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ALGORITHMIC INVENTIONS AND PATENTABILITY: A COMPARATIVE STUDY OF SOFTWARE PATENTS IN THE UNITED STATES, EUROPEAN UNION, AND INDIA

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Abstract:

The rapid global expansion of software-driven technologies has fundamentally reshaped the legal debate surrounding the patentability of algorithmic inventions. As artificial intelligence, machine learning, data-processing systems, and digital architectures increasingly form the core of innovation, legal systems across the world are compelled to determine whether such inventions should qualify for patent protection.[1] The United States, European Union, and India represent three distinct approaches to this issue, each balancing the tension between protecting genuine innovation and preventing monopolisation of abstract computational ideas.[2] This paper presents an extended comparative analysis of these jurisdictions, adopting a narrative-integrated structure rather than fragmented sub-sections, while exploring statutory texts, judicial developments, and evolving policy considerations. With a focus on the concept of 'technical effect', the abstract idea doctrine, and the exclusion of computer programs per se, this research further highlights the challenges posed by emerging technologies such as autonomous AI systems. The study ultimately argues for clearer and more harmonised standards of analysis to support consistent examination and promote robust technological growth.

Keywords:

Algorithmic inventions; software patents; patentability; abstract ideas; technical effect; computer-implemented inventions; CRI; United States; EU; Indian Patent Act.

Introduction:

Software has become the defining engine of contemporary technological advancement, powering applications ranging from global financial networks and cloud infrastructures to autonomous vehicles and predictive healthcare systems. The increasing reliance on algorithmic

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decision-making has created a complex legal challenge: whether such intangible yet highly functional processes should be granted the same level of patent protection historically reserved for mechanical and industrial innovations.[3] Traditional patent law was developed in an era dominated by physical machinery, chemical formulations, and manufacturing processes. Modern innovation, however, often exists in the form of mathematical models, data-driven architectures, and machine-learning algorithms that do not easily fit into the conventional categories of patent-eligible subject matter. The tension between incentivising innovation and preventing over-broad monopolies has therefore become central to discussions of software patentability.

Comparative Evolution of Software Patentability:

The evolution of software patentability in the United States, European Union, and India reflects the broader philosophical differences among these jurisdictions regarding the role of patents in digital innovation. In the United States, the statutory language of 35 U.S.C. § 101 has historically been interpreted expansively, leading courts to treat software as functionally equivalent to mechanical processes when implemented on a computer.[4] This permissive environment resulted in an explosion of software and business-method patents during the late 1990s and early 2000s, particularly following decisions such as *State Street Bank*, which embraced the idea that a practical, useful result rendered an algorithm patent-eligible. However, judicial attitudes shifted dramatically with a trio of landmark decisions: *Bilski*, *Mayo*, and ultimately *Alice*. The Supreme Court grew increasingly concerned that patents that merely automated long-standing commercial practices threatened to monopolise abstract ideas. The *Alice* framework introduced a two-limb test that asks whether a claim is directed to an abstract idea, and if so, whether there is an inventive concept sufficient to transform that idea into a patent-eligible application.[5] Although this test was intended to restrict only low-quality software patents, its ambiguous wording produced substantial uncertainty. Different courts have reached inconsistent conclusions even for similar types of inventions, and inventors frequently struggle to determine whether their algorithms constitute a technical improvement to computer functionality or merely an automation of existing logic. The European position differs fundamentally because its approach is grounded in the text of the European Patent Convention, which expressly excludes programs “as such” from patentable subject matter.[6] While this exclusion appears strict, the European Patent Office developed a nuanced interpretative framework that allows software patents where they produce a 'technical effect' beyond the normal physical interactions between software and hardware. Decisions such as

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IBM and *Comvik* shaped this analytical model, establishing that only technical features contribute to inventive step while non-technical features are disregarded.[7] This method enables examiners to filter out claims relating to business rules, administrative schemes, or purely mental acts. At the same time, it supports protection for inventions that improve computational efficiency, enhance data transmission, strengthen encryption, or optimise hardware usage. India's path reflects a hybrid between these two systems, constrained by the statutory exclusion under Section 3(k) yet increasingly influenced by global trends. The Indian Patent Office initially interpreted Section 3(k) in a rigid manner, rejecting most computer-implemented inventions regardless of technical merit. Over time, however, judicial developments—most notably the *Ferid Allani* decision—have signalled a shift toward recognising that modern inventions often manifest through software and that technical effect should serve as the primary indicator of patentability.[8] Revised CRI Guidelines further clarify that inventions demonstrating enhanced security, improved data processing, efficient resource management, or interaction with hardware may satisfy the requirement of technical contribution. Still, the practical reality is that Indian examiners differ in the degree to which they apply these guidelines, resulting in continued unpredictability. The divergence among these systems highlights a fundamental conceptual divide: whether software should be viewed primarily as logic or as technology. In jurisdictions that lean toward the logic-based view, software is treated cautiously, with concerns that patent protection may block essential computational techniques. In technology-oriented jurisdictions, software is regarded as a practical engineering tool capable of producing concrete technological advantages. Both perspectives hold merit, but achieving the correct balance is essential to maintaining healthy innovation ecosystems. A deeper comparative look reveals that the United States tends to frame software patentability in terms of abstractness, focusing on whether a claim monopolises a fundamental concept. The European Union, conversely, frames the issue around technicality—an invention must solve a technical problem using technical means. India, influenced by both philosophies, is gradually shaping a hybrid doctrine centred on technical effect while anchored in statutory language. Each approach attempts to address concerns over patent thickets, litigation abuse, and barriers to entry in fast-moving digital markets. Yet each approach also generates unique challenges. The American system struggles with inconsistent judicial outcomes; the European model faces criticism for vagueness in defining 'technical'; and India grapples with uneven implementation and limited jurisprudential guidance.

Despite these challenges, all three jurisdictions share an implicit acknowledgment that

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algorithmic inventions cannot be excluded wholesale. Digital technologies now underpin nearly every sector of the economy, from communication networks and fintech platforms to public administration and national security. As a result, outright prohibition of software-related patents risks undermining the incentive structures needed to promote investment in advanced computational research. The central task, therefore, is not whether algorithmic inventions should be patentable, but rather how to distinguish protectable technical innovations from unpatentable abstractions. This comparative analysis underscores the need for coherent standards that balance innovation incentives with societal interests.

The Role of Technical Effect and Abstract Idea Distinctions:

A central thread connecting the divergent practices of the United States, European Union, and India is their shared struggle to identify the boundary between an abstract computational idea and a genuinely technical contribution. In software patentability discourse, the notion of technical effect operates as the intellectual fulcrum on which legal interpretation pivots. In jurisdictions that treat software with greater scepticism, technical effect serves as the crucial gatekeeper that prevents monopolisation of fundamental logic and mathematical thought. In more permissive jurisdictions, it acts as a tool for distinguishing between meaningful innovation and routine implementation. In the European context, technical effect is not merely an evidentiary consideration but a doctrinal requirement grounded in the structure of the European Patent Convention.[9] Examiners use it to determine whether a computer-implemented invention crosses the conceptual threshold from software "as such" into the realm of patentable technology. For example, an algorithm designed to sort data alphabetically is unlikely to qualify unless it demonstrably improves the internal functioning of the processor, memory, or architecture. A similar algorithm embedded within a cybersecurity system that identifies anomalies in real time may, however, be deemed technical. The EPO's focus is thus on whether the claimed invention yields an engineering-type contribution when interacting with hardware or digital infrastructure.

The Comvik doctrine reinforces this approach by instructing that only technical elements may contribute to inventive step, with non-technical aspects essentially ignored.[10] This ensures that mere automation of business practices does not transform commercial logic into a patentable invention simply because a computer is used to execute it. The doctrine is now deeply entrenched, forming the analytical backbone of European software patent assessments. Yet critics argue that the flexibility inherent in determining what qualifies as "technical" risks

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inconsistency and allows subjective reasoning to influence outcomes. Nevertheless, the model remains the most structured and predictable among the three jurisdictions considered.

The United States, by contrast, frames the problem through the lens of abstract ideas rather than technicality. The Supreme Court's jurisprudence under *Mayo* and *Alice* centres on whether a patent attempts to monopolise a fundamental concept such as mathematical reasoning, financial hedging, or organising human activity.[11] Under this test, improvements to computer functionality are typically patent-eligible, as seen in decisions like *Enfish* and *DDR Holdings*, while applications that merely automating human decision-making often fails. This approach reflects an underlying policy concern about over-expansive patents that could restrict downstream innovation in computing industries. Yet the abstract-idea doctrine is notoriously unpredictable. Inventors must craft claims with extreme precision to avoid being characterised as directed toward an abstraction. The doctrine's malleability has contributed to an uneven landscape where nearly identical inventions may be treated differently by different courts. Furthermore, lower courts often struggle to interpret Supreme Court precedents, resulting in contradictory rulings at the district and appellate levels. Despite these challenges, the American framework continues to evolve as litigants and judges attempt to carve out clearer categories of patent eligibility. India's attempt to incorporate the technical-effect requirement into its software patent jurisprudence reflects both influence from European doctrine and the need to adapt to domestic economic realities. Section 3(k) of the Patent Act embodies a legislative choice to exclude computer programs per se, suggesting strong scepticism toward treating software as patentable. Yet courts and the Patent Office recognise that many modern technological innovations are software-driven, and a rigid application of Section 3(k) would exclude entire fields of technological development. The *Ferid Allani* case marked a turning point, emphasising that inventions demonstrating a technical effect—such as enhanced speed, security, or efficiency—should not be denied protection solely because software is involved.[12]

This shift reflects an understanding that the digital economy requires more nuanced legal tools than simple exclusionary rules. However, ambiguity persists because Indian examiners interpret Section 3(k) with varying degrees of strictness. Some apply a broad exclusion, rejecting most software-related applications, while others adopt a more European-style illustrative approach. As India's innovation ecosystem expands in domains such as AI, fintech, and telecommunications, pressure is mounting for more consistent and transparent standards. Across all three jurisdictions, determining what constitutes a technical effect requires

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attentiveness to technological context. An algorithm designed for image recognition may involve technical features when it enhances pixel processing or reduces computational load, but may resemble a mere mathematical model when applied abstractly. Similarly, machine-learning inventions often rely on statistical modelling, which courts may treat as non-technical unless the model improves performance at the system level. These complexities demonstrate why evaluation of software patents demands an understanding of computer science fundamentals, not only legal doctrine. The rapid rise of artificial intelligence compounds these difficulties. AI systems increasingly generate new algorithms without human intervention, blurring the boundary between human invention and autonomous machine creativity. This raises questions not only about inventorship—since current law requires a human inventor—but also about how to interpret technical effects when an algorithm optimises itself in ways even its creators cannot fully explain. Jurisdictions will soon need to determine whether technical effect should be satisfied by the observable performance improvements of an AI system, or whether human conceptual insight remains essential. In practice, AI inventions challenge all three frameworks. In the United States, AI claims risk being classified as abstract if framed as mathematical optimisation. In the EU, their patentability depends on whether the claimed features produce recognisable technical benefits. In India, examiners must determine whether AI-driven improvements meet the threshold of technical contribution required to escape Section 3(k). The complexity of these challenges demonstrates the necessity for clearer, more future-proof doctrines that address the realities of modern computing.

Economic, Policy, and Innovation Implications:

The economic implications of software patentability extend far beyond doctrinal debates, directly shaping patterns of innovation, market competition, and technological diffusion. In rapidly developing fields such as artificial intelligence, cloud computing, cybersecurity, and digital communication, patents operate not only as legal instruments but as strategic assets that influence investment decisions, market positioning, and research trajectories. The divergent approaches of the United States, European Union, and India therefore reflect deeper choices about how each jurisdiction conceptualises the role of intellectual property in the innovation ecosystem. In the United States, software patents historically played a crucial role in the growth of Silicon Valley and the broader digital economy.[13] Venture capital funding frequently depended on the presence of patent portfolios, which signalled technological credibility and offered protection against competitive imitation. The permissive environment prior to *Alice* encouraged startups and established firms alike to pursue broad software patents, leading to

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dense "patent thickets" in sectors such as e-commerce and mobile applications. While these thickets sometimes incentivised cross-licensing and collaboration, they also gave rise to strategic litigation by so-called "patent assertion entities," generating concerns about the social costs of excessive patenting. Following *Alice*, the United States witnessed a decline in software patent grants and a corresponding drop in litigation. Yet this shift produced a mixed economic impact. On one hand, it alleviated fears of monopolisation and reduced the power of non-practising entities. On the other hand, uncertainty surrounding subject-matter eligibility led some investors to become hesitant about supporting early-stage software ventures, particularly in fields where patent protection plays a critical role in securing competitive advantage. Critics argue that the narrowing of patent eligibility has placed the United States at a disadvantage relative to more structured jurisdictions, weakening the country's long-term technological competitiveness.[14] Supporters counter that it has restored balance by ensuring patents do not impede innovation in foundational digital tools. The European Union's approach shapes economic behaviour in a different way. The structured technical-effect requirement under the EPC creates a clearer, more predictable legal environment. Firms investing in highly technical fields—such as network protocols, embedded systems, and advanced processors—benefit from consistent examination standards, enabling them to draft claims strategically and allocate research funding more efficiently. However, the EU's approach may disadvantage sectors that rely heavily on abstract data processing, financial algorithms, or business logic, since such inventions often fail to demonstrate sufficient technical character.

As a result, innovative firms in these industries frequently pursue alternative protection strategies, such as trade secrets, rapid market deployment, or copyright in software code. The EU model thus channels investment into engineering-centric innovations, reinforcing its emphasis on technologically grounded contributions.[15] India's economic context presents a different set of challenges and opportunities. As a developing economy with a large software and IT services sector, India historically relied more on labour-driven technological output than on patent-intensive innovation. The strict exclusion of software under Section 3(k) was consistent with India's policy priority of maintaining low-cost access to technology and avoiding monopolies in fundamental software tools. However, as India transitions toward a more innovation-oriented digital economy—driven by domestic developments in fintech, telecommunications, artificial intelligence, and e-governance—the need for a more nuanced approach to software patents has become evident.[16] The *Ferid Allani* decision and revised CRI Guidelines reflect this shift, signalling to investors and innovators that India is willing to

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protect software inventions that make genuinely technical contributions. Yet economic obstacles remain. India's patent filing rates for software-driven inventions remain comparatively low, partly due to uncertainty in examination standards and partly due to a historical reliance on service-based business models rather than proprietary technological development. To fully transition toward a research- and innovation-based ecosystem, India may need to provide clearer, more harmonised rules for computer-related inventions. A transparent and predictable patent system would encourage domestic firms to invest in advanced algorithmic research and attract foreign companies seeking reliable IP protection.

Beyond jurisdiction-specific considerations, the broader global economy underscores the need for coherent software patent policies. Digital technologies increasingly operate across borders, and companies developing software products frequently seek protection in multiple jurisdictions. Divergent patent standards impose significant transaction costs, requiring inventors to tailor applications to each region's conceptual framework. A firm seeking protection for the same algorithm may need to emphasise technical effect before the EPO, inventive concept before the USPTO, and hardware integration before the Indian Patent Office. These inconsistencies hinder innovation and complicate international technology transfer.[17]The economic implications of algorithmic patents also extend into labour markets and industrial competition. Stronger patent protection may encourage firms to invest in high-skilled research positions, accelerating the development of domestic AI ecosystems. Conversely, overly broad or ambiguous patents may hinder new entrants by raising barriers to market entry. Striking an appropriate balance is therefore essential, particularly for emerging economies that aim to cultivate competitive digital industries. The interplay between intellectual property and industrial strategy thus assumes central importance in shaping the future direction of global technological competition. The rise of AI-specific technologies further complicates these economic considerations. AI patents often involve technical contributions at the system level—such as optimised training processes, improved neural network architectures, or enhanced decision-making accuracy—but they also frequently rely on abstract mathematical models. Jurisdictions with more structured frameworks may find it easier to distinguish patentable technical improvements from non-technical abstractions. Those with flexible or ambiguous doctrines risk generating uncertainty that could deter investment in AI research.[18] As AI becomes a cornerstone of global economic growth, ensuring clarity in software patent eligibility will be vital for maintaining innovation momentum.

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Global Harmonisation, Doctrinal Tensions, and Future Directions:

The growing interconnectedness of the global digital economy has intensified the need for some level of harmonisation in the treatment of algorithmic inventions. As multinational technology firms increasingly file patent applications across diverse jurisdictions, divergent eligibility standards have become a source of significant legal and economic friction. The challenges that arise from these divergences are not merely academic; they directly affect investment strategies, cross-border licensing, international R&D collaboration, and technology transfer.[19] Given that software markets operate globally and digital products provide value across multiple legal territories simultaneously, the absence of convergence among patent doctrines can create substantial uncertainty for innovators. Although complete harmonisation may be impractical due to the deeply rooted philosophical differences among jurisdictions, a degree of soft alignment may be achievable. International organisations such as WIPO have periodically encouraged dialogue on software patentability, recognising that issues such as AI autonomy, machine-generated algorithms, and platform-based innovation will require coordinated legal responses. However, global progress has been slow, as nations weigh the benefits of aligning their doctrines against the perceived risks of granting excessive patent rights over rapidly evolving digital technologies. The principal obstacle to harmonisation lies in the doctrinal tensions surrounding what constitutes a technological contribution. In the United States, the emphasis on abstract ideas reflects a jurisprudential tradition rooted in constitutional limitations on patent monopolies. The Supreme Court's reluctance to endorse broad eligibility standards stems partly from a desire to prevent the privatisation of essential tools of human knowledge.[20] In Europe, by contrast, the technical-effect doctrine is grounded in the EPC's structure and reflects a deliberate choice to channel innovation incentives toward engineering-oriented research. India, meanwhile, continues to negotiate an internal balance between encouraging domestic innovation and preventing overreach that could stifle growth in a price-sensitive, rapidly digitising economy. These underlying philosophies make it difficult to imagine a single unified standard emerging in the near future. This does not mean that harmonisation is impossible. Convergence may instead take the form of shared analytical principles, such as transparency in reasoning, clearer definitional boundaries, and consistency in applying doctrinal tests. For example, jurisdictions could benefit from articulating explicit lists of factors that indicate technical effect—such as improved hardware utilisation, enhanced system-level efficiency, or increased security resilience. Likewise, clearer guidance on distinguishing mathematical methods from technical processes would reduce uncertainty.[21] International collaboration could also be facilitated by the development of model guidelines or

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interpretative tools that enable applicants to align their claims more effectively with the expectations of different patent offices. Doctrinal tensions intensify further when algorithmic inventions involving machine learning and autonomous systems are considered. Machine learning methods typically rely on statistical optimisation, classification techniques, and probabilistic modelling—concepts that courts often treat as mathematical abstractions. However, when integrated into broader systems, such algorithms can significantly improve performance, stability, and precision. Determining whether such improvements constitute technical effect therefore demands a contextual understanding of how the algorithm interacts with system architecture.[22] In many cases, the "black-box" nature advanced AI models complicate this assessment. Examiners frequently struggle to determine whether the claimed improvement results from a technical contribution or from a mere mathematical refinement. A further complication arises from the growing autonomy of AI systems. Modern neural networks and reinforcement learning algorithms often generate new strategies and optimisations without direct human guidance. This raises questions about inventorship, as patent law traditionally requires that an invention originated from a natural person.[23] Courts in the United Kingdom, United States, and other jurisdictions have explicitly rejected the possibility of listing an AI system as an inventor, insisting on human intellectual contribution. While such decisions maintain coherence with existing legal doctrine, they expose a deeper conceptual issue: if a significant portion of the inventive process is carried out autonomously by an AI, can it still be said that the resulting invention truly reflects human ingenuity? These concerns suggest that patent systems worldwide may need to reconsider how they define both inventorship and technical contribution in the context of AI. Some scholars argue for a shift toward recognising AI-assisted invention as a distinct category, where human oversight or meaningful input can satisfy the inventorship requirement even if the AI performs key creative steps. Others propose entirely new frameworks for evaluating algorithmic inventions, focusing less on the mental aspects of creativity and more on measurable outcomes such as system performance improvements.[24] Although no consensus yet exists, the debate underscores the need for flexible doctrines capable of adapting to the accelerating pace of technological change. The global technology landscape also raises issues concerning equitable access to digital tools. Overly restrictive patent systems may inhibit the availability of essential computational methods, particularly in developing countries that rely on affordable software solutions. Conversely, overly permissive systems may diminish the incentives required for high-risk technological research. A balanced approach would involve affirming patent protection for substantial engineering advances while safeguarding the public domain for foundational algorithmic

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principles. This balance is essential to ensure that emerging economies can adopt cutting-edge technologies without becoming overdependent on foreign intellectual property portfolios.[25] Ultimately, the future of software patentability depends on the ability of legal systems to reconcile competing interests: innovation and access, protection and flexibility, national policy and global interoperability. The United States may need legislative clarification to stabilise its abstract-idea doctrine. The European Patent Office may need to articulate clearer boundaries for determining technical effect, particularly in AI-driven contexts. India may need continued judicial refinement and administrative consistency to support its emerging innovation ecosystem. Global harmonisation will not mean the adoption of identical rules but the alignment of core principles to reduce unpredictability and enhance fairness in an increasingly digital world.

Conclusion

The comparative study of algorithmic inventions and their patentability across the United States, European Union, and India reveals the deep conceptual and structural challenges of adapting traditional patent frameworks to a digital, algorithm-driven world. Each jurisdiction reflects a distinct legal philosophy: the United States foregrounds the abstract-idea doctrine, the European Union centres its analysis around technical effect, and India negotiates a statutory exclusion shaped increasingly by judicial refinement. Despite these differences, all three systems grapple with the same underlying question: how to distinguish genuine technological innovations from unpatentable abstract logic. A key insight emerging from this analysis is that the evolution of software patentability is inseparable from economic policy, technological progress, and the rise of artificial intelligence. Algorithmic inventions today constitute far more than computer-implemented mathematics; they influence infrastructure, healthcare, finance, communication, national security, and social administration. As a result, overly restrictive doctrines risk stifling innovation, while overly permissive regimes may encourage monopolies over foundational computational principles. A balanced approach must therefore recognise technical contribution as the essential gateway to patent protection, while maintaining a strong public domain for basic algorithms and mathematical models. In the United States, legislative clarification may ultimately be necessary to stabilise the post-*Alice* landscape and provide greater certainty for innovators. The European Union, though more structured, faces ongoing challenges in defining and applying the concept of technical effect consistently across AI-driven technologies. India, meanwhile, stands at a pivotal moment: with a rapidly growing digital economy, it must refine its jurisprudence to ensure that Section 3(k) does not hinder

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meaningful technological advancement while still safeguarding societal access to essential software tools. The future of global software innovation depends on the ability of patent systems to adapt. While complete harmonisation across jurisdictions may remain elusive, greater convergence in core principles—clarity of doctrine, transparent reasoning, consistent application, and recognition of genuine technical contribution—is both achievable and necessary. As the digital world becomes increasingly interconnected, patent law must move toward frameworks capable of supporting innovation without undermining the open, interoperable nature of modern computing. Ultimately, algorithmic inventions will continue to reshape society, and the legal systems governing them must evolve accordingly to protect progress while preserving equitable access.

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