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Bridging Gaps with AI: From Web to Healthcare Information Systems at York University

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I. CONTEXT

The Information Retrieval and Knowledge Management Lab at York University is a top-notch research group that focuses on a range of important fields. We work on finding and organizing information, like searching for people or data, especially in big datasets. Our expertise spans various areas including health informatics, analyzing text and websites, computer vision, and understanding human languages with computers. We're committed to advancing knowledge and developing practical solutions in these vital areas of research.

II. MISSION & RESEARCH FOCUS

The Research Lab for Information Retrieval and Knowledge Management at York University is committed to shaping the future of how we interact with and understand the ever-growing sea of data. Our mission is multifaceted:

- Creating statistical models and machine learning methods that make finding information efficient and accurate.
- Tackling big data challenges to pull out useful details and patterns.
- Improving how the web gives you information based on your current situation or what you need at the moment.
- Searching through medical documents to get valuable information that can help in healthcare.
- Pulling precise information from very large data sets quickly and accurately.
- Working with different languages, including Chinese, to find and share information.
- Looking at search data to make search engines work better.

- Providing data-backed tools to help healthcare providers offer customized care.

III. PROJECTS AND ACHIEVEMENTS

A. Current Projects

1) Validating the Evaluations of Large Language Models: An Opinion Piece based on a Systematic Survey: Our lab is currently engaged in a thorough examination of Large Language Models (LLMs). Given their growing popularity and their expanding role across various sectors, there is a pressing need for a more nuanced evaluation of these models. This project aims to move beyond traditional benchmarks like MMLU, PIQA, SIQA, HumanEval, and ELO, which might not fully reflect the true performance and limitations of LLMs. We are conducting a comprehensive review that scrutinizes how LLMs function in both general and specialized scenarios, paying particular attention to the variety of examples used and the types of tasks given to ensure a robust assessment of models. We're also evaluating the correlation between standard evaluation metrics and the practical usefulness of LLMs, particularly in terms of processing speed, memory usage, and accuracy. Additionally, our research is investigating the reliability of scripts used to evaluate responses generated by LLMs and examining potential biases when LLMs are utilized as part of the evaluation process. The project is geared towards charting new courses for LLM benchmarking, calling for inventive metrics, analyses of data integrity, and relevance to real-world applications.

Expected Outcome: The anticipated outcome of this project is the publication of our findings in both peer-reviewed conferences and journal papers. Our goal is to contribute meaningful insights toward the ongoing discourse on LLMs, helping to shape the development of more effective and equitable models for future research and application

2) The Evolution of Re-identification Technologies: From Early Approaches to LLM Integration: Our present work centers on tracing the evolution of Re-identification (ReID) technologies from their inception to the present day. Starting with the foundational non-deep learning methods that used basic features and matching algorithms, our study documents the evolution to sophisticated deep learning approaches and the subsequent integration of LLMs. The initial stage of ReID technologies, which relied on handcrafted features, faced significant limitations due to variable factors like changes in lighting and pose. The emergence of deep learning propelled the field into a new era where neural networks could learn intricate and representative features from data, enhancing the precision and robustness of ReID systems. Now, by integrating LLMs, ReID technologies embark on a new phase. This combination promises to enhance the identification process by bringing in a more profound understanding of context and a flexible interaction mechanism. Our comprehensive review not only addresses key developments and challenges but also considers the potential transformative impacts of current trends on the future of ReID technologies.

Expected Outcome: The expected deliverable of this in-depth study is a detailed exposition of our findings, to be shared with the academic community through peer-reviewed conferences and journal publications. Our objective is to

offer a substantive contribution to the field of ReID technologies by providing a clear understanding of its historical progression and anticipating future advancements, which may further redefine this technological domain.

B. Past Achievement

1) Leveraging Large Language Models across Diverse Domains: An Integrated Evaluation and Application Framework: The rapid advancement of artificial intelligence (AI) and LLMs like ChatGPT has opened new frontiers in computational research, spanning from natural language processing (NLP) to biomedical text analysis and information retrieval. This comprehensive collection of studies provides an in-depth evaluation of ChatGPT and other LLMs across a spectrum of computational tasks and datasets, highlighting the models' capabilities and limitations, along with novel applications. Our first study undertakes a detailed examination of Chat-GPT's performance on 140 diverse NLP tasks, marking the most extensive assessment in benchmark academic datasets. We uncover strengths, weaknesses, and emergent abilities in multi-query instruction, offering valuable insights for future LLM utilization. Subsequently, we explore LLMs' prowess in the biomedical domain, presenting the first thorough comparison in this area across 26 datasets and 6 tasks. Results suggest that zero-shot LLMs can sometimes surpass state-of-the-art models in datasets with smaller training sets, indicating pretraining's significant impact on domain specialization.

Another study investigates the potential of LLMs, specifically ChatGPT and PaLM, in correcting data annotation errors within the Debatepedia dataset. From this, the study proposes a hybrid approach of rule-based sampling and LLM query regeneration for enhanced dataset quality. Additionally, we examine ChatGPT's role in revolutionizing information retrieval (IR) by identifying the model's unique contributions in the field, and the ensuing challenges and opportunities. Finally, a zero-shot comparison of ChatGPT with fine-tuned generative transformers in biomedical tasks demonstrates ChatGPT's unexpected su-

periority in contexts with limited annotated data. Together, these studies not only underscore the transformative potential of LLMs across various disciplines, but also chart a course for leveraging their capabilities in addressing complex computational challenges. This will pave the way for innovative applications and methodologies in AI-driven research.

2) Advancements in BERT Applications: Bridging Information Retrieval, Semantic Analysis, and Biomedical Text Mining: The transformative impact of Bidirectional Encoder Representations from Transformers (BERT) across various Natural Language Processing (NLP) challenges has prompted a surge in innovative applications, from IR to semantic analysis, to advanced uses in biomedical text mining. This project presents a holistic examination of BERT's versatility and efficacy in addressing complex NLP problems. Our first investigation surveys the application of BERT in IR, categorizing techniques into six pivotal areas, including handling long documents and integrating semantic information. It highlights BERT's advantage in encoder-based tasks over decoder-based models like LLMs, underscoring its efficiency and effectiveness. Another study introduces a probabilistic framework that integrates sentence-level semantics via BERT into pseudo-relevance feedback for query expansion, demonstrating significant improvements in query relevance and semantic consistency. Furthermore, we explore Bert-QAnet, a novel model that leverages BERT's encoding capabilities for detecting duplicate questions in Community question-answering platforms through sophisticated cross-attention mechanisms. This approach excels in utilizing semantic information at both word and sentence levels, achieving unprecedented accuracy. Lastly, our review of BERT's applications in biomedical and clinical text mining categorizes models into pretrained and fine-tuned frameworks, with each discussing contributions, datasets, and potential research directions. This comprehensive review not only underscores BERT's transformative role across diverse domains but also sets a foundation for future explorations, aiming to harness and refine BERT's capabilities for complex NLP

tasks. In turn, this will foster the development of more advanced, efficient, and contextually aware NLP models.

3) Enhancing User-System Interaction: Integrative Strategies for Conversational Search and Product Discovery: The intersection of NLP technology and conversational systems has ushered in a new era of human-machine interaction, notably through Conversational Search Systems (CSS) such as chatbots and Virtual Personal Assistants like Siri, Alexa, Cortana, and Google Assistant. These systems offer immense potential for transforming the way users search for information and products online. However, they face significant challenges, particularly in interpreting ambiguous user queries and predicting intent accurately for effective IR and product discovery. This project explores innovative strategies for improving conversational interfaces in both search and e-commerce contexts. Our first study presents a comprehensive analysis of ambiguous query clarification tasks within CSS, highlighting various approaches to enhance query understanding and document retrieval. It emphasizes the critical role of disambiguating unclear queries to meet user needs effectively. In parallel, our second study introduces ConvPS, a novel model for conversational product search that leverages representation learning to integrate user, query, item, and conversation semantics. This model adopts greedy and explore-exploit strategies to refine user interactions, aiming to clarify product preferences through targeted questions. Together, these studies contribute to the development of conversational interfaces that are more intuitive, responsive, and capable of delivering personalized search experiences and product recommendations. This work lays the foundation for future advancements in conversational technology applications by addressing the challenges of query ambiguity and preference clarification.

4) Searching Beyond Traditional Probabilistic IR: Information Retrieval (IR) systems have traditionally been built on the assumption that search terms and documents are unrelated entities and that a document's relevance is determined without considering other documents. This approach can lead to redundancy and a lack of variety in

search outcomes. In recent years, our research has focused on developing new theoretical models to better understand the connections between terms and how to diversify search results. Since 2013, we've proposed several models aimed at identifying and leveraging the relationships between search terms, known as Cross Term associations, through our novel n-gram Cross Term Retrieval (CRTER) models. These models aim to enhance search accuracy and bring a richer variety to the results presented. To further support diversity in search results, particularly for biomedical searches, we have introduced survival modeling techniques. These techniques are designed to refine the ranking process, ensuring that a broader range of relevant documents is displayed. Our efforts have led to substantial improvements in probabilistic IR models, which we continue to refine to make them more robust. Our research has yielded excellent results, outperforming traditional methods and contributing significantly to industry practices, where our methods are being adopted by major tech companies. The innovative models we've developed have made a profound impact on IR, particularly within web searches and the biomedical field, and promise to enhance how we retrieve and interact with information in these domains.

5) Modeling and Mining Real-world Knowledge for Large-Scale Unstructured Text Analysis: Text analysis and the search for relevant questions in community question and answer (cQA) platforms have become critical due to the surge of user-generated content such as reviews and blogs. These analyses often face challenges stemming from the vast number of domains this data spans, making it hard to label and train models across all of them. Bridging the lexical gap between searched questions and archived questions is another obstacle in efficiently retrieving related questions.

To overcome these issues, we developed a specialized method to extract and apply domain knowledge across various sentiment analysis domains. This method uses a collaborative technique known as joint non-negative matrix factorization. One of the challenges in sentiment classification is that a model trained on data from one domain may underperform on data from another due to differences in language use. To tackle this, we introduced a novel domain adaptation method named Bi-Transferring Deep Neural Networks (BTDNNs). BTDNNs work by mapping data from the original domain to the target domain while also ensuring that data distribution remains consistent. This consistency is maintained through a linear transformation, which is further supported by a linear data reconstruction model. In the field of cQA, our focus is the lexical gap that often hinders question retrieval. To address this, we leveraged metadata from cQA pages, particularly category information, to train two innovative models, MB-NET and ME-NET. These models are adept at understanding word distribution and significantly mitigate the issue of the lexical gap. This approach improves the ability to find previously asked questions that are semantically similar to the new queries, enhancing the relevance of search results in cQA systems.

6) Context Modeling for Boosting Traditional and Neural IR: Context-based IR has attracted much attention in both academia and industry. We first proposed a time-aware kernel density estimation method to characterize the fine-grained word-level temporal relevance for Microblog search, with this work published in TKDE'18. We also proposed a context-aware topic model that mined the query topics from the pseudo-relevant contextual snippets to satisfy topic match. To effectively and efficiently apply topical information, we proposed a novel probabilistic framework TopPRF via integrating our new concept of Topic Space into pseudo-relevance feedback (PRF). Our proposed ideas demonstrate excellent results and provide a promising avenue for constructing better Topic Space based IR systems (e.g. context-aware and topic-sensitive query representations), which are capable of searching documents beyond traditional term matching.

Moreover, we investigated two new context modeling approaches to boost neural IR, motivated by the great success of deep learning in recent years. We first proposed a context-aligned RNN model (CA-RNN) that integrated a con-text alignment gating to enhance question answering and paraphrase identification, with this work published in AAAI'18. It was the first work to embed a context alignment gating mechanism in RNNs, marking a unique contribution. Following this, we proposed a collaborative and adversarial network (CAN) and published it in SIGIR'18. This was the first work to extract common contextual features for sentence similarity modeling by building a generator and a discriminator to play a collaborative and adversarial game for common features extraction. It was also the first attempt to explicitly model the common features by incorporating collaborative learning into the GAN framework. In addition, we proposed a positional attention mechanism to incorporate the positional context of the question words into the answers' attentive representations, as published in SIGIR'17.

7) Modeling Feature-based Medical IR: Text-based image retrieval (TBIR) has proven highly effective for finding images that are tagged with descriptive text. Within this system, each word in both the search query and the image descriptions is given equal importance. Recognizing that specific medical terms might influence the outcomes of image searches, we aimed to refine TBIR by incorporating unique medical-dependent features (MDF). These features are a combination of image properties and medical terms, which we crafted to enhance how images are matched to queries. In our previous work, we pioneered the process of categorizing search queries to improve retrieval systems. We did this by considering not just the medical terms but also generic characteristics like how specific or vague a query is. The integration of MDF into our systems helped streamline the re-ranking process, allowing us to better gauge the impact on search results. We observed a substantial gain in efficiency, cutting down on both time and computational resources. Furthermore, we employed these MDFs within a Bayesian Network-based image retrieval framework. Although building Bayesian Networks is complex and resource-intensive, the inclusion of MDF is anticipated to bring substantial benefits. Our experiments with various medical image databases have shown that our

new models substantially outperform the established baseline models in retrieving images, marking a significant advancement in the field.

8) Machine Learning (ML) and Deep Learning (DL) for IR and Healthcare Decision Making: In the research lab, we have made significant strides in the integration of ML and DL in the advancement of IR systems, as outlined in our wide range of publications. Notably, the laboratory innovated a novel feedback strategy incorporating co-training with pseudo-relevance feedback (PRF), which has proven effective in IR, in particular scenarios lacking labeled data. This method has demonstrated its value through improved IR performance.

The IRLab also formulated a learning-to-rank model with a focus on quality-aware PRF. The approaches we have pioneered for embedding ML and DL into PRF for IR have consistently delivered superior performance.

In real-world applications, this lab has applied a composite DL model (DBN+SVM) to streamline automated diagnosis and decision-making processes in healthcare We enhanced convolutional deep belief networks and achieved notable performance gains over well-established benchmarks on extensive datasets Additionally, the laboratory has effectively employed a sparse Bayesian multi-instance multi-label model for the analysis of skin biopsy images, developing a robust ML model using deep convolutional neural networks (CNNs) to classify cell images for malaria screening These innovations signify IRLab's commitment to advancing medical diagnostics through cutting-edge IR technologies.

9) Additional Information on Contribution: The lab has established a significant track record of contributions to the field of information retrieval. Under the guidance of the laboratory's director, Professor Jimmy Huang, who serves as author and co-author, the lab has produced over 320 peer-reviewed publications in the past six years. These works are often led by graduate students and postdoc fellows of the lab, with senior researchers contributing through ideation, critical feedback, algorithmic development, and, in many cases, extensive revision of manuscripts to elevate the writing to academic standards (especially for international students).

The research endeavors at this lab are strategically directed toward the most revered academic journals and conferences. These include esteemed journals such as ACM Transactions on Information Systems (TOIS), IEEE Transactions on Knowledge and Data Engineering (TKDE), and conferences like ACM SIGIR and IJCAI. The selection of these venues is intentional, with each chosen for their rigorous peer review processes and the impact their publications have on the research community.

The efforts of this lab are accelerated towards pioneering areas of IR, including task-oriented and context-sensitive frameworks, with noticeable advancements in conversational search technologies and models like ChatGPT and BERT. These initiatives are part of the lab's NSERC Discovery Grant-sponsored research and have garnered recognition, including accolades such as best paper awards. For instance, the paper titled "Hypergraph contrastive collaborative filtering" presented at ACM SIGIR 2022 was celebrated as one of the most influential papers in the subsequent year.

Leadership within this lab extends to significant roles in organizing major conferences, evidencing the lab's commitment to fostering scholarly exchange and progress in the field. For instance, the director of this lab, Professor Jimmy Huang, was the General Conference Chair for the 19th International ACM CIKM Conference, the Program Chair for IEEE/ACM International Joint Conferences on Web Intelligence & Intelligent Agent Technology in 2010, and the General Conference Chair for the 43rd International ACM SIGIR Conference in 2020. He has been the Chair of the IEEE Technical Committee on Intelligent Informatics (TCII) since 2023.

The research from our lab has been enormously significant, reaching beyond academia to influence major companies like Google, Microsoft, Baidu, IBM, eBay, and Dapasoft, all of whom have used our findings to enhance their products. We've also formed strong bonds with organizations such as Southlake Regional Health Centre, Institute for Clinical Evaluative Sciences, Dapasoft, IBM, Google, Microsoft, Baidu, Manifold Data Mining, National Institute of Standards and Technology, and the Ontario Ministry of Health, further building a bridge between our research and real-world applications.

IV. Collaborations and Partnerships

We are always interested in collaborations with partners who have interests that intersect with ours. Current and past collaborating organizations are listed below:

- OpenText Corporation
- Institute for Clinical Evaluative Sciences (ICES)
- MRC-CRC (Medical Research Council - Clinical Research Centre)
- IBM
- Microsoft Research
- Yahoo!
- City University London
- InfoBright
- Scuola Superiore Sant'Anna

V. Funding & Acknowledgements

Fig. 1. Team Members.

- NSERC (Natural Sciences and Engineering Research Council of Canada)
- York University
- SSHRC (Social Sciences and Humanities Research Council of Canada)
- CIHR (Canadian Institutes of Health Research)

VI. LOOKING TO THE FUTURE

Our vision is to establish a center of excellence for research that transcends traditional boundaries and serves as a catalyst for transformative applications in IR and knowledge management. We are dedicated to:

- Innovation in the field of person re-identification and retrieval by enhancing the capability to recognize and distinguish individuals within data systems to improve security, customer experience, and personalization.
- Exploring search tasks to understand how users engage with IR systems, aiming to streamline the search process and deliver results that align closely with user intentions.
- Conducting groundbreaking research on LLMs that explores their potential to enhance the interpretability and responsiveness of search systems, thereby improving how machines understand and process human language.

VII. REPRESENTATIVE PUBLICATIONS

- Wang, J., **Huang, J. X.**, Tu, X., Wang, J., Huang, A.J., MD Tahmid Rahman Laskar and Amran Bhuiyan. "Utilizing BERT for Information Retrieval: Survey, Applications, Resources, and Challenges" *ACM Computing Surveys (CSUR)*. ACM Publisher. Accepted on February 09, 2024. ISSN: 0360-0300 and EISSN:1557-7341 (ACM Computing Surveys is a quarterly peer-reviewed scientific journal published by the Association for Computing Machinery. It receives the highest rank "A*", and publishes survey articles and tutorials related to computer science and computing. I am the contact author of this paper. Jiajia Wang, Junmei Wang, Angela Huang and MD Tahmid Rahman Laskar was my PhD student working in my research lab. Amran Bhuiyan is my postdoc under my supervision in my research lab. This research was supported by my NSERC DG grant). ISI Journal Impact Factor: 10.282 (2020), ranking it 4 out of 137; 14.324 (2021); 16.6 (2022), ranking 3 out of 109 in Computer Science Theory & Methods.
- Keyvan, K. and **Huang, J. X.** "How to Approach Ambiguous Queries in Conversational Search? A Survey of Techniques, Approaches, Tools and Challenges" *ACM Computing Surveys (CSUR)*. ACM Publisher. Vol. 55, No. 6, Article 129, 1-40 pages. June 2023. ISSN: 0360-0300 and EISSN:1557-7341 (ACM Computing Surveys is a quarterly peer-reviewed scientific journal published by the Association for Computing Machinery. It receives the highest rank "A*", and publishes survey articles and tutorials related to computer science and computing. Kimiya Keyvan was a graduate student working in my research lab. This research was supported by my NSERC DG grant). ISI Journal Impact Factor: 10.282 (2020), ranking it 4 out of 137; 14.324 (2021); 16.6 (2022), ranking 3 out of 109 in Computer Science Theory & Methods.
- Laskar, M.T.R., Bari, M.S., Rahman, M., Bhuiyan, M.A.H., Joty, S. and **Huang, J.X.** "A Systematic Study and Comprehensive Evaluation of ChatGPT on Benchmark Datasets" (full paper), *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Findings of ACL 2023)*, Toronto, Ontario, Canada. July 9-14, 2023 (**ACL** is the top-tier conference in the fields of NLP and Computational Linguistics and I am the contact author).
- Zou, J., **Huang, J. X.**, Ren, Z. and Kanoulas, E. "Learning to Ask: Conversational Product Search via Representation Learning", *ACM Transactions on Information Systems (TOIS)*. ACM Publisher. Accepted on July 23, 2023. ISSN: 1046-8188 and EISSN:1558-2868 (ACM TOIS is a top-tier journal

in information systems. J. Zou was a visiting PhD student working in my research lab since July 2020. This research was supported by my NSERC DG grant). ISI Journal Impact Factor: 4.797 (2020).

- Zhao, J., **Huang, J. X.**, Deng, H, Chang, Y. and Xia, L. "Are Topics Interesting or Not? An LDA-based Topic-graph Probabilistic Model for Web Search Personalization" *ACM Transactions on Information Systems (TOIS)*. ACM Publisher. Vol. 40, No. 3, Article 51, 1-24 pages. July 2022. ISSN: 1046-8188 and EISSN:1558-2868 (ACM TOIS is a top-tier journal in information systems. J. Zhao was a former PhD student in my research lab and L. Xia is a postdoc fellow working in my research lab. This research was supported by my NSERC DG grant). ISI Journal Impact Factor: 4.797 (2020).

- Xia, L., Huang, C., Xu, Y., Zhao, J., Yin, D. and **Huang, J. X.** "Hypergraph Contrastive Collaborative Filtering" (full paper), *Proceedings of the 45th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval (SIGIR 2022)*, Madrid, Spain. July 11-15, 2022. 749-758 (20.27% acceptance rate: 161 regular research papers accepted out of 1,469 submissions which include 794 valid full paper and 675 valid short paper submissions conference in the fields of Information Retrieval and Web search. This research was supported in part by my NSERC DG grant). This paper was ranked as the **Most Influential SIGIR Papers (2023-04)** by Best Paper Digest in New York (https://www.paperdigest.org/2023/04/most-influential-sigir-papers-2023-04/).

- Tan, X. and **Huang, J. X.** "A Complexity-theoretic Analysis of Green Pickup-and-Delivery Problems" (full research paper and invited for oral presentation), *Proceedings of the Thirty-Fifth AAAI Conference on Artificial Intelligence (AAAI 2021)*, Vancouver, Canada. February 2-9, 2021. 11990-11997 (21.0% acceptance rate: 1,692 papers accepted out of a record 9,034 submissions. **AAAI** [1] is the top-tier and premier interdisciplinary conference in the field of artificial intelligence. X. Tan was a postdoc fellow working in my research lab. This research is supported by my NSERC DG grant).

- Tal, O., Liu, Y., **Huang, J. X.**., Yu, X. and Aljbaw, B. "Neural Attention Frameworks for Explainable Recommendation", *IEEE Transactions on Knowledge and Data Engineering (TKDE)*. IEEE Publisher. Vol 33, No 5, pp. 2137-2150, 2021. ISSN: 1041-4347 (IEEE TKDE is a top tier journal in data mining. I am the contact author of this paper. O. Tal was graduate student and Y. Liu was my former Ph.D. student. This research was supported by NSERC DG grant). ISI Journal Impact Factor: 3.438 (2017); 3.857 (2018); 4.561 (2019); 4.935 (2020).

- Huang, C., Chen, J., Xia, L., Dai, P., Chen, Y., Bo, L, Zhao, J. and **Huang, J. X.** "Graph-Enhanced Multi-Task Learning of Multi-Level Transition Dynamics for Session-based Recommendation" (full research paper and invited for oral presentation), *Proceedings of the Thirty-Fifth AAAI Conference on Artificial Intelligence (AAAI 2021)*, Vancouver, Canada. February 2-9, 2021. 4123-4130 (21.0% acceptance rate: 1,692 papers accepted out of a record 9,034 submissions. C. Huang was a PhD student and J. Zhao was a former PhD student in my research lab. This research is supported in part by my NSERC DG grant).

- Chen, X., Xiong, K., Zhang, Y., Xia, L., Yin, D. and **Huang, J. X.** "Neural Feature-aware Recommendation with Signed Hypergraph Convolutional Network", *ACM Transactions on Information Systems (TOIS)*. ACM Publisher. Vol 39, No. 1, Article 8, 22 pages. November 2020. ISSN: 1046-8188 and EISSN:1558-2868 (ACM TOIS is a top tier journal in information systems. L. Xia is a postdoc fellow working in my research lab. This research was supported by my NSERC DG grant). ISI Journal Impact Factor: 4.797 (2020).

- Zhou, L., Xia, L., Gu, Y., Liu, W., **Huang, J. X.** and Yin, D. "Neural Interactive Collaborative Filtering" (full paper), *Proceedings of the 43rd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval (SIGIR 2020)*, Xi'an, China. July 25-30, 2020. 749-758 (26.49% acceptance rate: 147 regular papers accepted out of 1,180 submissions which include 555 long papers and 512 short papers etc. **ACM SIGIR** is the top tier conference in the fields of Information Retrieval and Web search. L. Xia is a postdoc fellow working in my research lab. This research was supported by my NSERC DG grant).

- Wang, P., Fan, Y., Xia, L., Zhao, W. X., Niu, S. and **Huang, J. X.** "KERL: A Knowledge-Guided Reinforcement Learning Model for Sequential Recommendation" (full paper), *Proceedings of the 43rd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval (SIGIR 2020)*, Xi'an, China. July 25-30, 2020. 209-218 (26.49% acceptance rate: 147 regular papers accepted out of 1,180 submissions which include 555 long papers and 512 short papers etc. **ACM SIGIR** is the top tier conference in the fields of Information Retrieval and Web search. L. Xia is a postdoc fellow working in my research lab. This research was supported by my NSERC DG grant).

- Xie, Z., Zhou, G.Y., Liu, J. and **Huang, J.X.** "ReInceptionE: Relation-Aware Inception Network with Joint Local-Global Structural Information for

[1] AAAI stands for the Association for the Advancement of Artificial Intelligence (formerly the American Association for Artificial Intelligence)

Knowledge Graph Embedding" (full paper and invited for oral presentation), *Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics (ACL 2020)*, Seattle, Washington, USA. July 5-10, 2020. 5929-5939 (25.4% long paper acceptance rate for presentation: 571 regular full papers accepted for presentation at ACL out of 3,429 paper submissions with 2,244 for long papers and 1,185 for short papers. **ACL** is the top tier conference in the fields of Computational Linguistics and NLP).

- Tan, X. and **Huang, J. X.** "On Computational Complexity of Pickup-and-Delivery Problems with Precedence Constraints or Time Windows" (full research paper and invited for oral presentation), *Proceedings of the 28th International Joint Conference on Artificial Intelligence (IJCAI 2019)*, pp. 5635-5643. Macao, China. August 10-16, 2019 (13.7% acceptance rate: 650 papers accepted out of 4752 paper submissions. **IJCAI** is a premier international conference for AI researchers and practitioners and IJ-CAIs were held biennially in odd-numbered years since 1969. X. Tan was a postdoctoral fellow from 2016 to 2019 in my research lab. This research is supported by my NSERC DG grant & CREATE award).

- Chen, Q., Hu, Q. and **Huang, J. X.**. "TAKer: Time-Aware Microblog Search with Kernel Density Estimation", *IEEE Transactions on Knowledge and Data Engineering (TKDE)*. IEEE Publisher. Vol 30, No 8, pp. 1602-1615, 2018. ISSN: 1041-4347 (IEEE TKDE is a top tier journal in data mining. I am the contact author of this paper. Q. Chen was a visiting Ph.D. student in my research lab. Q. Hu was my former Ph.D. student. This research was supported by my NSERC DG grant & CREATE award). ISI Journal Impact Factor: 3.438 (2017).

- **Huang, J. X.**, He, B. and Zhao, J. "Mining Authoritative and Topical Evidence from Blogosphere for Improving Opinion Retrieval", *Information Systems (IS)*. Vol 78, pp. 199-213, 2018. ISSN: 0306-4379 ELSEVIER Publisher. In press (IS is a leading peer-reviewed journal covering data-intensive technologies underlying database systems, business processes, social media, and data science. I am the contact author of this paper. B. He was a postdoctoral fellow and J. Zhao was my Ph.D. student under my supervision and completed her Ph.D. in March 2015. This research was supported by my NSERC DG grant and NSERC CREATE Award). Impact Factor: 2.777 (2016) and 5-Year Impact Factor: 2.822 (2016).

- Chen, Q., Hu, Q. and **Huang, J. X.** "CAN: Enhancing Sentence Similarity Modeling with Collaborative and Adversarial Network" (full paper), *Proceedings of the 41st Annual International ACM SIGIR Conference on Research and Development in Information Retrieval (SIGIR 2018)*, Ann Arbor, Michigan, U.S.A. July 8-12, 2018 (21% acceptance rate: 86 regular papers accepted out of 409 long paper and 327 short paper submissions. **ACM SIGIR** is the top tier conference in the field of Information Retrieval. Q. Chen was a visiting Ph.D. student in my research lab. Q. Hu was my former Ph.D. student. This research was supported by my NSERC DG grant & CREATE award).

- Chen, Q., Hu, Q. and **Huang, J. X.** "CA-RNN: Using Context-Aligned Recurrent Neural Networks for Modeling Sentence Similarity" (full research paper and invited for oral presentation), *Proceedings of the Thirty-Second AAAI Conference on Artificial Intelligence (AAAI 2018)*, New Orleans, Louisiana, USA. February 2-7, 2018 (24.5% acceptance rate: 933 papers accepted out of over 3800 paper submissions. **AAAI** is the top-tier and premier interdisciplinary conference in the field

of artifical intelligence. Q. Chen was a visiting PhD student in my research lab from November 17, 2017 to March 17, 2018. This research is supported by my NSERC DG grant & CREATE award).

- Gan, G. and **Huang, J. X.** "A Data Mining Framework for Valuing Large Portfolios of Variable Annuities" (full paper and invited for oral presentation), *Proceedings of the 23rd ACM SIGKDD International Conference of Knowledge, Discovery and Data Mining (KDD 2017)*, Halifax, Nova Scotia, Canada. August 13-17, 2017 (8.65% acceptance rate for oral presentation: 99 accepted full papers with oral presentation in which 35 come from data science track and 64 come from research track, and 10.23% acceptance rate for posters: 117 accepted posters in which 50 come from data science track and 67 come from research track out of 1,144 full paper submissions where 396 were submitted from data science track and 748 were submitted from research track. **ACM SIGKDD** is the top-tier and premier interdisciplinary conference bringing together researchers and practitioners from data science, data mining, knowledge discovery, large-scale data analytics, and big data. This research is supported by my NSERC DG grant).

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Exploring Student Usage of ICT Tools in Project-based Learning

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Abstract— **Interactions with ICT tools may affect students' mental (cognitive), behavioural, and emotional experiences differently. This paper examines the relationship between the emotional experiences of students in a postgraduate ICT course at a major Australian university, technology used in the course, and their academic performance. The research question is: Which attributes (cognitive, emotional, or behavioural) does a learner exhibit when interacting with online ICT education tools? A survey consisting of closed-ended and open-ended questions was used to understand the effect of prior experience on learner engagement. Our findings indicate that: 1) the behavioural element was most affected by ICT usage, 2) there was more engagement between students and teachers than between students and other students, and 3) students were more productive if they had previous experience with online tools. Based on these results, we argue that design specification requirements should focus on ensuring that students have familiarity and background with online learning, to enhance their help-seeking, information literacy and communication.**

Index Terms— **ICT Tools, Cognitive, Emotional, Behavioural, Educational Technology**

I. INTRODUCTION

Previous research on learning technology indicates that an intentional curriculum design focusing on the interplay between technology and learning can lead to educational improvements in students (Vasimalairaja et al., 2020). Building expertise in technology also contributes to enhancing professional conduct in education for both students and teachers (Garrett et al., 2018). McTighe et al. (2020) note that technology-enhanced learning tools in the classroom should suit specific purposes of the course; however, there is still a lack of theoretical guidance on how course designers can implement this consistently (Bartolomé et al., 2018). Since the education spectrum is vast and complex, developing theoretical frameworks is challenging (Dao et al., 2019). In particular, the increasing demand for online learning and delivery modes mean that ICT tools need to be considered more carefully for a comprehensive educational experience.

This study investigates the impact of educational ICT tools on learner engagement, in the context of a postgraduate ICT course at a major university in Australia, delivered online. This course focused on Project-based Learning (PBL), with students completing individual projects. Due to the range of projects, the scope of this research is solely on the communication and interaction tools used by students to complete their assessments. We developed a survey instrument based on three dimensions of student engagement (Fredricks et al., 2004): cognitive, behavioural, or emotional. These dimensions are used to explore how students are most affected when using or interacting with educational ICT tools in the online setting.

This research seeks to answer the following research question: *Which attribute (cognitive, emotional, or behavioural) does a learner present when interacting with online ICT education tools?*

II. BACKGROUND

Educational technology has a substantial effect on students' cognitive, behavioural, and emotional development. Due to this development, many educational institutions use technology to elevate modern-day academic teaching (Karaka-Clarke, 2020; Singh & Tiwari, 2020). ICT may provide learners with engaging and efficient information when used in conjunction with traditional educational systems. In particular, they can contribute towards personalised education experiences, which positively affects the learning process (Vasimalairaja et al., 2020), and might lead to elevated intellectual skills.

Elevated intellectual skills include self-reliance, creativity, communication, cooperation and digital attainment. According to Calder and Murphy (2018), technologically supported learning environments that embrace self-regulated education alongside knowledge-based learning can help students be more contemplative, creative, and innovative. They posit that, in turn, this has the capacity to lead to enhanced aspects of learning, such as self-directed education, cooperative learning, independent study, and simple response and feedback. Students that can be encouraged to develop or experience these skills in their educational setting can be more prepared and resilient for professional careers post-university.

Adopting intentional educational technology in the learning process also fosters creative thinking and ensures that learners

are equipped with relevant resources to aid them in their learning process. Creative thinking can be made explicit in several learning contexts. Gardner (1983; 1999), for example, saw creative thinking as a cognitive process in which several intelligences worked in harmony and could be used anywhere, with thinking and innovating two common outcomes. But the notion of creative thinking is complex and an area of learning in need of more investigation. Teachers need to justify their use of ICT and explain the effectiveness of computer-supported learning in the form of measurable student attainment.

Evidence shows that adopting ICT tools improves students' learning (Vasimalairaja et al., 2020). Students who have incremental experience with ICT tools are better positioned to learn than those who have no access to the same tools. Customised tools such as instant feedback functionality enhance real-time interactions and assist learners in meeting specific educational goals (McTighe et al., 2020). However, for this to be effective, incorporation of ICT tools into the learning process requires a rational approach (Lieder & Griffiths, 2020). A customised learning experience contributes to student's connection and experience, which affects their prosocial conduct as the quality of societal interaction is linked to learners' overall knowledge (Wittek et al., 2020). This experience, in turn, affects the user in the cognitive, emotional, and behavioural dimensions. Each of these are important concepts in student engagement research.

Cognitive engagement as a concept draws from different research streams, with the first seeing it as a person's psychological investment in learning and the other considering it strategic learning (Fredricks et al., 2004). Emotional engagement refers to the affective reactions in an educational setting such as interest, enjoyment, or sense of belonging, while behavioral engagement is the extent to which students comply with behavioural norms such as attendance and involvement or showing positive conduct (Trowler, 2010). While these concepts of engagement are entirely individual and thus difficult to predict, technology can be used to facilitate positive emotional and psychological involvement in scholarly activities (Bond et al., 2020).

A systematic review by Loderer et al. (2020) that surveyed a total of 186 studies concluded that emotions are key drivers of learning in technology-based settings, with the characteristics of these settings having a significant capacity to shape learners' emotional experiences. In an empirical study focusing on cognitive engagement in particular, Iqbal et al. (2022) found that emotional intelligence (self-awareness, self-motivation, regulation of emotion, social skills) were critical predictors in the development of cognitive engagement in higher education students. There is a need to understand further how particular ICT tools can affect learner engagement.

When using an online ICT tool, the interaction may have an impact on users' mental wellbeing (cognitive), observable actions and reactions (behavioural), and feelings (emotional). However, to develop effective educational ICT tools and utilise

them within a particular curriculum, it is essential to determine which learning attributes (cognitive, behavioural, or emotional) the ICT tools affect most. This knowledge will enable course developers to design efficient and personalised ICT education tools that optimize student engagement.

III. METHODOLOGY

We adopted a survey design using a mixed-methods approach, consisting of qualitative and quantitative questions. By breaking down the problems into subgroups that correspond to emotional engagement and prior experiences, the researchers determined the relationship between the user attributes and the overall user experience. The qualitative approach was utilised to answer why and how specific events occurred, incorporating quantitative questions. This dual approach aimed to understand the connection between individuals' emotional, behavioural, and cognitive experiences and their use of technology in learning in a postgraduate ICT course at a major university.

A. Participants

Our study setting was a PBL postgraduate course in the IT program at a major Australian university. The cohort contained domestic and international students, which is an appropriate selection for technology-based research (Chen & Yang, 2019). The participants were pursuing different Majors, which provided this research with a broad scope. For assessment, students were enrolled in shared research topics that were supervised by a member of the teaching team. While students may have used the same datasets, each student was required to develop a unique research question to ensure assignments were conducted individually. The critical learning outcomes (CLOs) in the course were information literacy, research skills, and academic writing. Course content was delivered through lectures and tutorials, while students were expected to access the library and academic advisors for additional research support.

Communication in the subject was largely digital, with project teams using online platforms such as Slack or university forums throughout the semester. In addition, as part of assessment (and depending on datasets), students needed to utilize individual tools and technologies to complete their research. Students were expected to be self-directed and demonstrate self-efficacy in accessing resources such as the external co-curricular support services. As part of the research scope, we only consider communication tools for cognitive, emotional and behavioral engagement.

B. Data Collection

A survey was administered to the entire course cohort in the middle of semester 2. Out of 267 students, 43 completed and returned the surveys. The survey was approved by the university's human research ethics committee. This study used convenience sampling, given that the researchers were involved

in the course.

Personal data was collected from the participants, including gender, age, nationality, domestic or international student status, language, and course. Data related to students' engagement with ICT tools, previous experiences, and attitudes were also collected. The survey contained open-ended and closed-ended questions. The researchers developed the quantitative questions based on a five-point, Likert-type (1–5) scale. Table 1 shows the closed-ended survey questions, which were designed to understand the interplay between students and technology in the course. These questions were shaped by a *focus*, or the underlying nature of the question. In addition, we used three open-ended questions to understand the learners' experience while using the ICT tools. The questions are shown in Table 2. These questions were multiple choice, offering different options, with students then asked to elaborate qualitatively about why it was their preferred approach. Students could not skip these questions without providing a qualitative response, resulting in rich responses for analysis.

TABLE I: CLOSED-ENDED SURVEY QUESTIONS, THEIR FOCUS, ESSENTIAL ELEMENTS, AND THEMES.

Question	Focus
"My experience with technology reduces the effort I need to get better grades in this unit's tasks."	Determine whether a student's prior experience with technology has an impact on their current performance.
"Students should receive training on using the virtual learning environment and ICT tools when they enroll in a unit task."	Determine the student's general viewpoint on the impact of training on fundamental understanding and experience when using ICT tools in learning.

TABLE II: OPEN-ENDED SURVEY QUESTIONS, THEIR FOCUS, ESSENTIAL ELEMENTS, AND THEMES.

Question	Focus	Key attributes	Discovered traits
"How are you interacting with other learners or staff while participating in this project?"	Determine the student's interaction levels with colleagues and tutors.	Endeavour, focus, requesting help, supporting others, optimism	Student engagement, cooperation
"Have you ever finished an online course in the past? If yes, what attracted you the most?"	Determine whether the student has had prior experience with online studying, and, if so, what they liked about it.	Student activity states optimism, self-assurance, focus, punctuality, trying	Online experience, cooperation, and student engagement
"While attending to your assignments in a unit, how do you plan your advancement?"	Determine whether the student does assignments out of free will or feels forced by the course requirements.	Student activity state, punctuality, endeavor, focus optimism, trying, and self-assurance	Course requirement, student engagement

These sets of questions analyze students' emotional, cognitive, and behavioral experiences when engaging with communication technology tools for learning. The am is to understand how and why students have these experiences during their engagement with ICT tools. The quantitative and qualitative approaches ensure that both the quality and quantity of the data are incorporated into the research and support and enhance the findings' credibility (Sechelski & Onwuegbuzie, 2019).

C. Data Analysis

The researchers analyzed to what extent these relationships impacted the user attributes (emotional, cognitive, or emotional) and overall learning experience (Apuke, 2017). Statistical Package for Social Sciences (SPSS) version 22 (IBM Corporation) and ANOVA software were used to analyze the quantitative results for the closed-ended questions. To analyze the qualitative data, we followed an exploratory approach derived from the open-ended questions similar to Kaur et al. (2018). Narrative analysis was used to generate themes from the responses (Kiger & Varpio, 2020). The researchers analyzed each response individually to determine patterns, then developed codes from the responses corresponding to the patterns to serve as keywords. Keywords were then categorized into themes, and each pattern was grouped into categories to determine the themes (Vanaken & Hermans, 2021). The next step involved merging or deleting the compositions according to relevancy. This ensured that only relevant data was retained for further analysis.

IV. QUANTITATIVE RESULTS

A. Demographic Information

Of the 43 responses, 30 were male and 13 were female. Participants came from diverse age groups, as indicated in Figure 1.
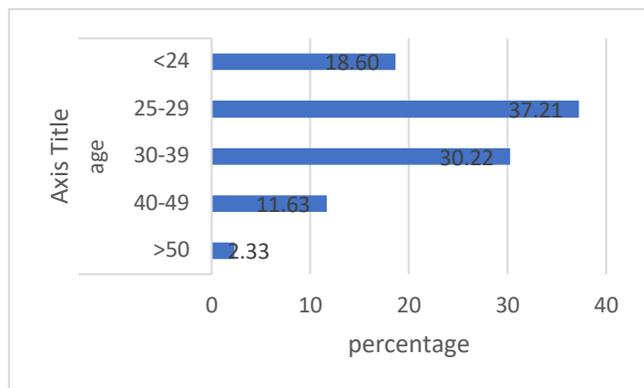
Fig. 1: Age range of the participants.

A total of 65% were international students and 35% were domestic. Figure 2 shows the breakdown of majors in the course, with computer science being the most strongly represented.
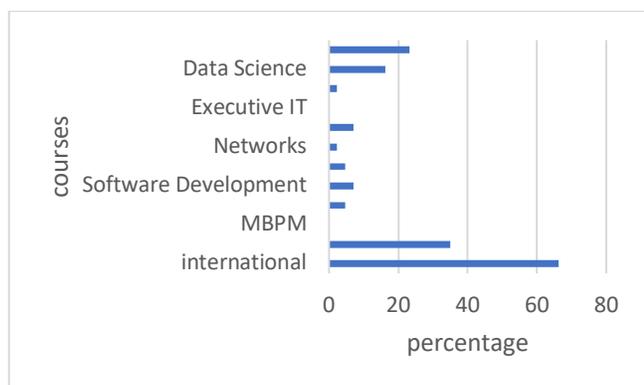
Fig. 2: Current majors of the study population in the course.

B. *Behavioural Attributes and Technology Use*

In Figure 3, we can observe that ten participants (23.6%) strongly agreed and seventeen participants (39.53%) agreed that their previous experience with technology made it easier for them to attain higher grades. Figure 4 demonstrates that most respondents believe that students should receive training in the ICT tools of a course at the beginning of the semester, with 14 (32.56%) strongly agreeing and 19 (44.19%) agreeing.
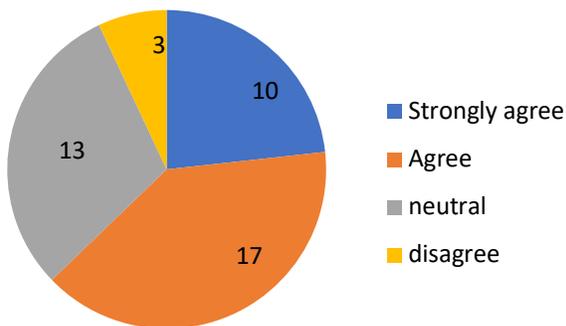
Fig. 3: "My experience with technology reduces the effort I need to get better grades in this unit's tasks."
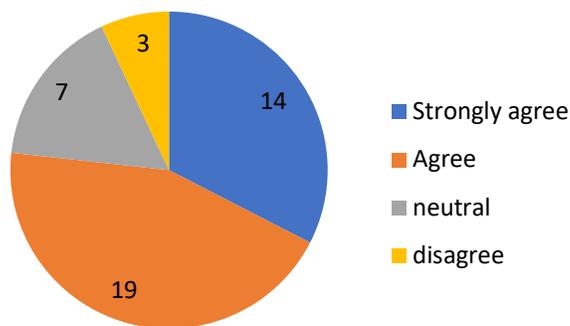
Fig. 4: "Students should receive training on using the virtual learning environment and ICT tools when they enroll in a unit task."

These results show that students believed their experience with technology significantly impacts their attainment of higher grades. Furthermore, the students believed they should receive training on how to use technology tools upon enrolling in the course. This aligns with previous studies, which note that training makes it easier for students to fully utilise available resources (Lawrence & Tar, 2018). Training also improves students' ICT literacy and forms a basis for the students to explore creativity and nature, which are both key behavioural aspects. Being ICT literate also improves students' attainment levels.
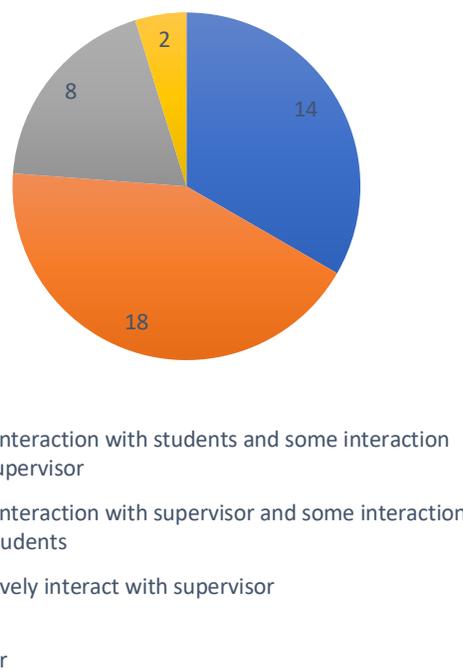
Fig. 5: "How are you interacting with other learners or staff while participating in this project?"

Figure 5 shows that the majority of participants had a mixed interaction within the course, with 18 (41.86%) specifying that they interacted more with their supervisor, while 14 (34.88%) indicated that they interacted more with other students. The importance of this result is that it showed most of the students were actively engaging in communication with others. Students were not mandated to engage with peers or staff as the course was largely self-directed and had limited group activities, however, the students still desired interaction and were actively doing so through Slack and email. Interaction fosters active learning by keeping students engaged with others sharing a common goal; through the exchange, idea sharing, and shared goals, students can achieve more as a team than they can as individuals (Lamb et al., 2018). However, students may perceive that interaction with the supervisor is more helpful than interactions with fellow students.

Figure 6 shows the results for the students' previous experiences with online courses.
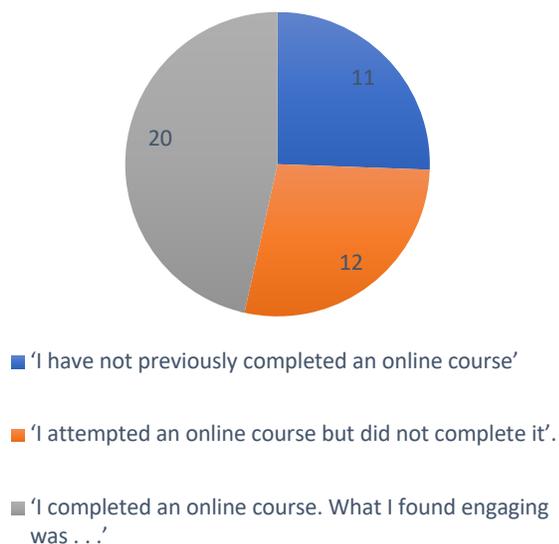
Fig. 6: "Have you ever finished an online course in the past? If yes, what attracted you the most?"

Of the total sample, 31% responded that they had never previously finished an online course. Another 31.88% had attempted an online course but not completed it, and 48.86% had completed an online course at least once. This question explored previous experience with online learning. Its relevance to this study is that most of the peer and supervisor interaction was through online platforms or email. Therefore, a learner who has previously taken an online course using ICT tools may be better positioned to approaching PBL using this online learning system compared to a student who has never taken an online course before. Even if the infrastructure is different, experienced students may have basic fundamentals. Familiarity makes it easier for a user to quickly identify and understand learning features and maximise the tools necessary for the online learning experience. Experience also gives them

confidence and self-assurance that they are well equipped to handle the tasks beforehand (Didee, 2020). Figure 7 shows the results of the final question in Table 2, in which we ask the students for their learning style, or more specifically, their approach to completing assessment tasks.
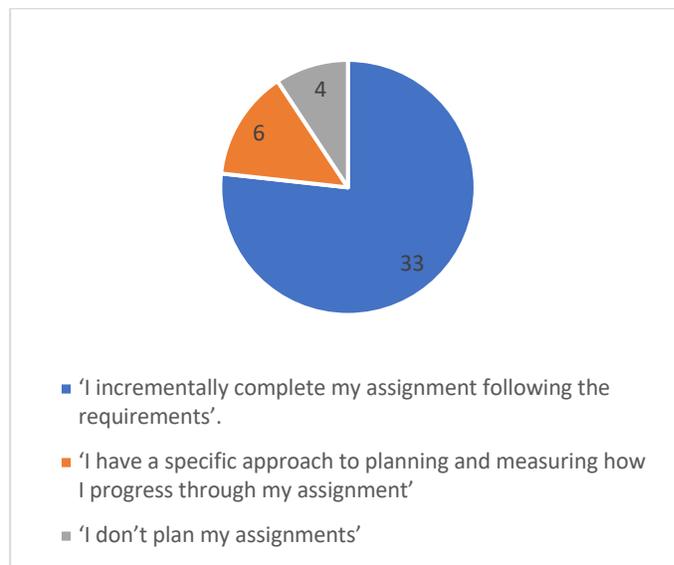
Fig. 7: "While attending to your assignments in a unit, how do you plan your advancement?"

The data shows that most (76%) incrementally completed their assignments following the requirements, which means that their motivation to complete their tasks was dictated by academic requirements. This factor measures whether a student feels either self-driven or forced by the course requirements. Online courses require consistent effort to complete assignments and self-driven traits are key to cognitive, emotional, and behavioral engagement. Some students may complete their assignments out of passion, while others meet their deadlines because their course requires it for attainment of their academic qualifications. In this study, the students were optimistic and focused on achieving their educational goals through positive behavior.

C. Qualitative Analysis: Trait Development

The open-ended questions in Table 2 asked respondents to explain why they selected the MCQ answer. These qualitative responses were analyzed using the process described in Section III C. One researcher coded the qualitative data into codes, and the researchers then grouped codes into high-level themes. These were derived from the language of participants, either from verbatim words given in the response or a theme being a word that encapsulated similar meaning from multiple respondents. In Table III, the themes are distributed across two categories: *key attributes* about individual student emotions, and *discovered traits* being high-level, program-oriented traits.

TABLE III: OPEN-ENDED SURVEY QUESTIONS CATEGORIES.

Question	Key attributes	Discovered traits
"How are you interacting with other learners or staff while participating in this project?"	Endeavor, requesting help, supporting others	Student engagement, Cooperation
"Have you ever finished an online course in the past? If yes, what attracted you the most?"	Studentship, optimism, self-assurance, focus, trying	Online experience
"While attending to your assignments in a unit, how do you plan your advancement?"	Studentship, punctuality, endeavor, focus optimism, trying, self-assurance	Course requirements

The themes in the key attributes column broach across each of the engagement concepts. For example, 'studentship' was a type of cognitive engagement alluded to by several students as underlying a desired state that drove them to invest in their learning. Emotional engagement was shown in attributes like 'optimism' and behavioral engagement was shown in attributes such as 'punctuality' and 'trying'. Table 3 indicates that these attributes were observed across each of the questions, highlighting their importance. The themes in the discovered traits column are high level in that they encompass most of the engagement concepts. For example, 'cooperation' was indicated by students as being a driver for their communication with tutors and peers, and as a concept, 'cooperation' can be considered each of cognitive, emotional, and behavioral engagement.

To answer the research question for the study, our findings indicate that all engagement attributes are present among students in a PBL course, however, cognitive engagement showed the most in themes such as 'endeavor', 'supporting others', 'studentship' and 'cooperation'. More importantly, prior experience with technology and the online course environment better prepare students for the demands of PBL, in particular developing skills like help-seeking, information literacy and communication. If students do not have this familiarity and background, then courses need to train students with the technology and how to use them for these attributes upon enrolment in the course.

V. FINDINGS

The data showed a positive relationship between learners' previous experience and their study unit performance. Experience also contributed to learners' interactions with the ICT tools: the more exposure students have had, the more accustomed they become (Kompen et al., 2019). The learners develop confidence in what they are doing. Elements such as previous online experience, communication, and student proactiveness with assessment also boost and contribute to the behavioural element (Pietarinen et al., 2019).

Student engagement contributes positively to performance, consistent with Bond and Bedenlier (2019), who noted that more engagement translated to better understanding. More engaged students perceived themselves as performing better than disengaged students. Thematic qualitative analysis depicted that the course requirements pushed them to complete their assignments, and most of the students engaged more with their supervisors than with their colleagues. This shows that the cognitive dimension of engagement gets more credit than the other elements with regard to the connection between students' performance and their interaction with ICT tools.

The results showed that most students engaged more with their supervisors than their fellow students, translating to their engagement mode. The students believed that to gain help, their supervisor was better positioned to offer assistance than their fellow students, another cognitive trait. This confirms earlier studies that found students tended to be more motivated if they could communicate with and get help from their teachers (Ozkara & Cakir, 2018). According to a study by Pınar and Dönel (2020), learners prefer classical courses, finding them more motivating, intelligible, and understandable when they got assistance from their teachers. In this and previous studies, teachers agreed with students that active interaction was very important, and students were optimistic that their performance would increase if they had experience with educational ICT tools.

A. Study Limitations

Our small sample size has a negative impact on the generalizability of the findings; the data collection methods are reflective of the time and geographic restrictions of the investigators. Nevertheless, participants' responses helped the investigators better understand learners' perspectives.

B. Recommendations

1) A PBL course should foster and encourage more interactions between students, even if the assessment is individual. Most respondents described more interaction with their supervisors than with their fellow students. Although the majority of students believe that most information comes from supervisors, fellow students can also provide ideas. Interaction with fellow students can foster idea sharing and overall growth and achievement.

2) Accessibility to learning resources should be improved,

such as having an online assignment protocol to improve students' assignment uptake. Most respondents stated that the course requirements compelled them to complete their assignments. More compelling yet accessible online assignment access and submissions to boost students' assignment uptake would be helpful.

3) The course should offer training for learners to explore ICT educational tools. Some students were not familiar with the setup because many had not experienced an online course before, so they were not familiar with expectations involved in using Slack, university forums, Zoom, and recorded lectures. As Ballesta and Céspedes (2015) argued, being suitably trained in the use and educational possibilities of ICT is one of the major factors in inclusivity. Instructors need to ensure all students have access to learning, geared towards assisting students to improve their key qualifications (Valdés et al., 2015).

VI. CONCLUSION

This study was motivated to explore what dimensions of student engagement among cognitive, emotional, and behavioral engagement were present in an online PBL course. It found that cognitive engagement was most present, especially in the use of ICT tools for communication. This study found that most students relied on experience to utilise ICT tools effectively for student engagement and learning. The online ICT learning tools elevate interactive and overall delivery in the education system (Fisk et al., 2020). Our findings suggest that most students spend more time engaging with their supervisors than their fellow students. This indicates the cognitive engagement dimension of learning (Hong et al., 2017), in that it is an investment of learning and strategic. Future improvements made to the ICT tools should foster inter-student engagement and interaction. This modification can be achieved by simplifying design to make tools easier to use, especially for students with no prior experience using online ICT educational tools (Yang et al., 2018).

Recommendations to improve the efficiency and tool reliability in ICT systems will also contribute to overall academic development (Tarus et al., 2018). These findings depict the general trend in educational ICT technology globally, contributing new information to the knowledge pool in this field. The findings can be applied in many educational scenarios as a basis for problem resolution.

This research has some limitations. Due to the small sample size, these findings cannot be generalised. This study also involves only two variables: learner engagement and learners' experience. Many factors contribute to the application of ICT tools in learning other than the two variables in this study. Therefore, there is a need for further research in this area. Further research can incorporate a larger sample group that is also geographically expansive and include more variables to understand the relationships in educational ICT tools, focusing not only on the effect of the design but also on the systems' effectiveness.

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Intelligent and Adaptive Learning Techniques for Human Emotion Recognition

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Abstract— **Human emotion recognition has a very wide variety of applications in medical treatment, sociable robots, human computer interaction, and recommendation systems. However, existing ML and DL algorithms for human emotion recognition are inefficient in terms of performance, limiting its adoption in widespread applications. The main objective of this work is to present intelligent algorithms for implementation in human emotion recognition through macro-facial expressions, as well as micro-facial expressions and EEG signals. For macro-facial expression recognition, we have exploited each of a feature fusion framework, self-attention mechanism, and discrete wavelet transform for classification of emotions. Humans possess an intrinsic ability to hide their true emotions through basic facial expressions, however, micro-expressions are subtle changes in facial muscles that are involuntary by nature and difficult to hide. To address this issue, a vision transformer model is used. Furthermore, while humans can hide their true emotion, this can be easily detected through physiological signals; thus, a bidirectional-long short-term memory is used for emotion recognition task. These models have been trained and tested on standard benchmark datasets.**

Index terms— **Deep Learning, Emotion Recognition, Self-Attention, Vision Transformer, Bidirectional Long Short-Term Memory, Transfer Learning, Data Augmentation.**

I. INTRODUCTION

Humans have an intrinsic ability to both express themselves and comprehend others' sentiments through emotions. Emotion can be defined as the response generated by humans against some external event [1]. Generally, human emotions are expressed by physically visible features, such as facial expressions [2], textual data [3], body gestures [4], verbal communication [5], eye movements [6], or physically invisible physiological signals such as electroencephalogram (EEG), electromyogram (EMG), electrocardiogram (ECG) [7], respiration (RSP) [8] and galvanic skin response (GSR) [9].

Human emotion recognition is an active research area due to its wide range of applications in human-computer interaction. There exist two different approaches to modeling emotions. The first approach discretely categorizes emotions as happy, sad, fear, disgust, anger, contempt, and surprise, whereas the second approach uses multiple dimensions to label emotions.

This paper aims to provide intelligent and adaptive learning algorithms for human emotion recognition based on facial expressions, micro-expressions, and physiological signals. In particular, effective deep learning models for the classification of human emotions using posed and spontaneous facial expressions are presented. These models exploit the self-attention mechanism and discrete wavelet transform for accurate computational algorithms. Furthermore, literature shows that transformer models are widely accepted in language processing tasks due to their remarkable performance. Thus, in this work, a modified version of an existing vision transformer has been exploited to perform human emotion recognition through micro-expressions. Moreover, a deep learning model has been proposed for human emotion recognition through physiological signals, specifically the EEG. The objectives of this work are twofold: (i) to perform emotion recognition through facial expressions and physiological patterns; and (ii) to propose intelligent and adaptive deep learning frameworks that address the existing issues of human emotion recognition.

Facial expression is a widely adopted approach for expressing emotions [10]. This research introduces three facial expression-based emotion recognition frameworks. To utilize both shallow and deep aspects of face expressions, first, a dual-stream feature fusion-based model has been presented, which shows that the proposed deep learning method attains higher classification accuracy with feature fusion. However, the performance of facial recognition models is affected by intra-class variation and inter-class similarity. Thus, the second framework addresses this issue by employing a modified self-attention mechanism. We also provide a detailed comparison of a primitive self-attention mechanism with the proposed self-attention model. The third framework focuses on improving feature representation through the wavelet domain combined with a self-attention mechanism. These three frameworks are validated on posed and spontaneous benchmark datasets: CK+ [11], JAFFE [12], MUG [13], FER2013 [14], and RAF [15]

Humans can hide their true emotions through facial expressions. Therefore, micro-expressions are another important category of facial expressions. They are typically seen when someone tries to hide their true sentiments. Accurate recognition of emotions through micro-expressions is helpful in a wide variety of applications. Thus, we have proposed a novel vision transformer that exploits local as well as global features of the input facial expressions. This model has been validated on three benchmark datasets: CASME-I [16], CASME-II [17], and SAM [18]. Finally, emotion recognition based on EEG

signals is also analyzed. EEG signals are usually contaminated by unconscious movements such as eye blinks. For this purpose, we have used fast Fourier transform as a preprocessing technique. Furthermore, spatio-temporal features of EEG signals have been exploited by utilizing a bi-directional long-short-term memory deep learning model. This proposed model is validated on two benchmark datasets: DEAP and SEED.

In this work, various deep learning approaches are used to explore and analyze the recognition of human emotions through facial expressions, micro-expressions, and EEG signals. The following are the major contributions of this work:

i.   An exhaustive literature review that includes the detailed descriptions and representations of facial expressions, micro-expressions, and EEG signals, along with insightful discussions of datasets, ML and DL methods for human emotion recognition.

ii.   Deep learning models for facial expression recognition with self-attention mechanism are proposed to address the issues of illumination, head pose, intra-class variations, and inter-class similarity. The proposed models exploit the use of data augmentation and discrete wavelet transform (DWT) to improve performance.

iii. For micro-expression recognition, a new vision transformer model is proposed using a convolution operation for generating feature maps to exploit global receptive field.

iv.   A method for EEG based emotion recognition is proposed using bi-directional long short-term memory (BiLSTM) model in conjunction with a fast Fourier transform (FFT).

Overall structure of the paper is as follows. Section II presents the proposed models for macro-facial expression recognition. Section III illustrates the proposed vision transformer for micro-expression recognition. In section IV, the proposed bidirectional model is discussed. Finally, section V provides a brief conclusion of the paper.

II.   FACIAL EXPRESSION RECOGNITION

Facial expressions can be defined as a medium through which an individual can convey an emotional state to others [19]. Several applications based on facial expression recognition (FER) have been developed in recent years, including virtual reality [20], autonomous robotics [21], autonomous driving [22], entertainment, healthcare [23] and gaming [24]. Motivated by the wide variety of applications, we have proposed three deep learning models. The first model incorporates a dual stream feature fusion-based deep model that exploits shallow as well as deep features of facial expressions. Experimental results of this model show that feature fusion improves the performance of the model; thus, in the other two proposed models, feature fusion is exploited. Furthermore, studies show that the performance of FER model can be improved by considering only relevant facial regions. So, the second model incorporates self-attention mechanism to identify the relevant facial regions required for FER. The third proposed model is a fusion framework that exploits self-attention mechanism in wavelet domain for better feature representation.

A.   Deep Feature Fusion for Posed FER

A dual-stream feature fusion-based deep model (as shown in Figure 1) is proposed to exploit shallow as well as deep features of facial expressions [25]. For preprocessing, the facial portion in an image is detected through the Voila Jones algorithm [26]. It returns coordinates for region of interest (facial region), which is used to crop the facial region. Then, the cropped facial
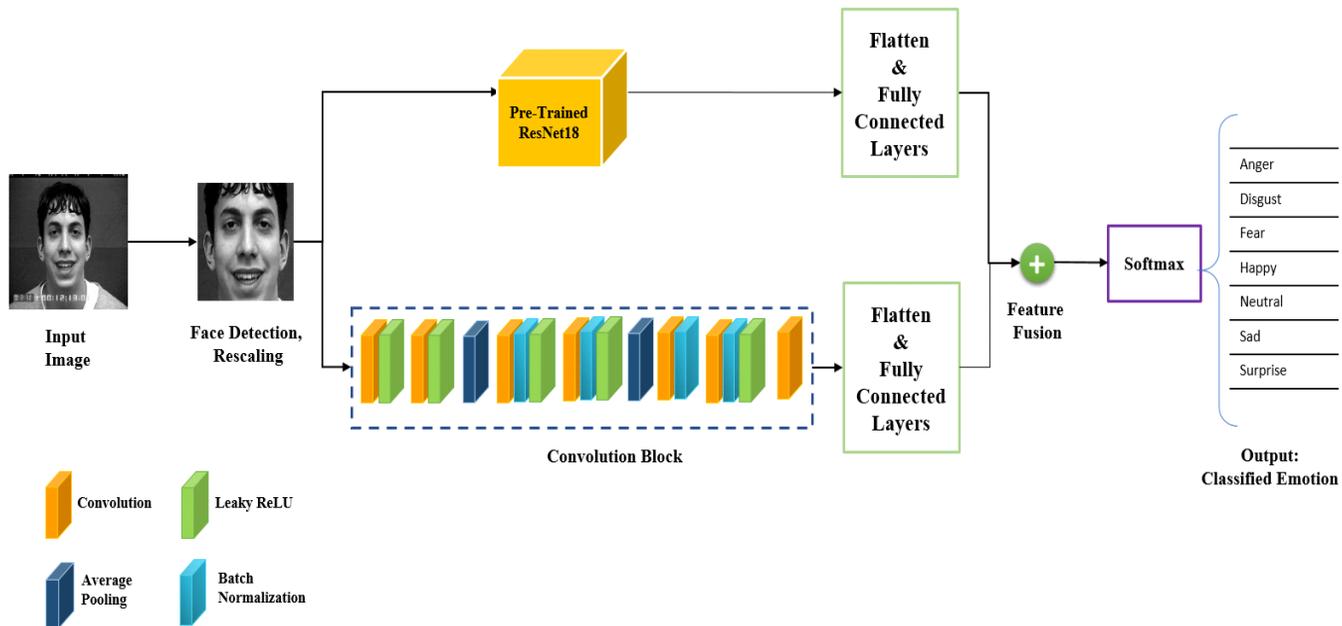

Fig. 1. FER through deep feature fusion for posed FER.

region is size normalized between 0 to 1. Due to the small size of the datasets, in-place data augmentation [27] is used to increase overall size of these datasets by the factor of 3 through application of geometric transformations such as scaling, width shift, height shift, rotation etc.

For the classification phase, we have divided this architecture into two branches. The preprocessed data is passed simultaneously to both the branches. The first branch incorporates a pre-trained ResNet18 model to extract features from the data. For experimental use, the last two layers of ResNet18 have been removed. Then, these features are passed to the fully connected block, which flattens the features and passes them to linear layers. The second branch consists of a sequence of seven convolutional layers with ReLU activation function. To reduce the size of input and the number of epochs, we exploited average pooling and batch normalization, respectively. Then, similar to the first branch, a fully connected block is used. Element-wise summation operation is performed on outputs received from both branches to perform feature fusion. Softmax activation function is applied to compute the probabilistic score required to classify the facial expressions.

Performance of the proposed network architecture has been evaluated in terms of classification accuracy on four benchmark datasets i.e., CK+, JAFFE, MUG, and YALE. The proposed model generated 90.62%, 98.36%, 88.36%, and 72.22% classification accuracy on JAFFE, CK+, MUG, and YALE datasets, respectively. Comparison with existing deep learning models shows that feature fusion helps the model achieve better classification accuracy.

B. Self-Attention Mechanism and Transfer Learning

CNN has played a very crucial role in FER. The convolution operation is performed by considering a local receptive field applied over input data. Due to this phenomenon, information associated with the entire data is lost. The attention mechanism addresses this problem by computing attention weights for a given input with respect to the entire input image.

Originally, an attention mechanism was introduced for natural language processing (NLP) applications. Conventional deep learning models in NLP are incapable of processing information in bidirectional sequence data and cannot handle long-term dependencies [28]. These issues can be addressed by using attention mechanism. Recent studies [29], [30] show that attention models are exploited in FER.

The performance of FER is degraded by intra-class variation and inter-class similarity. We resolve this issue by employing a specific variation of the attention models, i.e., self-attention mechanism, which identifies localized facial regions required for FER. Furthermore, the primitive self-attention mechanism has been improved by employing sigmoid activation function, and a detailed comparison of a primitive self-attention with the proposed self-attention model illustrates the efficacy of the proposed self-attention model.

The proposed dual stream ResNet18 attention (DSResNetAtt) based model (shown in Figure 2) is divided into two modules: preprocessing of faces and self-attention based classification [31]. The preprocessing phase is the same as that of the first model. For classification, the model takes the preprocessed and augmented images and passes them to the pre-trained ResNet18 network. For experimental purposes, the last two layers of ResNet18 have been removed. Therefore, ResNet18 generates feature maps of $512 \times 7 \times 7$ pixel dimensions. These feature maps are further passed to convolution block 1 and convolution block 2, as shown in Figure 2. Convolution block 1 generates feature maps of $Fc \times h \times w$ dimension that are passed to the self-attention block. Now, $Attention Fc \times h \times w$ generated by attention block is passed through convolution block 3, and the generated result is added to the result produced by the convolution block
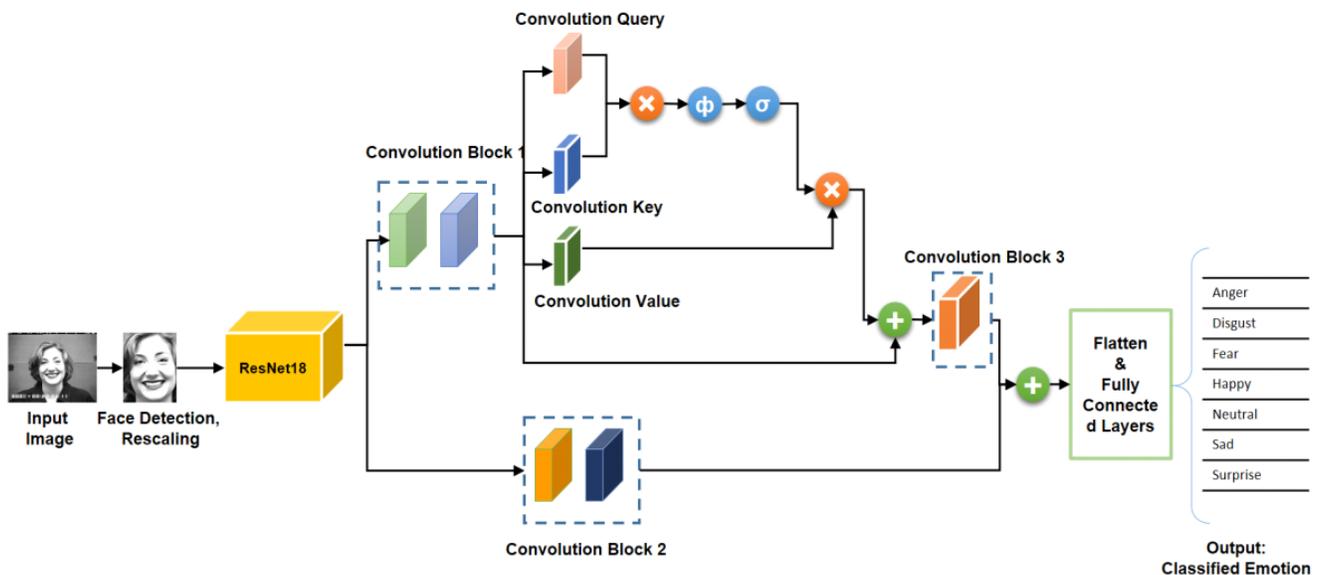

Fig. 2. FER through self-attention mechanism and transfer learning.

2, as shown in Figure 2. Thereafter, the result is flattened and passed to the block of fully connected layers. Then, we apply softmax activation σ(z) to compute the probabilistic score. Afterwards, the loss is computed through cross-entropy loss before the model is optimized by using the Adam optimizer.

Performance of the proposed model has been evaluated on JAFFE, CK+, RAF, MUG, YALE, and FER2013 dataset, shown in Table 1. It can be observed that the performance of the model improved when self-attention mechanism is incorporated.

TABLE I: RESULTS WITH SELF-ATTENTION BLOCK ON DIFFERENT DATASETS USING AUGMENTED SAMPLES

Dataset	Number of classes	Total number of samples	Accuracy without self-attention	Accuracy with self-attention
JAFFE	7	852	94.53%	97.00%
CK+	7	1218	98.91%	99.00%
RAF	7	15339	80.18%	81.06%
MUG	7	1203	91.68%	94.73 %
YALE	4	180	83.33%	87.03%
FER2013	7	32298	64.96%	64.89%

C. Self-Attention Based Fusion Framework in Wavelet Domain

This model is based on better feature representation through the wavelet domain combined with self-attention mechanism (as shown in Figure 3) [32]. The proposed model transforms the input image to wavelet domain through discrete wavelet transform. The framework employs two parallel branches for shallow and deep features, which are fused together for improved feature representation.

Initially, the preprocessing is employed to increase the overall size of small datasets such as JAFFE, MUG and YALE through data augmentation, and face detection is performed through Voila Jones algorithm. Then, the cropped image is passed through DWT to extract relevant features from an image. It decomposes the image into the following four sub-bands: LL, LH, HL, and HH, which provide approximate image, horizontal features, vertical features, and diagonal features extracted from the original image, respectively.

In this work, the LL sub-band is used as it has better feature representation capability and contains less noise. Thereafter, classification is performed by employing two parallel branches that take feature maps of $7 \times 7 \times 512$ pixel size generated by the pre-trained ResNet18 model and follow the same steps as mentioned in Section II B. Performance of the proposed self-attention mechanism exploiting DWT domain is trained and validated on four benchmark datasets i.e., JAFFE, CK+, MUG, and YALE, which generates 96.87%, 99.18%, 94.18%, and 83.33% classification accuracy, respectively, which is comparable to the self-attention model without DWT.

III. MICRO-EXPRESSION RECOGNITION

Facial expression is an important aspect of social interaction among human beings. Basic facial expressions include anger, contempt, disgust, fear, happy, sad, and surprise [33]. Facial expressions can be broadly categorized as macro and micro-facial expressions. Macro expressions are visible, prolonged in nature and can be easily identified by human beings. However, these expressions can be suppressed, posed, and disguised to hide the true emotion of a person. Micro-expressions on the other hand, are involuntary in nature, cannot be posed, are visible for a very short duration of time (0:04 sec to 0:50 sec) and reflect the true emotion of a person. Based on these properties, micro-expression recognition (MER) has a variety
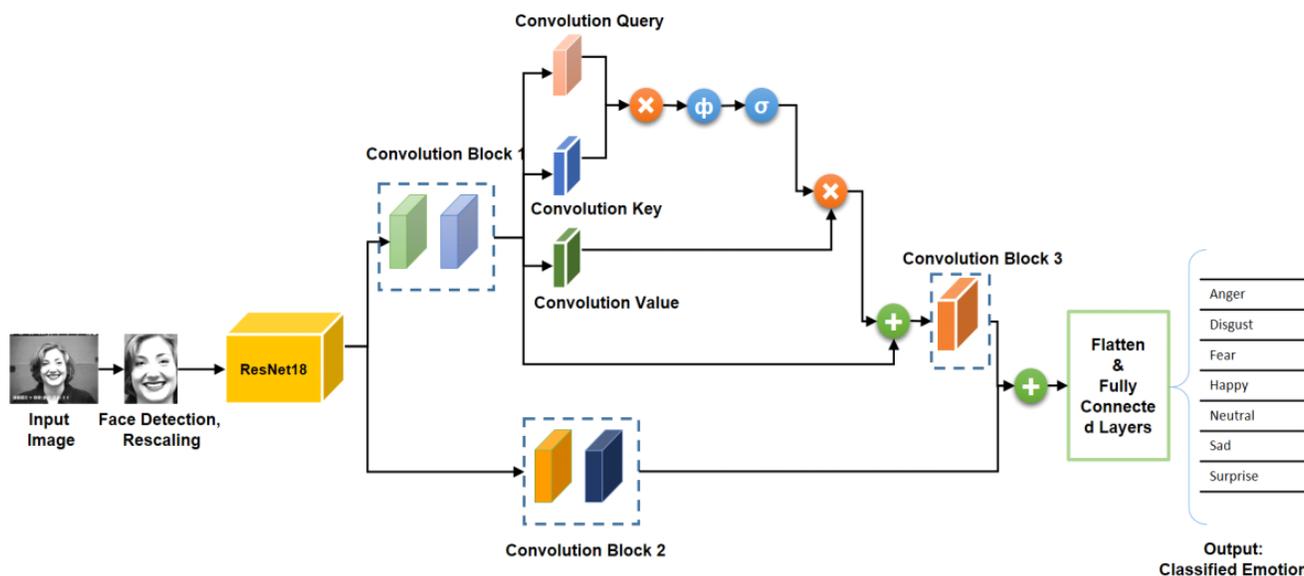

Fig. 3. FER through self-attention based fusion framework in wavelet domain.

of potential applications such as lie detection, security, surveillance systems, online learning, entertainment, healthcare systems (depression detection, clinical diagnosis), and forensics.

Attention mechanisms can be used to identify relevant facial region for classification. The ability of attention mechanisms to learn to concentrate on certain locations makes them effective. Attention mechanism is either employed in conjunction with CNN or it replaces certain components of CNN. In this work, we show that effective and accurate classification can be performed without deep CNN by exploiting vision transformer, which depends on self-attention mechanism. In the past few years, vision transformers have attained remarkable results on vision related classification tasks with substantially fewer computational resources.

Existing vision transformer models [34] create fixed-size patches from an input image, which are flattened and provided to the transformer for classification. However, this technique limits the performance of vision-based algorithms, because image pixels exhibit correlation with their neighboring pixels. Dividing images into fixed-size patches can deteriorate the correlation with neighboring pixels. Thus, a major limitation of this technique is that it cannot handle correlation among pixels in an image. To address this issue, the proposed algorithm (shown in Figure 4) generates c feature maps by applying c filters on an input image [35]. These feature maps are considered fixed-size image patches and passed to the transformer model that consists of transformer encoder (shown in Figure 5) for classification. The comparison of the number of heads in the transformer encoder in terms of classification accuracy is shown in Table II.

TABLE II COMPARISON OF NUMBER OF HEADS IN TRANSFORMER ENCODER

Number of Heads	Classification Accuracy
1	96.31%
2	95.62%
4	96.31%
8	97.08%
16	96.74%

The proposed model was evaluated on three benchmark datasets, CASME-I, CAMSE-II and SAMM, with classification accuracies of 95.97%, 98.59%, and 100% respectively.

IV. HUMAN EMOTION RECOGNITION BASED ON EEG SIGNALS

The human body generally exhibits some physical changes as a result of environmental events. Different emotional states are triggered in the human body as a response to these physical changes. Various physiological signals can be analyzed to monitor the emotional response to these physical changes. Although human beings can express their emotions through various visual factors, including body language and facial expressions depending on the situation, they may intentionally hide these visible emotions. Therefore, evaluating physiological data (which cannot be intentionally modified) gathered from various sensors can help determine a person's feelings in a variety of applications such as healthcare (depression, sleep disorders, epilepsy, Alzheimer, etc), human-computer interaction, surveillance systems, entertainment, and police interrogations.
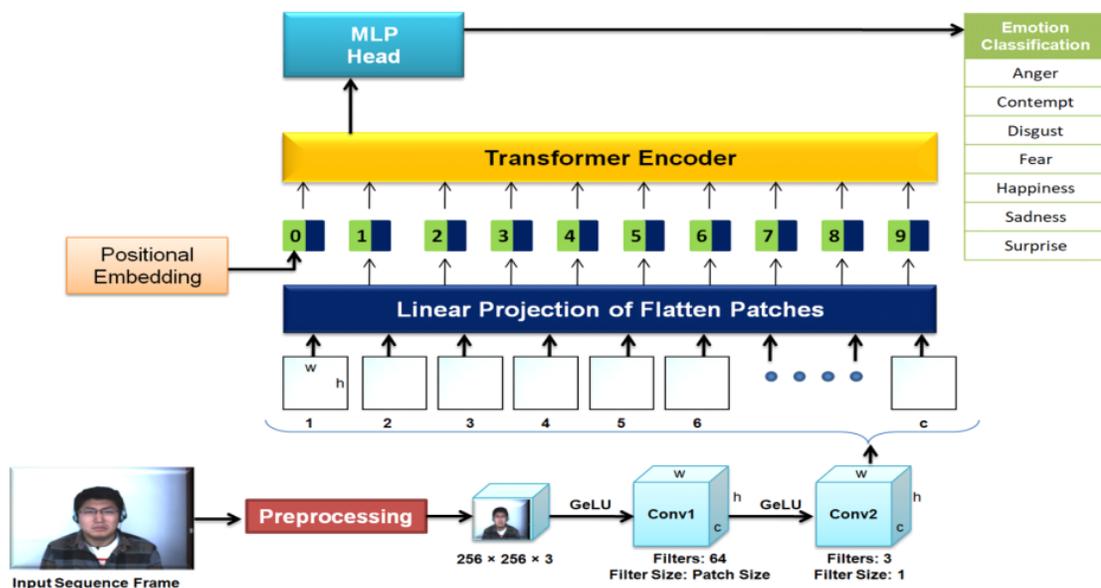
Fig. 4. Proposed vision transformer with convolution patches.
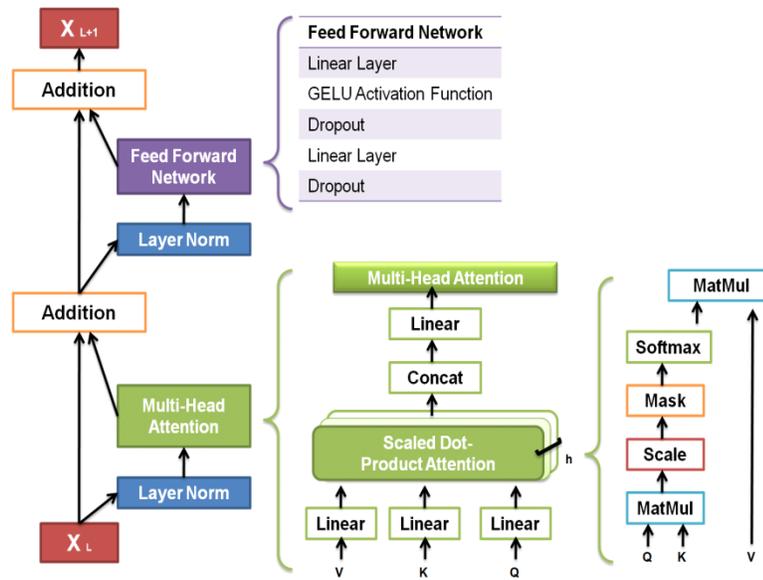
Fig. 5. Transformer encoder.

In this work, we have employed bi-directional long short-term memory for emotion recognition through EEG signals (as shown in Figure 6). The EEG signals are contaminated by unconscious movements such as eye blink. Thus, fast-fourier transforms have been applied in the proposed model as a preprocessing and feature extraction technique for enhancing performance of the model. Literature shows that EEG signals contain temporal as well as spatial information, thus, in this work, bi-directional long short-term memory is incorporated in the proposed model to exploit EEG signals. Performance of the proposed model has been evaluated on two benchmark datasets i.e., DEAP [36] and SEED [37]. DEAP dataset generated 91.53%, 90.55%, 89.77%, and 90.24% for valence, arousal, dominance, and liking, whereas 98.68% classification accuracy

was produced by the proposed model for the SEED dataset.

V. CONCLUSIONS AND FUTURE WORKS

The work described in this paper includes human emotion recognition through facial expressions, micro-expressions, and EEG signals. In this work, accurate facial expression recognition is demonstrated through the proposed models, which incorporate feature fusion, self-attention mechanisms, and wavelet domain techniques. These models generated state-of-the-art results for laboratory-controlled datasets, however, they did not perform as expected on in-the-wild datasets. Micro-expression recognition is a challenging task. Vision transformers have demonstrated their classification performance in various domains. Motivated by the success of
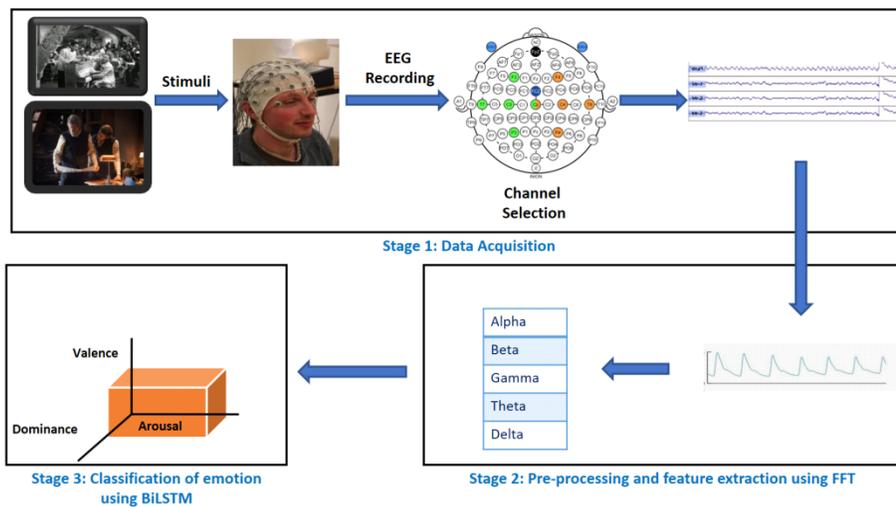
Fig. 6. Pipeline for human emotion recognition through EEG signals.

vision transformers, we proposed a convolutional patch-based vision transformer, which outperformed many state-of-the-art MER models. With the exceptional results generated by our proposed vision transformer on MER, we aim to test it on in-the-wild FER datasets and compare the results with self-attention-based models in the near future. Furthermore, we have performed human emotion recognition through EEG signals using the Bi-LSTM model. Spatial and temporal information from these signals can also be captured through the transformer model, which will be our future direction in this field.

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Selected Ph.D. Thesis Abstracts

This Ph.D thesis abstracts section presents theses defended in 2022 and 2023. These submissions cover a range of research topics and themes under intelligent informatics, such as prophylactic treatments to misinformation and disinformation, fatal disease detection using hybrid deep learning, geriatric care monitoring, graph model, interactive visualization, machine learning-assisted corpus exploration, large scale data exploration, remote patient monitoring, representation learning, secure content delivery in IoT, soft biometrics-based person retrieval, and safety solutions in smart cities.

Advancing Tropical Cyclone Forecasting through Data-driven Machine Learning

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TROPICAL cyclone is one of the extreme natural disasters with the greatest impact on human beings, and timely and accurate forecasting is of great significance to safeguard people's lives and properties. Traditional tropical cyclone forecasting methods commonly use numerical models based on the set of dynamical equations, which are inefficient in operation and have huge computational demands. Additionally, there is a bottleneck in forecasting due to the lack of clarity in the physical mechanism of tropical cyclone intensity and other related parameters. With the accumulation of modern meteorological and oceanographic data, and the development of artificial intelligence technology, data-driven machine learning methods can be a way to solve the problem.

Based on the practical needs of tropical cyclone forecasting operations, this paper focuses on the key scientific issues and technical problems in tropical cyclone intensity, track and wave height forecasting, and comprehensively applies the research method of cross-disciplinary integration of meteorology, oceanography and machine learning, and researches a set of robust and lightweight forecasting methods using multi-source meteorological and oceanographic data, while focusing on the forecast uncertainty. The main research work includes:

(1) A machine learning model incorporating distributed gradient boosting and natural gradient boosting is proposed for probabilistic forecasting of tropical cyclone intensity. According to the literature, this is the first time that a machine learning approach has been used to quantify the uncertainty in tropical cyclone intensity forecasts. Although studies using machine learning for intensity forecasting have emerged in recent years, these models can only provide single-point forecasts. Due to the complexity and uncertainty of the atmospheric system, relying exclusively on machine learning models for single-point forecasts of natural hazards can lead to catastrophic consequences. The probabilistic intensity prediction method proposed in this study addresses the shortcomings of traditional single-point prediction that cannot quantify uncertainty by combining the advantages of two types of gradient boosting methods and obtaining a calibrated model through a Bayesian approach, which improves prediction accuracy while providing reliable prediction distributions and intervals. In this paper, a machine learning model is trained using predictors from a statistical hurricane intensity prediction scheme of more than 30 years for forecasting intensity changes of tropical cyclones in the next 24 hours. During the evaluation period from 2010 to 2020, the model's deterministic forecasts can outperform the current state-of-the-art operationally run dynamical-statistical model, and more importantly, interval forecasts and reliable probabilistic forecasts can be obtained, which are critical for disaster warning. In this paper, two of the strongest hurricanes in 2020 are used as examples to verify the effectiveness of the proposed method in practical applications. An interpretable machine learning method is constructed to provide an in-depth analysis of the importance of predictors, which provides a deeper understanding of tropical cyclone intensity forecasting.

(2) A deep learning model for multimodal data fusion is proposed for probabilistic forecasting of tropical cyclone intensity. This study is an extension of the previous study in the spatio-temporal dimension, which was motivated by the fact that the previous study required a large number of forecast factors as model inputs. This study makes full use of the superiority of deep learning techniques in feature extraction, proposes heteroskedastic regression as the overall framework, takes the normal distribution as the forecasting objective, adopts three-dimensional environmental field data as well as easily accessible statistical features as inputs, and realizes the full mining of implied modes through the construction of multiple feature extraction and fusion modules to obtain accurate deterministic forecasts and reliable probabilistic forecasts. In this paper, probabilistic forecasts of tropical cyclone intensity are made 6-24 hours in advance. The experimental results show that the performance of the proposed method in deterministic forecasting is comparable to that of the major global weather forecasting organizations in a sustained 4-year independent testing phase. In addition, several uncertainty quantification methods are constructed in this study for comparing the performance of probabilistic and interval forecasts. The results show that the proposed method yields more reliable forecast intervals and forecast distributions. In this paper, two super typhoons are used as examples to examine the performance of the model in actual forecasting.

(3) It is the first time to propose the uncertainty forecasting of tropical cyclone paths based on Conformal prediction (CP), which provides new methods and ideas in this field. The

uncertainty prediction of tropical cyclone paths in operational operation is usually based on super ensemble forecasts formed by multiple runs of complex dynamical models with adjusted parameters, and large-scale and long-time calculations are performed using supercomputers. In contrast, the conformal prediction method proposed in this paper is a model-independent machine learning approach that is able to construct rigorous uncertainty regions for path forecasts with very low computational effort.

In this paper, we jointly examine the path forecasting performance of 10 machine learning models, as well as 10 conformal prediction methods by means of a comparative study. The research work is modeled for 6-, 12-, and 24-hour forecast horizons, and the study covers hurricanes in the Atlantic Ocean from 1975 to 2021. The experimental results show that the model's deterministic forecasts are comparable to the skill level of the operationally run benchmark model, demonstrating that the proposed model possesses forecast skill while also providing tight uncertainty intervals about the path forecasts. Another contribution of this study is the proposed "track forecast ellipse" method, which can obtain the ellipse intervals of the future track of a tropical cyclone in a map by using the latitude and longitude intervals predicted by the machine learning method. In this study, the effectiveness of conformal prediction in solving this problem is examined by taking three major hurricane track forecasts as examples.

(4) A tropical cyclone wave height forecasting method based on ensemble empirical mode decomposition and long and short-term memory neural networks is proposed. Wave height prediction due to tropical cyclones is one of the key factors in tropical cyclone forecasting, which is of great significance for offshore operations and coastal safety. Previous studies have hardly considered the nonlinear and nonsmooth characteristics of tropical cyclone wave heights. In this study, we propose to combine an adaptive time-frequency decomposition method with a deep learning method to solve this problem, and realize robust, accurate, and interpretable tropical cyclone wave height forecasts. The study is based on wave height data obtained from 14 buoy sensors distributed around offshore China, involving 28 tropical cyclone events in the Northwest Pacific Ocean over a period of 9 years. The experimental results show that the method proposed in this paper is significantly better than the baseline model and previous studies. By comparing the operational results with those of the state-of-the-art operational numerical models, the present method has certain advantages in short-range forecasting. In addition, the prediction performance of wave height caused by Super Typhoon Connie is further examined.

This paper systematically provides new ideas and methods for tropical cyclone forecasting, and solves the problems of lack of uncertainty quantification, high computational cost, and low forecast performance. It is expected to be an effective complementary program for the actual operational forecasting of tropical cyclones.

AUTOMATING MODERATORS' ACTIONS IN ONLINE QUESTION-ANSWERING COMMUNITIES

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ONLINE question-answering (Q&A) communities have specific rules to maintain their content quality and to remain as reliable sources for a topic. Due to the large sizes of these systems in terms of the number of users and posts, manual control and approval of all posts by administrators are not possible or scalable. The current dominant solution is the use of crowdsourcing and relying on user reports, which itself has serious problems, including the slow speed of handling violations, the waste of regular and experienced users' time, the low quality of user reports, and discouraging feedback to new users from the community. Furthermore, the previous efforts to automate moderation actions via AI failed to replace the crowdsourcing method, mostly due to their low accuracy, limited scope of target actions (mostly tag recommendation), and limitations on target users (mostly fit for experienced users).

In this thesis, by examining the problems of current approaches and considering the recent NLP advances, a six-component process is proposed to classify questions based on their accordance with user guidelines on the target community. We utilized a recent NER model [1], BERT sentence embedding, and neural networks to form three feature extraction components that depend only on the textual content of the post and do not use features from user profiles or community feedback. These techniques, in conjunction with several state-of-the-art visualization and exploration [2] approaches were utilized to increase the accuracy and speed of the proposed solution. The evaluation results for classifying questions based on quality and suggesting edits show precisions between 79 and 92 percent. The results based on the F1-score metric indicate a 9-19% improvement compared to the baseline models and a 7-16% positive impact as a direct result of the feature extraction components related to the system context and questions' subjective features.

By using our proposed solution in real Q&A platforms, violations would be instantly detected or prevented from publication, new users would have a safe training system, and all users would benefit from a higher-quality forum. Future research can utilize the overall process, as well as the individual feature extraction components, to solve similar tasks of content moderation. The methodology and results of this thesis are published in [3]. The model and data for extracting subjective features of questions are detailed in [4]; and the overall requirements for automating moderation in community question-answering websites are discussed in [5]. A broader scope of the research is published as a book chapter in the Encyclopedia of Machine Learning and Data Science [6]. Furthermore, the original dataset accompanying the research is made publicly available on Kaggle.

Link to the official soft-copy version (in Persian): http://library.sharif.ir/parvan/resource/496181/a

COMPUTATIONAL APPROACHES FOR CROWD BEHAVIOR UNDERSTANDING IN REAL SCENES

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THIS thesis is a comprehensive study of computational approaches for crowd behaviour understanding in real-life scenes. It has numerous applications in the real world, such as crowd management, public space design, crowd security, video surveillance, etc. There are many challenges associated with these tasks, including severe occlusion, complex backgrounds, illumination effects, scale variation, non-uniformity, feature similarity, and a lack of labelled data for training. Deep learning-based methods available for crowd modelling have commendable performance, but the problems associated with these approaches are feature representation and computational parameters. This thesis provides a detailed implementation and analysis of crowd behaviour understanding models, which primarily include crowd counting and density estimation, object detection and tracking, and behaviour detection. For crowd counting and density estimation, a deep learning-based model is proposed to count the crowd and estimate its density. The proposed model incorporates the features of multi-scale, multi-column, and attention-based networks. We have proposed a Modified Pyramid Scale Network and a Scale-Aware Deep Convolutional Pyramid Network to deal with two major challenges, i.e., scale variation and feature similarity associated with crowd counting. The proposed model incorporates message passing and global attention mechanisms into a multi- column network to tackle scale variation. A multi-column variance loss function is used to minimise feature similarity. The analysis of the model was demonstrated on the UCF_CC_50 and ShanghaiTech datasets for sparse and dense crowds, respectively. For comparison among the models, MAE and RMSE metrics were used.

For object detection, a deep learning-based algorithm, i.e., You Look Only Once (YOLO), is used. We have only focused on the detection of the person in an image. Here, we have used transfer learning to generate the person detection system using the YOLOv3 model. We have generated the content-specific and customised dataset and annotated the dataset manually by using the Label Tool. Further, an improved architecture for object tracking is proposed. It is built on fine-tuned YOLOv3 and DeepSORT algorithms. DeepSORT, along with the Kalman filter and Hungarian algorithm, is used for object tracking. The Kalman filter is used to deal with the occlusion challenge. The performance of the proposed models has been demonstrated on the COCO-person, MOT16, and MOT17 datasets. Performance metrics used for comparison for object detection and tracking methods were mean accuracy precision, multiple object tracking accuracy, false positive, false negative, and switch identity.

We have implemented a MobileNetv2-based model for violence detection in videos, which has a smaller number of computational parameters. The model was compared with other state-of- the-art methods such as InceptionV3, VGG-19, MobileNet, and MobileNetv2. The proposed model reports the minimum number of computational parameters and comparable accuracy with other existing methods. To demonstrate the performance of the model, two publicly available datasets, Real Life Violence Situations and Hockey Fight Detection, were used. Precision, recall, accuracy, and F1-Score were used to compare the models, along with their computation parameters.

DEEP LEARNING BASED APPROACH FOR CLOUD REMOVAL IN REMOTE SENSING DATA

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I. REMOTE SENSING

Remote sensing is one of the key technologies which have transformed the social and economic parameters of many countries. Remote sensing data are being utilized to understand the features of earth surface. Due to the extensive spatial and temporal coverage of satellites, the information received from them is enormous and have many advantages for the society. In the undeveloped world, agricultural remote sensing applications, especially for crop statistics and soil mapping, have proven challenging to implement. Using remote sensing accurate image interpretation can yield samples that truly reflect the agricultural growing conditions. Also, Remote Sensing is immensely useful in disaster management and data generated by models helps in providing pre-warning information for many disasters like forest fire, cyclones, earthquakes which helps in saving precious human life and valuable goods.

II. RESEARCH AGENDA

Many times satellite imagery has gap areas, mainly due to cloud presence, which largely affects their quality and limits their usability for Earth Observation purpose. Further, several times the data may be of low quality due to technical glitches and get a miss for some unavoidable human errors or due to environmental factors. Remote Sensing data acquired from satellites often shows gaps and the data is not continuous. Further, as clouds are the main hindrances in optical remote sensing imagery and India having a tropical climate with agriculture contributing significantly in the Indian economy, removing clouds and reconstructing remote sensing imagery is a major area of concern and poses a significant challenge even today.

Our study in this thesis is aimed to explore deep learning technology for a novel work of removing gaps, mainly clouds, from remote sensing data. This will enhance the usability and quality of images for Earth observation, natural resource management and planning, disaster management and support, whereby significantly contributing towards societal benefits and improvement of Indian economy and world at large.

III. METHODOLOGY & OUTCOME

In order to conduct this work we collected the spatial data pertaining to different locations of varying terrains and topography between time periods 2017 to 2020 from open sources of Landsat and Sentinel satellites. The area of interest

and scenes covered with clouds were extracted. The scenes were chosen with different types of clouds and varying cloud cover percentage for vast applicability of algorithms. Near real time temporal cloud free images were selected for comparison and accuracy evaluation of the algorithms and models applied. We started with traditional approaches for cloud removal in distorted images and reconstructing the spatial data. Further, different deep learning algorithms were applied them. The reconstructed output image was compared with ground truth (temporal cloud free image) to evaluate the performance of these algorithms and models. Visual observations and evaluation metrices were used for evaluation. Upgraded models and algorithms were proposed as a outcome of the study for cloud removal and reconstruction of remote sensing data. One of the future prospects could be to explore alternative architectures and parameters.

TOWARDS EFFECTIVE PERFORMANCE DIAGNOSIS FOR DISTRIBUTED APPLICATIONS

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C LOUD computing provides elastic and on-demand resources for distributed applications to deliver high-quality ser- vices. However, the dynamism of underlying cloud infrastructures and complex dependencies between services introduce abnormal performance phenomena, e.g., degradation, which severely affect the quality of services and the user experience. To make services in applications continuously operational, performance diagnosis systems aiming to detect performance anomalies, such as slow response times, and localize their root causes are required. Such kinds of systems have been studied in recent years. A typical performance diagnosis system comprises components for collecting and pre-processing monitoring data, detecting performance anomalies, and localizing root causes. The data collection and pre-processing components reduce noise in the monitoring data and make it available for the performance anomaly detection component to diagnose the system, e.g., using statistical or machine learning methods. To be effective, anomaly detection has to be accurate, robust in fitting different data distributions in real scenarios, and predictive to prevent potential application violations. The root cause localization component aims to accurately identify the underlying causes of performance anomalies, such as resource-related metrics in faulty services. However, a large number of anomalous metrics and complex anomaly propagation paths make it challenging to determine the root cause.

To tackle the above challenges, we first review the state-of-the- art research and methods for creating a reliable performance diagnosis system from a technical perspective. Based on the review, we propose a comprehensive performance diagnosis system that can effectively detect performance anomalies with existing detection methods and localize their root causes based on anomaly propagation paths to provide actionable insights to oper- ators [1]. We also observed that existing

detection methods have varying performance for different datasets because they focus on different features in the data. Furthermore, effective anomaly detection methods should meet challenging requirements, in- cluding high accuracy in detecting anomalies and robustness to changing data patterns, while few studies have addressed both challenges simultaneously. To address these issues, we propose an ensemble learning-based detection (ELBD) framework that integrates well-selected existing methods, including three classic linear ensemble methods and a novel deep ensemble method. Our deep ensemble method, which is weakly supervised, achieves the highest accuracy and robustness for performance anomaly detection in distributed applications [2]. In addition, we propose an unsupervised detection method called CGNN-MHSA-AR for multivariate time series anomaly detection [3]. This method leverages temporal and feature information to achieve superior accuracy compared to baseline detection methods. As for root cause localization, considering that currently used CI methods have limitations, such as the linear causal relations assumption and strict data distribution requirements, we propose a root cause localization framework working with gradient-based causal inference and named CausalRCA [4]. The CausalRCA uses a gradient-based causal structure learning method to generate weighted causal graphs and a root cause inference method to localize root cause metrics, achieving fine-grained, automated, and real-time root cause localization. We conduct coarse- and fine-grained root cause localization to evaluate the localization performance of CausalRCA. Experimental results show that CausalRCA significantly outperforms baseline methods in localization accuracy.

TOWARDS A SMARTER HEALTHCARE: THE ROLE OF DEEP LEARNING SUPPORTING BIOMEDICAL ANALYSIS

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M EDICAL imaging has always been increasingly relevant in modern healthcare, and tremendously progressed in the last few decades. In addition, the latest years also witnessed the incredibly fast rise of Artificial Intelligence (AI) and its application in a wide range of application domains. Interestingly, AI techniques proved to be quite effective at tackling tasks in the healthcare sector, and are considered crucial, for instance when applied to medical imaging, in the journey towards more precise diagnoses and more effective treatments. Among all AI techniques industry, academia and popular culture have all recently taken a particular interest in Machine Learning (ML), largely due to very effective developments like the breakthroughs in Deep Learning (DL), that allow one to locate patterns in vast amounts of data by applying a proper set of algorithms and methodologies. Several image analysis techniques are subject of constant attention by the scientific community, including image synthesis, segmentation, disease diagnosis and computerized surgeries.

In this thesis, we present the findings of our studies in the field along with our research activities, that have been mainly focused on two important topics: Image synthesis for MR-only radiotherapy and Lesion segmentation. Our first topic is related to image synthesis. In image synthesis, images are artificially generated that contain specific content. An analogy would be generating an image containing the visual content associated with any given label as the inverse of the classification problem. Medical images can be produced using diverse imaging protocols, each with unique characteristics. A medical image synthesis method has been extensively explored for clinical applications owing to the high costs associated with scanning high-quality single modalities of images or homogeneous multiple modalities of images. For medical image synthesis, deep learning approaches, particularly convolutional neural networks (CNNs) and generative adversarial networks (GANs), have become increasingly popular over the past few years. MR-based CT synthesis is the objective of this thesis as it pertains to MR-only radiotherapy. Using clinically relevant quality measures, we evaluated different categories of CT synthesis methods. For the brain images specifically, we have implemented a Deep Convolutional Neural Network (DCNN) based method and provided a variety of loss functions, which compare favorably to state-of-the-art methods. Next, we review recent methods of image synthesis through systematic literature reviews. In our next effort, we substantially improved our model by using the attention mechanism to improve the quality of images not only in terms of intensities but also based on structural similarity. Since the scientific community is more focused towards the intensities of the images but the structure and borders of the image are also important for the synthetic image accuracy.

The second topic of this thesis explores how to segment lesion patterns in Computed Tomography (CT) scans. Segmentation is an important operation in Computer Vision. By segmenting images, we group objects that belong to the same class in an image. It is also referred to as pixel-level classification. Another way to describe it is splitting an image (or video frame) into multiple segments or objects. In medicine, image segmentation is often used to estimate tissue volumes or extract tumor boundaries. For example, image databases can be created that can be used to analyze pandemics and fast-spreading diseases. Medical imaging data for emerging infectious diseases is constrained by a limited size of publicly available datasets, which requires large scale annotations for better performance. Using convolutional neural networks (CNN) the thesis proposes an unsupervised method that combines Generative Adversarial Network (GAN) with a Convolutional Neural Network (CNN) ensemble to overcome data constraints and effective lesion segmentation. Using Cycle-GAN, we develop an unsupervised method for converting infected images into healthy ones. In our proposed adversarial network, an attention-based mask generator is used to improve this method. Data infected with COVID-19 was used to demonstrate this. Comparatively to state-of-the-art approaches, this method gives us a more accurate representation of lesions. Lesion segmentation can be done efficiently with this approach since it does not require annotated data and it is completely unsupervised. This manuscript is presented in two parts: the first one illustrates some background theoretical concepts and reports about our studies of the state-of-the-art in medical imaging and DL, while the second one presents the results of our works on biomedical image analysis via DL techniques. In this thesis, we have provided all the contribution to the scientific community using DL techniques in details.

WILDLIFE-VEHICLE COLLISIONS MITIGATION MEASURES USING ROAD ECOLOGICAL DATA AND DEEP LEARNING

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THE typical mitigation measures for wildlife-vehicle collisions (WVCs) include traditional methods such as overpasses, underpasses, and wildlife fencing. Other measures are intelligent systems like break-the-beam, area-cover, buried cable animal detection systems and machine learning approaches, which have been increasingly successful due to advancements in computational facilities. These methods have the potential to mitigate WVC, improve road safety, and enhance biodiversity by redirecting wildlife to non-hotspot areas and alerting drivers of wildlife presence on high- ways. However, these advanced techniques are not widely implemented in Africa, especially in South Africa, where WVC incidents are increasing due to difficulties in identifying wildlife concentration areas. This multidisciplinary thesis investigated the application of machine learning on road ecological data to ad- dress the challenge of WVC through different types of interventions.

Firstly, an ethically aligned framework was developed following an inductive method using grounded theory. The framework guides stakeholders on what to consider when implementing machine learning wildlife monitoring tools. Secondly, an error correction-based deep neural network was implemented to model and predict WVC using data collected in Limpopo region in South Africa as WVC cases, taking into account the immersive non-linear tendencies of wildlife crossing patterns. Finally, a novel approach to create awareness about potential WVC areas was proposed using traditional wildlife fencing and machine learning. This approach introduces a recognition and segmentation algorithm to detect wildlife electric fences and associated features to alert road users about potentially unsafe and insecure WVC areas, in turn improving the safety of road users and mitigating WVC incidents. This approach could also positively influence tourist destinations and tourism in the country. Future research opportunities are discussed.

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https://www.wi-iat.com/wi-iat2024/

The 2024 IEEE/WIC International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT'24) provides a premier international forum to bring together researchers and practitioners from diverse fields for presentation of original research results, as well as exchange and dissemination of innovative and practical development experiences on Web intelligence and intelligent agent technology research and applications. Academia, professionals and industry people can exchange their ideas, findings and strategies in deepening the understanding of all Web's entities, phenomena, and developments in utilizing the power of human brains and man-made networks to create a better world and intelligent societies. More specifically, the fields of how artificial intelligence is impacting the Web of People, the Web of Data, the Web of Things, the Web of Trust, the Web of Agents, the Web in industry, society, health, and smart living, the Web of Everything, and emerging AIGC in WI-IAT.

The goal of WI-IAT conferences is to provide a global forum for scientists, engineers and educators to present the latest WI-IAT technologies, discuss how to develop future intelligent systems for complex applications. After these years, in 2016, WI-IAT conferences have been merged as one brand (WI'16 in Omaha, USA, WI'17 in Leipzig, Germany, WI'18 in Santiago de Chile, and WI'19 in Thessaloniki, Greece) by redefining and vitalizing the WI aims and topics. In recognition of the strong connection of Web Intelligence and Intelligent Agent Technology, the classic brand of WI-IAT was resumed in 2020. After the great successful

online WI-IAT'20, hybrid WI-IAT'21, WI-IAT'22, and WI-IAT'23, WI-IAT'24 will be held in Bangkok, Thailand, and once again, in the hybrid mode. Therefore, the theme of WI-IAT '24 will be: "Web Intelligence = AI in the Connected World".

Web Intelligence and Intelligent Agent Technology (WI-IAT) aims to achieve a multi-disciplinary balance between research advances in theories and methods usually associated with collective intelligence, data science, human-centric computing, knowledge management, network science, autonomous agents and multi-agent systems. It is committed to addressing research that both deepen the understanding of computational, logical, cognitive, physical, and social foundations of the future Web, and enable the development and application of intelligent technologies. WI-IAT'24 provides a premier forum and features high-quality, original research papers and real-world applications in all theoretical and technology areas that make up the field of Web Intelligence and Intelligent Agent Technology. WI-IAT'24 welcomes research, and application as well as Workshop and Special-Session proposals and papers. WI-IAT'24 in Bangkok (Thailand) is officially sponsored by IEEE Computer Society Technical Committee on Intelligent Informatics (TCII) and Web Intelligence Consortium (WIC).

WI-IAT'24 will provide a broad forum that academia, professionals and industry people can exchange their ideas, findings and strategies in deepening the understanding of all Web's entities, phenomena, and developments in utilizing the power of human brains and man-made networks to create a better world. WI-IAT'24 is soliciting high-quality original research. Relevant topics include (but are not limited to) the fields of how artificial intelligence is impacting: the Web of People, the Web of Data, the Web of Things, the Web of Trust, the Web of Agents, the Web of Everything, and emerging FAccT in WI-IAT. This year features two special tracks: Web in Industry, Society, Education, Health and Smart Living, and the Web of Everything; and FAccT, LLM and AIGC.

Important dates for WI-IAT'24 include May 15,

2024, the due date for Workshop proposal submissions, and July 15, 2024, as the due date for paper submissions for the main conference. Workshop papers submissions are due by July 30, 2024. Papers must be submitted electronically via CyberChair in standard IEEE Conference Proceedings format (max 8 pages, templates at https://www.ieee.org/conferences/publishing/templates.html). Industry and Demo papers must specify "industry" or "demo" in their title, and they are limited to 4 pages including references. Submitted papers will undergo a peer review process, coordinated by the International Program Committee. Accepted papers will be published in the conference proceedings by IEEE and submitted to EI. Selected WI-IAT'24 papers will be further invited for expansion and publication in Web Intelligence journal and other international journals. Detailed submission guidelines can be found at https://www.wi-iat.com/wi-iat2024/Participant-Submission.html.

The conference also offers Journal publication opportunities for Web Intelligence Journal, Brain Informatics and Natural Language Processing Journal. This year's conference is taking place at the KX Knowledge Exchange Center in Bangkok, Thailand. Workshops and special sessions will run on December 9, ahead of the main conference starting on December 10, 2024. Please refer to the conference website for further information about the venue and attendance.

IEEE ICDM 2024
The 24th IEEE International Conference on Data Mining
Abu Dhabi, UAE
December 9-12, 2024
https://icdm2024.org/

The IEEE International Conference on Data Mining (ICDM) has established itself as the world's premier research conference in data mining. It provides an international forum for sharing original research results, as well as exchanging and disseminating innovative and practical development experiences. The conference covers all aspects of data mining, including algorithms, software, systems, and applications. ICDM draws researchers,

application developers, and practitioners from a wide range of data mining related areas such as big data, deep learning, pattern recognition, statistical and machine learning, databases, data warehousing, data visualization, knowledge-based systems, high-performance computing, and large models. By promoting novel, high-quality research findings, and innovative solutions to challenging data mining problems, the conference seeks to advance the state-of-the-art in data mining.

Topics of interest at this year's conference include, but are not limited to: foundations, algorithms, models and theory of data mining, including big data mining; deep learning and statistical methods for data mining; mining from heterogeneous data sources, including text, semi-structured, spatio-temporal, streaming, graph, web, and multimedia data; data mining systems and platforms, and their efficiency, scalability, security and privacy; data mining for modelling, visualization, personalization, and recommendation; data mining for cyber-physical systems and complex, time-evolving networks; and applications of data mining in social sciences, physical sciences, engineering, life sciences, web, marketing, finance, precision medicine, health informatics, and other domains.

ICDM 2024 particularly encourages submissions in emerging topics of high importance such as ethical data analytics, automated data analytics, data-driven reasoning, interpretable modeling, modeling with evolving environments, multi-modal data mining, and heterogeneous data integration and mining. Authors are invited to submit original papers, which have not been published elsewhere and which are not currently under consideration for another journal, conference or workshop. Paper submissions should be limited to a maximum of ten (10) pages, in the IEEE 2-column format (https://www.ieee.org/conferences/publishing/templates.html), including the bibliography and any possible appendices. There is a current call for papers with a paper submission deadline of June 14, 2024. For further questions regarding the call for papers at ICDM 2024, please email Dr. Mingming Gong: mingming.gong@mbzuai.ac.ae.

The 24th IEEE International Conference on Data Mining (IEEE ICDM 2024) includes half- or full-day workshops that complement the main conference technical program, with the goal of expanding new directions and applications of data mining for both practitioners and researchers in a particular field. Accepted workshops are expected to be held on December 9th, 2024. These workshops provide a more focused, in-depth venue for presentations, discussions and interaction. Each workshop will solicit papers (max 8 pages plus 2 extra pages) for peer review. Furthermore, as in previous years, papers that are not accepted by the main conference will be automatically sent to a workshop selected by the authors when the papers were submitted to the main conference. By the unique ICDM tradition, all accepted workshop papers will be published in the dedicated ICDMW proceedings published by the IEEE Computer Society Press. Please see the conference website for full information about Workshop proposal formats. Workshop proposals should be submitted in plain text or PDF, by email (subject: "IEEE ICDM Workshop proposal") to the Workshops Chairs, Wassim Hamidouche (wassim.hamidouche@tii.ae) and Imran Razzak (imran.razzak@unsw.edu.au). These are due by April 10, 2024, with the workshops taking place prior to the conference on December 9, 2024.

ICDM is a premier forum for presenting and discussing current research in data mining. Therefore, at least one author of each accepted paper must complete the conference registration and present the paper at the conference, in order for the paper to be included in the proceedings and conference program. The exact format of the conference (in person, online, or hybrid) will be decided later. Please regularly check the conference website for updates.

This year's conference is hosted by Abu Dhabi. Abu Dhabi is truly a one-of-a-kind destination, unlike anywhere else. The city is vibrant, modern and is known for being the safest city in the world. It's ideally positioned so that half of the world's population is within a five-hour flight. Abu Dhabi's year-round sunshine along with its growing knowledge economy and numerous attractions are all enabling the city to emerge as a popular business hub and a favoured spot for tourists. ICDM 2024 is more than a conference; it's an opportunity to engage with the vibrant community of Abu Dhabi. Whether you're exploring its rich cultural heritage, indulging in local cuisine, or networking with fellow attendees against the backdrop of this stunning city, your experience at ICDM 2024 promises to be unforgettable.

Early-bird Registration Fees are due by September 27，2024 for Non-Authors, or Co-Authors not registering a paper. Registration for the conference closes on October 11, 2024. Please check the conference website regularly for updates about registration.

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ICHI 2024
The 12th IEEE International Conference on Healthcare Informatics
Orlando, Florida, USA
June 3-6, 2024
https://ieeeichi2024.github.io/

ICHI 2024 is a premier community forum concerned with the application of computer science, information science, data science, and informatics principles, as well as information technology, and communication science and technology to address problems and support research in healthcare, medicine, life science, public health, and everyday wellness.

The conference highlights the most novel technical contributions to stakeholder-centered technology innovation for benefiting human health and the related social and ethical implications. ICHI 2024 will feature keynotes, a multi-track technical program including papers, posters, panels, workshops, tutorials, an industrial track, a doctoral consortium, and a women in healthcare informatics event.

Authors are strongly encouraged to submit their original contributions describing their algorithmic, methodological or empirical contributions, and theories relevant to the broader context of health informatics. Submissions can focus on one or more specific aspects of theory, design, development, evaluation, or deployment. The conference covers three tracks: Analytics, Human Factors and Systems. The Analytics track invites submissions on novel methods for exploring and analyzing healthcare data such as biomedical pattern recognition, biomarker discovery, disease profiling and personalized treatment, natural language processing and text mining, recommender systems, clinical phenotyping, visual analytics, explainability, and epidemiological modeling. For the Human Factors track, contributions in the realm of Human Factors may include empirical studies on the use and needs of health information technology in everyday life, socio-technical studies on the implementation and utilization of health information technology in clinical settings, investigations into the community-level impact and implications of health informatics, design

and evaluative efforts centered on innovative user-centered health information technology, as well as empirical research on public policies that leverage health informatics infrastructures. The Systems track welcomes submissions related to the design, development, deployment, and evaluation of high-performing, privacy-preserving and secure software or hardware systems. In particular, the Systems track invites submissions on the development of large language model (LLM) applications, such as ChatGPT, their utilization in clinical settings, and the strengths and limitations of LLMs in enhancing the efficiency and effectiveness of clinical research, education, and practice.

When submitting papers, the authors must select a track that is most appropriate for their submission. For example, a paper on information systems for healthcare delivery can be submitted to either the Systems track, or the Human Factors track, depending on the focus of the work. Before a submission is sent to the reviewers, the program chairs will also perform an assessment to determine the best fit for the submission. Further information about each track is available on the website. The conference will accept both regular and short papers. Regular papers (10 pages including references) will describe mature ideas, where a substantial amount of implementation, experimentation, or data collection and analysis has been completed. Short papers (6 pages including references) will describe innovative ideas, where preliminary implementation and validation work have been conducted. Paper submissions must adhere to the IEEE Proceedings Format. The deadline for submission of papers is January 31, 2024.

Posters and demos are an excellent way to present innovative ideas, late-breaking work, concepts, work-in-progress, early stages of research, and preliminary results from implementation and validations to academic and industrial audience. These must also fit the three tracks and should be 1-2 pages (excluding references) in the same format as full and short papers. These are also due by January 31, 2024.

Workshops will be held on the day prior to the start of the main program (June 3, 2024) and should address topics relevant to healthcare informatics. This year's conference will include the First Workshop on Applying LLMs in LMICs for Healthcare Solutions; a workshop on Data privacy and data analysis in healthcare systems; The 2nd International Workshop on Ethics and Bias of Artificial Intelligence in

Clinical Applications; Multimodal Representation Learning for Healthcare; Human-Centred XAI: Enhancing AI Acceptability for Healthcare; and The Third International Workshop on Health Informatics Education. Full paper submissions are due by March 21, 2024.

ICHI 2024 also offers a Doctoral Consortium that provides an outstanding opportunity for doctoral students working on health informatics problems to discuss their work in progress and receive feedback and guidance from Consortium mentors. There is also a call for papers for the Industry track where submissions are invited to describe practical implementations of healthcare informatics, and following the success in previous years, a call for tutorial proposals. Tutorials at ICHI 2024 will be presented by domain experts to cover current topics directly relevant to the conference theme of computing-oriented health informatics. A list of topics of interest to ICHI 2024 include health data science, health informatics, innovative technologies and implementation science. Tutorials can be half day (3 hours) or full day (6 hours) in length. Tutorial instructors must make a commitment to prepare tutorial materials (including slides and activities) that reflect the high-quality standard of ICHI. Please check the ICHI 2024 conference website for submission dates for each of these calls.

All submissions will be published in IEEE Xplore and indexed in other Abstracting and Indexing (A&I) databases. Accepted papers have an oral presentation slot at the conference. Selected papers will be invited to submit the extended version to the Journal of Healthcare Informatics Research, and a fast-track review will be conducted for the extended papers. All submissions for papers, posters and demos, workshops, the Doctoral Consortium, Industry track and tutorials must be made through the EasyChair system on the conference website. Please see the conference website for the link.

IEEE BigData 2024
The 2024 IEEE International Conference on Big Data (IEEE BigData 2024)
Washington DC, USA
December 15-18, 2024
https://bigdataieee.org/BigData2024/index.html

In recent years, "Big Data" has become a new ubiquitous term. Big Data is transforming

science, engineering, medicine, healthcare, finance, business, and ultimately our society itself. The IEEE Big Data conference series started in 2013 has established itself as the top tier research conference in Big Data. The 2024 IEEE International Conference on Big Data (IEEE BigData 2024) will continue the success of the previous IEEE Big Data conferences. It will provide a leading forum for disseminating the latest results in Big Data Research, Development, and Applications.

IEEE BigData 2024 will cover topics of interest such as Big Data Science and Foundations, Big Data Infrastructure, Big Data Management, Big Data Search and Mining, Big Data Learning and Analytics, Data Ecosystem, Foundation Models for Big Data, and Big Data Applications. Each topic covers a number themes and sub-topics relevant to Big Data research and industry.

This year's conference has an Industrial Track, which solicits papers describing implementations of Big Data solutions relevant to industrial settings. The focus of the industry track is on papers that address the practical, applied, or pragmatic or new research challenge issues related to the use of Big Data in industry. Both full papers (up to 10 pages) and extended abstracts (2-4 pages) are accepted.

A Government Track welcomes papers discussing the usefulness and need for publicly-contribution big data and open data and their use. Specifically, data utilization scenarios, needs analysis, data utilization obstacle analysis and solutions, data integration processes, interfaces as data utilization solutions, visualization, use cases, evidence-based policy making, building an ecosystem for solving social issues, analyzing their cases, comparing international and regional differences, and conducting comparative surveys before and after specific events (like Covid-19). We are also looking for other big data solutions related to national and local governments, and public services. An extended abstract (2-4 pages) OR a full-length paper (up to 10 pages) should be submitted through the online submission page (Industrial & Government Track dedicated page)

The deadline for electronic submission of fulle papers is September 3, 2024. There is now also a new 'Vision' paper category. Either a full-length paper (up to 10 page IEEE 2-column format, reference pages counted in the 10 pages, or a short Vision paper (up to 5 pages IEEE 2-column format, including references) can be submitted

through the online submission system: https://wi-lab.com/cyberchair/2024/bigdata24/index.php

The conference will be held in Washington DC, USA in 2024. Please refer to the website for announcements, details and registration for IEEE BigData 2024.

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IEEE ICKG 2024
2024 IEEE International Conference on Knowledge Graphs (ICKG)
TBA

Knowledge Graph represents knowledge from heterogeneous, and autonomous information sources for complex and evolving data and structural, semantic and contextual relationships, in addition to domain expertise, embedded in the data. The IEEE International Conference on Knowledge Graph (ICKG) is a premier international forum for presentation of original research results in knowledge graphs' opportunities and challenges, as well as exchange and dissemination of innovative, practical development experiences. The conference covers all aspects of knowledge graphs, including algorithms, software, platforms, and applications for knowledge Graph construction, deployment, maintenance, and inference.

ICKG 2024 draws researchers and application developers from a wide range of knowledge graph related areas such as knowledge engineering, big data analytics, statistics, machine learning, pattern recognition, data mining, knowledge visualization, graph mining, machine learning for graphs, high performance computing, and World Wide Web. By promoting novel, high quality research findings, and innovative solutions to challenging knowledge graph problems, the conference seeks to continuously advance the state-of-the-art in knowledge graphs. ICKG aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Knowledge Graphs. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered, and solutions adopted in the fields of Knowledge Graphs.

Prospective authors are kindly encouraged to contribute to and help shape the conference

through submissions of their research abstracts, papers and e-posters. Also, high quality research contributions describing original and unpublished results of conceptual, constructive, empirical, experimental, or theoretical work in all areas of Knowledge Graphs are cordially invited for presentation at the conference.

Please check the conference website when available for details about the format, paper submission and registration.

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AAMAS 2024
The 23rd International Conference on Autonomous Agents and Multi-Agent Systems
Auckland, New Zealand
May 6-10, 2024
https://www.aamas2024-conference.auckland.ac.nz/

Autonomous Agents and Multiagent Systems (AAMAS) is the largest and most influential conference in the area of agents and multiagent systems, bringing together researchers and practitioners in all areas of agent technology and providing and internationally renowned high-profile forum for publishing and finding out about the latest developments in the field. AAMAS is the flagship conference of the non-profit International Foundation for Autonomous Agents and Multiagent Systems (IFAAMAS). In 2024, AAMAS finally comes to New Zealand as a fully offline conference.

The AAMAS conference series was initiated in 2002 in Bologna, Italy as a joint event comprising the 6th International Conference on Autonomous Agents (AA), the 5th International Conference on Multiagent Systems (ICMAS), and the 9th International Workshop on Agent Theories, Architectures, and Languages (ATAL).

AAMAS 2024 will feature Tutorials, Demos, Competitions, a Doctoral Consortium, a JAAMAS track for presentation of articles that have appeared or been accepted for publication in the Journal of Autonomous Agents and Multi-Agent Systems, and the Blue Sky Ideas special track for visionary ideas, long-term challenges, new research opportunities, and controversial debate. The conference also features a workshop program, to be held on May 6-7, immediately prior to the main program of the AAMAS conference. The objective of the AAMAS 2024 workshop program is to stimulate

and facilitate discussion, interaction, and comparison of approaches, methods, and ideas related to specific topics, both theoretical and applied, in the general area of Autonomous Agents and Multiagent Systems. There is an invitation for workshop proposals, particularly those that focus on emerging topics and applications, open research questions and challenges, and broader topics of interest to the wider community.

The AAMAS Demo track aims to provide opportunities for participants from academia and industry to present their latest developments in agent-based software and robotic systems. Novel applications and interactive systems are particularly welcome. Student researchers are encouraged to submit. Demonstrations of interest include systems implementing agents in real-world applications, systems using agents in virtual settings, and systems supporting the development of agents. There is also a call for Diversity and Inclusion activities. Participation in AI by groups that are underrepresented in computer science is a fraction of what is needed to have an AI workforce that reflects the diversity in society. Diversity has many facets, including race, ethnicity, gender, age, religion, disability, sexual orientation, socioeconomic status, cultural background, and geographic region. AAMAS 2024 invites submissions of proposals for activities that will help broaden participation in the Autonomous Agents and Multiagent Systems field.

This year's venue is the Cordis Hotel in Auckland. Submission for papers were due by October 9 last year and authors were notified on December 20 of 2023. Camera-ready papers are due by February 20, 2024. For information about Visas, accommodation and the venue, please visit the conference website.

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AAAI 2024
The 38th Annual AAAI Conference on Artificial Intelligence
Vancouver, Canada
February 20-27, 2024
https://aaai.org/aaai-conference/

The purpose of the AAAI conference series is to promote research in Artificial Intelligence (AI) and foster scientific exchange between researchers, practitioners, scientists, students, and engineers across the entirety of AI and its affiliated disciplines. AAAI-24 will feature

technical paper presentations, special tracks, invited speakers, workshops, tutorials, poster sessions, senior member presentations, competitions, and exhibit programs, and a range of other activities to be announced.

AAAI-24 is the Thirty-Eighth AAAI Conference on Artificial Intelligence. As with AAAI-23, the theme of this conference is to create collaborative bridges within and beyond AI. In addition to the bridge theme, we emphasize the importance of AI for social impact and responsible AI. Like AAAI 2023 conference, AAAI-24 will feature technical paper presentations, special tracks, invited speakers, workshops, tutorials, poster sessions, senior member presentations, competitions, and exhibition programs, and two other activities: a Bridge Program and a Lab Program. Many of these activities are tailored to the theme of bridges and are selected according to the highest standards, with additional programs for students and young researchers. AAAI-24 also features a Demonstration program, New Faculty Highlight talks, a Senior Member Presentation Track (SMPT), a student abstract and poster program, a Tutorial and Lab Forum, the 28th AAAI/SIGAI Doctoral Consortium and an Undergraduate Consortium, which will provide students who are more than one year from graduation with significant enrichment opportunities in a professional setting.

AAAI-24 welcomes submissions reporting research that advances artificial intelligence, broadly conceived. The conference scope includes machine learning, natural language processing, computer vision, data mining, multiagent systems, knowledge representation, human-in-the-loop AI, search, planning, reasoning, robotics and perception, and ethics. In addition to fundamental work focused on any one of these areas, work is expressly encouraged if it cuts across technical areas of AI (e.g., machine learning and computer vision; computer vision and natural language processing; or machine learning and planning), bridges between AI and a related research area (e.g., neuroscience; cognitive science), or develops AI techniques in the context of important application domains, such as healthcare, sustainability, transportation, and commerce.

This conference has two special tracks, which focus on AI for Social Impact, and Safe, Robust, and Responsible AI. Papers in the special tracks will be reviewed according to a different evaluation rubric than papers in the main track.

There will be special diversity and inclusion activities, such as workshops to discuss present challenges and propose changes related to justice, equity, diversity and inclusion in AI, underexplored research perspectives to benefit underrepresented communities (e.g. low-resource languages), respective panels and roundtables, or mentoring sessions to empower underrepresented researchers. Equally encouraged are activities revolving around inclusive community building, networking and social gatherings, diversity lunches, outreach activities and reports, and activities to expose K-12 students to AI.

There will be several pre-conference programs on February 20 and 21, before the main technical conference begins on February 22. Workshops are scheduled to be held at the end of the conference, February 26 – 27, 2024 (Monday-Tuesday). Workshop participants will have the opportunity to meet and discuss issues with a selected focus — providing an informal setting for active exchange among researchers, developers and users on topics of current interest. To foster interaction and exchange of ideas, the workshops will be kept small, with approximately 25-65 participants. Attendance is occasionally limited to active participants only, but most workshops allow general registration by all interested individuals.

AAAI-24 is expected to be an in-person conference – one author of all accepted papers will be expected to present work in person unless there are exceptional circumstances that prevent this. The conference will be held at the Vancouver Convention Centre. Please refer to the AAAI-24 conference website for information about travel, accommodation, and registration.

SDM24
The 2024 SIAM International Conference on Data Mining
Westin Houston, Memorial City, Houston, USA
April 18-20, 2024
https://www.siam.org/conferences/cm/conference/sdm24

Data mining is the computational process for discovering valuable knowledge from data – the core of Data Science. It has enormous application in numerous fields, including science, engineering, healthcare, business, and medicine. Typical datasets in these fields are large, complex, and often noisy. Extracting knowledge from these datasets requires the use of sophisticated,

high-performance, and principled analysis techniques and algorithms, which are based on sound theoretical and statistical foundations. These techniques in turn require implementations on high performance computational infrastructure that are carefully tuned for performance. Powerful visualization technologies along with effective user interfaces are also essential to make data mining tools appealing to researchers, analysts, data scientists and application developers from different disciplines, as well as usable by stakeholders.

The 2024 SIAM International Conference on Data Mining (SDM24) conference provides a venue for researchers who are addressing these problems to present their work in a peer-reviewed forum. It also provides an ideal setting for graduate students to network and get feedback for their work (as part of the doctoral forum). Everyone new to the field can also learn about cutting-edge research by hearing outstanding invited speakers and attending presentations and tutorials (included with conference registration). A set of focused workshops will be held on the last day of the conference. The proceedings of the conference are published in archival form and will also be made available online.

SDM24 has three main themes: Methods and Algorithms, Applications and Human Factors and Social Issues. Each of these main themes has a broad number of relevant topics, including but not limited to areas such as machine learning, data analytics, data mining, data science, IoT, ethics, and privacy, across different fields and applications.

This year's conference will have invited presentations and special events such as the IBM Early Career Data Mining Research Award and the SDM24 Doctoral Forum, which provides a unique opportunity for PhD students in data science (including data mining, machine learning, databases, and pattern recognition) to present their doctoral dissertation in poster format and get feedback from SDM24 participants and senior leaders in the field. SDM24 will host multiple two-hour minitutorials, including topics such as: From Feature Selection to Instance-wise Feature Acquisition; Intelligent Seismic Data Processing: A Data Science Perspective; Discovering High-Ordered Semantic Structures in Massive Time Series: Algorithms and Applications; Trustworthy Anomaly Detection; Large-Scale Graph Neural Networks: Navigating the Past and Pioneering New Horizons; Heterogeneity in Federated Learning; Data

Quality-Aware Graph Machine Learning; and Data Heterogeneity Analysis for Prediction and Decision. The program also includes full day workshops on Data Science for Smart Manufacturing and Healthcare, and AI4TS: AI for Time Series Analysis: Theory, Algorithm, and Applications. This year's conference will also host multiple 2-hour minitutorials on a variety of topics related to the main themes of SDM24. Please check the website for further details and updates about these events.

As a professional society, SIAM is committed to empowering equitable, diverse, and inclusive participation in all aspects of the community. SIAM will provide a climate that encourages the open expression and exchange of ideas, that is free from all forms of discrimination, harassment, and retaliation, and that is welcoming and comfortable to all members and to those who participate in its activities. Early registration for SDM24 is on or before March 18, 2024. The Travel Fund application deadline has been extended to February 17, 2024. All registrations must be processed using the online registration system. Payments will not be accepted onsite. Conference participants must use the online registration form to register for the conference during either the Early Registration or Standard Registration Periods. Please refer to the SDM24 website for further information about registration and access a wealth of resources about getting to the venue.

IJCAI 2024
The 33rd International Joint Conference on Artificial Intelligence
Jeju, South Korea
August 3-9, 2024
https://ijcai24.org/

The International Joint Conferences on Artificial Intelligence, IJCAI, is the most prestigious international gathering of Artificial Intelligence researchers. Every year IJCAI is held in a different country jointly sponsored by the IJCAI organization and the national AI society of the host nation. Starting from 1969, IJCAI has remained the premier conference bringing together the international AI community to communicate the advances and achievements of artificial intelligence research. Submissions to IJCAI-2024 should report on significant, original, and previously unpublished results on any aspect of artificial intelligence. Papers on novel AI research problems, on AI techniques for novel application domains, and papers that cross discipline boundaries within AI are especially encouraged.

In addition to the main track, authors will be able to submit papers to the two multiyear special tracks (AI for Good and AI, The Arts and Creativity), as well as the survey track; these tracks will post their own calls for papers later this year, and their deadlines, procedures and policies may differ from what is described on the IJCAI-2024 website. The special track on AI and Social Good is dedicated to research triggered by real-world key questions, is carried out in collaboration with civil society stakeholders, and uses AI to work towards the SDGs and LNOB. The track aims to encourage the application of AI to solve current global and local challenges and to strengthen the civil society-science-policy interface.

In 2024, IJCAI note that Generative AI models, including Chat-GPT, BARD, LLaMA, or similar LLMs, do not satisfy the criteria for authorship of papers published in IJCAI 2024. If authors use an LLM in any part of the paper-writing process they assume full responsibility for all content, including checking for plagiarism and correctness of all text. Papers that describe research on or involving LLMs are encouraged. Text generated by an LLM as part of the paper's methodology or experimental analysis is allowed but needs to be properly documented and described in the paper.

The conference is inviting proposals for workshops to be held on August 3-5, 2024, immediately prior to the main conference. The aim of the workshop program is to provide a structured setting for the discussion of specialized technical topics, and the format of proposed workshops should be designed to promote an active exchange of ideas between attendees. Several forms of workshops are encouraged, including classical workshops that focus on a particular research area, workshops that focus on emerging topics and applications or on open research questions and challenges, cross-discipline workshops that foster exchange of ideas between groups that are unaware of each other's research, and miscellaneous topics of interest to the AI community. Proposal deadlines for workshops are February 5, 2024, and notification of acceptance will be on March 11, 2024.

Based on previous IJCAI conferences, there is expected attendance of over 3,000 participants, drawn from the world's top technical universities, research labs, and industry companies. The IJCAI-24 technical standards are very high. Typically, only about 20%, or fewer, of submitted papers are selected for oral or poster presentation at IJCAI conferences. This means that participants are drawn from the world's best AI experts.

This year's conference will be held at Jeju Island. Situated in the center of Northeast Asia, Jeju lies equidistant among South Korea, China, and Japan. A selection of the best papers submitted to IJCAI-2024 will be invited for a fast track in the Artificial Intelligence Journal and/or the Journal of AI Research. Abstract submission deadline is January 10, 2024, with full paper submission due by January 17, 2024. The author response period will be March 18-21, and paper notification by April 16, 2024. Please refer to the website for more information about registration and the venue. Queries about local arrangements can be made to local@ijcai24.org.

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