Global Journal of Machine Learning and Computing

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

A Survey of Foundational Concepts and Emerging Frontiers in Computer Science

Ankur singh[1*]

[1]University of North America

[1]Singhan@live.uona.edu

Corresponding Author

Ankur singh

Singhan@live.uona.edu

Article History:
Submitted: 27-06-2025
Accepted: 25-07-2025
Published: 02-08-2025

Keywords

Algorithms, artificial intelligence, cybersecurity, data science, interdisciplinary computing, machine learning.

ABSTRACT

This paper gives a thorough survey of principles and frontiers of Computer Science. It starts with defining its basic concepts, which is algorithms, data structure, computer architecture and programming paradigm, which are central concepts of computational thinking and/or system design. It is next followed by the discussion of transformative technologies such as those that involve artificial intelligence, quantum computing, cybersecurity, IoT and block chain, their potential, and challenges. Other interdisciplinary areas of use in the health care, biology and environmental science are also discussed in the article which highlights the increasing domains of computing opening up. Also, it discusses development of trends in Computer Science education and ethical dimension that is of paramount concern to responsible innovation. As a wrap-up to the article, the section on research challenges and future research directions emphasize the necessity to have a more inclusive, sustainable, and humanized advancement in the digital era.

INTRODUCTION

The science of Computer Science has changed tremendously in recent few decades and transformed how we all engage with the world and transformed almost all industries. It is the study of computation including everything about computation both theoretically and practically. Algorithms and programming languages were the first subjects studied, and today Computer Science is an ever-growing and diverse scientific discipline moving to the field of artificial intelligence and quantum computing [1]. The interest to implement this survey comes with the complexity and increased

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

heterogeneity in the Computer Science environment. On the one hand, traditional concepts like algorithms, data structures, and computer architecture continue to be very important, but on the other, there has never been a higher number of rapidly emerging technologies, including machine learning, block chain, and quantum computing [2]. Convergence of these areas has resulted in revolutionized fields of healthcare, finance, education, and governance, among others. Because of this, there is an urgent need to also revisit the fundamental practise of Computer Science in a systematic way as we delve into the latest processes that are redefining its perimeters [3].

This paper is supposed to give an extensive description of both foundational and frontier issues of Computer Science. In particular, it attempts to: Describe the building blocks of the field that any practitioner or student ought to be familiar with. Present new spheres of investigation and implementation which are rapidly becoming popular. Provide the information about interdisciplinary trends and ethical implication that modern computing technologies have. Understand what an open issue is and what directions future studies can take [4]. In such a manner, the article can be used as a source of learning among new scholars as well as a reference paper among scholars and individuals wishing to keep in pace with the recent trends.

This survey is deliberately broad with the intention of looking at the depth of spheres of Computer Science. The introductory segment touches on well laid fields like programming languages, algorithms, databases and networking. In the emerging frontiers section, it addresses more modern aspects such as AI, cybersecurity and quantum computing. The handpicking of the information was conducted by analyzing peer-reviewed journals, conference proceedings, white papers, and academic textbooks [5]. To provide the informative synthesis, the selection criteria were reliance on relevance, the impact and the regency to preserve the balance. The article is not too technical so it is easy to follow but gives references when somebody would want to know more about a particular topic then the reader could read more in the sources. Images in the form of tables and diagrams should also be used to show complicated association as well as data pattern where possible [6].

PRINCIPLES OF COMPUTER SCIENCE

The subjects that are discussed during the foundation of Computer Science constitute the main body of knowledge, with regards to which all the remaining disciplines of the sphere are developed. These core subjects give the theoretic and practical foundation upon which innovations, problem-solving, and system design are facilitated. Comprehension of such foundations is vital to the students and researchers as well as practitioners in a fast-changing industry [7]. This section gives a summary of important topics such as algorithms and data structures, computer architecture, paradigms of programming, databases, computing networks and also theoretical computer science.

Global Journal of Machine Learning and Computing
ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

Algorithms and data structures play the most dominant role in Computer science as the most widely used tools of solving computational problems efficiently. An algorithm is a procedure of doing a task step-by-step whereas data structures are the forms of organizing data as well as managing it. As it can be seen with some classics such as binary search, quick sorts and algorithm, proper logic development can greatly improve the performance [8]. Also relevant are the structures of data like arrays, linked lists, trees, graphs, stacks, and queues that are customized according to the problem and the operations.

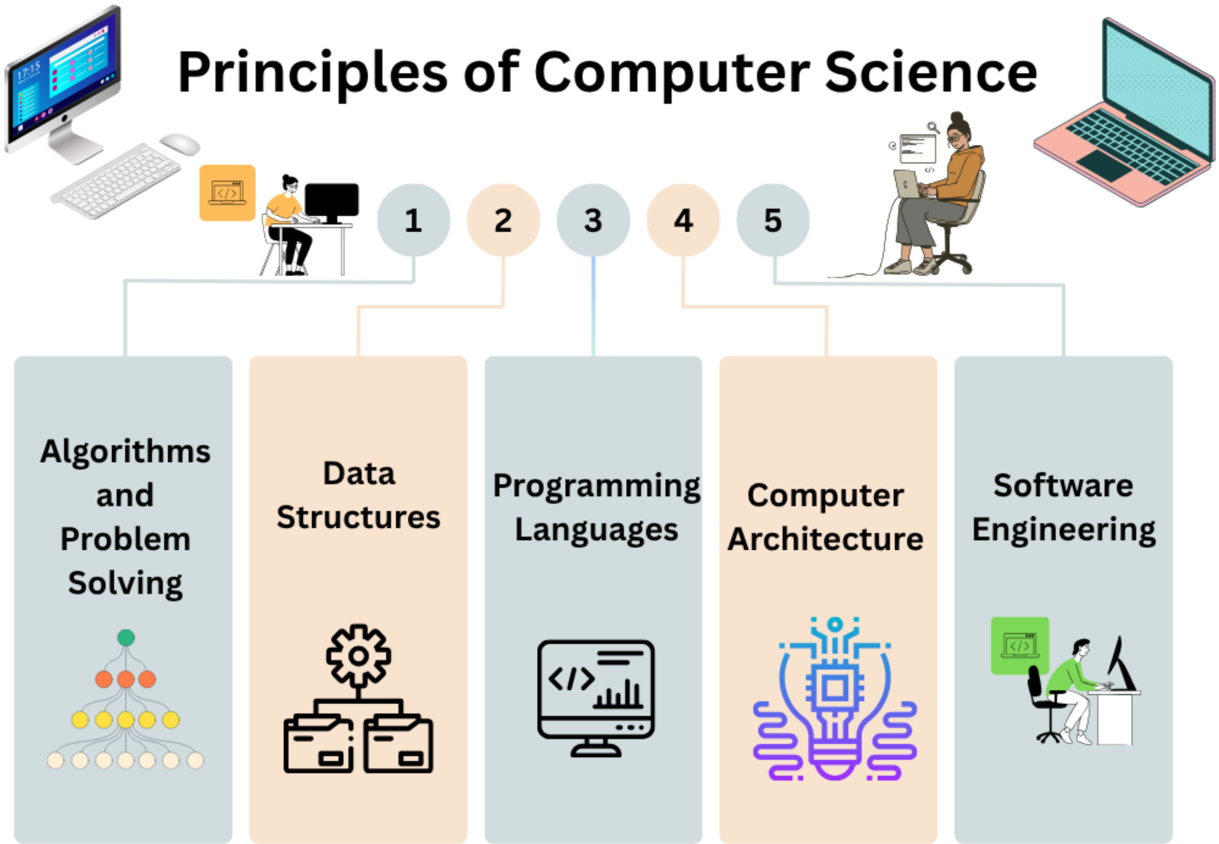

Figure: 1 showing principles of Computer science

Such fundamental tools are highly interconnected; the selection of data structure may severely influence the adequacy of an algorithm. It is also imperative to master these concepts in order to write the best code, where time and space matters, e.g. in embedded devices or real-time applications. Architecture of computers is a way of organization of computers and their functioning within the framework of a computer at the hardware level [9]. It includes architecture of the central processor, memory hierarchy, input/output systems and instruction sets. Knowledge of architecture allows developers to code in an efficient manner with regards to interaction with the hardware, especially when dealing with performance sensitive systems. In conjunction with architecture, there is the study of operating systems (OS) that operate hardware resources as well as present a degree of abstraction

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

to application software [10]. Among the major subjects of study, there are process scheduling, memory management, file systems, and concurrency. The key to comprehending the inner workings of OS and its execution patterns, resources and its relation with system environment lies, therefore, in the foundational knowledge on the concepts [11].

It is through the use of programming languages that human beings convey information to the machine. Every language has either one or many paradigms that can be considered as structured, object-oriented, functional, and declarative and so on and each of them has its own possibilities to express and solve the problems. Programs such as C, Java, Python, and Haskell show a diversity of methods of organizing programs, dealing with errors and allocating memory [12]. Awareness about the paradigms of programming assists developers to select the appropriate tool that will best handle the tasks and program more unmaintainable, scalable and reusable software. The language features of concepts like recursion, modularity, inheritance, and immutability are not mere language features but the manifestation of more comprehensive ideas of computational thinking [13].

Databases play a very important role in storage, retrieval and manipulation of structured data. Basic topics are relational databases, SQL, normalization, transactions, indexing and concurrency control. The increased requirements of the modern applications are based on scalable and distributed database systems, which introduce MySQL and new design philosophies. Knowledge of databases and the concepts about them is a requirement in data-driven apps such as e-commerce systems and money's traditions [14]. The knowledge of the security, backup, and recovery procedures of databases will guarantee the availability and the integrity of data in mission-critical systems. Computer networks support inter-system exchanges of data that support distributed computing, internet usage and cloud computing. The OSI and TCP/IP models, IP address, routing, DNS, and HTTP are the fundamental ideas. Such concerns as latency, bandwidth, fault tolerance and security will need to be addressed by the protocols and architectures [15].

Networking forms part of the underpinning of Systems design, cybersecurity, and application development. As an example, it may be interesting to learn how HTTP functions at such a lower level to optimize web applications and resolve network-related problems. The entire discipline is supported by the Theoretical Computer Science that considers the mathematical basis of computation [16]. Areas like automata theory, formal languages, computability and computational complexity give great insight into just what problems are soluble and to what extent they are efficiently soluble. The concept of nondeterministic polynomial time and P, NP, and NP-complete helps classify as well as quantify the ease or difficulty of problems that affect the design or the feasibility of algorithms [17]. Turing machines and finite automata form a very important part of compiler construction, natural language

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

processing and software verification.

The latter ideas are the building blocks to further applications and study of Computer Science. Such a thorough knowledge in these fields not only makes people ready to solve even more complicated problems but also increases their chances to make innovations in the sphere. The same traditional areas will be seen as the starting ground of new emerging technologies that are transforming the computing world, as a result of these new developments as will be discussed in the next section [18].

NEW FRONTIERS IN COMPUTER SCIENCE

Due to the ever-changing nature of Computer Science newer technologies and research fields are being discovered, and Computer Science is fast establishing these, which would change our lives forever and how we perform our work as well as interacting with machines. Such frontiers do not merely expand the frontiers of computation, but also yield new challenges and possibilities of innovation. This covers some of the most profound new frontiers within Computer Science such as Artificial Intelligence (AI) and Machine Learning (ML), Quantum Computing, Cybersecurity, the Internet of Things (IoT), Human-Computer Interaction (HCI), Blockchain, and Distributed Systems [19]. The most impactful fields of the current Computer Science can be characterized by Artificial Intelligence and Machine Learning. AI represents a body of methodologies that are used to copy aspects of human cognition, which include the learning, problem-solving, reasoning and perception. A part of AI is referred to as ML, which concerns itself with algorithms that enable systems to learn patterns based on data and be able to make predictions without having such programs enter psychology into the system explicitly [20].

Even now AI and ML already have an influence on our daily life. Virtual reality in the form of virtual assistants like Siri and Alexa, autonomous vehicles, and more are all products of IA, which most industries (including healthcare, finance, entertainment, and manufacturing) are utilizing. Such high-end methods as deep learning, reinforcement learning, and natural language processing are advancing the AI abilities to unprecedented levels, as now computers can understand pictures, process audio recordings, and even generate new material [21]. The issues in AI and ML involve fairness and transparency, issues of ML algorithms bias, and the so-called black-box problem where models are too complex to understand even by human beings, particularly deep learning networks. In addition, the increasing capability of AI to do jobs that were acquired by human beings is quite ethically questionable in terms of lost jobs and privacy [22].

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

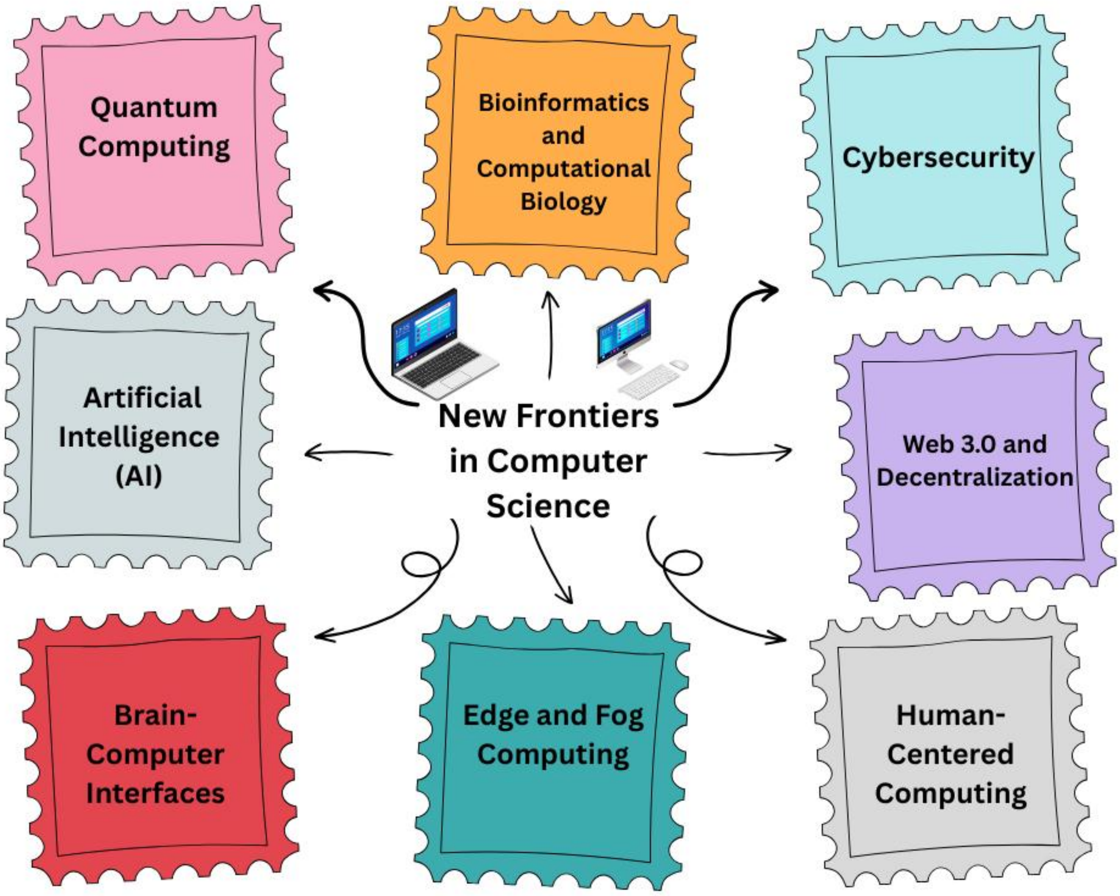

Figure: 2 showing new frontiers in computer science

Quantum Computing is a breakthrough towards standard computing in that it takes advantage of the characteristics of the quantum mechanics in computing. Unlike the classical computers that read data as binary digits (bits) of value 0 or 1, a quantum computer stores and encodes information as quantum bits, or qubits, which can be both in a superposition of states and entangled as well [23]. With this capability, quantum computers can exponentially solve some problems than the classical systems especially in areas like cryptography, optimization, drug discovery, and material science. Suppose, Shor integer factorization algorithm threatens to break very popular cryptographic algorithms such as RSA, and this is a major challenge to cyber security [24].

Nevertheless, quantum computing is not at the level yet. Constructing scalable quantum computers is an important engineering problem because of such problems as qubit stability and error correction. Nevertheless, recent breakthroughs in quantum hardware and algorithms indeed point to the possibility that quantum computing may provide an essential capability in just a couple of decades, leading to the solution of all kinds of problems that were hitherto unsolvable [25]. The role of cybersecurity is not to be underestimated as the entire world is becoming more and more digitized. Cybersecurity is concerned with the protection of systems, networks, and data again cyber threats

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

whereas privacy is concerned with ensuring that personal data is not accessed by outside people [26]. The increasing speed of Internet, cloud services and Internet of Things fuelled devices has introduced new attack vectors that can be exploited by malicious parties; consequently raising cyber-attack rates like information theft, ransom ware virus, and denial-of-service (DoS) attacks [27].

Modern cybersecurity solutions relate to preventing such threats, which can be encrypted data use, multi-factor authentication, intrusion detection systems, and block chain models of security protection. Nevertheless, we are faced with more advanced cyber-attacks and therefore our defenses should be more advanced. Cybersecurity uses of AI represent a two-mode situation, where AI may be employed to identify abnormalities and prevent unforeseen attacks, but also allow hackers to automate attacks using AI [28]. Another big issue is privacy. Data mining, surveillance, and use of personal information are some of the practices that are intensely disputing in terms of ethics as technologies that gather data are increasingly being adopted and deployed. Research into differential privacy, zero-knowledge proofs, and other concepts is being done so that sharing of data can be achieved with privacy protection [29].

Internet of Things (IoT) refers to the aspect of the ever-increasing number of interconnected things that are connected and share information with each other without human interaction. These gadgets are found in every space of a smart home product, wearable devices, industrial sensors and self-driving cars. With the real-time information collection and analysis, IoT could increase productivity and efficiency, streamline processes and improve the quality of life. Nevertheless, the enormousness of the IoT itself is a challenge [30]. That is the problem with such large levels of data produced by such devices, which edge computing enables. Edge computing brings computation and data storage near the origination of the data cutting latency and bandwidth consumption in the process, as well as guaranteeing that the IoT systems are able to process data in real-time. It is believed that through the integration of IoT and edge computing, the world of smart cities, self-driving transportation, and automation of industries will evolve. However, it is a serious problem that IoT security is comprehensively deficient since a vast number of devices lack proper protection and thus they can be attacked and exploited [31].

Human-Computer Interaction (HCI) is concerned with how human beings communicate with the computers and other technology. Technology is entering more and more deeply into everyday life, so user interface and experience design has grown in importance. Incorporating a user-experience design, or UX design (based on making an experience intuitive, accessible, and pleasant to use), is an interdisciplinary subject covering some aspects of other disciplines, such as psychology, design, and engineering [32]. Augmented reality (AR) and virtual reality (VR) are upcoming technologies in the

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

field of HCI and are transforming the entire entertainment, healthcare and education sectors. AFTER connecting the brain directly to the computer, brain-computer interfaces (BCIs) where individuals control equipment with their mind offer another frontier that is just liable to transformers: how people utilize their device [33].

But with the technology increasingly becoming more immersive and pervasive, we need to consider accessibility, privacy, and mental health issues associated with extended screen time and interaction with the products based on machine learning and incorporating AI. The most important challenge ahead is to make sure that the technology is not only human-centered but that particular topic is not forgotten [34]. Block chain technology achieved mainstream exposure because of being related to digital currencies such as Bit coin, yet the opportunities of its use irrevocably stretch much further. Block chain is an intelligent but decentralized and incorruptible record book that enables data to be safely used and recorded in a distributed network of nodes. Some of its uses are supply chain management, voting systems, identity verification, and smart contracts [35].

This is one of the most prominent benefits of block chain, which is a trust-free way to get a decentralized system and you do not have to use the banks or the government service to do this. Nevertheless, the problem of scalability, energy use and regulatory issues are still serious limiting factors to its widespread implementation. With further development, block chain technology is bound to make a revolutionary change in every industry such as in the financial sector, healthcare, logistics, raising new debates regarding the future of the digital state and decentralization [36].

Distributed systems are associated with two or more computers that share the same objective. Cloud computing is based on distributed systems and enables their users to access computing services (such systems as storage capacity and processing power) online. This has changed the way businesses and individuals store, run an application and scale the infrastructure [37]. The amount of applications that are run by distributed systems continues to increase not only in e-commerce platforms but also in scientific simulations. Nonetheless, consistency, fault tolerance, latency are the issues when running such systems. Such technologies as micro services and containerization are contributing to some of these problems being solved by offering more modular and scalable system designs [38].

The development of hybrid and multi-cloud environments is an ongoing process in cloud computing, and it provides even greater flexibility and cost-focused business solutions. As the world continues to expand cloud services, it will only necessitate the use of strong and efficient distributed systems. Computer Science has new frontiers that are an exhilarating prospect in solving complex worldwide issues, improving the daily lives of people and invention into new areas of industries [39]. But there are also new challenges that accompany these opportunities that need more research, development

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

and ethical speculations. As the two areas develop, they will keep defining the future of technology and both experts and the common people will have to respond critically to changes they usher in [40].

BREAKAWAY TRENDS AND USES OF COMPUTER SCIENCE

Computer Science has been developed much more than even its usual scope being unusually applied in various fields of sciences, industry, and society itself. This growth has spurred the increase in interdisciplinary work, with the application of computational methods that are being applied to address complex issues in the fields of biology, medicine, environmental science, and the social sciences [41]. In this part, we discuss some important interdisciplinary trends and applications explaining how Computer Science can change the world not only in the framework of its traditional interests. Bioinformatics is one of the most celebrated interdisciplinary fields that incorporate CS, the study of life, and statistical analysis in studying the data in biology [42]. The large datasets that are processed and interpreted by computational tools include, but are not limited to, DNA sequences, protein structures, and gene expression profiles. Sequence alignment, genome assembly and phylogenetic tree building also require stringent algorithms, which are key in current biological studies [43].

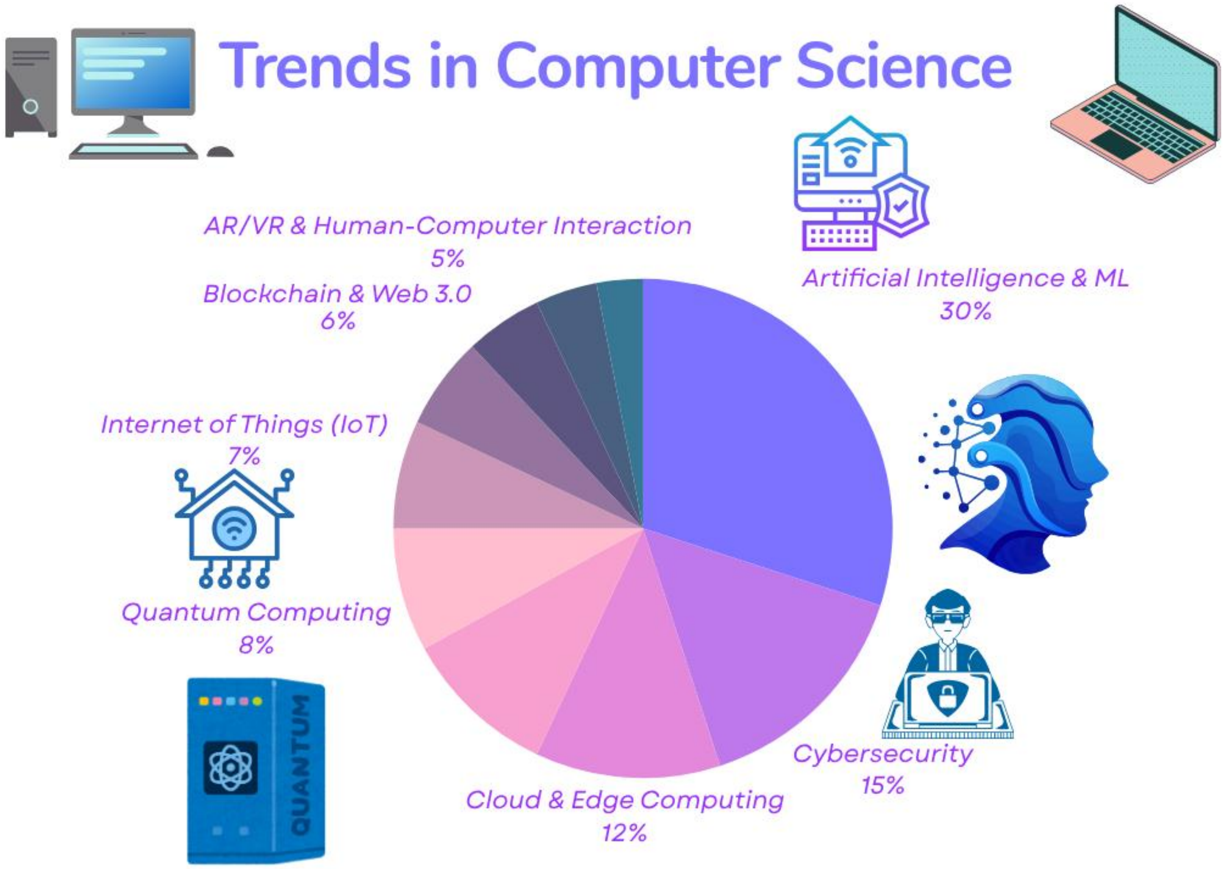

Figure: 3 showing trends in computer science

The use of machine learning is becoming common to recognize patterns within the genomic data,

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

make predictions about protein structure (as evidenced by the AlphaFold), and simulate the transmission of an infectious disease. The applications have the capacity of enhancing the speed of drug discovery, enhance diagnostic tools and learn more about the complicated biological systems. Increasingly complex and large biomedical data sets will keep bioinformatics a serious field in which people with computational expertise will be important [44]. It is also in the field of healthcare and medical research that computer Science is transforming medical research to help in improving medical research, diagnosis, treatment, and patient care. EHRS, medical imaging, and wearable devices produce enormous amounts of information that could be analyzed to obtain the insights into patient behavior, disease development, and the effectiveness of the treatment [45].

AI and ML are applied to spot anomalies on medical imagery (e.g., a tumor in an MRI scan), suggesting individualized treatment regimes, and define patient outcomes. Real-time video streaming, secure data transfer, and high-performance have made the telemedicine platform a means of increasing access to healthcare services, particularly in orphaned and underserved locations [46]. Surgery, too, has been refined by the use of robotics and computer-aided surgery whereby surgical precision and recovery time have also been enhanced. Although there are some great advances, there are also considerations over the privacy of data and ethics and regulatory compliance of integrating Computer Science in the healthcare when involved in sensitive matters concerning the patient [47].

The reliance of the society on technology continues to increase; consequently, Computer Science is starting to play a more vital role in resolving the environmental and social impacts that affect society. Climate change processes are carried out using computational models which are used to monitor deforestation, and forecast natural calamities. With the help of AI and satellite imagery, it is possible to keep track of ecosystems in order to prevent environmentally hazardous activities such as illegal mining or logging and maximize agricultural productivity using precision farming. [48] In the social study, data analytics and machine learning are applied in observing human behavior, simulating social organization and even changing public policy. Applications like sentiment analysis, fake news detection and moderation of online spaces are social computing applications crucial to the health of online spaces [49].

Nonetheless, one cannot ignore the ecological price of computing itself. Data centers come with high energy consumption and there are high carbon emissions associated with the training of large AI models. In this regard, green computing-related issues, such as green algorithms and architectures, are becoming an important area of research and development. Robotics involves a combination of Computer Science, mechanical engineering, and electronics in order to create machines that may perform some tasks without or minimal assistance of humans. Its uses are applicable in manufacturing

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

and logistics as well as in the areas of exploration, defense, and personal assistance [50]. Examples of autonomous systems that depend upon the Computer Science concepts are self-driving cars, drones, and Computer Science concepts computer vision, real-time processing, and control algorithms. These systems will have to process sensor data, make dynamic environment decisions, and be safe to share the work with human beings [51].

Robotics ethics and regulation are also topics of ethical and regulatory concerns, especially about liability concerns such as safety, employment displacement, decision-making in important situations (e.g. autonomous vehicles making choices in conditions of a possible accident). Modern Computer Science is interdisciplinary, which further emphasizes the fact that the field is an innovation driver in a broad sphere of disciplines [52]. Whether that means healthier outcomes, knowledge of all the wonders of biology, making a difference in the environment, or making autonomous technologies possible, Computer Science keeps finding new frontiers to explore together. The ethical and responsible use of said computational tools in multidisciplinary areas will be a necessary condition of achieving a sustainable and fair future as future tools become more powerful and more accessible [53].

EDUCATIONAL AND ETHICAL PERSPECTIVES

With computer science becoming more complex and shifting the face of society, it is imperative that we look both at the systems of education that teach others to become a part of the industry, and the ethical philosophies that encompass the use of technology in a controlled manner. The part dwells on the changes in Computer Science education to keep pace with the contemporary needs, the moral issues of sophisticated technologies, and the role of responsible innovation towards creating the future that can fall in line with human values [54]. Computer Science learning has become in-demand at a high level in the world market as it demonstrates the importance of computing skills to various sectors. Colleges and educational institutions, and online platforms are increasing the access to educational materials in CS, providing such courses as data science, programming, artificial intelligence, and cybersecurity education [55].

The new curricula are not only focused on learning the theory but are also focused on being practically used in a project. More and more students are motivated to work on real problems by taking internships, contributing to open-source projects, hackathons, and carrying out research project. Coding sandbox and interactive tools, virtual labs, have led to increased accessibility and curiosity towards CS education, which is also necessary in distance learning. In addition, interdisciplinary education is becoming a trend [56]. Programs are currently integrating Computer Science and biology, economics, design and other fields of study to enable students realize careers that cut across more

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

than two fields. To illustrate, a student majoring in both CS and healthcare could take bioinformatics or medical AI programs, whereas a student who majors in both CS and business could become one that works on data-driven entrepreneurship [57].

Several difficulties still exist despite the mentioned advancements. A continuous gender and diversity disparity exists on CS programs, women and underrepresented minorities find it more difficult to get entry and success. Breaking these gaps with diverse pedagogical choices, mentorship schemes, and engaging outreach which increase prospects into a more impartial technological environment is the key to dissolving these gaps [58]. When power is involved, there should be responsibility, and it becomes particularly applicable to such powerful technologies as AI, surveillance, and deepfakes. In Computer Science, the ethics are based around the topic of fairness, accountability, transparency, and misuse [59].

Algorithmic bias, when machine learning algorithms have the properties of models that the society might have at the training level or even exaggerated can be considered a pressing issue. Discriminatory algorithms are likely to cause prejudice in such a crucial sphere as hiring, lending, policing, and healthcare. Algorithmic fairness depends on the quality of training data rather than the homogeneity thereof, strong systems of auditing, as well as diverse teams with knowledge about the social consequences of technical choices [60]. Another major issue is that of privacy. With the accumulation of a huge number of personal information by digital systems, there is a greater likelihood of a lack of authorization access, spying, and control. Such forms of technology as facial recognition, location tracking and behavioral analytics should be used balanced to ensure the safety of the rights of individuals [61].

In addition, autonomous technologies like self-driving vehicles and drones raise the question of liability, decision, and control. Who will be liable in case an accident happens as a result of an autonomous vehicle? Is it possible to leave life-and-death decision to machines? These are questions that stress the importance of ethical literacy by technologists. The Studies and Workforce of Computer Science students and professionals should be educated about computer technicalities, as well as moral judgment, societal evaluation, and government change knowledge [62]. With the increase of computing power and abilities to automate on the rise, the role of responsible innovation becomes more significant. This is creating technologies that not just work and work well but are socially helpful and inclusive and long term favored to human interests [63].

The AI ethics is one of the larger emphasis points as it deals with the fact that artificial intelligence systems can run in a way that is transparent, can be explained to the people who use them, and ultimately be developed given thought to human supervision. To provide a framework to govern the

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

implementation of AI technologies, organizations and researchers are coming up with structures like the human-in-the-loop systems, ethical considerations of the development of AI, and potential regulatory safeguards like the EU AI Act [64]. Governments, industry leaders and academic institutions should work together in order to put up norms, standards and a legal structure under which there is no scope of misuse as well as the space to innovate. The development of algorithms must be transparent, the processes of tech policy must be open to the population, and the dialogue between spheres must become interdisciplinary to create a trustworthy technological future [65].

The sustainable development in Computer Science supports education and ethics. We have to teach the next generation of computer scientists not only the skills but also the moral and the social awareness that people need to be able to grapple with these complexities they are going to be faced with. Similarly, with the development of new technologies, there is a need to have ethical foresight and responsible innovation through which such technologies can be developed and implemented [66]. Quality of education and ethical responsibility are two aspects that must be addressed, the only way to make sure Computer Science will stay useful to the human overall population.

PROBLEMS AND ISSUES OF RESEARCH IN COMPUTER SCIENCE

Computer Science is on the edge of a historical time. Improvement in technology is fast and with this comes opportunity as well as complexity. With groundbreaking applications generated on the basis of foundation concepts, and emerging technologies transforming whole sectors, new challenges present a wide range of challenges on the researchers; technical, ethical, and social challenges emerge. This section establishes some of the research issues of significance in the field and presents some of the questionable research avenues that could be explored and innovative in the future [67]. Regardless of all the achievements made in the basic areas, there are still a few fundamental problems underlying the Computer Science which are either not solved or understood partially. Another example is the P vs NP problem in algorithms and computational complexity; that is, one of the least answered and yet most significant questions in theoretical computer science. Upon verification, the outcome would be a redefining of what will be computationally solvable [68].

On the same note, there are also effective parallel algorithms, ideal graph searching algorithms and the real-time decision algorithms that continue to be an active research program. These root problems are increasingly relevant the more data-intensive and time sensitive the systems get, which may be the case in autonomous vehicles or real-time analytics [69]. The decreasing rate of Moore and Dennard scaling, part of computer architecture, has led to researchers seeking alternatives to using silicon as the traditional base. Number of research studies on neuromorphic computing, optical processors and other forms of heterogeneous computing are under development to maintain the

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

hardware capability and cost in energy consumption due to the increased developments in the field of high-performance computing [70].

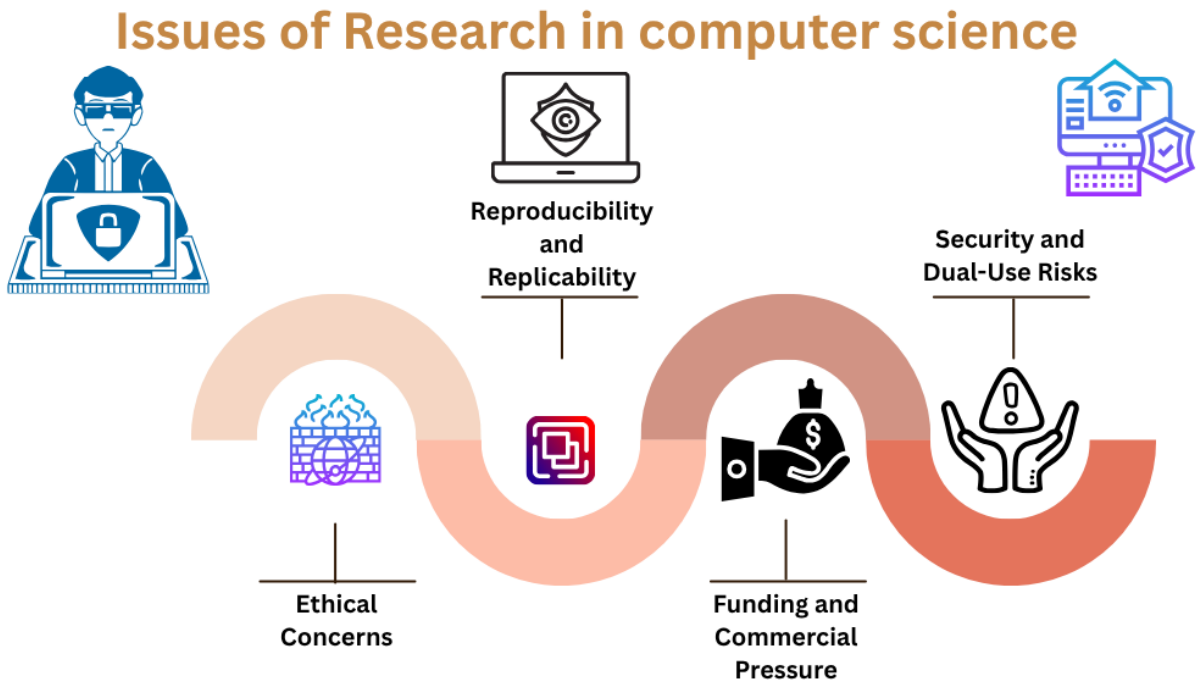

Figure: 4 showing issues of research in computer science

Although the new technologies, such as artificial intelligence, quantum computing, and block chain have demonstrated great potential, they remain in the exploration stage and are limited in several ways. Models in AI and Machine Learning may be very powerful, yet they need to be more explainable and of higher robustness. A system such as deep learning may, say, perform better than humans in a certain task, yet also may be quite vulnerable to adversarial attack a small modification of the inputs causing massive changes in the outputs [71]. Models are required to be more interpretable through research to be secure. Besides, there is still no general artificial intelligence, that is, systems that can reason broadly like humans. The majority of the existing AI is narrow and task-oriented. It is a complex theoretical and engineering problem to develop AI that is capable of reasoning, learning in one domain and generalizing it, and more generally being able to do so flexibly [72].

The quantum computing platforms are an outstanding but constrained project in that they are hampered with hardware instability, DE coherence, and their error rates. Development is on constructing fault-tolerant quantum systems, quantum algorithms, and practical applications that could be used in the real world to illustrate quantum advantage over the laboratory settings. Scalability and energy efficiency are still being dealt with in the smart and block chain technology and distributed ledgers [73]. The resource demanding consensus algorithms, such as Proof of Work,

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

are then compared to some alternatives, such as Proof of Stake and Directed Acyclic Graphs (DAGs), which have their own trade-offs on decentralization, security, and speed. Still, the work on more ethically and environmentally sustainable block chain ecosystems is still evolving, and the undeveloped technology of cross-platform integration builds on an interoperability framework [74].

Computer Science is converging with a number of other fields in some interesting ways. The issue of real-world problems in biology, physics, healthcare, and environmental science in which computing is used to solve them interdisciplinary computing is bringing about new ways of conducting impactful research. As an example, a system based on AI could predict natural disasters solely on the basis on which climate data is trained, whereas simulations and digital twins are transforming personalized medicine [75]. Human-centered computing is another essential direction which focuses on using technologies which are designed according to the needs of users, social situation and ethical values. This does not only mean good usability and accessibility but also inclusive, culturally aware systems, and equity. Such domains as affective computing (the systems capable of recognizing and responding to human emotion) and AI ethics are on the rise [76].

Among the areas of high research priority are cybersecurity and privacy-preserving computation. Many people depend increasingly on cloud services, smart objects, and digital identities, so it is necessary to guarantee the safety and privacy of the communication. Solutions to privacy based on homomorphic encryption, differential privacy, and secure multi-party computation are being developed, and in some cases efficiency and scalability challenges remain in practical implementation. In the field of sustainable computing, data centers and algorithms environmental footprint minimization is now an important issue [77]. Large AI models draw a lot of energy; therefore, a study of green AI, energy-conscious scheduling, and carbon-efficient architecture is emerging.

Programmable biology and bio-computing is another frontier-in this case using biological molecules as computing devices. The field of DNA computing and synthetic biology has presented academic proposals that may prove to be revolutionary in the storage and processing of information, at the molecular level. Lastly, research on scalable and inclusive pedagogies is needed in the Computer Science education and workforce development of the future [78]. Research based on AI in teaching-learning (e.g., intelligent tutoring systems), gasification, and VR/AR platforms have the potential to enhance the ways of teaching and learning CS by making them responsive and perceptible. Computer Science is a subject that is developing. Since it cuts across almost all spheres of life today, the criticality of research in promotion of knowledge and in the resolution of upcoming issues cannot be over-emphasized [79]. The research field in the coming decades will be characterized by solving open

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

problems in more abstract areas, by overcoming practical constraints in some emerging technologies, and by searching out interdisciplinary applications [80].

A researcher should not only be impervious to technical excellence but also be cost-effective in societal, ethical and environmental way to ensure sustainability of progress that will add value. Multidisciplinary research and collaborative innovation will be at the forefront to address global challenges and create a future where technology is effective in benefiting humanity and where they are developed and deployed responsibly [81].

CONCLUSION

Computer Science was initially viewed as narrow subject matter pertaining to programming and algorithms only but now has positioned itself as the mainstay of the new digital age. It has also been used to innovate nearly any domain; science, industry, education, healthcare, communication, and governance. This track has scanned the underlying philosophy to support the field as well as those new boundaries that are likely to dominate the field in future. Through this it has given us an overview look at the contemporary landscape and the interdisciplinary scope it is in and the moral consequences it bears. The early principles of Computer Science are important now as much as they were. The essential subjects, including algorithms and data structures, computer architecture, operating systems, programming languages and theoretical computing form the intellectual basis upon which further developments are based. The knowledge of these fundamental aspects provides students, researchers, and professionals with problem-solving attitude in order to tackle the intricate systems.

Such foundations are not fixed but they keep on evolving as they are responding to new challenges. As an example, the growing need in terms of efficiency, an instantaneity of response, and extensiveness is transforming the fashion of customary algorithms development and optimization. On the same note, parallel processing and memory architecture, as well as system-level design are making hard limits on hardwares performance. Theoretical research is still posing important questions regarding what can be computed, which directs the investigation into novel technologies at large.

In addition to these areas, a phenomenal growth of Computer Science has occurred into new frontiers. Machine Learning and Artificial Intelligence have come with a new dawn of intelligent systems having capability of perception, reasoning and decision-making. Quantum computing is an engineering question which implies the overturning of our concepts of computations and offers new paradigmatic trends which utilize the facts of quantum mechanics. By joining the physical and digital universes, the Internet of Things and edge computing are introducing smart environments and real-time analytics. Block chain technologies are also reimporting digital trust and decentralization and Human-Computer Interaction is attempting how we can better interact with the machines to make it

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

more natural, accessible and human friendly.

All these frontiers come with astonishing opportunities as well as severe issues. They present potentially revolutionary changes in terms of productivity and healthcare, transport, etc, but they also bring about important technical, ethical and social issues. These problems need to be proactively handled, i. e. algorithmic bias, data privacy, energy consumption, and technological unemployment have to be mitigated in a responsible manner. The need to combine Computer Science with other areas is one of the most electrifying trends in the Computer Science field. All these interdisciplinary scrambling are opening up solutions to some complicated real-world problems. Computational tools in biology are used to analyze the genetic, predicted protein folding and personalized medicine. In environmental science, artificial intelligence models can be used to predict climate change and to minimize the energy expenditure. Big data analytics is also being used in social sciences to discover new trends in human behavior, assist with public policy, and to provide better digital governance.

Through such applications, it is evident that Computer Science is not a discrete field, but instead a multi-utility accessory in the comprehension of the world and reshaping it. Yet, at the same time, they emphasize the need to have a cross-domain collaboration, ethical and cultural understanding, and which should be given prominence to in the production of these technologies that greatly affect human lives and societies at large. Technology is increasingly more powerful and capable of reaching larger numbers of people, and this means that the method of educating the next generations of computer scientists will require changes. Contemporary teaching of Computer Science not only focuses only on instructions on how to code, but also on the creativity, working as a team, communicating, and making ethical decisions. There is increased interdisciplinary education, broader inclusivity, and project-based learning of curricula to make students ready-fitted to handle real-life issues.

Meanwhile, ethics has become one of the most important foundations of accountable innovation. It should base the development and deployment of technology in terms of fairness, accountability, and transparency. It can be a medical diagnosis system based on artificial intelligence or a block chain protocol by which digital goods are registered, developers and researchers in any field need to remember the social consequences of their creations. Computer scientists ought to have a basic knowledge of ethical literacy that is as essential as a knowledge of programming. Computer Science is challenging as well as exhilarating in the future. There are still numerous grand challenges to be solved: the creation of understandable AI, fault-tolerant quantum computers, cybersecurity in an increasingly connected world, and making large-scale computing systems less environmentally demanding. There is not merely a technical challenge but also a human one. They need a long term vision and multidisciplinary cooperation and inclusive leadership.

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

Also, it is crucial that the field have to reckon with the pace at which it changes. Technologies are undergoing rapid development even quicker than social and regulatory systems could be adapted. This gap will have to be filled with proactive policymaking, informing the citizens, and healthy communication between the government, civil societies and the technologists. Other new fields such as neuromorphic computing, bio-computing, green artificial intelligence, and immersive computing are going to push even further the limits of what is achievable. Meanwhile, education will need to be more accessible, equitable, and the benefits of digital innovation will need to be spread. Computer Science is now something more than makes faster computers or develops effective code, now it is about making digital future of mankind. Looking towards the future, the only question we can ask is not how we can create new technologies, but how we can create this in a manner that is ethical, including, and sustainable.

With solid knowledge as the basis of innovations, interdisciplinary collaboration and ethics, the Computer Science global community will be able to make the next period of digital evolution prosperous to the entire society. This is not only the obligation of researchers or institutions, but also of each of us working on the design, development and deployment of computing technologies.

REFERENCES

[1]. Shibata N, Kajikawa Y, Takeda Y, Matsushima K. Comparative study on methods of detecting research fronts using different types of citation. Journal of the American Society for information Science and Technology. 2009; 60(3):571-80.

[2]. Tattershall E, Nenadic G, Stevens RD. Detecting bursty terms in computer science research. Scientometrics. 2020; 122(1):681-99.

[3]. Wu Y, Venkatramanan S, Chiu DM. Research Collaboration and Topic Trends in Computer Science: An Analysis Based on UCP Authors. Proceedings of the 24th International Conference on World Wide Web. Florence, USA: ACM; 2015; 1045- 50.

[4]. Hoonlor A, Szymanski BK, Zaki MJ. Trends in computer science research. Communications of the ACM. 2013; 56(10):74-83.

[5]. Takuma Yoneda, Jiading Fang, Peng Li, Huanyu Zhang, Tianchong Jiang, Shengjie Lin, Ben Picker, David Yunis, Hongyuan Mei, and Matthew R. Walter. 2024. Statler: State-maintaining language models for embodied reasoning. In ICRA.

[6]. Hongyi Yuan, Zheng Yuan, Chuanqi Tan, Wei Wang, Songfang Huang, and Fei Huang. 2023. RRHF: Rank responses to align language models with human feedback. In NeurIPS.

[7]. Brackmann, C., Román, M., Robles, G., Moreno, J., Casali, A., and Barone, D. (2017). "Development of computational thinking skills through unplugged activities in primary

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

school," in Proceedings of the 12th Workshop on Primary and Secondary Computing Education (Madrid), 65–72. doi: 10.1145/3137065.3137069

[8]. Brown, N., and Wilson, G. (2018). Ten quick tips for teaching programming. PLoS Comput. Biol. 14, e1006023. doi: 10.1371/journal.pcbi.1006023

[9]. Buitrago, F., Casallas, R., Hernández, M., Reyes, A., Restrepo, S., and Danies, G. (2017). Changing a generation's way of thinking: teaching computational thinking through programming. Rev. Educ. Res. 87, 834–860. doi: 10.3102/0034654317710096

[10]. Calderon, A., Catherine, T., and Crick, T. (2017). An Investigation into Susceptibility to Learn Computational Thinking in Post-Compulsory Education. doi: 10.1007/978-3-319-93566-9_14

[11]. Coppelli, G. (2018). Economic globalization in the 21st century. Between globalization and de-globalization. Estudios Int. 50, 57–80. doi: 10.5354/0719-3769.2018.52048

[12]. Daungcharone, K., Panjaburee, P., and Thongkoo, K. (2019). A mobile game-based C programming language learning: results of university students' achievement and motivations. Int. J. Mob. Learn. Organ. 13, 171–192. doi: 10.1504/IJMLO.2019.0 98184

[13]. De Paula, B., Burn, A., Noss, R., and Valente, J. (2018). Playing beowulf: bridging computational thinking, arts and literature through gamemaking. Int. J. Child Comp. Interact. 16, 39–46. doi: 10.1016/j.ijcci.2017. 11.003

[14]. Naveen Gupta, Medha Sawhney, Arka Daw, Youzuo Lin, and Anuj Karpatne. 2024. A Unified Framework for Forward and Inverse Problems in Subsurface Imaging using Latent Space Translations. arXiv preprint arXiv:2410.11247 (2024).

[15]. José M Gutiérrez, Daniel San-Martín, Swen Brands, Rodrigo Manzanas, and Sixto Herrera. 2013. Reassessing statistical downscaling techniques for their robust application under climate change conditions. Journal of Climate 26, 1 (2013), 171–188.

[16]. Oliver Hamelijnck, Theodoros Damoulas, Kangrui Wang, and Mark A. Girolami. 2019. Multi-resolution multi-task Gaussian processes. In Advances in Neural Information Processing Systems.

[17]. Tao Han, Song Guo, Fenghua Ling, Kang Chen, Junchao Gong, Jingjia Luo, Junxia Gu, Kan Dai, Wanli Ouyang, and Lei Bai. 2024. Fengwu-ghr: Learning the kilometer-scale medium-range global weather forecasting. arXiv preprint arXiv:2402.00059 (2024).

[18]. Xue Han, Yi-Tong Wang, Jun-Lan Feng, Chao Deng, Zhan-Heng Chen, Yu-An Huang, Hui Su, Lun Hu, and Peng-Wei Hu. 2023. A survey of transformer-based multimodal pre-trained modals. Neurocomputing 515 (2023), 89–106.

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

[19]. Paul C Hanson, Aviah B Stillman, Xiaowei Jia, et al. 2020. Predicting Lake Surface water phosphorus dynamics using process-guided machine learning. Ecological Modelling 430 (2020), 109136

[20]. Erhu He, Yiqun Xie, Weiye Chen, Sergii Skakun, Han Bao, Rahul Ghosh, Praveen Ravirathinam, and Xiaowei Jia. 2024. Learning with location-based fairness: A statistically-robust framework and acceleration. IEEE Transactions on Knowledge and Data Engineering (2024).

[21]. Erhu He, Yiqun Xie, Licheng Liu, Weiye Chen, Zhenong Jin, and Xiaowei Jia. 2023. Physics guided neural networks for time-aware fairness: an application in crop yield prediction. In Proceedings of the AAAI Conference on Artificial Intelligence, Vol. 37. 14223–14231.

[22]. Erhu He, Yiqun Xie, Licheng Liu, Zhenong Jin, Dajun Zhang, and Xiaowei Jia. 2024. Knowledge guided machine learning for extracting, preserving, and adapting physics-aware features. In Proceedings of the 2024 SIAM International Conference on Data Mining (SDM). SIAM, 715–723.

[23]. Erhu He, Yiqun Xie, Alexander Sun, Jacob Zwart, Jie Yang, Zhenong Jin, Yang Wang, Hassan Karimi, and Xiaowei Jia. 2024. Fair graph learning using constraint-aware priority adjustment and graph masking in river networks. In Proceedings of the AAAI Conference on Artificial Intelligence, Vol. 38. 22087–22095.

[24]. Pradeep Hewage, Marcello Trovati, Ella Pereira, and Ardhendu Behera. 2021. Deep learning-based effective fine-grained weather forecasting model. Pattern Analysis and Applications 24, 1 (2021), 343–366.

[25]. Tony Hey, Stewart Tansley, Kristin Michele Tolle, et al. 2009. The fourth paradigm: data-intensive scientific discovery. Vol. 1. Microsoft research Redmond, WA.

[26]. Collin G Homer, Joyce A Fry, and Christopher A Barnes. 2012. The national land cover database. Technical Report. US Geological Survey.

[27]. Fanchamps, N., Specht, M., Hennissen, P., and Slangen, L. (2020). The Effect of Teacher Interventions and SRA Robot Programming on the Development of Computational Thinking. Hong Kong: The Education University of Hong Kong.

[28]. Fotaris, P., Mastoras, T., Leinfellner, R., and Rosunally, Y. (2016). Climbing up the leaderboard: an empirical study of applying gamification techniques to a computer programming class. Electro. J. e-learn. 14, 94–110. García, F. (2018). Editorial computational thinking. IEEE Rev.

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

[29]. Grgurina, N. (2021). Getting the Picture: Modeling and Simulation in Secondary Computer Science Education Naples: University Press. Grover, S., and Pea, R. (2018). Computational thinking: a competency whose time has come. Comp. Sci. Educ. Perspect. Teach. Learn. Sch. 19:1257–58. doi: 10.5040/9781350057142.ch-003

[30]. Peng Jin, Xitong Zhang, Yinpeng Chen, Sharon Xiaolei Huang, Zicheng Liu, and Youzuo Lin. 2021. Unsupervised learning of full-waveform inversion: Connecting CNN and partial differential equation in a loop. arXiv preprint arXiv:2110.07584 (2021).

[31]. Dae-Hyun Jung, Hyoung Seok Kim, Changho Jhin, Hak-Jin Kim, and Soo Hyun Park. 2020. Time-serial analysis of deep neural network models for prediction of climatic conditions inside a greenhouse. Computers and Electronics in Agriculture 173 (2020), 105402.

[32]. Nasrin Kalanat, Yiqun Xie, Yanhua Li, and Xiaowei Jia. 2024. Spatial-Temporal Augmented Adaptation via Cycle-Consistent Adversarial Network: An Application in Streamflow Prediction. In Proceedings of the 2024 SIAM International Conference on Data Mining (SDM). SIAM, 598–606.

[33]. Katikapalli Subramanyam Kalyan. 2023. A survey of GPT-3 family large language models including ChatGPT and GPT-4. Natural Language Processing Journal (2023), 100048.

[34]. Anuj Karpatne. 2017. Theory-guided Data Science: A New Paradigm for Scientific Discovery in the Era of Big Data. In 2017 AIChE Annual Meeting. AIChE

[35]. Anuj Karpatne, Imme Ebert-Uphoff, Sai Ravela, Hassan Ali Babaie, and Vipin Kumar. 2018. Machine learning for the geosciences: Challenges and opportunities. IEEE Transactions on Knowledge and Data Engineering 31, 8 (2018), 1544–1554

[36]. Anuj Karpatne, Xiaowei Jia, and Vipin Kumar. 2024. Knowledge-guided Machine Learning: Current Trends and Future Prospects. arXiv preprint arXiv:2403.15989 (2024).

[37]. Anuj Karpatne, Zhe Jiang, Ranga Raju Vatsavai, Shashi Shekhar, and Vipin Kumar. 2016. Monitoring land-cover changes: A machinelearning perspective. IEEE Geoscience and Remote Sensing Magazine 4, 2 (2016), 8–21.

[38]. Sedrick Scott Keh, Zheyuan Ryan Shi, David J Patterson, Nirmal Bhagabati, Karun Dewan, Areendran Gopala, Pablo Izquierdo, Debojyoti Mallick, Ambika Sharma, Pooja Shrestha, et al. 2023. Newspanda: Media monitoring for timely conservation action. In Proceedings of the AAAI Conference on Artificial Intelligence, Vol. 37. 15528–15536.

[39]. Hsu, Y. C., Irie, N. R., and Ching, Y. H. (2019). Computational thinking educational policy initiatives (CTEPI) across the globe. TechTrends 63, 260–270. doi: 10.1007/s11528-019-00384-4

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

[40]. Huang, P., and Hwang, Y. (2013). An exploration of EFL learners' anxiety and e-learning environments. J. Lang. Teach. Res. 4, 27. Jiménez Toledo, J. A., Collazos, C. A., and Ortega, M. (2021). Discovery model based on analogies for teaching computer programming. Mathematics 9, 1354. doi: 10.3390/math9121354

[41]. Alexey Dosovitskiy, Lucas Beyer, Alexander Kolesnikov, Dirk Weissenborn, Xiaohua Zhai, Thomas Unterthiner, Mostafa Dehghani, Matthias Minderer, Georg Heigold, Sylvain Gelly, et al. 2020. An image is worth 16x16 words: Transformers for image recognition at scale. arXiv preprint arXiv:2010.11929 (2020)

[42]. Guangyao Dou, Zheng Zhou, and Xiaodong Qu. 2022. Time Majority Voting, a PC-Based EEG Classifier for Non-expert Users. In HCI International 2022-Late Breaking Papers. Multimodality in Advanced Interaction Environments: 24th International Conference on Human-Computer Interaction, HCII 2022, Virtual Event, June 26–July 1, 2022, Proceedings. Springer, 415–428.

[43]. Ruo-Nan Duan, Jia-Yi Zhu, and Bao-Liang Lu. 2013. Differential entropy feature for EEG-based emotion classification. In 2013 6th International IEEE/EMBS Conference on Neural Engineering (NER). IEEE, 81–84.

[44]. Shu Gong, Kaibo Xing, Andrzej Cichocki, and Junhua Li. 2021. Deep learning in EEG: Advance of the last ten-year critical period. IEEE Transactions on Cognitive and Developmental Systems 14, 2 (2021), 348–365.

[45]. Khondoker Murad Hossain, Md Islam, Shahera Hossain, Anton Nijholt, Md Atiqur Rahman Ahad, et al. 2023. Status of deep learning for EEG-based brain–computer interface applications. UMBC Student Collection (2023).

[46]. Essam H Houssein, Asmaa Hammad, and Abdelmgeid A Ali. 2022. Human emotion recognition from EEG-based brain–computer interface using machine learning: a comprehensive review. Neural Computing and Applications 34, 15 (2022), 12527–12557.

[47]. Chao Jiang, Victoria Ngo, Richard Chapman, Yue Yu, Hongfang Liu, Guoqian Jiang, and Nansu Zong. 2022. Deep Denoising of Raw Biomedical Knowledge Graph from COVID-19 Literature, LitCovid, and Pubtator: Framework Development and Validation. Journal of medical Internet research 24, 7 (2022), e38584.

[48]. Jiannan Kang, Xiaoya Han, Jiajia Song, Zikang Niu, and Xiaoli Li. 2020. The identification of children with autism spectrum disorder by SVM approach on EEG and eye-tracking data. Computers in biology and medicine 120 (2020), 103722.

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

[49]. Ard Kastrati, Martyna Beata Płomecka, Damián Pascual, Lukas Wolf, Victor Gillioz, Roger Wattenhofer, and Nicolas Langer. 2021. EEGEyeNet: a simultaneous electroencephalography and eye-tracking dataset and benchmark for eye movement prediction. arXiv preprint arXiv:2111.05100 (2021).

[50]. Sander Koelstra, Christian Muhl, Mohammad Soleymani, Jong-Seok Lee, Ashkan Yazdani, Touradj Ebrahimi, Thierry Pun, Anton Nijholt, and Ioannis Patras. 2011. Deap: A database for emotion analysis; using physiological signals. IEEE transactions on affective computing 3, 1 (2011), 18–31.

[51]. Sander Koelstra, Christian Muhl, Mohammad Soleymani, Jong-Seok Lee, Ashkan Yazdani, Touradj Ebrahimi, Thierry Pun, Anton Nijholt, and Ioannis Patras. 2012. DEAP: A Database for Emotion Analysis; Using Physiological Signals. IEEE Transactions on Affective Computing 3, 1 (2012), 18–31. https://doi.org/10.1109/TAFFC.2011.15

[52]. Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., et al. (2020). On computational thinking and STEM education. J. STEM Educ. Res. 3, 147–166. doi: 10.1007/s41979-020-00044-w

[53]. Liang, Y., and Hsu, T. (2020). Comparison of the learning behaviors of the third grader students integrating robots and the computational thinking board game in Singapore and Taiwan. CoolThink@ JC 47, 47–51.

[54]. Polina Charters, Michael J. Lee, Amy J. Ko, and Dastyni Loksa. 2014. Challenging Stereotypes and Changing Attitudes: The Effect of a Brief Programming Encounter on Adults' Attitudes toward Programming. In Proceedings of the 45th ACM Technical Symposium on Computer Science Education (Atlanta, Georgia, USA) (SIGCSE '14). Association for Computing Machinery, New York, NY, USA, 653–658. https://doi.org/10.1145/2538862.2538938

[55]. Code.org and CSTA. 2020. 2020 State of Computer Science Education - Illuminating Disparities. code.org (2020). https://advocacy.code.org/2020_state_of_cs.pdf

[56]. Jason Freeman, Brian Magerko, Tom McKlin, Mike Reilly, Justin Permar, Cameron Summers, and Eric Fruchter. 2014. Engaging Underrepresented Groups in High School Introductory Computing through Computational Remixing with EarSketch. In Proceedings of the 45th ACM Technical Symposium on Computer Science Education (Atlanta, Georgia, USA) (SIGCSE '14). Association for Computing Machinery, New York, NY, USA, 85–90. https://doi.org/10.1145/2538862.2538906

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

[57]. Geneva Gay. 2013. Teaching to and through cultural diversity. Curriculum inquiry 43, 1 (2013), 48–70.

[58]. Jamie Gorson, Nikita Patel, Elham Beheshti, Brian Magerko, and Michael Horn. 2017. TunePad: Computational thinking through sound composition. In Proceedings of the 2017 Conference on Interaction Design and Children. 484–489.

[59]. Philip J. Guo. 2017. Older Adults Learning Computer Programming: Motivations, Frustrations, and Design Opportunities. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (Denver, Colorado, USA) (CHI '17). Association for Computing Machinery, New York, NY, USA, 7070–7083. https://doi.org/10.1145/3025453.3025945

[60]. Maren Krafft, Gordon Fraser, and Neil Walkinshaw. 2020. Motivating Adult Learners by Introducing Programming Concepts with Scratch. In Proceedings of the 4th European Conference on Software Engineering Education (Seeon/Bavaria, Germany) (ECSEE '20). Association for Computing Machinery, New York, NY, USA, 22–26. https://doi.org/10.1145/3396802.3396818

[61]. Douglas Lusa Krug, Edtwuan Bowman, Taylor Barnett, Lori Pollock, and David Shepherd. 2021. Code Beats: A Virtual Camp for Middle Schoolers Coding Hip Hop. Association for Computing Machinery, New York, NY, USA, 397–403. https://doi.org/10.1145/3408877.3432424

[62]. Brian Magerko, Jason Freeman, Tom McKlin, Scott McCoid, Tom Jenkins, and Elise Livingston. 2013. Tackling Engagement in Computing with Computational Music Remixing. In Proceeding of the 44th ACM Technical Symposium on Computer Science Education (Denver, Colorado, USA) (SIGCSE '13). Association for Computing Machinery, New York, NY, USA, 657–662. https://doi.org/10.1145/2445196.2445390

[63]. Saida Mamedova, Emily Pawlowski, and Lisa Hudson. 2018. A description of US adults who are not digitally literate. Statistics in Brief (2018).

[64]. Bill Manaris, Blake Stevens, and Andrew R Brown. 2016. JythonMusic: An environment for teaching algorithmic music composition, dynamic coding and musical performativity. Journal of Music, Technology & Education 9, 1 (2016), 33–56.

[65]. United States Bureau of Labor Statistics. 2020. Occupational projections and worker characteristics. Retrieved October 04, 2021 from https://www.bls.gov/emp/tables/occupationalprojections-and-characteristics.html

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

[66]. Joslenne Peña, Benjamin V. Hanrahan, Mary Beth Rosson, and Carmen Cole. 2021. After-Hours Learning: Workshops for Professional Women to Learn Web Development. ACM Trans. Comput. Educ. 21, 2, Article 15 (mar 2021), 31 pages. https://doi.org/10.1145/3446964

[67]. Gang Peng. 2017. Do computer skills affect worker employment? An empirical study from CPS surveys. Computers in Human Behavior 74 (2017), 26–34. https://doi.org/10.1016/j.chb.2017.04.013

[68]. Alexander Repenning, Corrina Smith, Robert Owen, and Nadia Repenning. 2012. AgentCubes: Enabling 3D Creativity by Addressing Cognitive and Affective Programming Challenges. In Proceedings of EdMedia + Innovate Learning 2012, Tel Amiel and Brent Wilson (Eds.). Association for the Advancement of Computing in Education (AACE), Denver, Colorado, USA, 2762–2771. https://www.learntechlib.org/p/41159

[69]. Mitchel Resnick, John Maloney, Andrés Monroy-Hernández, Natalie Rusk, Evelyn Eastmond, Karen Brennan, Amon Millner, Eric Rosenbaum, Jay Silver, Brian Silverman, and Yasmin Kafai. 2009. Scratch: Programming for All. Commun. ACM 52, 11 (Nov. 2009), 60–67. https://doi.org/10.1145/1592761.1592779

[70]. Bernat Romagosa i Carrasquer. 2019. The Snap! Programming System. Springer International Publishing, Cham, 1–10. https://doi.org/10.1007/978-3-319-60013-028-2

[71]. Sergio Sayago and Ángel Bergantiños. 2021. Exploring the first experiences of computer programming of older people with low levels of formal education: A participant observational case study. International Journal of Human-Computer Studies 148 (2021), 102577. https://doi.org/10.1016/j.ijhcs.2020.102577

[72]. Sherry Seibel and Nanette Veilleux. 2019. Factors influencing women entering the software development field through coding bootcamps vs. computer science bachelor's degrees. Journal of Computing Sciences in Colleges 34, 6 (2019), 84–96.

[73]. Kyle Thayer and Amy J. Ko. 2017. Barriers Faced by Coding Bootcamp Students. In Proceedings of the 2017 ACM Conference on International Computing Education Research (Tacoma, Washington, USA) (ICER '17). Association for Computing Machinery, New York, NY, USA, 245–253. https://doi.org/10.1145/3105726.3106176

[74]. Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P., et al. (2017). A future that works: automation. Employ. Product. 148, 1–135.

[75]. Master, A., Cheryan, S., Moscatelli, A., and Meltzoff, A. N. (2017). Programming experience promotes higher STEM motivation among first-grade girls. J. Exp. Child Psychol. 160, 92–106. doi: 10.1016/j.jecp.2017.03.013

ISSN : 3079-692X
Volume 1, Number 2, 2025
https://doi.org/10.70445/gjmlc.1.2.2025.17-42

[76]. McLaren, B., Adams, D., Mayer, R., and Forlizzi, J. (2017). A computer-based game that promotes mathematics learning more than a conventional approach. Int. J. Game Based Learn. 7, 36–56. doi: 10.4018/IJGBL.2017010103

[77]. Uddin A, Singh VK. Mapping the Computer Science Research in SAARC Countries. IETE Technical Review. 2014; 31(4):287-96.

[78]. Singh VK, Uddin A, Pinto D. Computer science research: The top 100 institutions in India and in the world. Scientometrics. 2015; 104(2):529-53.

[79]. Small H, Boyack KW, Klavans R. Identifying emerging topics in science and technology. Research Policy. 2014; 43(8):1450-67.

[80]. Cui Y, Wang S, Gao X, Yang H, Cao X. Detecting and Characterizing Research Fronts Topics Based on Global-Micro Model (in Chinese). Library and Information Service. 2018; 62(15):75-82.

[81]. Ferrari EP, Wong A, Khmelevsky Y. Cybersecurity education within a computing science program-a literature review. InProceedings of the 26th Western Canadian Conference on Computing Education 2024 May 2 (pp. 1-5).