain. The analysis of stress detection

that used social networking sites post, clinical records, blogs, student's data, Biosignal like (EEG, ECG, and HRV) resulted in which algorithm is best suited for a particular dataset. Although, accuracy depends on how much large dataset fed into the machine. Clinical datasets collected over some time then insights are derived from them. The predictive model analyzes provide onset alerts if there are any abnormalities. Among, ML technique SVM is widely used in the health domain. In some areas, Naive Bayesian shows high accuracy in sentiment analysis of Facebook status. Comparative analysis against classifiers shows those hybrid classifiers shows high accuracy and improve overall performance and f-measures used for sentiment analysis against traditional.

ML yields better outcomes in the health care sector. As healthcare produces a huge amount of data, the challenge is to accumulate and effectively use it for analysis, prediction and treatment. It helps health professionals in decision-making, identifying patterns and innovation, enhancing the ability of research and clinical trials. Leveraging real-time data (lab test results, BP, family history) and historical data allows building models for analysis and deriving results. According to Framingham, 56% accuracy for a long-term cardiovascular disease predicted. ML considered new areas in the clinical trial like drug abuse. Around 90% of drugs can't detect in trials. Automatic drug discovery can reduce cost by up to 70% approximately, according to Carnegie Mellon.

ML-based Electronic Health Record (EHR) helps to apply the predictive model across different EHR systems. These systems have a diverse source of data - structured and unstructured like images, audios, text, medical imaging etc. Technologies like optical character recognition, image processing (radiology, pathology, dermatology) and NLP help to convert these data into symmetrical patterns. Google collaboration with University College London Hospital develops an algorithm to detect cancerous and healthy tissue to improve radiotherapy treatments. ML is extensively used to predict and monitor epidemics outbreaks based on data collected from diverse sources like social media, web-based, and satellites. Finally, use of ML application to derive insights from any data help to aid analysis, prediction, and treatment so it is necessary to examine the practicality of these insights whether they can be interpreted and executed in the clinic trails.

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