African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

SCALABILITY AND EFFICIENCY OF DEEP LEARNING MODELS ON HIGH-PERFORMANCE COMPUTING CLUSTERS: BIBLIOMETRIC ANALYSIS

Gbedawo, W.V.[1], Dzikunu, A.[2], and Nyamadi, M.[3]
[1,3] Department of Computer Science, Ho Technical University, Ho, Ghana.
[2]Department of Computer Science, Zhejiang Normal University, China.
[1]vgbedawo@htu.edu.gh

ABSTRACT

Purpose: This systematic review identifies the main advancements, core papers, voids, and outlooks regarding utilising high-performance computing (HPC) clusters for large-scale deep learning models. Moreover, it aims to assess research trends, significant approaches, and methods to improve the effectiveness and adaptability of these models.

Design/Methodology/Approach*:* This paper involves a systematic literature review and bibliometric analysis of published articles from 2018-2023. To limit the results, some specific keywords have been introduced: Web of Science, deep learning efficiency, scalability, and HPC clusters. Studies were screened according to the PRISMA flowchart, covering 364 articles, 19 of which were included in the systematic review based on further criteria.

Findings*:* The bibliometric analysis revealed that the most globally cited articles were from IEEE Transactions on Emerging Topics in Computing and Joule. However, the most relevant sources identified were the Journal of Supercomputing, Concurrency and Computation: Practice and Experience, and IEEE Access. Researchers from the USA, China, Korea, and the UK authored the most significant contributions.

Research Limitation: The study examined only works from the Web of Science database from 2018 to 2023.

Practical Implication: The proposed research results contribute crucial information to enhance the effectiveness of deep predictive models in large-scale HPC environments, which are essential for enterprises adopting artificial intelligence (AI) and machine learning (ML) methodologies in colossal data analysis applications.

Social Implication: Propelling deep learning models with the help of HPC clusters can create more vital AI solutions that can respond to society's needs.

Originality/ Value: The novelty of the research stems from the bibliometric assessment and the question of which sources and authors in this field are the most important.

Keywords*: Anomaly detection. autoencoder. bibliometric. deep learning. efficiency*

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

INTRODUCTION

Deep learning (DL) has had meteoric growth in recent years and has constantly required growing computational resources for training and deploying complex models (Tsai et al., 2018). Meeting these high resource requirements has become the need for high-performance computing (HPC) clusters (Lopez-Martinez et al., 2023). Perhaps its capability to work with big data and simulate deep structures and representations has made several industries, for instance, autonomous driving, possible through deep learning (Wang et al., 2021). Nevertheless, problems with scalability and efficiency grow when models are more significant and datasets are larger too (Fernandez Musoles, 2020). Another problem: Deciphering the conceptual complexity of deep learning and engendering its maximum practical impact involves resolving those complications (van Zalm et al., 2022). To enhance the implementation of deep learning models on HPC clusters for more extensive scale and performance, the current research undertakes a systematic literature review of the available literature. It is orientated to strategies, methods, and innovations. This work aims to offer a brief analysis of the current state of knowledge in this area and to establish a clear roadmap of the gaps and further directions in one of the most important subfields of deep learning and HPC through a systematic literature review (Perez-Verdejo et al., 2020) and bibliometric analysis (Bhagat & Spector, 2018; Dakudjie et al., 2018).

There needs to be a broader understanding of techniques, methods and emerging kinetics for the optimisation or the scalability of deep learning models in this arrangement, even though high-performance computing cluster facilities are increasingly employed for deep learning tasks. To harden out the research gaps and provide an extensive literature review in this significant field, this research problem requires a systematic literature review and bibliometric analysis. This will help to build more insight into scalable deep learning applications on large compute clusters.

Since this review aims to minimise knowledge gaps and establish current insights and emerging trends regarding deep learning models, scalability and efficiency when implemented in HPC clusters, a systematic literature review and bibliometric analysis were conducted. Research goals that are consistent with the research questions for the study on improving deep learning models' scalability and effectiveness on HPC clusters through a thorough literature evaluation and bibliometric analysis are as follows: To conduct a bibliometric analysis to provide an exhaustive picture of the research environment by identifying the major research trends, hot topics, important publications, and collaborative networks within the field of deep learning on high-performance computing clusters. To synthesise the findings from the literature review and bibliometric analysis to identify the research gaps, constraints, and possibilities in the field, focusing on areas that need additional investigation and development to improve the scalability and effectiveness of deep learning models on high-performance computing clusters.

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

This study aims to bring to the forefront the latest improvements in the scalability and effectiveness of deep learning models on high-performance computing clusters through a thorough literature evaluation and bibliometric analysis.

LITERATURE REVIEW

HPC and deep learning are known to have the most decisive matches and have shown impressive growth in recent years due to challenges posed by the complexity of the models alongside the enhanced need for speed for training and applying the AI/ML models. HPC clusters having GPU (Graphics Processing Unit) accelerators, (Tensor Processing Unit) TPU, and faster interconnects are available to provide the computing capability to solve these challenges. In this section, more light is shed on the thematic areas of the study.

Data Parallelism

Data parallelism is the most common technique for partitioning computations associated with deep learning across various GPUs or nodes (Van Zalm et al., 2022). This section will explain how data parallelism is performed, its associated issues, and how those issues can be solved.

Model Parallelism

Model parallelism helps train large models that do not fit in a single GPU or node (Kirsal et al., 2022). This paper will focus on elucidating model parallelism and its possibilities and challenges.

Tools for systematic Literature review and Bibliometrics

There are many logical and analytical tools for use across the different programs, but a discussion of all these tools is out of the scope of this paper. Instead, the following vital tools are highlighted for focus:

- PRISMA Flow Diagram
- VOSviewer Software
- Biblioshiny

PRISMA Guidelines

Whenever there is a systematic review, the PRISMA Flow diagram helps improve the review process (Haddaway et al., 2022). However, even in its basic form, its use is not limited to acting as an illustrative placeholder; it can be far more effective as a means of communication and a

ISSN: 2408-7920

GBPA Ghana Book Publishers Association

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

completely transparent 'site map' for reviews. All flow diagrams are built with elementary components: input, process, and output. In the context of systematic reviews, the "nodes" refer to the points based on which records are included or excluded, while edges depict the flow of records from the initial sources to the set of studies. Every node contains additional specifics on the records the paper embodies, the number of excluded papers during the full-text scrutiny, and the reasons for such exclusion. The review process becomes more straightforward and more understood when such an approach offers a detailed description of the procedures.

VOS viewer software

Regarding maps made from network data, a special VOS viewer software can be used to visualise and explore them (Van Eck & Waltman, 2010). The following succinctly describes the VOS viewer's features:

Making maps based on network data: A network may be planned before a map is drawn, or a map may be drawn based on a network. The VOS viewer can be used to construct networks of researchers, research institutes, countries, keywords or concepts like research papers, journals, publications, etc. Connections such as co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation linkages may link items in these networks.

Visualising and exploring maps: The visualisations that can be made using the VOS viewer are the network map, overlay map, and density map. It is crucial that zooming and scrolling features can be implemented in practice, as a large map containing several thousands of elements must be examined in detail.

Biblioshiny

Biblioshiny is the shiny app for bibliometrics, an R-tool for performing profound science mapping analysis. This data analysis software is written in the R programming language to promote flexibility and facilitate integration with other statistical and graphical software. As mentioned, bibliometrics is a dynamic field, and the authors provided enough room for easy upgrades and integration in developing bibliometrics. Its development can take advantage of a large and active community of developers formed by prominent scholars.

For bibliometric analysis and generation of data matrices for co-citation, coupling, scientific collaboration analysis, and co-word analysis, bibliometrics has different routines for importing bibliographic data from SCOPUS, Web of Science from Clarivate Analytics, Dimensions, PubMed, and Cochrane databases.

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

METHODOLOGY

Research Strategy

This paper presents a systematic Literature review coupled with bibliometric analysis of pertinent literature on Deep Learning Models in High-Performance Computing Clusters. This analytical approach provides several critical advantages for comprehensive literature reviews and trend analyses. The bibliometric analysis provides a quantitative and objective assessment of a research area, allowing for the identification of influential works, authors, and institutions that have shaped the field (Aria & Cuccurullo, 2017). Also, it enables the visualisation of complex relationships and patterns within the literature, revealing research clusters, collaborations, and emerging topics that might not be apparent through traditional review methods (Van Eck & Waltman, 2010)In addition, bibliometric analysis facilitates tracking research trends over time, providing insights into the field's evolution and potential future directions (Batistič & Van Der Laken, 2019; Cobo et al., 2011; Xie et al., 2020)

Data Collection

The biblioshiny library in the R software environment was used to conduct this bibliometric analysis. Biblioshiny, a part of the bibliometrix R-package, was chosen for its comprehensive suite of tools for science mapping and its user-friendly interface, which allows for both robust analysis and intuitive visualisation of bibliometric data (Aria & Cuccurullo, 2017). The data for this analysis was extracted from the Scopus database, covering 2018 to 2023.

Literature Search

To begin with, an exhaustive search was conducted on the Web of Science database using the search query: [(TI=("Efficiency of Deep Learning Models" OR "Scalability of Deep Learning Models" OR "Scalability and Efficiency of Deep Learning Models" OR "High-Performance Computing Clusters" OR "High-Performance Computing Clusters" OR "High-Performance Computing (HPC)" OR "High-Performance Computing")) AND PY=(2018-2023) and Preprint Citation Index (Exclude – Database) and Article or Review Article (Document Types) and Meeting or Other or Early Access or Editorial Material or Retracted Publication or Book or Unspecified (Exclude – Document Types) and MEDLINE® or KCI-Korean Journal Database or SciELO Citation Index (Exclude – Database)]. The initial screening of the search results was done using abstracts of highly cited papers. In contrast, full article screening and data extraction were conducted to obtain articles that were fit for purpose and speak to the subject matter.

Inclusion and Exclusion Criteria

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

A clear criteria for including or excluding papers was based on relevance and quality. The selection criteria included all highly cited, peer-reviewed articles focusing on deep learning and high-performance computing clusters. 2018-2023 was the publication range. Only English text publications were included. The search was last conducted on 3rd September, 2023. Figure 1 is the PRISMA Flowchart indicating how the search results were logically screened to identify potentially relevant records for full-text screening. The titles and abstracts of all remaining records were screened for eligibility to identify records for full-text screening. All records identified for full-text screening were screened to identify records for inclusion in the review. All data potentially relevant to the review were then extracted from the studies selected for final inclusion and collated in a spreadsheet: publication details, particular authors with the number of citations. Therefore, a descriptive approach to data synthesis was adopted, whereby summaries of included studies were presented.

Systematic Literature Review

Data Synthesis: Following the systematic approach and PRISMA guidelines, Table 1 summarises selected papers according to the key themes, methodologies, and findings concerning the Scalable, Efficient, deep learning framework using the High-Performance Computing Clusters. This systematic approach allows consistency and the degree of objectivity necessary for such a critical enterprise.

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

Table 1: Summary of selected papers

Cited Article	Methodology	Research findings
(Borghesi et al., 2019)	Technique depended on the availability of monitoring data defining the state of the HPC system; as a result, the test case needed to be a supercomputer with an integrated monitoring framework based on a neural network called autoencoder.	The outcomes demonstrate that they are significantly outperformed by the autoencoder-based strategy, with an improvement in accuracy as high as 12%.
(Correa-Baena et al., 2018)	First, tool automation allows testing of potential materials quickly in experiments. Second, high-performance computing focuses experimental bandwidth on potential compounds by predicting and inferring bulk, interface, and defect-related features. Machine learning connects the first two thirdly by automatically refining theory and defining new experiments based on experimental outputs. **s**emi-supervised deep learning algorithms and Bayesian inference and design of experiments (DoE) algorithms	The combination of high-performance computing, automation, and machine learning should speed up the new materials' discovery rate.
(Wang et al., 2017)	Five different Cost Functions were employed. Evolutionary multi-objective optimisation (EMO) algorithms and B*-tree, and a multistep simulated annealing (MSA) algorithm were cooperatively used to solve this case.	EMO algorithms are used as high-speed computing to address the issue. A floor planning case study is offered as a final example of how our suggested technical framework works.
(Ahmad et al., 2018)	IV-Tier architecture model to use Hadoop and MapReduce. Parallel processing algorithm	The parallel algorithm-based proposed strategy significantly improves the processing power of HPC servers. The data was then aggregated using the four-layer architectural model to eliminate duplicate or inaccurate data, which helps improve computing skills.

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

(Pyzer-Knapp et al., 2022)	Making simulation workflows more effective and efficient using AI. One of the most recent efforts is RoboRXN, relying on an integration of three technologies: cloud, AI, and commercial automation	The commoditisation and democratisation of such different workflows will profoundly transform how we respond to upcoming discovery difficulties because there are demonstrable examples of this acceleration across all phases of the discovery process.
(Lei et al., 2022)	A mathematical model of the UAV with three degrees of freedom is established to describe the speed and bandwidth restrictions on the control commands in the actual system. Particle Swarm Optimization (PSO) Algorithm.	The AUNN network created for this study has a good convergence state, without gradient explosion, dispersion, disappearance, etc., demonstrating a good capacity for feature learning.
(Lee & Kumar, 2023)	A comparative analysis of emerging AI Technologies. “HPC-scale” neural network models	HPC-scale scientific AI landscape may evolve thanks to algorithmic and hardware improvements: models and data that cannot be considered today due to data, computing, and memory constraints.
(Graziani et al., 2020)	Pipeline deployed containerised on either local computers or high-performance computing resources. The self-sufficient design of Docker containers eliminates the need for high-performance computing knowledge, yet deep learning models and hyperparameter optimisation still offer much room for customisation.	The performance in terms of computational time is improved by parallelising the various tasks.
(Benchara & Youssfi, 2021)	Create and develop a distributed, parallel HPC program for MRI image segmentation that will be used in the cloud. A new distributed k-means method	Experimental data show that the suggested approach (DSCM) and its assigned model provide a high degree of scalability.
(Lopez-Martinez et al., 2023)	The Keras and Horovod frameworks were utilised to train the CNN models. Convolutional Neural Network Models	utilising six HPCC cores, the InceptionV3 model produced the best time of 37 min 55.193s, yielding an accuracy of 0.65.

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

(Q. Chen et al., 2021)	Five DL models were benchmarked, and the top-ranked systems for STS tasks were Convolutional Neural Network, BioSentVec, BioBERT, BlueBERT, and ClinicalBERT.	Only using the official training set did all models produce incredibly successful outcomes. The most significant average Pearson correlations (0.8497 and 0.8481, respectively) were attained by BioSentVec and BioBERT.
(Zhang et al., 2021)	The high-performance hyperparameter tuning model, which considered demographics like age, sex, and education, was applied to publicly available MRI data for AD.	Results showed that computational efficiency increased by 96%, which helped to shed light on future diagnostic AD biomarker applications
(Cliff et al., 2019)	Using iterative random forest (iRF) leave-one-out prediction (iRF-LOOP), Predictive Expression Networks of 40,000 or more genes can be created.	Using iRF makes it possible to analyse biological data sets at scales that were not before achievable.
(S. Chen et al., 2019)	Exploration of brain functions using frameworks of Big data analysis**.** ultrahigh-performance analysis	This relationship's "one-way ratchet" predicts that brain science will rely more on big data and HPC techniques.
(Salimi et al., 2018)	A master-slave (or global) parallel genetic algorithm (GA) is implemented to reduce calculation time and effectively utilize the computer's full potential. Additionally, sensitivity analysis is utilized to determine the most effective number of parallelised cores and the most promising configuration for GA and to examine the effects of GA parameters on the overall effectiveness of the simulation-based optimisation model.	When NSGA-I was used as the optimisation algorithm, it produced near-optimal solutions that were superior to those produced by fast-messy GA.

Bibliometric Analysis

In addition, a bibliographic analysis using the VOS viewer software and Bibliometrix tools revealed the citation patterns, co-authorship pattern/affiliate, and keyword mapping to determine the most cited papers, research trends, and key contributors in scalability and efficiency of deep learning models on high-performance computing clusters. Their corresponding results have been

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

captured in the following tables and figures: Table 2, table 3, table 4, table 5, figure 2, figure 3, figure 4, figure 5, figure 6, figure 7 and figure 8.

RESULTS AND DISCUSSION

The electronic searches produced a total of 364 articles. After eliminating duplicates and articles without criteria after reading the abstracts, 63 were selected from the search. Thus, after applying the inclusion and exclusion criteria, the present review is marked by 19 articles. However, more studies were crossed off in line with other reviews (Lages et al., 2023), for failing to meet the topic's demands; they are represented in the PRISMA Flow chart in Figure 1.

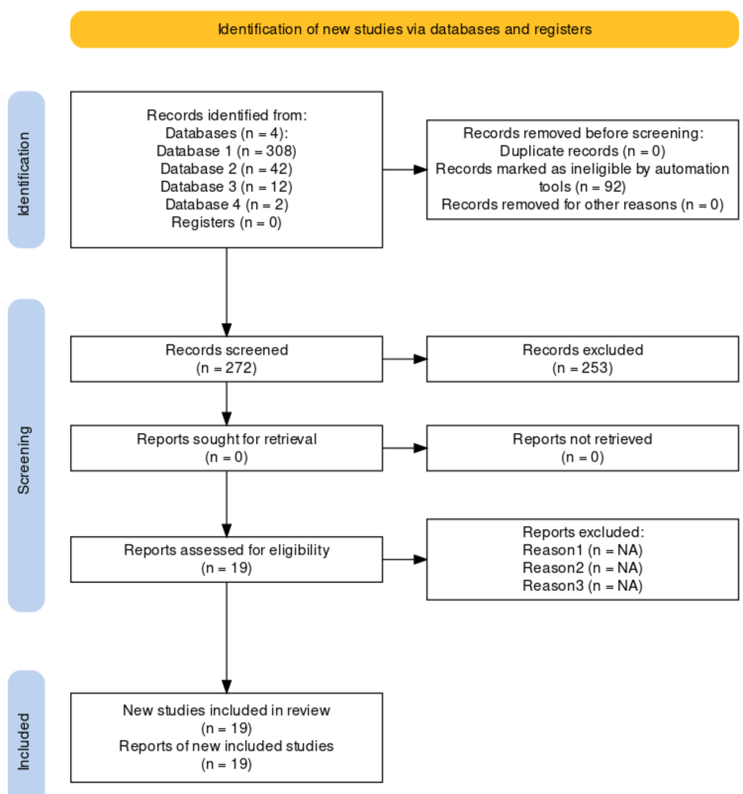

Figure 1: PRISMA Flow chart (Haddaway et al., 2022)

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

Table 2: Search Results from Web of Science database.

Description	**Results**
Timespan	2018:2023
Sources (Journals, Books, etc)	154
Documents	272
Average years from publication	2.36
Average citations per documents	7.125
Average citations per year per doc	1.715
References	1
DOCUMENT TYPES	
article	253
book review	1
review	18
DOCUMENT CONTENTS	
Keywords Plus (ID)	3
Author's Keywords (DE)	6
AUTHORS	
Authors	1339
Author Appearances	1425
Authors of single-authored documents	16
Authors of multi-authored documents	1323
AUTHORS COLLABORATION	
Single-authored documents	16
Documents per Author	0.203
Authors per Document	4.92
Co-Authors per Documents	5.24
Collaboration Index	5.17

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

Table 3 outlines the impact of the first twenty (20) Authors. The total number of citations (TC) scores range between 4 and 89, while the h-index, which measures the production and impact of a researcher or group of researchers, has a high score of 6 and a low score of 1.

Table 3: Author Impact

Author	TC	h_index	g_index	NP
Bartolini Andrea	89	6	7	7
Benini Luca	74	4	5	5
Czarnul Pawel	39	2	5	5
Proficz Jerzy	38	2	4	4
Borghesi Andrea	68	3	3	3
Cameron Kirk	9	2	3	3
Carns Philip	41	2	3	3
Chang Tyler	9	2	3	3
Diversi Roberto	15	3	3	3
Hoefler Torsten	33	2	3	3
Hong Yili	9	2	3	3
Hori Muneo	13	3	3	3
Lux Thomas	9	2	3	3
Milano Michela	68	3	3	3
Turek Wojciech	31	3	3	3
Watson Layne	9	2	3	3
Xu Li	9	2	3	3
Bernard Jon	4	1	2	2
Byrski Aleksander	13	2	2	2

In Table 4, it can be observed that among the Top 20 Institutions that have done extensive research into the fields of Deep Learning and HPC, the University of Bologna and Beihang University topped the pack with seven documents. No African Institution has found its way into the Top 20 Institutions with extensive research.

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

Table 4: Top Affiliation

Organisation	documents
Univ Bologna	7
Beihang Univ	6
Na	6
Gdansk Univ Technol	5
Agh Univ Sci and Technol	4
Keldysh Inst Appl Math	3
Natl Univ Def Technol	3
Argonne Natl Lab	2
Carleton Univ	2
Dept Comp Sci	2
Dept Phys	2
Dr Apj Abdul Kalam Tech Univ	2
Korea Inst Sci and Technol Informat	2
Lam	2
Mcgill Univ	2
Mississippi State Univ	2
Politecn Milan	2
Univ Extremadura	2
Univ Fed Rio Grande Do Sul	2
Univ N Carolina	2

Table 5 illustrates the Most Relevant Countries by corresponding authors; it can be observed that the USA and China are leading with a combined number of Articles of 59 and 34, respectively. This shows how extensively both countries have carried out research into the areas of Deep Learning and HPC.

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

Table 5: Most Relevant Countries by corresponding authors

Country	Articles	SCP	MCP
USA	59	59	0
CHINA	34	34	0
KOREA	12	12	0
UNITED KINGDOM	1	0	1

Figure 2 of the document clearly illustrates the Intra-country (SCP) and Inter-country (MCP) correspondence with the leading four countries by corresponding authors. The USA leads the pack of four, with the UK placing fourth in research conducted in Deep Learning and High-Performance Computing.

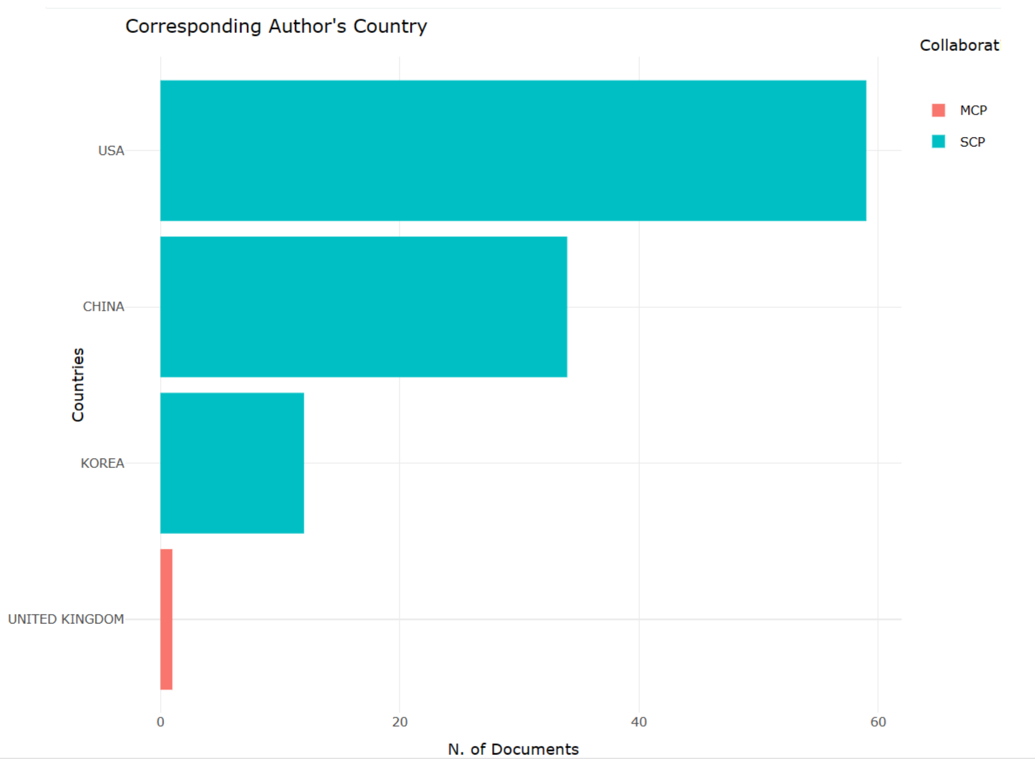

Figure 2: Corresponding Author's Country

ISSN: 2408-7920

Arca Academic Publisher

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

The co-authorship analysis in Figure 3 demonstrates the collaborative linkage between Deep Learning and HPC researchers from 2018 to 2023. The network contains several clusters representing research communities collaborating closely within specific domains. The central authors like "Bartolini, Andrea" and "Czarnul, Pawel" appear prominently, indicating their pivotal roles in their respective clusters as leading researchers. Meanwhile, authors such as "Papka, Michael" or "Lyakh, Dmitry I." may indicate lesser connectivity within the network. Meanwhile, (Kounta et al., 2022) presented a network showing the collaboration links between the authors. The relationships were strong when the collaboration connection was shorter.

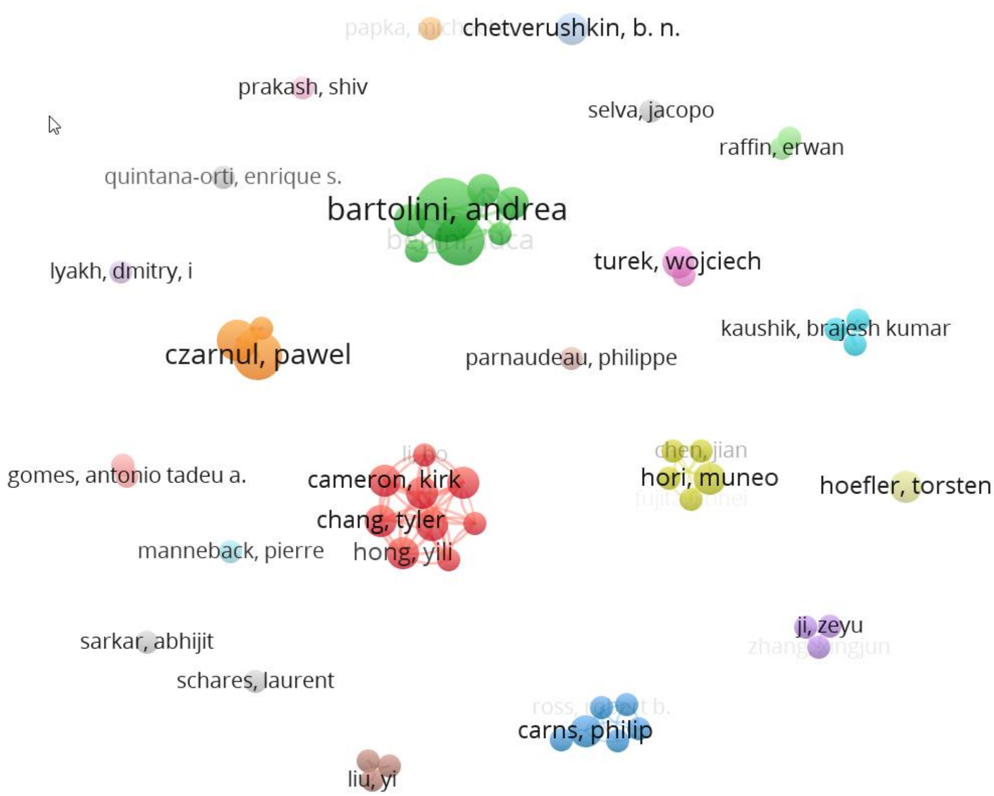

Figure 3: Co-authorship analysis (authors) biggest network node connect

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of
Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

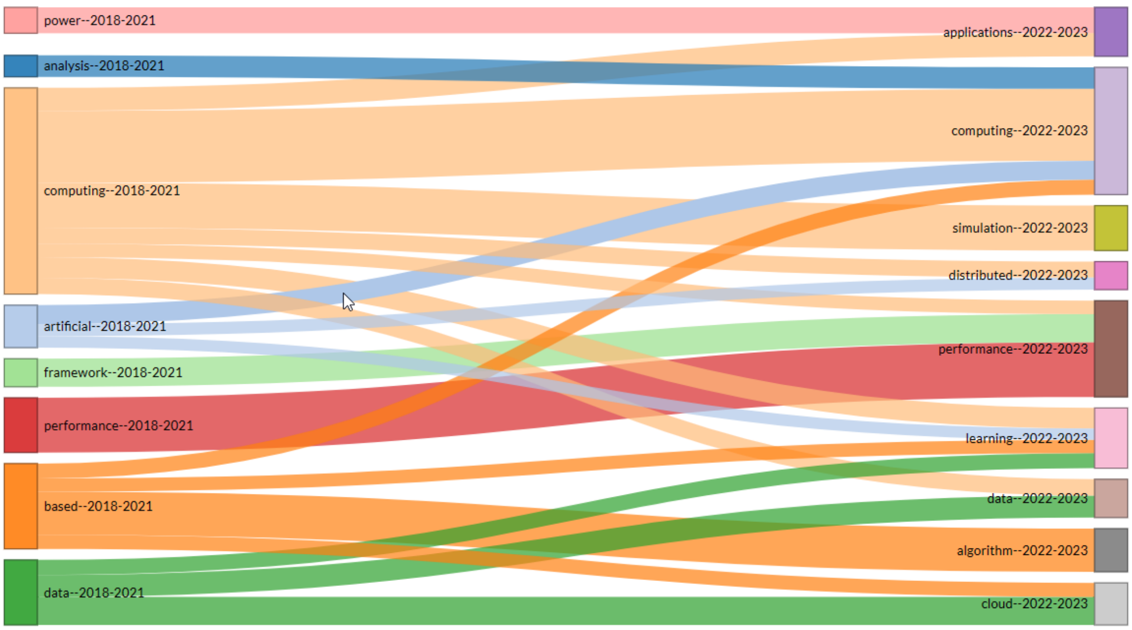

Figure 4: Thematic Evolution of Keywords

Figure 4 demonstrates the Thematic evolution of keywords from 2018 through to 2023, and Figure 5 shows, by way of colour saturation, a high level of collaboration among the Top 20 countries researching Deep Learning and HPC. The USA is the largest node in the network, indicating its central role in global academic research and citation influence. Meanwhile, European countries like France, Italy, and Switzerland are closely interconnected, reflecting robust intra-European research collaborations. Asian countries, such as China and South Korea, exhibit strong co-citation ties, likely driven by regional research initiatives in technology and manufacturing. Finally, Countries like Brazil and India connect to major research hubs (USA, China), indicating their growing presence in global research. In agreement, according to (Sidharta et al., 2022)The United States contributes more and collaborates with other countries, followed by China and India.

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

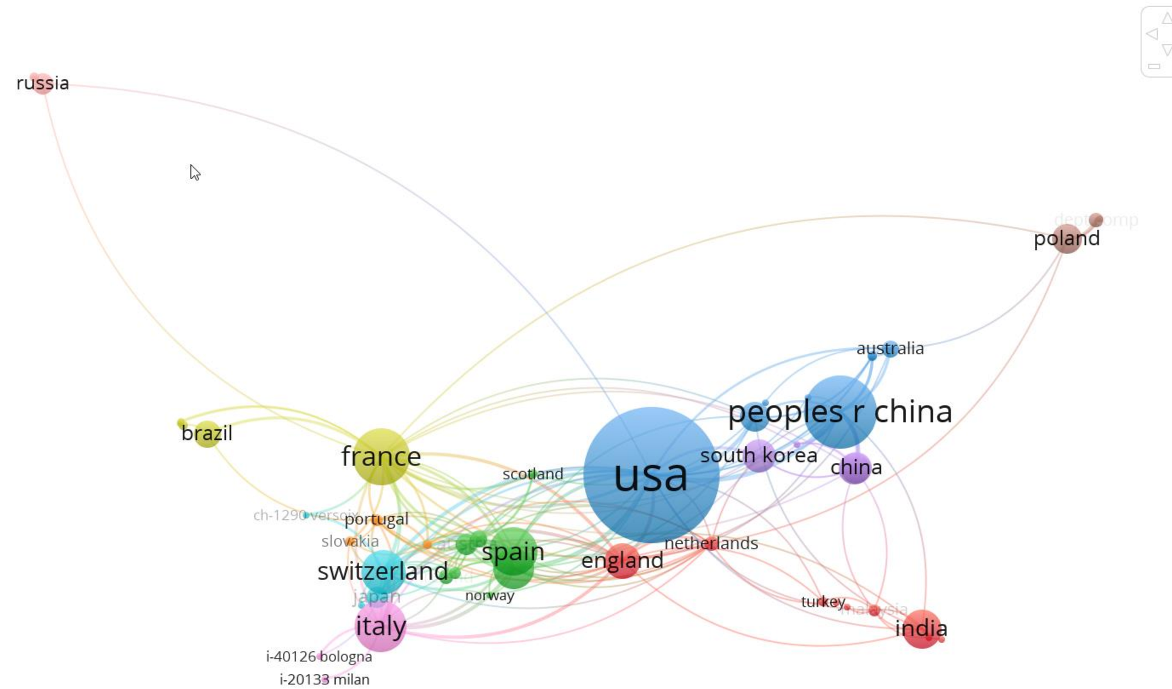

Figure 5: Biggest country network node connected

Figures 6 and 7 depict a bar chart showcasing the most relevant sources based on the number of documents and the graph that illustrates the growth of five different sources from 2018 to 2023. The vertical axis labelled "Annual occurrence & loess smoothing" represents the growth, suggesting that the data points were smoothed using a loess (locally weighted regression) method to visualise trends. It can also be seen that emphasis was placed on the Top 20 Journals where relevant materials were searched and comprehensively analysed with the Journal of Supercomputing and Concurrency and Computation-Practice, leading with appropriate materials that have been used as opposed to Li et al.,'s (2023) Journal of Applied Psychology and MIS Quarterly forming part of the top 5 most cited journals which dominated the research on human-machine collaboration in organisations, while Fan et al., (2023) Sees IEEE Transactions on Medical Imaging holds the highest number of journal articles.

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

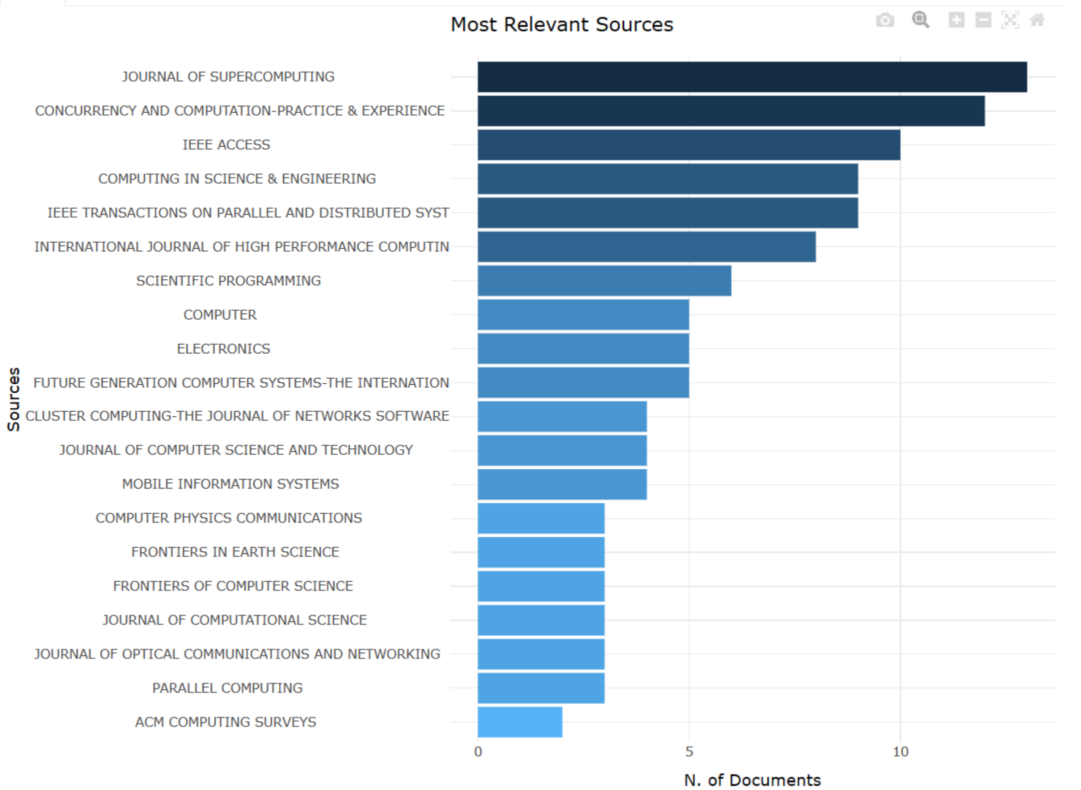

Figure 6: Most Relevant Sources

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

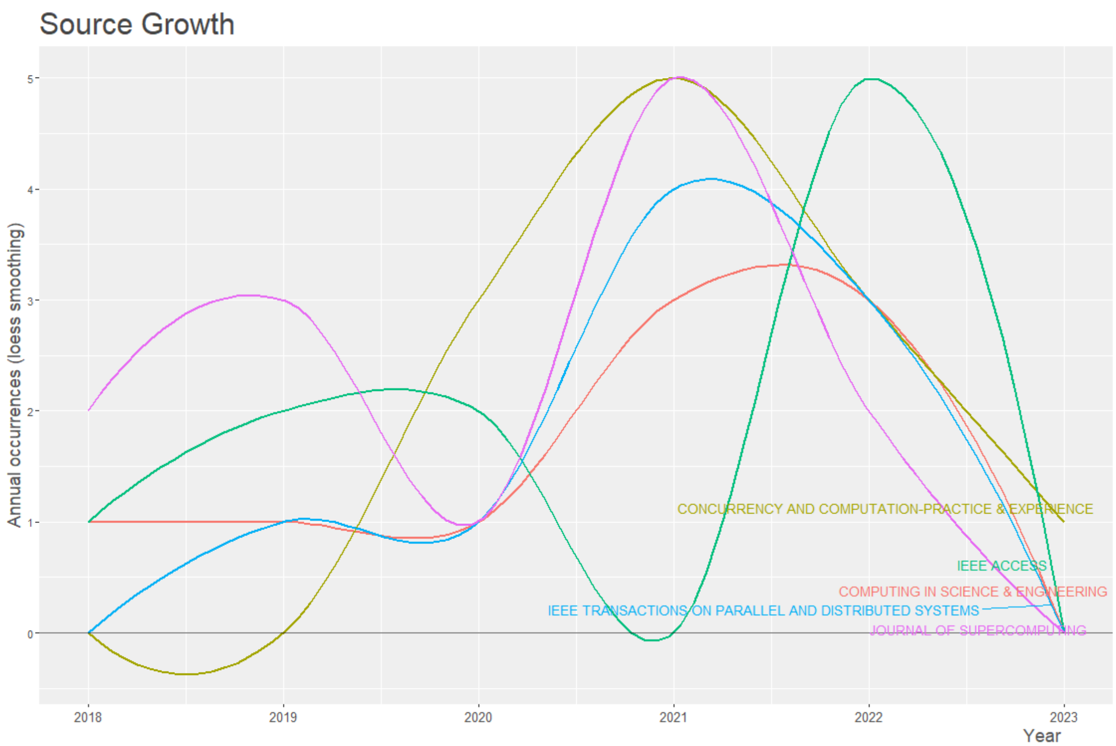

Figure 7: Source Growth

Figure 8 clearly shows the Top countries, showing where their interests lie regarding the Author's production from 2018 to 2023. This shows the extensive research they have conducted in the areas of Deep Learning and HPC.

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

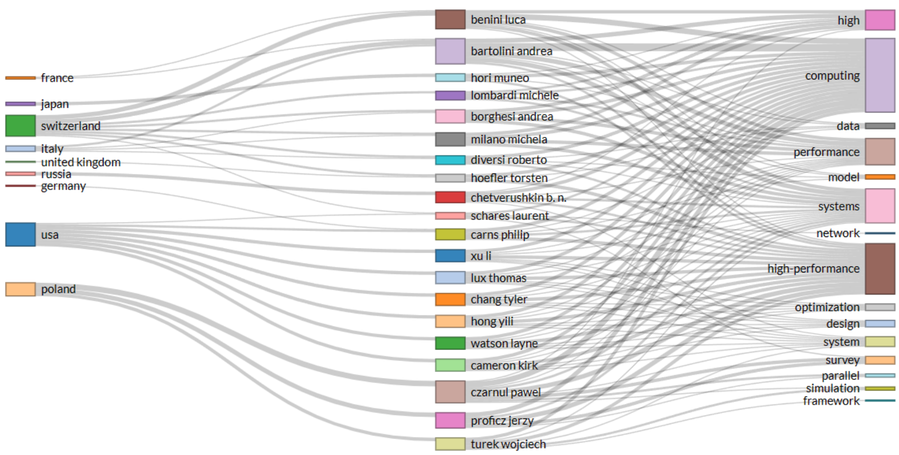

Figure 8: Three-Fields Plot of country's interest in relevant topics

The visualisation also uncovers trends in country-specific research collaboration and areas of interest, especially at the intersection of Deep Learning and HPC. This web of affiliation brings a wealth of information regarding the trends of research at the international level. In line with Dutta and Gupta (2023) In Internet of Things research observations, the density of the connecting lines strongly represents the USA researchers.

CONCLUSION

Lastly, based on this work's detailed investigation and evaluation, we have a rational perception of the challenge of enhancing the scalability and efficiency of the deep learning frameworks on the HPC clusters. Besides providing present research evidence, integrating findings also makes way for future research and innovation at this significant epoch of deep learning and High-Performance Computing for the sequential enhancement of both domains. The proposed research findings provide vital insights to improve the efficacy of deep predictive models in extensive high-performance computing (HPC) environments, which are critical for organisations implementing artificial intelligence (AI) and machine learning (ML) techniques in large-scale data analysis applications. Utilising HPC clusters to enhance deep learning models can transform several industries, such as healthcare and autonomous systems, to develop more robust AI solutions that address societal demands.

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

RECOMMENDATION

Artificial intelligence and machine learning have evolved as profound technologies during their development, and high-performance computing is an important part of current-generation computing. New trends in HPC and Deep learning are expected to usher in new advances in computing in future. This paper is an extended Review that introduces Deep learning and high performance and the latest trends, including adhering to the PRISMA guidelines and protocols for Surveying and analysing the literature in this field. Besides, it offers Bibliometric analysis of authors and articles specific to Deep learning and HPC research. This review paper should help order future research based on new phenomenon in computing. Furthermore, it will guide the researchers to which areas of study need more attention. The findings of only those Web of Science databases studies conducted in the last five years were emphasised.

REFERENCES

Ahmad, A., Paul, A., Din, S., Rathore, M. M., Choi, G. S., & Jeon, G. (2018). Multilevel Data Processing Using Parallel Algorithms for Analyzing Big Data in High-Performance Computing. *INTERNATIONAL JOURNAL OF PARALLEL PROGRAMMING*, *46*(3), 508–527. https://doi.org/10.1007/s10766-017-0498-x

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975.

Batistič, S., & Van Der Laken, P. (2019). History, Evolution and Future of Big Data and Analytics: A Bibliometric Analysis of Its Relationship to Performance in Organizations. British Journal of Management, 30(2), 229–251. https://doi.org/10.1111/1467-8551.12340

Benchara, F. Z., & Youssfi, M. (2021). A new scalable distributed k-means algorithm based on Cloud micro-services for High-performance computing. *PARALLEL COMPUTING*, *101*. https://doi.org/10.1016/j.parco.2020.102736

Borghesi, A., Bartolini, A., Lombardi, M., Milano, M., & Benini, L. (2019). A semisupervised autoencoder-based approach for anomaly detection in high performance computing systems. *ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE*, *85*, 634–644. https://doi.org/10.1016/j.engappai.2019.07.008

Chen, Q., Rankine, A., Peng, Y., Aghaarabi, E., & Lu, Z. (2021). Benchmarking Effectiveness and Efficiency of Deep Learning Models for Semantic Textual Similarity in the Clinical Domain: Validation Study. *JMIR Medical Informatics*, *9*(12), e27386–e27386. https://doi.org/10.2196/27386

Chen, S., He, Z., Han, X., He, X., Li, R., Zhu, H., Zhao, D., Dai, C., Zhang, Y., Lu, Z., Chi, X., & Niu, B. (2019). How Big Data and High-performance Computing Drive Brain Science.

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

GENOMICS PROTEOMICS & BIOINFORMATICS, *17*(4), 381–392. https://doi.org/10.1016/j.gpb.2019.09.003

Cliff, A., Romero, J., Kainer, D., Walker, A., Furches, A., & Jacobson, D. (2019). A High-Performance Computing Implementation of Iterative Random Forest for the Creation of Predictive Expression Networks. *GENES*, *10*(12). https://doi.org/10.3390/genes10120996

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools. Journal of the American Society for Information Science and Technology, 62(7), 1382–1402. https://doi.org/10.1002/asi.21525

Correa-Baena, J.-P., Hippalgaonkar, K., van Duren, J., Jaffer, S., Chandrasekhar, V. R., Stevanovic, V., Wadia, C., Guha, S., & Buonassisi, T. (2018). Accelerating Materials Development via Automation, Machine Learning, and High-Performance Computing. *JOULE*, *2*(8), 1410–1420. https://doi.org/10.1016/j.joule.2018.05.009

Dakudjie, J. K., Braye, A., & Otchere, A. A. (2018). An Investigation into System Components That Supports Biometric Frame in Ghana. African Journal of Applied Research, 4(2), 171-179.

Dutta, M., & Gupta, D. (2023). Bibliometric Analysis on Herbaceous Plants using Smart Precision Farming. *2023 IEEE Renewable Energy and Sustainable E-Mobility Conference (RESEM)*, 1–6. https://doi.org/10.1109/RESEM57584.2023.10236141

Fan, C., Hu, K., Yuan, Y., & Li, Y. (2023). A data-driven analysis of global research trends in medical image: A survey. *Neurocomputing*, *518*, 308–320. https://doi.org/10.1016/j.neucom.2022.10.047

Graziani, M., Eggel, I., Deligand, F., Bobak, M., Andrearczyk, V., & Mueller, H. (2020). BREAST HISTOPATHOLOGY WITH HIGH-PERFORMANCE COMPUTING AND DEEP LEARNING. *COMPUTING AND INFORMATICS*, *39*(4), 780–807. https://doi.org/10.31577/cai_2020_4_780

Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Systematic Reviews*, *18*(2), e1230. https://doi.org/10.1002/cl2.1230

Kounta, C. A. K. A., Arnaud, L., Kamsu-Foguem, B., & Tangara, F. (2022). Review of AI-based methods for chatter detection in machining based on bibliometric analysis. *The International Journal of Advanced Manufacturing Technology*, *122*(5–6), 2161–2186. https://doi.org/10.1007/s00170-022-10059-9

Lages, C. R., Perez-Vega, R., Kadić-Maglajlić, S., & Borghei-Razavi, N. (2023). A systematic review and bibliometric analysis of the dark side of customer behavior: An integrative customer incivility framework. *Journal of Business Research*, *161*, 113779. https://doi.org/10.1016/j.jbusres.2023.113779

ISSN: 2408-7920

African Journal of Applied Research
Vol. 10, No. 2 (2024), pp. 283-305
http://www.ajaronline.com
http://doi.org/10.26437/ajar.01.12.2024.15
Special Issue: Applied Research Conference of Technical Universities in Ghana 2024
Received: December 16, 2023
Peer reviewed: June 25, 2024
Revised: December 28, 2024
Published: December 2024

Lee, K. L. K., & Kumar, N. (2023). Artificial Intelligence for Scientific Discovery at High-Performance Computing Scales. *COMPUTER*, *56*(4), 116–122. https://doi.org/10.1109/MC.2023.3241692

Lei, Y., Yao, H., Jiang, B., Tian, T., & Xing, P. (2022). Anti-UAV High-Performance Computing Early Warning Neural Network Based on PSO Algorithm. *SCIENTIFIC PROGRAMMING*, *2022*. https://doi.org/10.1155/2022/7150128

Li, J.-M., Wu, T.-J., Wu, Y. J., & Goh, M. (2023). Systematic literature review of human–machine collaboration in organizations using bibliometric analysis. *Management Decision*. https://doi.org/10.1108/MD-09-2022-1183

Lopez-Martinez, M., Diaz-Florez, G., Villagrana-Barraza, S., Solis-Sanchez, L. O., Guerrero-Osuna, H. A., Soto-Zarazua, G. M., & Olvera-Olvera, C. A. (2023). A High-Performance Computing Cluster for Distributed Deep Learning: A Practical Case of Weed Classification Using Convolutional Neural Network Models. *APPLIED SCIENCES-BASEL*, *13*(10). https://doi.org/10.3390/app13106007

Pyzer-Knapp, E. O., Pitera, J. W., Staar, P. W. J., Takeda, S., Laino, T., Sanders, D. P., Sexton, J., Smith, J. R., & Curioni, A. (2022). Accelerating materials discovery using artificial intelligence, high performance computing and robotics. *NPJ COMPUTATIONAL MATERIALS*, *8*(1). https://doi.org/10.1038/s41524-022-00765-z

Sidharta, S., Warnars, H. L. H. S., Gaol, F. L., & Soewito, B. (2022). Building Damage Assessment Using Deep Learning: Bibliometric Analysis. *2022 IEEE 7th International Conference on Information Technology and Digital Applications (ICITDA)*, 1–6. https://doi.org/10.1109/ICITDA55840.2022.9971269

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Wang, G.-G., Cai, X., Cui, Z., Min, G., & Chen, J. (2017). High Performance Computing for Cyber Physical Social Systems by Using Evolutionary Multi-Objective Optimization Algorithm. *IEEE Transactions on Emerging Topics in Computing*, 1–1. https://doi.org/10.1109/TETC.2017.2703784

Xie, H., Zhang, Y., Wu, Z., & Lv, T. (2020). A Bibliometric Analysis on Land Degradation: Current Status, Development, and Future Directions. Land, 9(1), 28.

Zhang, F., Petersen, M., Johnson, L., Hall, J., & O'Bryant, S. E. (2021). Accelerating Hyperparameter Tuning in Machine Learning for Alzheimer's Disease With High Performance Computing. *Frontiers in Artificial Intelligence*, *4*, 798962–798962. https://doi.org/10.3389/frai.2021.798962

ISSN: 2408-7920