

DarkForest: Defending the Authentic and Humane Web

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Introduction

In Liu Cixin's science fiction masterpiece "The Dark Forest," he presents a chilling theory of civilizational interaction:

*"The universe is a **dark forest**. Every civilization is an armed hunter stalking through the trees like a ghost, gently pushing aside branches that block the path and trying to tread without sound. Even breathing is done with care. The hunter has to be careful, because everywhere in the forest are stealthy hunters like him. If he finds other life—another hunter, an angel or a demon, a delicate infant or a tottering old man, a fairy or a demigod—there's only one thing he can do: open fire and eliminate them."*

This haunting metaphor has found new relevance in our digital age, giving rise to the "Dark Forest Theory of the Internet." [\[0\]](#) As our online spaces become increasingly exposed and interconnected, many are retreating to private, encrypted, or invite-only platforms for communication and content sharing. This trend towards digital isolationism threatens the open, collaborative nature of the internet that has driven innovation and connection for decades.

The rise of generative AI is rapidly accelerating this "dark forestisation" of the internet. As AI-generated content becomes increasingly sophisticated and ubiquitous, users are losing trust in the authenticity of the information they encounter online. Studies have shown a growing aversion to AI-generated content, with users preferring human-created material and seeking verified, authentic spaces for interaction [\[1\]](#).

Content hosting platforms are already grappling with an influx of AI-generated material, often indistinguishable from human-created content. This flood of artificial content is driving users away from open, public spaces towards closed, verified communities [\[2\]](#). It's crucial to note that AI-generated content isn't inherently problematic; the issue arises when it masquerades as human-created work, eroding trust and authenticity in our digital interactions.

Traditional verification methods and CAPTCHA systems are no longer sufficient to address this challenge. Even verified human users may be incentivized to post AI-generated content, especially on platforms predominantly featuring human-created material, as it allows them to "outperform" other creators in terms of quantity and consistency of output.

Problem Overview

The dark forestisation of the internet, accelerated by the proliferation of AI-generated content, presents several critical challenges. A wealth of supporting literature corroborates these challenges, reinforcing our thesis.

- ❖ **Erosion of Trust:** As users become increasingly unable to distinguish between human and AI-generated content, overall trust in online information diminishes [3].
- ❖ **Decline of Open Discourse:** The retreat to closed, verified spaces limits the free exchange of ideas and information that has been a hallmark of the internet [4].
- ❖ **Content Authenticity Crisis:** The flood of AI-generated content makes it difficult for genuine human creators to stand out and be recognized [5].
- ❖ **Platform Integrity Challenges:** Content hosting platforms struggle to maintain the integrity and value of their services in the face of AI-generated content [6].
- ❖ **Digital Literacy Burden:** Users are forced to develop increasingly sophisticated skills to navigate and verify online content [7].
- ❖ **Creative Disincentivization:** The ease of generating AI content may discourage human creativity and original content creation [8].

These challenges threaten to fundamentally alter the nature of online interaction, potentially leading to a fragmented, less innovative, and less human internet ecosystem.

DarkForest

DarkForest proposes a novel approach to safeguarding the authentic and humane web. We aim to become the vanguard in the arms race between AI-generated content and human-centric online spaces. Rather than leaving platforms to design isolated and vulnerable human-content verification systems independently, we position DarkForest as a product-focused research lab. Our mission is to cultivate collective defences against the proliferation of AI-generated content, built on the following key components:

Human Content Verification Scores [Appendix A]: Leveraging an in-house applied research lab solely dedicated to advancing human-content verification, we develop proprietary algorithms that can distinguish between human and AI-generated content with high accuracy and transparency. We work alongside our customers to identify novel strategies for detecting AI-generated content on their platforms, and use these insights to improve our systems and help future customers.

DarkForest Certification: Similar to HTTPS and Cloudflare badges, we introduce a "DarkForest Certified" badge for both individual users and platforms committed to maintaining primarily human-generated content. Customers may either pay DarkForest to continually certify their entire platform as primarily human-content based, or they may wish to integrate DarkForest certifications and scores at the content-creator level, providing users greater transparency on the content they consume and encouraging the spread of authentic content.

Reputation System: We develop a blockchain-native reputation system that considers not just users, but also accounts for their consistent production of

human-verified content. We implement a unique fingerprinting system for each piece of content, stored immutably on a blockchain, allowing for tracking of content provenance and evolution. Customers will be able to understand the spread of AI-generated content at any level of abstraction: users, topics and networks. If they choose to do so, customers may make their reputation management public and open-source, providing transparency around their moderation actions and crowdsourcing feedback from their user-base.

Platform Integration Tools: We provide APIs and plugins that allow content hosting platforms to easily integrate our verification systems into their existing infrastructure. Customers will use the DarkForest admin dashboard to decide exactly how they want to respond to and monitor the spread of AI-generated content on their platforms.

By providing these tools and services, DarkForest aims to:

- ❖ Empower content platforms and creators to maintain the integrity and value of their human-generated content.
- ❖ Provide users with trusted spaces for authentic, human interaction online.
- ❖ Support and incentivize human creativity in the digital age.
- ❖ Contribute to the preservation of an open, innovative internet ecosystem.

Importantly, DarkForest is not anti-AI; rather, we advocate for transparent and ethical use of AI in content creation. Our goal is to create a digital environment where human creativity can flourish, maintaining the authenticity and value of human-generated content. In the rapidly evolving landscape of online content, DarkForest stands as a guardian of human authenticity, working to ensure that the internet remains a space for genuine human connection, creativity, and discourse.

Demo

Our goal for the hackathon was to create a realistic scenario that demonstrates the potential use cases of a DarkForest product. We focused on developing three key components:

1. A simple content hosting platform (TruthBlog), serving as an example customer [Appendix [B.1](#)]
2. DarkForest’s API with human-content verification scores and blockchain integration [Appendix [B.2](#)]
 - a. A novel research proposal on how we plan to approach human-content verification [Appendix [A](#)]
3. DarkForest’s admin dashboard with content and user analysis for web hosts to protect and monitor their sites [Appendix [B.3](#)]

While our demo is a simplified version of the envisioned DarkForest system, it successfully showcases the value of creating human-first content spaces with transparent verification processes.

Process

Timeframe	Goals
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Next 3 months	- Establish DarkForest Research Lab, hiring AI researchers and cybersecurity experts, leveraging the founder's existing talent network at The Alan Turing Institute - Develop MVP of content verification API and blockchain-based fingerprinting system - Initiate conversations with potential early adopters (e.g., Substack, Medium)
2025	- Launch beta version of DarkForest badge system with select partners - Expand research into new modalities and unconventional data points for content verification, collaborating closely with customers - Develop and release platform-specific integrations for major content hosting sites - Secure first major customer (aim: Substack or similar platform)
2026	- Scale operations globally, targeting diverse content platforms across various languages and cultures - Introduce advanced features like real-time content analysis and user reputation systems - Establish DarkForest as an industry standard for human-content verification - Launch educational initiatives to increase public awareness about AI-generated content
2027	- Expand into new verticals (e.g., digital government services, email providers, social media platforms) - Develop predictive models for emerging AI content generation techniques - Host first DarkForest Summit, bringing together industry leaders, researchers, and policymakers - Explore partnerships with governments and international organisations for broader implementation

Key Risks & Mitigations

Risk	Mitigation
Adversarial attacks on our verification system	- Maintain closed-source verification algorithms and provide API access only to trusted potential customers - Leverage blockchain for malicious activity detection
False positives/negatives in content verification	- Employ ensemble verification methods and crowdsource human oversight for continual model training data
Privacy concerns related to content analysis	- Adopt privacy-by-design principles, use differential privacy techniques, and be transparent about data usage.
Evolving AI capabilities outpacing our verification methods	- Maintain a dedicated research team, foster academic partnerships, and implement a rapid update protocol for our systems

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[A] Research Proposal: Graph-Based Reinforcement Learning for Holistic Content Verification

Traditional approaches to content verification often rely on static analysis of the final content, overlooking valuable information embedded in the content creation process and its context within the broader digital ecosystem. We propose a novel framework that combines sequential decision-making with graph-based modelling, leveraging Reinforcement Learning (RL) to create a dynamic, adaptive system that learns from user workflows, content relationships, and network structures.

This approach promises to create a more robust, context-aware verification system capable of detecting sophisticated AI-generated content and coordinated inauthentic behaviour. By considering both the temporal aspects of content creation and the interconnected nature of digital content, we aim to push the boundaries of content verification technology.

Problem Formulation

We model the content ecosystem as a heterogeneous graph $G = (V, E)$, where:

- **Vertices (V):** Represent different entities (posts, users, websites, topics)
- **Edges (E):** Represent relationships between entities (authorship, similarity, interaction)

Within this graph structure, we formulate content verification as a Markov Decision Process (MDP):

- **States (S):** Represent the current state of the content, associated metadata, and the local graph structure around the content.
- **Actions (A):** Correspond to the system's decisions about the content's authenticity at each step (e.g., human-likely, AI-likely, uncertain).
- **Transitions (T):** Capture how user actions and network interactions change the state of the content and its surrounding graph structure.
- **Rewards (R):** Reflect the accuracy of the system's decisions, validated through various means (e.g., user feedback, expert review, cross-platform verification) and incorporating feedback from connected entities in the graph.
- **Policy (π):** A function that maps from graph-structured states to actions, determining the strategy for making decisions about content authenticity.

Methodology

Data Collection:

- Capture fine-grained user interactions during content creation (keystrokes, pauses, edits, cursor movements).
- Record metadata (time of day, user history, device information).
- Log intermediate content states throughout the creation process.
- Collect relational data to construct the content graph (user interactions, content similarities, sharing patterns).

Feature Engineering:

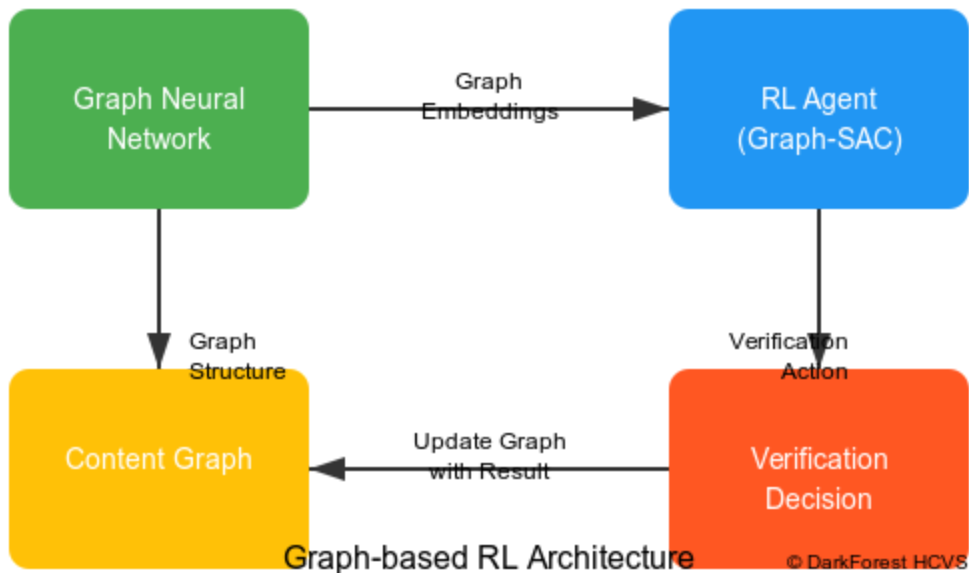
- Develop temporal features that capture the evolution of content over time.
- Create user behaviour profiles based on interaction patterns.

- Extract linguistic features at various stages of content development.
- Design graph-based features that capture the structural properties of content within its network.

Graph Construction:

- Create nodes for users, posts, websites, and topics.
- Establish edges based on authorship, content similarity, user interactions, and topical relationships.
- Assign initial attributes to nodes based on available metadata and preliminary content analysis.
- Implement methods for dynamically updating the graph as new content is created and new relationships form.

Graph Neural Network Architecture:



- Implement a multi-layer Graph Attention Network (GAT) to process the heterogeneous graph.
- Use attention mechanisms to weigh the importance of different types of neighbouring nodes.
- Incorporate temporal information by using recurrent layers in node update functions.

Reinforcement Learning Algorithm:

- Implement a Graph-based Soft Actor-Critic (Graph-SAC) algorithm as the base RL method.
- Utilise the graph embeddings produced by the GNN as part of the state representation for the RL agent.
- Implement prioritised experience replay to focus on the most informative trajectories.
- Design a reward function that considers both local content authenticity and global graph coherence.

Training Process:

- Start with a pre-training phase on historical data to initialise the graph structure and RL policy.
- Continuously update the graph and policy in an online manner as new content is created.
- Periodically perform batch updates to refine the global graph structure and policy.

Real-time Adaptation:

- Deploy the trained policy in an online learning setting.
- Continuously update the policy based on new interactions and feedback.
- Implement drift detection to identify when the policy needs significant retraining.

Novel Contributions

- **Multi-modal Input Processing:** Incorporate not just textual content, but also user behaviour data, temporal patterns, and platform-specific metadata into the state representation.
- **Hierarchical Reinforcement Learning:** Implement a hierarchical structure where high-level policies make decisions about overall content authenticity, while low-level policies focus on specific aspects (e.g., writing style, factual consistency).
- **Adversarial Training:** Regularly pit the verification system against AI content generators, creating a self-improving loop that enhances robustness.
- **Explainable AI Integration:** Develop methods to extract human-interpretable rules from the learned policy, enhancing transparency and trust in the verification process.
- **Cross-platform Learning:** Design the RL framework to transfer knowledge between different content platforms, allowing for faster adaptation to new environments.
- **Multi-entity Verification:** Develop a system that simultaneously verifies multiple related pieces of content, considering their interconnections and mutual influence.
- **User-Content Co-evolution:** Model how user trustworthiness and content authenticity evolve together over time, capturing the dynamic nature of online ecosystems.
- **Graph-based Anomaly Detection:** Utilise graph structure to identify unusual patterns or clusters of potentially inauthentic content that might not be apparent when examining posts in isolation.

Expected Outcomes

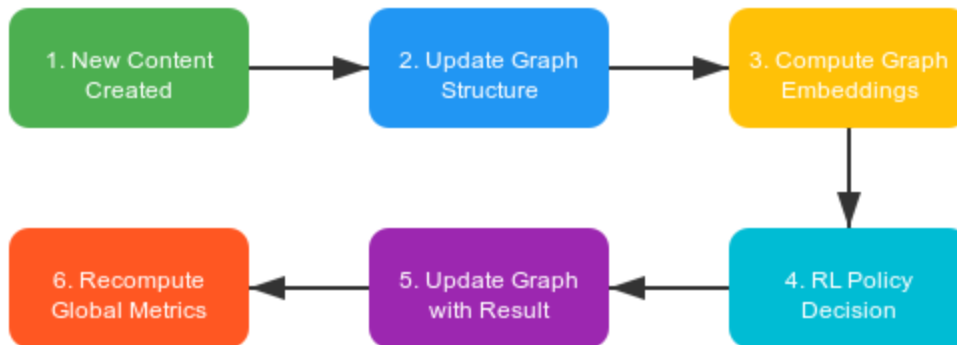
- A real-time, adaptive content verification system that improves with each user interaction and network change.
- Insights into human vs. AI content creation patterns that evolve over time and across network structures.
- A flexible framework that can be customised for different content platforms and types.
- Improved accuracy in detecting sophisticated AI-generated content that mimics human behaviour.

- A holistic verification system that considers the broader context of content creation and dissemination.
- Enhanced capability to detect coordinated inauthentic behaviour across multiple posts or users.
- Deep insights into how information and content authenticity propagate through online networks.

Challenges and Mitigations

- **Data Privacy:** Implement differential privacy techniques to protect user information.
- **Computational Efficiency:** Utilise efficient RL algorithms and distributed computing for real-time processing.
- **Bias Mitigation:** Regularly audit the system for biases and implement fairness constraints in the RL objective.
- **Scalability:** Implement efficient graph neural network architectures and sampling techniques to handle large-scale graphs.
- **Dynamic Nature:** Develop methods for incremental learning and graph updating to handle the rapidly changing nature of online content.
- **Interpretability:** Design visualisation tools to help understand how graph structure influences verification decisions.

Verification Workflow



Content Verification Workflow

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1. When new content is created, dynamically update the graph structure.
2. Use the GNN to compute embeddings for the new content and its local graph neighbourhood.
3. Feed these embeddings into the RL policy to make a verification decision.
4. Update the graph based on the verification result and any subsequent user interactions.
5. Periodically recompute global graph metrics to identify large-scale patterns or anomalies.

[B] Demo Components

The repository and instructions for replicating this demo can be found at <https://github.com/muzz-yasir/apart/tree/main>

[B.1] Example Customer:

TruthBlog is a fictional blogging platform that integrates our Human Content Verification System (HCVS). Key features include:

- Real-time content analysis as users type
- Visual representation of human vs. AI probability for each post
- Integration with our HCVS API for content verification
- Display of verification badges on published posts

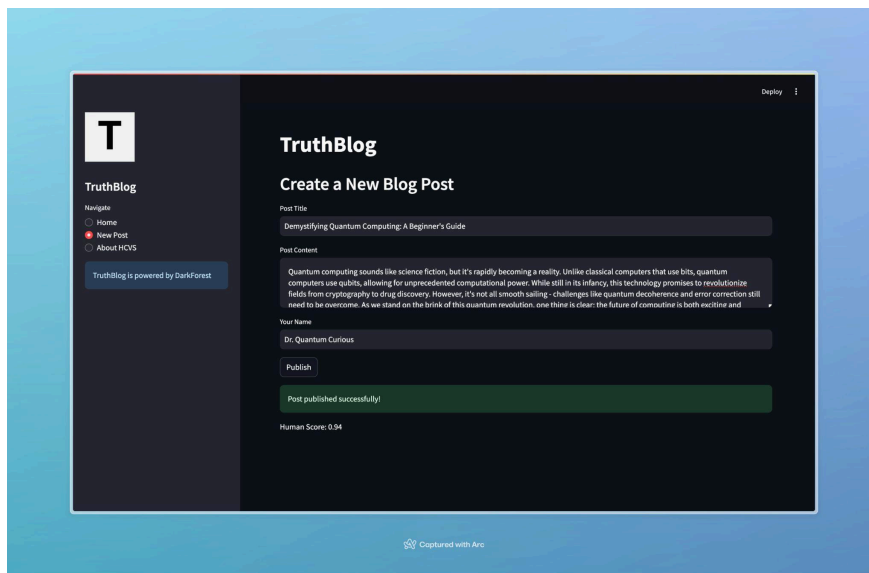


Figure 1: TruthBlog user interface showing real-time content analysis

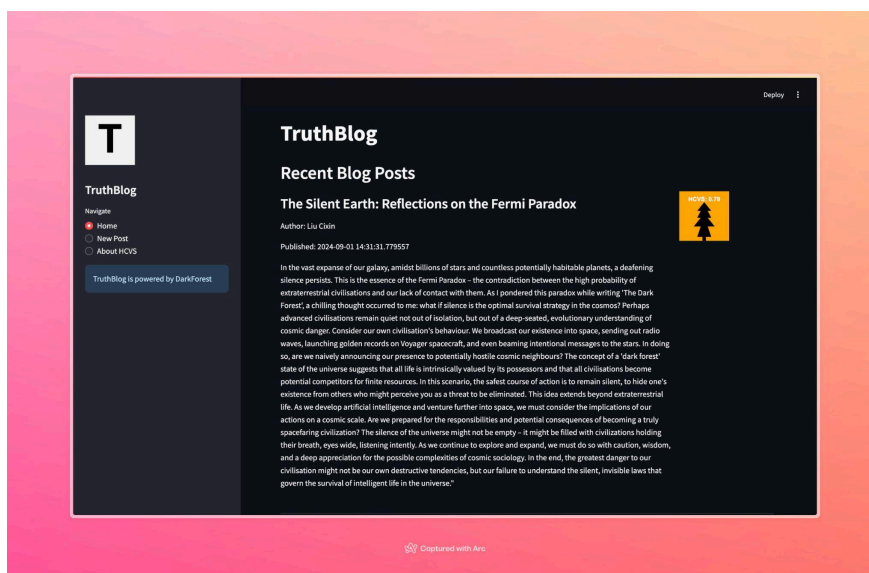


Figure 2: TruthBlog post view showing DarkForest verification badge and score for a given post

[B.2] DarkForest API

Our API provides the backbone for content verification:

- Content fingerprinting using SHA-256 hashing
 - Basic fingerprinting system using SHA-256 hashing, allowing for quick similarity checks between posts.
- Simulated AI detection using a basic linguistic model
- Blockchain integration for immutable record-keeping
 - Simple blockchain structure to store verification records, ensuring transparency and immutability.
- Endpoints for content verification and creator authentication

```
def calculate_human_score(content):  
    # Tokenize the content  
    tokens = word_tokenize(content.lower())  
  
    # Remove stopwords  
    stop_words = set(stopwords.words('english'))  
    tokens = [token for token in tokens if token not in stop_words]  
  
    # Calculate lexical diversity  
    lexical_diversity = len(set(tokens)) / len(tokens) if tokens else 0  
  
    # Calculate sentence length variation  
    sentences = sent_tokenize(content)  
    sentence_lengths = [len(word_tokenize(sentence)) for sentence in sentences if sentence.strip()]  
    sentence_length_variation = statistics.stdev(sentence_lengths) if len(sentence_lengths) > 1 else 0  
  
    # Check for overused words or phrases (common in AI-generated text)  
    word_freq = Counter(tokens)  
    overused_words = sum(1 for word, count in word_freq.items() if count > len(tokens) * 0.1)  
  
    # Calculate final score (adjust weights as needed)  
    score = (  
        0.4 * lexical_diversity +  
        0.3 * min(sentence_length_variation / 5, 1) +  
        0.3 * (1 - overused_words / len(set(tokens)) if set(tokens) else 0)  
    )  
  
    return min(max(score, 0), 1) # Ensure score is between 0 and 1
```

Figure 3: Simulated AI content detection

```

class Block:
    def __init__(self, index, timestamp, data, previous_hash):
        self.index = index
        self.timestamp = timestamp
        self.data = data
        self.previous_hash = previous_hash
        self.hash = self.calculate_hash()

    def calculate_hash(self):
        block_string = json.dumps(self.__dict__, sort_keys=True)
        return hashlib.sha256(block_string.encode()).hexdigest()

class Blockchain:
    def __init__(self):
        self.chain = [self.create_genesis_block()]

    def create_genesis_block(self):
        return Block(0, str(datetime.now()), "Genesis Block", "0")

    def get_latest_block(self):
        return self.chain[-1]

    def add_block(self, data):
        previous_block = self.get_latest_block()
        new_block = Block(len(self.chain), str(datetime.now()), data, previous_block.hash)
        self.chain.append(new_block)
        return new_block.hash

    def is_chain_valid(self):
        for i in range(1, len(self.chain)):
            current_block = self.chain[i]
            previous_block = self.chain[i-1]
            if current_block.hash != current_block.calculate_hash():
                return False
            if current_block.previous_hash != previous_block.hash:
                return False
        return True

```

Figure 4: Basic blockchain integration

```

@app.post("/v1/verify")
async def verify_content(request: ContentVerificationRequest):
    verification_id = str(uuid.uuid4())

    if request.type == "text":
        human_score = calculate_human_score(request.content)
    else:
        # For non-text content, use a placeholder score
        # In a real system, you'd implement specific verification for images, videos, etc.
        human_score = 0.5

    transaction_data = {
        "verification_id": verification_id,
        "content_hash": hashlib.sha256(request.content.encode()).hexdigest(),
        "human_score": human_score,
        "timestamp": str(datetime.now())
    }
    block_hash = blockchain.add_block(transaction_data)

    post = {
        "id": verification_id,
        "title": request.metadata.get("title", "Untitled"),
        "content": request.content,
        "author": request.metadata.get("author", "Anonymous"),
        "human_score": human_score,
        "blockchain_hash": block_hash,
        "timestamp": str(datetime.now())
    }
    posts.append(post)

    return {
        "verification_id": verification_id,
        "human_score": human_score,
        "ai_probability": 1 - human_score,
        "certification_token": f"HCVS-{random.randint(1000000, 9999999)}",
        "blockchain_hash": block_hash,
        "timestamp": str(datetime.now())
    }

```

Figure 5: Verification endpoint

[B.3] DarkForest Dashboard: Visualizing Content Integrity

The HCVS Dashboard provides platform administrators with insights into content authenticity:

- Overview of human vs. AI-generated content ratios
- Content similarity detection and visualisation
- Blockchain explorer for verification transparency
- User trust score tracking

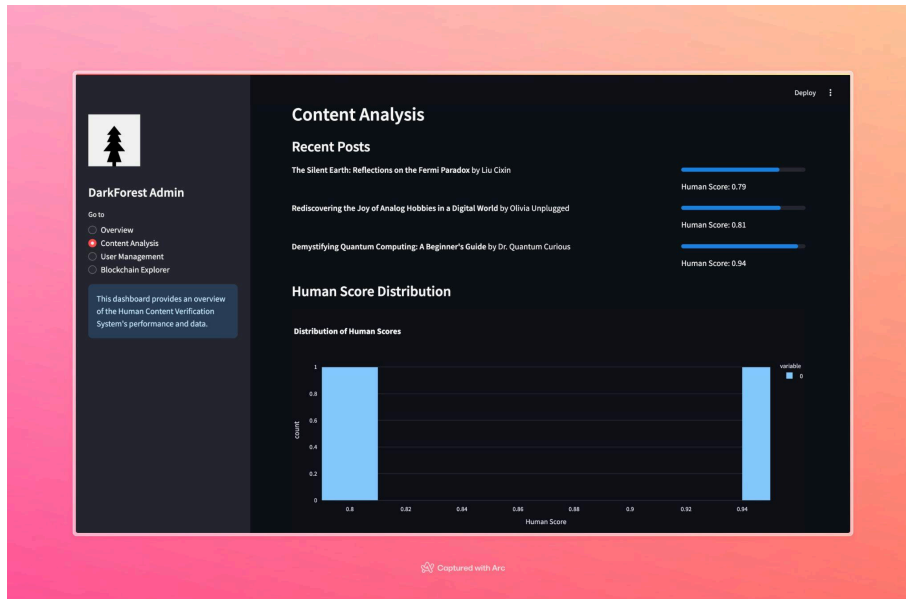


Figure 6: DarkForest Dashboard showing content score analysis

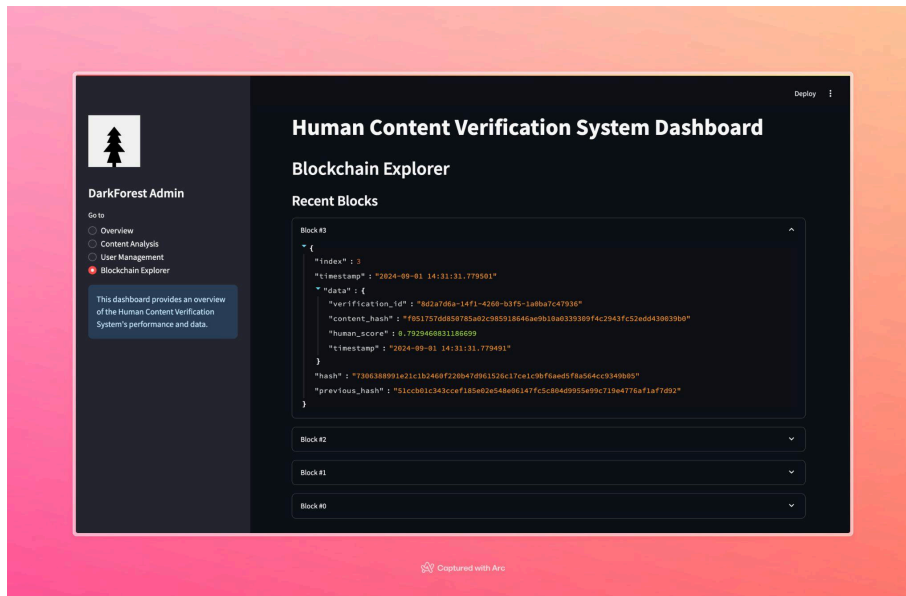


Figure 7: DarkForest Dashboard for blockchain exploration