Autonomous Construction Safety Incentive Mechanism using Blockchain-Enabled Tokens and Vision-Based Techniques

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INTRODUCTION

MOTIVATION
Introduction and Motivation

Safety Performance in Construction Industry
- Reducing likelihood of workers accidents
- Improved productivities and efficiency
- Contractor reputation

Incentive Mechanism in Construction Industry
- Reinforce positive safety culture
- Encourage safe behavior
- Improve Safety Performance
LIMITATION
## Existing Challenges of Incentive Mechanism in Construction Industry

<table>
<thead>
<tr>
<th>Intermediary-based Architecture</th>
<th>Massive paperwork</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Traceability</td>
<td>Lack of social recognition-based reward</td>
</tr>
<tr>
<td>Lack of Transparency</td>
<td>Lack of Anti-fraud reward</td>
</tr>
<tr>
<td>Lack of Real-time inspection</td>
<td>Lack of Enforceability</td>
</tr>
</tbody>
</table>
RELATED WORK
Construction payment automation using blockchain-enabled smart contracts and robotic reality capture technologies

Hesam Hamledari a, *, Martin Fischer b
Related work

Digital building twins and blockchain for performance-based (smart) contracts
Jens J. Hunheicza,*, Mahshid Motiea,b, Daniel M. Hall

Incentivize contractor in energy optimization effort
Proposed research
Research Goals

Propose an industry-wide **Dapp framework** that automates incentive management using FTs and NFTs across construction companies

**Implementation** of a full-stack version of the Dapp to validate the feasibility and applicability of the proposed framework
Study method adapted from Design science research (DSR) approach
Why blockchain?

How Can a Blockchain-Based Solution Address Existing Issues?
Framework Overview

Overall architecture of the proposed Dapp
Decentralized oracle network (DON)

The mechanism of decentralized oracle network (DON) and its interaction with other modules
Design of SafetyCredit smart contracts and the interactions between functions
Decentralized App Implementation
Decentralized Application development

(a) Planning Stage
- Define Scope
- Define Safety Performance

(b) Back-End Development
- Develop computer vision model
- Develop smart contracts

(c) Front-End Development
- Home Page
- Owner Page
- Contractors Page

(d) Implementation Stage
- Preparation
- Performance testing
- Results
Planning stage

Safety performance index (SP)

This model detects the number of people wearing/not wearing safety helmets, calculates the safety performance score

\[
SP = \frac{\text{(Number of safe behavior)}}{\text{(Total number of behavior observed)}} \times 100
\]

e.g. SP = 2/5
Front-End Development

Tools:
- Metamask
- Web3.Js
- Javascript
- ReactJs
- HTML
- CSS
Back-End Development:

Smart contract

Tools: Solidity

Remix IDE
Training Details

**YOLOv5**
PyTorch learning framework

**Dataset:**
7,580 images (SHWDr)
2 classes: Head and Helmet
Training and Validation set ratio: 85:15
Test: 180 images

**Hardware configuration:**
Windows 10 operating system
AMD Ryzen Threadripper 3960X CPU
GeForce RTX 3090 GPU

Test images

Predicted
Workflow of Computer Vision module
Computer vision module performance

(a) Mean Average Precision (b) Precision-Recall curve

<table>
<thead>
<tr>
<th>Class</th>
<th>mAP@0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>94.1%</td>
</tr>
<tr>
<td>Helmet</td>
<td>86.5%</td>
</tr>
<tr>
<td>All</td>
<td>90.3%</td>
</tr>
</tbody>
</table>

The performance of the Helmet Detection model
Implementation flow

Sequence diagram of implementing the Dapp
Implementation Result
## Transaction results of implementing the Dapp on the Rinkeby testnet

<table>
<thead>
<tr>
<th>Operations</th>
<th>From</th>
<th>Step</th>
<th>Smart Contract</th>
<th>Gas usage</th>
<th>Tx fee (eth)</th>
<th>fee (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract deployment</td>
<td>Owner</td>
<td>(b)</td>
<td>SCTFactory</td>
<td>1,793,391</td>
<td>0.004483</td>
<td>6.42</td>
</tr>
<tr>
<td>Contract deployment</td>
<td>Owner</td>
<td>(b)</td>
<td>SCO</td>
<td>3,287,458</td>
<td>0.008218</td>
<td>11.77</td>
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<tr>
<td>Contract deployment</td>
<td>Owner</td>
<td>(b)</td>
<td>SCNFT</td>
<td>3,517,441</td>
<td>0.0087936</td>
<td>12.60</td>
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<tr>
<td>Link contracts</td>
<td>Owner</td>
<td>(c)</td>
<td>SCFactory</td>
<td>46,519</td>
<td>0.000116</td>
<td>0.17</td>
</tr>
<tr>
<td>Link contracts</td>
<td>Owner</td>
<td>(c)</td>
<td>SCO</td>
<td>68,504</td>
<td>0.000171</td>
<td>0.25</td>
</tr>
<tr>
<td>Prepare NFT</td>
<td>Owner</td>
<td>(c)</td>
<td>SCNFT</td>
<td>114,917</td>
<td>0.000287</td>
<td>0.41</td>
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<tr>
<td>fund Oracle</td>
<td>Owner</td>
<td>(c)</td>
<td>SCO</td>
<td>31,087</td>
<td>0.000078</td>
<td>0.11</td>
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<tr>
<td>Link contracts</td>
<td>Owner</td>
<td>(c)</td>
<td>SCNFT</td>
<td>46,857</td>
<td>0.000117</td>
<td>0.17</td>
</tr>
<tr>
<td>Register contractors</td>
<td>Owner</td>
<td>(e)</td>
<td>SCFactory</td>
<td>226,391</td>
<td>0.000566</td>
<td>0.81</td>
</tr>
<tr>
<td>Retrieve 3 reports for week 1</td>
<td>Owner</td>
<td>(f)</td>
<td>SCO</td>
<td>1,064,721</td>
<td>0.002662</td>
<td>3.55</td>
</tr>
<tr>
<td>Claim tokens for week 1</td>
<td>Contractors</td>
<td>(h)</td>
<td>SCO</td>
<td>384,204</td>
<td>0.000961</td>
<td>1.28</td>
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<tr>
<td>Retrieve 3 reports for week 2</td>
<td>Owner</td>
<td>(f)</td>
<td>SCO</td>
<td>560,937</td>
<td>0.001402</td>
<td>1.81</td>
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<tr>
<td>Claim tokens for week 2</td>
<td>Contractors</td>
<td>(h)</td>
<td>SCO</td>
<td>179,004</td>
<td>0.000448</td>
<td>0.58</td>
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<tr>
<td>Retrieve 3 reports for week 3</td>
<td>Owner</td>
<td>(f)</td>
<td>SCO</td>
<td>812,829</td>
<td>0.002032</td>
<td>2.59</td>
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<tr>
<td>Claim tokens for week 3</td>
<td>Contractors</td>
<td>(h)</td>
<td>SCO</td>
<td>281,604</td>
<td>0.000704</td>
<td>0.90</td>
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<tr>
<td>Generate NFT</td>
<td>Contractors</td>
<td>(i)</td>
<td>SCO</td>
<td>189,781</td>
<td>0.000474</td>
<td>0.61</td>
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</tbody>
</table>
Comparison of transaction fees on Rinkeby testnet, Ethereum Mainnet, and Polygon Mainnet
Contribution

• Providing a novel FT- and NFT-based Dapp that is integrated with vision-based techniques to incentivize construction companies based on their safe behavior

• Applying a decentralized oracle to bridge the on-chain and off-chain worlds which addresses the primary limitation in automated blockchain-based solutions in the AEC

• Developing an open-access and interactive front-end interface for the proposed Dapp which can be used as a template for other blockchain-based solutions.
Demo
Thank you!