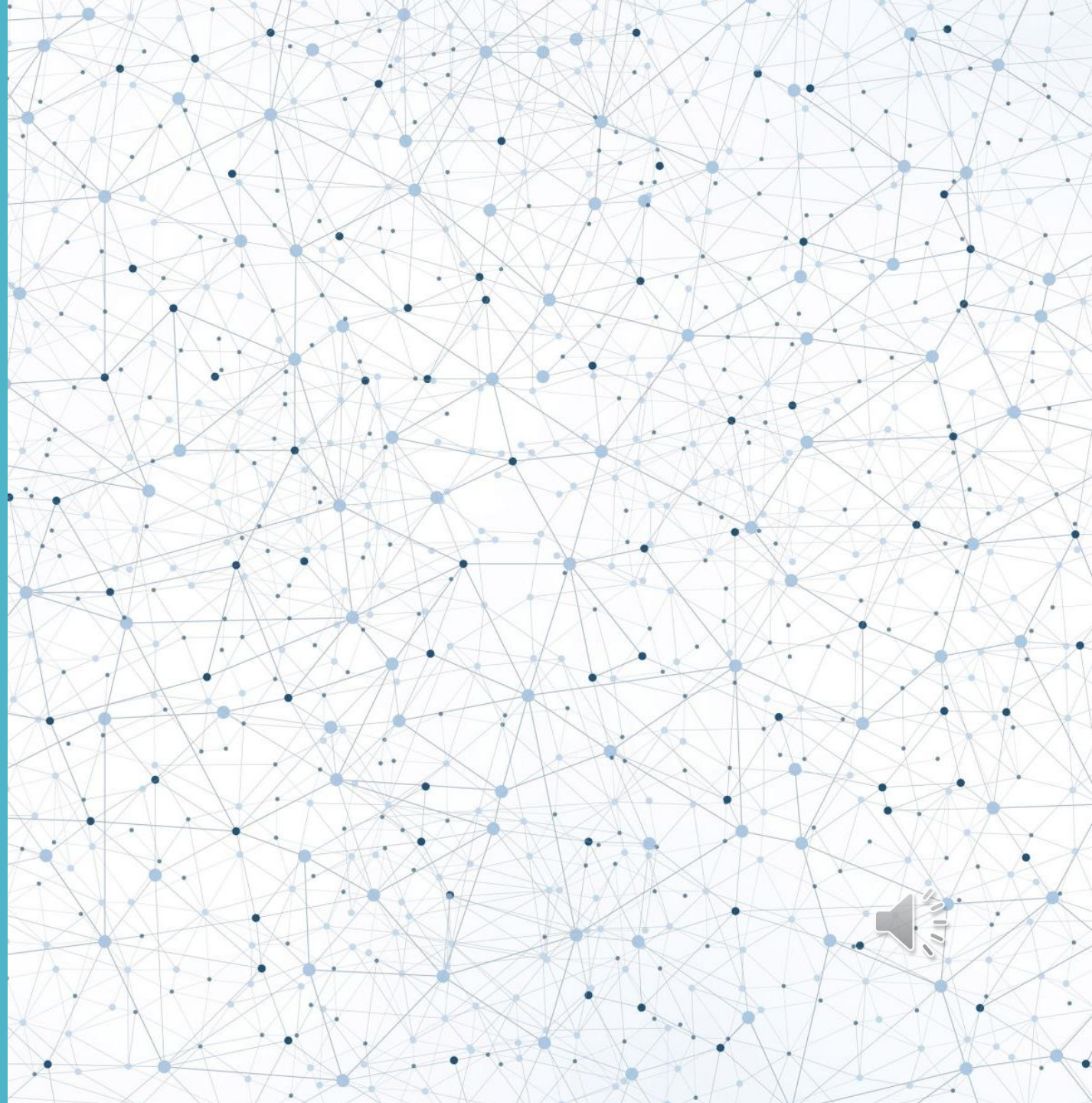
Efficient Implementation of Advanced Machine Learning Techniques for Context-Rich Sentiment Analysis

Ben Zapka
University of Essex Online
Research Methods and Professional Practice
Unit 10



Significance and Contribution to the Discipline

Significance:

- Sentiment analysis categorises text based on the emotional tone as positive, negative, or neutral (Ashbaugh and Zhang, 2024; Sakhdiah et al., 2024)
- It helps businesses track customer sentiment over time (Barunaha, Prakash and Naresh, 2023).
- Crucial in public opinion sensing, political discourse, and healthcare (Malik et al., 2022; Schmidt et al., 2022)
- Real-world use cases: Analysing customer feedback; monitoring social media (Wörner et al., 2022; Myint, Lo and Zhang, 2024)

Contribution to the Discipline:

- Advanced machine learning models achieve better accuracy than traditional techniques (Semary et al., 2023; Ashbaugh and Zhang, 2024).
- Machine learning algorithms can efficiently handle and analyse larger volumes of data (Kaur et at., 2021; Brandao et al., 2025).
- Integration of multiple data modalities, enabling a more holistic analysis of sentiment (Devi and Indira, 2024; Cai et al., 2025).
- Domain adaptability captures linguistic features and sentiment expressions for given contexts (Liu et al., 2019; He et al., 2021).

Research Challenges:

- Machine learning models often struggle to accurately interpret sarcasm and irony (Tan et al., 2023; Kumar, Dikshit and Albuquerque, 2021).
- Capturing the context in which a sentiment is expressed is crucial (Hu, Pan and Wang, 2024; Du, Li and Luo, 2021).
- The quality of training data significantly impacts model performance (Plisiecki et al., 2025; Wang et al., 2019).
- Extending sentiment analysis to multiple languages and across different domains (Miah et al., 2024; Krasitskii et al., 2024)

Research Question

How can advanced machine learning techniques, particularly transformer-based models, improve the accuracy, contextual understanding, and domain adaptability of sentiment analysis systems?

Aims and Objectives

Aim:

Implement and evaluate transformer-based machine learning models for improving sentiment analysis performance within a multi-domain context

Objectives:

1. Review of recent literature on machine learning in sentiment analysis
2. Sentiment analysis system based on fine-tuned transformer models
3. Apply domain adaptation techniques to enhance performance across domains
4. Benchmark performance against classical models to ensure robust evaluation (Rostami et al., 2023; Semary et al., 2023)
5. Complete evaluation, analysis, and deliver a deployable sentiment analysis pipeline along with a report

References for the structure and set-up of objectives: Kutzias et al. (2023); Chiesa and Sikder (2024)

Key Literature Related to the Project

Research Problem	Approach of the proposed study
Irony Detection	▪ Leverage fine-tuning of transformer-based models on irony detection (Van Hee et al., 2018) ▪ Incorporate contextual and pragmatic cues using multi-modal or meta-data enriched models (Grover and Banati, 2022)
Context-Awareness	▪ BERT (Devlin et al., 2019) and its successors (Liu et al., 2019; He et al., 2021) used to improve generalisability across domains
Domain Adaption	▪ Fine-tuning transformer models on domain-specific data can significantly improve their performance in capturing nuanced sentiments (Anwar et al., 2024; Bandaranayake and Usoof, 2025)
Multi Modality	▪ Has shown promise in enhancing sentiment analysis systems' ability to detect sarcasm and irony and general subtleties (Devi and Indira, 2024; Cai et al., 2025; Ahamad and Mishra, 2025)

Methodology and Research Design

Research Approach:

A hybrid agile and experimental approach will be used to facilitate the rapid implementation of models and iterative testing (Reiff and Schlegel, 2022; Tettey et al., 2025)

Phases:

Literature Review

- Inform model choices and identify gaps (Luft et al., 2022; Schmidt Goecks et al., 2021)

Data Selection

- Focused on secondary, numerical, and labeled data (SAGE, 2021; University of Liverpool Academic Skills, n. d.)
- Use of distinct domains (Ijaz et al., 2024; Rostami et al., 2023)

Model Development

- Fine-tuning of pre-trained transformers (Liu et al., 2019; He et al., 2021)
- Use of transfer learning, domain adaptation, and training optimisation (Fan, Luyi and Pengcheng, 2022)
- Design-oriented research (Thuan et al., 2023)

Benchmark Models

- Comparing new models against established baselines
- Control comparison strategy in experimental design (Willmington et al., 2022; Ashbaugh and Zhang, 2024)

Evaluation Metrics

- Accuracy, Precision, Recall, and F1-score are status quo for evaluating classifications (Ashbaugh and Zhang, 2024; Devi and Indira, 2024)
- Using them implies the “positivist epistemological stance” (Hicks et al., 2022; Mkansi and Mkalipi, 2023)

Ethical Considerations and Risk Assessment

Data Ethics:
Even with anonymised datasets, caution is mandatory (Khalid, Ahmed and Kim, 2023; Sung, Cha and Park, 2021).

Bias:
Explore potential biases in model outputs and document them following ethical guidelines (Mitchell et al., 2019).

Time Constraints:
Mitigated by focusing on pre-trained models and limiting domains to two
(Rostami et al., 2023; Arefyev, Kharchev and Shelmanov, 2021)

Computational Risks:
Cloud-based GPU services (Google Colab Pro) will be used to prevent delays due to hardware limitations
(Hakimi et al., 2024; Nama, Pattanayak and Meka, 2023).

Risk of Mistrust:
Be transparent about training processes and ensure explainability (Cheong, 2024; Habiba et al., 2024).

Potential Social Impact:
Sentiment analysis can have far-reaching societal consequences (Karoo and Chitte, 2023; Sanei, Cheng and Adams, 2021).

Timeline

Month 1	Focused literature review; select datasets; finalise research plan.
Month 2	Preprocessing datasets; implement baseline models.
Month 3	Fine-tune transformer model on primary domain data.
Month 4	Conduct domain adaptation and fine-tuning on secondary domain data.
Month 5	Model evaluation and comparison.
Month 6	Finalisation of all artifacts.

References for this timeline: University of Essex Online (2024); Kutzias et al. (2023); Chiesa and Sikder (2024)

Created Artifacts

- Sentiment analysis pipeline with a fine-tuned model for two domains
- Comparative performance report benchmarking the model’s performance
- Formal research report
- Jupyter Notebooks or a lightweight Python package

References: Kutzias et al. (2023); Chiesa and Sikder (2024)

List of References

- Ahamad, R. and Mishra, N. K. (2025) 'Exploring sentiment analysis in handwritten and E-text documents using advanced machine learning techniques: a novel approach', *Journal of Big Data* 12. Available at: https://journalofbigdata.springeropen.com/articles/10.1186/s40537-025-01064-2
- Anwar, Z., Afzal, H., Altaf, N., Kadry, S. and Kim, J. (2024) 'Fuzzy ensemble of fined tuned BERT models for domain-specific sentiment analysis of software engineering dataset', *PLOS ONE* 19(5). Available at: https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0300279
- Arefyev, N., Kharchev, D. and Shelmanov, A. (2021) 'NB-MLM: Efficient Domain Adaptation of Masked Language Models for Sentiment Analysis', *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pp. 9114-9124. Available at: https://aclanthology.org/2021.emnlp-main.717/
- Ashbaugh, L. and Zhang, Y. (2024) 'A Comparative Study of Sentiment Analysis on Customer Reviews Using Machine Learning and Deep Learning', *Computers* 13(12). Available at: https://www.mdpi.com/2073-431X/13/12/340
- Bandaranayake, I. and Usoof, H. (2025) 'Sentiment Analysis of Sinhala News Comments Using Transformers', *Proceedings of the First Workshop on Natural Language Processing for Indo-Aryan and Dravidian Languages*, pp. 74-82. Available at: https://aclanthology.org/2025.indonlp-1.9/
- Barunaha, A., Prakash, M. R. and Naresh, R. (2023) 'Real-Time Sentiment Analysis of Social Media Content for Brand Improvement and Topic Tracking', *Proceedings of the 6th International Conference on Intelligent Computing (ICIC-6 2023)*, pp. 26-31. Available at: https://www.atlantis-press.com/proceedings/icic-6-23/125993050
- Brandão, J. G., Castro Junior, A.P., Gomes Pacheco, V. M., Gonçalves Rodrigues, C., Oliveira Belo, O. M., Coimbra, A. P. and Calixto, W. P. (2025) 'Optimization of machine learning models for sentiment analysis in social media', *Information Sciences* 694. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0020025524016189
- Cai, Y., Li, X., Zhang, Y., Li, J., Zhu, F. and Rao, L. (2025) 'Multimodal sentiment analysis based on multi-layer feature fusion and multi-task learning', *Scientific Reports* 15. Available at: https://www.nature.com/articles/s41598-025-85859-6
- Cheong, B. C. (2024) 'Transparency and accountability in AI systems: safeguarding wellbeing in the age of algorithmic decision-making', *Frontiers in Human Dynamics* 6. Available at: https://www.frontiersin.org/journals/human-dynamics/articles/10.3389/fhumd.2024.1421273/full
- Chiesa, S. D. and Sikder, S. K. (2024) 'Rethinking Data Management Planning: Introducing Research Output Management Planning (ROMPi) Approach', *Data Science Journal* 23(34), pp. 1-7. Available at: https://datascience.codata.org/articles/1644/files/6656fc7830dab.pdf
- Devi, M. S. and Indira, B. (2024) 'Multimodal Sentiment Analysis using Multiple Neural Networks and Natural Language Processing Models', *International Journal of Intelligent Systems and Applications in Engineering* 12(4), pp. 2905-2910. Available at: https://www.ijisae.org/index.php/IJISAE/article/view/6774
- Devlin, J., Chang, M.-W., Lee, K. and Toutanova, K. (2019) 'BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding', *arXiv preprint*. Available at: https://arxiv.org/abs/1810.04805#:~:text=Unlike%20recent%20language%20representation%20models%2C%20BERT%20is%20designed,both%20left%20and%20right%20context%20in%20all%20layers.
- Du, M., Li, X. and Luo, L. (2021) 'A Training-Optimization-Based Method for Constructing Domain-Specific Sentiment Lexicon', *Complexity* 1. Available at: https://onlinelibrary.wiley.com/doi/10.1155/2021/6152494

List of References

- Fan, O., Luyi, Z. and Pengcheng, J. (2022) 'Artificial Intelligence in Online Higher Education: A Systematic Review of Empirical Research from 2011 to 2020', *Education and Information Technologies* 27(6), pp. 7893-7925. Available at: https://eric.ed.gov/?id=EJ1346186
- Grover, V. and Banati, H. (2022) 'Understanding the Sarcastic Nature of Emojis with SarcOji', *Proceedings of the Fifth International Workshop on Emoji Understanding and Applications in Social Media*, pp. 29-39. Available at: https://aclanthology.org/2022.emoji-1.4/
- Habiba, U., Habib, M. K., Bogner, J., Fritzsch, J. and Wagner, S. (2024) 'How do ML practitioners perceive explainability? an interview study of practices and challenges', *Empirical Software Engineering* 30. Available at: https://link.springer.com/article/10.1007/s10664-024-10565-2
- Hakimi, M., Amiri, G. A., Jalalzai, S., Darmel, F. A. and Ezam, Z. (2024) 'Exploring the Integration of AI and Cloud Computing: Navigating Opportunities and Overcoming Challenges', *TIERS Information Technology Journal* 5(1), pp. 57-69. Available at: https://www.researchgate.net/publication/383465131_Exploring_the_Integration_of_AI_and_Cloud_Computing_Navigating_Opportunities_and_Overcoming_Challenges
- He, P., Liu, X. Gao, J. and Chen, W. (2021) 'DeBERTa: Decoding-enhanced BERT with Disentangled Attention', *arXiv preprint*. Available at: https://arxiv.org/abs/2006.03654
- Hicks, S. A., Strümke, I., Thambawita, V., Hammou, M., Riegler, M. A., Halvorsen, P. and Parasa, S. (2022) 'On evaluation metrics for medical applications of artificial intelligence', *Scientific Reports* 12(1). Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC8993826/
- Hu, F., Pan, J. and Wang, H. (2024) 'Unveiling the spatial and temporal variation of customer sentiment in hotel experiences: a case study of Beppu City, Japan', *Humanities & Social Sciences Communications* 11. Available at: https://www.nature.com/articles/s41599-024-04226-4
- Ijaz, M., Anwar, N., Safran, M., Alfarhood, S., Sadad, T. and Imran (2024) 'Domain adaptive learning for multi realm sentiment classification on big data', *PLOS ONE* 19(4). Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC10984522/
- Karoo, K. and Chitte, V. (2023) 'Ethical Considerations in Sentiment Analysis: Navigating the Complex Landscape', *International Research Journal of Modernization in Engineering Technology and Science* 5(11), pp. 2991-3006. Available at: https://www.irjmets.com/uploadedfiles/paper/issue_11_november_2023/46811/final/fin_irjmets1701254801.pdf
- Kaur, H., Ahsaan, S. U., Alankar, B. and Chang, V. (2021) 'A Proposed Sentiment Analysis Deep Learning Algorithm for Analyzing COVID-19 Tweets', *Information Systems Frontiers* 23, pp. 1417-1429. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC8057010/
- Khalid, M. I., Ahmed, M. and Kim, J. (2023) 'Enhancing Data Protection in Dynamic Consent Management Systems: Formalizing Privacy and Security Definitions with Differential Privacy, Decentralization, and Zero-Knowledge Proofs', *Sensors* 23(17). Available at: https://www.mdpi.com/1424-8220/23/17/7604
- Krasitskii, M., Kolesnikova, O., Hernandez, L. C., Sidorov, G. and Gelbukh, A. (2024) 'Multilingual Approaches to Sentiment Analysis of Texts in Linguistically Diverse Languages: A Case Study of Finnish, Hungarian, and Bulgarian', *Proceedings of the 9th International Workshop on Computational Linguistics for Uralic Languages*, pp. 49-58. Available at: https://aclanthology.org/2024.iwclul-1.6/
- Kumar, A., Dikshit, S. and Albuquerque, V. H. C. (2021) 'Explainable Artificial Intelligence for Sarcasm Detection in Dialogues', *Wireless Communications and Mobile Computing*. Available at: https://onlinelibrary.wiley.com/doi/10.1155/2021/2939334
- Kutzias, D., Dukino, C., Kötter, F. and Kett, H. J. (2023) 'Comparative Analysis of Process Models for Data Science Projects', *ICAART 2023, 15th International Conference on Agents and Artificial Intelligence* 3. Available at: https://publica.fraunhofer.de/entities/publication/e969c73a-c9a8-414a-ba85-0ee2292d97f6

List of References

- Liu, Y., Ott, M., Goyal, N., Du, J., Joshi, M., Chen, D., Levy, O., Lewis, M., Zettlemoyer, L. and Stoyanov, V. (2019) 'RoBERTa: A Robustly Optimized BERT Pretraining Approach', *arXiv preprint*. Available at: https://www.semanticscholar.org/paper/RoBERTa%3A-A-Robustly-Optimized-BERT-Pretraining-Liu-Ott/077f8329a7b6fa3b7c877a57b81eb6c18b5f87de
- Luft, J. A., Jeong, S., Idsardi, R. and Gardner, G. (2022) 'Literature Reviews, Theoretical Frameworks, and Conceptual Frameworks: An Introduction for New Biology Education Researchers', *CBE Life Sciences Education* 21(3). Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC9582830/
- Malik, T., Tahir, A., Bilal, A., Dashtipour, K., Imran, M. A. and Abbasi, Q. H. (2022) 'Social Sensing for Sentiment Analysis of Policing Authority Performance in Smart Cities', *Frontiers in Communications and Networks* 2. Available at: https://www.frontiersin.org/journals/communications-and-networks/articles/10.3389/frcmn.2021.821090/full
- Miah, S. U., Kabir, M., Bin Sarwar, T., Safran, M., Alfarhood, S. and Mridha, M. F. (2024) 'A multimodal approach to cross-lingual sentiment analysis with ensemble of transformer and LLM', *Scientific Reports* 14. Available at: https://www.nature.com/articles/s41598-024-60210-7
- Mitchell, M., Wu, S., Zaldivar, A., Barnes, P., Vasserman, L., Hutchinson, B., Spitzer, E., Raji, I. D. and Gebru, T. (2019) 'Model Cards for Model Reporting', *Proceedings of the Conference on Fairness, Accountability, and Transparency*, pp.220-229. Available at: https://dl.acm.org/doi/10.1145/3287560.3287596
- Mkansi, M. and Mkalipi, N. (2023) 'Natural Language Processing and Machine Learning Approach to Teaching and Learning Research Philosophies and Paradigms', *The Electronic Journal of Business Research Methods* 21(1), pp. 14-30. Available at: https://www.researchgate.net/publication/371593086_Natural_Language_Processing_and_Machine_Learning_Approach_to_Teaching_and_Learning_Research_Philosophies_and_Paradigms
- Myint, P. Y. W., Lo, S. L. and Zhang, Y. (2024) 'Unveiling the dynamics of crisis events: Sentiment and emotion analysis via multi-task learning with attention mechanism and subject-based intent prediction', *Information Processing & Management* 61(4). Available at: https://www.sciencedirect.com/science/article/pii/S0306457324000554
- Nama, P., Pattanayak, S. and Meka, H. S. (2023) 'AI-Driven Innovations in Cloud Computing: Transforming Scalability, Resource Management, and Predictive Analytics in Distributed Systems', *International Research Journal of Modernization in Engineering Technology and Science* 5(12), pp. 4165-4174. Available at: https://www.irjmets.com/uploadedfiles/paper/issue_12_december_2023/47900/final/fin_irjmets1728654918.pdf
- Plisiecki, H., Lenartowicz, P., Flakus, M. and Pokropek, A. (2025) 'High risk of political bias in black box emotion inference models', *Scientific Reports* 15. Available at: https://www.nature.com/articles/s41598-025-86766-6
- Reiff, J. and Schlegel, D. (2022) 'Hybrid project management – a systematic literature review', *International Journal of Information Systems and Project Management* 10(2), pp. 45-63. Available at: https://ijispm.sciencesphere.org/archive/ijispm-100203.pdf
- Rostami, M., Bose, D., Narayanan, S. and Galstyan, A. (2023) 'Domain Adaptation for Sentiment Analysis Using Robust Internal Representations', *Findings of the Association for Computational Linguistics*: EMNLP 2023, pp. 11484-11498. Available at: https://aclanthology.org/2023.findings-emnlp.769/
- SAGE (2021) SAGE Research Methods: Methods Map. Available at: https://methods.sagepub.com/methods-map/ (Accessed: 30 March 2025)
- Sakhdiah, M., Salma, A., Permana, D. and Fitria, D. (2024) 'Sentiment Analysis Using Support Vector Machine (SVM) of ChatGPT Application Users in Play Store', *UNP Journal of Statistics and Data Science* 2(2). Available at: https://ujsds.ppj.unp.ac.id/index.php/ujsds/article/view/158
- Sanei, A. Cheng, J. and Adams, B. (2021) 'The Impacts of Sentiments and Tones in Community-Generated Issue Discussions', *International Conference on Connected Health: Applications, Systems and Engineering Technologies*. Available at: https://www.semanticscholar.org/paper/The-Impacts-of-Sentiments-and-Tones-in-Issue-Sanei-Cheng/6f5adcf56de1c911b42de307a2f99d058dbde6b5

List of References

- Schmidt, T., Fehle, J., Weissenbacher, M., Richter, J., Gottschalk, P. and Wolff, C. (2022) 'Sentiment Analysis on Twitter for the Major German Parties during the 2021 German Federal Election', *Proceedings of the 18th Conference on Natural Language Processing (KONVENS 2022)*, pp. 74-87. Available at: https://aclanthology.org/2022.konvens-1.9/
- Schmidt Goecks, L., de Souza, M., Pereira Librelato, T. and Trento, L. R. (2021) 'Design Science Research in practice: review of applications in Industrial Engineering', *Gestão & Produção* 28(4). Available at: https://www.scielo.br/j/gp/a/6kbDqBTfTgCt7WHKjTqxJbn/?format=pdf
- Semary, N. A., Ahmed, W., Amin, K., Pławiak, P. and Hammad, M. (2023) 'Improving sentiment classification using a RoBERTa-based hybrid model', *Frontiers in Human Neuroscience* 17. Available at: https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2023.1292010/full
- Sung, M., Cha, D. and Park, Y. R. (2021) 'Local Differential Privacy in the Medical Domain to Protect Sensitive Information: Algorithm Development and Real-World Validation', *JMIR Medical Informatics* 9(11). Available at: https://pubmed.ncbi.nlm.nih.gov/34747711/
- Tan, Y. Y., Chow, C.-O., Kanesan, J., Chuah, J. H. and Lim, Y. (2023) 'Sentiment Analysis and Sarcasm Detection using Deep Multi-Task Learning', *Wireless Personal Communications* 129(3), pp. 2213-2237. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC9985100/
- Tettey, D. J., Sunday, O. E., Azumah, N. C., Peter, N. N. C., Oluwatobi, B. T. & Chrisben, D. (2025) 'Agile Hybrid Methodologies for Complex Project Execution: Balancing Flexibility, Control, and Stakeholder Value Maximization.', *International Journal of Research Publication and Reviews* 6(3), pp. 6190-6204. Available at: https://ijrpr.com/uploads/V6ISSUE3/IJRPR40505.pdf
- Thuan, N. H., Tate, M., Drechsler, A. and Antunes, P. (2023) 'Special Edition Editorial: Introduction to Design Science Education', *Journal of Information Systems Education* 34(3), pp. 256-263. Available at: https://aisel.aisnet.org/jise/vol34/iss3/1/
- University of Essex Online (2024) Postgraduate 2025 Dissertation. Available at: https://www.my-course.co.uk/mod/page/view.php?id=1012042 (Accessed: 05 April 2025)
- University of Liverpool Academic Skills (n.d.) Introduction to research methods and methodologies. Available at: https://www.youtube.com/watch?v=nv7MOoHMM2k (Accessed: 30 March 2025)
- Van Hee, C., Lefever, E. and Hoste, V. (2018) 'SemEval-2018 Task 3: Irony Detection in English Tweets', *Proceedings of The 12th International Workshop on Semantic Evaluation*, pp. 39-50. Available at: https://www.researchgate.net/publication/325447252_SemEval-2018_Task_3_Irony_Detection_in_English_Tweets
- Wang, H., Liu, B., Li, C., Yang, Y. and Li, T. (2019) 'Learning with Noisy Labels for Sentence-level Sentiment Classification', *Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP)*. Available at: https://aclanthology.org/D19-1655/
- Willmington, C., Belardi, P., Murante, A. M. and Vainieri, M. (2022) 'The contribution of benchmarking to quality improvement in healthcare. A systematic literature review', *BMC Health Services Research* 22(1). Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC8812166/
- Wörner, J., Konadl, D., Schmid, I. and Leist, S. (2022) 'Supporting Product Development by a Trend Analysis Tool Applying Aspect-Based Sentiment Detection', *The Transdisciplinary Reach of Design Science Research*, pp. 68-80. Available at: https://link.springer.com/chapter/10.1007/978-3-031-06516-3_6