

The Relative Review of Machine Learning in Natural Language Processing (NLP)

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ABSTRACT

Natural Language Processing (NLP) has experienced essential transformations thanks to machine learning (ML) technical implementations. This research discusses the integrated nature of NLP and ML through data driven methodologies that led to radical evolution in text classification and sentiment analysis and machine translation and question-answering systems. Deep learning architectures, particularly transformers like BERT, GPT, and T5, which utilize extensive datasets and contextual embeddings, have largely replaced traditional rule-based methods. This study examines crucial ML approaches, such as supervised, unsupervised, and reinforcement learning, and assesses their influence on NLP performance metrics. Additionally, the paper explores current trends, including prompt engineering, fine-tuning of large language models, and ethical issues in AI-powered NLP applications. By consolidating recent developments, this investigation aims to offer perspectives on the future direction of ML in NLP and its potential impact across various industries and real-world applications. The applications are Email filters, Smart assistants, Search results, Predictive text, Language translation, Digital phone calls, Data analysis, Text analytics.

Keywords: Machine Learning, NLP, Deep Learning, Science and Technology.

I. INTRODUCTION

Our modern lives heavily depend on artificial intelligence (AI) because it controls autonomous factory operations as well as smartwatches and other devices. The presence of AI extends from vast corporations to modest businesses to deliver happier customers and achieve higher sales figures. Artificial

intelligence (AI) describes the computer or machine ability to operate with intelligence like humans. Artificial intelligence employs multiple technologies which allow machines to display human-like perception reasoning capabilities while acting to learn. The two core subfields of artificial intelligence emerge as machine learning and natural language processing. The concept of AI encompasses ML as its smaller

constituent part. An automatic data processing method through ML helps machines derive knowledge through processed algorithms and data. The essential attributes of AI work together in ML systems to produce automatic decision making that happens independently of human programming. Natural language processing forms an AI component that enables computers to both interpret written text and spoken words. The utilization of NLP represents one of the top AI applications because it maintains a direct relationship with modern-day digital assistants together with chatbots and virtual assistants along with their capabilities to detect spam. Sentiment analysis through NLP extracts product-related emotions and service attitudes from text-based data.

A. MACHINE LEARNING

Development making it the essential component of current times. Computers and systems obtain learning capabilities from data to enhance their functionality through automatic development of programs designed without manual coding. Training data samples allow machine learning algorithms to build predictive models that generate forecasts from available data. The field of machine learning needs development because it enables the execution of its algorithms across diverse applications including computer vision and email filtering along with speech recognition and agriculture and medical tasks which traditional programming methods struggle to handle. The significance of machine learning continues its expansion because of enlarged diverse data pools combined with affordable computing resources alongside fast internet access. Organizations benefit from machine learning technology to produce novel products through understanding company operational patterns while gaining insight into customer and corporate market dynamics. Multiple top companies such as Facebook, Google and Uber heavily rely on machine learning during their daily business operations. AI and ML are transforming the way businesses operate in many

industries, from healthcare to manufacturing to transportation. By identifying the most impactful use cases, investing in a strong data infrastructure, and developing the necessary skills and expertise, organizations can gain a competitive advantage and unlock new opportunities for growth and innovation. With the increasing availability of AI and ML tools and platforms, businesses of all sizes can leverage these transformative technologies to improve efficiency, personalize customer experiences, and detect potential threats before they occur. The future of business is AI and ML, and those that embrace these technologies will be best positioned for success in the years ahead.

B. THE PRIMARY ADVANTAGES THAT BUSINESSES DERIVED FROM NLP

Traditional thinking about AI asserts that computers outperform human beings in information processing while humans remain their superior in qualitative decision making. That, however, is changing. NLP tools now enable advanced capability to support writing and coding as well as domain-specific logical operations. The adoption of new tech requires companies to follow several key steps including identifying text data assets and developing methods to enhance firm value through current techniques as well as understanding potential benefits from AI-based language technologies for decision making and workforce reorganization and experimental utilization of various language-based AI tools regarding their function and potential for transformation.

C. THE PRIMARY ADVANTAGES OF

Organizations use detection methods on diverse sources including social media and online reviews and news reports to get brand performance insights together with problems detection that improves both performance and data processing functions and shares vital information for sentiment analysis and content classification. NLP stands as a Natural Language

Processing field which trains computers to interpret and create human speech through the capabilities of Machine Learning which serves as the core processing element that runs NLP applications by processing large linguistic datasets; thus, NLP strongly depends on ML functions for proper operation. Human beings pose the biggest threat to modern civilization since they perform lethal and violent offenses such as murder while also committing assault and robbery crimes. Employees who work in isolated night shifts face danger to their safety with a major risk to women's well-being. All immediate threatening situations in real time produce audible or detectable sounds which can become useful for identifying dangers early. Multiple safety measures exist but they prove ineffective since they show inaccurate results or take too much time to detect emerging threats. The development of a groundbreaking software-based prototype allows users to detect surrounding threats by sound or noise elements to send prompt alerts to registered contacts via email SMS and WhatsApp-based messages through their smartphone devices. The Kaggle dataset undergoes Exploratory Data Analytics (EDA) visual analysis and signal evaluation of audio data.

II.LITERATURE REVIEW

Machine learning systems form part of artificial intelligence through which they acquire models automatically from data to enhance their decision abilities. The combination of corpora and learning approaches in natural language processing helps achieve high performance in statistical tasks that include text classification and sentiment mining (**Le Glaz et al., 2021**) [1]

Medical literature about germline genetics shows an increasing exponential growth rate. Medical practitioners require research monitoring platforms which help them identify and rank scientific findings about pathogenic genetic variant clinical effects. The

research team built and assessed two machine learning systems to determine whether abstracts matched criteria for penetrance information about cancer risks for mutation carriers or data regarding the prevalence of such mutations in the general population. Research in PubMed produced paper titles and abstracts which formed the basis for annotated dataset development for two machine learning model assessments. The SVM approaches training by learning linear rules from title and abstract sequences expressed as bag-of-ngrams features. The convolutional neural network (CNN) uses raw title and abstract data to learn an elaborate nonlinear decision rule. The evaluative study examined the ability of two classification approaches to identify papers related to penetrance or prevalence. Our study examined 3740 paper titles and abstracts with 60% used for training and 20% for model tuning and 20% reserved for model evaluation in penetrance classification. Having been trained on the same dataset both SVM and CNN models reached similar performance levels at 89.53% and 88.95% respectively for paper classification accuracy. A total of 3753 paper titles and abstracts received annotation for prevalence classification purposes. The SVM model demonstrates 89.14% accuracy rate which matches the accuracy score of 89.13 % achieved by the CNN model. The created models demonstrate exceptional effectiveness when identifying abstracts regarding penetrance or prevalence classification. This tool would enable both clinicians and researchers to maintain their awareness of growing gene-cancer correlation knowledge and ensure the data accuracy in clinical decision support frameworks remains current. (**Bao et al., 2019**) [2]

Radiology staff must perform daily manual evaluation of received referrals to guarantee their appropriateness. Proficiency in manual radiology referrals vetting depends on experienced clinical practitioners but poses difficulties to the staff. Artificial intelligence technology along with natural language processing development induces most machine learning-based NLP models to concentrate on healthcare quality and

research cohort creation. The current medical protocol for automatic radiology referral assessment within the system shows limited effective coding capability. Lack of suitable research exists to tackle vital issues concerning class imbalance as well as human-focused evaluations. The research team created machine learning and deep learning systems which performed automatic LSMRI referral assessment for scanning suitability through data obtained from two hospital networks. One of the text augmentation techniques serves as the focal point to measure its impact on the performance metrics for developed models. This document reviews how four different techniques performed when executed for feature extraction. Adding augmented data led to enhanced performance metrics for the models through F1 score improvements that reached between 1% to 8%. A combination of support vector machine with bag of words produced the optimal AUC score that reached 0.99. The convolutional neural network achieved an AUC value of 0.97 as the second highest score in the model testing. The tested models demonstrated superior performance than the professional radiologists during evaluation on unknown image data. (Alanazi et al., 2022) [3]

The chapter explores handling big data challenges through data science techniques. The analytical data comes in various forms which include volume in addition to velocity and variety and veracity measures. The analysis focuses on resolving real-world problems through natural language processing to transform unstructured data into meaningful structured information combined with machine learning for extracting valuable insights from available or derived information. Multiple algorithms working together constitute a significant factor that enhances the development of cognitive computing. The chapter provides sufficient explanations about important methodology application points to use. There exist several open research problems available to potential aspiring data scientists. The introductory part of data

science can be found within this chapter. (Mustafi, 2016) [4]

Artificial intelligence together with machine learning has intensely integrated itself into the technologies that guide modern life. The extensive revolution in scientific research and industrial operations through machine learning technology also demonstrates potential benefits for resolving weaknesses in mental healthcare delivery mechanisms. This paper examines how machine learning combined with natural language processing constitutes methodology combinations which may serve to create automated assessments of therapeutic content. Prediction of therapeutic alliance through session recordings serves as the main example of this study. Automatic speech recognition software processed 1,235 therapy sessions that involved 386 clients who received help from 40 therapists operating at a university counselling centre. The connection of therapeutic alliance ratings and session linguistic content operated solely through machine learning algorithm training. A set of data served to train the model before algorithms utilized the independent test set to generate predictions about session content relationship with alliance ratings (Spearman's $\rho = .15$, $p < .001$). The predictions achieved using natural language processing and machine learning demonstrate promise for predicting a critical psychotherapy process variable which exists at a considerable distance from linguistic content. The paper introduces six implementable research methods that combine machine learning with psychotherapy research in addition to providing future research guidelines. The improvement of machine learning capabilities to automate psychotherapy assessment requires research on dissemination and implementation methods. (Goldberg et al., 2020) [5]

The treatment of neuropsychiatric disorders creates significant societal expenses because existing objective results and fidelity measurement methods are insufficient. Numerous AI-based technologies are

currently serving as tools for analysing mental health interventions (MHI) through their fundamental language communications. Studies indicate that NLP continues to display unknown capacity in solving clinical and research problems. A pre-registered systematic review was conducted using PRISMA guidelines (osf.io/s52jh) to assess NLP-MHI models as well as their clinical potentials and detect biases and knowledge gaps. Research on candidates ($n = 19,756$) took place through PubMed, PsycINFO, Scopus, Google Scholar, and Arrive up until January 2023. This investigation analysed 102 selected articles to understand their technical attributes involving NLP algorithms with audio capabilities, machine learning frameworks, outcome assessment procedures as well as clinical evaluation aspects along with system limitations. Many NLP MHI studies emerged rapidly starting in 2019 as illustrated by increased participant and large language model implementation. The largest contributors of Medical Health Indicators data came from digital health platforms. The ground truth data used for supervised learning algorithms originated from three sources including clinician ratings of thirty-one cases along with patient self-report from twenty-nine respondents and twenty-six cases evaluated by raters. The characteristics derived from text sources delivered better accuracy rates for the analysis than the data stored through audio. The clinical categories studied most frequently in NLP MHI analyses consisted of patients' clinical presentation ($n = 34$), response to intervention ($n = 11$), intervention monitoring ($n = 20$), providers' characteristics ($n = 12$), relational dynamics ($n = 14$), and data preparation ($n = 4$). as a and the limitations in results stemmed from excluding minority languages and matching results between studies and including select patient groups in analysis. A validated research framework named NLP MHI serves as a tool to help computational and clinical experts address present challenges in NLP applications to MHI while advancing clinical usefulness and data availability together with fairness. (Malgaroli et al., 2023) [6]

This study employs artificial intelligence techniques particularly machine learning methods to study the emotional reactions that social media users display when they share information about their mental health conditions. Our study explores how people emotionally react to mental health information on Instagram whereas past work mainly analysed psychopathologies. Since young people actively use this platform. The analysis of mental health through machine learning on Instagram marks a first since existing research investigated Twitter platforms only. This research method involves building a new labelled collection to analyse responses from Instagram influencers and celebrities when they post about mental health which includes the five emotional categories of love/admiration and anger/contempt/mockery and gratitude and identification/empathy and sadness. The study integrates an assessment of machine learning algorithms which identify emotions experienced during web interactions with mental health declarations on Instagram through the utilization of the assembled corpus data. Research findings demonstrate that machine learning algorithms demonstrate success in recognizing such emotional reactions. Random Forest proved effective but required low computational power (50%) to achieve results while deep learning and BERT algorithms produced very satisfactory outcomes. During testing the BERT protocols obtained between 86–90% accuracy rates and the deep learning model demonstrated 72% accuracy results. The achieved performance meets expectations since emotional prediction within social media platforms remains detailed due to inconsistent evaluation between users and cultural variations in emotional perception. This multilayer study combining mental health research with AI enables examination of emotional reactions that mental health social media content creates in youth audiences particularly when popular celebrities post this content. (Merayo et al., 2024) [7]

NLP stands as a linguistic and computer science discipline within artificial intelligence which develops techniques for computers to understand large human language datasets and analyse them. The computer development process aims to build machine systems capable of interpreting document contents while understanding linguistic context. NLP applies computational linguistic rule-based approaches and statistical machine learning and deep learning networks for processing human language data. These technologies unite to let computers analyse human-written text and voice content while developing complete comprehension of meaning including writer and speaker purpose and emotional undertones. Most of the NLP difficulties deal with speech recognition alongside natural language understanding and natural language generation capabilities. The paper investigates multiple aspects of Natural Language Processing including current trends together with future project expectations alongside its different applications and challenges. **(Shreyashi Chowdhury & Asoke Nath, 2021) [8]**

Natural Language Processing (NLP) operates as an AI subfield and computer science discipline that manages human-computer interactions through natural human language. Computers should gain the capability to both understand and generate human language with the goal of NLP so they can execute duties that need human level intelligence. The dramatic expansion of NLP results from the rising digital content availability while organizations need to extract intelligent information from these sources. The analysis examines modern developments in NLP which encompass text classification and named entity recognition and sentiment analysis and machine translation and speech recognition. Some of the upcoming priorities along with challenges for NLP research form a key part of the review. **(Abhay A. Dande & Dr. M. A. Pund, 2023) [9]**

A surge in industry demand exists for natural language processing applications during the recent years. The list of natural language processing applications consists of "semantic" enterprise search engines, document categorizers, speech recognizers together with conversational agents also known as virtual assistants or "chatbots". Customer care teams highly prioritize this artificial intelligence solution as they want to add an automated system that extends the capabilities of human representatives to assist users in their tasks. This paper analyses industrial chatbot limitations while focusing on human-in-the-loop techniques which enable co-operation between machines and humans. The research discusses the implementation of this aspect across multiple industrial natural language processing applications. **(Quarteroni, 2018) [10]**

Modern language processing has evolved by leveraging new model architectural designs combined with advanced pretraining methods. The Transformer architecture allows higher-capacity model construction while pretraining provides methods to use this capacity effectively across multiple tasks. The library contains expert-optimized state-of-the-art Transformer frameworks that operate through a single API. The library boasts a collection of pretrained models that stem from the community and are curated for public accessibility. Transformers serves the needs of researchers through extensibility and enables practitioners to operate it efficiently while ensuring both quick and reliable outcomes in industrial scenarios. **(Wolf et al., 2020) [11]**

BERT functions as an acronym for Bidirectional Encoder Representations from Transformers — it represents a modern language representation model. BERT employs a distinct model architecture than embedding-based models (Peters et al., 2018a; Radford et al., 2018) by directly obtaining deep bidirectional representations from unlabelled textual data that combines the left and right contexts through all layers. During its pre-training phase BERT builds an initial

model which developers can transform into excellent text processing systems by attaching an output layer to the pre-trained architecture without major design changes. Raw unlabelled text data produces exceptional practical performance from BERT due to its basic concepts. BERT achieves eleven state-of-the-art NLP results through its performance at 80.5% GLUE score (7.7% absolute gain) and 86.7% Multani accuracy (4.6% absolute gain) while delivering a Squad v1.1 question answering Test F1 score of 93.2 points (1.5 point absolute gain) and a Squad v2.0 Test F1 score of 83.1 points (5.1 point absolute gain). (Devlin et al., 2019) [12]

Evaluating NLP models simply based on held-out accuracy has spurred wrong performance benchmarks, since all existing studies either focus only on the task or only the individual behaviour. Check List detects these defects. After conducting extensive model evaluations as part of a research study, a group of product sentiment model maintainers noticed large bugs in this model. In terms of numbers, NLP practitioners using (Ribeiro et al., 2021) [13]

This article aims to provide a high-level overview of machine learning, its subfields, and some of the ways in which this technology is being used to enhance knowledge and improve work performance. (Angra & Ahuja, 2017)[14]

III. RESULTS AND DISCUSSION

This table 1 shows all research articles grouped according to authors and research topics with tables detailing technological approaches and publication year and corresponding data set sizes. The application of AI, ML, NLP and CNNs within mental health and cancer diagnosis and spinal imaging comprises the essential technologies. The largest research data set of 85 belongs to mental health studies from 2024 whereas the smallest data set of 0.018 originates from NLP trends research in 2021. The articles discuss systematic reviews and therapeutic alliances and disorder detection methods.

Table 1 Detailing technological approaches and publication year and corresponding data set sizes.

S.no	Author Name	Topic name	Year of Publication	Technology used	Data set size
1	Shreyashi Chowdhury at all.	Trends In Natural Language Processing Scope and Challenges	2021	Natural Language processing, Artificial Intelligence, Computer Linguistics, Speech Recognition, Natural Language Generation.	0.018
2	Yujia Bao, Zhengyi at all.	Machine Learning and Natural Language Processing in Mental Health: Systematic Review	2021	machine learning, natural language processing, artificial intelligence, data mining, mental health, psychiatry	82
3	Yujia Bao, Zhengyi Deng, at all.	Using Machine Learning and Natural Language Processing to Review and Classify the Medical Literature on Cancer Susceptibility Genes	2019	The support vector machine (SVM) functions together with the convolutional neural network (CNN) as main analytical instruments	64

S.no	Author Name	Topic name	Year of Publication	Technology used	Data set size
4	Simon B. Goldberg, at all.	Machine Learning and Natural Language Processing in Psychotherapy Research Alliance as Example Use Case	2020	Machine learning, natural language processing, methodology, artificial intelligence, therapeutic alliance	5.4
5	Noemi Merayo, at all	Machine learning and natural language processing to assess the emotional impact of influencers' mental health content on Instagram	2024	A research design implements machine learning and natural language processing to study mental health disorders together with eating disorders.	85
6	Ghofrane Merhbene, a all	Investigating machine learning and natural language processing techniques applied for detecting eating disorders: a systematic literature review	2021	artificial intelligence, anorexia, bulimia, binge eating	0.93
7	Ali H. Alanazi a, at all	Machine learning and deep learning-based Natural Language Processing for auto-vetting the appropriateness of Lumbar Spine Magnetic Resonance Imaging Referrals	2022	Deep learning and Machine learning work together with natural language processing and magnetic resonance imaging evaluation.	0.97

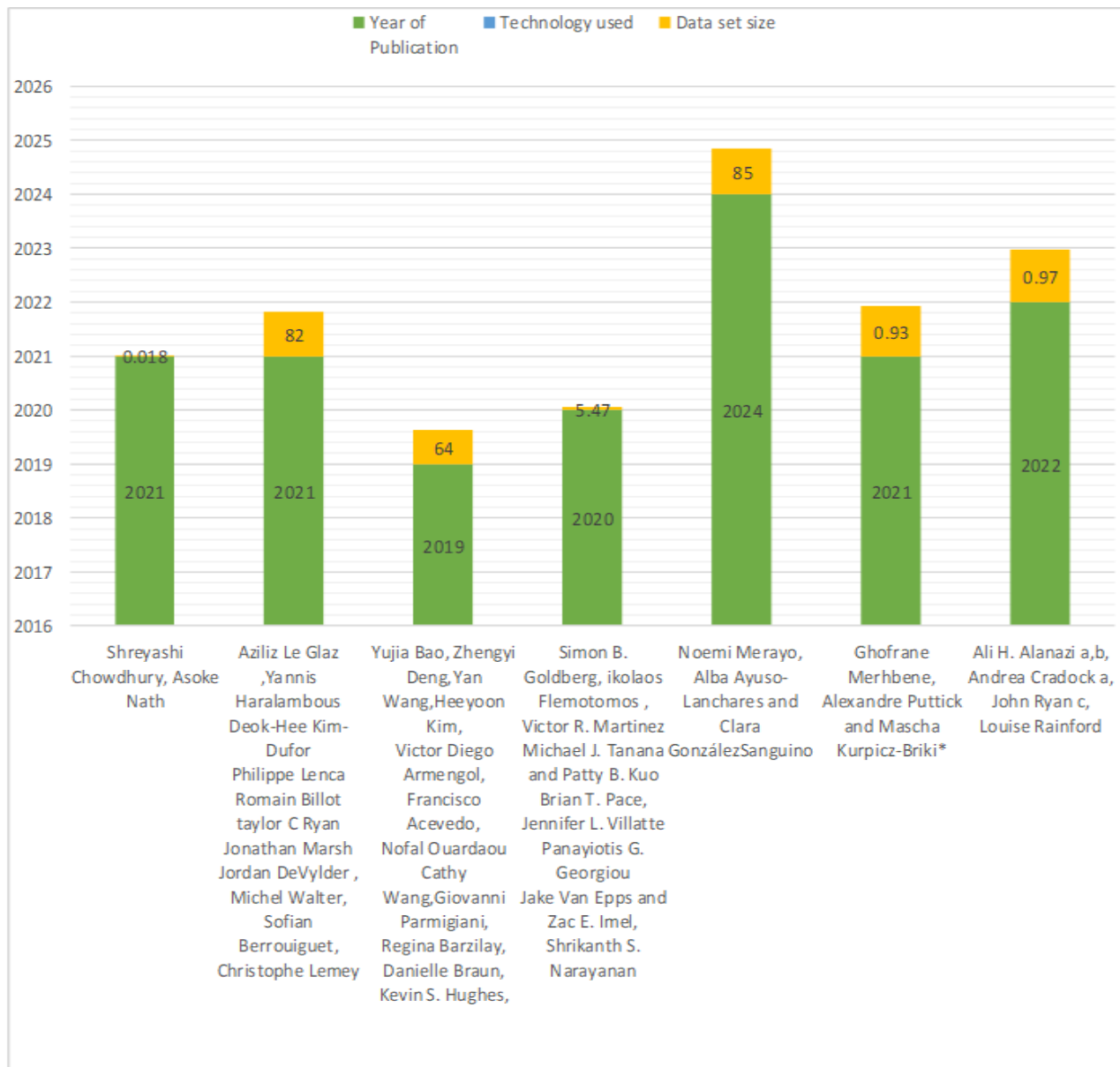


Fig: - 1 Technological usage and data volume measurements.

The data visualization shows research publication data regarding yearly trends combined with technological usage and data volume measurements. The research publication with the largest data set of 85 was published in 2024 regarding mental health yet the smallest recorded set appeared in 2021 with data amounting to 0.018. This graph presents different research technologies used in different research sections across time.

Table: - 2 Technology used

S.no	Year of Publication	Technology used	Data set size
1	2021	Natural Language processing, Artificial Intelligence, Computer Linguistics, Speech Recognition, Natural Language Generation.	0.018

2	2021	machine learning, natural language processing, artificial intelligence, data mining, mental health, psychiatry	82
3	2019	The support vector machine (SVM) functions together with the convolutional neural network (CNN) as main analytical instruments	64
4	2020	Machine learning, natural language processing, methodology, artificial intelligence, therapeutic alliance	5.47
5	2024	A research design implements machine learning and natural language processing to study mental health disorders together with eating disorders.	85
6	2021	artificial intelligence, anorexia, bulimia, binge eating	0.93
7	2022	Deep learning and Machine learning work together with natural language processing and magnetic resonance imaging evaluation and referrals' appropriateness of the lumbar spine.	0.97

The table 2 summarizes technological approaches with their corresponding publication dates together with the measurement of their associated data sets. Key points:

1. Variety of Technologies: Includes artificial intelligence (AI), natural language processing (NLP), machine learning (ML), and specific tools like support vector machines (SVM) and convolutional neural networks (CNN).
2. The research applications in this field operate in psychiatry alongside mental health and support eating disorder assessment and therapeutic alliance development as well as spinal imaging analysis.
3. In 2024 the study analyzes mental health and eating disorders using a large data set (85) whereas 2021 demonstrates the smallest data set (0.018) for testing NLP and AI technologies.
4. The research trends section of the table indicates how deep learning and ML and AI technologies have been united within multiple domains across various years.

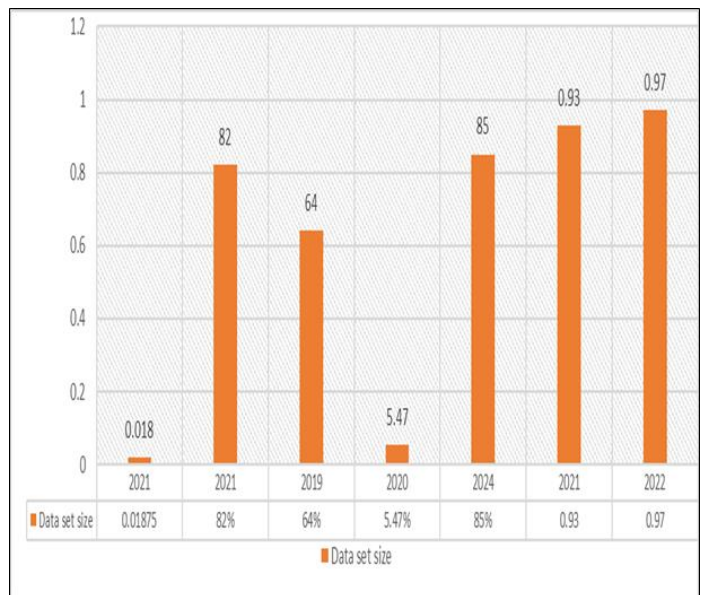


Fig: - 2 Technology used in year wise

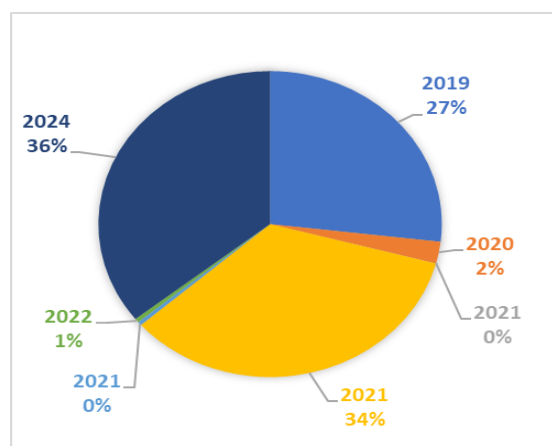
The bar chart (fig 2) displays data set size variations according to different years all together. 2024 and 2021 display the greatest sizes with 85 and 82 values apart from the smaller numbers in 2021 with 0.018 and 2022 with 0.97 and 2020 with 5.47.

Table: - 3 Data set size

S.no	Year of Publication	Data set size
1	2021	0.018
2	2021	82
3	2019	64
4	2020	5.47
5	2024	85
6	2021	0.93
7	2022	0.97

The data set sizes related to publication years appear in table 3. Key observations:

1. The data set size reaches its maximum value at 85 during year 2024.
2. The data in 2021 demonstrates size variation between its small data sets measured at 0.018 and 0.93 and its large data set with a measurement of 82.
3. The data set sizes in 2019 and 2020 amount to 64 and 5.47 respectively.
4. The smallest publication in 2022 used a data set with a size measurement of 0.97.

**Fig: - 3 Data set size according to year**

The distribution of data spans five years from 2019 through 2024 based on this pie chart (fig 3). A majority of 36% falls in 2024 whereas 2021 accounts for 34% and 2019 represents 27% of the whole pie. Very small percentages (2% and 1%) belong to 2020 and 2022.

The distribution of data spans five years from 2019 through 2024 based on this pie chart (fig 3). A majority of 36% falls in 2024 whereas 2021 accounts for 34% and 2019 represents 27% of the whole pie. Very small percentages (2% and 1%) belong to 2020 and 2022.

All reference papers used for writing our review on Machine Learning effects on Natural Language Processing exist in the accompanying table (1).

The article Trends in Natural Language Processing Scope and Challenges from 2021 utilizes Natural Language processing (NLP), Artificial Intelligence (AI), Computer Linguistics, Speech Recognition, Natural Language Generation with 0.018 accuracy. Two parallel studies achieved results of 82 and 0.97 through their evaluation of Machine Learning and Natural Language Processing in Mental Health: Systematic Review and Investigating machine learning and natural language processing techniques applied for detecting eating disorders: a systematic literature review.

In 2019 and 2020 the paper used Machine Learning and Natural Language Processing to Review and Classify the Medical Literature on Cancer Susceptibility Genes and Machine Learning and Natural Language Processing in Psychotherapy Research Alliance as Example Use Case which achieved accuracy measurements of 64 and 5.47. Researchers published two works in 2022 and 2024 about Machine learning and deep learning-based Natural Language Processing for auto-vetting the appropriateness of Lumbar Spine Magnetic Resonance Imaging Referrals along with Machine learning and natural language processing to assess the emotional impact of influencers' mental health content on Instagram that reach 0.97 and 85 accuracy levels.

I. CONCLUSION

The study presented in Machine learning and natural language processing to assess the emotional impact of influencers' mental health content on Instagram reaches the highest accuracy level at 85 percent in 2024. The scientific research links machine learning algorithms to natural language processing for studying both eating disorders and mental health conditions. The research article Trends in Natural Language Processing Scope and Challenges has the lowest accuracy rating of 0.018 because it relies on Natural Language processing (NLP), Artificial Intelligence (AI), Computer Linguistics, Speech Recognition, and Natural Language.

AUTHOR CONTRIBUTION

Author First Harsh Koushal

Conceptualized the review topic, conducted the literature search, drafted the introduction and discussion sections.

Author Second Rimpal Kaur

Performed data analysis, wrote the results section, and critically reviewed the manuscript.

Author Third Chhinder Kaur

Provided expert feedback on the methodology and revised the manuscript for accuracy

CONFLICTS OF INTEREST

NO

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