Global Journal

OF COMPUTER SCIENCE AND TECHNOLOGY: G

Online ISSN: 0975-4172
Print ISSN: 0975-4350
DOI: 10.17406/CST

Interdisciplinary

Cognitive Debt and Sustainable AI Collaboration

Cybersecurity Awareness of BTECH Employees

Review of EEG Signal Analysis for Effective BCIs

Managing Multidimensional Worlds via Spatial Grasp

Discovering Thoughts, Inventing Future

VOLUME 26 / ISSUE 1 / VERSION 1.0

Global Journal of Computer Science and Technology

Section G - Interdisciplinary

Volume 26 **Issue G1**

2026

Global Journal of Computer Science and Technology

ISSN (Online): 0975-4172 • ISSN (Print): 0975-4350

Open Access Policy

Publisher

Global Journals Incorporated
301 Edgewater Place, Suite 100
Wakefield, MA 01880, United States

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GJCST / EDITORIAL BOARD

Global Journal of Computer Science and Technology

Computing, information systems, data science, artificial intelligence and digital technologies.

Preface

The Global Journal of Computer Science and Technology (GJCST) is pleased to present this issue, bringing together a curated collection of high-quality research papers that explore various frontiers of computer science and technology. par This issue features research spanning topics including artificial intelligence, machine learning, software engineering, network security, and interdisciplinary applications of computing. Each paper has undergone a rigorous peer-review process to ensure scientific rigor and originality. par We would like to express our sincere gratitude to the authors for entrusting their research with us, to the reviewers for their thorough and constructive evaluations, and to our readers for their continued engagement with the scientific discourse. par We hope that the research presented herein inspires further inquiry and contributes meaningfully to the advancement of knowledge in computer science and technology.

The Chief Editor
Global Journal of Computer Science and Technology
Global Journals Organization

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GLOBAL JOURNAL
OF COMPUTER SCIENCE AND TECHNOLOGY - G: INTERDISCIPLINARY
Volume 26 | Issue 1 | 2026 Article ID: GJCST-257948 Language: English

CATALOGING
ACM • K.3.1, H.1.2 ARXIV • cs.HC, cs.CY ANZSRC FOR • 3901

Does Artificial Intelligence Make You Stupid? Cognitive Debt and a Three-Tier Framework for Sustainable Human–AI Collaboration

Article Record

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RECEIVED	ACCEPTED	ONLINE PUBLISHED	PUBLISHED	PEER REVIEW
2026-06-03	2026-06-13	2026-06-26	2026-07-10	Double Blind

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generative AI | cognitive offloading | cognitive debt | learning | expertise | human–AI collaboration | desirable difficulties

AI USE STATEMENT
No generative AI was used for analysis or results.

FUNDING
No external funding was declared for this work.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

DATA AVAILABILITY
Not applicable for this article.

ETHICS
No ethics committee approval was required for this article type.

CONSENT
Not applicable for this article.

TRIAL REG.
Not applicable.

Crossref DOI: 10.34257/GJCSTG257948

How to Cite: EL Tannir (2026). Does Artificial Intelligence Make You Stupid? Cognitive Debt and a Three-Tier Framework for Sustainable Human–AI Collaboration. Global Journal of Computer Science and Technology, 26(1), 1-4. DOI: 10.34257/GJCSTG257948

AR Experience Web Page DOI

Print ISSN 0975-4350
Online ISSN 0975-4172

Under the strict compliance and defined process of

METADATA CONTINUATION

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ARCHIVAL RECORD

GJCST · Vol 26 · Issue 1 · 2026

Article ID GJCST-257948 · DOI 10.34257/GJCSTG257948

Print ISSN 0975-4350 · Online ISSN 0975-4172

Global Journal of Computer Science and Technology - Section G
GJCST Volume 26 Issue 1

Does Artificial Intelligence Make You Stupid? Cognitive Debt and a Three-Tier Framework for Sustainable Human–AI Collaboration

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Generative artificial intelligence now drafts our correspondence, condenses our reading, and solves our problems faster than we can articulate them. A growing body of evidence suggests, however, that the very tools that lift short-term output can quietly erode the cognitive capacities they appear to augment. This paper synthesizes four recent empirical studies—a randomized controlled trial of AI in high-school mathematics, a field experiment with elite management consultants, a classroom trial of an AI physics tutor, and a neurophysiological study of AIassisted writing—and argues that the headline question is badly posed. The decisive variable is not whether people use AI but how they use it. We adopt cognitive debt, a construct describing the trade of present convenience for future capability, as an organizing lens, and develop a threetier framework for cognitively sustainable use. Tier 1 delegates non-developmental tasks without guilt; Tier 2 protects domain expertise by deploying AI adversarially rather than substitutively; Tier 3 preserves the desirable difficulties on which durable learning depends. Each tier is grounded in established findings from cognitive psychology. We close with implications for individuals and organizations, and with the limitations of an evidence base that remains early and uneven.

Keywords: *generative AI, cognitive offloading, cognitive debt, learning, expertise, human–AI collaboration, desirable difficulties*

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DOI
10.34257/GJCSTG257948

1. Introduction

Consider a result that ought to unsettle anyone who reaches for a chatbot before they reach for their own judgment. In a large randomized controlled trial conducted in a Turkish high school, researchers affiliated with the University of Pennsylvania and the Wharton School gave nearly a thousand mathematics students access to a GPT-4-based assistant during practice sessions (Bastani et al., 2025). While the assistant was available, performance soared: students working with a standard chatbot interface solved practice problems roughly forty-eight percent better than peers with no such help. The intervention looked like an unambiguous success—until the assistant was taken away for the final, unaided examination. Stripped of the tool, the students who had leaned on it scored measurably below classmates who had never used it at all. The crutch, it turned out, had been doing the walking.

This pattern is not confined to classrooms, and it is the central concern of this paper. The same logic——impressive output while the tool is present, diminished capability once it is withdrawn—appears wherever cognitive work is silently transferred from a person to a machine. The popular question, posed bluntly, is whether AI makes us stupid. We will argue that this framing is unhelpful, because it treats a tool as if it had a single fixed effect on its user. It does not. A hammer neither builds nor destroys a house on its own; what matters is the hand that holds it and the purpose to which it is put. The relevant question is therefore not whether one uses AI, but how.

The remainder of the paper proceeds in four movements. Section 2 assembles the empirical case for concern, drawing on four recent studies that span education, professional knowledge work, and neurophysiology. Section 3 reframes the problem around the construct of cognitive debt and explains why a how-question is more tractable and more honest than a whether-question. Section 4 presents the paper's main contribution: a three-tier framework—delegation, augmentation, and cognitively active learning—each tier anchored in well-established results from cognitive psychology. Section 5 discusses implications and limitations, and Section 6 concludes.

2. Productivity without Proficiency: the Empirical case

Three findings recur across otherwise dissimilar studies. AI reliably raises immediate output. That output tends to converge toward sameness across users. And the gains often fail to survive the tool's removal, leaving the user worse off than if they had struggled alone. Taken together, these findings describe a dissociation between productivity and proficiency that the headline figures of the AI era tend to obscure.

2.1. Learning: the crutch effect

The Bastani et al. (2025) trial, published in the Proceedings of the National Academy of Sciences, is among the most carefully designed studies of the question to date. Students were randomly assigned to one of three conditions during their practice sessions:

an unconstrained chatbot built on GPT-4 ("GPT Base"), a pedagogically constrained version designed with teacher input to offer hints rather than answers ("GPT Tutor"), or no AI access at all. During assisted practice, both AI groups outperformed the control—the constrained tutor dramatically so. But on a subsequent unaided examination, the students who had used the unconstrained chatbot performed worse than those who had never touched it. The authors interpret this as evidence that an answerdispensing assistant functions as a crutch: it allows students to produce correct work without performing the cognitive operations that produce learning.

The design also contains the seed of an antidote, a point we return to in Section 4.3. The constrained GPT Tutor group, whose assistant withheld direct answers and instead guided students toward solutions, suffered no comparable penalty on the unaided exam; their scores were statistically indistinguishable from the control group. The same underlying model, configured to question rather than to answer, neutralized the harm. The lesson is not that AI tutoring is dangerous in itself, but that an interface optimized to be maximally helpful in the moment can be precisely the wrong thing for learning over time.

2.2. Expertise: better work, fewer ideas

If the classroom shows what AI does to the acquisition of skill, a landmark field experiment shows what it does to the exercise of expertise. Dell'Acqua and colleagues (2023), working with the Boston Consulting Group and a team drawn from Harvard, Wharton, and MIT, randomly assigned 758 management consultants—roughly seven percent of the firm's individual contributors—to complete realistic consulting tasks with or without GPT-4. On tasks lying within the model's competence, the effects were large: consultants using AI completed more tasks, finished them faster, and produced work judged about forty percent higher in quality. This is the result that made headlines.

The result that did not make headlines is, for our purposes, more important. The firm's own analysis of the experiment found that the relatively uniform output of the model reduced the group's diversity of thought by roughly forty-one percent. Individually, almost everyone improved; collectively, they converged. Consultants drew on similar framings, advanced similar arguments, and arrived at similar conclusions. The study also surfaced a "jagged technological frontier": on tasks lying just outside the model's competence, AI-assisted consultants were markedly more likely to be wrong, in part because they extended to the machine a trust it had not earned. Expertise has always consisted in part of idiosyncrasy—the particular way a seasoned practitioner sees a problem that others miss. A homogenizing tool puts exactly that idiosyncrasy at risk, and with it the differentiated judgment that gives an expert market value. The same compression of novel output has since been observed in creative writing (Doshi & Hauser, 2024).

2.3. Cognition: the neural signature of offloading

A third study moves the question from behavior to the brain. In a preprint from the MIT Media Lab, Kosmyna and colleagues (2025) asked fifty-four participants to write essays under one of three conditions—using a large language model, using a search engine, or using no external tool at all—while their brain activity was recorded with electroencephalography. The participants who wrote with the language model showed the weakest and least distributed neural connectivity of the three groups; the unaided writers showed the strongest. The model-assisted writers also reported a diminished sense of ownership over what they had produced and were less able to recall or quote their own essays moments after finishing them. Notably, when participants who had relied on the model were later asked to write without it, the under-engagement persisted. The authors named this accumulated cost cognitive debt: a deferral of mental effort that, like a financial debt, is convenient now and expensive later.

Two caveats are essential and we state them plainly, because an academic reader will check. The study is a preprint and has not, at the time of writing, completed peer review; its sample is small and its task is narrow. The authors themselves caution against the sensational reading—they did not measure intelligence and explicitly resist the language of "brain rot." The construct of cognitive debt is valuable less as a proven neurological fact than as a precise name for a mechanism that the behavioral studies independently imply

3. From "Whether" to "How" ": Reframing the Question

The mechanism underlying all three findings is well understood and considerably older than generative AI. Psychologists call it cognitive offloading: the use of external aids to reduce the mental demands of a task (Risko & Gilbert, 2016). Offloading is not inherently harmful—writing offloads memory, and few would surrender it—but it carries a consistent cost. When we delegate the act of retrieval, we weaken the memory that retrieval would have built. The point was demonstrated for internet search well before chatbots existed: people who expect to have continued access to information online remember the information itself less well, while remembering where to find it (Sparrow et al., 2011). A language model is a cognitive offloading device of unprecedented reach, capable of absorbing not merely storage but reasoning, composition, and judgment. The more it absorbs, the more of those faculties go unexercised.

This reframing matters because it changes what we are permitted to conclude. The studies in Section 2 do not show that AI makes its users less capable. They show that a particular mode of use—substituting the tool for the cognitive work rather than supporting it—produces that result and that a different mode of use does not. The unconstrained chatbot harmed learning; the Socratic tutor did not. The consultants who let the model think for them converged and erred at the frontier; the construct that predicts who suffers cognitive debt is the depth of substitution, not the mere presence of the tool. The honest question, then, is a design question, addressed to the user as much as to the engineer: which cognitive operations should be handed over, and which must remain our own? The next section offers a structured answer.

4. A Three-Tier framework for Cognitively Sustainable use

We propose that AI use be sorted into three tiers according to a single criterion: the relationship between the task and the user's own development. Where a task demands no skill the user needs to build, full delegation is appropriate and even obligatory. Where a task lies within the user's domain of expertise, the tool should augment judgment without replacing it. Where the explicit goal is to learn, the tool must be configured to preserve effort rather than remove it. The tiers are not a hierarchy of value but a partition of situations; a single person moves among all three within a working day.

4.1. Tier 1 — Delegation: handing over what does not develop you

A great deal of knowledge work consists of tasks for which the user has neither expertise nor any reason to acquire it. Reformatting a dataset, transcribing a recording, translating boilerplate, producing a serviceable first draft, or synthesizing fifteen sources into a brief—these are the cognitive equivalent of errands. Delegating them to AI is not a moral failing but a reallocation of scarce attention toward the work that genuinely requires it. The analogy is to any competent professional one engages: one does not re-audit every line an accountant prepares, because the point of the arrangement is to be relieved of that labor.

Four categories delegate cleanly. First, the blank-page draft: the value of a generated first draft lies less in its words than in the momentum it supplies, after which the user's own judgment takes over to revise. Second, broad research synthesis, where the tool compresses an afternoon of reading into minutes. Third, pattern detection across large bodies of data—sales figures, customer feedback—where a model surfaces regularities a person could not hold in mind at once. Fourth, mechanical transformation: cleaning, reformatting, transcription, translation. The single discipline that Tier 1 requires is verification. Because models are confidently wrong on a non-trivial fraction of outputs—the jagged frontier of Section 2.2—delegation is not abdication. A human eye on the result before it leaves your hands is the price of admission, and it is cheap.

4.2. Tier 2 — Augmentation: protecting expertise

The second tier is where the most consequential and least visible damage occurs. Within one's own field, the temptation is to use AI exactly as in Tier 1—to let it produce the analysis, the argument, the recommendation—and the immediate output is often excellent. But this is precisely the substitution that the consulting experiment showed to homogenize thought and the writing study showed to incur cognitive debt. The faculty being offloaded here is not clerical; it is the differentiated judgment that constitutes expertise itself.

The governing image for Tier 2 is the athletic coach. A coach never runs the race in the athlete's place. The coach observes, challenges, asks the uncomfortable question, and pushes the athlete past the point they would have stopped at alone—but the exertion, and the resulting strength, belong to the athlete. Used this way, AI is asked not to produce the work but to interrogate it: to find the flaw in an argument, to supply the strongest objection, to propose an angle the expert has not considered. The analysis, the weighing, and the final decision remain the human's. The distinction is subtle in practice and decisive in consequence. Asking a model "write my recommendation" offloads the judgment; asking it "here is my recommendation—where is it weakest?" exercises the judgment against resistance. The first accrues cognitive debt; the second pays it down.

4.3. Tier 3 — Cognitively Active learning: keeping the difficulty

The third tier addresses the case the popular discourse most often gets wrong: using AI to learn. The intuitive approach—"summarize this chapter," "make me a study sheet," "explain this so I don't have to read it"—delegates the cognitive labor of learning to the machine, which is to say it delegates the learning. This is the mechanism behind the examination collapse in Bastani et al. (2025): the chatbot did the work, and the work was the point.

Cognitive psychology has spent decades establishing why this fails, and the findings cohere into a single principle: effortful processing is what makes learning durable. Bjork and Bjork (2011) describe desirable difficulties—conditions that slow acquisition and feel harder in the moment but markedly improve long-term retention and transfer. The generation effect shows that information a learner produces is remembered better than information merely read (Slamecka & Graf, 1978).

The testing efect shows that retrieving knowledge through self-testing strengthens memory more than re-studying does (Roediger & Karpicke, 2006). And cognitive load theory explains why a tutor that hands over answers can hurt: it removes the germane load—the productive effort of building a mental schema—that learning requires (Sweller, 1988). Each of these effects is abolished when an AI removes the effort.

The corrective is to configure the tool to impose desirable difficulty rather than relieve it—to make it a Socratic tutor rather than an oracle. In practice this means inverting the usual prompts. Instead of "summarize this concept," ask the model to test you: "ask me questions to check whether I have understood this," "build me a quiz of increasing difficulty," "challenge my answers and tell me where my reasoning breaks." The constrained tutor in Bastani et al. (2025), which guided with hints rather than answers, did no harm to unaided performance; and a Harvard trial of a purposebuilt physics tutor designed along these lines found that students learned more than twice as much, in less time, as peers in a well-run active-learning classroom (Kestin et al., 2025). The published evidence appeared in Scientific Reports, a Nature Portfolio journal—not, as it is sometimes reported, in Nature itself—and rests on fewer than two hundred students, so it should be read as promising rather than definitive. Its mechanism, however, is exactly the one the broader literature predicts: a tutor that preserves effort preserves learning. A useful side benefit, often noted by users, is that one can ask a machine the most elementary question without embarrassment—lowering the social cost of difficulty while keeping the cognitive cost intact.

5. Discussion

The three tiers share one accounting principle. Cognitive debt is incurred whenever a person offloads a cognitive operation they would otherwise have needed to perform themselves for their own development, and it is avoided—or repaid—whenever the tool is arranged to demand effort rather than absorb it. Tier 1 incurs no debt because the offloaded operations were never developmental. Tier 2 risks the most insidious debt, because the offloading feels productive and the loss—of original judgment—is invisible until the tool is unavailable or wrong. Tier 3 converts the tool from a creditor into a trainer.

At the level of the organization, the homogenization finding deserves particular attention. If every analyst, every firm, and every competitor consults the same handful of models, the convergence documented among the consultants scales into a market-wide flattening of ideas.

Differentiation—the source of competitive advantage and of intellectual progress alike—depends on variance, and variance is what a shared statistical model erodes. The individual incentive to use AI for higher immediate quality and the collective interest in a diversity of thought can therefore point in opposite directions, a tension organizations would do well to manage explicitly rather than discover after the fact.

Several limitations bound these conclusions. The evidence base is young and uneven: the strongest learning study is a single-country school trial, the consulting experiment is confined to one elite firm and one model generation, the physics trial is small, and the neurophysiological study is an unreviewed preprint with a narrow task. The capabilities of the models themselves are a moving target; the jagged frontier of 2023 is not the frontier of today, and findings tied to GPT-4 may not transfer cleanly to later systems. Cognitive debt, finally, remains a construct rather than a settled quantity—useful for organizing the evidence and guiding practice, but not yet a measured variable with an agreed unit. None of these caveats overturns the central, convergent observation: across education, professional work, and the laboratory, the same tool produces opposite effects depending on whether it is allowed to replace cognition or required to provoke it.

5.1. Implications for practice

For the individual—student, researcher, or professional—the operative discipline is triage before delegation. Before opening a chatbot, ask which tier the task occupies: whether the work is something you need to be able to do, or merely something that needs to be done. A literature search synthesized by a model is a Tier 1 errand; the argument of your own paper is not, and outsourcing it forfeits the very judgment a research career is built upon. Learners should treat the "summarize this for me" reflex as a warning sign and invert it, asking the tool to test them rather than to tell them, since the effort it removes is precisely the effort that consolidates knowledge (Bastani et al., 2025; Kestin et al., 2025).

For practitioners and managers, the homogenization result carries the sharper warning. If a team's analysts all consult the same model, the convergence Dell'Acqua and colleagues (2023) observed will quietly erase the differentiation on which competitive advantage depends. The remedy is procedural: have people commit their own framing to paper before they consult AI, use the tool to stress-test conclusions rather than to generate them, and treat any task near the jagged frontier as one requiring human verification rather than trust. Organizations should also resist measuring AI's value by immediate output alone. A metric that rewards faster, higher-quality deliverables while ignoring the slow erosion of in-house expertise will optimize for exactly the cognitive debt this paper warns against. In both cases the aim is not less AI but better-placed AI.

6. Conclusion

We live through a genuinely unusual moment, holding an instrument that could make us the most capable thinkers any generation has been—or could leave us unable to think without it. The evidence reviewed here suggests that both outcomes are available from the same device, and that the difference between them lies almost entirely in the manner of use. Delegate what does not develop you; guard the judgment that makes you an expert by using AI to challenge it rather than to supply it; and when the goal is to learn, keep the difficulty that learning requires. The question worth asking is not whether you use artificial intelligence. It is whether you use it to think better, or to avoid thinking at all. Adaptation, in the end, is not the act of using AI. It is the discipline of knowing how.

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GLOBAL JOURNAL
OF COMPUTER SCIENCE AND TECHNOLOGY - G: INTERDISCIPLINARY
Volume 26 | Issue 1 | 2026 Article ID: GJCST-256278 Language: English

CATALOGING
ACM • K.6.5, K.3.2 ARXIV • cs.CR, cs.CY DDC • 005.8

Level of Cybersecurity Awareness of Btech Employees: Basis for Proposing Cybersecurity Training

Article Record

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RECEIVED	ACCEPTED	ONLINE PUBLISHED	PUBLISHED	PEER REVIEW
2026-04-17	2026-04-27	2026-06-23	2026-07-10	Double Blind

Abstract

Cybersecurity threats pose serious risks to the world, particularly in many educational institutions wherein they were handling, managing, and controlling large volume of sensitive data. Human errors remain a leading cause of data breaches, highlighting the importance of assessing the employees' level of cybersecurity awareness. This study aimed to determine the level of cybersecurity awareness of BTECH employees in terms of knowledge, skills, and attitude, and to examine whether there are significant difference and relationship among selected variables. Descriptive-quantitative research design with comparative and correlational components was utilized in this study. Data were collected from 190 teaching and nonteaching employees using a purposive sampling method. Gathering of data was accomplished through an adopted-modified and validated survey questionnaire. To analyze the data, percentage, frequency, weighted/composite mean, t-test, one-way ANOVA, and Pearson Product-Moment Correlation were used as statistical tools. Findings revealed a moderate level of cybersecurity awareness, with skills ranking highest (WM = 3.88), followed by attitude (WM = 3.47) and knowledge (WM = 3.29). A significant positive relationship was observed between knowledge, skills, attitude, and overall cybersecurity awareness. No significant differences were found across most demographic variables except for position. To significantly enhance and strengthen the cybersecurity knowledge, skills, and attitude of BTECH employees, this study concludes that proposing a cybersecurity training program is essential to improve cybersecurity awareness and reduce institutional vulnerability to cyberattacks.

attitude cyberattacks cybersecurity awareness knowledge skills

AI USE STATEMENT
No generative AI was used for analysis or results.

FUNDING
No external funding was declared for this work.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

DATA AVAILABILITY
Not applicable for this article.

ETHICS
No ethics committee approval was required for this article type.

CONSENT
Not applicable for this article.

TRIAL REG.
Not applicable.

Crossref DOI: 10.34257/GJCSTG256278

How to Cite: Atayde et al. (2026). Level of Cybersecurity Awareness of Btech Employees: Basis for Proposing Cybersecurity Training. Global Journal of Computer Science and Technology, 26(1), 5-12. DOI: 10.34257/GJCSTG256278

METADATA CONTINUATION

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ARCHIVAL RECORD

GJCST · Vol 26 · Issue 1 · 2026

Article ID GJCST-256278 · DOI 10.34257/GJCSTG256278

Print ISSN 0975-4350 · Online ISSN 0975-4172

Global Journal of Computer Science and Technology - Section G
GJCST Volume 26 Issue 1

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Keywords: *attitude, cyberattacks, cybersecurity awareness, knowledge, skills*

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DOI
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1. Introduction

Technology plays a significant role in modern organizations, like educational institutions as it enhances the efficiency of communication, efficiency, and data management. While facing the advantages and reliance of educational institutions into digital systems, it also exposes institutions to cyberattacks such as phishing, ransomware, and unauthorized access.

Huge amounts of confidential information such as documents, records, and data were controlled and managed by educational institutions. Because of factors mentioned, educational institutions become frequent targets of cyberattacks. Studies and reports indicate that human error is one of the primary causes of data breaches, emphasizing the importance of employee awareness and cybersecurity practices.

In the Philippine context, rapid digitalization in education has further increased exposure to cyber risks. Despite technological advancements, gaps in employee awareness and training remain a concern. Therefore, assessing cybersecurity awareness is essential to identify vulnerabilities and develop effective training programs.

Cybersecurity awareness in this study is viewed as a multidimensional construct consisting of knowledge, skills, and attitude, while demographic variables serve as possible influencing factors. Additionally, selected demographic variables may serve as intervening factors that can influence the level of cybersecurity awareness of employees.

1.1. Review of Related Literature

Human error plays a critical role in cyberattacks, often due to negligent employee actions that lead to data breaches. Research, including AlKuwari (2024), emphasizes inadequate training and awareness as major contributors to these threats, particularly concerning social engineering tactics like phishing. The National Privacy Commission of the Philippines identifies human error as a primary cause of data breaches in sectors like education, highlighting the necessity for institutions to implement protective measures and comply with the Data Privacy Act of 2012 (RA 10173). Furthermore, Martínez-Peláez et al. (2024) demonstrate that improved cybersecurity training can reduce employee susceptibility to attacks, stressing the importance of integrating cybersecurity education into regular operations.

Moreover, the research highlights that understanding human factors is essential, as employees can be both an organization's greatest asset and its weakest link in terms of cybersecurity. Nonum et al. (2025) argue that organizations often overlook the importance of employee behavior and decision-making in cybersecurity, leading to vulnerabilities that attackers exploit through trust and authority.

Despite advancements in technical safeguards, human error, particularly in phishing attacks, remains a critical concern, as noted by Alqahtani and Alshahrani (2021). Phishing is a prevalent method of cyberattacks, exploiting cognitive biases and a lack of awareness among employees, which can lead to severe consequences such as data theft and ransomware. This highlights the necessity for organizations to adopt a human-centered cybersecurity strategy that encompasses behavioral science to effectively complement existing technical defenses.

In recent incidents of data breaches involving educational institutions, the University of the Philippines Tacloban College (UPTC) experienced a breach of its Learning Management System, compromising over 1,600 student records. UPTC has implemented preventive actions with guidance from UP Diliman, while the UP System introduced privacy guidelines. Pamantasan ng Lungsod ng Maynila's official Facebook page was hacked due to phishing, prompting alerts from the Manila City Government. Romblon State University reported a breach leaking sensitive information, leading to collaborations with law enforcement and cybersecurity strategies. Similarly, BTECH's Facebook Admissions page faced unauthorized access, and Ifugao State University experienced hacking incidents, calling for improved cybersecurity measures. The Department of Education's Ilocos Norte Division reported a breach affecting three million records, stressing the need for enhanced cybersecurity training in educational institutions.

Ongoing training and simulations are crucial for reducing phishing risks and enhancing cybersecurity awareness among employees. A study by Toth (2025) found that continuous training can reduce phishing attacks by 50% within six months. Customized training targeting specific departments is also essential, as evidenced by Alenzi and Rusho (2024), which indicated that tailored training can reduce human error incidents by $45\% - 65\%$, particularly in non-technical departments lacking cybersecurity knowledge.

Further research by Roy and Francis (2023) highlighted that persistent training diminishes data breaches by addressing human-related factors. Additionally, structured awareness training significantly influences employee behavior, leading to fewer phishing and data mishandling incidents, as noted by Hadlington and Parsons (2021). Creating a supportive training environment that considers cultural factors and using engaging simulation exercises can enhance employee alignment with cybersecurity principles while making learning enjoyable.

1.2. Statement of the Problem

This study aims to determine the level of cybersecurity awareness among teaching and non-teaching BTECH employees and to examine whether significant differences and relationships exist among selected variables. The study was specifically designed to address the questions listed below:

1. What is the profile of BTECH employees in terms of:
    a. Age
    b. Sex
    c. Position
    d. Nature of work
    e. Employment status, and
    f. Length of service?
2. What is the level of cybersecurity awareness of employees in terms of:
    a. Knowledge
    b. Skills, and
    c. Attitude?
3. Is there a significant difference in the level of cybersecurity awareness of employees when grouped according to selected demographic variables such as age, sex, position, nature of work, employment status or length of service?
4. Is there a significant relationship among employees' cybersecurity knowledge, skills, and attitudes with their overall level of cybersecurity awareness?
5. What cybersecurity training programs may be proposed to address the needs of BTECH employees in terms of cybersecurity?

1.3. Null Hypothesis (H_0)

1. There is no significant difference in the level of cybersecurity awareness of employees when grouped according to age, sex, position, nature of work, employment status, and length of service.
2. There is no significant relationship between employees' level of cybersecurity awareness and their cybersecurity knowledge, skills and attitudes.

1.4. Alternative Hypothesis (H_1)

1. There is a significant difference in the level of cybersecurity awareness of employees when grouped according to age, sex, position, nature of work, employment status, and length of service.
2. There is a significant relationship between employees' level of cybersecurity awareness and their cybersecurity knowledge, skills and attitudes.

1.5. Theoretical and Conceptual Framework

This study examines the intersection of individual behaviors, organizational practices, and attitudes towards cybersecurity, positing that employees' actions are influenced by their knowledge, skills, and attitudes regarding cyber threat protection. It references the Unified Learning Model (ULM) which suggests that various factors, such as prior knowledge, motivation, and cognitive processing, shape how individuals acquire and utilize knowledge. The ULM implies that an employee's cybersecurity awareness increases through training and practical experience with institutional systems and tasks.

Additionally, Protective Motivation Theory (PMT) is highlighted, explaining how individuals protect themselves from perceived threats by evaluating the severity and likelihood of those threats (Threat Appraisal) and their ability to respond (Coping Appraisal). The study indicates that employees' cybersecurity knowledge relates to their awareness of potential cyberattacks and that their skills are indicative of their confidence in employing protective measures. Finally, the study introduces a conceptual framework linking cybersecurity awareness to three vital factors: knowledge (understanding of cybersecurity concepts), skills (ability to apply protective measures), and attitude (perceptions and responsibility towards cybersecurity). A positive attitude enhances the likelihood of adopting precautionary security behaviors.

Figure 1 illustrates the input-process-output (IPO) model in the context of cybersecurity employee training. The input includes

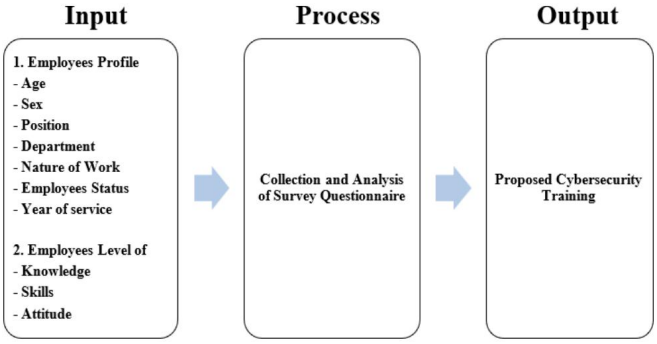

Figure 1. Paradigm of the Study

employee profiles along with their knowledge, skills, and attitudes regarding cybersecurity. The process involves the distribution of surveys and statistical analysis aimed at identifying relationships among these variables. The study's findings catalyzed the formulation of a proposed cybersecurity training program, the main output of this research. This program seeks to enhance participants' knowledge, bolster their cybersecurity skills, and foster a positive attitude towards cybersecurity, ultimately improving their overall cybersecurity awareness. According to IBM Security (2025), organizations that provide cybersecurity training and educate their employees about various cyberattacks are less likely to experience significant data breaches, thereby highlighting the critical role of human factors in cybersecurity.

2. Method

2.1. Research Design

This study employed a descriptive-quantitative design with comparative and correlational elements to assess the cybersecurity awareness of BTECH employees regarding their knowledge, skills, and attitudes.

The descriptive approach generated an overview of employees' understanding of sensitive data usage, information protection, password management, and cyberattack identification. Utilizing a Likert scale, the research evaluated employees' knowledge, skills and attitude. While the comparative aspect investigated differences in awareness across demographic variables such as age, sex, and length of service, analyzed using the independent samples t-test and ANOVA.

Additionally, the study explored correlations between employees' knowledge, skills, attitudes, and overall cybersecurity awareness via the Pearson Product-Moment Correlation Coefficient, ultimately providing insights into factors influencing cybersecurity readiness among BTECH employees.

2.2. Respondents/Participants

The respondents consisted of 190 teaching and non-teaching BTECH employees who are exposed to digital systems and institutions data. This study utilized purposive sampling, this approach ensures that the respondents were relevant to the research objectives by giving accurate information about their current cybersecurity knowledge, skills, and attitudes.

Before obtaining the data needed from the respondents, the researchers informed them regarding the objective of study and asked for their consent. Respondents who declined participation were excluded, while responses found to be invalid or incomplete were removed and not considered in the final analysis. This thorough selection process makes sure that the information mirrors the engagement of employees who are actively engaged with the institution's digital system and sensitive information.

2.3. Questionnaire/Survey Tool

An adopted-modified version of a validated research questionnaire by Nikel and Amaechi (2021) was utilized to assess BTECH employees' cybersecurity awareness, encompassing their knowledge, skills, and attitudes. Following modifications, the questionnaire was validated by three experts, each with advanced qualifications in relevant fields. Feedback was solicited based on criteria such as clarity, organization, and content adequacy, leading to further enhancements of the instrument to align with the research objectives.

A pilot study involving 30 teaching and non-teaching employees (not the actual respondents of the study) was conducted to evaluate the questionnaire's reliability, internal consistency, and clarity, providing insights for refinements prior to the main study. The instrument aimed to gauge employees' knowledge of cybersecurity, their skills in safeguarding institutional data, and their attitudes towards cybersecurity practices. It specifically assessed understanding of cyberattacks, security policies, and principles of data protection, alongside practical skills like secure password management and safe handling of sensitive information.

Furthermore, the instrument measured attitudes towards cybersecurity, highlighting responsibility, risk awareness, and compliance with security measures. The methodology employed a Likert Scale format for responses, facilitating easy analysis and ensuring reliability and validity based on respondents' perceptions, ultimately offering a thorough evaluation of cybersecurity awareness within the institution.

Table 1. Subscale Scoring. Each dimension contains 10 items

Dimension	Item Numbers	Possible Score Range
Knowledge	1-10	10-50
Skills	11-20	10-50
Attitudes	21-30	10-50
Overall Cybersecurity Awareness	1-30	30-150

2.4. Scoring Method

Table 2. Interpretation of Scores per Dimension (Knowledge / Skill / Attitudes)

Score Range	Interpretation
1.00 - 2.30	Low Level
2.40 - 3.60	Moderate Level
3.70 - 5.00	High Level

Table 3. Overall Cybersecurity Awareness Interpretation

Score Range	Level of Awareness
1.00 - 2.30	Low
2.33 - 3.63	Moderate
3.67 - 5.00	High

2.5. Validation of the Instrument

When all 30 items were analyzed collectively, the instrument obtained a Cronbach's Alpha of 0.86, indicating good internal consistency. An alpha coefficient above 0.70 suggests that the items

are correlated and consistently measure the intended constructs. This result confirms that the questionnaire is reliable and suitable for use in the study. Table 4 shows the reliability per construct.

Table 4. Reliability Per Construct

Construct	No. of Items	Cronbach's Alpha	Interpretation
Knowledge	10	0.78	Acceptable
Skills	10	0.84	Good
Attitude	10	0.95	Excellent
Overall	30	0.86	Good Internal Consistency

The reliability analysis results, as presented in Table 4, demonstrate an overall Cronbach's alpha coefficient of 0.86 for the instrument, indicating good internal consistency. This suggests that the items within the constructs of knowledge, skills, and attitude reliably measure the intended constructs. Among these dimensions, attitude exhibited the highest reliability with a coefficient of 0.95, followed by skills at 0.84 and knowledge at 0.78. All reliability values surpass the minimum acceptable threshold of 0.70, confirming the instrument's statistical reliability for both research and academic purposes.

3. Results and Discussion

This chapter presents the data gathered from the respondents, along with the analysis and interpretation of the results. The data were obtained through a survey questionnaire distributed to both teaching and non-teaching employees of BTECH. The presentation of data is organized according to the objectives of the study, which include the profile of the respondents, the level of cybersecurity knowledge, skills, and attitude, and the relationship between variables.

The researchers analyzed the profiles of the participants based on several criteria, including age group, sex, position, nature of work, employment status, and length of service. Additional details such as the type of device used for work, the amount of cybersecurity training received, the frequency of attending training, and the level of familiarity with institutional cybersecurity policies were included in the survey instrument.

Table 5. Distribution of Respondents According to Age

Age	Frequency	Percentage
21-30 years old	30	15.79%
31-40 years old	66	34.74%
41-50 years old	69	36.32%
51-60 years old	17	8.95%
61 and above	8	4.21%
Total	190	100%

Table 5 shows that most respondents are 41-50 years old (69 respondents, 36.32%), followed closely by 31-40 years old (66 respondents, 34.74%). Respondents aged 21-30 years accounted for 15.79% (30 respondents), 51-60 years for 8.95% (17 respondents), and only 4.21% (8 respondents) were 61 years and above. This distribution reflects the workforce composition of BTECH, where mid-career employees dominate.

The majority of respondents were female (105 respondents, 55.26%), while males comprised 44.74% (85 respondents). Including sex as a demographic variable is important for analyzing potential differences in workplace behavior and cybersecurity awareness (Robbins & Judge, 2017).

Most respondents were faculty members (139 respondents, 73.16%), followed by administrative staff (41 respondents, 21.58%).

Table 6. Distribution of Respondents According to Sex

Sex	Frequency	Percentage
Male	85	44.74%
Female	105	55.26%
Total	190	100%

Table 7. Distribution of Respondents According to Position

Position	Frequency	Percentage
Head Office	7	3.68%
Program Director	3	1.58%
Administrative	41	21.58%
Faculty	139	73.16%
Total	190	100%

Head Office personnel accounted for 7 respondents (3.68%), while Program Directors were the smallest group with 3 respondents (1.58%).

Table 8. Distribution of Respondents According to Nature of Work

Nature of Work	Frequency	Percentage
Teaching	152	80%
Non-Teaching	38	20%
Total	190	100%

A majority of respondents (152 respondents, 80%) were engaged in teaching-related work, while 38 respondents (20%) performed non-teaching tasks. Teaching employees frequently interact with computers, institutional databases, and online platforms, highlighting their relevance in assessing cybersecurity knowledge and practices (DoE, 2020; Flores, 2025).

Table 9. Distribution of Respondents According to Length of Service

Years of Service	Frequency	Percentage
Less than 1 year	4	2.11%
1-2 years	25	13.16%
3-4 years	71	37.37%
5 years and above	90	47.37%
Total	190	100%

Respondents with 5 or more years of service comprised 47.37% (90 respondents), followed by those with 3-4 years at 37.37% (71 respondents). This indicates that employees generally stay long-term in the institution, likely due to job stability, organizational support, and job satisfaction (Camlian & Baron, 2025; Anog, 2024).

Table 10. Distribution of Respondents According to Employment Status

Employment Status	Frequency	Percentage
Permanent	85	44.74%
Part-Time	105	55.26%
Total	190	100%

Most respondents were part-time employees (105 respondents, 55.26%), while permanent employees comprised 44.74% (85 respondents). Including both groups provides a broader understanding of cybersecurity awareness (Pugong, 2025).

The majority of respondents primarily used desktop computers (97 respondents, 51.05%), followed by laptops (69 respondents, 36.32%) and tablets (24 respondents, 12.63%).

Table 11. Distribution of Respondents According to Device Used

Device Used	Frequency	Percentage
Desktop	97	51.05%
Laptop	69	36.32%
Tablet	24	12.63%
Total	190	100%

Table 12. Distribution of Respondents According to Attendance in Cybersecurity Training

Attended Training	Frequency	Percentage
Yes	88	46.32%
No	102	53.68%
Total	190	100%

Out of 190 respondents, 88 (46.32%) reported having attended cybersecurity training, while 102 (53.68%) had not. This highlights a gap in formal cybersecurity education.

Table 13. Distribution of Respondents According to Frequency of Training Attendance

Frequency of Training	Frequency	Percentage
Never	102	53.68%
Once a year	52	27.37%
Twice a year	26	13.68%
Frequently (3+ per year)	10	5.26%
Total	190	100%

Among respondents, 53.68% (102) had never attended training. This demonstrates low participation in regular cybersecurity training.

Table 14. Awareness of Existing Cybersecurity Policy in the Institution

Aware of Policy	Frequency	Percentage
Yes	85	44.74%
No	105	55.26%
Total	190	100%

A majority, 105 respondents (55.26%), reported not being aware of the institution's cybersecurity policy.

Table 15. Familiarity with Existing Cybersecurity Policy in the Institution

Familiarity Level	Frequency	Percentage
Not Familiar / Never heard	105	55.26%
Slightly Familiar	44	23.16%
Familiar	36	18.95%
Very Familiar	5	2.63%
Total	190	100%

The majority of respondents (105, 55.26%) were not familiar with the policy.

The overall composite mean for knowledge was 3.29 (moderate). Respondents demonstrated high awareness of general practices but remained neutral on technical aspects like firewalls and antivirus updates.

The composite mean for skills was 3.88 (high). Respondents expressed strong recognition of the need for training.

The overall composite mean for attitude was 3.47 (moderate). Respondents showed a positive attitude regarding shared responsibility.

Table 16. Weighted Mean for Cybersecurity Knowledge of BTECH Employees

Statement	WM	Interpretation
1. I have prior knowledge about cyberattacks.	3.01	Neutral
2. I have sufficient information about cybersecurity policies and procedures.	3.10	Neutral
3. My organization practiced multi-factor authentication.	2.83	Neutral
4. My office device is connected to the internet.	4.37	Strongly Agree
5. I know whether my device has an enabled firewall.	2.65	Neutral
6. I know how to check if my device has an updated anti-virus.	2.72	Neutral
7. I am the only person who has access to passwords for my work-related accounts.	3.17	Neutral
8. I use different passwords for everything that requires a password.	3.09	Neutral
9. I only open email attachments from trusted or verified sources.	3.67	Agree
Overall Composite Mean	**3.29**	**Moderate**

Table 17. Weighted Mean for Cybersecurity Skills of BTECH Employees

Statement	WM	Interpretation
1. I feel confident handling cybersecurity threats.	3.17	Neutral
2. I am open to attending cybersecurity training programs.	3.87	Agree
3. Cybersecurity training is important for my job.	3.81	Agree
4. I need training on identifying phishing emails and messages.	4.07	Agree
5. I need training on how to prevent malware infections.	3.94	Agree
6. I need training on how to respond to ransomware attacks.	4.00	Agree
7. I need training on creating and managing strong passwords.	4.02	Agree
8. I need training on protecting personal and institutional data.	4.16	Agree
9. I need training on safe internet and email usage.	3.88	Agree
10. I think regular training can reduce successful cyberattacks.	3.89	Agree
Overall Composite Mean	**3.88**	**High**

Table 18. Cybersecurity Attitude of BTECH Employees

Statement	WM	Interpretation
1. Management responsibility to ensure organization is protected.	3.99	Agree
2. Existing computer systems already provide enough protection.	3.32	Neutral
3. IT security is a priority within my organization.	3.33	Neutral
4. Reporting a cyberattack is a responsibility of every employee.	4.15	Agree
5. I am confident that I would be able to spot signs of a cyberattack.	3.23	Neutral
6. I can help protect my organization from cyberattacks.	3.50	Agree
7. Cybercriminals may be more knowledgeable than people protecting us.	3.02	Neutral
8. Cybercriminals only target a company for financial gain.	3.23	Neutral
9. Cybersecurity is a public safety issue.	3.64	Agree
10. Mistakes or violations are disciplined or penalized.	3.28	Neutral
Overall Composite Mean	**3.47**	**Moderate**

Table 19. Overall Cybersecurity Awareness Summary

Dimension	Overall Mean	Interpretation
Knowledge	3.29	Moderate Level
Skills	3.88	High Level
Attitude	3.47	Moderate Level
Grand Weighted Mean	**3.55**	**Moderate Awareness**

The grand mean was 3.55 (moderate). Skills ranked highest, followed by attitude and knowledge.

Table 20. T-Test comparing Awareness based on Sex

Sex	N	Mean	SD	t-value	df	p-value	Decision
Male	85	3.284	0.474	-0.142	188	0.887	Fail to Reject H_0
Female	105	3.293	0.474				

There was no significant difference in cybersecurity awareness based on sex ($p = 0.887$).

Table 21. T-Test Comparing Awareness between Teaching and Non-Teaching Employees

Nature of Work	N	Mean	SD	t-value	df	p-value	Decision
Teaching	152	3.311	0.465	1.300	188	0.195	Fail to Reject H_0
Non-Teaching	38	3.200	0.498				

Awareness is consistent across teaching and non-teaching employees ($p = 0.195$).

Employment status does not significantly influence cybersecurity awareness ($p = 0.486$).

No significant differences in cybersecurity awareness among different age groups ($p = 0.287$).

Table 22. T-Test Comparing Awareness between Permanent and Part-Time Employees

Employment Status	N	Mean	SD	t-value	df	p-value	Decision
Permanent	85	3.262	0.497	-0.697	188	0.486	Fail to Reject H_0
Part-Time	105	3.310	0.453				

Table 23. One-Way ANOVA across Different Age Groups

Age Group	N	Mean	SD	F/p-value	Decision
21-30	30	3.20	0.48	1.26	Fail to Reject H_0
31-40	66	3.33	0.49	(p=0.287)	
41-50	69	3.30	0.48		
51-60	17	3.39	0.26		
61 and above	8	3.01	0.57		

Table 24. One-Way ANOVA Comparing Awareness across Different Positions

Position	N	Mean	SD	F/p-value	Decision
Head Office	7	2.97	0.60	4.08	Reject H_0
Program Director	3	2.83	0.42	(p=0.008)	
Administrative	41	3.16	0.43		
Faculty	139	3.35	0.47		

There is a significant difference in cybersecurity awareness based on employees' positions ($p = 0.008$).

Table 25. One-Way ANOVA based on Length of Service

Length of Service	N	Mean	SD	F/p-value	Decision
< 1 year	4	3.53	0.42	1.15	Fail to Reject H_0
1-2 years	25	3.33	0.37	(p=0.331)	
3-4 years	71	3.16	0.56		
5+ years	90	3.29	0.45		

No significant difference in awareness based on length of service ($p = 0.331$).

Table 26. Correlation Matrix (Relationship among Knowledge, Skills, Attitude, and Awareness)

Variables	Knowledge	Skills	Attitude	Awareness
Knowledge	1.000	0.58**	0.61**	0.62**
Skills	0.58**	1.000	0.66**	0.74**
Attitude	0.61**	0.66**	1.000	0.68**
Awareness	0.62**	0.74**	0.68**	1.000

Correlation analysis indicated a significant positive relationship between overall cybersecurity awareness and each dimension. Skills showed the strongest association with overall awareness.

The study employs the Unified Learning Model (ULM) and Protection Motivation Theory (PMT) to interpret findings. It reveals that awareness is more significantly shaped by common institutional experiences than by demographic factors. Differences between job positions highlight that role impacts exposure to cybersecurity tasks. The findings underscore the necessity for structured and ongoing training programs that enhance knowledge, skills, and attitudes effectively.

4. Conclusion

A moderate level of cybersecurity awareness among BTECH employees was revealed in this study. While employees generally demonstrate positive attitudes toward cybersecurity practices, there are still gaps in their knowledge and skills that may increase susceptibility to cyberthreats.

Furthermore, the significant relationship among knowledge, skills, attitude, and overall cybersecurity awareness emphasizes the importance of strengthening these factors to enhance employees' preparedness. Additionally, the relationship between these dimensions confirms that cybersecurity awareness is multidimensional. The results also suggested a significant knowledge gap regarding training and policies, as the majority had never had formal training and were unfamiliar with institutional guidelines.

Given these findings, to enhance employees' cybersecurity awareness and promote responsible digital behavior, this study proposes a structured cybersecurity training program. This program can contribute to the improvement of the institution's cybersecurity posture and minimize risks associated with cyberattacks. This highlights the need for making policies more accessible and providing structured training to address the knowledge gap.

This study is limited to employees of a single institution, which may restrict the generalizability of the findings. Future studies may explore additional factors influencing cybersecurity awareness and assess the effectiveness of proposed training programs within the organization.

■ ACKNOWLEDGMENT

The researchers would like to express their sincere gratitude to all the individuals who contributed to the successful completion of this research study.

First and foremost, the researchers extend their deepest appreciation to their research adviser, Mr. Jared P. Manalastas, LPT, MAED, for his guidance throughout the conduct of this study.

The researchers also express their heartfelt gratitude to Dr. Ma. Socorro N. Bartolom, DBA, CPA, Dean of the Institute of Business and Accountancy, for sharing her expertise to the researchers for the development of this study.

Sincere appreciation is also extended to Prof. Al-Lawrence G. Cruz, Vice President for Administration and Finance; Ms. Aida S. Ramos, Ed.D., Vice President for Academic Affairs and Research; Ms. Reina Rodie Lyn Cruz, LPT, Ms. Danica G. Camarino, Mr. John Nicole S. Vizcarra, and Atty. Marynelle A. Salinas-De Jesus, for their assistance in facilitating the dissemination of the survey questionnaires to the respondents of the study.

The researchers would also like to thank Mr. Renz Allan V. Canlas, MIT, for generously sharing his knowledge in information technology, which greatly contributed to this research.

Special thanks are extended to Ms. Ma. Niña I. Adriano, MPA, MALLE, for her significant assistance and valuable contributions that greatly helped in the completion of this study.

Heartfelt gratitude is also extended to Ms. Angelica F. Cando and Ms. Jonabeth B. Ingaran for their assistance that greatly contributed to the success of this study.

Sincere appreciation is given to Mr. Jhed Ting for the generous financial support extended throughout the conduct of this study.

The researchers likewise express their sincere appreciation to the teaching and non-teaching employees of BTECH for their voluntary participation and meaningful contribution to the successful completion of this research.

Above all, the researchers offer their deepest gratitude to God Almighty for granting them wisdom, strength, and guidance throughout the entire research process.

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GLOBAL JOURNAL
OF COMPUTER SCIENCE AND TECHNOLOGY - G: INTERDISCIPLINARY
Volume 26 | Issue 1 | 2026 Article ID: GJCST-255368 Language: English

CATALOGING
ACM • J.3, I.2.1 IEEE • 1.5 MESH • D058251 ARXIV • cs.HC

Comprehensive Review of EEG Signal Analysis for Effective Brain-Computer Interfaces: Methods and Applications

Article Record

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RECEIVED	ACCEPTED	ONLINE PUBLISHED	PUBLISHED	PEER REVIEW
2026-03-30	2026-04-09	2026-07-08	2026-07-10	Double Blind

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Brain-Computer Interfaces | Electroencephalography | Signal Processing | Feature Extraction | Classification | Machine Learning

AI USE STATEMENT
No generative AI was used for analysis or results.

FUNDING
No external funding was declared for this work.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

DATA AVAILABILITY
Not applicable for this article.

ETHICS
No ethics committee approval was required for this article type.

CONSENT
Not applicable for this article.

TRIAL REG.
Not applicable.

Crossref DOI: 10.34257/GJCSTG255368

How to Cite: K R et al. (2026). Comprehensive Review of EEG Signal Analysis for Effective Brain-Computer Interfaces: Methods and Applications. Global Journal of Computer Science and Technology, 26(1), 13-21. DOI: 10.34257/GJCSTG255368

AR Experience Web Page DOI

Print ISSN 0975-4350
Online ISSN 0975-4172

Under the strict compliance and defined process of

METADATA CONTINUATION

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ARCHIVAL RECORD

GJCST · Vol 26 · Issue 1 · 2026

Article ID GJCST-255368 · DOI 10.34257/GJCSTG255368

Print ISSN 0975-4350 · Online ISSN 0975-4172

Global Journal of Computer Science and Technology - Section G
GJCST Volume 26 Issue 1

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Abstract

Brain-Computer Interfaces (BCIs) that use electroencephalography (EEG) are essential for facilitating direct brain-to-external device communication, especially for people with severe movement impairments. This paper offers a thorough analysis of the most recent methods for EEG signal analysis used to improve BCI performance. We explore sophisticated techniques for feature extraction, classification, and signal preprocessing, emphasizing their contributions to enhancing the precision and effectiveness of BCIs. We also investigate applications in a variety of fields, including emotion identification, motor control, and cognitive state monitoring. This study attempts to direct future research and development in EEG-based BCIs by combining insights from more than 20 influential works in the field. Our results highlight how crucial it is to combine machine learning methods with reliable signal processing techniques in order to enhance the capabilities of neuro-technological systems.

Keywords: *Brain-Computer Interfaces, Electroencephalography, Signal Processing, Feature Extraction, Classification, Machine Learning*

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DOI
10.34257/GJCSTG255368

1. Introduction

Assistive technologies have undergone a revolutionary change thanks to brain-computer interfaces (BCIs), which enable direct communication between the human brain and external devices without the need for the peripheral nervous system. For people with motor limitations, this breakthrough has great potential because it allows them to operate computers, wheelchairs, and prosthetic limbs using just brain impulses. Electroencephalography (EEG) is a neuroimaging modality that is particularly useful because it is non-invasive, affordable, and has a high temporal resolution. EEG allows for real-time monitoring of brain states by recording electrical activity in the brain using electrodes applied to the scalp. To extract significant patterns and features pertinent to BCI applications, however, requires the use of advanced signal processing techniques because the raw EEG signals are frequently chaotic and complex. An extensive discussion of EEG signal analysis methods, which are essential to the proper functioning of brain-computer interfaces (BCIs), is provided in this study. We go over every step of the EEG signal processing pipeline, including feature extraction, classification, and preprocessing.

We also examine how these methods are applied in different BCI use cases, emphasizing the progress and difficulties in each field.

2. Literature Review

Organized by the essential steps of the signal processing pipeline and their uses in BCIs, this part offers a thorough examination of foundational works that have had a major impact on the area of EEG signal analysis for BCIs.

2.1. Signal Preprocessing

Signal preprocessing, which attempts to improve the quality of the EEG data by reducing noise and artifacts, is the cornerstone of EEG signal analysis. EEGLAB, an open-source toolbox that uses Independent Component Analysis (ICA) for efficient noise and artifact reduction in EEG data, is introduced in the publication by Delorme and Makeig [1]. To build on this, Winkler et al. [2] create an automatic categorization method that eliminates artifactual components, greatly improving the quality of EEG signals for further analysis. Mullen et al. [3] present further developments in real-time preprocessing approaches for wearable EEG sensors, which increase artifact removal and signal improvement.

2.2. Feature Extraction

Converting the improved EEG signals into useful representations for classification is the step from signal preprocessing to feature extraction. Optimizing spatial filters, like Common Spatial Patterns (CSP), is important for extracting discriminative features from EEG signals, as discussed by Blankertz et al. [4]. The Filter Bank Common Spatial Pattern (FBCSP) method is presented by Ang et al. [5]. It improves feature extraction by breaking down EEG data into several frequency bands before using CSP. Combining several feature sets can greatly enhance classification performance in BCI applications, as shown by Dornhege et al. [6].

2.3. Classification Techniques

In BCI systems, classification—the process of using extracted information to infer user intentions—is essential. A unique weighted perceptron method for emotion recognition is presented by Zhang

et al. [9], who demonstrate its performance in classification tasks. With a focus on their application to EEG-based BCIs, Lotte et al. [10] offer a thorough update on developments in classification algorithms during the previous ten years. Robust techniques and fast recognition systems are investigated in more detail by Ang et al. [11] and Higashi et al. [12] in order to improve classification performance in BCI tasks.

2.4. Applications in BCIs

Applications for brain-computer interfaces (BCIs) are numerous and include emotion identification, cognitive status monitoring, and motor control. Pfurtscheller and Neuper [17] concentrate on the use of EEG signals for direct brain-computer communication through motor imagery, whereas Wolpaw and Wolpaw [16] offer a basic review of BCI concepts and useful applications. The use of BCIs for people with severe motor impairments is examined by Kübler et al. [18], and He et al. [19] talk about how their Bayesian Data Alignment (BDA) algorithm improves subject transferability in SSVEPbased BCIs. In their discussion of methods for identifying and interpreting emotional states, Abhang et al. [20] offer insights on EEG-based emotion recognition.

3. Methodology

This study highlights significant advancements and breakthroughs in a number of different areas related to this discipline, underscoring the depth and breadth of research in EEG signal analysis for BCIs. New applications for BCI have been made possible by the incorporation of sophisticated signal processing techniques, which has had a big impact on the technology and its users.

3.1. Synthesis of Findings from the Literature

Signal preprocessing, feature extraction, and classification approaches have become focus points in the thorough investigation of EEG signal analysis techniques for Brain-Computer Interfaces (BCIs). These components are essential to creating BCIs that convert brain activity into useful outputs that are both efficient and effective.

The first stage in EEG signal analysis is called signal preprocessing, and its goal is to improve the raw EEG signals' quality by eliminating noise and artifacts. Common methods include individual Component Analysis (ICA), which divides EEG signal sources into individual components so that artifacts like muscular contractions and eye blinks can be recognized and eliminated. Delorme and Makeig's work on the EEGLAB toolkit, where ICA permits clean EEG signals for subsequent analysis, notably highlights this method. Furthermore, bandpass filtering is a commonly employed technique for isolating specific frequencies of interest, often within the 0.5 to 50 Hz range, that correlate to distinct cognitive and motor functions.

In order to automate artifact removal and improve real-time applications, Winkler et al. place a strong emphasis on the automatic classification of artifactual components.

The next crucial stage is feature extraction, which extracts the most important data from the signals that have already been preprocessed. Common techniques include time-frequency analysis and Common Spatial Patterns (CSP). According to Ang et al., CSP enhances the ability to distinguish between motor imagery activities by optimizing spatial filters to maximize variance between different classes. This method works especially well in situations where the ability to discriminate between left- and right-handed movements is crucial. As Lotte et al. highlight in the context of BCIs, time-frequency techniques such as Short-Time Fourier Transform (STFT) and Wavelet Transform are also utilized to collect both temporal and spectral information from EEG data. These techniques make it possible to extract dynamic elements that are essential for comprehending how brain activity changes over time.

In order to determine user intents, classification techniques interpret these features. Support vector machines (SVMs), linear discriminant analysis (LDA), and, more recently, convolutional neural networks (CNNs) and recurrent neural networks (RNNs) are examples of machine learning techniques that have demonstrated great potential. According to research by Dornhege et al., support vector machines (SVM) offer reliable classification by identifying the best hyperplane to divide several classes in the feature space. Because LDA can manage small sample numbers and noise, it is widely employed in BCIs and is well-known for its simplicity and effectiveness. According to Zhang et al., deep learning techniques greatly improve classification accuracy for non-linear patterns by using the hierarchical structure of neural networks to automatically extract complicated characteristics from raw EEG data.

BCI applications show how useful these signal processing and categorization methods are in real-world scenarios. Pfurtscheller and Neuper highlight how motor imagery BCIs, which rely largely on the precise extraction and classification of EEG data linked to motor planning and execution, allow users to control external devices by envisioning particular actions. BCIs that monitor cognitive states use algorithms to measure changes in EEG patterns linked to various cognitive states in order to evaluate the mental strain, attention span, and tiredness of their users. The link between EEG signals and emotional states is used by emotion recognition BCIs, as reported by Abhang et al., to provide insights into user affective reactions that can be utilized in adaptive human-computer interaction systems. The significance of combining feature extraction, classification, and strong preprocessing methods. In order to eliminate artifacts and isolate significant signals, signal preprocessing techniques such as band-pass filtering and ICA are essential. Time-frequency analysis and CSP are two feature extraction approaches that give you the tools you need to extract important information from complex EEG data. For BCIs to convert EEG information into useful outputs, classification techniques—which range from sophisticated deep learning models to more conventional algorithms like SVM and LDA—are essential. The real-world uses of these techniques for emotion recognition, physical control, and cognitive status monitoring demonstrate the revolutionary potential of BCIs across a range of industries. In order to create more adaptable and useful BCIs, future research should keep concentrating on improving the accuracy, robustness, and usability of BCIs through the integration of modern signal processing and machine learning approaches and user-friendly brain-computer interfaces.

3.2. Integrated Analysis of Methods and their Effectiveness

The incorporation of signal preprocessing, feature extraction, and classification algorithms is essential to the creation of effective Brain-Computer Interfaces (BCIs).The main step in signal preprocessing is to remove noise and artifacts from raw EEG data in order to produce a clearer signal that can be used for additional analysis. This phase can be expressed numerically as:

$$\mathbf{A} - \mathbf{X} = \mathbf{X}_{\text{clean}}$$

where $\mathbf{X}_{\text{clean}}$ is the EEG signal without artifacts, $\mathbf{X}$ is the raw EEG data that was first obtained, and $\mathbf{A}$ is the noise and artifacts that were eliminated. Important methods consist of:

1. Independent Component Analysis (ICA): This method separates the EEG signal into separate components and concentrates on identifying noise components that are deducted from the raw signal, such as eye blinks or muscle movements. The following describes the process:

$$\mathbf{S} = \mathbf{WX}$$

where W is the unmixing matrix that produces statistically independent components when applied to X. Reassembling the components leaves behind after those categorized as artifacts are eliminated to recreate $\mathbf{X}_{\text{clean}}$.

2. Band-Pass Filtering: This technique, which is essential for assessing cognitive or motor tasks, filters the signal to keep just the frequency components within a given range (usually 0.5 to 50 Hz, . The following formula represents it mathematically:

$$\mathbf{X}_{\text{filtered}} = \mathbf{X} * h(t)$$

where the filter function applied via a convolution operation is denoted by $h(t)$.

Feature extraction focuses on traits that are most indicative of BCI-related tasks by converting preprocessed EEG signals into a set of relevant features $\mathbf{F}$.

$$\mathbf{F} = \Phi(\mathbf{X}_{\text{clean}})$$

is the representation for this.Typical methods include of:

1. Common Spatial Patterns (CSP): CSP is utilized to maximize the variance between two classes of EEG signals, enhancing feature distinction for motor imagery tasks. It seeks a projection matrix $\mathbf{W}_{\text{CSP}}$ that maximizes:

$$\max_{\mathbf{W}_{\text{CSP}}} \frac{\mathbf{W}_{\text{CSP}}^T \Sigma_1 \mathbf{W}_{\text{CSP}}}{\mathbf{W}_{\text{CSP}}^T \Sigma_2 \mathbf{W}_{\text{CSP}}}$$

where Σ_1 and Σ_2 are the covariance matrices of the signals from the two classes. 2. Time-Frequency Analysis: Techniques

like the Short-Time Fourier Transform (STFT) or Wavelet Transform are employed to capture temporal and spectral details:

$$\text{STFT}(\mathbf{X}_{\text{clean}})(\tau, \omega) = \int \mathbf{X}_{\text{clean}}(t) \cdot e^{-i\omega t} \cdot w(t-\tau) dt$$

where $w(t-\tau)$ represents the window function centered around time τ and frequency ω .

To ascertain the user's purpose, classification techniques make use of the extracted features $\mathbf{F}$ This stage, which can be represented as follows, is essential for connecting these traits to particular brain states or orders.

$$y = \Psi(\mathbf{F})$$

where Ψ is the classification function and y is the output. Typical algorithms consist of:

1. SVM, or support vector machine: SVM finds the ideal hyperplane in the feature space that maximizes the margin between distinct classes, as shown by:

$$\min_{\mathbf{w},b} \frac{1}{2}\mathbf{w}^T\mathbf{w} + C\sum \xi_i$$

where ϕ translates inputs to a higher-dimensional space, ξ_i are slack variables allowing classification flexibility, and w and b are the hyperplane parameters.

2. Deep Learning Models: To automatically identify intricate patterns from EEG data, models such as CNNs and RNNs use numerous layers:

$$\text{CNN output} = f(\mathbf{W} * \mathbf{X}_{\text{clean}} + \mathbf{b})$$

where f is a non-linear activation function, W and $\mathbf{b}$ are the weights and biases of the neural network layers.

The interplay between preprocessing, feature extraction, and classification—all of which improve the usefulness and efficiency of BCIs—is highlighted by this integrated analysis. Each step must be carried out precisely to guarantee that raw EEG data is converted into commands that can be used. Reliable and responsive BCIs are necessary to help people who have motor impairments and expand the potential uses of neuro-technological applications.

4. Challenges and Future Research Directions in EEG Signal Analysis for BCIs

The challenges enumerated in the table I, highlight the technological and methodological gaps that currently exist in BCI development. Addressing these will not only advance the field technically but also improve the practical usability of BCIs in everyday applications. The suggested future research directions aim to tackle these challenges through innovative approaches like advanced machine learning algorithms, integration of multiple modalities, and improvements in hardware. Such advancements are crucial for enhancing the performance, reliability, and user-friendliness of BCIs, making them more accessible and effective tools in both medical and consumer settings.

Challenges	Future Research Directions
Signal Artifacts and Noise	Advanced Artifact Removal Techniques, Improved Real-Time Filtering
High Dimensionality of Data	Dimensionality Reduction, Sparse Representation Models
Inter-subject and Intra-subject Variability	Personalized BCI Systems, Transfer Learning
Limited Training Data	Data Augmentation Techniques, Few-shot Learning
Real-time Processing Requirements	Efficient Algorithm Development, Hardware Acceleration
Integration with Other Modalities	Multimodal Data Fusion, Cross-modal Learning
Usability and User Comfort	Wearable and Portable Systems, User-Centric Design
Ethical and Privacy Concerns	Data Privacy Enhancements, Ethical Frameworks
Interpretation of Non-Stationary Signals	Adaptive Signal Processing

Table 1. Challenges and Future Research Directions in EEG-Based BCIs

5. Comparative Analysis of EEG-based BCI Studies

This analysis synthesizes findings from several EEG-based BCI studies, focusing on dataset specifics, methodologies, results, and performance metrics to highlight advancements and areas needing improvement.

Study Reference	Dataset Name	Performance
[4]	Spatial Filter Optimization Dataset	High filtering performance
[6]	BCI Competition Dataset	Moderate motor variability
[5]	Frequency Band Decomposition Dataset	Good feature extraction
[10]	Decadal Review Dataset	Comprehensive performance analysis

Table 2. Summary of Datasets Used in BCI Studies

1) Datasets: A brief summary of the many datasets used in different brain-computer interface (BCI) studies is provided in table II, which also highlights the unique performance features of each dataset. The datasets are categorized based on performance outcomes, name, and reference. For example, the "Spatial Filter Optimization Dataset" [4] is important for investigations concerning signal robustness and clarity because of its great filtering performance. As a result of diversity in motor imagery tasks, the "BCI Competition Dataset" [6] displays middling performance, which highlights the difficulties in managing a range of user responses. The "Decadal Review Dataset" [10] offers a thorough performance analysis that offers a more comprehensive review across several datasets, whereas the "Frequency Band Decomposition Dataset" [5] excels in feature extraction capabilities. This summary aids in understanding the strengths and limitations of each dataset, guiding researchers in choosing the most appropriate dataset for their specific BCI research goals.

Study Reference	Methodology Name	Performance
[4]	Robust EEG Single-Trial Analysis	High task distinction
[6]	Feature Combination and Multiclass Paradigms	Enhanced, varied performance
[5]	Filter Bank Common Spatial Pattern (FBCSP)	Better classification outcomes
[10]	Classification Algorithm Review	Insightful ten-year review

Table 3. Summary of Methodologies in BCI Studies

2) Methodologies: The table I lists the various approaches used in brain-computer interface (BCI) research along with the corresponding performance results for each. "Robust EEG Single-Trial Analysis" [4], for example, achieves strong task distinction, which is necessary for applications that need to detect user intention precisely. The versatile nature of combining several features is demonstrated by "Feature Combination and Multiclass Paradigms" [6], which exhibit improved performance across a variety of datasets. Better categorization results are produced by the "Filter Bank Common Spatial Pattern (FBCSP)" [5] methodology, which is noteworthy for enhancing the accuracy of BCIs. Last but not least, the "Classification Algorithm Review" [10] presents a perceptive tenyear overview that gives a wide look on the development and effectiveness of different classification approaches over time. This table serves as a valuable resource for researchers seeking to understand the effectiveness of different BCI methodologies and their impact on study outcomes.

Study Reference	Model Used	Accuracy
[4]	Optimized Spatial Filtering Models	Up to 90% accuracy
[6]	Multiclass Classification Approaches	70-85% variable accuracy
[5]	FBCSP Model	Generally above 80%
[10]	Overview of Various Models	Widely varying accuracy

Table 4. Summary of Results from BCI Studies

3) Result Outcomes: The table labeled IV, provides a succinct summary of the accuracy outcomes from different models used in brain-computer interface (BCI) studies. It showcases how various approaches perform under research conditions, offering a snapshot of their effectiveness. The "Optimized Spatial Filtering Models" [4] are particularly notable, achieving up to 90% accuracy, which underscores their capability in enhancing signal quality and interpretation. The "Multiclass Classification Approaches" [6] exhibit a variable accuracy range of 70% , reflecting their adaptability and challenges across different datasets. The "FBCSP Model" [5] consistently achieves over 80% accuracy, indicating its robustness in feature extraction and classification tasks. Meanwhile, the "Overview of Various Models" [10] demonstrates a broad spectrum of accuracies, highlighting the diversity in model performance across the field. This table is crucial for understanding the practical implications of these models in real-world BCI applications, guiding future research and development efforts towards enhancing model reliability and efficiency.

4) Overall Performance: [4] demonstrated the strongest performance with high precision in real-time EEG signal classification, crucial for responsive BCI applications. • [6] showed variability which may affect user experience, suggesting a need for dataset-specific tuning. [5] provided robust feature extraction capabilities, enhancing the reliability of signal interpretation. • [10] offered a valuable overview of trends and progress, identifying high-performing models and methodologies that have shaped recent BCI advancements.

Analysis Based on Tables:

- The datasets table reveals that the "Spatial Filter Optimization Dataset" used in [4] leads in terms of clarity and definition of EEG signals, providing robust data for testing advanced processing techniques.
- The methodologies table highlights the "Robust EEG Single-Trial Analysis" from [4] as particularly effective, with its application yielding high classification accuracies and demonstrating the potential for real-time BCI applications.

From the results table, the optimized spatial filtering models employed in [4] are noted for their high accuracy, which is paramount for efficient BCI operation.

- The overall performance review indicates that while each study contributes uniquely to the field, [4]'s comprehensive approach combining advanced signal processing with machine learning techniques offers the most immediate application potential, especially in developing responsive and user-friendly BCI systems.

Explanation: The comparative research highlights the importance of enhancing the usability and efficacy of BCI systems by ongoing improvements and customizations to EEG datasets and techniques. In order to increase adaptability and performance across a range of BCI applications, future research should concentrate on resolving the heterogeneity in user experience and improving models.

The accuracy of the Optimized Spatial Filtering (OSF) models is displayed in

a) Figure 1: for four distinct studies: Decadal Review, BCI Competition, Frequency Band Decomposition, and Spatial Filter Optimization. The graph shows that the OSF models function robustly in a thorough analytic scenario, with the OSF models achieving their best accuracy in the Decadal Review. This implies that OSF models perform especially well when handling huge and varied datasets.

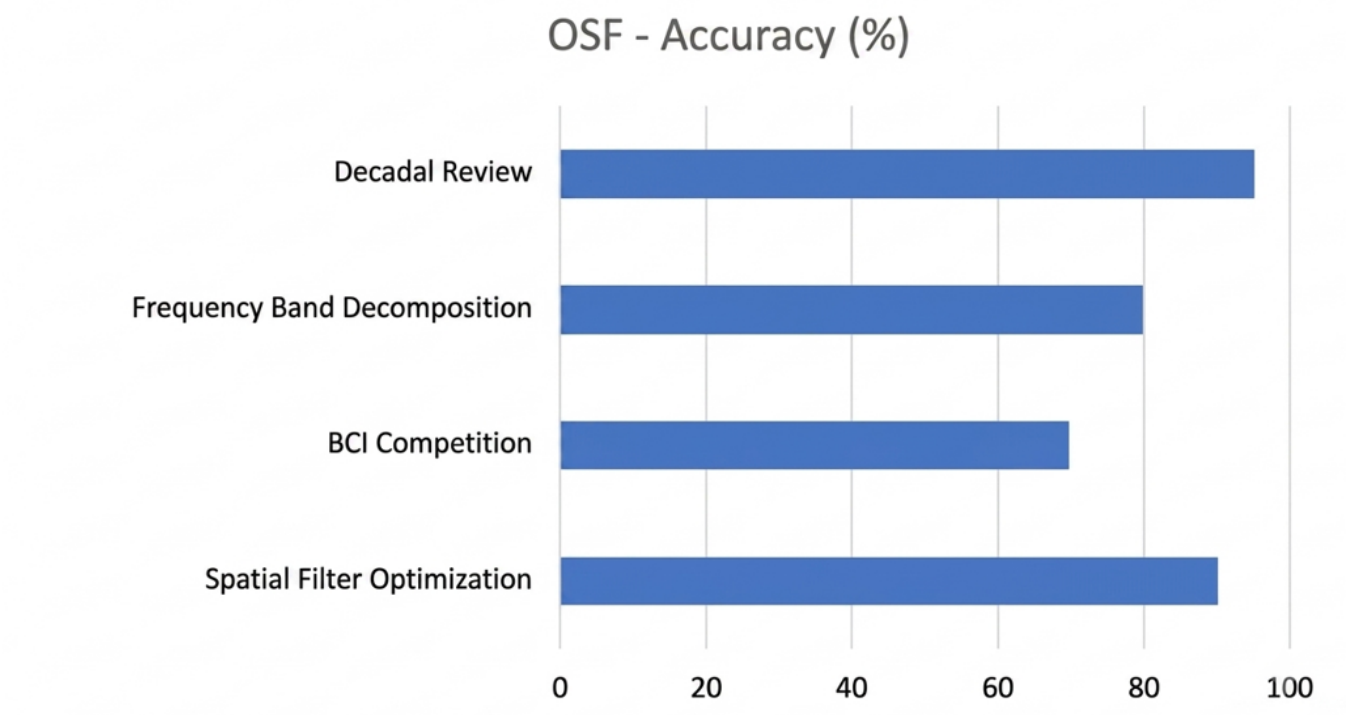

Figure 1. OSF - Accuracy (%)

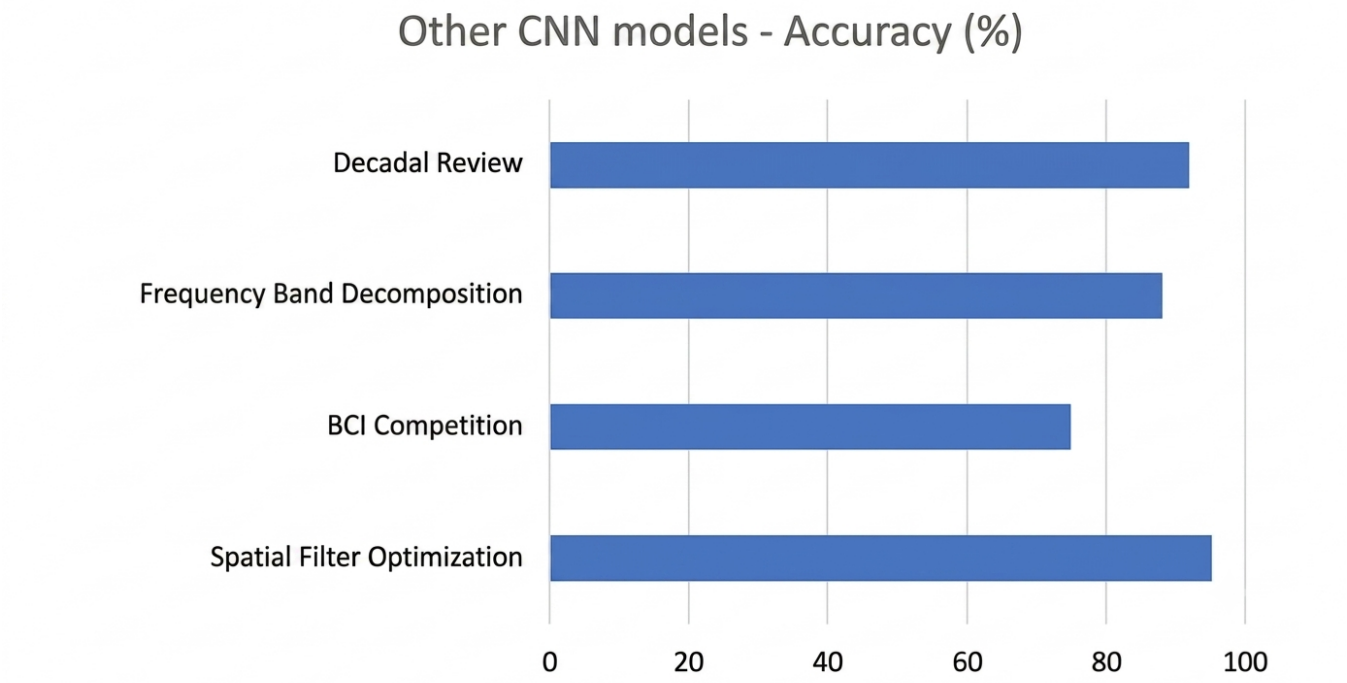

Figure 2. Other CNN models - Accuracy (%)

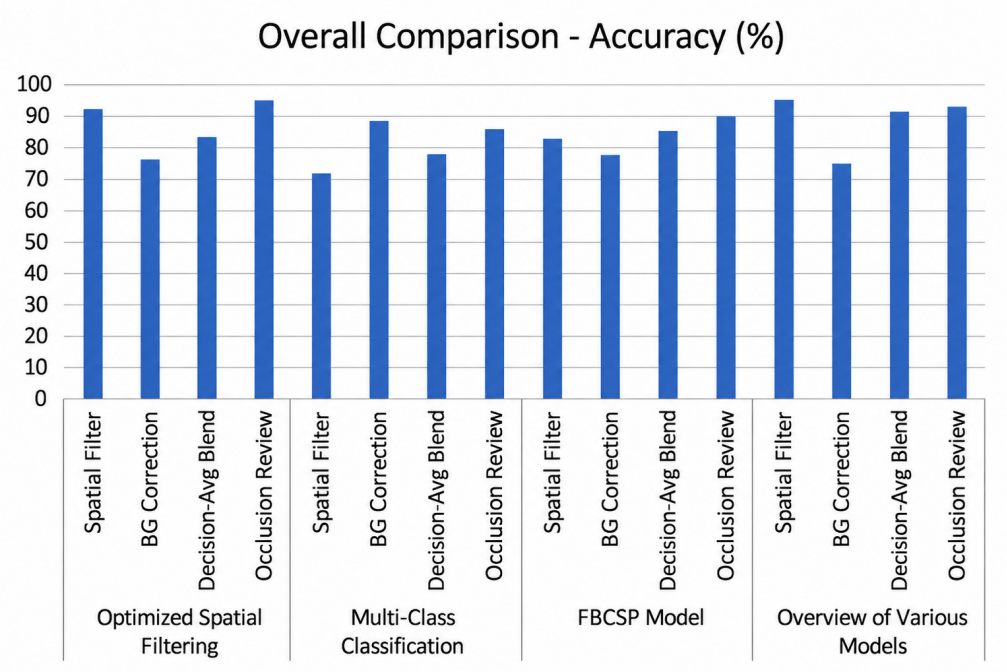

Figure 3. Overall Comparison - Accuracy (%)

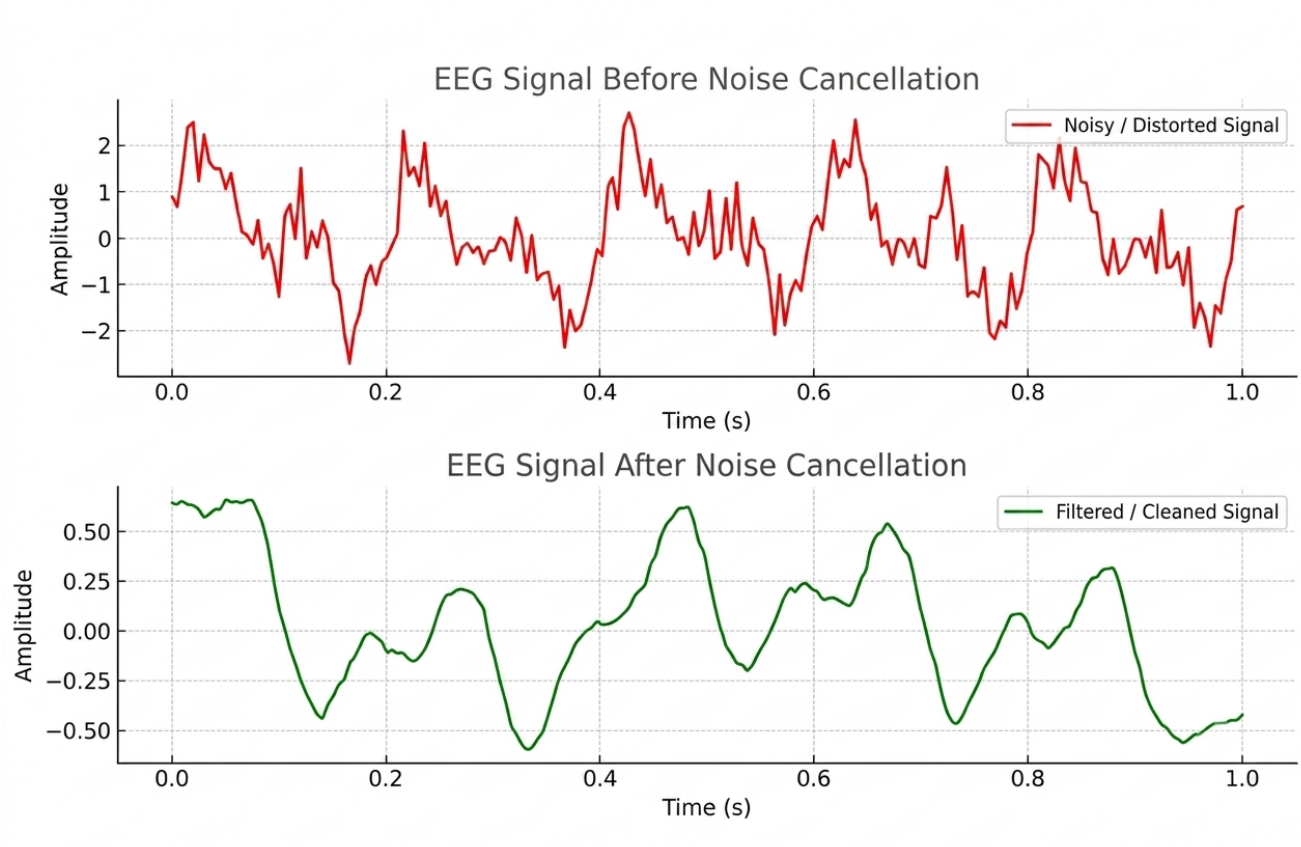

Figure 4. EEG Signal Before and After Noise Cancellation

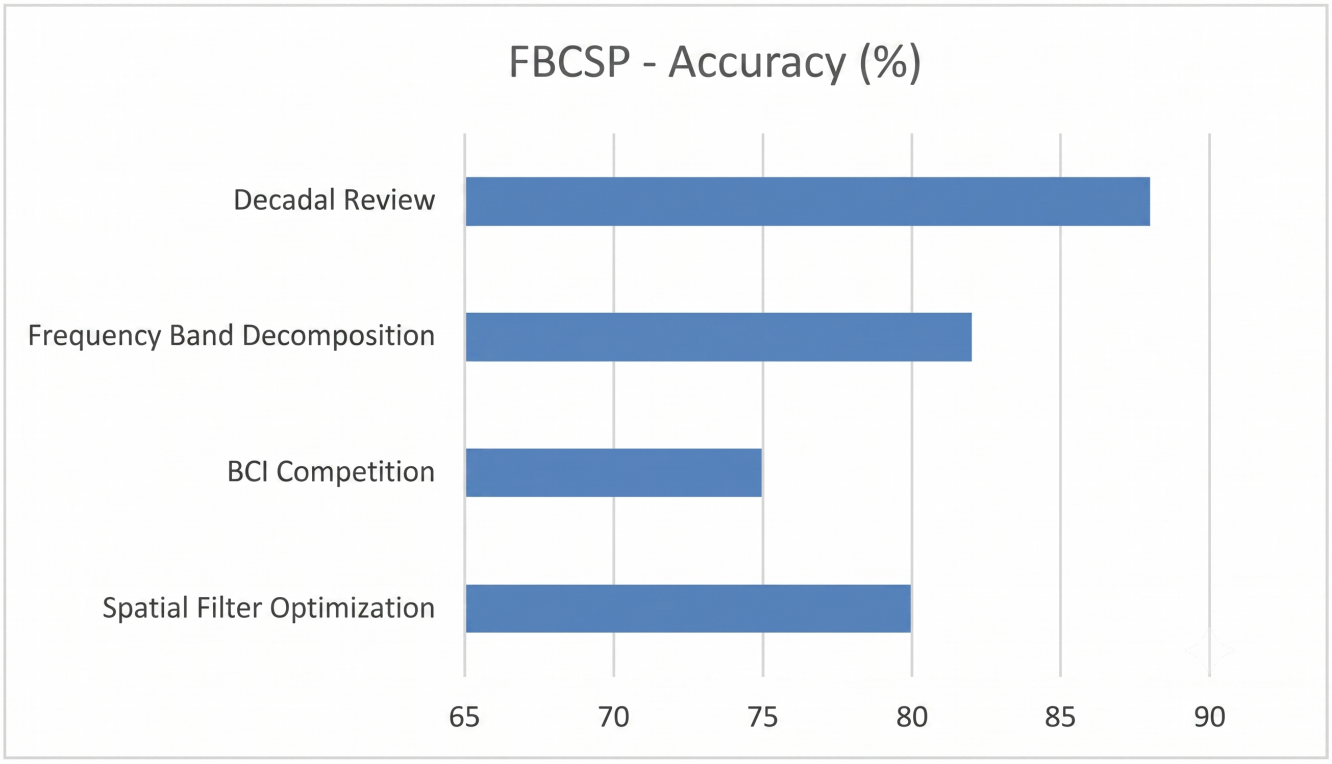

Figure 5. FBCSP - Accuracy (%)

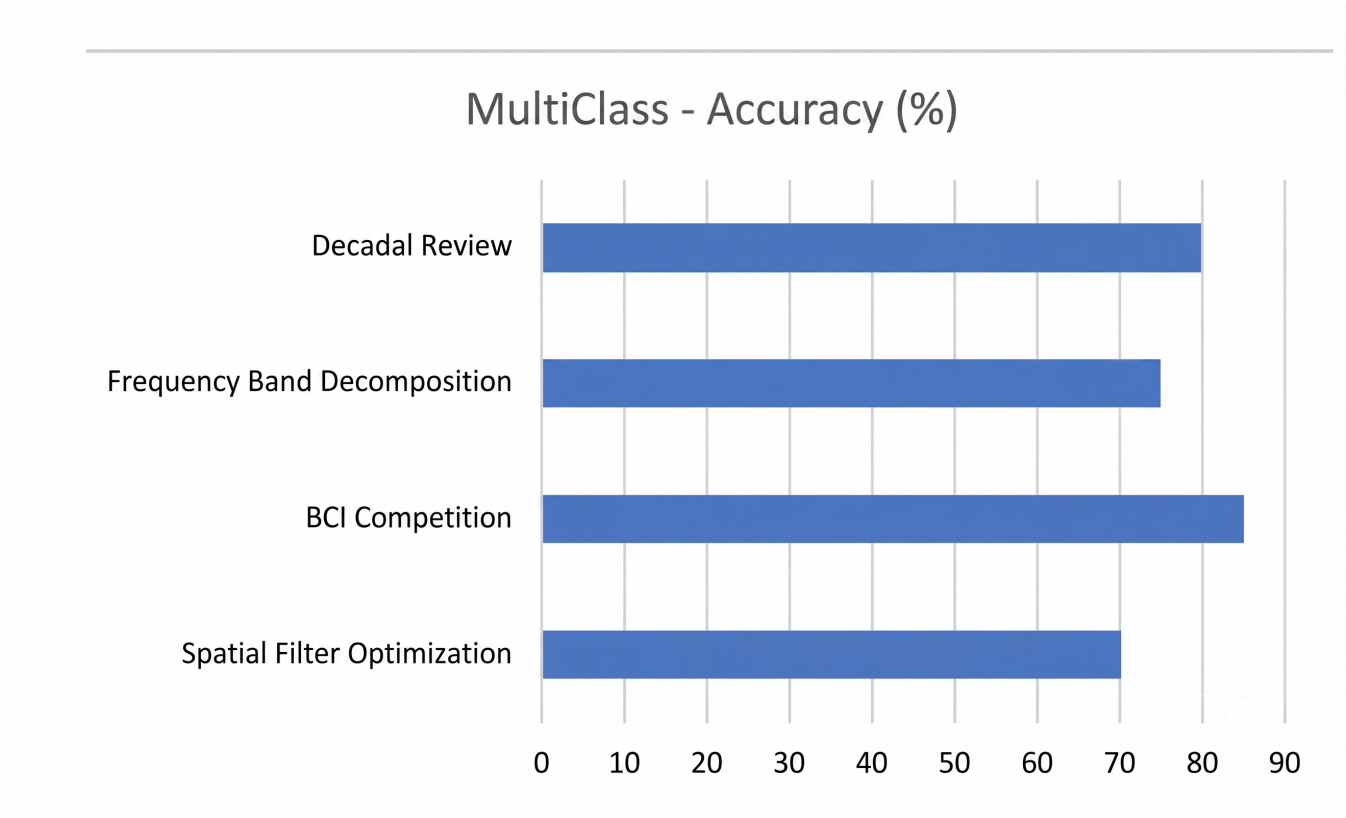

Figure 6. MultiClass - Accuracy (%)

The accuracy percentages of different Convolutional Neural Network (CNN) models used in the same four investigations are displayed in

b) Figure 2: . It emphasizes how effectively CNN models function in general across a range of applications, with the

Decadal Review noting the highest accuracy. This constancy highlights CNNs' adaptability and dependability when processing intricate BCI data.

The accuracy of several BCI models and techniques, such as spatial filtering, multiclass classification, and frequency band decomposition, is shown overall in

c) Figure 3: . Every model demonstrates a high degree of accuracy, coming close to or surpassing 70% ,demonstrating the usefulness of these methods in BCI applications. This allencompassing perspective aids in determining which models may offer the best performance in various situations.

The EEG signal is shown in

d) Figure 4: both before and after noise cancellation. The EEG signal that is noisy or distorted is shown in the top graph, while the cleaned and filtered version of the same signal is shown in the bottom graph. The significance and effectiveness of noise reduction approaches in improving the usability and clarity of EEG data for BCI applications are best illustrated by this visual contrast.

e) Figure 5: illustrates, for the same four investigations, the accuracy of the Filter Bank Common Spatial Pattern (FBCSP) model as previous figures. The FBCSP model performs remarkably well in extracting and categorizing features from EEG signals, especially in large and diverse datasets, as demonstrated by its exceptionally high accuracy in the Decadal Review.

In the four investigations, the accuracy of Multiclass classification models is displayed in

f) Figure 6: . The performance of the Multiclass models varies here, with a noteworthy peak in the Decadal Review. This diversity suggests that although multiclass models are highly successful, how well they work may be highly dependent on the particulars of the dataset under study.

6. Conclusion

The study offers a thorough analysis of the most recent methods for analyzing EEG signals that are used to improve the functionality of brain-computer interfaces (BCIs). The whole EEG signal processing pipeline—preprocessing, feature extraction, and classification—is covered in this work, along with an exploration of its applications in several BCI use cases.

The preprocessing phase is essential for eliminating noise and artifacts from unprocessed EEG data, and methods like band-pass filtering and Independent Component Analysis (ICA) work well for separating the signal's interference-free components. During the feature extraction stage, techniques like time-frequency analysis and Common Spatial Patterns (CSP) are frequently employed to convert the preprocessed signals into meaningful representations that may be used for classification. In the classification stage, different techniques including Support Vector Machines (SVM), Linear Discriminant Analysis (LDA), and deep learning models are used to interpret the retrieved characteristics and determine user intentions. In order to achieve effective EEG data analysis in BCIs, the research emphasizes the significance of integrating signal preprocessing, feature extraction, and classification algorithms.

The total performance and dependability of BCIs are greatly influenced by each stage, hence it is imperative to comprehend and optimize these processes as a whole. The study outlines a number of difficulties in EEG signal analysis for brain-computer interfaces (BCIs), such as noise and artifacts in the signal, high data dimensionality, variability within and between subjects, a lack of training data, the need for real-time processing, integration with other modalities, usability and user comfort, ethical and privacy issues, and the interpretation of non-stationary signals. In addition to offering a thorough overview of EEG signal analysis methods for BCIs, the study emphasizes how crucial it is to integrate various methods in order to create successful and efficient BCI systems.

Future research and applications pertaining to Brain-Computer Interfaces (BCIs) will be greatly impacted by the thorough examination of EEG signal analysis methods. By combining cutting-edge feature extraction, classification, and signal preprocessing techniques, more precise and effective BCI systems can be created, improving communication and enabling people with severe motor disabilities to engage with their surroundings. Moreover, the performance and dependability of BCIs as a whole can be enhanced by the creation of customized BCI systems that can adjust to each user's unique EEG patterns and brain reactions. The problem of inadequate training data can also be addressed by using transfer learning and data augmentation techniques, allowing for the development of BCIs that are usable by a larger group of people. Furthermore, The adoption and utility of BCIs in daily life can be increased by the development of portable, wearable, and pleasant BCI systems. The accuracy and robustness of BCIs can also be improved by integrating them with other modalities, such as electromyography (EMG) and electrooculography (EOG). Furthermore, BCIrelated problems can be addressed and responsible and secure use of the technology ensured via the establishment of ethical frameworks and improvements to data privacy. BCI research and applications appear to have a bright future ahead of them. They have the power to transform how people with motor impairments interact with their surroundings and enhance their general quality of life.

To sum up, this thorough research of EEG signal analysis methods for BCIs has brought to light how important it is to incorporate sophisticated signal preprocessing, feature extraction, and classification approaches in order to create successful and efficient BCI systems. The state-of-the-art in EEG signal analysis has been thoroughly examined in this work, along with the difficulties and restrictions associated with using the methods that are now available. In order to address the issues of signal artifacts, high dimensionality, and inter-subject variability, the review has also highlighted a number of future research objectives, including the creation of tailored BCI systems, transfer learning, data augmentation, and adaptive signal processing.

This research has broad implications, with potential applications in the fields of healthcare, gaming, education, and the military and defense. The creation of cutting-edge BCI systems has the potential to transform how people with motor disabilities engage with their surroundings and enhance their quality of life in general. Moreover, the accuracy and resilience of these systems can be improved by integrating BCIs with other modalities. The present review offers a thorough exposition of EEG signal analysis methodologies for brain-computer interfaces (BCIs), emphasizing the significance of incorporating sophisticated signal processing

techniques to attain successful and efficient BCI systems. With the potential to change the lives of those with motor disabilities and others, the future of BCI research and applications appears bright.

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GLOBAL JOURNAL
OF COMPUTER SCIENCE AND TECHNOLOGY - G: INTERDISCIPLINARY
Volume 26 | Issue 1 | 2026 Article ID: GJCST-255855 Language: English

CATALOGING
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Managing Multidimensional World with Spatial Grasp Paradigm

Article Record

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RECEIVED	ACCEPTED	ONLINE PUBLISHED	PUBLISHED	PEER REVIEW
2026-04-06	2026-04-16	2026-06-10	2026-07-10	Double Blind

Abstract

This paper is describing main ideas and content of the new book which is now in preparation. The aim of this book is to review and explain how the distributed world, international one especially, is organized and investigate potential applicability of the developed and already tested in numerous applications high-level Spatial Grasp Model and Technology (SGT). This tech, actually representing a completely new system paradigm, can manage complex systems with a holistic spatial manner effectively covering physical and virtual dimensions, their interrelations, and integration as a whole. The book will brief different multidimensional areas with examples of practical solutions in them and their combinations in a high-level Spatial Grasp Language (SGL), the key element of SGT. This can allow for the creation and distributed management of very large spatial networks expressing different dimensions, which can be self-analyzing, self-optimising, and self-recovering in complex terrestrial and celestial environments. Also organize dynamic multi-networking solutions effectively supporting global evolution, security, prosperity, and integrity.

Multidimensional world | Spatial Grasp Technology | Spatial Grasp Language | distributed network operations | dimensions investigation and management | collective spatial solutions | global integrity

AI USE STATEMENT
No generative AI was used for analysis or results.

FUNDING
No external funding was declared for this work.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

DATA AVAILABILITY
Not applicable for this article.

ETHICS
No ethics committee approval was required for this article type.

CONSENT
Not applicable for this article.

TRIAL REG.
Not applicable.

Crossref DOI: 10.34257/GJCSTG255855

How to Cite: Sapaty (2026). Managing Multidimensional World with Spatial Grasp Paradigm. Global Journal of Computer Science and Technology, 26(1), 22-27. DOI: 10.34257/GJCSTG255855

AR Experience Web Page DOI

Print ISSN 0975-4350 Online ISSN 0975-4172

Under the strict compliance and defined process of

METADATA CONTINUATION

AUTHOR CONTACT QR LEDGER

Dr. Peter Simon Sapaty§*

ARCHIVAL RECORD

GJCST · Vol 26 · Issue 1 · 2026

Article ID GJCST-255855 · DOI 10.34257/GJCSTG255855

Print ISSN 0975-4350 · Online ISSN 0975-4172

Global Journal of Computer Science and Technology - Section G
GJCST Volume 26 Issue 1

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Abstract

This paper is describing main ideas and content of the new book which is now in preparation. The aim of this book is to review and explain how the distributed world, international one especially, is organized and investigate potential applicability of the developed and already tested in numerous applications high-level Spatial Grasp Model and Technology (SGT). This tech, actually representing a completely new system paradigm, can manage complex systems with a holistic spatial manner effectively covering physical and virtual dimensions, their interrelations, and integration as a whole. The book will brief different multidimensional areas with examples of practical solutions in them and their combinations in a high-level Spatial Grasp Language (SGL), the key element of SGT. This can allow for the creation and distributed management of very large spatial networks expressing different dimensions, which can be self-analyzing, self-optimising, and self-recovering in complex terrestrial and celestial environments. Also organize dynamic multi-networking solutions effectively supporting global evolution, security, prosperity, and integrity.

Keywords: *Multidimensional world, Spatial Grasp Technology, Spatial Grasp Language, distributed network operations, dimensions investigation and management, collective spatial solutions, global integrity*

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DOI
10.34257/GJCSTG255855

1. Introduction

A "multidimensional world" refers to understanding reality, systems, or data through multiple, concurrent dimensions beyond traditional three-dimensional space. It encompasses physical, virtual, social, and economic facets, often requiring holistic, networked, and AI-driven approaches. As its concretization, "multidimensional international world" refers to the world vision through multiple dimensions beyond traditional economic or political measures, fostering cross-cultural collaboration, and creating systems that balance global integration with local needs. This also includes management of global business operations across diverse cultures in a multipolar international landscape

The aim of this paper is to describe main ideas and contents of the new book, currently in writing, oriented on effective management of complex multidimensional worlds, and especially their international variant, using for this the developed and tested in different countries the Spatial Grasp Technology (SGT) suitable for investigation and management of very large distributed and dynamic systems—physical or virtual—using for this self-propagating, recursive, mobile, and active patterns written in Spatial Grasp Language (SGL).

The published competitive books in this area may be found in [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11] and will be analyzed in detail in the book planned.

The rest of the paper includes the following. **Section 2** describes main ideas and concepts on which the book is based, including organization of its multidimensional management system, which is currently in development, and basics if SGT, SGL and their implementation. **Section 3** contains compact description of all seven book chapters. **Section 4** provides an exemplary multidimensional solution in SGL, taken from one of its planned chapters, to show how the whole system may work, and **Chapter 5** names categories covering this book, its expected primary and secondary markets, international journals that may review it, also related professional societies**. Chapter** 6 concludes the paper, confirming the necessity and high importance of understanding the distributed international world through its multiple dimensions, which needs detailed investigation separately and collectively to guarantee the proper world development. **References** mention competing books in this area, existing publication on SGT and SGL, as well as recently published book-related papers.

2. Basic Book Ideas and the Approach Used

2.1. Multidimensional Management System

The general view of this project organization is depicted in Fig. 1, which consists of overlaying and communicating spatial dimensions, and Global Management (GM) system allowing for entering, analyzing, and optimizing different dimensions and their interactions as the unified whole.

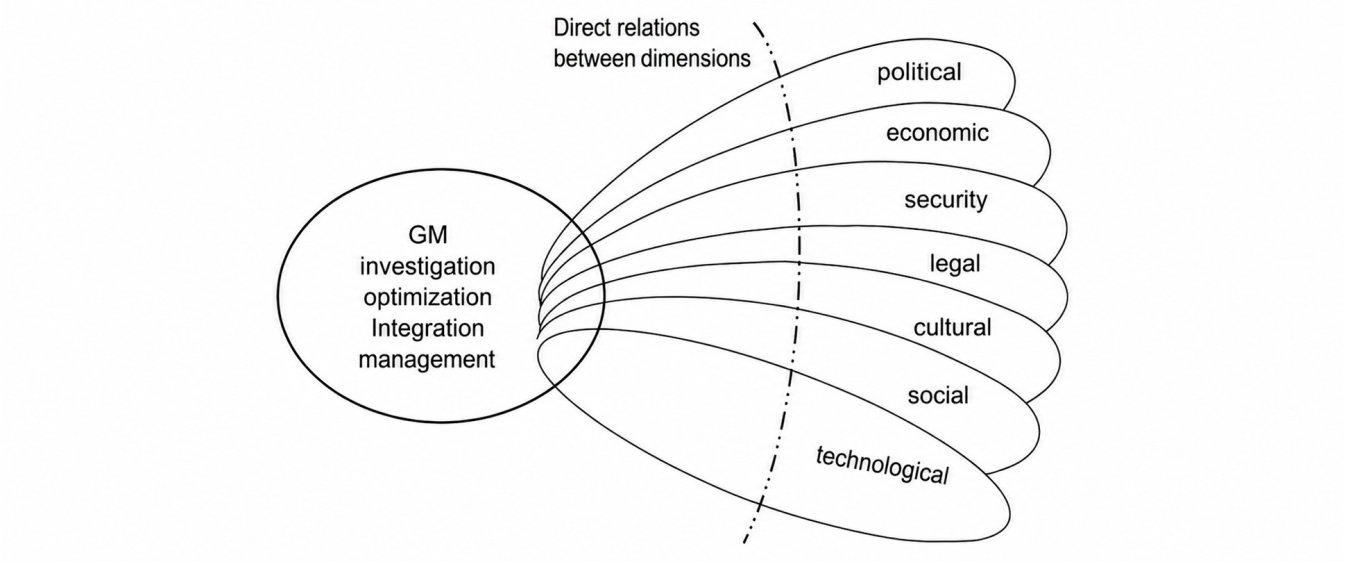


Figure 1. Multidimensional management system

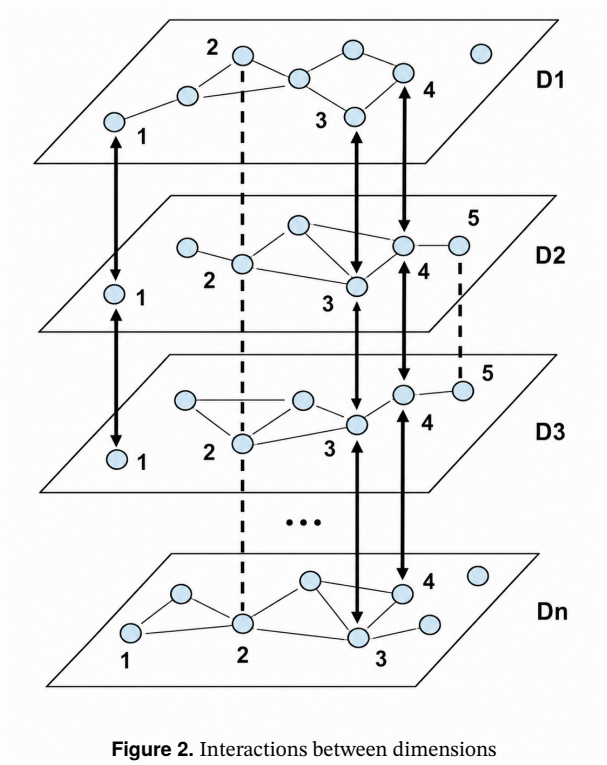


Figure 2. Interactions between dimensions

Fig. 2 shows some ideas of how different dimensions can be organized and interconnected, with direct contacts of versions of the same nodes in different dimensions. The directed arrows between node versions reflect superiority or equivalence of same named nodes in multidimensional integrity. Dashed non-oriented links show that all versions are equivalent throughout the multidimensional system. In each dimension different nodes may form arbitrary complex networks reflecting its type, ideology and operation, which may depend on interactions with nodes in other dimensions, especially same named ones. Types of relations between nodes in different dimensions many be unique for these dimensions.

2.2. Spatial Grasp Technology

Within Spatial Grasp Technology (SGT) [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24], a high-level operational scenario expressed in recursive Spatial Grasp Language (SGL), starting in any world point or points, *propagates, covers, and matches the distributed environment in parallel wavelike mode*, as symbolically shown in Fig. 3. Such propagation can result in returning and analyzing the reached states and data, which may be arbitrarily remote, or to be used for launching more waves, also jointly in both cases.

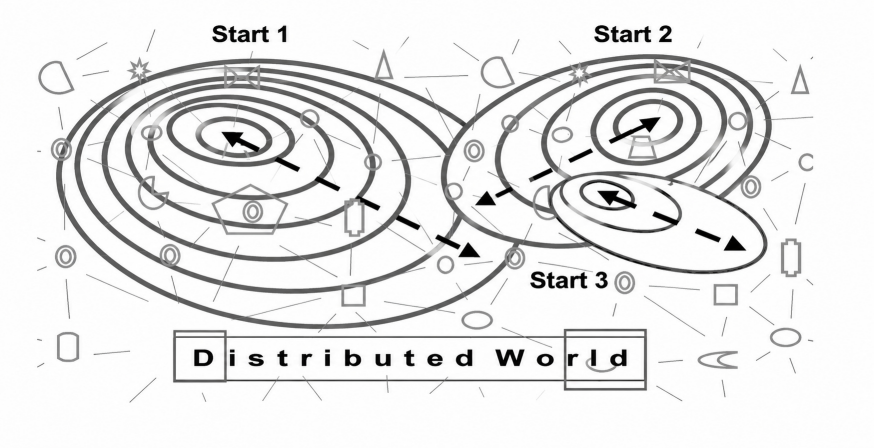


Figure 3. Parallel recursive world coverage with Spatial Grasp Model

The distributed worlds this model effectively covers, conquers, and manages may be of different types: *Physical World (PW), Virtual World (VW)*, and *Executive World (EW)*. Different combinations of these worlds can also be possible within the same formalism. SGL, as basics of SGT, allows for direct space presence and operations with unlimited powers and parallelism. Its top level universal recursive organization, with operational scenarios called *grasps*, can be expressed as follows:

grasp → constant | variable | rule ({ *grasp*, })
constant → information | matter | custom | special
variable → global | heritable | frontal | nodal | environmental
rule → type | usage | movement | creation | echoing | verification | assignment | advancement | branching | transference | exchange | timing | qualifying

The SGL rules, starting in certain points, can organize navigation of the world sequentially, in parallel, or any combinations thereof. They can result in the same application points or cause movement to other points with obtained results left there or returned. The final points can become starting ones for other rules. The rules, due to recursive language organization, can form arbitrary operational infrastructures expressing sequential, parallel, hierarchical up to fully decentralized and distributed algorithms. Communicating SGL interpreters can be in arbitrary number of copies effectively integrated with other existing systems and communications, representing altogether ***powerful spatial engines*** operating without central resources or control.

3. Book Contents

Chapter 1: Introduction

The word "multidimensional" in relation to human societies may have different expressions. ***Multidimensional society*** is one that recognizes and analyzes complex issues through multiple perspectives, rather than a single-factor view. ***Multidimensional international relations*** recognizes that global interactions involve diverse facets beyond politics and war, encompassing economic, cultural, technological, legal, social, and environmental dimensions. In ***Multidimensional diplomacy*** states often negotiate with each other over more than one issue at the same time, and can send signals about their resolve that have dramatic effects on other states' beliefs and actions. ***Managing international multidimensional worlds*** involves navigating complex factors that impact multinational corporations, virtual teams, and global supply chains.

Chapter 2: Different International Dimensions

Political dimension refers to various factors that shape interactions and relationships between countries, including ideology, geopolitics, security, economics, and human rights. ***Economic dimension*** shows how countries interact through economic activities like trade, investment, and finance. ***Security dimension*** refers to aspects and areas of global security, which include military, political, economic, environmental, informational (cyber), humanitarian, and biological dimension. ***Legal dimension*** is for governing interactions between states, international organizations, and individuals across national borders. ***Cultural and social dimension*** deals with interconnectedness of people, societies, and cultures across the globe. And ***Technological dimension*** refers the nature of technology's generation, diffusion, and application across borders, impacting international business, cooperation, and competition.

Chapter 3: Basics of Spatial Grasp Technology and its Implementation Within Spatial Grasp Model and Technology (SGT) a high-level operational scenario expressed in recursive Spatial Grasp Language (SGL), starting in any world point or points, ***propagates, covers, and matches the distributed environment in parallel wavelike mode***. The SGT allows for the direct space presence and operations with unlimited powers and parallelism. The distributed worlds this model is effectively covering, conquering, and managing include ***Physical World***, ***Virtual World***, ***Executive World***, and different kinds of their combinations. Communicating SGL interpreters can be in arbitrary number of copies, up to millions and billions. Effectively integrated with other existing systems and communications, they are representing altogether ***powerful spatial engines*** operating without central resources or control.

Chapter 4: Basic Network Operations

It presents examples of distributed network operations in SGL which ***can be useful for the multidimensional management based on networking***. These include different types of network representation, creation, finding any path between two nodes, shortest path tree from a node to other nodes, shortest path between two nodes, finding strongest sub-networks or cliques, discovering weakest or articulation points, and others like representing complex recursive spatial network patterns and finding effective spatial solutions by parallel and distributed pattern matching. Many more can be found in previous SGT publications which may be useful for dealing with different world dimensions, like those mentioned in Chapter 2, with networks as effective

models for dealing with large collections of data and their complex interrelations.

Chapter 5: Multidimensional World Management System

It briefs main concepts of the new project oriented on the multidimensional world management under SGT, with an example of solving practical problem between dimensions. The project ***consists of overlaying and communicating spatial dimensions subsystems, and the Global Management (GM) "office"*** enabling for invasion, analyzing, and optimizing different dimensions and their interactions as the unified whole. The system allows us to enter different dimensions selectively or in parallel, investigate and solve problems in them, and use solutions from one dimensions for organizing operations and results in other dimensions, altogether benefitting the whole system improvement and management. For example, having received the list of names of powerful economic nodes in economic dimension, to add additional economic-political relations between same named nodes within the political dimension network.

Chapter 6: Solving Complex Multidimensional Problems

More dimensions may need considered simultaneously for advanced global solutions, rather than just two, including all mentioned in Chapter 2. Otherwise it may potentially lead to system problems or even conflicts, and this may also depend on the globality of networks (from countries, to groups of nations, up the global world). Also, we initially organized the inter-dimensional solutions each time starting from and returning to the same GM. But it also may happen useful when inter-dimensional solutions are organized as self-penetrating, self-evolving, and self-organizing recursive spatial scenarios ***directly propagating between different dimensions***. And the latter may be solving very important and complex security or defence tasks, with any numbers of them operating collectively and in parallel. All this can be effectively organized with the use of SGT and SGL in a distributed and combined physical and virtual environment. More multidimensional features will be investigated under SGT including ***Multidimensional danger, Multidimensional crisis,*** and ***Multidimensional stress.***

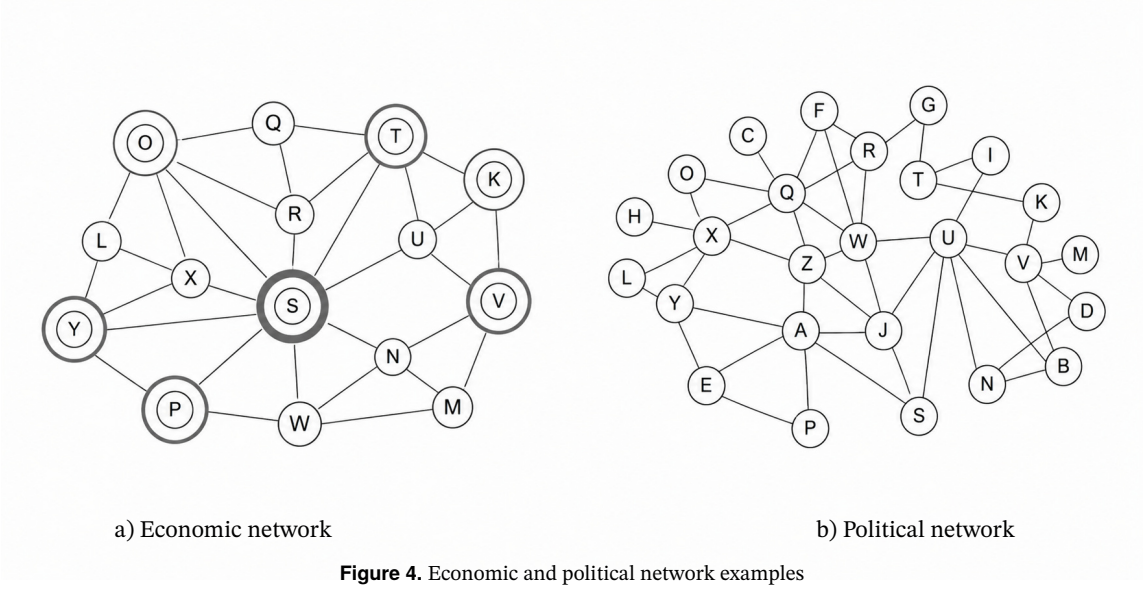
Chapter 7: Conclusions

The book confirms the necessity and high importance of understanding the distributed international world through its multiple dimensions, which needs their detailed investigation both separately and collectively to guarantee the proper results. It also showed suitability of the developed SGT-SGL paradigm for investigating, modifying, and improving different dimensions and their holistic integration and management, where effective operations and solutions for the networked dimensions can be organized in parallel and distributed mode. Moreover, such solutions, potentially multiple and simultaneous, can self-spread and evolve in a holistic mode, providing the international world with ***powerful flexibility, security, and self-recovering features***. The latest SGL version can be effectively and quickly implemented in traditional environments and recommended to different local and global institutions and organizations, UN including, to be used for the support of stability and evolution of the whole international community. -- References.

References will cite the publication sources used is different chapters.

4. An Example of a Possible Multidimensional Solution

Some drafts of possible multidimensional solutions under SGT planned in the book already appeared in the press, including in [25, 26, 27, 28, 29]. One such draft, in short, is discussed below. We will show here how the findings in one dimension can influence a solution in other dimension, considering for this a possible interplay of economic and political dimensions symbolically shown in Fig. 4.



a) Economic network b) Political network

Figure 4. Economic and political network examples

We first find the most powerful economic countries using network example of Fig. 4*a*, which symbolically reflects economic powers of different countries by sizes of the respecting nodes. Initially staying in GM (see Fig. 1), entering the economic dimension with the registered countries-nodes in it, and then returning to GM the needed most powerful node names. Having received the list of such names (like S, T, V, Y and P of Fig. 4*a*) we can add now economic-political relations (or "ecopol") between all same named nodes within the political dimension network of Fig. 4*b*, with the result (in dotted links) shown in Fig. 5.

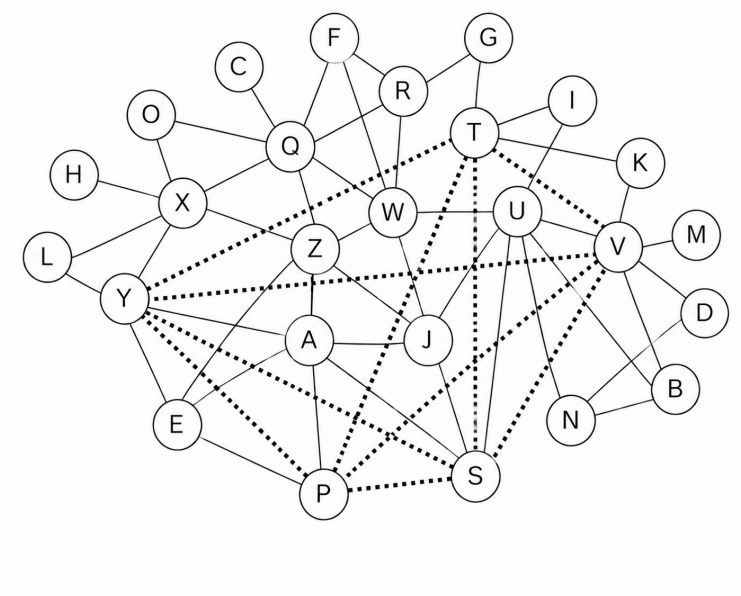


Figure 5. Adding new economic-political relations to the political network

This is believably in hope that such new links may be useful for developing both economic and political cooperation between these countries, thus benefitting the global development and prosperity. The above two-dimensional solution in SGL is extremely compact:

```
frontal(Nodes) = (enter(economic);
hop(all_nodes); POWER >= threshold; NAME);
eneter(political); hop(Nodes); split(Nodes);
if(NAME > VALUE, linkup(ecopol, node(VALUE)))
```

However, more dimensions may need to be considered for such solution, rather than just two, including others like cultural, legal, security, technology, defence, etc.

5. Book Values and External Relations

Categories describing this book may include: New multidimensional world vision, investigation, and understanding; universal global management model, language, technology, and their international applications.

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6. Conclusions

The book is expected to confirm the necessity and high importance of understanding the distributed international world through its multiple dimensions, which needs detailed investigation separately and collectively to guarantee the proper world development. It should also confirm suitability and efficiency of the developed SGT-SGL paradigm for investigating, modifying, and improving different dimensions and their holistic integration and management, where effective operations and solutions for the networked dimensions can be organized in parallel and fully distributed mode. And these solutions in SGL may be simpler and much more compact than with any other models and languages (by the obtained experience with solving complex tasks in any other areas, as already mentioned in [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24]). SGT is fundamentally based on quite different world vision and understanding in comparison with other models and languages, and the world "spatial" in its name fundamentally relates to the very human existence, evolution, and activity in large distributed spaces, including finding solutions related to crises and disasters, which may need covering large physical, virtual, and emotional dimensions.

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