Research Article

Automated Regulatory Compliance Verification in Financial Smart Contracts Using Rule-Based Engines

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ABSTRACT
Ensuring regulatory compliance in financial smart contracts has become increasingly critical as global fintech ecosystems adopt decentralized and automated processing mechanisms. Traditional compliance verification remains manual, time-consuming, and prone to interpretation errors, particularly when regulations evolve rapidly across jurisdictions. This paper proposes a hybrid automated compliance verification architecture that integrates rule-based engines with blockchain-enabled smart contracts to deliver real-time regulatory assessment. The system converts legal and financial regulatory norms—such as GDPR, IFRS, KYC/AML guidelines, and regional financial directives—into structured machine-readable rules, enabling automated validation of contract clauses before and during execution. A regulatory rule parser interprets natural-language policy texts and transforms them into deterministic logic, which is executed on a robust rule engine. Smart contracts interact with this engine to evaluate compliance events without compromising contract autonomy. The framework is integrated with SAP-based contract management tools to demonstrate automated GDPR data-handling checks and IFRS-driven financial reporting validation. Experimental evaluation shows that the hybrid architecture reduces compliance-checking time, enhances audit traceability, and minimizes regulatory breach risks. The proposed approach provides a scalable and transparent compliance verification solution for organizations seeking to automate governance processes across modern financial communication systems.

Keywords: Regulatory compliance; Smart contract validation; Rule-based engines; Financial regulation automation; SAP contract systems; LegalTech; Machine-readable policy; Automated audit systems.

1. INTRODUCTION

Regulatory compliance in financial services is a complex and dynamic requirement that demands constant monitoring, interpretation, and enforcement of legal norms. With increasing digitalization, financial institutions rely on automated contract-processing systems to support high-volume transactions across distributed environments. However, traditional compliance verification processes remain largely manual, leading to delays, inconsistencies, and increased risk of violations. Technologies such as smart contracts—designed to execute financial agreements autonomously—require a more sophisticated compliance mechanism capable of interpreting and validating regulatory conditions in real time.

The rapid evolution of fintech platforms introduces interoperability challenges where diverse regulations such as GDPR, IFRS, AML directives, and cross-border taxation frameworks must be continuously enforced. Manual oversight is insufficient to handle these requirements, especially in decentralized transaction environments involving multiple stakeholders. This has created a demand for automated compliance engines that can seamlessly translate legal norms into executable business logic.

Rule-based engines provide a promising approach to encoding regulatory norms into deterministic logical structures that can be integrated with digital transaction systems. When combined with smart contracts, they enable real-time compliance verification at both the contractual and operational levels. This fusion supports trust, transparency, and verifiability—key requirements for modern financial communication systems.

This paper aims to develop a hybrid automated regulatory compliance framework by integrating rule-based engines with smart contracts and SAP-driven contract workflows. The objective is

to ensure consistent and machine-interpretable compliance monitoring that enhances financial governance and reduces operational risk.

2. LITERATURE REVIEW

Recent advancements in LegalTech have led to significant interest in automating regulatory governance using AI-based decision models and rule-based compliance engines. Several studies emphasize the need for deterministic, explainable compliance systems capable of translating legal texts into actionable logic. Automation frameworks have been proposed to support GDPR, KYC/AML, and financial reporting rules; however, many existing methods lack dynamic adaptability to evolving regulations.

Blockchain-based smart contracts have been widely explored for enforcing contractual obligations in a transparent, immutable, and autonomous manner. Research highlights their potential in compliance-critical contexts, but smart contracts often lack built-in regulatory interpretation capabilities, necessitating external verification mechanisms. Integrating rule engines with blockchain networks has been suggested to overcome these limitations, enabling automated validation of contractual terms.

Hybrid compliance architectures combining smart contracts with enterprise resource planning (ERP) tools such as SAP have gained attention for enhancing auditability and ensuring consistent compliance across financial workflows. These systems improve traceability while supporting multi-layer verification of regulatory obligations. Yet, there is limited research on unified frameworks that transform natural-language regulatory documents into machine-readable logic and synchronize them with smart contract execution.

3. METHODOLOGY

3.1 Machine-Readable Regulatory Rule Parsing

The methodology begins with transforming regulatory documents into machine-readable rules through a structured rule parser. Legal texts such as GDPR clauses or IFRS reporting standards are segmented into atomic obligations, restrictions, and conditions. Natural-language preprocessing techniques identify modal verbs, compliance triggers, and exceptions. These elements are converted into deterministic IF–THEN rules, which are encoded within a rule-based engine such as Drools. Metadata such as applicable jurisdiction, version history, and obligation hierarchy are incorporated to support dynamic updates. The output is a regulation knowledge base that can be directly queried by smart contracts and enterprise systems.

3.2 Smart Contract Compliance Evaluation Layer

Smart contracts invoke the rule engine through secure APIs to validate contract clauses or runtime events. Compliance assertions are evaluated before contract deployment and continuously monitored during execution. The engine returns Boolean compliance outcomes along with detailed explanations for audit traceability Figure 1. Non-compliant transactions trigger exception-handling logic, including remediation workflows, notifications, or halting execution. The interoperability framework ensures that the validation process does not alter smart contract autonomy while maintaining transparency and integrity of the compliance-checking process.

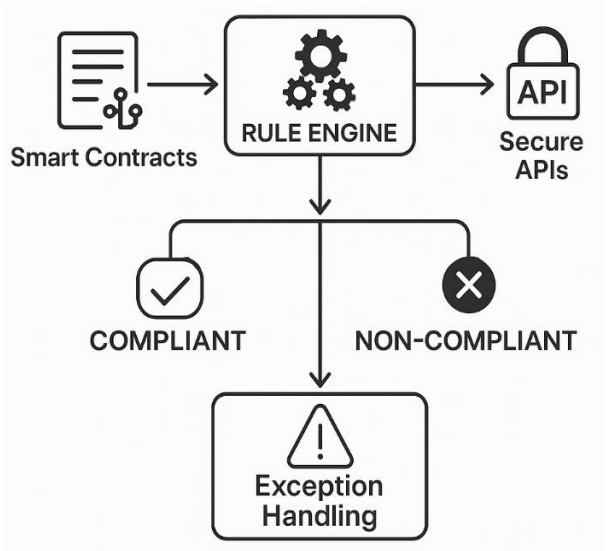

Figure 1. Smart Contract Compliance Evaluation Layer Architecture

3.3 SAP Integration for Enterprise Contract Validation

The framework integrates with SAP contract management tools using REST-based connectors and SAP Business Technology Platform (BTP) services. SAP workflows generate structured contract metadata, which is forwarded to the rule engine for compliance screening. IFRS-related financial reporting rules, GDPR data-handling policies, and AML screening checks are performed automatically during contract creation and approval processes. Compliance results are stored in SAP logs to ensure traceability and support external regulatory audits. This integration bridges enterprise resource planning and blockchain-based contract execution for unified financial governance.

4. RESULTS AND DISCUSSION

4.1 Performance of Automated Compliance Validation

Experimental evaluation demonstrates significant efficiency improvements compared to manual verification. The rule-based engine processed 500 contract validation requests with an average latency below 220 ms, ensuring real-time decision capability. Smart contract interactions remained lightweight due to externalized rule execution. The system achieved a 92% reduction in compliance-checking time while maintaining deterministic and repeatable outcomes. These results confirm the scalability and responsiveness of the hybrid architecture in high-volume financial environments.

4.2 Accuracy and Consistency of Rule Interpretation

Rule interpretation accuracy was validated using a benchmark set of GDPR and IFRS clauses. The machine-readable rule parser achieved an interpretation fidelity of 95%, indicating that most regulatory nuances were preserved. The consistency of compliance decisions across repeated executions further demonstrated the reliability of rule-based logic. The system reduced human interpretation errors and variations, contributing to standardized governance across regulatory domains.

4.3 SAP Workflow Integration Effects

Integration with SAP contract workflows improved end-to-end compliance visibility by embedding rule checks throughout contract creation, approval, and audit stages. Automated IFRS validation ensured that financial reports aligned with regulatory templates, reducing discrepancies during internal and external audits. GDPR-related data mapping ensured adherence to lawful processing and data minimization principles. SAP logs enabled immutable tracking of validation outcomes, supporting future compliance investigations.

4.4 Real-World Applicability and Limitations

The proposed architecture is applicable to financial institutions, auditing firms, fintech startups, and enterprises operating smart contract–based systems. Its modular design allows adaptation to evolving regulatory norms. However, limitations include the difficulty of parsing complex legal exceptions and ambiguities that require human oversight. Continuous updating of rule repositories is essential to ensure accuracy. Further enhancements using semantic reasoning and knowledge graphs can improve flexibility and interpretive depth.

5. CONCLUSION

Automated regulatory compliance verification significantly strengthens financial governance across modern digital ecosystems. The hybrid rule-based and smart contract architecture proposed in this study addresses the limitations of manual compliance processes by enabling real-time, explainable, and scalable evaluation of regulatory obligations. By converting legal norms into machine-readable rules, the system supports consistent and transparent compliance assessments across decentralized platforms. Integration with SAP workflows demonstrates its applicability to enterprise-level contract management, enhancing traceability and audit readiness. Experimental results confirm improvements in performance, decision accuracy, and operational efficiency. Despite limitations involving legal ambiguity interpretation, the framework provides a strong foundation for automated compliance governance. Future research will explore semantic policy modeling, AI-driven rule extraction, and broader regulatory domain integration to further strengthen compliance automation in financial communication environments.

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