



APPLICATION OF AI/ML/NLP TECHNOLOGY INTO THE BUSINESS PROCESS MODELLING

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ABSTRACT

The business process modelling proved to be an effective way in creating quantifiable and qualitative business impact with efficient use of digitized techniques for enhancing the business growth in the fiercely competitive and commoditized market. The various aspects of the business process that are taken into consideration results in increasing the efficiency and productivity of key metrics associated with the business agility. Hence, the use of the automated systems such as machine learning, artificial intelligence and natural language processing has improved the operational activities of the business evolving rapid and cost- efficient changes in the market environment. Therefore, the present study aims at analyzing the various applications of AI, ML and NLP techniques in the business process modelling. This has been considered as a major goal of this review study. Also, findings and discussion has been depicted by analyzing the literature review which focuses on the effectiveness of using these automated techniques into the business process modelling.

Key words: Artificial Intelligence, Machine learning, Natural language processing, Digitalization, Automation, Business process modelling.

Cite this Article: Milind Godbole and Anuja Agarwal, B S Sahay, Application of AI/ML/NLP Technology into the Business Process Modelling, *International Journal of Advanced Research in Engineering and Technology*, 12(5), 2021, pp. 37-50.

<https://iaeme.com/Home/issue/IJARET?Volume=12&Issue=5>

1. INTRODUCTION

The industrial revolution involves the mechanical production with labour and assembly line work for using electronic and automatic production that eventually are included under industrial revolution (Schwab,2016). The use of business process modelling includes the use of 4.0 step of the industrial revolution that confers the use of digitalization as well (Atiker,

2017). The established economy of the business is enhanced by the use of several automated technologies such as Internet of Things, artificial intelligence, Machine to Machine communication, Cloud Computing and many others. The use of Big Data has changed the scenario in the supply chain along with the customer requirements, process management and other automated techniques that have been capable of reducing the response time for avoiding backlogs, dissatisfied clients and processing errors. Therefore, the capability of enabling more

steps in the process management and automation, the use of machine learning (ML), artificial intelligence (AI) and NLP for business process modelling (BPM) has been effective with the implementation of digitalized transformation. This process management has been proved to be effective with implementation of automated and learning of such computer programming languages that enables the theory agility, flexibility and automation for the complete organization as well as for the process of the stakeholders.

The business process modelling has been considered as the management concept for controlling, adapting and optimization of the business processes (Paschek et al., 2017). It is the type of systematic approach which has the capability of capturing, shaping, executing, documenting, monitoring and steering the automatic and non-automatic process for reaching coordinated and sustainable company targets (Paschek et al., 2018). The assignments in BPM are followed by coordinating and executing the business process by every step (Schmelzer & Sesselmann, 2020). The process is monitored, identified and evaluated for any issues and trouble and the BPM enables the business to optimize their process issue (Schmelzer & Sesselmann, 2020). Hence, business process modelling is considered as the graphical representation of the organization's workflow involving the business process that enables the potential environment. It is basically used interchangeably with business process mapping. It deals specifically with low level process maps with the main purpose being used as process improvements.

The present study involves the use of machine learning (ML), artificial intelligence (AI) and natural language processing (NLP) in managing the business process at the time of digital transformation that is implicated as business process modelling. Artificial intelligence (AI) has been used as informatics and applied computer science for patterning the human proceedings using problem solving and transferring those data into the system for inventing efficient and new solutions along with course of actions. Hence AI is a computer program running on any possible devices and data centres with the skill to interact with its environment. Natural language processing (NLP) used in business process modelling has made it possible for the system to understand the human language. Some of the major examples of NLP in action involve virtual assistants such as Google Assist, Siri, and Alexa. Machine learning (ML) has been considered as another branch of AI that describes mathematical techniques and enables the machines for generating knowledge from the experiences (Bell, 2020). Machine Learning describes the development of algorithms based on empirical data as well as training data with the focus on the optimization of the results and the improvement of the predictions due to learning processes.

2. LITERATURE REVIEW

2.1. Overview of Business Process Modelling

Business process modelling (BPM) is the analytical representation or the elaboration and illustration of the organization's business process. Hence, the modelling process has been known as the critical element for handling the effective business process management. This process modelling software has given graphical representation involving as-in processes in the organization along with to-be processes for carrying out more efficient work processes. The process in the organization is digitized by understanding the workflow engine of the business process. Hence, this business process modelling can be transferred to the live automated process. This results in providing several benefits towards business process modelling by providing clear understanding regarding the workflow of the process, providing consistency and controlling the process, identifying and eliminating the redundancies and inefficiencies, and setting a clear start and end to the process. Also, the business process modelling has been capable of helping to group the similar processes together and anticipation of the operating

process. Hence, the business process modelling majorly aims for analyzing the current situation and stimulating the work process for achieving better results. Sometimes the process modelling becomes quite complex in business process modelling. Hence, a formal language can be used for the specification to avoid the problems. A thorough analysis of the business process is carried out for eliminating the risk of costly corrections due to errors found at the final stages of project execution.

Business process modelling aims for improving the business performance by optimising the efficiency of connecting activities in the provision of product or services. These modelling processes are concerned with the mapping and workflow to enable, understand, analyze and positive changes. The main purpose of adapting and implementing the business process modelling is to propose a final output for improving the flow of the business process working. These improvements majorly focus on the value-added actions that help in making customer service and better experience and on the reduction of wasting time and effort. A successful business modelling can be enhanced by competitive advantage along with involvement of market growth and good staff morale and retention. This induces added value among the customers involving external and internal customers. The business process model starts with the customer's need and ends with the satisfaction of the need. The business process modelling concentrates on the modelling system that uses sequence based techniques enhancing the quality and related factors of process, quality, monitoring, management, and change, etc.

2.2. Implementation of Digital Business Analysis

The role of business analyst implies the practice of changing the organization by understanding and fulfilling the needs and recommendation of solution by delivering the value to the stakeholders. Business analysis has become more digitized for meeting the demands of the stakeholders. The implementation of new digitalized techniques among the organizations needs business analysis for constantly building their digital skills and applying them for practicing business. Business analysis is becoming increasingly based on highly objective data and therefore more accurate. Also, the business analysis has become more consultative, communicative, and personal than intermediary that increases its effectiveness. The business analysis has involved regarding the customer experience. It has become more inclusive of customer representatives. Business analysis is transforming into highly agile practice. Digital skills are impacting business analysis for the better. Among other changes, the rise in digital skills across all industries is making the practice of business analysis more digital-focused, consultative, informed about the customer experience, succinct, and flexible. Business analysis is capable of fulfilling the demands of the organizations and by changing the rationale and designing and describing the solutions for delivery of the added value (IIBA, 2009). The main core of the business analysis lies in finding the solution that aims for addressing the demand for the purpose of delivering added value to some entity. Hence, simply this states that it is capable of analyzing the needs or problems of specific business for the purpose of finding and implementing a solution. For this, the role of business analyst plays an important role in uplifting the business in any organization. The business analyst performs the work of business analysis in different contexts and levels. The task in the business operations involve different levels involving from strategic to operational level or it can be confined to a single project aiming at improving a specific part of the business or involving several divisions of an organization. It is also depicted with introduction of new solutions or continuously improving existing solutions.

2.3. Applications of AI and ML and NLP in Enhancing Business Operations

Artificial intelligence (AI) has been used for enhancing the business operations that involves the fixing of algorithms into applications supporting the organizational processes. It has proved

to be the biggest achievement in the development of business. The process, system and application for increasing the business operations while increasing the profitability of the organization. AI has been used for making strategic decisions as it plays an important role. AI helps in predicting consumer behaviour and also helps in making product recommendations. It enables forecast consumer behaviour along with running of data-based campaigns yielding remarkable results. AI provides automated customer services through telephone and online chatbot. This has helped in employing huge customer services staffs for handling the customer's queries and providing them support while enabling the customer chatbots. All the queries of the customers are handled at an appropriate time that is dependent on the customers' needs. It has shown great efficiency in automating the workloads and managing operational processes. Monotonous tasks are automated through robotic process automation so that the operational processes in the business are easily carried out. The critical decisions in most of the organizations are dependent on the data management. Hence, AI enables the form filling and updating files along with the transfer and cross-reference of files as per the requirements. To ensure this capability, AI-empowered data management systems are implemented in the organizations for detection of fraudulent and prevention of cybersecurity threats along with the improvement of overall business operations. AI has enabled legation of difficult pattern recognition along with appropriate learning and other computer-based tasks approaches for dealing with large volumes of data (O'Leary, 2013). It has been found that approx one-half of the world's stock trades are done using AI-based systems. AI has also contributed towards the velocity of data by facilitating rapid computer-based decisions leading to other decisions. Also, several issues of the enterprises are resolved parallelizing and distribution of problems. These issues are mitigated by capturing, structuring, and understanding unstructured data using AI and other analytics. One of the studies reveals that stock market predictions of the Dow Jones Industrial average were improved considering the overall stock market that is based on structured data generated from Google, contributions from the AI (Bollen & Mao, 2011). The impact of issues related to unstructured data have been investigated involving firm's reputation. Also, it has been found that some of the firms are analyzing different types of data for continuous monitoring activities involving generated structured measures along with assessments of firms' and products' reputations (Spangler et al., 2009). The monitoring and auditing of financial and other data streams, mainly involving the fraud detection are done by implementing AI (O'Leary, 2012).

Machine learning has been considered as the complete tool set that facilitates the decision making process and predictions from the gained data. It further helps in generalizing the patterns from the previous data to evolve new sections of data. Hence, this leads towards the inclusion of predictive analytics and involvement of certain cases such as customer churns, fraudulent credit cards and other related frauds involving email spams. One of the studies has revealed that almost 51% of the organizations have been using ML with the involvement of almost 36% claiming as the early adopters and remaining 15% claiming as sophisticated users

(Lorica & Paco, 2018). A slight minority of 49% of organizations reported they were exploring or "just looking" into deploying ML. The successful organizations are incorporating the ML into their daily business operations that involves the initiation from driving growth along with optimizing the efficiencies for identification of the areas with capital savings and reduction of investment costs. Also, machine learning has been found to be efficient in a good decision making process. Decision makers require critical data more quickly and ML helps in making faster decisions. Another study has revealed that ML has been capable of making rapid educated decisions and almost 50% of such organizations have been found to achieve their desired goals by implementing ML in their organizations (Landset et al., 2015). The fluency of the ML has enabled the managers to gather correct information and find the solutions for the problems that cannot be solved. The successful data ecosystem is handled by communicating

with the vendors of data services and products. Also, ML has been used for customer segmentation and personalization to understand and serve the requirements and other related habits. ML has been also capable of building human-to-machine interactions. Hence, AI powered chatbots are enhanced by this phenomenon only. Businesses can also derive actionable insights from unstructured data with text mining and image processing and recognition. Applications range from spam detection to building recommendation systems, and much more. It has been found that machine learning (ML) is capable of solving complex problems without using any explicit programming. The applications of ML have shown efficiency in wireless communication. It has been found that a trained ML model has been used for inference on the less capable devices such as smartphones (Dean, 2017). The applications of ML in networking has shown specific treatment towards specific problems in networking (Buczak & Guven, 2015). ML techniques in networking have been specialized to particular network technology with implementation of cellular network, CRN and WSN (Bkassiny et al., 2012; Alsheikh et al., 2014). Machine learning has been successfully applied in the areas of computer vision, medical diagnosis, search engines and speech recognition (Mitchell, 2013). ML has shown efficiency in the form of robust fingerprinting patterns by using an auto-encoder involving the management of three dimensional space in the indoor localization of the enterprises (Xiao et al., 2017).

Natural Language Processing (NLP) has been successful in establishing the importance of business operations by providing actionable insights so that the organizations are capable of making better decision making which is dependent on the data. NLP has been able to provide solutions that have helped the business in deriving insights concerning the textual data assets that are transformed and automated through various business processes for more efficient driving growth. NLP has enabled the sentiment analysis that has helped the organizations in tracking the public sentiment on the web and social media. It has enabled the machine learning engineers for scanning and deriving important information concerning the customers queries across various digital channels. The techniques used by NLP have been found to show capability in capturing relevant variable-order structure from the sequences (Räsäne & Saarinen, 2016). Extraction and structuring of data in pathology reports have been developed through implementation of NLP based MOTTE for supporting the clinical solution applications in the healthcare organizations (Puppala et al., 2015). Also, NLP has shown equivalent efficiency in designing monolingual short message services based system retrieving frequently asked questions (Adesina et al., 2014). NLP has been used as the resulting reliability of the system (Shah & Jinwala, 2015). It has been used as an important task in generation of text and speech from non-linguistic input (Gatt & Krahmer, 2018).

2.4. Impact of ML, AI and NLP in Business Operations

The implementation of machine learning (ML) has been proven to be efficient in the core process of business operation concerning different strategic decisions in any organization. ML has provided certain benefits in the organization involving the ability for discovering patterns and correlations, improving customer segmentation and targeting that eventually helps in increasing the business's revenues along with appropriate growth and better market position in the competitive digitalized world. Also one of the positive aspects of machine learning is that it adapts new data independently and helps in good decision making and better recommendations based on various calculations and analysis. The operational processes are identified for different patterns that help in decision making while reducing the intervention from humans. Its implementation in the operational process in the organization increases the accuracy and efficiency and also eliminates the possibility of any type of error occurrence. ML tools enable organizations to more quickly identify profitable opportunities and potential risks.

The adapting of artificial intelligence in the business process has also involved the positive impact on the business operations. It has been used in day-to-day activities while performing various operational tasks for enhancing the business growth. Artificial intelligence has been proved to be a supporting tool by analyzing and processing of complex data more quickly with accuracy. The implementation of AI has a major impact on building positive correlation by changing the customer relationship management. A normal CRM system transforms into self-updation along with auto correction. The use of AI algorithms in the business operations has shown efficiency in increasing the productivity, time and cost efficiency along with the reduction of error occurrence, rapid decision making and accurate customer preference prediction.

The implementation of NLP in the operational process in any organization involves the computing area making sense of human and natural language. It has a major impact on the marketing stream for enhancing the business growth. Some of the major advantages of implementing NLP in the digitized technologies involve the recognition of the optical characters, speech recognition, machine translation, natural language generation, affective computing, etc. Also, the use of NLP in business operations have been proved to show efficiency in enabling natural conversations, reduction of cost, high customer satisfaction and improved analysis.

2.5. Evaluating the Business Process Modelling

Business process modelling has been effective in enhancing the performance of the business operations and achievement of competitive advantages in the digitized market. It has been considered as a framework for the collection of several activities that helps in achieving specific business objectives by fulfilling the business contract and satisfying the customer's needs (von Rosing et al., 2015). It further consists of various operational inputs and creates an output that adds value to the customers (Hammer & Champy, 2009). Hence, business process modelling has been considered as an important factor for designing, analyzing, implementing and controlling the business process by effective means (Pinggera et al., 2015). Business process modelling techniques have been used for analyzing the business process in any organization. One of the studies has revealed two approaches on which the BPM is dependent that involves graph-based and rule-based approaches (Lu et al., 2007). These approaches have analyzed the operation activities in terms of flexibility, adaptability, dynamism and complexity considerations (Nagm-Aldeen et al., 2015). Another study has involved the evaluation of the BPM techniques on the basis of some dimensions. These dimensions involve the use of Moody's quality that involves principles such as Discriminability, Human beings Limits, emphasis, Cognitive integration, perceptually direct representations, Identification, Structure, Expressiveness, and Simplicity (Johansson et al., 2012). Also, the quality of the process models are evaluated in the form of product dependent on the quality of the modeling process (de Oca et al., 2015). As mentioned above many different frameworks have been suggested to evaluate the Business Process Modeling Techniques.

3. RESEARCH GAP

The aspects of Business Process Modelling have been implicated in this paper. The importance of implementing digital business analysis has been discussed by analyzing the existing literature review on the business process modelling with implementation of AI, NLP and ML. Also, the role of automated and digital transformation in business operations have been implicated in this study. All the above mentioned literature review has explained the aspects of business process modelling. Therefore, this review has involved various discussions on the update on utilizing AI, ML and NLP in business process modelling. The present study analyses the impact of using

the mentioned automated process in business operations and the related literature review on application and impact of these automated systems helps in filling the gap. The table represented below helps in finding the research gap:

Table 1

S.No	Author	Year	Research Finding	Research Gap/Issues	Future Recommendations
1.	Chen et al.,	2020	Seek the potential of applying AI in physical classroom settings. Spare efforts to recognize detailed entailment relationships between learners' answers and the desired conceptual understanding within intelligent tutoring systems ng process; and 6) closely incorporate	Absence of comprehensive review on the increasing importance of Artificial Intelligence in Education (AIED). Lack of studies that both employ AI technologies and engage deeply with educational theories.	Understanding important topics and future directions concerning AIED research. The practical application of this study as it offers essential information to better understand the most concerning issues in AIED.
			the application of AI technologies with educational theories.		

2.	Mathews	2019	Representati on of three classification tasks by making use of LIME (Local Interpretable ModelAgnos tic Explanations) to explain predictions of deep learning models. LIME attempts to make these complex models at least partly understandab le by evaluating using three classification tasks.	no information is provided about what exactly causes Deep learning algorithms to arrive at their predictions. Limitation concerning the effectiveness of machine learning by the machine's current inability to explain its decisions and actions to human users.	Interpretabili ty could contribute to the design of more accurate and efficient classifiers, not only by inspecting and leveraging the input space's relevance, but also through the analysis of intermediate relevance values
3.	Schmidt et al.,	2019	How active learning and surrogate- based optimization can be applied to improve the rational design process and related	Lack of appropriate witness regarding explosion of works that develop and apply machine learning to solid-state systems.	Machine learning algorithms will certainly shape materials science for the years to come. Efficient statistical tools will be

			examples of applications. The different facets of interpretability and their importance in materials science.		capable of speeding up considerably both fundamental and applied research.
4.	Wei & Zou	2016	Conduction of comprehensive survey of recent computational methods, especially machine learning-based methods, for protein fold recognition.	With increasing numbers of proteins, the use of experimental techniques to determine protein folding is extremely difficult because these techniques are time consuming and expensive.	Assist researchers in their pursuit to systematically understand the computational recognition of protein folds.
5.	Nguyen et al.,	2019	Representation of recent time-slide comprehensive overview with comparisons as well as trends in development and usage of cutting-edge Artificial Intelligence software. Overview of massive parallelism support that is capable of scaling	While the number of Machine Learning algorithms is extensive and growing, their implementations through frameworks and libraries is also extensive and growing too. This has evolved the complexity in the community	Evolving myriad of frameworks, libraries, tools and approaches from divergent Machine Learning and Deep Learning user communities in different applicable areas.

			computation effectively and efficiently in the era of Big Data.	of software systems. Domain knowledge is not sufficient to tackle complex problems.	
6.	Wahl et al.,	2018	Overview of AI and how it can be used to improve health outcomes in resource- poor settings. Description of some of the current ethical debates around patient safety and privacy.	Lack of limited examples of AI being used in resource- poor settings. Involvement of health system hurdles in resource- poor settings.	Further research and investments in the development of AI tools tailored to resource- poor settings will accelerate realising the full potential of AI for improving global health.

4. FINDINGS AND DISCUSSIONS

The existing literature on the implementation of AI, NLP and ML in business process modelling has helped in fulfilling the major research gap as mentioned above. This review paper aims for analyzing the various applications of AI, NLP and ML in enhancing the business process by evaluating the business process modelling for the appropriate growth of the business in the market. These technologies have significant and positive impact on the business operational processes. The efficiencies in the operational activities and reduction of higher cost had led to developing a good decision making process along with fulfilling the customer's expectations and needs. These techniques have been effective in automating the operational tasks that are manually done with greater efficiency along with reduction of errors while offering valuable insights into the complexed and massive data being generated for execution. Also, these techniques have been effective in transforming the digitalized generation by implementing dynamic changes into the business system that proves to be effective in driving the next-generation flexible environment. These techniques have been found to be majorly involved in elimination of repetitive tasks, enabling more accurate and creative problem-solving skills, increasing the productivity in the business without increasing the workforce in the operational activities. But most of the efficiency has been observed in reduction of errors and improving the operational process in the organization with cost-efficiency. Hence, this results in development of effective business for enhancing its growth in the market with less reactive and more proactive along with better decision making for future and improving the customers' experiences. Some of the findings can be represented as constructive findings by analyzing the literature review and research gap:

- The NLP and AI based systems have been found efficient for the types of applications based on other neural network architectures involving character-based or recurrent network classifiers, or on other types of classification problems (e.g., sentiment analysis). The interpretability has contributed towards the designing of more appropriate and efficient classifiers. Hence, all these have majorly contributed to better understanding of deep network processing, deep network representation, and system-level explanation production.
- Adoption of AI among the value chains involving startups, private sector, PSUs and government entities have been found to be efficient in creating an ethical cycle of supply and demand in the organization. This adoption has involved the providence of accessing good infrastructure, fostering innovation through research and creating the demand by seeking solutions for addressing various needs among the organizations.
- The applications of AI, NLP and ML have benefited the high-income countries, mainly in enhancing the healthcare ecosystems. Advancement in these systems have resulted in strengthening the impact of digitized health technologies in resource-poor settings.
- The impact of new computing resources and techniques combined with an increasing avalanche of large datasets is transforming many research areas. This evolution involves several different faces, components and contexts. Machine Learning and Deep Learning have been considered as major research areas in computer science dealing with constant developments involving advancement in data analysis research in the Big Data era. This work provides the comprehensive survey with detailed comparisons of popular frameworks and libraries that exploit large-scale datasets.

5. CONCLUSION

The present study involves the analysis of the various applications of AI, NLP and ML on the business process modelling in any organization. These techniques are the part of the digital technologies that help in interconnecting the machines with the computer system for analyzing the complex form of data and evolving accurate results from with lower chances of error occurrence. Natural language Processing (NLP) and Machine Learning (ML) has been considered as an important advancement in information technology and its specific feature involves the interaction of machines with the human language. The combination of NLP and ML results in creation of a system that is capable of performing tasks on its own and gets improved according to their experience in the operational domain. The tools associated with these advanced technologies helps in classifying the system analysis by sentiments along with extracted name entities involving the business emails and other related stuff. Pre-trained models and development of customized solutions to huge business problems have been evolved by using advanced and digitalized technologies. These techniques use various tools as the support system for efficient operation activities to be carried out while performing the organizational tasks. Hence, all these effective use of automated techniques helps in identifying the process in the business for enhancing the business growth for better results.

REFERENCES

- [1] Schwab, K., 2016. *Die vierte industrielle Revolution*. Pantheon Verlag.
- [2] Atiker, Ö., 2017. *In einem Jahr digital: das Praxishandbuch für die digitale Transformation Ihres Unternehmens*. John Wiley & Sons.
- [3] <http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act> Accesed 2015
- [4] <http://ipt.ch/digitalisierung-mit-prozessautomatisierung-beginnen/> Accesed 2016

- [5] Paschek, D., Luminosu, C.T. and Draghici, A., 2017. Automated business process management–in times of digital transformation using machine learning or artificial intelligence. In *MATEC Web of Conferences* (Vol. 121, p. 04007). EDP Sciences.
- [6] Paschek, D., Ivascu, L. and Draghici, A., 2018. Knowledge management–the foundation for a successful business process management. *Procedia-Social and Behavioral Sciences*, 238, pp.182-191.
- [7] Schmelzer, H.J. and Sesselmann, W., 2020. *Geschäftsprozessmanagement in der Praxis: Kunden zufrieden stellen-Produktivität steigern-Wert erhöhen*. Carl Hanser Verlag GmbH Co KG.
- [8] Bell, J., 2020. *Machine learning: hands-on for developers and technical professionals*. John Wiley & Sons.
- [9] IIBA, K.B., 2009. *A Guide to the Business Analysis Body of Knowledge*. International Institute of Business Analysis.
- [10] Lorica, B. and Paco, N., 2018. *The State of Machine Learning Adoption in the Enterprise*. O'Reilly Media.
- [11] Landset, S., Khoshgoftaar, T.M., Richter, A.N. and Hasanin, T., 2015. A survey of open source tools for machine learning with big data in the Hadoop ecosystem. *Journal of Big Data*, 2(1), p.24.
- [12] von Rosing, M., Foldager, U., Hove, M., von Scheel, J. and Bøgebjerg, A.F., 2015. Working with the Business Process Management (BPM) Life Cycle.
- [13] Hammer, M. and Champy, J., 2009. *Reengineering the Corporation: Manifesto for Business Revolution*, A. Zondervan.
- [14] Pinggera, J., Soffer, P., Fahland, D., Weidlich, M., Zugel, S., Weber, B., Reijers, H.A. and Mendling, J., 2015. Styles in business process modeling: an exploration and a model. *Software & Systems Modeling*, 14(3), pp.1055-1080.
- [15] Lu, R. and Sadiq, S., 2007, April. A survey of comparative business process modeling approaches. In *International Conference on Business Information Systems* (pp. 82-94). Springer, Berlin, Heidelberg.
- [16] Nagm-Aldeen, Y., Abdel-Fattah, M.A. and El-Khedr, A., 2015. A literature review of business process modeling techniques. *International Journal*, 5(3).
- [17] Johansson, L.O., Wärrja, M. and Carlsson, S., 2012. An evaluation of business process model techniques, using Moody's quality criterion for a good diagram. In *BIR 2012: Emerging Topics in Business Informatics Research 2012, Nizhny Novgorod, Russia, September 24-26, 2012* (Vol. 963, pp. 54-64).
- [18] Rheinisch-Westfaelische Technische Hochschule Aachen, Lehrstuhl Informatik V. de Oca, I.M.M., Snoeck, M., Reijers, H.A. and Rodríguez-Morffi, A., 2015. A systematic literature review of studies on business process modeling quality. *Information and Software Technology*, 58, pp.187-205.
- [19] Liu, C., Li, Q. and Zhao, X., 2009. Challenges and opportunities in collaborative business process management: Overview of recent advances and introduction to the special issue. *Information Systems Frontiers*, 11(3), pp.201-209.
- [20] Aguilar, E.R., Ruiz, F., García, F. and Piattini, M., 2006, April. Evaluation measures for business process models. In *Proceedings of the 2006 ACM symposium on Applied computing* (pp. 1567-1568).
- [21] Simões, D., Antunes, P. and Cranefield, J., 2016. Enriching knowledge in business process modelling: a storytelling approach. In *Innovations in Knowledge Management* (pp. 241-267). Springer, Berlin, Heidelberg.

- [22] J. Bollen and H. Mao, "Twitter Mood as a Stock Market Predictor," *Computer*, vol. 44, no. 10, 2011, pp. 91–94.
- [23] O'Leary, D. E. (2013). Artificial intelligence and big data. *IEEE intelligent systems*, 28(2), 96-99.
- [24] Spangler, S., Chen, Y., Proctor, L., Lelescu, A., Behal, A., He, B., & Davis, T. (2009). COBRA–Mining web for corporate brand and reputation analysis. *Web Intelligence and Agent Systems: An International Journal*, 7(3), 243-254.
- [25] O'Leary, D. E. (2012). Knowledge discovery for continuous financial assurance using multiple types of digital information. *Available at SSRN 2118808*.
- [26] Dean, J. (2017, December). Machine learning for systems and systems for machine learning. In *Presentation at 2017 Conference on Neural Information Processing Systems*.
- [27] Buczak, A. L., & Guven, E. (2015). A survey of data mining and machine learning methods for cyber security intrusion detection. *IEEE Communications surveys & tutorials*, 18(2), 1153-1176.
- [28] Bkassiny, M., Li, Y., & Jayaweera, S. K. (2012). A survey on machine-learning techniques in cognitive radios. *IEEE Communications Surveys & Tutorials*, 15(3), 1136-1159.
- [29] Alsheikh, M. A., Lin, S., Niyato, D., & Tan, H. P. (2014). Machine learning in wireless sensor networks: Algorithms, strategies, and applications. *IEEE Communications Surveys & Tutorials*, 16(4), 1996-2018.
- [30] Mitchell, R. S., Michalski, J. G., & Carbonell, T. M. (2013). *An artificial intelligence approach*. Berlin: Springer.
- [31] Xiao, C., Yang, D., Chen, Z., & Tan, G. (2017). 3-D BLE indoor localization based on denoising autoencoder. *IEEE Access*, 5, 12751-12760.
- [32] Räsänen, O. J., & Saarinen, J. P. (2015). Sequence prediction with sparse distributed hyperdimensional coding applied to the analysis of mobile phone use patterns. *IEEE transactions on neural networks and learning systems*, 27(9), 1878-1889.
- [33] Puppala, M., He, T., Chen, S., Ogunti, R., Yu, X., Li, F., ... & Wong, S. T. (2015). METEOR: an enterprise health informatics environment to support evidence-based medicine. *IEEE Transactions on Biomedical Engineering*, 62(12), 2776-2786.
- [34] Adesina, A. O., Agbele, K. K., Abidoye, A. P., & Nyongesa, H. O. (2014). Text messaging and retrieval techniques for a mobile health information system. *Journal of information science*, 40(6), 736-748.
- [35] Shah, U. S., & Jinwala, D. C. (2015). Resolving ambiguities in natural language software requirements: a comprehensive survey. *ACM SIGSOFT Software Engineering Notes*, 40(5), 1-7.
- [36] Gatt, A., & Krahmer, E. (2018). Survey of the state of the art in natural language generation: Core tasks, applications and evaluation. *Journal of Artificial Intelligence Research*, 61, 65-170.
- [37] Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020). Application and theory gaps during the rise of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, 1, 100002.
- [38] Mathews, S. M. (2019, July). Explainable Artificial Intelligence Applications in NLP, Biomedical, and Malware Classification: A Literature Review. In *Intelligent Computing-Proceedings of the Computing Conference* (pp. 1269-1292). Springer, Cham.
- [39] Schmidt, J., Marques, M. R., Botti, S., & Marques, M. A. (2019). Recent advances and applications of machine learning in solid-state materials science. *npj Computational Materials*, 5 (1): 83.

- [40] Wei, L., & Zou, Q. (2016). Recent progress in machine learning-based methods for protein fold recognition. *International journal of molecular sciences*, 17(12), 2118.
- [41] Nguyen, G., Dlugolinsky, S., Bobák, M., Tran, V., García, Á. L., Heredia, I., & Hluchý, L. (2019). Machine Learning and Deep Learning frameworks and libraries for large-scale data mining: a survey. *Artificial Intelligence Review*, 52(1), 77-124.
- [42] Wahl, B., Cossy-Gantner, A., Germann, S., & Schwalbe, N. R. (2018). Artificial intelligence (AI) and global health: how can AI contribute to health in resource-poor settings?. *BMJ global health*, 3(4), e000798.