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

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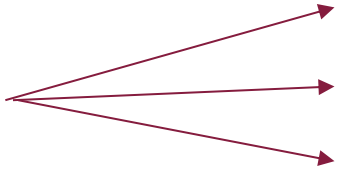
AGENDA

TABLE OF CONTENT

INTRODUCTION
MOTIVATION

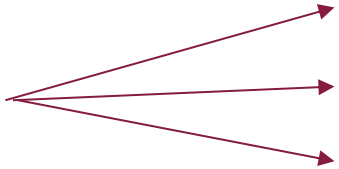
Introduction and Motivation

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

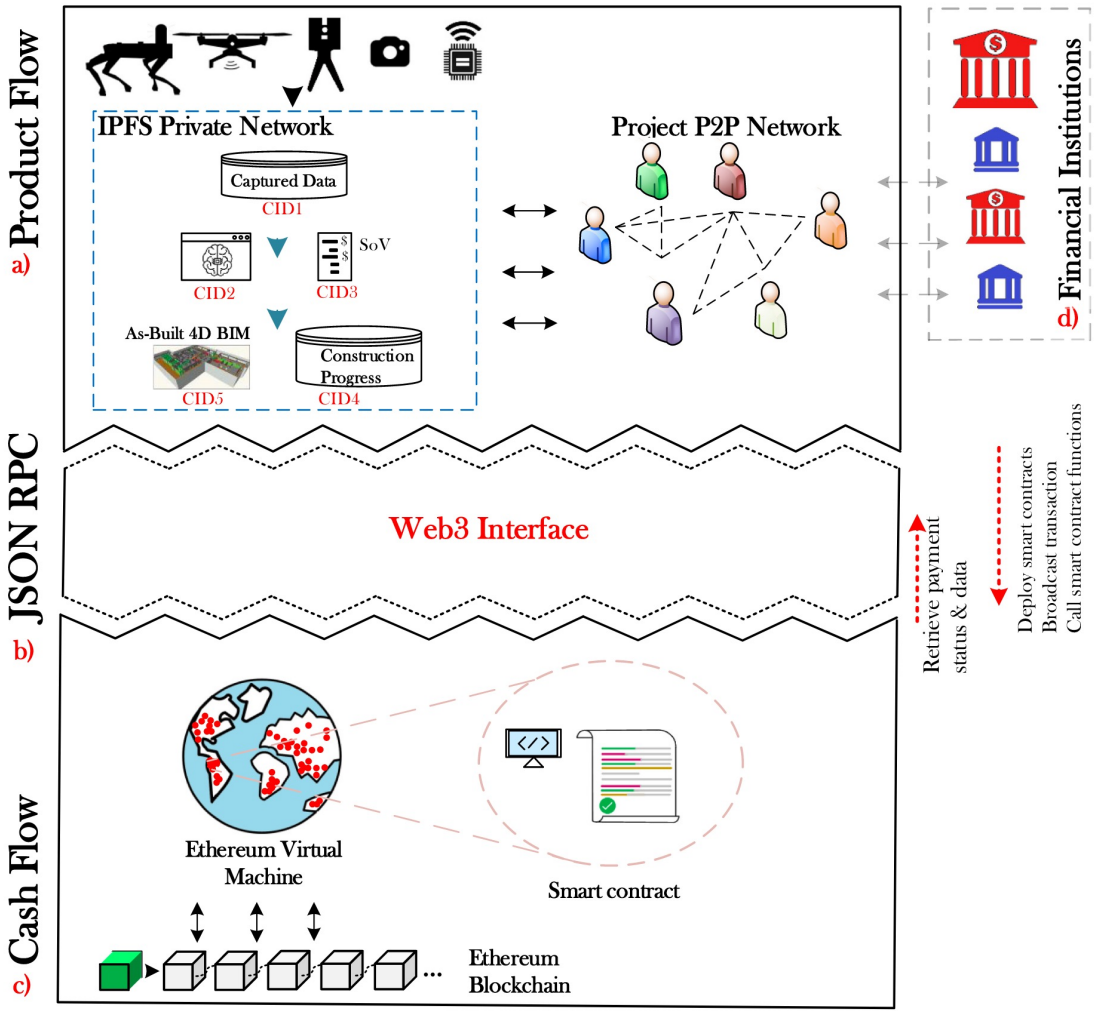
- Intermediary-based Architecture
- Lack of Traceability
- Lack of Transparency
- Lack of Real-time inspection
- Massive paperwork
- Lack of social recognition-based reward
- Lack of Anti-fraud reward
- Lack of Enforceability

RELATED WORK

Related work

Construction payment automation using blockchain-enabled smart contracts and robotic reality capture technologies

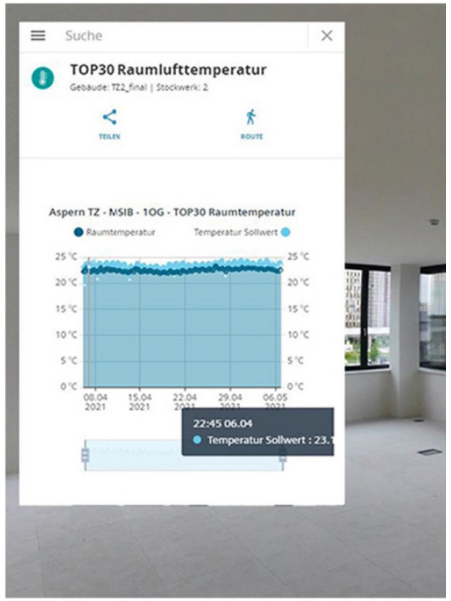
Hesam Hamledari a,, Martin Fischer b*



Related work

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

Incentivize contractor in energy optimization effort



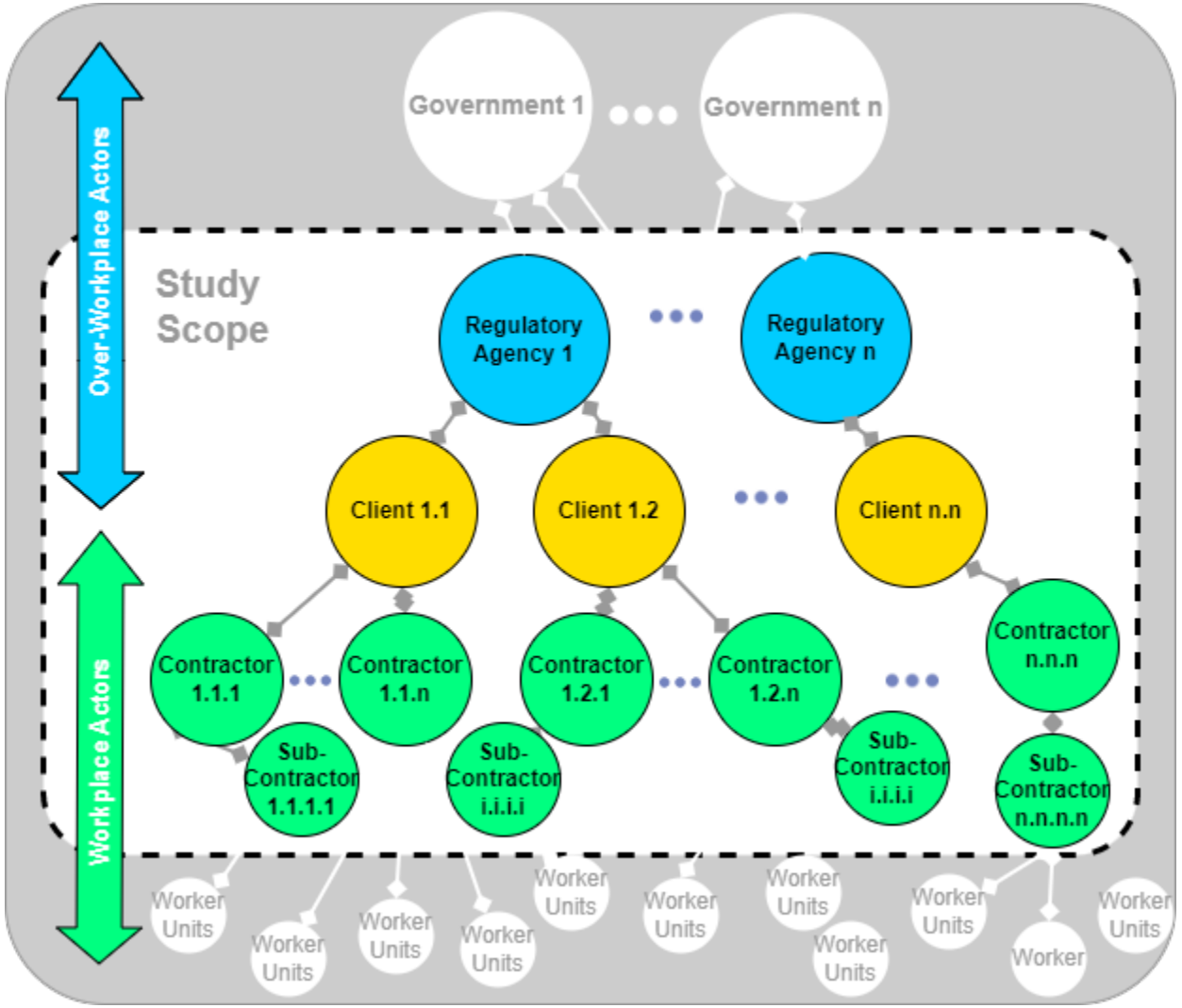
Proposed research

Research Goals

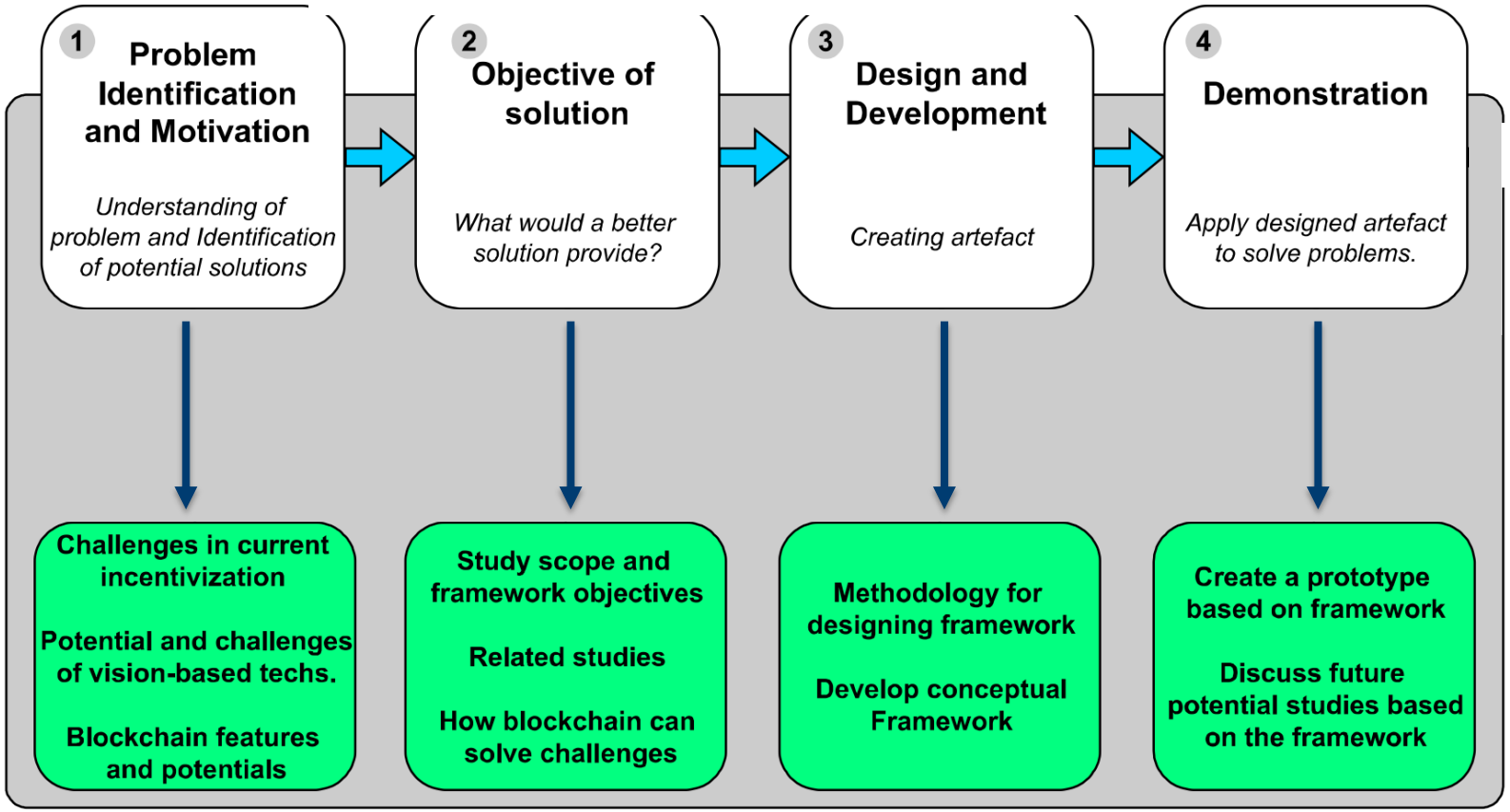
Propose an industry-wide **Dapp framework** that automates incentive management using FTs and NFTs across construction companies

Implementation of a full-stack version of the Dapp to validate the feasibility and applicability of the proposed framework

Research Scope



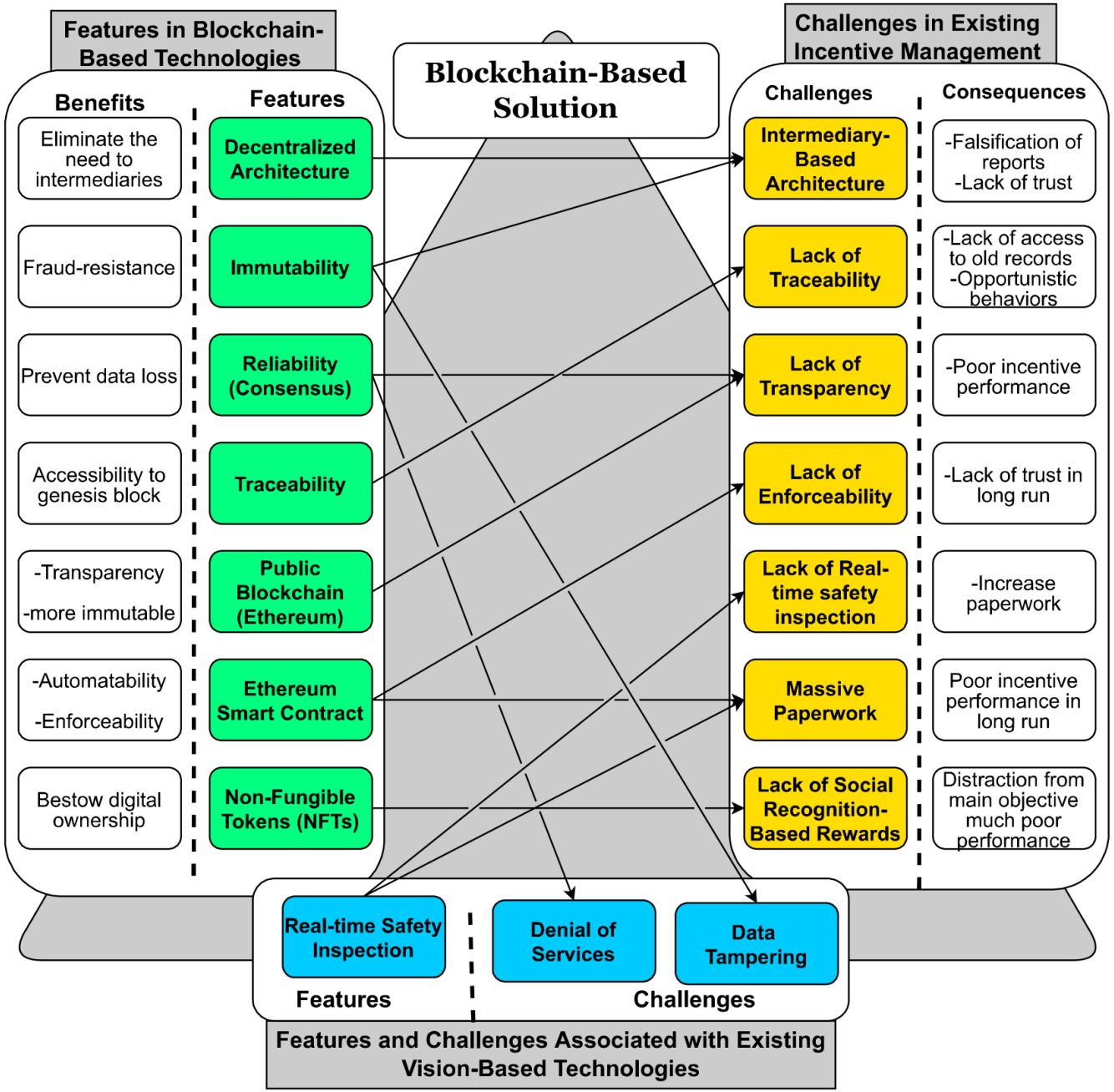
Research Technique



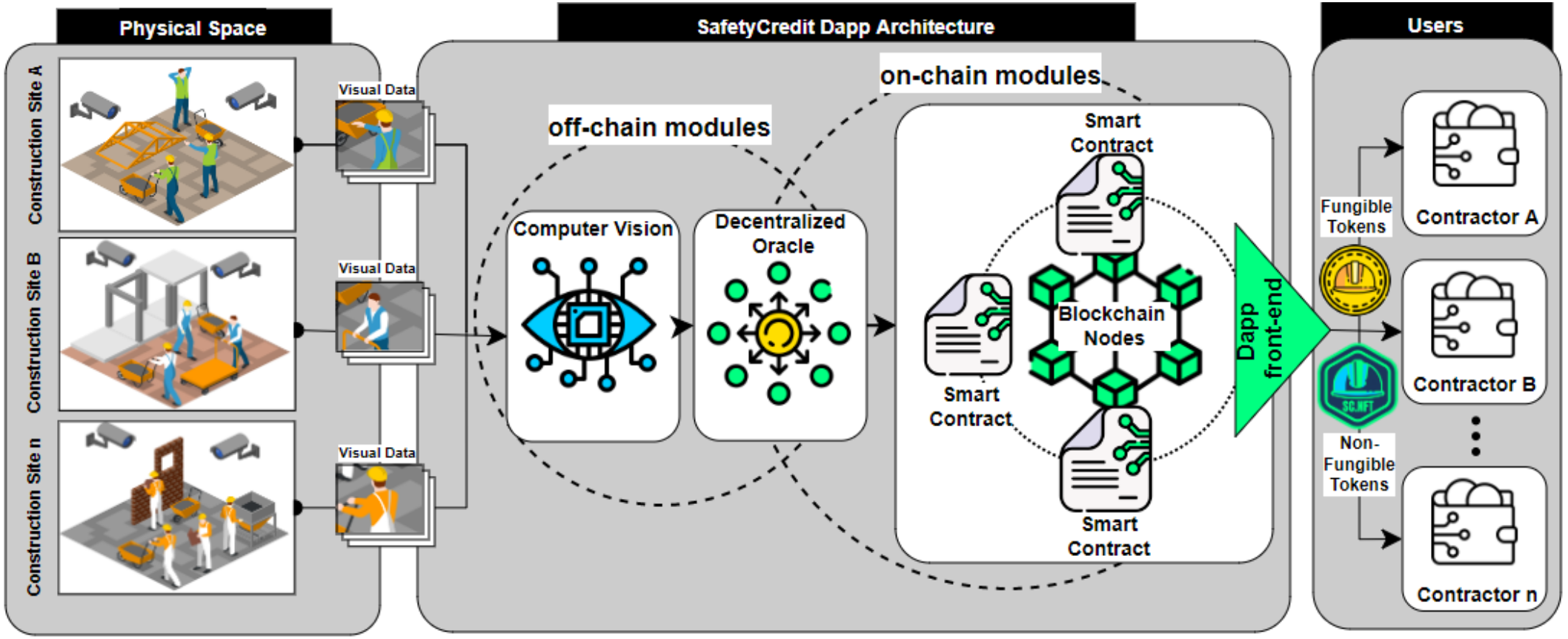
Study method adapted from Design science research (DSR) approach

Why blockchain ?

How Can a Blockchain-Based Solution Address Existing Issues?

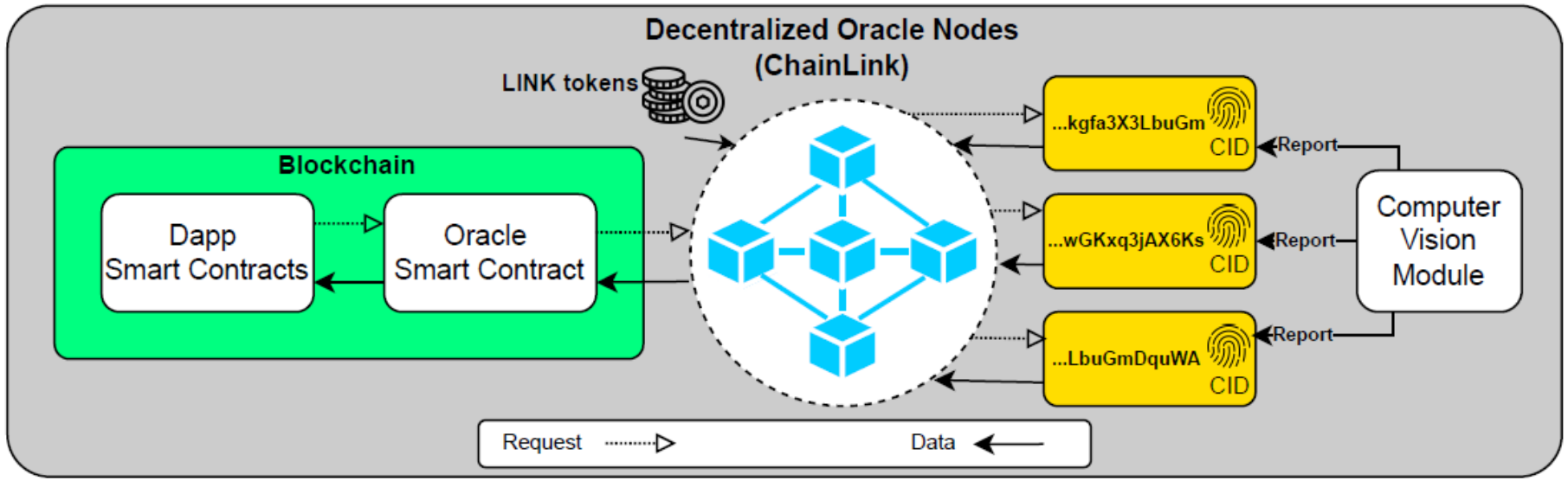


Framework Overview



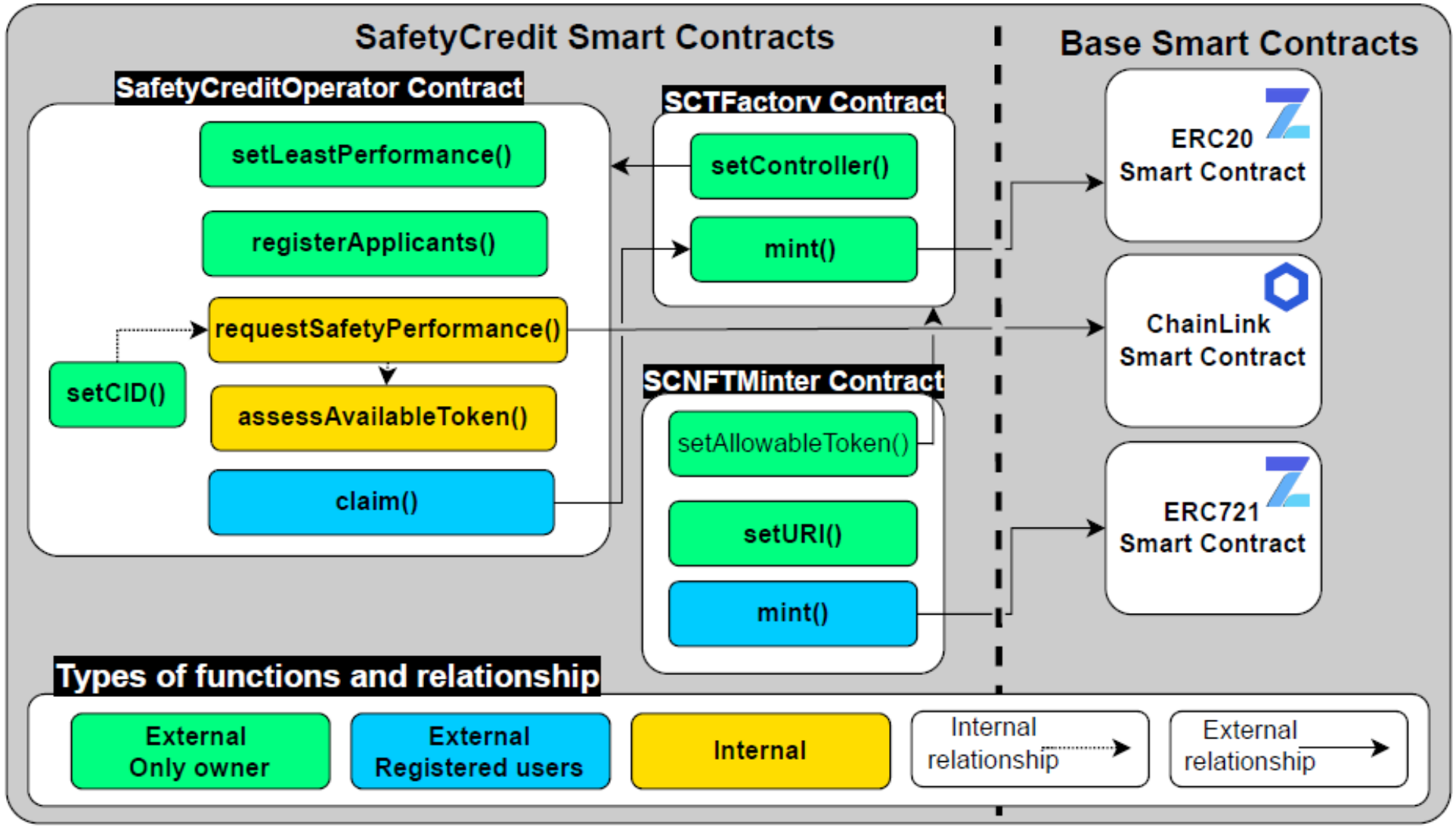
Overall architecture of the proposed Dapp

Decentralized oracle network (DON)



The mechanism of decentralized oracle network (DON) and its interaction with other modules

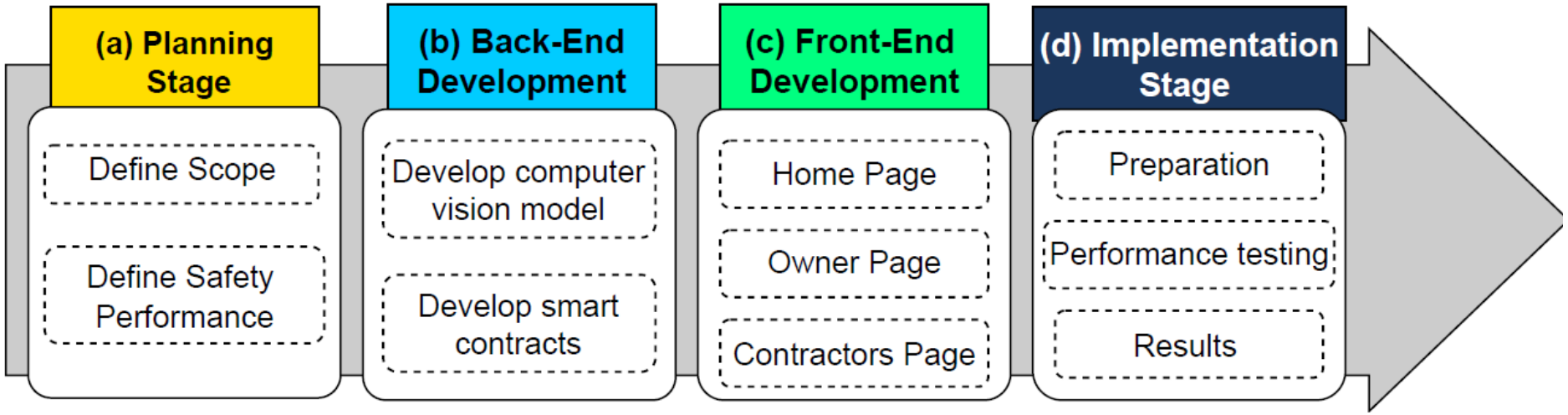
Smart contracts Design



Design of SafetyCredit smart contracts and the interactions between functions

Decentralized App Implementation

Decentralized Application development



Planning stage

Safety performance index (SP)

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

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

e.g. SP = 2/5

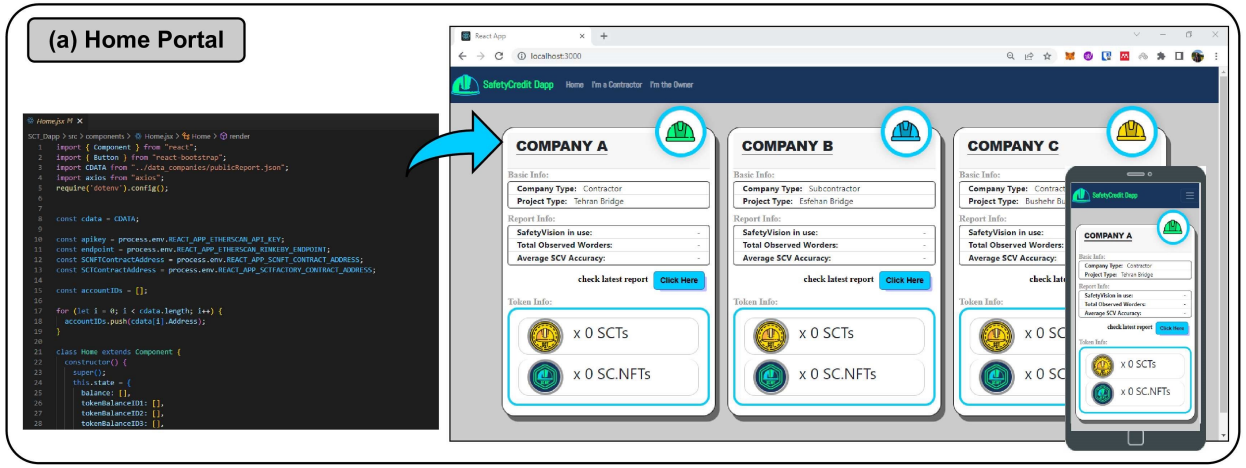
Front-End Development

Tools:

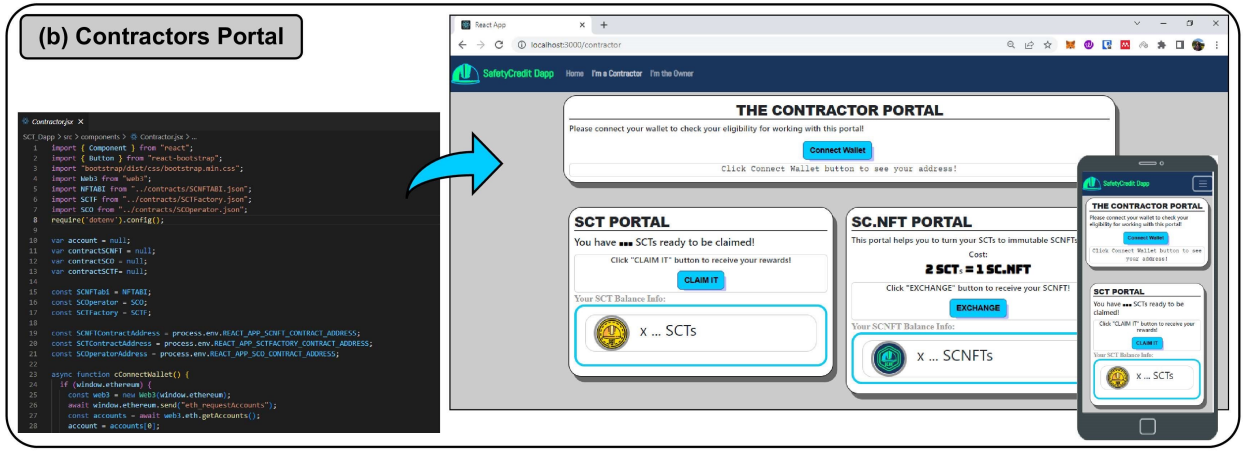
Metamask
Web3.Js

Javascript
ReactJs
HTML
CSS

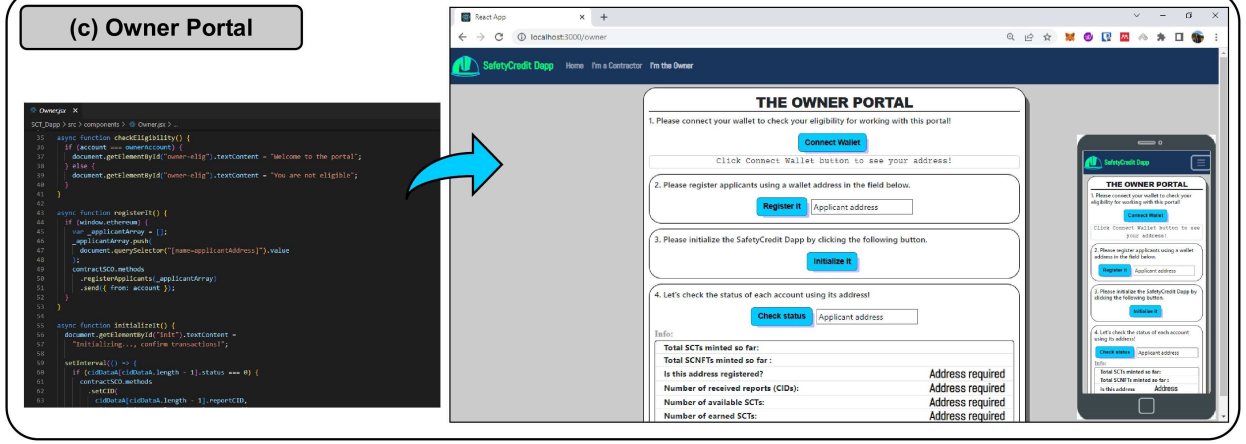
(a) Home Portal



(b) Contractors Portal

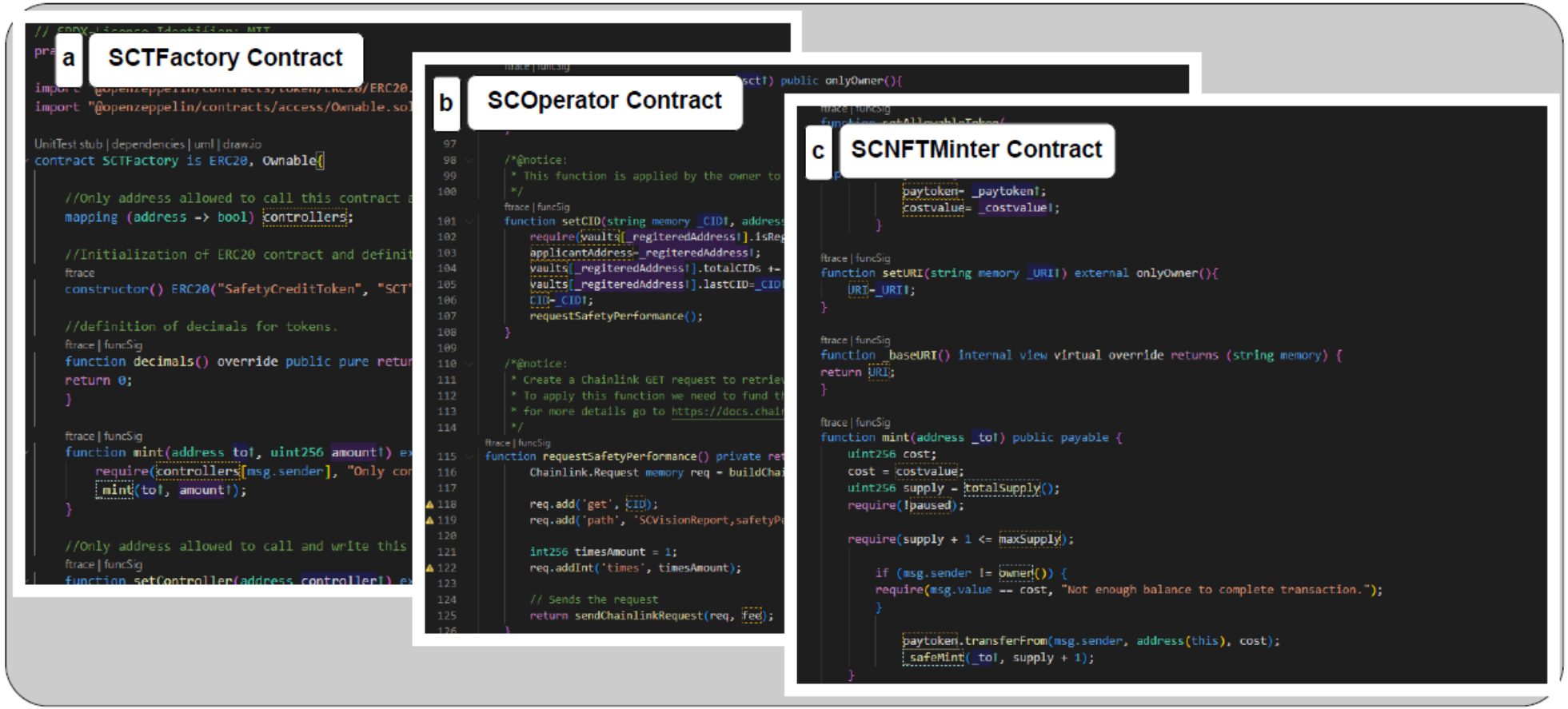


(c) Owner Portal



Back-End Development :
Smart contract

Tools: **Solidity**
Remix IDE



Back-End Development : Computer Vision module

Training Details

YOLOv5
PyTorch learning framework

Dataset:
7,580 images (SHWD[1])
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

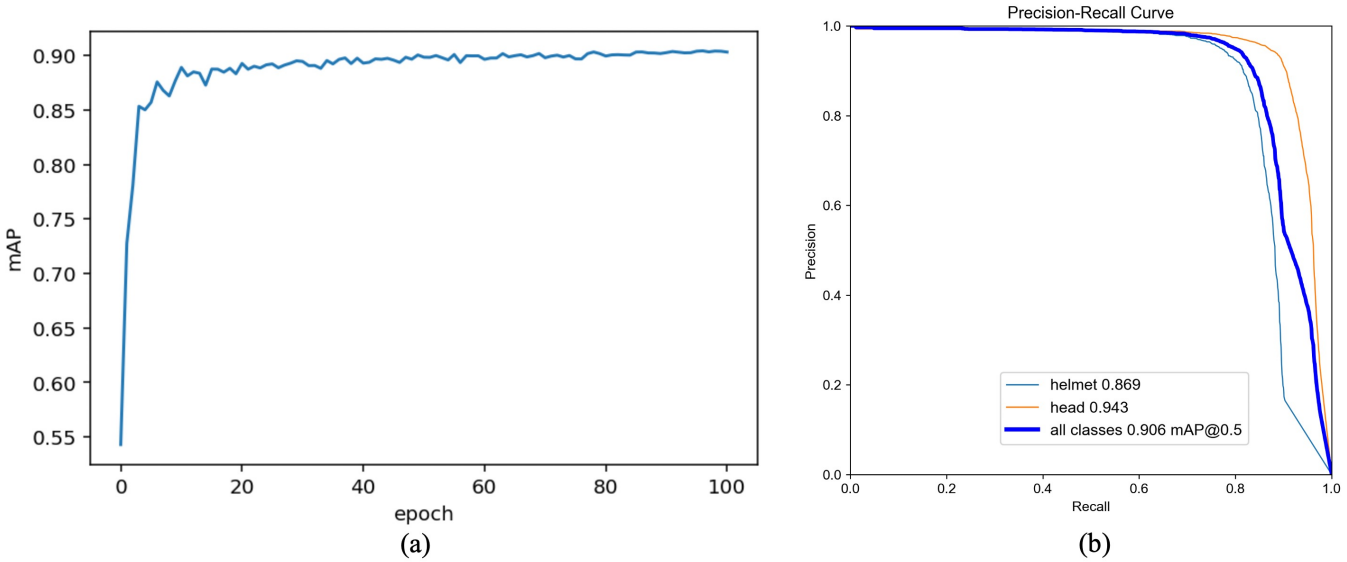
1. https://github.com/njvisionpower/Safety-Helmet-Wearing-Dataset

Test images

Predicted

Workflow of Computer Vision module

Computer vision module performance

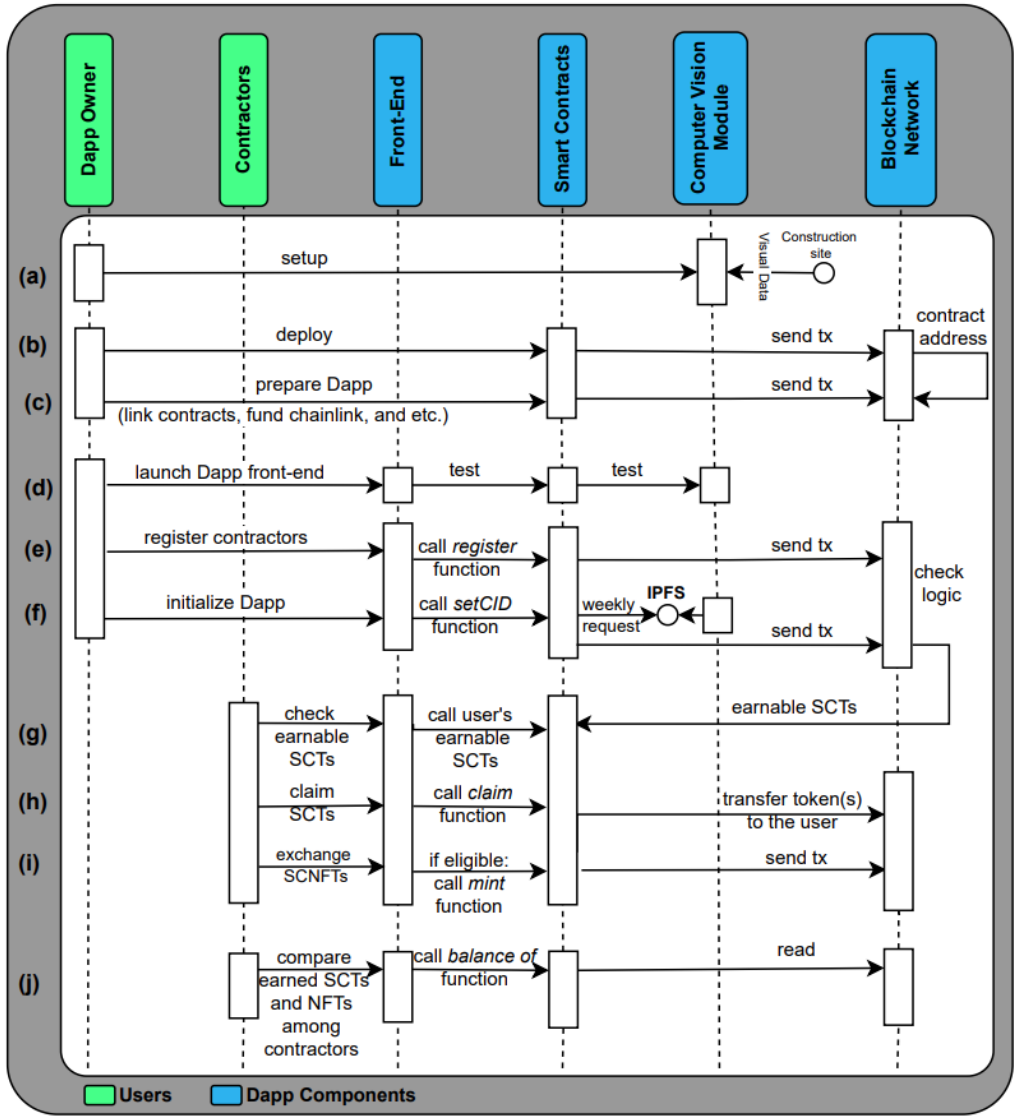


(a) Mean Average Precision (b) Precision-Recall curve

Class	mAP@0.5
Head	94.1%
Helmet	86.5%
All	90.3%

The performance of the Helmet Detection model

Implementation flow



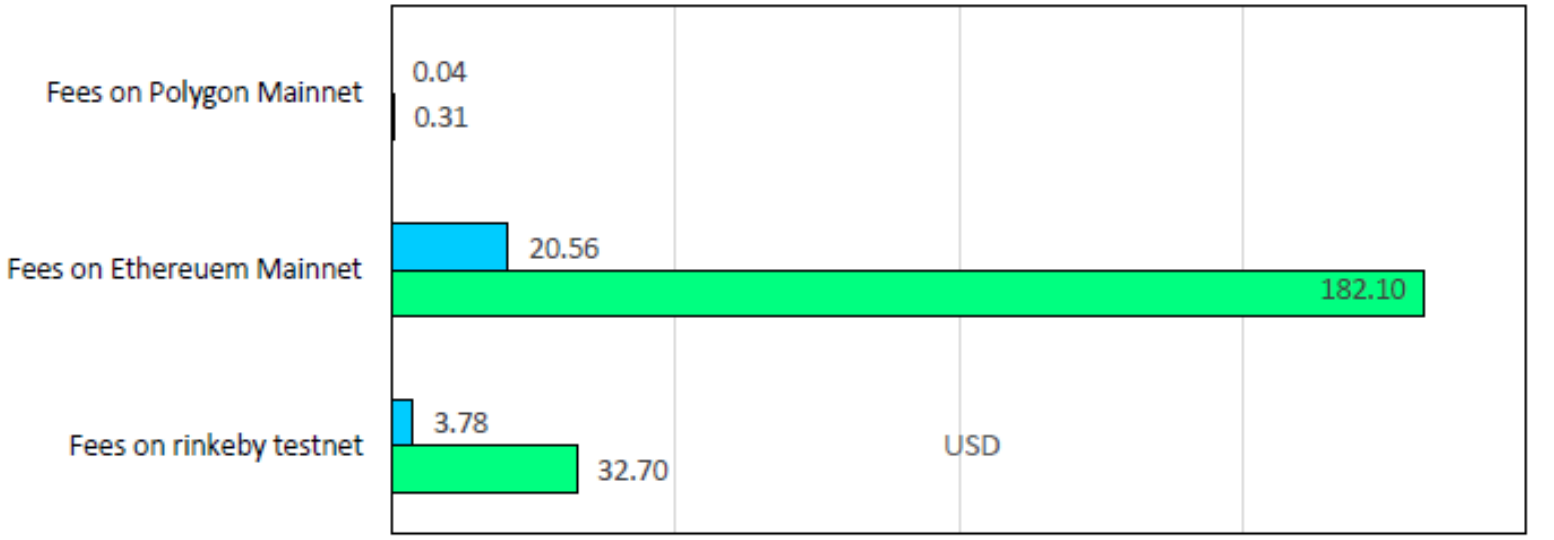
Sequence diagram of implementing the Dapp

Implementation Result

Transaction results of implementing the Dapp on the Rinkeby testnet

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

Comparison of transaction fees on Rinkeby testnet, Ethereum Mainnet, and Polygon Mainnet



	Fees on rinkeby testnet	Fees on Ethereuem Mainnet	Fees on Polygon Mainnet
Weekly cost per company	3.78	20.56	0.04
Preparation cost	32.70	182.10	0.31

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.

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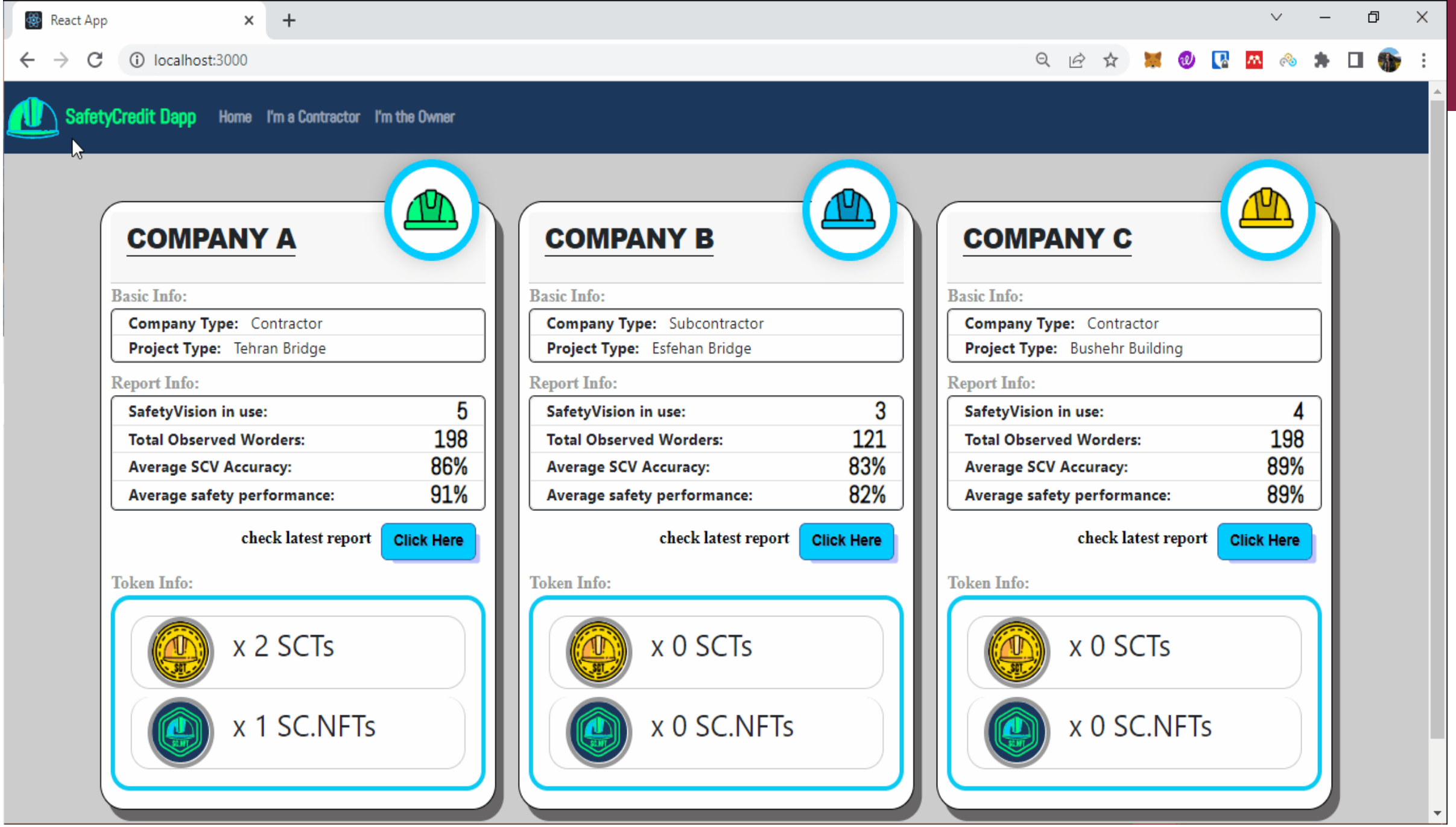
Demo


React App
localhost:3000
SafetyCredit Dapp
Home
I'm a Contractor
I'm the Owner
COMPANY A
Basic Info:
Company Type: Contractor
Project Type: Tehran Bridge
Report Info:
SafetyVision in use: 5
Total Observed Worders: 198
Average SCV Accuracy: 86%
Average safety performance: 91%
check latest report
Click Here
Token Info:
x 2 SCTs
x 1 SC.NFTs
COMPANY B
Basic Info:
Company Type: Subcontractor
Project Type: Esfehan Bridge
Report Info:
SafetyVision in use: 3
Total Observed Worders: 121
Average SCV Accuracy: 83%
Average safety performance: 82%
check latest report
Click Here
Token Info:
x 0 SCTs
x 0 SC.NFTs
COMPANY C
Basic Info:
Company Type: Contractor
Project Type: Bushehr Building
Report Info:
SafetyVision in use: 4
Total Observed Worders: 198
Average SCV Accuracy: 89%
Average safety performance: 89%
check latest report
Click Here
Token Info:
x 0 SCTs
x 0 SC.NFTs

Thank you !