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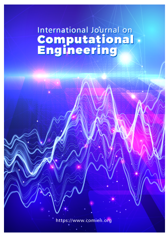

Applying Artificial Intelligence in Malaria Mosquito Research: A Bibliometric Study on Species Identification and Automated Detection

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***Abstract*— This study presents a bibliometric analysis on the integration of Artificial Intelligence in identifying and automatically detecting malaria mosquito species. The research explores trends and patterns in malaria research literature using a bibliometric data analysis approach. Data from 321 malaria research publications were collected and analyzed to identify frequently occurring keywords, authors, institutions, and collaborations among researchers. The analysis process involved sorting 1304 keywords by frequency, with "malaria," "artificial intelligence," and "machine learning" emerging as dominant keywords. Visualization techniques such as bar charts, word clouds, and network graphs were employed to understand keyword distribution, relationships, and evolution over time. The study highlights the interdisciplinary approach in current malaria research, combining medical, biological, and computational sciences to address this global health issue. By utilizing Python programming for analysis and visualization, this research demonstrates the effective processing and visualization of bibliometric data, providing deep insights into the patterns and trends in malaria research.**

***Keywords*— Malaria research; bibliometric analysis; species identification; automatic detection; Python programming; co-occurrence network; data visualization; interdisciplinary research; global health.**

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I. Introduction

Malaria is an infectious disease caused by the Plasmodium parasite and transmitted through the bite of an infected Anopheles mosquito. This disease is commonly found in tropical and subtropical regions, including Africa, South Asia, Latin America, and parts of the Pacific. Symptoms of malaria include fever, chills, headache, and in severe cases, it can lead to serious complications such as severe anemia, kidney failure, and even death. According to the World Health Organization (WHO), in 2020, an estimated 241 million cases of malaria occurred globally with 627,000 deaths, the majority of which were in sub-Saharan Africa [1].

Malaria is a significant public health issue as it affects millions of people each year, particularly in developing countries. In addition to the health burden, malaria also has substantial economic impacts due to medical treatment costs, loss of productivity, and premature deaths. Efforts to control and eradicate malaria include strategies such as the use of insecticide-treated bed nets, indoor residual spraying with insecticides, and the administration of antimalarial drugs. Despite significant progress in recent decades, challenges such as drug and insecticide resistance, as well as limited access to health interventions, remain major obstacles in eliminating malaria [1].

Research plays a crucial role in the global efforts to control and eradicate malaria. Through research, scientists can gain a deeper understanding of the biology and life cycle of Plasmodium, the Anopheles mosquito vector, and the mechanisms of disease transmission. Research has also facilitated the development of more accurate diagnostic tools, more effective treatments, and more efficient prevention strategies. For example, the development of long-lasting insecticide-treated bed nets and indoor residual spraying with insecticides has proven effective in reducing malaria incidence in various endemic countries[2]. Additionally, clinical and epidemiological research has provided insights into the distribution of the disease and the most vulnerable groups, enabling more targeted and efficient interventions[1][2].

On the other hand, research is also crucial in addressing emerging challenges such as resistance to antimalarial drugs and insecticides. Drug resistance developing in Plasmodium parasites, particularly Plasmodium falciparum, threatens the effectiveness of existing therapies and necessitates the ongoing development of new medications [3]. Similarly, insecticide resistance in mosquito populations requires new approaches in vector management. Ongoing research in genetics, molecular biology, and computational technology also offers opportunities for innovation in malaria vaccines, which could be key to eradicating the disease in the future. Therefore, investment in malaria research is not only essential for tackling current challenges but also for ensuring preparedness against future threats and achieving the global goal of malaria elimination [4].

Bibliometric analysis aims to provide an in-depth understanding of research trends in a specific field by mapping and measuring various aspects of the scientific literature. In the context of malaria research, this analysis helps identify key topics, patterns of collaboration among researchers, and the evolution of research focus over time. By using analytical tools such as VOSviewer with Python, we can illustrate keyword networks that show the relationships between various concepts and relevant study areas. Additionally, bibliometric analysis can reveal existing research gaps and direct attention to areas requiring further investigation. This knowledge is crucial for formulating more effective research strategies and focusing resources on interventions with significant potential in the global fight against malaria ([5].

The purpose of bibliometric analysis in malaria research is to identify the main focuses and research gaps in the existing literature, thereby providing strategic guidance for researchers and policymakers. By mapping scientific publications and analyzing keywords, we can determine the most frequently discussed topics and the relationships between various aspects of malaria research. This analysis also allows for the identification of research areas that have received less attention but have significant potential for further development. Recognizing these research gaps enables scientists to formulate new hypotheses, direct research efforts toward unexplored areas, and maximize the impact of developed interventions. Additionally, bibliometric analysis aids in understanding the collaboration trends among researchers and institutions, which can strengthen global research networks and enhance the effectiveness in addressing malaria challenges[6].

II. Material and Methods

This study employs a bibliometric analysis design to explore trends and patterns in malaria research literature. This approach involves collecting and analyzing data from the Scopus scientific publication database, which includes journal articles, conference papers, and other documents relevant to the topic of malaria. The analysis process involves identifying frequently occurring keywords, authors, institutions, and collaborations among researchers. This bibliographic data is then used to construct network maps that depict the relationships between various elements in the research literature. This analysis helps in identifying major topics, the evolution of research over time, and gaps that require further attention[5].

This study employs a bibliometric data analysis approach to identify and visualize frequently occurring keywords in malaria research publications, using the Python programming language for analysis and visualization. Data is sourced from a CSV file containing a list of publications with an 'Author Keywords' column separated by semicolons and a 'Year' column indicating the year of publication. The analysis process begins with separating and cleaning the keywords using Python, followed by calculating the frequency of each keyword using the collections. Counter module. These frequencies are then converted into a DataFrame using pandas for easier data manipulation. The most frequently occurring keywords are visualized using bar graphs with matplotlib and word clouds with WordCloud from the wordcloud module. Subsequently, a co-occurrence analysis is conducted to build a keyword co-occurrence matrix, which is then used to create a keyword network graph with networkx. This network is visualized to show the relationships between keywords. The modularity clustering method available in networkx is used to identify communities or clusters of keywords within the network. Each cluster is visualized separately to understand its internal structure and relationships. Additionally, the temporal trends of the main keywords are analyzed by linking keyword occurrences to the year of publication, which is then visualized to show the development of keyword frequencies over time. This analysis provides deep insights into the patterns and trends in malaria research, demonstrating Python's capability in processing and visualizing bibliometric data effectively[2][4][7][8].

The selection of the Scopus database as the data source for this bibliometric analysis is based on its extensive coverage and quality, as well as its reputation as one of the largest and most comprehensive scientific databases in the world. Scopus includes over 75 million documents encompassing journal articles, conference proceedings, and patents from various fields of science, including health sciences, physical sciences, engineering, and social sciences. The primary advantage of Scopus is its high inclusivity of reputable and internationally indexed journals, ensuring that the collected data accurately reflects global research trends. Additionally, the detailed analytics and search features in Scopus enable researchers to identify the most relevant and up-to-date publications, providing a solid foundation for in-depth and comprehensive bibliometric analysis [9].

In this bibliometric analysis, the inclusion and exclusion criteria for the publications analyzed are crucial to ensure the relevance and quality of the data used. The inclusion criteria encompass all articles published in Scopus-indexed journals that focus on malaria research, including epidemiological, clinical, molecular biology, and computational technology studies related to malaria. The selected publications cover the period from 1992 to 2024 to provide an overview of recent research trends. The exclusion criteria include non-peer-reviewed articles such as editorials, letters to the editor, and news articles, as well as publications that do not have direct relevance to the topic of malaria, such as studies that only mention malaria incidentally or in an irrelevant context. By setting these criteria, the analysis can be focused on the most relevant and high-quality literature, thereby ensuring more accurate and meaningful results[10].

The analysis procedure in this study begins with importing the necessary libraries and loading the CSV file containing malaria research publication data. The 'Author Keywords' column is processed by splitting the keywords based on ';' and ensuring the presence of the 'Year' column. The list of keywords is then flattened, whitespace is removed, and all keywords are converted to lowercase. The total number of keywords is counted, and the frequency of each keyword is recorded using Counter, which is then converted into a DataFrame and sorted by frequency. The top keywords are displayed, and visualization is performed using bar charts and word clouds. A co-occurrence matrix is created to build a keyword co-occurrence network, which is then visualized using network graphs. Cluster analysis is conducted to identify communities of frequently co-occurring keywords, which are also visualized in separate graphs. The trends of keywords over time are analyzed by collecting the publication year for each keyword, grouping the data by keyword and year, and visualizing the main trends in line graphs. This process provides a deep understanding of the distribution, relationships, and evolution of keywords in malaria research over time[5][10][11][12][13][14].

III. Result and Discussion

A. Total Keywords dan Frequency

In this bibliometric analysis, we identified and analyzed the total keywords used in 321 malaria research publications. After processing the data from the CSV file, we found that there are a total of 1304 keywords used in the research. These keywords were then sorted by their frequency, and we displayed the 10 most frequently occurring keywords. The results show that keywords such as "malaria," "artificial intelligence," "machine learning," "deep learning," "diagnosis," "plasmodium," "convolutional neural network," "malaria diagnosis," "classification," and "computer vision" are the most dominant, reflecting the primary focus in malaria research.

B. Visualization of Top Keywords

To provide a clearer picture of keyword distribution, we created visualizations in the form of bar charts and word clouds. The bar chart shows the frequency of the top 10 keywords, while the word cloud offers an engaging visual representation of all keywords based on their frequency. These visualizations help in understanding the main focus and topic distribution in malaria research. The bar chart highlights the high frequency of key terms, indicating the importance of these topics in the literature.

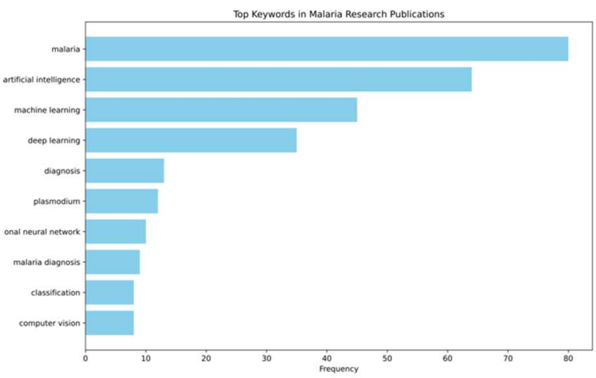

Fig. 1 Top Keywords in Malaria Research Publications

The image offers a comprehensive analysis of the most frequently occurring keywords in malaria research publications. "Malaria" emerges as the most dominant keyword, appearing 80 times, underscoring its central role in the research. Following this, "artificial intelligence" and "machine learning" occur 64 and 45 times respectively, indicating the substantial integration of advanced computational techniques in the field. Other significant keywords include "deep learning" (35 occurrences), "diagnosis" (13 occurrences), and "plasmodium" (12 occurrences), highlighting the importance of both technological and biological aspects in malaria research. Additionally, keywords such as "convolutional neural network," "malaria diagnosis," "classification," and "computer vision," though less frequent, indicate a growing trend towards using sophisticated machine learning and AI techniques for diagnosing and studying malaria. This variety of keywords reflects the interdisciplinary approach in current malaria research, combining medical, biological, and computational sciences to address this global health issue.

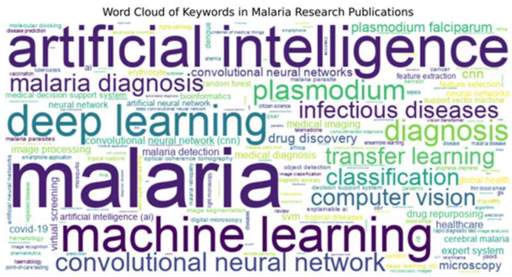

Fig. 2 Word Cloud of Keywords in Malaria Research Publications

C. Keyword Co-occurrence Network

We also analyzed the relationships between keywords by creating a co-occurrence matrix. This matrix was used to build a keyword co-occurrence network, which was then visualized using network graphs. These graphs depict how different keywords are related within the same publications, revealing patterns of collaboration and topic integration in malaria research. The network graph visualization shows strong connections between key keywords, reflecting the interactions and interrelationships in the research.

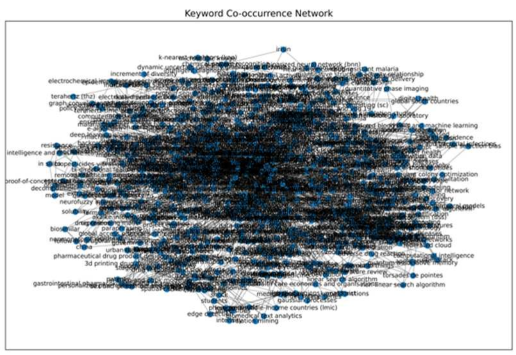

Fig. 3 Keyword Co-occurance Network

D. Keyword Clustering

To better understand the structure and subtopics within malaria research, we conducted cluster analysis using the greedy modularity algorithm. The identified clusters were then visualized separately, with each cluster color-coded differently to facilitate interpretation. The cluster analysis results revealed several communities of frequently co-occurring keywords, such as clusters focusing on "malaria" and "artificial intelligence." In this study, we present 10 clusters with the 10 graphs that most frequently feature these keywords to provide a clear visualization of the keyword co-occurrence network.

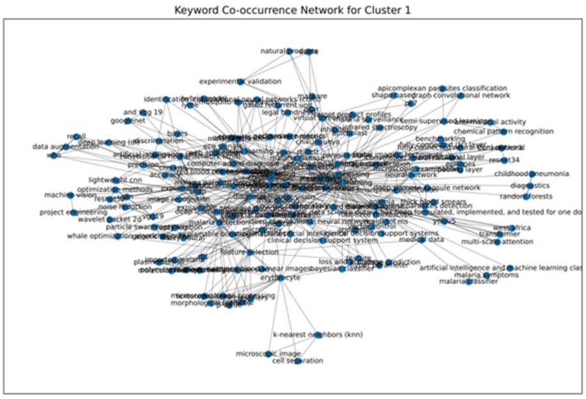

Fig. 4 Keyword Co-occurance Network for Cluster 1 (163 Keyword)\

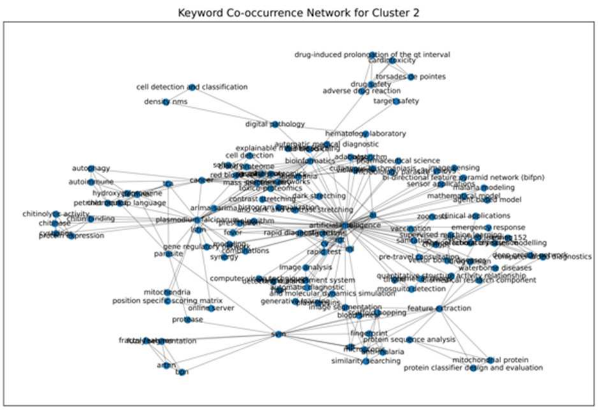

Fig. 5 Keyword Co-occurance Network for Cluster 2 (125 Keyword)

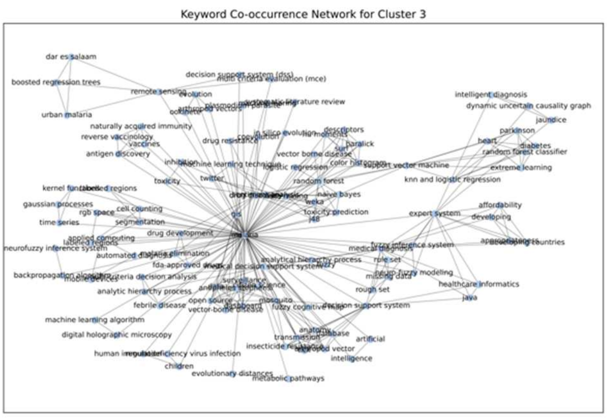

Fig. 6 Keyword Co-occurance Network for Cluster 3 (110 Keyword)

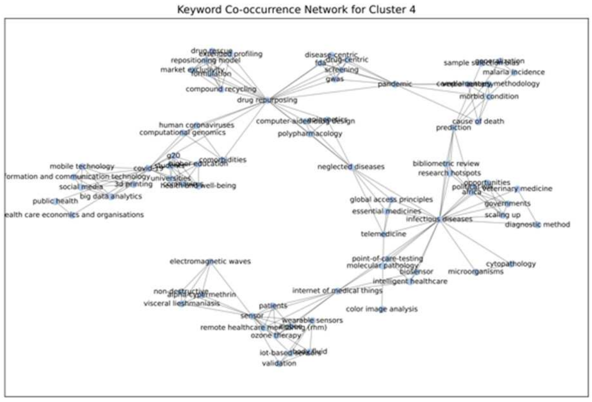

Fig. 7 Keyword Co-occurance Network for Cluster 4 (76 Keyword)

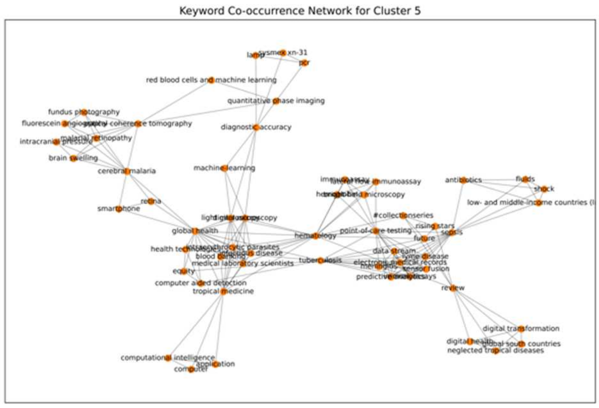

Fig. 8 Keyword Co-occurance Network for Cluster 5 (57 Keyword)

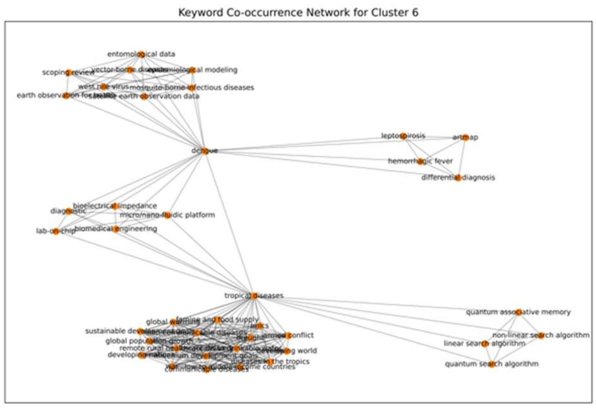

Fig. 9 Keyword Co-occurance Network for Cluster 6 (40 Keyword)

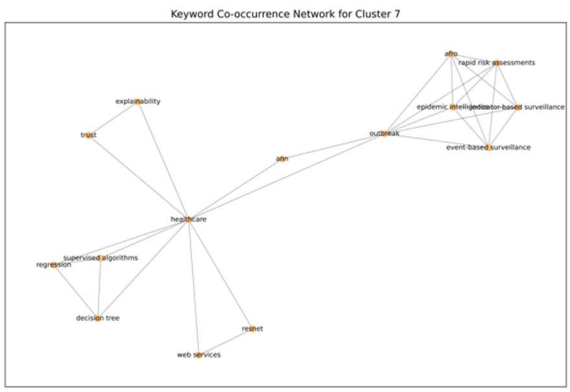

Fig. 10 Keyword Co-occurance Network for Cluster 7 (15 Keyword)

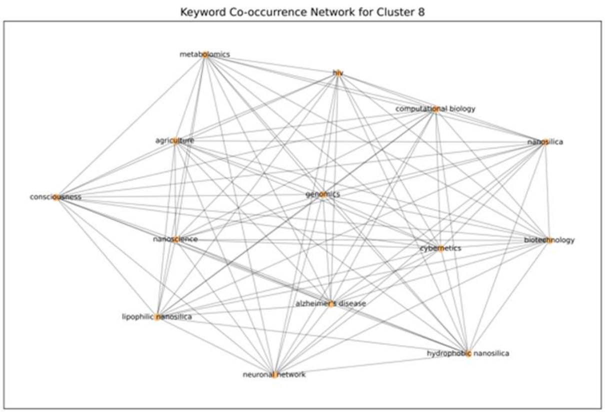

Fig. 10 Keyword Co-occurance Network for Cluster 8 (14 Keyword)

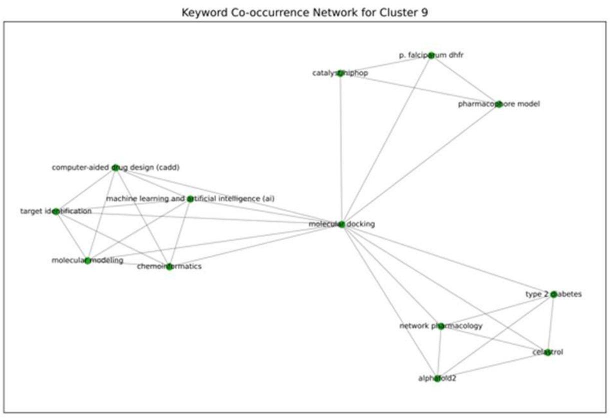

Fig. 11 Keyword Co-occurance Network for Cluster 9 (13 Keyword)

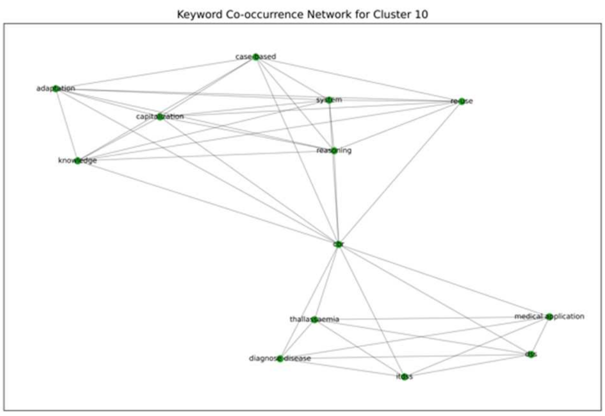

Fig. 12 Keyword Co-occurance Network for Cluster 10 (13 Keyword)

TABLE I
LIST OF KEYWORDS FOR EACH CLUSTER

Cluster	Identify keyword clusters
1	malaria diagnosis, anopheles, inhibitor, who, chemical pattern recognition, morphological features, and vgg 19, rt-detr, object detection, digital imaging techniques, lightweight cnn, fine gaussian svm, target product profiles, noise reduction, arrhythmia, deep learning (dl), convolutional neural network, microscopic image processing, cnn-knn, image recognition, west africa, cnn, identification, computer-added diagnosis, explainable boosting machines, bayes, medical data, disease detection, robotized microscope, bayesian classifier, apicomplexan parasites classification, smartphone application, malaria parasite detection, whale optimization algorithm, recall, disease prediction, microscopic images, multi-scale attention, data augmentation, deep convolutional neural network, vector control, lyme, classifiers, machine vision, plasmodiumsp, deep learning algorithm, artificial neural networks, molecular methods, artificial intelligence (ai), apicoplast, convolutional layer, computer vision, web application, p-value, semi-supervised learning, transfer learning, yolo, flow cytometry, qsar, random forests, natural products, vision transformer, google colaboratory, neural networks, diagnostics, erythrocyte, fuzzy neural, wavelet packet 2d, performance metrics, convolutional, artificial neural network, explainable ai, convolutional neural network (cnn), dsml 2: proof-of-concept: data science output has been formulated, implemented, and tested for one domain/problem, machine learning, red blood cell examination, image classification, malaria classifier, childhood pneumonia, ecg signals, convolutional neural networks (cnns), pooling layer, polymerase chain reaction, resnet50, hybrid model, clinical decision support system, computer-aided diagnosis, artificial intelligence and machine learning classifier, graph convolutional network, stained blood smear images, malaria surveillance, anemia, maldi-tof ms, diagnosis, adme, image processing, medical imaging, legal blindness, malaria parasite, deep learning, microscopy, anti-malarial activity, experimental validation, shape-based, epitopes, fully-connected neural (fcn) network, texture, cell separation, benchmarking, shap, transformer, genetic algorithm, googlenet, malaria parasites detection, hyper parameter, parasite stage, resnet34, thin blood smear, fully-connected (fc) layer, particle swarm optimization, fuzzy logic, pk7, project engineering, convolutional neural networks, z-score, imported malaria, explainable artificial intelligence, optimization methods, plasmodium, discrimination, medical, virtual screening, explainaility, mosquito-borne illness, classification, k-nearest neighbors (knn), texture features, feature selection, max pooling, microscopic image, rtd, deep siamese capsule network, accuracy, precision, malware, infrared spectroscopy, thick blood smears, gan, malaria parasites, yolov5, yolov7, malaria detection, malaria disease, loss and accuracy, neural network, chikungunya, malaria symptoms, microscopic examination, vgg19, convolution neural network, gated recurrent unit, clinical decision support systems, computer-assisted techniques
2	feature extraction, biomedical research component, sift, mitochondrial protein, pre-travel consultation, toxico-proteomics, dark stretching, cysteines, leishmania, cutaneous leishmaniasis, synergy, prescription, protease, microbiology parasite, anti-malaria, position specific scoring matrix, malaria assessment system, gene regulatory network, mathematical model, blood proteome, clinical applications, fingerprint, mass spectrometry, pharmaceutical science, e-algorithm, malaria modeling, cv, similarity searching, sensor applications, quantitative structure activity relationship, viola-jones, ml, chitinolytic activity, plasmepsins, cell detection, arima-sarima, artnn, combinations, algorithm, drug design, autophagy, fractal features, microscopic, detecting malaria, software, supervised learning, infectious diseases modelling, computer-aided diagnostics, online server, supervised machine learning, plasmodium falciparum, petri net, drug-induced prolongation of the qt interval, complex networks, chatgpt, modeling, cell detection and classification, parasite, image analysis, rdt, fever, zoonosis, density nms, artificial intelligence, emergency response, waterborne diseases, mitochondria, agent-based model, parasite proteomics, resnet 152, bioinformatics, ai algorithms, computer vision techniques, target safety, protein expression, vector borne diseases, automatic diagnostic, petrinet markup language, image sensing, protein sequence analysis, rapid test, digital pathology, cardiotoxicity, explainable machine learning, internet of things, hematology laboratory, red blood cells, bi-directional feature pyramid network (bifpn), scaffold hopping, image segmentation, deep greedy network, ai, cancer, chitinase, adaboost, autoimmune, histogram equalization, blood smear, tinyml, fuzzy segmentation, mosquito detection, protein classifier design and evaluation, vaccination, tca, drug safety, haar, contrast stretching, bpn, torsades de pointes, adverse drug reaction,

Cluster	Identify keyword clusters
	chloroquine, svm, lstm, and molecular dynamics simulation, hydroxychloroquine, rapid diagnostic test, medical laboratory science, automatic medical diagnostic, graph theory, red blood cell, generative learning, sanitation, c3tr-yolov5, and dark and contrast stretching, chitin binding
3	arthropod vector, labeled regions, random forest classifier, database, machine learing, kernel functions, random forest, drug resistance, fuzzy inference system, multi-criteria decision analysis, applied computing, sentiment analysis, cell counting, drug discovery, dar es salaam, expert system, backpropagation algorithm, j48, descriptors, vector-borne disease, open source, analytical hierarchy process, drug development, hu moments, mosquito, diabetes, color histogram, inhibition, vaccines, antigen discovery, remote sensing, rough set, regulation, naturally acquired immunity, neuro-fuzzy modeling, insecticide resistance, segmentation, anopheles stephensi, toxicity, fuzzy cognitive map, analytic hierarchy process, boosted regression trees, machine learning algorithm, gis, reverse vaccinology, febrile disease, heart, intelligence, mobile devices, urban malaria, intelligent diagnosis, artificial, dynamic uncertain causality graph, extreme learning, medical diagnosis, vector borne disease, data, neurofuzzy inference system, haralick, surveillance, surf, appropriateness, medical decision support system, affordability, parkinson, rgb space, developing, machine learning technique, time series, anatomy, missing data, gaussian processes, systematic literature review, metabolic pathways, malaria elimination, coevolution, multi criteria evaluation (mce), rule set, human immunodeficiency virus infection, automated diagnosis, ookinete, decision support system (dss), healthcare informatics, data mining, citizen science, tick, fda-approved drugs, weka, in silico evolution, malaria, digital holographic microscopy, knn and logistic regression, children, support vector machine, evolutionary distances, transmission, toxicity prediction, decision support system, java, jaundice, naïve bayes, evolution, twitter, logistic regression, labelled regions, plasmodium parasite, dashboard, arthropod vectors, fuzzy, developing countries
4	g20, body fluid, intelligent healthcare, sensor, color image analysis, non-destructive, epigenetics, opportunities, research hotspots, sample selection bias, social media, political will, screening, repositioning model, disease-centric, complementary methodology, gwas, drug rescue, validation, global access principles, telemedicine, alpha-cypermethrin, drug repurposing, biosensor, cause of death, computer-aided drug design, scaling up, covid-19, africa, zigbee, iot-based sensors, drug-centric, electromagnetic waves, wearable sensors, big data analytics, pandemic, 3d printing, verbal autopsy, students, diagnostic method, market exclusivity, ozone therapy, information and communication technology, polypharmacology, extended profiling, visceral lieshmaniasis, internet of medical things, human coronaviruses, governments, morbid condition, higher education, generalization, essential medicines, coronavirus, bibliometric review, public health, molecular pathology, microorganisms, mobile technology, universities, prediction, cytopathology, compound recycling, patients, fda, point-of-care-testing, veterinary medicine, formulation, computational genomics, health care economics and organisations, neglected diseases, remote healthcare monitoring (rhm), comorbidities, health and well-being, infectious diseases, malaria incidence
5	global south countries, quantitative phase imaging, computational intelligence, optical coherence tomography, brain swelling, cerebral malaria, immunoassay, light microscopy, predictive analytics, data stream, blood banking, antibiotics, electronic medical records, digital transformation, tropical medicine, global health, health technologies, hemoglobin, smartphone, bright-field microscopy, lamp, application, low- and middle-income countries (lmic), immunoassays, #collectionseries, shock, computer aided detection, medical laboratory scientists, point-of-care testing, retina, intraerythrocytic parasites, sensor fusion, malarial retinopathy, rising stars, digital health, diagnostic accuracy, fluorescein angiography, meningitis, review, computer, tuberculosis, infectious disease, future, fluids, fundus photography, hematology, sysmex xn-31, intracranial pressure, lyme disease, machine-learning, pcr, sepsis, digital microscopy, red blood cells and machine learning, neglected tropical diseases, equity, lateral flow immunoassay
6	remote rural healthcare delivery, leptospirosis, linear search algorithm, scoping review, developing nations, global warming, sustainable development goals, lmics, access to drinkable water, hemorrhagic fever, lab-on-chip, war, diseases in the tropics, dengue, diagnostic, non-communicable diseases, artmap, low-to middle-income countries, quantum associative memory, satellite earth observation data, vector-borne diseases, armed conflict, non-linear search algorithm, differential diagnosis, developing world, bioelectrical impedance, famine and food supply, millenium development goals, epidemiological modeling, global population growth, micro/nano-fluidic platform, drought, biomedical engineering, entomological data, west nile virus, tropical diseases, communicable diseases, mosquito-borne infectious diseases, earth observation for health, quantum search algorithm
7	resnet, trust, explainability, indicator-based surveillance, rapid risk assessments, regression, outbreak, afro, supervised algorithms, event-based surveillance, healthcare, decision tree, epidemic intelligence, web services, ann
8	cybernetics, lipophilic nanosilica, agriculture, nanoscience, biotechnology, computational biology, neuronal network, consciousness, hydrophobic nanosilica, alzheimer's disease, genomics, metabolomics, hiv, nanosilica
9	alphafold2, pharmacophore model, molecular docking, target identification, p. falciparum dhfr, computer-aided drug design (cadd), type 2 diabetes, molecular modeling, catalyst/hiphop, network pharmacology, chemoinformatics, celastrol, machine learning and artificial intelligence (ai)
10	itdss, case-based, reasoning, knowledge, cbr, system, re-use, dss, capitalization, medical application, adaptation, diagnose disease, thallassaemia

E. Trends in Keywords Over Time

Furthermore, we also analyzed the trends in keyword usage over time. By collecting the publication years for each keyword, we were able to observe how the frequency of key keywords has changed over time. Visualization in the form of line graphs illustrates these trends, which helps in identifying shifts in focus and developments in malaria research.

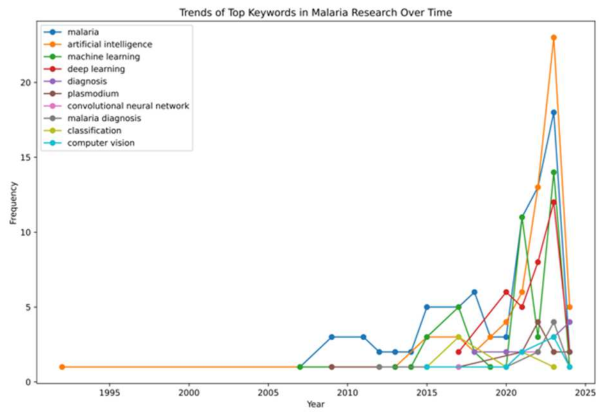

Fig. 13 Trends of Top Keywords in Malaria Research Over Time

The line graph depicting the trends of top keywords in malaria research over time highlights significant shifts in research focus within the field. The keyword "malaria" remains consistently prevalent, reflecting its central role in research efforts. However, there is a notable surge in the use of technology-related keywords such as "artificial intelligence" and "machine learning" starting around 2015 and peaking significantly in recent years. This indicates an increasing integration of advanced computational techniques into malaria research. Keywords like "deep learning," "diagnosis," "plasmodium," and "convolutional neural network" also show a rising trend, suggesting a multidisciplinary approach that combines traditional biological research with modern technological advancements. The prominence of these keywords illustrates the evolving landscape of malaria research, where innovative methodologies are being employed to enhance diagnostic accuracy and disease understanding, ultimately aiming to improve malaria control and eradication strategies.

IV. Conclusion

In the context of research on the integration of artificial intelligence in species identification and automatic malaria detection in mosquitoes, it can be concluded that the use of advanced technologies such as artificial intelligence and machine learning has significantly contributed to malaria research. With a multidisciplinary approach that combines traditional biological sciences with modern technological advances, malaria research is increasingly progressing towards improved diagnostic accuracy and disease understanding, with the ultimate goal of enhancing malaria control and eradication strategies.

Thus, the integration of artificial intelligence in malaria research not only aids in species identification and automatic detection in mosquitoes but also reflects the evolving landscape of malaria research, where innovative methodologies are used to enhance diagnostic accuracy and disease understanding, aiming to improve malaria control and eradication strategies.

The knowledge gained from this research can provide strategic guidance for researchers and policymakers in identifying key focus areas and research gaps in the existing literature. By understanding collaboration trends among researchers and institutions, we can strengthen the global research network and enhance effectiveness in addressing malaria challenges.

Finally, it is crucial to continue developing this research to expand knowledge on the integration of artificial intelligence in malaria research, thereby making a significant contribution to global efforts to control and eradicate this disease.

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