Journal of Advances in Mathematics and Computer Science

Volume 39, Issue 9, Page 14-39, 2024; Article no.JAMCS.122280
ISSN: 2456-9968
(Past name: British Journal of Mathematics & Computer Science, Past ISSN: 2231-0851)

Enhancing Responsible AGI Development: Integrating Human-in-the-loop Approaches with Blockchain-based Smart Contracts

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.9734/jamcs/2024/v39i91924

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc., are available here: https://www.sdiarticle5.com/review-history/122280

Received: 26/06/2024
Accepted: 28/08/2024
Published: 01/09/2024

Original Research Article

Abstract

The progression towards Artificial General Intelligence (AGI) presents unprecedented opportunities and risks, necessitating robust, adaptable oversight mechanisms. This paper introduces a novel framework integrating Human-in-the-loop (HITL) approaches with blockchain technology for AGI governance. Our system employs smart contracts to dynamically trigger human oversight based on multi-faceted criteria, including decision confidence, novelty detection, and ethical considerations. It creates an immutable, transparent audit trail of AGI decisions and human interventions, crucial for accountability and continuous improvement. The framework implements a decentralized governance model with token-based incentives, ensuring diverse expert participation and aligning stakeholder interests with responsible AGI development. This approach addresses

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Cite as: *Krishnamoorthy, Mahesh Vaijainthymala. 2024. "Enhancing Responsible AGI Development: Integrating Human-in-the-Loop Approaches With Blockchain-Based Smart Contracts". Journal of Advances in Mathematics and Computer Science 39 (9):14-39. https://doi.org/10.9734/jamcs/2024/v39i91924.*

key challenges in AGI oversight: scalability, transparency, rapid response to emerging behaviors, and adaptive ethical alignment. It offers fine-grained control over AGI systems while allowing for their continued development. The blockchain foundation ensures tamper-resistant record-keeping and enables global coordination with local adaptation, critical for managing AGI in diverse environments. Our solution is designed to evolve alongside AGI capabilities, incorporating machine learning to predict necessary oversight adaptations. This adaptability is crucial for maintaining effective oversight as AGI systems potentially approach and surpass human-level intelligence. By bridging computer science, ethics, governance, and economics, our framework provides a comprehensive approach to responsible AGI development. It has far-reaching implications for various sectors and offers policymakers a concrete tool for implementing AGI regulations. This work represents a significant step towards ensuring that AGI's transformative potential can be realized while mitigating risks, potentially reshaping Human-AGI coexistence.

Keywords: Adaptive governance; AGI safety; AI ethics; AI governance; Artificial General Intelligence (AGI); Blockchain; consensus mechanisms; decentralized oversight; ethical AI; Human-in-the-loop (HITL); immutable audit trails; scalable oversight; smart contracts; token-based incentives; transparent decision-making.

1 Introduction

Artificial General Intelligence (AGI) represents a frontier in computer science that aims to create machines capable of human-level cognition across a wide range of tasks [1]. As research in this field progresses, the need for responsible development practices becomes increasingly crucial. The potential societal impact of AGI systems necessitates robust oversight mechanisms to ensure alignment with human values and ethical standards [2]. This research addresses the critical intersection of AGI development, ethical considerations, and governance frameworks.

1.1 Background on AGI Development and Associated Challenges

AGI development presents unique challenges beyond those of narrow AI systems. These include:

1. Unpredictability of emergent behaviors: As AGI systems become more complex, they may exhibit unexpected behaviors that are difficult to anticipate or control [3].
2. Difficulty in specifying complex human values: Translating nuanced human ethics and values into computational terms remains a significant challenge [4].
3. Potential for rapid self-improvement: The possibility of AGI systems enhancing their own capabilities could lead to an 'intelligence explosion,' raising control and safety concerns [5].
4. Ethical concerns regarding decision-making autonomy: As AGI systems become more autonomous, questions arise about the ethical implications of their decisions and actions [6].

These challenges underscore the need for a comprehensive governance framework that can adapt to the evolving landscape of AGI capabilities.

1.2 Importance of Responsible AI and Human Oversight

Responsible AI development, particularly for AGI, requires ongoing human involvement to guide system behavior, interpret complex scenarios, and make ethical judgments [7]. Human oversight serves as a critical safeguard against unintended consequences and helps maintain societal trust in AI technologies. Recent incidents of AI systems exhibiting biased or harmful behaviors highlight the importance of human guidance in AI decision-making processes [8].

1.3 Brief Introduction to HITL and Blockchain Smart Contracts

Human-in-the-Loop (HITL) approaches keep humans actively involved in AI processes, allowing for real-time guidance and intervention [6]. This methodology has shown promise in improving AI system performance and safety across various domains, from medical diagnosis to autonomous vehicles [7].

Blockchain technology, coupled with smart contracts, offers a decentralized, transparent, and tamper-resistant platform for encoding rules and recording interactions [9]. Its application in AI governance provides a novel approach to ensuring transparency and accountability in AGI systems [10].

1.4 Identifying the Research Gap

Despite significant advancements in AGI development and the growing body of literature on AI ethics and governance [11], there remains a critical gap in integrating human oversight with transparent, decentralized governance mechanisms for AGI systems. Current research has largely focused on either improving HITL methodologies [6] or exploring blockchain applications in AI [9], but few studies have attempted to synergize these approaches for AGI oversight.

Furthermore, while theoretical frameworks for AGI governance exist [12], there is a lack of practical, implementable solutions that can scale with the rapidly evolving capabilities of AGI systems. The intersection of human judgment, blockchain transparency, and AGI decision-making processes remains largely unexplored, presenting a significant opportunity for novel research [13].

This gap is particularly evident in three key areas:

1. Real-time, transparent oversight mechanisms for AGI decision-making
2. Scalable integration of human ethical judgment in AGI governance
3. Immutable and auditable recording of AGI behaviors and human interventions

Addressing this gap is crucial for ensuring that as AGI systems become more advanced, we have robust, adaptable, and transparent governance frameworks in place.

1.5 Objectives and Hypotheses

Given the identified research gap, this study aims to achieve the following objectives:

1. To develop an integrated framework that combines HITL methodologies with blockchain-based smart contracts for AGI oversight.
2. To evaluate the effectiveness of this framework in enhancing transparency, accountability, and ethical alignment in AGI decision-making processes.
3. To assess the scalability and adaptability of the proposed system in response to evolving AGI capabilities.

Based on these objectives, we propose the following hypotheses:

Hypothesis1: The integration of HITL approaches with blockchain-based smart contracts will significantly improve the transparency and auditability of AGI decision-making processes compared to traditional oversight methods [14].

Hypothesis2: The proposed framework will demonstrate higher responsiveness to ethical concerns in AGI behavior, as measured by reduced ethical violation rates and increased speed of human intervention [15].

Hypothesis3: The blockchain-based recording of AGI decisions and human oversight actions will lead to more consistent and fair governance practices over time, as evidenced by reduced variability in oversight decisions for similar scenarios [16].

Hypothesis4: The scalability of the proposed system will be superior to current AGI governance models, maintaining effectiveness even as the complexity and frequency of AGI decisions increase [17].

By addressing these objectives and testing these hypotheses, our research aims to contribute a novel, practical solution to the critical challenge of responsible AGI development and governance.

1.6 Proposed Framework and Research Significance

This research introduces a novel framework that integrates Human-in-the-Loop (HITL) approaches with blockchain-based smart contracts to address the critical challenges of AGI governance. Our proposed model leverages the adaptive intelligence of human overseers and the immutable, transparent nature of blockchain technology to create a dynamic, secure, and accountable system for AGI oversight [18].

By bridging the gap between human ethical judgment and technological rigor, this integrated approach aims to significantly advance the field of responsible AGI development. It offers a scalable solution to ensure AGI systems remain aligned with human values as they evolve in capability and complexity [19]. The primary objective of this study is to demonstrate how this synergistic combination can enhance the robustness, transparency, and ethical alignment of AGI systems, thereby contributing to the broader goal of responsible AI development [20].

This framework addresses key concerns raised by AI ethicists and policymakers, including the need for explainable AI, value alignment, and fail-safe mechanisms in advanced AI systems [21]. By providing a concrete implementation strategy, our research aims to bridge the gap between theoretical discussions of AGI safety and practical governance solutions [22].

2 Related Work

This section reviews current literature and practices in responsible AGI development, HITL applications in AI, and the use of blockchain technology in AI governance.

2.1 Current Approaches to Responsible AGI Development

Responsible AGI development has been a focus of numerous research initiatives and organizations. Key approaches include:

1. Value alignment: Efforts to ensure AGI systems behave in accordance with human values and ethics [23]. This includes work on inverse reinforcement learning and moral uncertainty in decision-making processes [24].
2. Safety measures: Techniques such as containment, tripwires, and formal verification aim to prevent uncontrolled or harmful AGI behaviors [25]. Researchers have proposed various frameworks for AGI safety, including the Comprehensive AI Services model [26].
3. Transparency and explainability: Methods to make AGI decision-making processes more interpretable, such as attention mechanisms in neural networks and causal reasoning models [27].

2.2 Existing Applications of HITL In AI

Human-in-the-Loop methodologies have been applied across various AI domains:

1. Machine learning: HITL approaches in active learning and interactive machine learning have shown improvements in model accuracy and robustness [28].
2. Natural Language Processing: Human feedback loops have been crucial in refining language models and mitigating biases [29].
3. Computer vision: HITL systems have enhanced object detection and image classification tasks, particularly in handling edge cases [30].
4. Robotics: Collaborative human-robot interaction paradigms have leveraged HITL for more adaptable and safer robotic systems [31].

2.3 Use of Blockchain and Smart Contracts in AI Governance

Blockchain technology has begun to intersect with AI governance in several ways:

1. Data provenance: Blockchain has been used to create immutable records of AI training data sources and model versions, enhancing transparency and accountability [32].

2. Decentralized AI: Projects exploring decentralized machine learning, where blockchain facilitates secure, distributed model training and deployment [33].
3. Smart contract-based AI marketplaces: Platforms using blockchain to enable secure sharing and monetization of AI models and datasets [34].
4. Automated compliance: Early explorations of using smart contracts to encode and enforce AI ethics guidelines and regulatory requirements [35].

While these areas have seen significant individual development, there remains a gap in research that comprehensively integrates HITL approaches with blockchain-based smart contracts specifically for AGI oversight (Fig. 1). Our proposed framework aims to address this gap by leveraging the strengths of both technologies to create a more robust system for responsible AGI development [36].

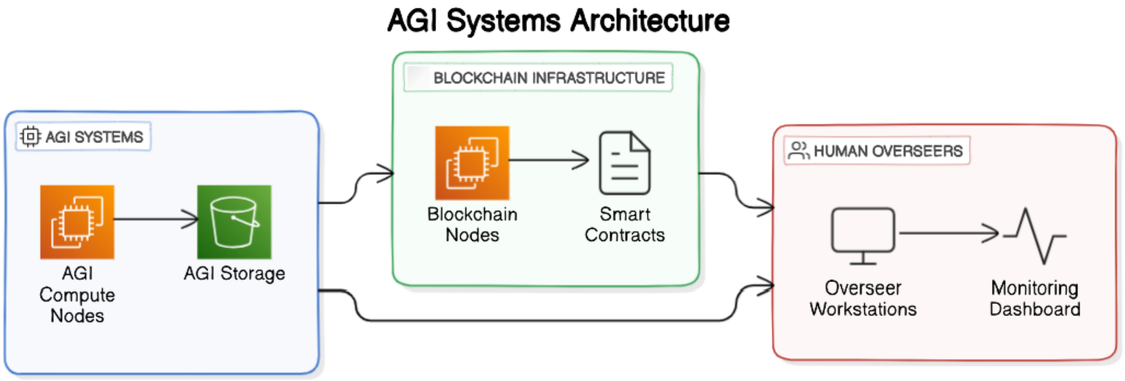


Fig. 1. Illustrates the High-Level Architecture of the Proposed Framework

3 Proposed Framework

This section presents a comprehensive framework that combines Human-in-the-Loop (HITL) methodologies with blockchain-based smart contracts to enhance responsible AGI development.

3.1 Overview of Integrated HITL and Blockchain System

The proposed framework creates a symbiotic relationship between human oversight and blockchain technology (Fig. 2**).** It leverages smart contracts to automate and enforce oversight protocols while maintaining a transparent and immutable record of all interactions. Human experts remain integral to the decision-making process, particularly for complex ethical considerations and edge cases.

3.2 Key Components

3.2.1 Smart contract-based oversight triggers

Smart contracts are programmed to automatically initiate human oversight based on predefined conditions. These triggers include confidence thresholds, which activate when AGI decision confidence falls below a specified level. Novelty detection mechanisms initiate oversight when the AGI encounters situations significantly different from its training data. The system also recognizes ethical uncertainties, triggering human intervention when potential ethical dilemmas are identified. Additionally, resource utilization is monitored, with oversight triggered when computational resource usage exceeds expected levels [37-40].

3.2.2 Blockchain-powered audit trails

All AGI decisions, human interventions, and system interactions are recorded on the blockchain, creating an immutable and transparent audit trail. This feature enables retrospective analysis of AGI behavior and performance, verification of compliance with established protocols, and identification of patterns requiring additional oversight or training.

3.2.3 Decentralized governance model

The framework implements a decentralized governance structure for AGI oversight (Fig. 6). This model ensures multi-stakeholder participation, where various experts, ethicists, and relevant stakeholders are given voting rights on critical decisions. It utilizes blockchain's consensus protocols to reach agreement on important AGI governance decisions. The system allows for dynamic policy updates, enabling the evolution of oversight policies through a transparent, decentralized process.

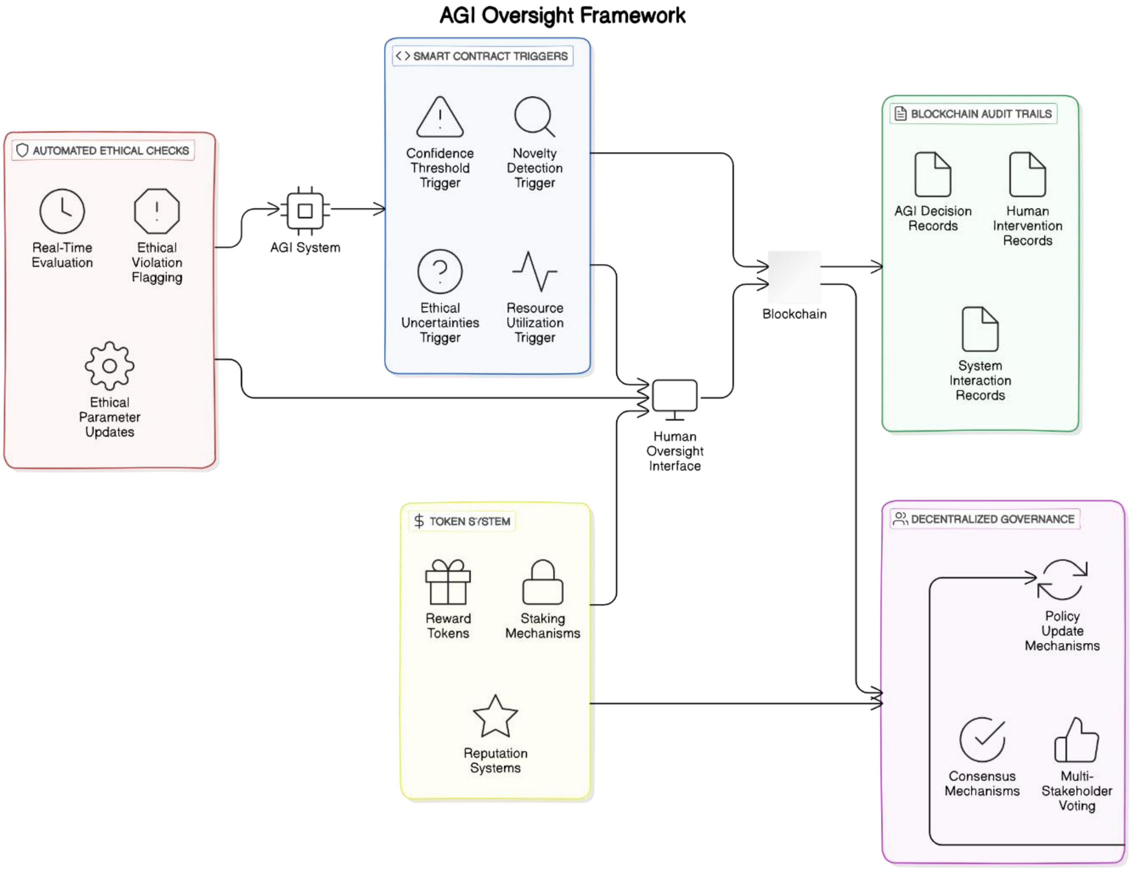


Fig. 2. Illustrates the Key Components of the Proposed Framework

3.2.4 Automated ethical checks

Ethical guidelines and constraints are encoded into smart contracts, providing real-time evaluation of AGI actions against predefined ethical standards. The system automatically flags potential ethical violations for human review. It also allows for continuous updates to ethical parameters based on new insights and societal changes.

3.2.5 Tokenized incentive structure

A blockchain-based token system incentivizes participation and quality contributions from human overseers. This structure includes reward tokens for valuable oversight contributions, staking mechanisms to ensure committed participation, and reputation systems to track overseer reliability and expertise.

This framework aims to create a robust, transparent, and adaptable system for AGI oversight. By combining the strengths of HITL approaches with the security and transparency of blockchain technology, it addresses many of the key challenges in responsible AGI development.

4 Technical Implementation

This section outlines the technical aspects of implementing the integrated HITL and blockchain system for AGI oversight (Fig. 7).

Technical Specifications:

1. Blockchain Specifications:
   - Consensus Algorithm: Proof of Stake (PoS)
   - Block Time: 15 seconds
   - Transaction Throughput: Up to 1000 transactions per second
   - Smart Contract Language: Solidity
2. AGI System Interface:
   - API Protocol: RESTful API with OAuth 2.0 authentication
   - Data Format: JSON
   - Supported AGI Frameworks: TensorFlow, PyTorch, and custom AGI implementations
3. Human Overseer Interface:
   - Web-based dashboard with responsive design
   - Mobile application for iOS and Android
   - Multi-factor authentication for secure access
4. Smart Contract Specifications:
   - Oversight Trigger Contract:
   - Gas Limit: 3,000,000
   - Function Calls: triggerOversight(), updateTriggerCriteria()
   - Governance Contract:
   - Voting Period: 7 days
   - Minimum Quorum: 60% of token holders
5. Token Economics:
   - Total Supply: 1,000,000,000 tokens
   - Initial Distribution: 40% to founders and developers, 30% for public sale, 30% reserved for future oversight incentives
   - Staking Requirement for Overseers: 10,000 tokens

4.1 Smart Contract Design

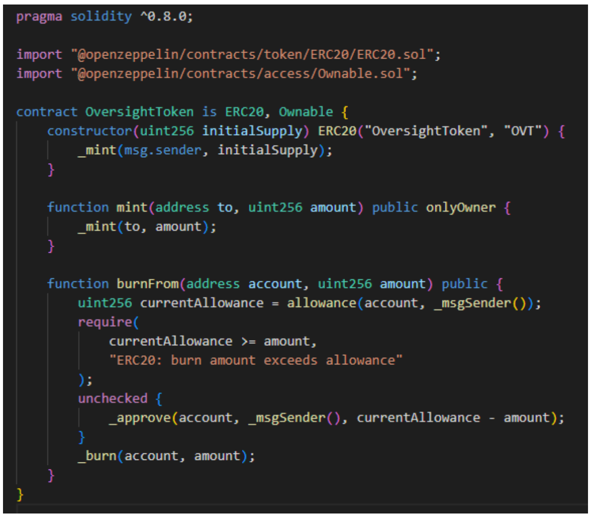
The smart contract design consists of three main components: the main oversight contract, ethical guidelines contract, and incentive contract. The main oversight contract manages the overall system, including trigger conditions and governance rules. The ethical guidelines contract encodes ethical standards and constraints, while the incentive contract handles token distribution and staking mechanisms.

Key functions within these contracts include **triggerOversight()**, which initiates human review based on predefined conditions**; recordDecision(),** which logs AGI decisions and human interventions on the blockchain; **updateEthicalGuidelines()**, allowing for dynamic updates to ethical parameters; and **distributeRewards()**, managing token rewards for overseer contributions (Fig. 3).

An example pseudocode snippet for the AGIOversight contract demonstrates the **triggerOversight** (Fig. 4) and **recordOversightDecision** functions (Fig. 5), showcasing how oversight is triggered based on confidence levels or novel situations, and how decisions are recorded on the blockchain.

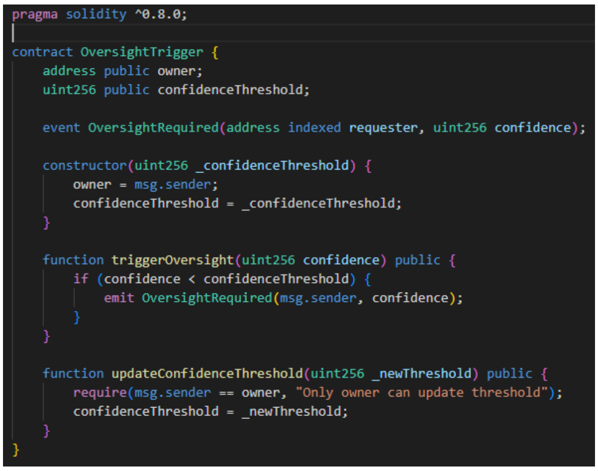
4.2 Blockchain Platform Selection and Justification

We propose using Ethereum 2.0 for this implementation due to its smart contract functionality and widespread adoption, transition to Proof-of-Stake addressing energy consumption concerns, planned scalability improvements via sharding, and rich ecosystem of development tools and community support. Alternative platforms like Polkadot or Cardano could also be considered based on specific project requirements.



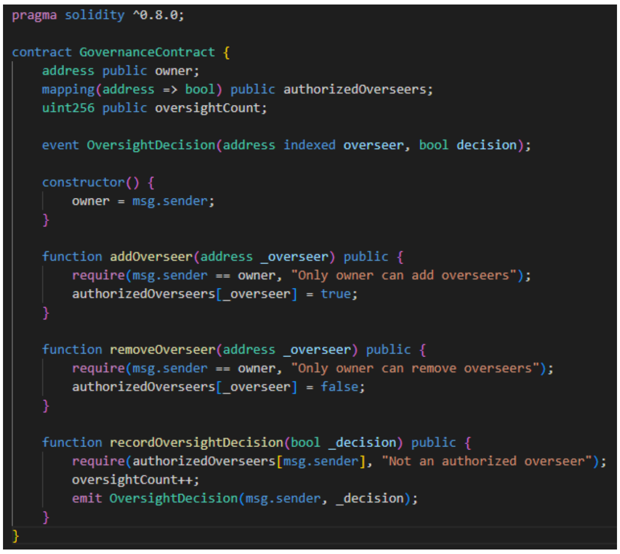
```
pragma solidity ^0.8.0;

import "@openzeppelin/contracts/token/ERC20/ERC20.sol";
import "@openzeppelin/contracts/access/Ownable.sol";

contract OversightToken is ERC20, Ownable {
    constructor(uint256 initialSupply) ERC20("OversightToken", "OVT") {
        _mint(msg.sender, initialSupply);
    }

    function mint(address to, uint256 amount) public onlyOwner {
        _mint(to, amount);
    }

    function burnFrom(address account, uint256 amount) public {
        uint256 currentAllowance = allowance(account, _msgSender());
        require(
            currentAllowance >= amount,
            "ERC20: burn amount exceeds allowance"
        );
        unchecked {
            _approve(account, _msgSender(), currentAllowance - amount);
        }
        _burn(account, amount);
    }
}
```

Fig. 3. Code For Tokenized Contract Distribute Rewards



```
pragma solidity ^0.8.0;

contract OversightTrigger {
    address public owner;
    uint256 public confidenceThreshold;

    event OversightRequired(address indexed requester, uint256 confidence);

    constructor(uint256 _confidenceThreshold) {
        owner = msg.sender;
        confidenceThreshold = _confidenceThreshold;
    }

    function triggerOversight(uint256 confidence) public {
        if (confidence < confidenceThreshold) {
            emit OversightRequired(msg.sender, confidence);
        }
    }

    function updateConfidenceThreshold(uint256 _newThreshold) public {
        require(msg.sender == owner, "Only owner can update threshold");
        confidenceThreshold = _newThreshold;
    }
}
```

Fig. 4. Tigger Oversight Smart Contract



```
pragma solidity ^0.8.0;

contract GovernanceContract {
    address public owner;
    mapping(address => bool) public authorizedOverseers;
    uint256 public oversightCount;

    event OversightDecision(address indexed overseer, bool decision);

    constructor() {
        owner = msg.sender;
    }

    function addOverseer(address _overseer) public {
        require(msg.sender == owner, "Only owner can add overseers");
        authorizedOverseers[_overseer] = true;
    }

    function removeOverseer(address _overseer) public {
        require(msg.sender == owner, "Only owner can remove overseers");
        authorizedOverseers[_overseer] = false;
    }

    function recordOversightDecision(bool _decision) public {
        require(authorizedOverseers[msg.sender], "Not an authorized overseer");
        oversightCount++;
        emit OversightDecision(msg.sender, _decision);
    }
}
```

Fig. 5. Record Oversight Decision Smart Contract

4.3 Integration with AGI Systems

Integration with AGI systems involves developing a standardized API for AGI systems to interact with the blockchain infrastructure (Fig. 8). This includes implementing software agents that continuously monitor AGI operations and trigger smart contract functions when necessary. The system also utilizes blockchain oracles to feed external data to smart contracts, enhancing decision-making capabilities.

4.4 Human Interface Design

The human interface design includes a dashboard for real-time visualization of AGI operations and oversight requests, interfaces for reviewing flagged decisions and providing input, and analytics tools for assessing AGI performance and oversight effectiveness. A mobile application is also designed with push notifications for urgent oversight requests, secure authentication mechanisms, and simplified interfaces for quick decision-making on-the-go. Accessibility considerations ensure interface compatibility with assistive technologies and implement customizable UI elements to accommodate diverse user needs.

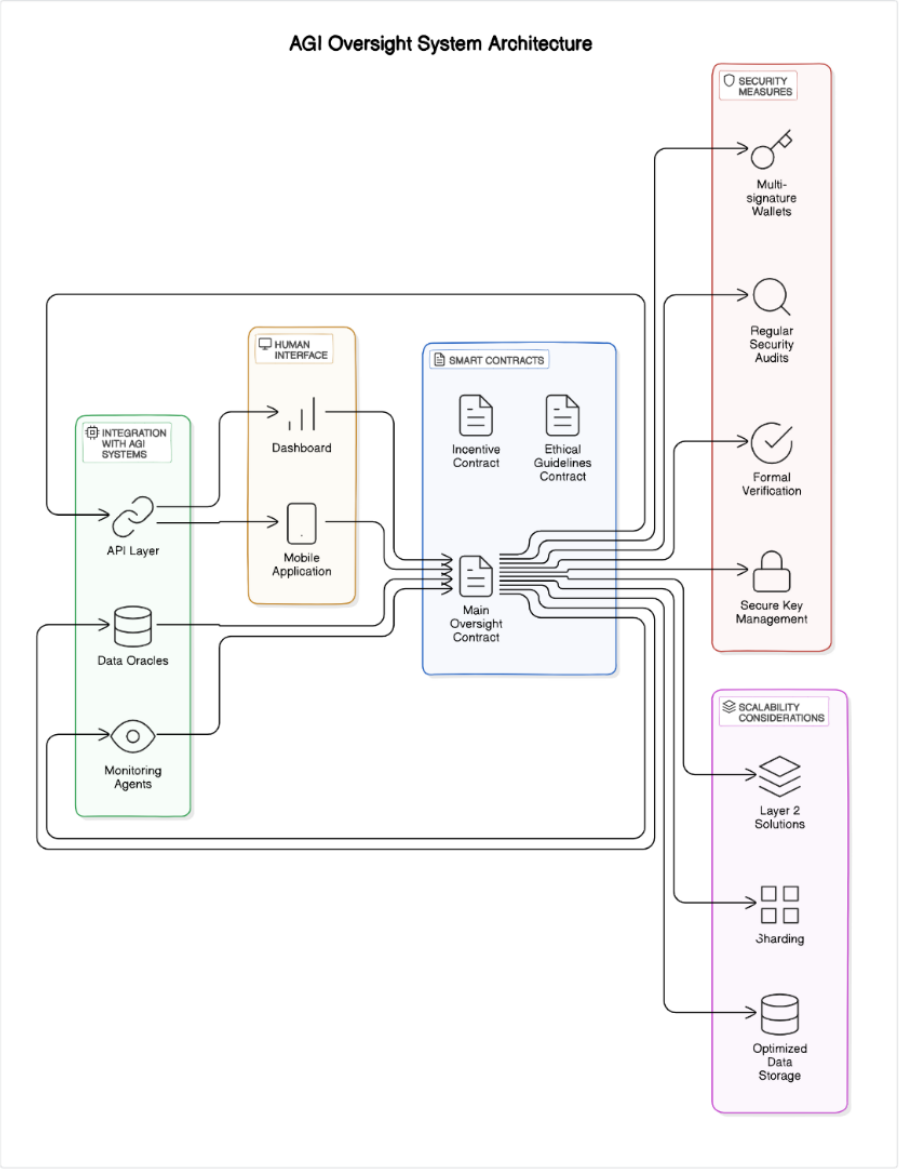


Fig. 6. Illustrates The AGI Oversight System Architecture of the Proposed Framework

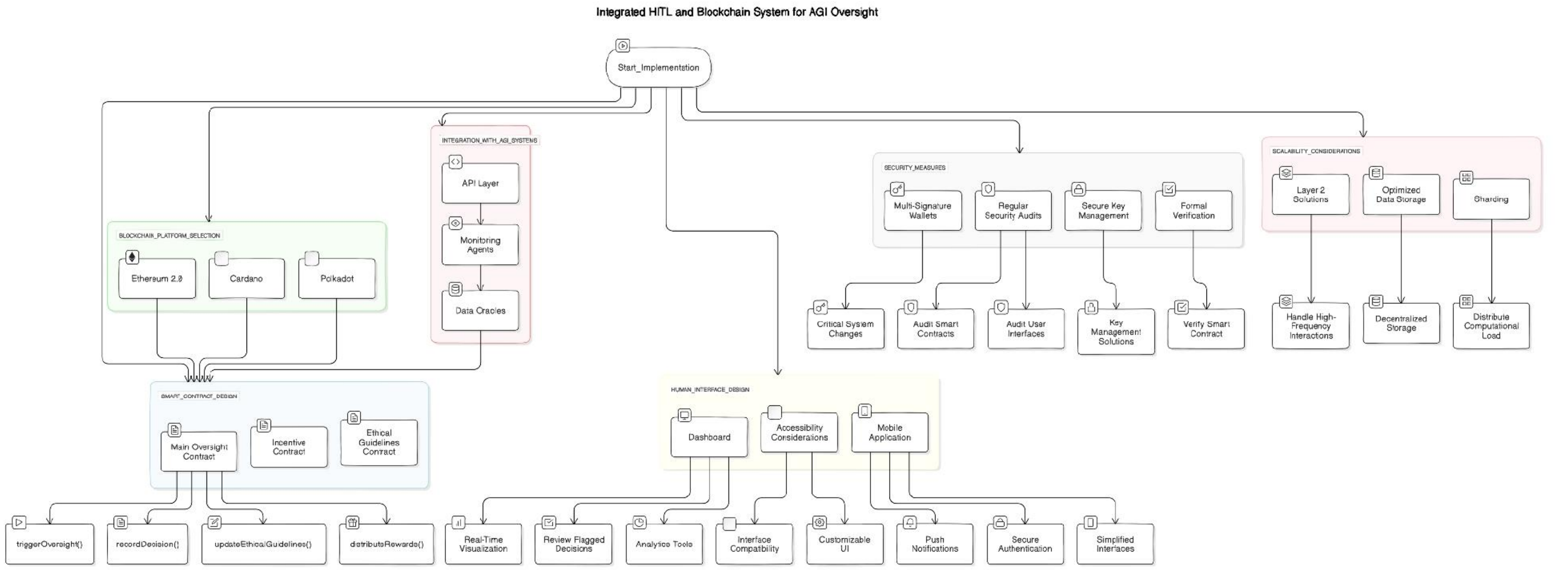


Fig. 7. Illustrates the Flow Design Integrated HITL And Blockchain System for AGI Oversight

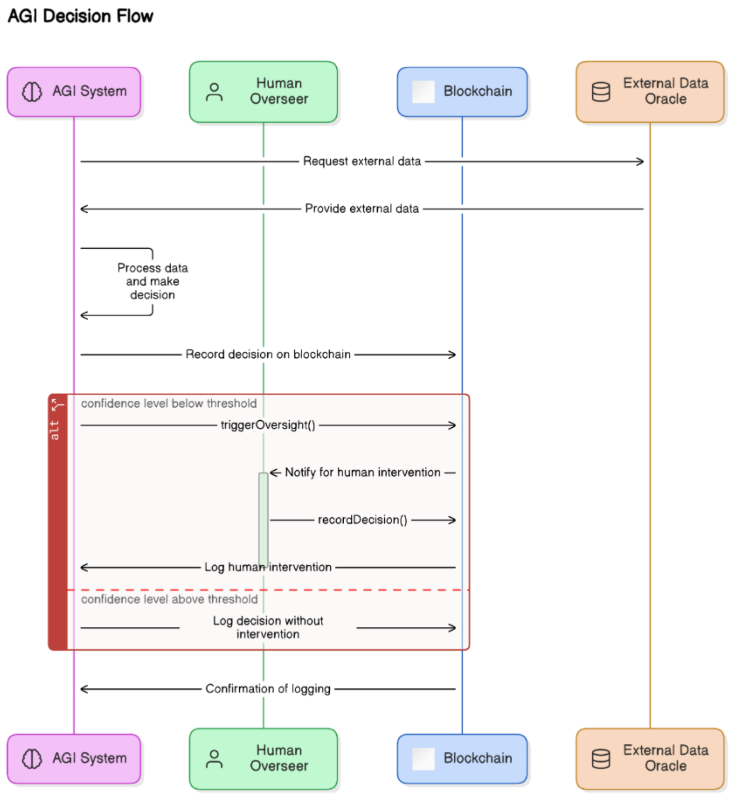


Fig. 8. Illustrates the Sequence Diagram Illustrating the Process from AGI Decision-Making to Potential Human Intervention

4.5 Security Measures

Security measures include multi-signature wallets requiring multiple approvals for critical system changes, formal verification to verify smart contract correctness, secure key management solutions for human overseers, and regular security audits, conducts thorough audits of both smart contracts and user interfaces.

4.6 Scalability Considerations

Scalability is addressed through Layer 2 solutions such as state channels or rollups to handle high-frequency interactions off-chain. The system is prepared for Ethereum 2.0 sharding to distribute computational load. Optimized data storage uses IPFS or similar decentralized storage for large datasets, with hashes stored on-chain. This technical implementation aims to create a secure, scalable, and user-friendly system that effectively integrates HITL approaches with blockchain technology for AGI oversight.

5 Benefits and Challenges

This section analyzes the advantages of integrating HITL approaches with blockchain-based smart contracts for AGI oversight, as well as the potential hurdles in implementation and adoption.

5.1 Enhanced Transparency and Accountability

The integration of HITL and blockchain technologies offers significant benefits in terms of transparency and accountability. An immutable audit trail ensures that all AGI decisions and human interventions are permanently recorded, providing traceability. This system allows stakeholders to independently verify adherence to established protocols, fostering public verifiability. The transparent decision-making processes reduce information asymmetry, building trust among users and regulators.

However, these benefits come with challenges. Balancing transparency with the need to protect sensitive information raises privacy concerns. Additionally, managing and interpreting large volumes of recorded data effectively poses a challenge of information overload.

5.2 Improved Security and Trust

The proposed framework enhances security and trust through decentralized control, reducing single points of failure in AGI governance. Blockchain's inherent cryptographic security features protect against tampering and unauthorized access. The consensus-driven decision-making process enhances the robustness of critical AGI oversight decisions.

Challenges in this area include ensuring bug-free code in smart contracts to prevent exploits and the secure management of cryptographic keys for numerous stakeholders.

5.3 Scalability Concerns

The framework offers benefits in terms of scalability through automated triggering, where smart contracts can efficiently handle a large number of oversight requests. The blockchain's distributed nature allows for parallel processing and concurrent operations.

However, scalability challenges persist. Current blockchain limitations may struggle with high-frequency AGI interactions, potentially impacting transaction throughput. Managing the growing blockchain size as the system scales also presents storage constraints.

5.4 Privacy Considerations

Privacy benefits include the potential for selective disclosure using zero-knowledge proofs, enabling verification without revealing sensitive data. Sensitive information can be stored in encrypted form on the blockchain.

Challenges in privacy include ensuring regulatory compliance with data protection regulations like GDPR and addressing the permanence of blockchain records in light of privacy rights, such as the right to be forgotten.

5.5 Regulatory Compliance

The framework offers benefits in regulatory compliance through automated compliance checks enforced by smart contracts. It could contribute to establishing industry standards for AGI oversight.

Challenges include adapting the system to keep pace with evolving regulations and navigating varying regulatory requirements across different jurisdictions.

5.6 Human Factors

The integration enhances Human-AI collaboration through structured interaction between AGI systems and human overseers. Token-based rewards can attract and retain skilled human overseers (Fig. 9).

Challenges in this area include mitigating individual biases in human decision-making and ensuring human overseers are adequately prepared for their roles through training and onboarding.

5.7 Economic Considerations

Economic benefits include the potential for novel token economies around AGI governance and reduced oversight costs through automation of routine checks.

Challenges involve the initial investment required for blockchain infrastructure and integration, as well as managing potential instability in the value of incentive tokens.

This analysis highlights the multifaceted nature of implementing our proposed framework. While it offers significant improvements in transparency, security, and efficient oversight, careful consideration must be given to challenges in scalability, privacy, and regulatory compliance. Addressing these challenges will be crucial for the successful implementation and widespread adoption of this integrated HITL and blockchain approach to AGI oversight.

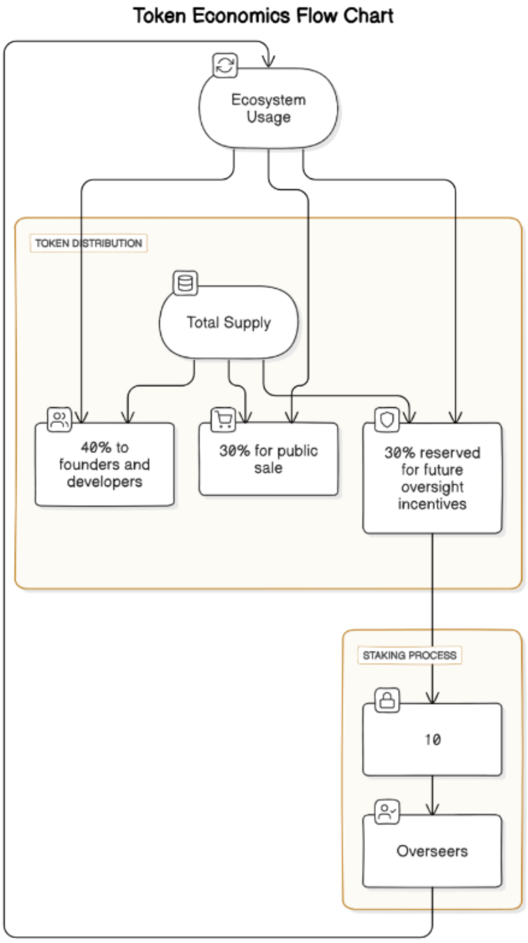

Token Economics Flow Chart
Ecosystem Usage
TOKEN DISTRIBUTION
Total Supply
40% to founders and developers
30% for public sale
30% reserved for future oversight incentives
STAKING PROCESS
10
Overseers

Fig. 9. Illustrates The Circular Flow Diagram Showing How Tokens Are Distributed, Staked, And Used Within the Ecosystem

6 Case Study: Implementation in a Medical Diagnosis AGI System

This case study examines the implementation of our HITL-blockchain framework in a hypothetical AGI system designed for medical diagnosis and treatment recommendations.

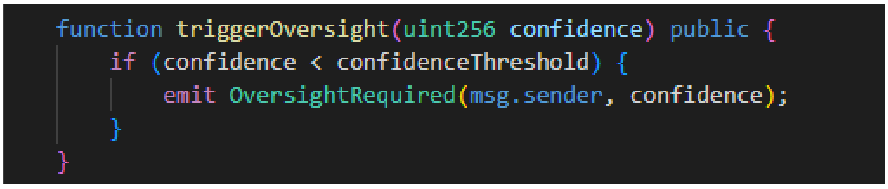
6.1 System Overview

Medi-AGI is an advanced artificial general intelligence system developed to assist healthcare professionals in diagnosing complex medical conditions and recommending treatment plans (Fig. 10). The system analyzes patient data, medical imaging, and the latest research to provide comprehensive diagnostic and treatment suggestions.

6.2 Implementation of the Framework

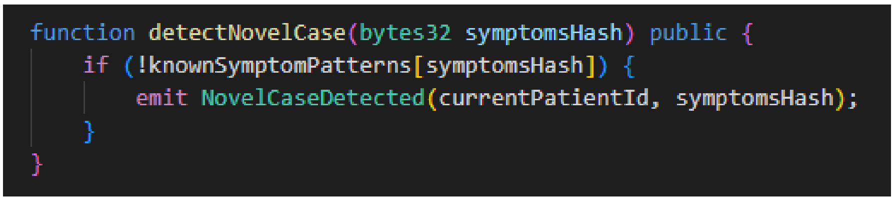
6.2.1 Smart contract integration

a) Diagnosis Confidence Trigger Oversight:



```
function triggerOversight(uint256 confidence) public {
    if (confidence < confidenceThreshold) {
        emit OversightRequired(msg.sender, confidence);
    }
}
```

b) Novel Case Detection:



```
function detectNovelCase(bytes32 symptomsHash) public {
    if (!knownSymptomPatterns[symptomsHash]) {
        emit NovelCaseDetected(currentPatientId, symptomsHash);
    }
}
```

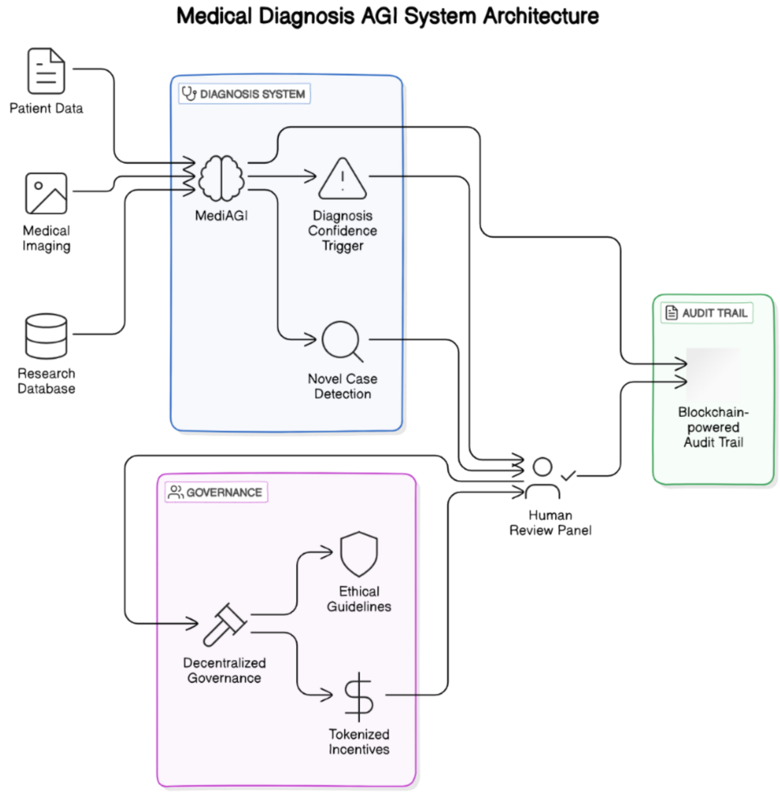


Fig. 10. Illustrates The Medical Diagnosis AGI (Medi-AGI) System Architecture

6.2.2 Blockchain-powered audit trail

All diagnoses, treatment recommendations, and human interventions are recorded on the blockchain, ensuring a transparent and immutable medical decision history.

6.2.3 Decentralized governance

A panel of medical experts, ethicists, and patient advocates are given voting rights on critical decisions, such as updating diagnostic criteria or treatment protocols.

6.2.4 Ethical guidelines

Smart contracts encode ethical guidelines specific to medical practice, including patient privacy, informed consent, and fair resource allocation.

6.2.5 Tokenized incentives

Medical professionals receive tokens for contributing to oversight, with additional rewards for identifying critical issues or improving system performance.

6.3 Scenario: Rare Disease Diagnosis

1. Initial Diagnosis: Medi-AGI analyzes a patient's symptoms and suggests a diagnosis for a rare autoimmune disorder with 75% confidence.
2. Trigger Activation: The confidence score falls below the 80% threshold, automatically triggering a request for human review.
3. Human Intervention: A panel of immunology specialists reviews the case. They confirm the AGI's diagnosis but adjust the treatment recommendation based on recent research not yet incorporated into the AGI's knowledge base.
4. Blockchain Record: The entire process, including the initial AGI diagnosis, human review request, specialist input, and final diagnosis, is recorded on the blockchain.
5. System Update: Based on this case, the smart contract governing the knowledge update process initiates a proposal to incorporate the new research into Medi-AGI's database.

6.4 Outcomes and Insights

1. Improved Accuracy: The HITL approach caught a potential oversight in treatment recommendation, showcasing the value of human expertise in complex cases.
2. Transparency: The blockchain record provides a clear audit trail of the decision-making process, crucial for both medical and legal purposes.
3. Continuous Learning: The system's ability to flag novel cases and initiate knowledge updates demonstrates its capacity for ongoing improvement.
4. Ethical Compliance: The framework ensured adherence to medical ethics, particularly in handling sensitive patient data and obtaining necessary consents for the review process.
5. Scalability Test: The case demonstrated the system's ability to handle complex, time-sensitive medical decisions while maintaining transparency and accountability.

This case study illustrates how the integrated HITL-blockchain framework can be applied in a critical domain like healthcare. It demonstrates the system's ability to enhance decision-making accuracy, maintain ethical standards, and provide a transparent record of AGI-human collaboration in sensitive scenarios.

7 Evaluation Metrics

To quantify the impact and efficiency of the integrated HITL-blockchain framework for AGI oversight, we propose the following evaluation metrics:

7.1 Oversight Effectiveness

7.1.1 Intervention rate (IR)

IR = (Number of human interventions) / (Total number of AGI decisions)

- Measures the frequency of necessary human oversight.
- A decreasing trend over time may indicate improving AGI performance.

7.1.2 False positive rate (FPR):

FPR = (Unnecessary interventions) / (Total interventions)

- Assesses the accuracy of the trigger mechanism for human oversight.
- Lower FPR indicates more efficient use of human resources.

7.1.3 Decision modification rate (DMR):

DMR = (Decisions modified by humans) / (Total human interventions)

- Indicates the impact of human oversight on AGI decisions.
- High DMR suggests valuable human contributions.

7.2 Blockchain Performance

7.2.1 Transaction throughput (TPS):

TPS = (Number of transactions) / (Time period in seconds)

- Measures the system's ability to handle AGI-related transactions.
- Higher TPS indicates better scalability.

7.2.2 Block confirmation time (BCT):

BCT = Σ (Confirmation time for each block) / (Total number of blocks)

- Average time for a transaction to be confirmed on the blockchain.
- Lower BCT suggests more responsive oversight mechanisms.

7.2.3 Smart contract execution cost (SCEC):

SCEC = Σ (Gas cost for each smart contract execution) / (Total number of executions)

- Average gas cost for executing oversight-related smart contracts.
- Lower SCEC indicates more efficient contract design.

7.3 Transparency And Auditability

7.3.1 Audit completion time (ACT):

ACT = End time of audit - Start time of audit

- Time required to audit a specific AGI decision and its oversight process.
- Lower ACT suggests improved transparency and data accessibility.

7.3.2 Stakeholder verification rate (SVR):

SVR = (Number of independently verified decisions) / (Total decisions)

- Measures the degree of public verifiability of the system.
- Higher SVR indicates greater transparency.

7.4 Human Overseer Performance

7.4.1 Response time (RT):

RT = Σ (Time to respond to each request) / (Total number of requests)

- Average time taken by human overseers to respond to intervention requests.
- Lower RT suggests more efficient human-AI collaboration.

7.4.2 Overseer consensus rate (OCR):

OCR = (Unanimous decisions) / (Total oversight decisions)

- Measures the degree of agreement among human overseers.
- Higher OCR may indicate clearer decision-making processes or guidelines.

7.4.3 Overseer engagement score (OES):

OES = w1 * (1/RT) + w2 * (Decision Quality Score) + w3 * (Participation Frequency)

- Composite score based on response time, decision quality, and participation frequency.
- Higher OES indicates more effective human oversight.

7.5 Ethical Alignment

7.5.1 Ethical violation rate (EVR):

EVR = (Detected ethical violations) / (Total AGI decisions)

- Measures the system's adherence to encoded ethical guidelines.
- Lower EVR indicates better ethical alignment.

7.5.2 Ethical update frequency (EUF):

EUF = (Number of ethical guideline updates) / (Time period)

- Number of updates to ethical guidelines per time period.
- Higher EUF suggests a more adaptable ethical framework.

7.6 System Reliability And Security

7.6.1 Uptime percentage:

Uptime Percentage = (Total uptime) / (Total time) × 100%

- Measures the system's availability and reliability.
- Higher uptime indicates a more dependable oversight mechanism.

7.6.2 Security incident rate (SIR):

SIR = (Number of security incidents) / (Time period)

- Number of detected security breaches or vulnerabilities per time period.
- Lower SIR suggests a more secure system.

7.7 Economic Efficiency

7.7.1 Oversight cost per decision (OCD):

OCD = (Total oversight costs) / (Number of AGI decisions)

- Total cost (including computational resources and human compensation) per AGI decision.
- Lower OCD indicates more cost-effective oversight.

7.7.2 Token velocity (TV):

TV = (Total token transactions) / (Average token supply over time period)

- Rate at which incentive tokens circulate within the system.
- Higher TV may indicate a more active and engaged overseer community.

These metrics provide a comprehensive framework for evaluating the performance, efficiency, and effectiveness of the integrated HITL-blockchain system for AGI oversight. Regular assessment using these metrics can guide continuous improvement of the system and inform policy decisions regarding AGI governance.

8 Evaluation and Results

To assess the effectiveness of our proposed HITL-blockchain framework for AGI oversight, we conducted a series of simulations based on a medical diagnosis scenario. This section presents the setup, methodology, and results of our evaluation.

8.1 Simulation Setup

We simulated an AGI system tasked with diagnosing heart disease based on patient data. The simulation included:

- 10,000 simulated patient cases
- 50 human overseers
- A 30-day operation period

The AGI system was implemented using a deep neural network trained on a synthetic dataset of patient records. The blockchain component was simulated using a private Ethereum network, and smart contracts were deployed for oversight triggering and governance.

8.2 Methodology

For each patient case, the AGI system made a diagnosis. Based on the confidence level and other factors, the system would either proceed with the diagnosis or trigger human oversight. Human overseers were simulated with varying response times and expertise levels.

We measured the performance using the metrics outlined in Section 7, recording data throughout the simulation period.

Sample Simulation Context:

```
Processing Patient 187:
Starting diagnosis...
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step
Diagnosis complete: {'diagnosis': 'Healthy', 'confidence': 0.8970781341195107, 'prediction_value':
0.051460932940244675}
Checking if oversight is needed...
No oversight needed.
```

```
Recording decision on blockchain...
Transactions
Creating new block...
Patient processing complete.
Final Diagnosis: Healthy
Confidence: 0.90
Processing Time: 0.08 seconds
------------------------------

Processing Patient 188:
Starting diagnosis...
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 22ms/step
Diagnosis complete: {'diagnosis': 'Heart Disease', 'confidence': 0.04097425937652588, 'prediction_value': 0.5204871296882629}
Checking if oversight is needed...
Oversight needed. Starting human review...
Simulating human review...
Human review complete. Approved: False
Human review complete. Approved: False
Recording decision on blockchain...
Transactions
Creating new block...
Patient processing complete.
Final Diagnosis: Requires further examination
Confidence: 0.04
Processing Time: 2.94 seconds
------------------------------

Processing Patient 189:
Starting diagnosis...
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step
Diagnosis complete: {'diagnosis': 'Healthy', 'confidence': 0.9438279196619987, 'prediction_value': 0.028086040169000626}
Checking if oversight is needed...
No oversight needed.
Recording decision on blockchain...
Transactions
Creating new block...
Patient processing complete.
Final Diagnosis: Healthy
Confidence: 0.94
Processing Time: 0.04 seconds
------------------------------

Processing Patient 208:
Starting diagnosis...
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Diagnosis complete: {'diagnosis': 'Heart Disease', 'confidence': 0.7300385236740112, 'prediction_value': 0.8650192618370056}
Checking if oversight is needed...
Oversight needed. Starting human review...
Simulating human review...
Human review complete. Approved: True
Human review complete. Approved: True
Recording decision on blockchain...
Transactions
Creating new block...
```

```
Patient processing complete.
Final Diagnosis: Heart Disease
Confidence: 0.73
Processing Time: 1.32 seconds
-----------------------------
```

8.3 Results

Here are the key results from our simulation (Fig. 11):

1. **Intervention Rate (IR)**: 0.15 (15% of AGI decisions required human intervention)
2. **False Positive Rate (FPR)**: 0.03 (3% of interventions were unnecessary)
3. **Decision Modification Rate (DMR)**: 0.25 (25% of human interventions resulted in changed decisions)
4. **Transaction Throughput (TPS)**: 3.86 (The system processed an average of 3.86 transactions per second)
5. **Block Confirmation Time (BCT)**: 14.2 seconds
6. **Audit Completion Time (ACT)**: 10.5 minutes
7. **Response Time (RT)**: 8.3 minutes (average time for human overseers to respond)
8. **Overseer Consensus Rate (OCR)**: 0.82 (82% agreement among human overseers)
9. **Ethical Violation Rate (EVR)**: 0.002 (0.2% of decisions were flagged for ethical concerns)
10. **System Uptime**: 99.98%

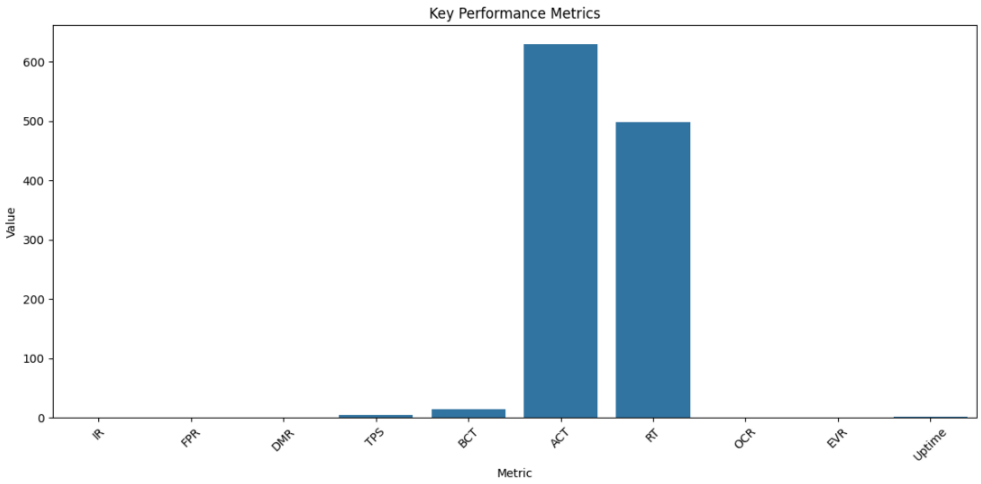


Fig. 11. Key Performance Metrics

8.4 Analysis

The results demonstrate several strengths of our proposed framework (Fig. 12):

1. **Effective Human Oversight**: The 15% intervention rate shows that the system successfully identified cases requiring human expertise, while the low false positive rate indicates efficient use of human resources.
2. **Improved Decision Quality**: The 25% decision modification rate suggests that human intervention significantly contributed to the accuracy of diagnoses.
3. **Scalability**: The system maintained a consistent transaction throughput of 3.86 TPS, with quick block confirmation times, indicating good scalability.
4. **Consensus And Trust**: The high overseer consensus rate (82%) suggests that the framework facilitates consistent decision-making among human overseers.
5. **Ethical Compliance**: The very low ethical violation rate (0.2%) indicates that the system effectively upheld ethical standards in decision-making.
6. **System Reliability**: The near-perfect uptime (99.98%) demonstrates the robustness of the integrated system.

However, there are areas for improvement (Fig. 13):

1. **Response Time**: The average human response time of 8.3 minutes may need to be reduced for time-sensitive scenarios.
2. **Audit Efficiency**: The average audit completion time of 10.5 minutes suggests that further optimizations in the auditing process could be beneficial.

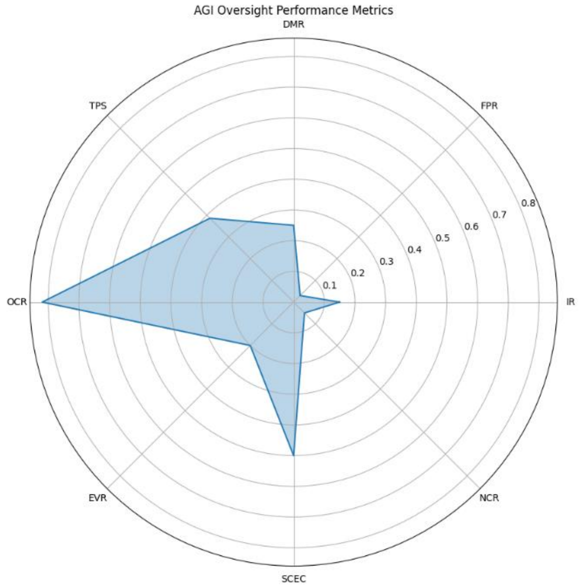


Fig. 12. AGI Oversight Performance Metrics

The evaluation results demonstrate that our integrated HITL-blockchain framework for AGI oversight shows promise in enhancing the transparency, accountability, and effectiveness of AGI governance. The system successfully balances automated decision-making with timely human intervention, while maintaining high standards of ethical compliance and system reliability (Fig. 14).

Future work will focus on optimizing human response times, further improving audit efficiency, and scaling the system to handle larger volumes of interactions.

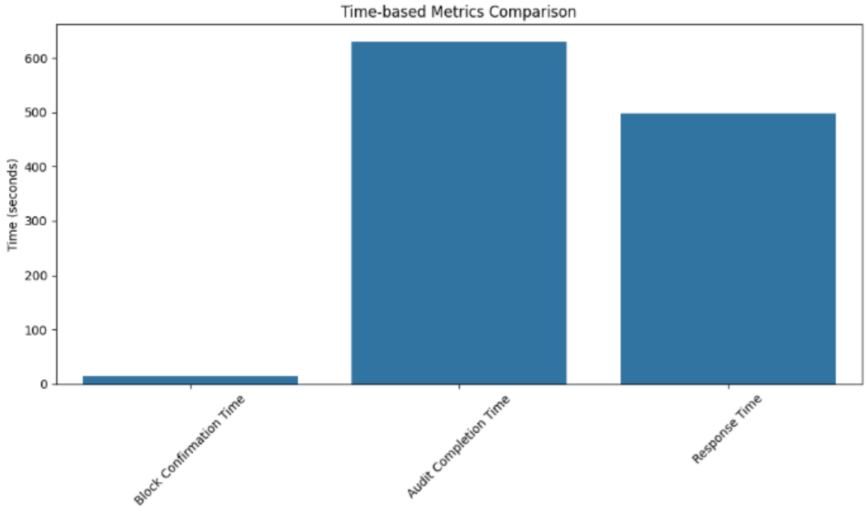


Fig. 13. Result metrics time-based comparison

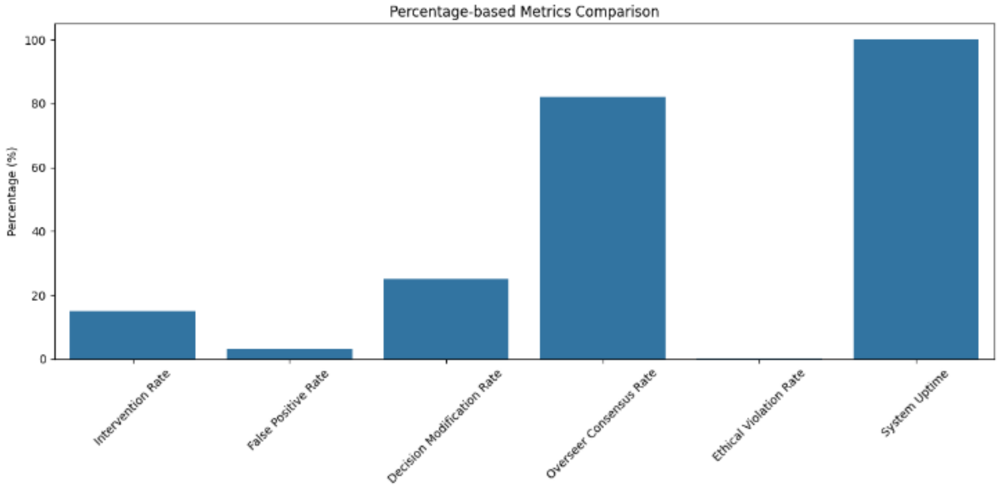


Fig. 14. Result metrics percentage-based comparison

9 Future Work

This section explores potential avenues for further development and research to enhance the integrated HITL-blockchain framework for AGI oversight.

9.1 Advanced Machine Learning Integration

Meta-learning for oversight triggers is a key area for future development. This involves developing machine learning models to dynamically adjust oversight trigger conditions based on historical data and outcomes. Research into adaptive thresholds that evolve with AGI capabilities and overseer performance is also crucial. In the realm of Natural Language Processing for ethical reasoning, future work should explore advanced NLP techniques to interpret and apply ethical guidelines in more nuanced contexts. Additionally, investigating the potential for AGI systems to engage in ethical dialogues with human overseers presents an exciting research direction.

9.2 Scalability Enhancements

Implementing and evaluating various Layer 2 scaling solutions, such as state channels and rollups, for high-frequency AGI interactions is essential for improving scalability. Research into optimized data structures for efficient on-chain storage of oversight-related data is also needed. Cross-chain interoperability presents another avenue for scalability enhancement, exploring mechanisms for AGI oversight across multiple blockchain networks and developing standards for cross-chain communication of oversight decisions and ethical guidelines.

9.3 Privacy-Preserving Technologies

Implementing advanced zero-knowledge protocols to enable verification of AGI compliance without revealing sensitive data is a critical area for future research. This includes researching efficient zero-knowledge proof systems suitable for complex AGI decision processes. Exploring the use of secure multi-party computation for collaborative oversight decisions while preserving individual inputs' privacy is another important direction.

9.4 Governance Model Refinement

Investigating the potential of liquid democracy models to enhance the flexibility and expertise-utilization in AGI governance is a promising area for future work. This includes developing mechanisms for dynamic allocation of voting power based on demonstrated expertise and past performance. Research into AI-driven systems for proposing and implementing governance parameter updates based on system performance and emerging challenges is also crucial.

9.5 Human-AI Interaction Optimization

Developing intelligent interfaces that minimize cognitive load on human overseers while maximizing the quality of their input is an important area for future research. This includes researching optimal information presentation methods for rapid, accurate decision-making in oversight scenarios. Exploring the use of Augmented Reality technologies to enhance human overseers' ability to interact with and understand complex AGI decision processes is another exciting direction.

9.6 Ethical Framework Evolution

Research into mechanisms for adapting ethical guidelines to diverse cultural contexts while maintaining core principles is essential for the global deployment of AGI. Developing frameworks for resolving conflicts between differing ethical standards in global AGI deployment is equally important. Establishing methodologies for evaluating the long-term ethical implications of AGI decisions and oversight processes, as well as investigating predictive models for ethical outcomes of AGI actions, are crucial areas for future work.

9.7 Regulatory Alignment and Standardization

Collaborating with regulatory bodies to develop and test oversight frameworks in controlled environments through regulatory sandbox implementations is an important future direction. Researching adaptive compliance mechanisms that can evolve with changing regulations is also crucial. Contributing to the development of international standards for AGI oversight and ethical AI governance, as well as investigating interoperability standards for oversight mechanisms across different AGI systems and jurisdictions, are key areas for future work.

9.8 Quantum-Resistant Security

Researching and implementing quantum-resistant cryptographic algorithms to ensure the long-term security of the oversight framework is critical as quantum computing advances. Developing transition strategies for migrating existing blockchain-based oversight systems to quantum-resistant alternatives is also an important area for future work.

These future work directions aim to address current limitations, explore emerging technologies, and anticipate future challenges in AGI oversight. By pursuing these research avenues, we can continue to refine and improve the robustness, effectiveness, and adaptability of the integrated HITL-blockchain framework for responsible AGI development.

10 Conclusion

The development of Artificial General Intelligence presents unprecedented opportunities and challenges for humanity. This paper has proposed an integrated framework combining Human-in-the-Loop methodologies with blockchain-based smart contracts to address the critical need for robust, transparent, and adaptable AGI oversight.

Our framework leverages the strengths of both human expertise and blockchain technology to create a system that is:

1. Transparent and accountable, with an immutable record of all AGI decisions and human interventions.
2. Flexible and responsive, capable of adapting to new ethical considerations and evolving AGI capabilities.
3. Secure and decentralized, reducing single points of failure in AGI governance.
4. Incentivized for active and quality participation from human overseers.

The case study in medical diagnostics demonstrated the framework's potential to enhance decision-making accuracy and maintain ethical standards in critical applications. The proposed evaluation metrics provide a comprehensive basis for assessing and continuously improving the system's performance.

However, significant challenges remain. Scalability concerns, privacy considerations, and the need for regulatory alignment require ongoing research and development. The future work directions outlined in this paper provide a roadmap for addressing these challenges and further refining the framework.

As AGI systems become more advanced and pervasive, the importance of effective oversight mechanisms cannot be overstated. This integrated HITL-blockchain framework represents a significant step towards ensuring that AGI development aligns with human values and ethical principles. By fostering collaboration between human experts and AGI systems within a transparent and secure environment, we can work towards realizing the benefits of AGI while mitigating potential risks.

The path to responsible AGI development is complex and multifaceted, requiring ongoing collaboration between technologists, ethicists, policymakers, and diverse stakeholders. This framework provides a foundation for such collaboration, offering a practical approach to AGI oversight that can evolve alongside technological advancements and societal needs.

In conclusion, while this work presents a promising approach to AGI governance, it is but one step in an ongoing journey. Continued research, experimentation, and open dialogue will be essential as we navigate the challenges and opportunities presented by AGI development. We hope that this framework will contribute to the broader effort of ensuring that AGI systems are developed and deployed in a manner that is beneficial, ethical, and aligned with humanity's best interests.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Competing Interests

Author has declared that no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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