

SUMMARY REVIEW EDITING

Status	Published	Vol 15, No 2: April 2026
Initiated	2026-04-19	
Last modified	2026-04-19	

Name	Yusuf Kurnia
ORCID iD	http://orcid.org/0000-0002-2897-5569
Affiliation	Buddhi Dharma University
Country	Indonesia
Bio Statement	—
Principal contact for editorial correspondence.	
Name	Rino Rino
ORCID iD	http://orcid.org/0000-0003-1664-0910
Affiliation	Buddhi Dharma University
Country	Indonesia
Bio Statement	—
Name	Edy Edy
ORCID iD	http://orcid.org/0000-0002-9139-7167
Affiliation	Buddhi Dharma University
Country	Indonesia
Bio Statement	—
Name	Junaedi Junaedi
ORCID iD	http://orcid.org/0000-0001-8075-5566
Affiliation	Buddhi Dharma University
Country	Indonesia
Bio Statement	—
Name	Aditiya Hermawan
ORCID iD	http://orcid.org/0000-0002-3372-8562
Affiliation	Buddhi Dharma University
Country	Indonesia
Bio Statement	—
Name	Kevin Kevin
ORCID iD	http://orcid.org/0009-0001-6700-2006
Affiliation	Universitas Buddhi Dharma
Country	Indonesia
Bio Statement	—

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Title and Abstract

Title	Enhancing digital asset ownership through decentralized non fungible token applications
Abstract	The rapid expansion of the digital ecosystem has introduced pressing challenges surrounding identity, authenticity, trust, and transparency. The ease with which digital content can be duplicated often undermines creators, whose works are distributed without consent or fair compensation. Blockchain technology offers a transformative solution through its decentralized, transparent, and tamper-resistant structure. Among its innovations, non-fungible tokens (NFTs) provide a mechanism to verify the authenticity and ownership of unique digital assets. This study explores the transformative potential of NFTs in strengthening digital ownership and authenticity while identifying critical challenges such as market concentration, interoperability limitations, and security vulnerabilities within public NFT platforms. Employing the extreme programming (XP) methodology, this research proposes a secure framework for NFT creation outside public marketplaces to enhance the protection of smart contracts and user accounts. The findings demonstrate that this approach grants users’ greater control, minimizes exposure to platform-level risks, and promotes trust in decentralized asset management. Overall, this study underscores NFTs’ pivotal role in reshaping digital ownership models and highlights the need for continued innovation to ensure security, transparency, and equitable value distribution in the evolving digital economy.

Indexing

Academic discipline and sub-disciplines	—
Keywords	Blockchain; Decentralized; Non-fungible token; Private asset; Smart contract
Language	en

Supporting Agencies

Agencies	—
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References

References	—
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Home > User > Author > Submissions > #27354 > Review

#27354 Review

SUMMARY REVIEW EDITING

Submission

Authors	Yusuf Kurnia, Rino Rino, Edy Edy, Junaedi Junaedi, Aditiya Hermawan, Kevin Kevin
Title	Enhancing digital asset ownership through decentralized non fungible token applications
Section	Others
Editor	Shaikh Abdul Hannan Abdul Mannan (Review) Muhammad Shahid Farid (Review) Saleh Mirheidari (Review)

Peer Review

Round 1

Review Version	27354-55354-1-RV.DOCX	2024-11-05
Initiated	2024-11-06	
Last modified	2025-09-29	
Uploaded file	None	
Editor Version	None	
Author Version	27354-63368-1-ED.DOCX	2025-10-30
	27354-63368-2-ED.DOCX	2025-10-30

Round 2

Review Version	27354-55354-2-RV.DOCX	2025-11-06
Initiated	2025-11-06	
Last modified	2025-11-07	
Uploaded file	None	
Editor Version	None	
Author Version	27354-63368-3-ED.DOCX	2025-12-30

Round 3

Review Version	27354-55354-3-RV.DOCX	2026-01-14
Initiated	2026-01-14	
Last modified	2026-01-23	
Uploaded file	None	

Editor Decision

Decision	Accept Submission 2026-01-22
Notify Editor	Editor/Author Email Record 2026-02-06
Editor Version	None
Author Version	27354-63368-4-ED.DOCX 2026-01-27 DELETE
Upload Author Version	Choose file No file chosen Upload

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AUTHOR

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IAES IJ-AI2026-04-17 10:59

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Prof. Dr. Eugene Yu-Dong Zhang2026-02-06 18:54

• [IJAI] Decision ACCEPTED - "Enhancing Digital...

Prof. Dr. Eugene Yu-Dong Zhang2026-01-22 23:08

• [IJAI] Decision ACCEPTED - "Enhancing Asset ...

Prof. Dr. Eugene Yu-Dong Zhang2025-12-18 15:41

• [IJAI] Editor Decision: revisions required (Scop...

Prof. Dr. Eugene Yu-Dong Zhang2025-10-30 09:56

• Enhancing Asset Security and Ownership in D...

Prof. Dr. Eugene Yu-Dong Zhang2025-10-18 18:46

• [IJAI] Editor Decision

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1

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From Prof. Dr. Eugene Yu-Dong Zhang on 2025-10-18 18:46

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Dear Prof/Dr/Mr/Mrs Junaedi Junaedi,

We have reached a decision regarding your submission entitled "Enhancing Asset Security and Ownership in Decentralized Applications through NFT Innovations" to IAES International Journal of Artificial Intelligence (IJ-AI). This journal is indexed in Scopus (<https://www.scopus.com/sourceid/21100901206>) and all published papers since 2018 issues were included in scopus.com. This journal has been included in SCImago Journal Rank (<https://www.scimagojr.com/journalsearch.php?q=21100901206&tip=sid&clean=0>)

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Our decision is to major revisions required

Please revise your manuscript based on the reviewers' comments. Please include a response letter in your resubmission that addresses each point made by the reviewers. Additionally, ensure that you adhere to every detail outlined in the author's guide (available in MS Word: <http://iaescore.com/gfa/ijai.docx> or LaTeX: <http://iaescore.com/gfa/ijai.rar>). Carefully check your manuscript for spelling and grammatical errors. The aim of your revised paper is to present a polished document that showcases all your new ideas and results, including novel technical findings on the topic.

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1. Avoid self-citations by the author, as well as self-citations from this journal and its publisher.
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3. Make sure to present each reference as thoroughly as possible, adhering to IEEE style, which includes the volume, issue number, page numbers, and DOIs. Additionally, pay careful attention to the Acknowledgment, Funding, and CREDIT sections of our new TEMPLATE (<http://iaescore.com/gfa/ijai.docx>).
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Drafts	IAES IJ-AI 2026-04-17 10:59	
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Archive	Prof. Dr. Eugene Yu-Dong Zhang 2026-02-06 18:54	Best Regards, Prof. Dr. Eugene Yu-Dong Zhang University of Leicester ijai@iaesjournal.com
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68%	Messages 1 to 7 of 7 1	Such a document clarifies everything and will aid the reviewers in evaluating the work fast. When providing your amended primary document files, you must also upload your corrections statement. Before your manuscript, the declaration of revisions should appear. Reviewer H: Does the paper contain an original contribution to the field?: Yes Is the paper technically sound?:
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Inbox 243	Q ijai	Is the paper technically sound?: Yes
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Junk	IAES IJ-AI 2026-04-17 08:12	Does the title of the paper accurately reflect the major focus contribution of this paper?: Yes
Trash	• #PROOFREAD ID 27354, IAES International Jo...	Please suggest change of the title as appropriate within 10 words :
Archive	Prof. Dr. Eugene Yu-Dong Zhang 2026-02-06 18:54	
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	Prof. Dr. Eugene Yu-Dong Zhang 2025-12-18 15:41	Is the abstract a clear description of the paper?: No
	• [IJAI] Editor Decision: revisions required (Scop...	
	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-30 09:56	Is the paper well written (clear, concise, and well organized?): Yes
	• Enhancing Asset Security and Ownership in D...	
	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-18 18:46	Are the equations, figures and tables in this journal style, clear, relevant, and are the captions adequate?: No
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Sent	• #PROOFREAD ID 27354, IAES International Jo...	Prof. Dr. Eugene Yu-Dong Zhang 2026-02-06 18:54	- Abstract: simplify the abstract to the max. 200 words.
Junk	• [IJAI] Decision ACCEPTED - "Enhancing Digital...	Prof. Dr. Eugene Yu-Dong Zhang 2026-01-22 23:08	- Avoid incomplete paragraphs. Every paragraph should be composed of at least three sentences, with one sentence as the main or key sentence and at least two sentences as supporting sentences
Trash	• [IJAI] Decision ACCEPTED - "Enhancing Asset ...	Prof. Dr. Eugene Yu-Dong Zhang 2025-12-18 15:41	- Ref. 21: provide the complete information on this source
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			This paper discusses an important topic, but there are significant issues that need to be revised, specifically:
			- The abstract is too long for the standard journal format. Ideally, it should be under 200 words and focus on the objective, methodology, main findings, and contribution.
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Sent	• #PROOFREAD ID 27354, IAES International Jo...	Prof. Dr. Eugene Yu-Dong Zhang 2026-02-06 18:54	- The conclusion of your manuscript is quite comprehensive, but it could be shortened to a single paragraph to help readers focus on the results of your paper.
Junk	• [IJAI] Decision ACCEPTED - "Enhancing Digital...	Prof. Dr. Eugene Yu-Dong Zhang 2026-01-22 23:08	- It is recommended to add more recent literature (particularly from the 2020-2025 range) to strengthen the novelty aspect of the study and to demonstrate its connection with state-of-the-art developments.
Trash	• [IJAI] Decision ACCEPTED - "Enhancing Asset ...	Prof. Dr. Eugene Yu-Dong Zhang 2025-12-18 15:41	- Reference from the web, please provide the accessed date.
Archive	• [IJAI] Editor Decision: revisions required (Scop...	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-30 09:56	- For better author transparency, include a concise biography for each author. This should mention institutional affiliation, email, and ORCID id (mandatory). If possible, provide links to public academic profiles (Google Scholar, Scopus, etc.) and include a clear, high-quality photo of each contributor.
	• Enhancing Asset Security and Ownership in D...	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-18 18:46	- To align with editorial standards, we recommend using the latest manuscript template provided by the journal. This ensures a smoother review process and avoids formatting issues.
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	Prof. Dr. Eugene Yu-Dong Zhang 2026-01-22 23:08	-- Please upload the revised paper within 6 weeks. Failing to do proper revision may lead to the rejection of your paper.
	• [IJAI] Decision ACCEPTED - "Enhancing Asset ...	-- As soon as you make changes to your paper and upload it, please let the editor know and answer their comments in detail !!!
	Prof. Dr. Eugene Yu-Dong Zhang 2025-12-18 15:41	Dear Prof/Dr/Mr/Mrs: Junaedi Junaedi,
	• [IJAI] Editor Decision: revisions required (Scop...	We have reached a decision regarding your submission entitled "Enhancing Asset Security and Ownership in Decentralized Applications through NFT Innovations" to IAES International Journal of Artificial Intelligence (IJ-AI), a Scopus indexed journal (https://www.scopus.com/sourceid/21100901206). This journal is indexed by Scopus/Scimagojr, with a SJR of 0.341 (2020), Q2 under Electrical and
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Inbox 243	Q ijai	Our decision is revisions required.
Drafts	IAES IJ-AI 2026-04-17 10:59	Please revise your manuscript according to the reviewers' comments. In a response letter that should be sent with your re-submission, you should talk about each of the reviewers' points. Please also adhere to every detail of the guide of the authors (MS Word: http://iaescore.com/gfa/ijai.docx , or LaTeX: http://iaescore.com/gfa/ijai.rar), and check it for spelling and grammatical mistakes. The goal of your revised paper is to present a polished paper that shows all of your new ideas and results (novel technical results) on the topic.
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	Prof. Dr. Eugene Yu-Dong Zhang 2025-12-18 15:41	In preparing your final paper, you should pay attention to our guidelines (https://ijai.iaescore.com/index.php/IJAI/about/editorialPolicies#custom-5). Pay attention: Avoid author self-citations, as well as this journal and the publisher's self-citations!
	• [IJAI] Editor Decision: revisions required (Scop...	
	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-30 09:56	Please submit your revised paper within ten (10) weeks via our online system, in the REVIEW tab, by uploading the author version. After uploading your revised paper, please notify the editor and respond to the reviewers' and editors' comments point-by-point.
	• Enhancing Asset Security and Ownership in D...	
	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-18 18:46	I look forward to hearing from you.
	• [IJAI] Editor Decision	Thank you
		Best Regards, Prof. Dr. Eugene Yu-Dong Zhang University of Leicester ijai@iaesjournal.com

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Inbox 243	Q Ijai	IAES IJ-AI 2026-04-17 10:59	Reviewer A:
Drafts	• Re: #PROOFREAD ID 27354, IAES International...	IAES IJ-AI 2026-04-17 08:12	- Insufficient evaluation: Run and report experiments: (1) cost-per-mint on chosen network(s), (2) end-to-end latency (IPFS + mint confirmation), (3) usability questionnaire with several users, (4) interoperability test: importing external NFTs, reading third-party contract metadata.
Sent	• #PROOFREAD ID 27354, IAES International Jo...	Prof. Dr. Eugene Yu-Dong Zhang 2026-02-06 18:54	- Lack of technical detail & reproducibility: Add a reproducibility section + provide code or at minimum pseudocode and exact versions. Include sample transaction hashes from deploy/mint on a testnet.
Junk	• [IAI] Decision ACCEPTED - "Enhancing Digital...	Prof. Dr. Eugene Yu-Dong Zhang 2026-01-22 23:08	- Reproducibility & technical specifics: Add a Reproducibility subsection with: Add an explicit threat model table (assets, adversaries, attack vectors) and mitigation measures (use of hardware wallets, rate-limiting, contract upgradability, input sanitization). Add experiments and results: Gas cost per mint (meantstd over 10 runs). Upload & pin time to IPFS via Infura ± mean/std. Usability: small N (6-12) user test with SUS or Likert scores. Interoperability manual test: import/display two external NFTs; report success/failure.
Trash	• [IAI] Decision ACCEPTED - "Enhancing Asset ...	Prof. Dr. Eugene Yu-Dong Zhang 2025-12-18 15:41	State which token standard you implement (ERC-721/1155), metadata JSON example, royalties (EIP-2981?) and OpenSea compatibility notes.
Archive	• [IAI] Editor Decision: revisions required (Scop...	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-30 09:56	Add a short section on private key guidance, data encryption at rest (for
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junaedi@ubd.ac.id		Select Threads Options Refresh	Reply Reply all Forward Delete Archive Junk Mark More
Inbox 243	Q Ijai	IAES IJ-AI 20 KB	State which token standard you implement (ERC-721/1155), metadata JSON example, royalties (EIP-2981?) and OpenSea compatibility notes.
Drafts	• Re: #PROOFREAD ID 27354, IAES International...	IAES IJ-AI 2026-04-17 08:12	Add a short section on private key guidance, data encryption at rest (for off-chain content), and legal considerations (copyright transfer vs. token sale).
Sent	• #PROOFREAD ID 27354, IAES International Jo...	Prof. Dr. Eugene Yu-Dong Zhang 2026-02-06 18:54	
Junk	• [IAI] Decision ACCEPTED - "Enhancing Digital...	Prof. Dr. Eugene Yu-Dong Zhang 2026-01-22 23:08	Reviewer B:
Trash	• [IAI] Decision ACCEPTED - "Enhancing Asset ...	Prof. Dr. Eugene Yu-Dong Zhang 2025-12-18 15:41	Overall, this paper is well-written and has a clear structure. The topic is relevant and timely in the context of strengthening digital asset ownership through decentralized NFT technology. The abstract is informative and effectively summarizes the research objectives, methods, and results. The introduction is also well-organized and provides a strong background for the research's significance.
Archive	• [IAI] Editor Decision: revisions required (Scop...	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-30 09:56	The grammar is generally good, but some sentences could be simplified to improve readability and effectiveness.
	• Enhancing Asset Security and Ownership in D...	Prof. Dr. Eugene Yu-Dong Zhang 2025-10-18 18:46	
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Archive	Prof. Dr. Eugene Yu-Dong Zhang 2026-02-06 18:54				
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	Prof. Dr. Eugene Yu-Dong Zhang 2026-01-22 23:08	University of Leicester
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Re: [IJAI] Decision ACCEPTED - "Enhancing Asset Security and Ownership in Decentralized Applications through NFT Innovations"

To Prof. Dr. Eugene Yu-Dong Zhang on 2026-01-27 12:00

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27354-55354-3-Review Version 3 - Final.docx (~534 KB)

Proof of payment.jpeg (~113 KB)

Similarity 13% - Enhancing Digital Asset Ownership through Decentralized NFT Applicatio... (~1.0 MB)

Dear Prof. Dr. Eugene Yu-Dong Zhang,

Thank you very much for your kind notification regarding the initial acceptance of our manuscript entitled "Enhancing Digital Asset Ownership through Decentralized NFT Application for publication in the IAES International Journal of Artificial Intelligence (IJ-AI)". We sincerely appreciate the positive evaluation and the opportunity to proceed to the final publication stage.

In accordance with the journal's guidelines and publication requirements, we hereby submit the following documents for your consideration:

1. Final camera-ready manuscript (MS Word source file)
2. Similarity report generated via Turnitin (similarity score 13%)
3. Proof of payment with the following details:
 - Manuscript ID: 27354
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 - Additional pages (3 pages): USD 150
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 - Equivalent amount: IDR 10,164,803 (exchange rate as of January 27, 2026, via www.xe.com)

All revisions have been carefully implemented following the provided template, including improvements in the Method section, complete IEEE-style references with DOIs, and the updated Acknowledgment, Funding, and CRediT author contribution sections.

Should any additional information or revisions be required, please do not hesitate to inform us. We would be pleased to address them promptly.

Thank you once again for your kind cooperation and support throughout the review and publication process.

Sincerely yours,

Junaedi

On 2026-01-22 23:08, Prof. Dr. Eugene Yu-Dong Zhang wrote:
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Dear Prof/Dr/Mr/Mrs. Junaedi Junaedi,

It is my great pleasure to inform you that your paper entitled "Enhancing Digital Asset Ownership through Decentralized NFT Applications" is initially ACCEPTED and will be published in the forthcoming issue of the IAES International Journal of Artificial Intelligence (IJ-AI), a Scopus indexed journal (see: <https://www.scopus.com/sourceid/21100901206>). Congratulations!!

We are pleased to inform you that your paper will be published in a future issue of the journal (tentatively the April 2026 issue). Our layout and editing team will contact you to assist with the preparation of the final manuscript and the galley proofs. As part of the journal's publication requirements, authors are requested to submit a 15-minute video presentation of their paper, recorded using Zoom or similar software and using the official virtual background template available at <https://bit.ly/iaes> ("Use template for new design"), with the presentation title, author

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International Journal of Artificial Intelligence (IJ-AI), a Scopus indexed journal (see: <https://www.scopus.com/sourceid/21100901206>). Congratulations!!

We are pleased to inform you that your paper will be published in a future issue of the journal (tentatively the April 2026 issue). Our layout and editing team will contact you to assist with the preparation of the final manuscript and the galley proofs. As part of the journal's publication requirements, authors are requested to submit a 15-minute video presentation of their paper, recorded using Zoom or similar software and using the official virtual background template available at <https://bit.ly/iaes> ("Use template for new design"), with the presentation title, author name, and affiliation updated accordingly. The presentation should follow the IMRDC structure (Introduction, Methods, Results, Discussion, and Conclusion), highlight the key findings, and provide sufficient methodological detail to ensure reproducibility. Please share the video file (MP4 format) via Google Drive or another file-sharing service and include your paper ID number and paper title when submitting.

Your cooperation is very appreciated

Sincerely yours,
Prof. Dr. Eugene Yu-Dong Zhang
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ijai@iaesjournal.com

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Dear Dr. Yusuf Kurnia *et al.*,

I am Isma, writing on behalf of the Layout and Editing Team under the auspices of the *IAES International Journal of Artificial Intelligence (IJ-AI)*. We are pleased to inform you that your manuscript is in the final stages before publication in an upcoming Issue of the journal.

Please find attached the camera-ready version of your paper in PDF format. We kindly request your cooperation in carefully reviewing the entire document. Please pay special attention to the first page, particularly the **title**, **author names**, and **affiliation**.

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Thank you for sharing the camera-ready version of our manuscript.

We have carefully reviewed the entire document, including the first page, title, author names, affiliations, email address, acknowledgment, citation names, and abbreviations. We confirm that the article is already correct and there are no typographical errors or corrections needed.

Therefore, the manuscript is approved and is ready for publication.

Thank you for your assistance and support throughout the publication process.

Kind regards,

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Submission

Authors Yusuf Kurnia, Rino Rino, Edy Edy, Junaedi Junaedi, Aditiya Hermawan, Kevin Kevin 

Title Enhancing digital asset ownership through decentralized non fungible token applications

Section Others

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- By Author
- By Title



Home > Vol 15, No 2

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- Reviewers
- Author Guidelines
- **Online Submission**
- **Peer Review Process**
- **Publication Fee**
- Abstracting and Indexing
- Publication Ethics
- Visitor Statistics
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JOURNAL CONTENT

Search

Search Scope
All ▼
[Search](#)

Browse

- By Issue
- By Author
- By Title



Home > About the Journal > **Editorial Team**

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- **Publication Fee**
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Search Scope

All

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- By Issue
- By Author
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Vol 15, No 2

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Table of Contents

[An exploratory review on conceptualizing generative artificial intelligence literacy](#)
Mohammed Afandi Zainal, Mohd Effendi Mohd Matore, Siti Mistima Maat

PDF1023-1035

[Venture capital and risks in growth stages of artificial intelligence tech start-ups](#)
Sara Aziz, Noorlizawati Abd Rahim

PDF1036-1049

[Structured data collection and deep learning for retinal OCT image-to-text translation: a comprehensive framework](#)
Uday Mande, Shafi Pathan, Pankaj Chandre, Sharvari Mande

PDF1050-1061

[Assessing student perspectives on ChatGPT in higher education: a quantitative analysis](#)
Muhammad Amin, Bimaa Mustaqim, Wegig Pratama, Abdul Muin Sibuea

PDF1062-1070

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- Contact Us
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The role of prompt engineering in enhancing LLMs: a systematic review of applications and ethical implications Izzul Fatawi, Muhammad Roil Bilad, Muhammad Asy'ari	PDF 1071-1086
Applications of artificial intelligence in analyzing Aquilaria essential oils: a review of current machine learning techniques Noor Aida Syakira Ahmad Sabri, Nur Athirah Syafiqah Noramli, Muhammad Ikhsan Roslan, Nurlaila Ismail, Zakiah Mohd Yusoff, Ali Abd Almisreb, Mohd Nasir Taib	PDF 1087-1096
Intelligent self-organizing microservice composition using hybrid learning for neonatal ward Sharon Poormima, Ashok Immanuel V	PDF 1097-1108
An intelligent and explainable IoT-Edge-Cloud architecture for real-time water quality monitoring Sara Bouziane, Badraddine Aghoutane, Aniss Moumen, Anas El Ouali, Ali Essahlaoui, Abdellah El Hmadi	PDF 1109-1120
Generative artificial intelligence as powered writing tools in academic writing Exequiel B. Gonzaga, Nasrah A. Manguda, Rodelina B. Tado, Ivy F. Amante, Rovy M. Banguis, Shem A. Cedeño, Joveth Jay D. Montaña, Jai Rondo S. Apilar	PDF 1121-1131
Automated bacteria and fungi classification using convolutional neural network on embedded system Tarik Bouganssa, Maryem Ait Moulay, Samar Aarabi, Abdelali Lasfar, Abdelatif EL Afia	PDF 1132-1142
Multi-dimensional performance-optimized array design framework for efficient mmWave energy harvesting Shalini Mirle Gajendra, Naveen Kalenahalli Bhoganna	PDF 1143-1154
Gradient-based stochastic depth with convolutional neural network for coconut tree leaf disease classification Kavitha Magadi Gopalakrishna, Raviprakash Madenur Lingaraju, Ananda Babu Jayachandra	PDF 1155-1165
Recognition system based on artificial vision using OpenCV for discarding and detecting ceramics with defects Fernando Alvarado, Ricardo Yauri	PDF 1166-1173
Double-hop of reconfigurable intelligent surfaces-aided for wireless optical link under log-normal fading channels Duong Huu Ai, Van Loi Nguyen, Khanh Ty Luong	PDF 1174-1180
Knowledge graph-based enhanced virtual network embedding for 6G cloud datacenter deployment Shourok Abdelrahim, Samy Ghoniemy, Mohamed Aborizka	PDF 1181-1193
IoT-enabled smart nutrition scale using fuzzy logic for dietary assessment and recommendation Wahyu Wijaya Widiyanto, Edy Susanto, Sri Suparti	PDF 1194-1201
Adaptive control of ball and beam system using SNA-PID combined with recurrent fuzzy neural network identifier Minh-Thanh Le, Chi-Ngon Nguyen	PDF 1202-1210
Deep neural network classification in chatbot system family health counseling services Andi Riansyah, Sam Farisa Chaerul Haviana, Ratna Supradewi, Muhammad Ainul Wahib	PDF 1211-1218
An efficient approach for cyber-attack detection by using machine learning and deep learning algorithms Yasir Hussein Shakir, Mahmoud Mohamed Abdelhamied, Eshaq Aziz Awadh AL Mandhari, Ali Alkhazraji, Naglaa M. Reda	PDF 1219-1235
Technical analysis model for stock prediction using a grammatical evolution algorithm Aditya Kusuma Setyanegara, Imas Sukaesih Sitanggang, Mushthofa Mushthofa	PDF 1236-1246
Genetic algorithm-based chicken manure weight prediction system development Rida Hudaya, Septiandi Wirayoga, Moechammad Sarosa, Muhammad Yusuf, Armanda Dwi Prayugo	PDF 1247-1260
Genetic algorithm for generalized time-window assignment problem Ali Kansou, Bilal Kansou, Houssein Wehbe, Haydar Bazzi, Ali Mcheik	PDF 1261-1274

Search

Search Scope

All

▼

Search

Browse

- By Issue
- By Author
- By Title

Energy-efficient and secure WSN clustering for IoT using particle swarm optimization and advanced encryption standard S. Swapna Kumar, Kalli Satyanarayan Reddy	PDF 1275-1285
Energy-efficient virtual machine allocation using directional and boundary-aware bobcat optimization Nida Kousar Gouse, Gopala Krishnan Chandrasekaran	PDF 1286-1299
Heart disease detection and classification using grid search with random forest Ramakrishna Reddy Badveli, Nijaguna Gollara Siddappa, Sundeeep Kumar Kanipakapatnam	PDF 1300-1315
Hybrid kernel support vector machine with cuckoo search optimization for malaria detection from blood smear images Sri Huning Anwaningsih, Indrarini Dyah Irawati	PDF 1316-1326
Attribute optimization to improve breast cancer prediction using machine learning techniques Raghavendra Srinivasaiah, Santosh Kumar Jankatti, Niranjana Shravanabelagola Jinachandra, Manjunath Ramanna Lamani, Bellam Vijaya Lakshmi, Rishita Bhelwa	PDF 1327-1338
Identification of chemical markers for species differentiation in Aquilaria essential oils using self-organizing maps Nur Athirah Syafiqah Noramli, Muhammad Ikhsan Roslan, Noor Aida Syakira Ahmad Sabri, Nurlaila Ismail, Zakiah Mohd Yusoff, Mohd Nasir Taib	PDF 1339-1348
NN-SVM: a hybrid neural network-support vector machine framework for accurate pneumonia detection from chest X-rays Santosh Kumar Jankatti, Raghavendra Srinivasaiah, Mohammad Shahina Parveen, Harish H. Kenchannavar, Danthuluri Sudha, Srihari Sharma Karigiri Narah, Mahadev Shivaraj	PDF 1349-1361
Machine learning-based solar power prediction for major Indian metro cities Komal Kumar Napa, Rajkumar Govindarajan, J. Senthil Murugan, Billa Manindhar	PDF 1362-1370
Blockchain-enabled framework using diversity mutation with siberian tiger optimization for offloading in fog computing Srikanta Murthy Rajini, Reginald Shilpa	PDF 1371-1380
Automated classification of apple bruises from hyperspectral images: an approach for fruit quality assessment Peddireddy Venkateswara Reddy, Alaguchamy Parivazhagan	PDF 1381-1389
Accurate stroke area classification using extreme gradient boosting with multi-feature extraction Kavikondala Praveen Kumar Rao, Maha Lakshmi Bondla, Bommaraju Srinivasa Rao, Ambidi Naveena, K. V. Balaramakrishna, Srinivasarao Goda	PDF 1390-1401
The effects of data imbalance on fraud detection model accuracy Rusma Anieza Ruslan, Nureize Arbaly, Pei-Chun Lin	PDF 1402-1408
Real-time detection of rider fatigue: a comparative study of black-box and glass-box artificial intelligence approaches Cynthia Hayat, Iwan Aang Soenandi, Budi Harsono	PDF 1409-1417
Novel convolution neural network model for dysgraphia affected handwriting classification Nisha Ameya Vanjari, Prasanna J. Shete	PDF 1418-1427
Drone-assisted deep learning weed detection for sustainable agriculture and environmental resilience Agustan Latif, Handaru Jati, Herman Dwi Surjono, Mani Yusuf	PDF 1428-1440
TMA-Net: a transformer-based multi-modal attention network for abnormal behavior detection Huong-Giang Doan, Ngoc-Trung Nguyen	PDF 1441-1450
Exponential long short-term memory with Levy flight optimization for lung nodule classification Kaliba Gowthami, Kamalakannan Jayaseelan	PDF 1451-1463
Explainable social media disaster image classification using a lightweight attention-based deep learning approach Rashmi Kangokar Taranath, Geeta Chidanandappa Mara	PDF 1464-1472

Scaler enhanced deformable attention with graph neural network for video compression Revathi Kasinathaperumal, Hosanna Princye Periapandi	PDF 1473-1485
RBC Frame Net: a hybrid deep learning framework for detection of red blood cells in malaria diagnostic smear Muhammad Shameem P., Mathiarasi Balakrishnan	PDF 1486-1496
A reinforcement-guided multi-phase hybrid architecture for threat profiling and defense towards IoT handheld device Pushpa Rajput Narayana Singh, Neelambike Siddalingaiah	PDF 1497-1504
Zoneout regularization-gated recurrent unit algorithm on NIDS with class imbalance handling Mala Kariyappa, Manjunath Hanumanthappa Rangappa, Venugopal Dasappa, Gururaja Hebbur Satyanarayana, Girish Keshava Rao, Gousia Thahniyath	PDF 1505-1512
MNetNCR: MobileNet model for efficient traditional Nusanlara script character recognition Untari Novia Wisesty, Aditya Firman Ihsan, Mahmud Dwi Sulistiyo, Donni Richasdy, Prasti Eko Yunanto, Gamma Kosala, Arfive Gandhi, Febryanti Sthevanie	PDF 1513-1528
2D-CNN-GACL-ECGNet graph attention: a robust framework for electrocardiogram-based stress detection P. Kavitha, L. Shakkeera	PDF 1529-1538
Session click sentiment behavior aware personalized recommendations system Suraj Bevinahalli Suresh, Padma Muthalambikashettahally Cheluvegowda	PDF 1539-1547
A novel approach to detect tomato leaf disease using vision transformer Sanjeela Sagar, Jaswinder Singh	PDF 1548-1565
Multimodal facial expression recognition using residual mogrifier long short-term memory Mamatha Kariyappa Rajanna, Thejaswini Shankar, Rashmi Narasimhamurthy, Nandhini Annivedu Lakshmanan, Hariprasad S. Ananthapadmanabharao	PDF 1566-1577
Image feature extraction for road surface damage classification Octaviani Hutapea, Sanfuddin Madenda, Hustinawaty Hustinawaty, Iffatul Mardhiyah	PDF 1578-1592
Fetal organ detection using feature enhancement with attention and residual block Nuswil Bernolian, Siti Nurmaini, Ade Iriani Sapitri, Annisa Darmawahyuni, Muhammad Naufal Rachmatullah, Bambang Tutuko, Firdaus Firdaus	PDF 1593-1604
Deep learning ensembles for lung cancer detection in thoracic CT scans leveraging generative adversarial network technology Bineesh Moozhippurath, Jayapandian Natarajan	PDF 1605-1612
Enhancing imbalanced dataset diagnosis using class-based input image composition Azzeddine Hlali, Majid Ben Yakhlef, Soulaïman El Hazzat	PDF 1613-1622
Analysis of tuberculosis detection using deep learning technique and explainable artificial intelligence Shashikiran Srinivas, Kavita Avinash Patil, Kushalatha Monappa Rama, Sudha Venkateshlu, Jayanthi Muthuswamy, Srinivas Babu Narayanappa	PDF 1623-1631
Breast cancer detection using residual DenseNets in deep learning Naganandini Gururajarao, Vishwanath R. Hulipalled	PDF 1632-1645
Unified voting-based ensemble learning for rice leaf disease detection using improved pretrained models Govindarajan Subburaman, Mary Vennila Selvadurai	PDF 1646-1663
Efficient text detection and recognition in natural scene images using novel blended ensemble deep learning Rajeswari Reddy Patil, Aradhana Dammergidda	PDF 1664-1679
Climate change and pollinator dynamics: integrating social media insights and ecological data for conservation strategies Pooja Hadimane, Ashoka Kukkuvaada, Gangamma Hediylad, Govardhan Hegade Kota, Rajeswari Kisan, Shivanand Patil, Arjun Myala, Basavaraja Anekonda Subhash	PDF 1680-1690

Enhanced VGG-19 model for rice plant disease detection and classification	PDF
Aye Thida Win, Khin Mar Soe, Myint Myint Lwin	1691-1700
A deep learning-based approach for hearing loss detection	PDF
Deepa Deepa, Manjula Gururaj Rao	1701-1708
YOLOv8-TMS: spatiotemporal attention networks for real-time occlusion-resilient urban traffic monitoring	PDF
Vidhya Kandasamy, Antony Taurshi, Thavittupalayam M. Thiyaagu, Catherine Joy RusselRaj, Jenefa Archpaul	1709-1718
Comparative deep learning study for downy mildew detection in vegetables	PDF
Supreetha Shivaraj, Manjula Sunkadakatte Haladappa	1719-1732
ResNet based deep learning approach for chronic obstructive pulmonary disease prediction using lung sound analysis	PDF
Babitha Sudhakar Ullal, Veena Kalludi Narasimhaiah, Rithul Kamesh	1733-1745
Deep learning for early detection of cardiovascular diseases via auscultation sound classification	PDF
Shreyas Kasture, Sudhanshu Maurya, Amit Kumar Sharma, Santhosh Chitraju Gopal Varma, Kashish Mirza, Firdous Sadaf Mohammad Ismail	1746-1761
Deep learning for mental health analysis: long short-term memory approach to text-based condition classification	PDF
Zaqqi Yamani, Dinda Lestari, Sarifah Putri Raflesia, Purwita Sari, Ghita Athalina	1762-1770
Transformer-based Hindi image description and storytelling using enhanced attention and FastText embeddings	PDF
Anjali Sharma, Mayank Aggrwal, Jitin Khanna	1771-1782
Hybrid machine learning for imbalanced lettuce disease classification	PDF
Fazlur Ihzanurahman, Wayan Firdaus Mahmudy	1783-1789
A sequential attention-enhanced deep learning framework for robust potato leaf disease diagnosis under real field conditions	PDF
Watcharkorn Yoochomboon, Nithizethe Mhuadthongon, Piyaporn Krachodnok	1790-1803
IndoBERT for educational assessment: comparative analysis of transformer models in Indonesian question generation	PDF
Handaru Jati, Yuniar Indrihapsari, Pradana Setialana, Danang Wijaya, Satya Adhiyaksa Ardy, Dhista Dwi Nur Ardiansyah	1804-1813
Semantic-syntactic graph network for aspect-based sentiment analysis	PDF
Rekha Bdurga Harish, Neelambike Siddalingaiah	1814-1824
A hybrid model for enhanced aspect-based sentiment analysis using large language models	PDF
Mohammed Ziaulla, Arun Biradar	1825-1838
Revolutionising essay writing: a systematic review of Google Gemini	PDF
Shirley Ling Jen, Abdul Rahim Salam, Hamidah Mat, Wong Wei Lun	1839-1850
Sentiment-aware user-item recommendation combining weighted XGBoost and optimized similarity metrics	PDF
Snehal Bhogan, Vijay S. Rajpurohit, Sanjeev S. Sannakki	1851-1862
Research themes and trends in the field of blockchain engineering: a topic modelling analysis	PDF
Dinara Zhaisanova, Madina Mansurova	1863-1875
A comparative study of Arabic morphological analyzers	PDF
Omar Saadiyeh, Alaaeddine Ramadan, Chamseddine Zaki, Mohamad Hajjar, Gilles Bernard	1876-1890
TunDC: a public benchmark dataset for sentiment analysis and language modeling in the Tunisian dialect	PDF
Ahmed Khalil Boulahia, Mourad Mars	1891-1908

Evaluating document chunking approaches for retrieval augmented generation in editorial content	PDF
Erwann Lavarec, Yu Du	1909-1918
Summarization of IndoSum dataset using enhanced TextRank with weighted word embedding	PDF
Evi Yulianti, Piawai Said Umbara	1919-1930
Hybrid recommender for computer aided design software	PDF
Younes Zidani, Younes Zahrou, Salah Nissabouni, Moulay El Houssine Ech-Chibat, Khalifa Mansouri	1931-1946
Unimodal and multimodal techniques for depression diagnosis: a comprehensive survey	PDF
Swathy Jayasree, Yashawini Sridhar	1947-1954
Usability analysis of the individual creativity assessment tool using the adjusted system usability scale	PDF
Mohamad Rahimi Mohamad Rosman, Noor Arina Md Arifin, Siti Aishah Mokhtar, Nur Ainatul Mardiah Mat Naw, Huda Hamidon, Salliza Md Radzi	1955-1962
AI-induced fatigue among students in higher education: a latent profile analysis	PDF
Dynah D. Soriano, Jordan L. Salenga, John Paul P. Miranda, Juvy C. Grume, Emerson Q. Fernando, Amado B. Martinez, Jr., Raymond A. Cabrera, Jaymark A. Yambao	1963-1971
Enhancing digital asset ownership through decentralized non fungible token applications	PDF
Yusuf Kurmia, Rino Rino, Edy Edy, Junaedi Junaedi, Aditiya Hermawan, Kevin Kevin	1972-1981
Development of rough set based machine learning approach to screen breast cancer	PDF
Sangeetha Sivakumar, Shakeela Sathish, Debabrata Datta	1982-1998
Improved mask faster recurrent convolutional neural network for breast cancer classification using histopathology images	PDF
Pattan M. D. Ali Khan, Xavier Arputha Rathina	1999-2008

Enhancing digital asset ownership through decentralized non-fungible token applications

Yusuf Kurnia¹, Rino¹, Edy², Junaedi³, Aditiya Hermawan¹, Kevin¹

¹Department of Informatics Engineering, Faculty of Sains and Technology, Buddhi Dharma University, Banten, Indonesia

²Department of Software Engineering, Faculty of Sains and Technology, Buddhi Dharma University, Banten, Indonesia

³Department of Information Systems, Faculty of Sains and Technology, Buddhi Dharma University, Banten, Indonesia

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Smart contract

ABSTRACT

The rapid expansion of the digital ecosystem has introduced pressing challenges surrounding identity, authenticity, trust, and transparency. The ease with which digital content can be duplicated often undermines creators, whose works are distributed without consent or fair compensation. Blockchain technology offers a transformative solution through its decentralized, transparent, and tamper-resistant structure. Among its innovations, non-fungible tokens (NFTs) provide a mechanism to verify the authenticity and ownership of unique digital assets. This study explores the transformative potential of NFTs in strengthening digital ownership and authenticity while identifying critical challenges such as market concentration, interoperability limitations, and security vulnerabilities within public NFT platforms. Employing the extreme programming (XP) methodology, this research proposes a secure framework for NFT creation outside public marketplaces to enhance the protection of smart contracts and user accounts. The findings demonstrate that this approach grants users' greater control, minimizes exposure to platform-level risks, and promotes trust in decentralized asset management. Overall, this study underscores NFTs' pivotal role in reshaping digital ownership models and highlights the need for continued innovation to ensure security, transparency, and equitable value distribution in the evolving digital economy.

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Corresponding Author:

Yusuf Kurnia

Department of Informatics Engineering, Faculty of Sains and Technology, Buddhi Dharma University

41 Imam Bonjol Street, Karawaci, Tangerang, Banten, Indonesia

Email: yusuf.kurnia@ubd.ac.id

1. INTRODUCTION

In today's digital age, the availability of information is abundant and easy to obtain, access, exchange, distribute, and transmit at any time, anywhere, via the internet. In addition to bringing many benefits, it has raised new challenges and problems in identity, authenticity, trust, and transparency. Through the internet, all kinds of digital media can be easily shared and copied, with or without the permission or consent of the original content's creator or owner, whose distribution is a problem for the creator because their work can be copied and distributed without consent or remuneration. There is no widely accepted way to determine a digital artwork's "original" part. Nor is there a widely accepted way of proving or diverting its ownership. It is becoming a challenge and a problem that still needs to be faced in today's digital age. One of the critical advantages of blockchain is its ability to provide a highly secure and transparent platform for transactions. This can help mitigate fraud, data manipulation, and lack of trust in various industries [1].

Blockchain is a digital book technology whose databases are shared and replicated by many parties and can only be updated by following pre-established rules [1], [2]. A data update has been verified, approved, and distributed to all parties. It will add a new block to the chain copy. Each block has a unique hash, and if someone tries to change the data in the block, the hash in that block will change. This blockchain technology has revolutionized the creation of ownership records for digital works as exciting innovations such as creating proprietary records or books that cannot be changed and decentralized [3].

Non-fungible tokens (NFTs) are digital information units stored on the blockchain that authenticate digital assets as unique and, therefore, cannot be inherently exchanged for NFTs with other non-fungible assets [4]. NFT has received significant attention as a digital asset for various purposes, such as photos, videos, audio, profile images, identities, and other types of digital files [5]. Ownership of an NFT can be likened to possessing a priceless masterpiece, where individuals can download it from the internet or acquire it in a printed format for personal use. However, the essential truth regarding ownership remains unaltered, with only one individual trusting its authenticity. The immutable and tamper-proof nature of blockchain technology enables the recording and interlinking of transactions related to artworks, establishing a transparent and verifiable lineage of ownership [6]. Moreover, the rise of NFTs has created a paradigm shift in how society perceives and values digital content. These tokens empower creators to assert their ownership and authenticity over digital creations in an unprecedented manner, opening up new avenues for artists, content creators, and collectors alike to participate in a digital economy underpinned by the principles of blockchain technology.

Based on research conducted by Alizadeh *et al.* [5] shows that the NFT market has experienced a significant rise in NFT manufacturing and trading. However, only a few participants made most of the sales and purchases, while most addresses had some NFT transactions. Some marketplaces provide NFT manufacturing services, but they have just supported some formats, so there are still quite limited files that can do NFT manufacturing. Furthermore, transferring ownership of an NFT within a marketplace necessitates the obligation of covering associated costs within that specific marketplace. This financial responsibility may include transaction fees incurred while transferring the NFT from one owner to another. These fees contribute to maintaining and operating the marketplace infrastructure and ensure participants' secure and efficient exchange of NFTs. NFT buyers and sellers need to be aware of and consider these costs as they engage in transactions within the marketplace ecosystem, as they can vary and impact the overall economic aspects of NFT trading and ownership transfers. Also, the vulnerability of the existing marketplace website can cause a chance of losing our NFT. Based on reports of a hack on nifty gateway, a popular exchange for NFTs, there has been a security vulnerability in its system, which has resulted in the account of Michael Miraflor, a media strategist, being hacked and his entire collection of NFTs being deleted within minutes [7]. So, with the creation of NFTs themselves, whose operations are not for the public, users can ensure the security of smart contracts and user accounts because access is not like the public marketplace exists. So, by creating private NFTs, users can ensure the security of smart contracts and user accounts because access is different from the public markets.

2. METHOD

This research uses extreme programming (XP) as a strategic methodology, as shown in Figure 1. XP selection is supported by an established reputation as a fast, highly efficient, and exceptionally low-risk approach to software development. XP is one of the popular software development methodologies from the Agile family, used for small-scale projects [8]. The adoption of XP aligns with the fundamental objectives of this research, which aim to address the complexities of developing innovative solutions in the context of decentralized and NFT applications for personal asset management. XP's emphasis on flexibility, collaboration, and iterative development makes it particularly well-suited to the dynamic nature of blockchain technology and NFT integration, providing a systematic framework for achieving research goals while minimizing potential risks. Since XP requires minimal supporting procedures, it eliminates the need for extensive project specifications and documentation [9]. The fact that it is team-oriented implies that everyone on the development team, not just the team's owner or manager, is responsible for the project's successful completion [9]. This methodology choice helps maintain consistency and reliability throughout the research process, ensuring the validity of the findings.

To ensure a comprehensive evaluation, several additional experiments will be conducted to assess the system's performance across various dimensions. These experiments will include a cost-per-mint analysis on selected blockchain networks to evaluate the financial efficiency of minting NFTs. In addition, an end-to-end latency measurement will be performed, capturing both the InterPlanetary file system (IPFS) upload time and the mint confirmation period, providing insight into the system's responsiveness. Usability testing will also be conducted via a questionnaire administered to multiple users, enabling an evaluation of the user experience. Finally, interoperability testing will assess the system's ability to import external NFTs

and read third-party contract metadata, ensuring compatibility with other platforms. These evaluations will generate empirical data, substantiating the findings and ensuring a thorough and multifaceted performance assessment of the system.

Figure 1 shows the planning phase, which involves identifying in-depth research objectives, a careful planning strategy of application features, measurable resource allocation, and developing a structured, iterative plan. This stage serves as a solid foundation for further development. During the design stage, a comprehensive application conceptual design process was carried out, considering comprehensively the integration of NFTs in the context of personal digital asset management. Besides that, selecting the appropriate blockchain technology and detailing an accurate initial test plan is also integral to this stage. While in the development (coding) stage, the research team started implementation based on the design that had been made with a high level of accuracy and thoroughness. This phase includes implementing the designed features, including the ability to create, store, and manage NFTs in the context of personal digital asset management. Finally, the testing phase involves a series of systematic tests, including rigorous unit testing, comprehensive integration testing, and overall testing to verify the functionality of the NFT in the application and ensure that its performance and security aspects are met with a high level of confidence. With this highly structured XP-software life cycle (SLC) approach, developing NFT applications for personal digital asset management follows strict scientific procedures and guarantees success in achieving the stated research objectives.

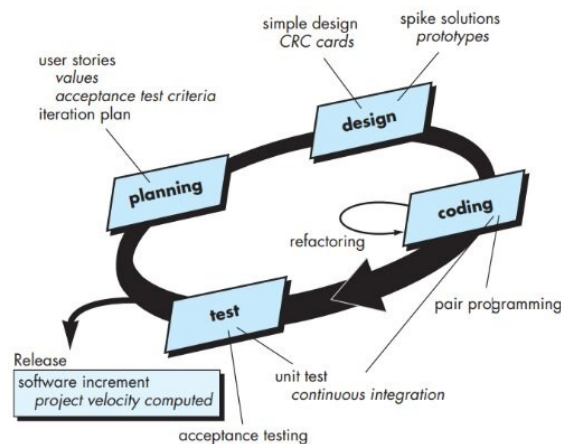


Figure 1. XP software life cycle

2.1. Blockchain

Blockchain is a type of database that is both decentralized and distributed. It is frequently used to preserve the record of every single transaction in a block, which is then secured with cryptographic hashes [10]–[13]. When Satoshi Nakamoto published a white paper on the decentralized cryptocurrency Bitcoin in 2008, the first application of blockchain technology was suggested [14], [15]. By combining various pre-existing technologies, such as asymmetrical encryption, Merkle Tree structures, and Hashcash (a cryptographic algorithm that makes verifying a proof simple but computing it complex), he managed to create a novel solution [15].

According to [16], here is a possible explanation for a blockchain: a blockchain is an immutable and read-only data structure. It works by appending new entries (blocks) to the end of a ledger. These blocks are linked to the previous block's 'hash' identifier.

2.2. Non-fungible tokens

NFTs have emerged as a subject of rigorous examination across various interdisciplinary academic domains, such as finance, real estate economics, law (with a focus on intellectual property rights), and information technology [17]. Researchers like Sunyaev *et al.* [18] have delineated two approaches for integrating tokens into an existing distributed ledger. The first method involves the utilization of a private distributed ledger, which restricts access solely to authorized agents, allowing them to partake in reading transactions from and append new transactions to the ledger. On the other hand, the second approach

empowers agents to design bespoke tokens by employing smart contracts, thus offering flexibility while utilizing an existing distributed ledger to implement the token-based economy [17]. Furthermore, the research conducted by Peres *et al.* [19] and Taherdoost [20], has emphasized that NFTs represent cryptographic assets within the blockchain ecosystem, characterized by their possession of unique identification information and code, which sets them apart from one another. This distinctiveness is a crucial attribute contributing to the growing popularity and adoption of NFTs. Additionally, NFTs have demonstrated their potential in mitigating fraudulent activities, primarily because each token bears the digital signature of its owner, thus ensuring its uniqueness and authenticity within the blockchain system [20]. Consequently, NFTs are gaining increasing prominence and application across various academic disciplines and industries thanks to their unique properties and versatility in use cases.

2.3. Smart contract

Smart contracts are computer programs that are an essential part of the blockchain network. They describe the triggers, conditions, and business logic, allowing intricate programmable transactions [21], [22]. A smart contract is a set of code-based instructions that can be executed automatically on a blockchain network according to predetermined agreements or conditions. These smart contracts consist of a set of pre-defined rules; if these rules are met, they trigger the automatic execution of the programmed agreement. In other words, a smart contract functions as a set of instructions written in a programming language that contains a certain logic. With smart contracts, the agreement process becomes more efficient because it does not require intermediaries or third parties to verify or enforce the agreement. For example, suppose all the terms and conditions specified in the smart contract are met in a buying and selling transaction. In that case, the transaction will be carried out automatically without human intervention. This helps facilitate, verify, and enforce agreements more efficiently in the blockchain environment.

Smart contracts concentrate solely on the technological aspect of contracts, disregarding the social environments in which contracts function and the intricate methods individuals utilize them [23]–[25]. Consequently, smart contracts cannot be considered identical to traditional contracts [23], [26]. Smart contracts extend the utility of a blockchain from storing transactions to enforcing the terms of multi-party agreements. Smart contracts also help enter multi-party agreements involving anything of value, be it money, property transactions, or other entities, without needing a third-party intermediary. Thus, when using it, the parties involved do not have to rely on lawyers or banks to conclude contracts, but when certain conditions are met, the smart contract will automatically run to issue payments. The implementation of smart contracts on the blockchain makes them immutable. That is, the contract used can never be canceled or deleted.

2.4. InterPlanetary file system

IPFS is an innovation developed by Juan Benet in 2014. This system is designed as a solution for the efficient storage and distribution of large files in a distributed manner. It aims to replace the currently dominant HTTP request-response protocol. IPFS was developed as open-source software and boasted the absence of a single point of failure, thereby allowing nodes in a network to operate without establishing trust between them. The infrastructure offered by IPFS can identify, verify, and transfer files using cryptographic hashes to guarantee the authenticity of files, regardless of their storage location on the network [27].

The existing systems within IPFS have proven efficient and secure in document retrieval, management, and validation while preventing malicious data modification [28]. Like public blockchains, files stored on IPFS can be accessed and viewed by anyone connected to IPFS nodes. Unlike in a central server, these files are not stored. Instead, they are distributed across multiple nodes, which creates a vital decentralization feature. It is important to note that storing data in a blockchain has a different fee model depending on the size of the data, and transactions on a blockchain store only a small amount of data. Therefore, it is crucial to consider wisely which data should be placed on-chain and which data is more appropriate to store off-chain. As such, IPFS becomes an essential solution for ample file storage on the blockchain, as it provides a peer-to-peer distributed file system that fragments, encrypts, and distributes files to various nodes in the network, maintaining their security and availability.

3. RESULTS AND DISCUSSION

The creation of NFT applications for these digital works and assets uses Python as a programming language and Brownie as a framework for developing smart contracts targeting the ethereum virtual machine. In addition, PYQT5 is utilized as a framework for creating the application's graphical user interface (GUI), offering a wide range of pre-built design elements. Figure 2 is a visual representation that clearly and in detail depicts the entire process involved in designing an NFT creation application. This process starts from the initial stage, where the user uploads the data that will be converted into an NFT into the application. Once the data is uploaded, the next step is to store it in smart contracts running on the Ethereum network. Storing

data in smart contracts is very important because smart contracts act as smart entities that facilitate NFT transactions and management. In smart contracts, NFT data will be assigned a unique ID token, which will then become the official identity of the NFT on the blockchain network. The token standard implemented is ERC-721, which ensures the uniqueness of each NFT. Additionally, metadata for each NFT is stored in JSON format, including information such as the token ID, name, description, and creator details. Furthermore, the royalties for each NFT are implemented using EIP-2981, which allows creators to define royalty fees for secondary sales of their NFTs. In addition, Figure 2 also includes the stage where the data uploaded by users is integrated with the IPFS blockchain network. This data is uploaded to IPFS via the Infura API, which ensures secure and distributed storage. After uploading, IPFS generates a hash value reflecting the data storage location on the IPFS network. This ensures that the data remains secure and accessible across the decentralized storage network.

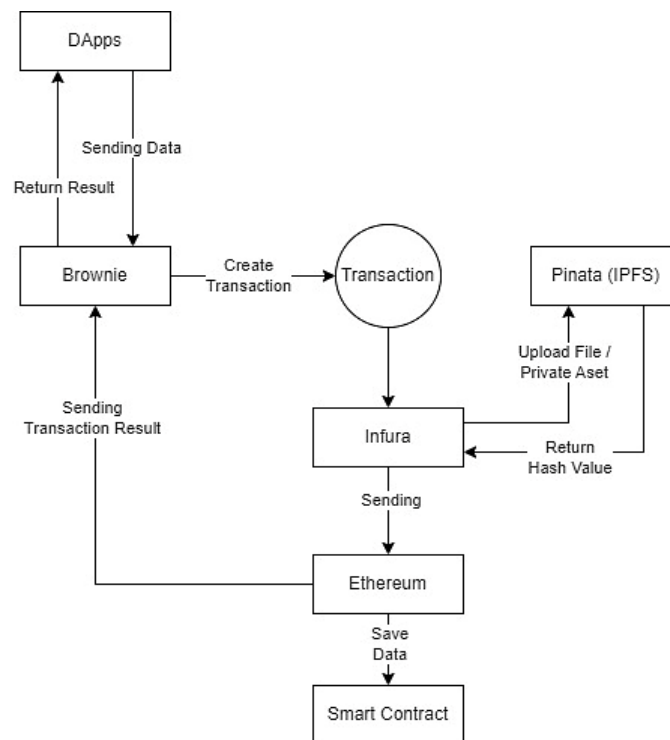


Figure 2. Proposed model

This entire process is reflected in Figure 2, which allows users and interested parties to quickly understand how the application works from the data upload stage to data storage in smart contracts and IPFS. This image provides a comprehensive and in-depth visual view of the mechanisms underlying the creation and management of NFTs in the context of such applications. Users must enter a private key before using the application. The private key serves as a cryptographic key used by the blockchain algorithm to encrypt or decrypt data or to sign transactions performed during the minting of NFTs. It is important that users store their private keys securely, ideally in a hardware wallet, to prevent unauthorized access. After this, users will be directed to the main menu and select the desired options according to the file type for NFT creation. After filling in the form and entering the file you want to use as NFT, the application will upload the file to IPFS, returning the hash value of the file stored on IPFS. The stored hash will be re-entered into the data format as JSON, which will be uploaded back to the IPFS to obtain the hash value. The hash is put together in a link format, where the link will be sent as a transaction into the blockchain to validate the transaction.

Figures 3 and 4 show creating an NFT on decentralized application (DApp). The first stage is to choose the type of asset the NFT will be created from, and then fill in the detailed information on the created asset. Then, the mint process is carried out on the blockchain via a smart contract, and the assets are stored on IPFS. Once the mint process is complete and at least two blockchain nodes have validated the transaction, the application will display a pop-up message that can display the NFT created on the OpenSea NFT marketplace website. Users can also view the NFT information that has been created through the Asset menu on the

application, which will display a variety of information such as token ID, NFT name, description, file link NFT, information about the website, file type, creator name, artist name, registration date, date of expiration, image NFT cover link, type of NFT created, and transaction ID as a link to <https://etherscan.io> so that users can directly perform NFT self-checking on the Ethereum blockchain that they already have through the etherscan website.

In its application, the Infura API is used as a node provider. In the blockchain, each node holds a copy of every significant block, then called the blockchain. Moreover, every interaction on the blockchain requires a node to communicate and validate a transaction. Using Infura as a node provider to access the Ethereum blockchain will be much easier and faster, as users do not have to build their nodes and synchronize against the Ethereum blockchain. Also, using this blockchain node provider makes DApp scaling safer and eliminates the need to develop and construct its infrastructure in the DApp infrastructure. Figure 5 shows data that has been stored on the blockchain and can be traced through the scanner on the blockchain to ensure that the data has been entered and validated by the nodes on the blockchain. The application was tested using the Black Box testing method, and the results are obtained in Table 1.

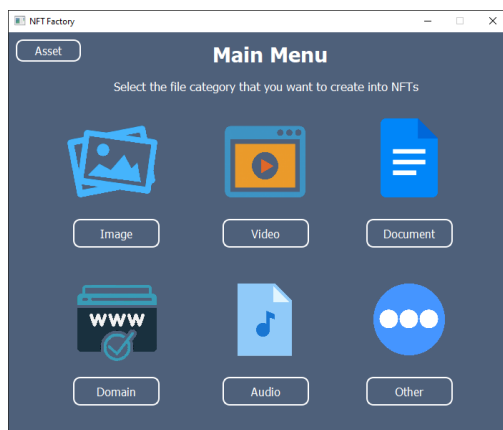


Figure 3. Application main menu view

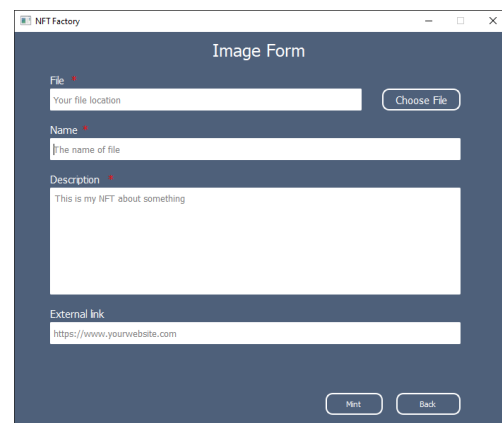


Figure 4. Application image menu view

Registration Date	Expired Date	Image Cover	Type of	TXID (url)
1	1990-01-10 ...	https://...	Audio	https://rinkeby.etherscan.io/tx/0x5b4b413b04b1cf6f4f114c90e28...
2	2020-08-0...	https://...	Docu...	https://rinkeby.etherscan.io/tx/0x561c9c7edbeadd1bbe9250c9f1...
3	https://...	https://...	Video	https://rinkeby.etherscan.io/tx/0x4f5380c09b5c5e73c15e7cd1e7e35d...
4	https://...	https://...	Other	https://rinkeby.etherscan.io/tx/0xb5633bfa43fd96ed58028d3c4d4...
5		https://...	Image	https://rinkeby.etherscan.io/tx/0x7aa268efc7482ac3794b90016a092c...
6		https://...	Image	https://rinkeby.etherscan.io/tx/0x62c16d975c127140cb394f18aa8...
7		https://...	Image	https://rinkeby.etherscan.io/tx/0xd260b6aaf429228b366dfc760adff...
8		https://...	Image	https://rinkeby.etherscan.io/tx/0x1d4156809a03cfc827b09dedc17e8...
9		https://...	Docu...	https://rinkeby.etherscan.io/tx/0xb4c36bad4a335051738285a2867c...
10		https://...	Docu...	https://rinkeby.etherscan.io/tx/0xb4c36bad4a335051738285a2867c...
11		https://...	Video	https://rinkeby.etherscan.io/tx/0x77cc029fac66262013d279a7828...
12		https://...	Image	https://rinkeby.etherscan.io/tx/0x482735e5689157f6ccdb629af4f0...

Token Id	Name	Description	File	Website	File Extension	Creator	Artist	Registration Date
1	11	Suara ...	Kejadian di ...	https://gateway.pinata.clo...	mp3	Acep ...	Siapa...	
2	10	Website ...	Website ...	https://...				1990-01-10 ...
3	9	Dokum...	Draf akhir ...	https://gateway.pinata.clo...	pdf			
4	8	Tragedi ...	kejadian di ...	https://gateway.pinata.clo...	3gp	Acep ...		
5	7	Koding...	Dibuat saat ...	https://gateway.pinata.clo...	java			
6	6	Gemba...	Diambil ...	https://gateway.pinata.clo...	png			
7	5	Penna...	malam jum...	https://gateway.pinata.clo...	png			
8	4	testing 2	deskripsi	https://gateway.pinata.clo...	png			
9	3	Penam...	Saya meliha...	https://gateway.pinata.clo...	bmp			
10	2	Lapora...	Laporan ...	https://gateway.pinata.clo...	pdf			
11	1	Penam...	Ketika saya ...	https://gateway.pinata.clo...	mp4	Ucup ...		
12	0	Bojone...	Pelabuhan ...	https://gateway.pinata.clo...	png			

Figure 5. Assets menu view

Researchers have identified several areas for improvement in developing the proposed NFT model that hinder its features. An in-depth evaluation of these deficiencies provides valuable insights for improvement and better future development. One drawback of this proposed model is that it cannot display NFTs that did not originate or were created through this platform, which suggests the potential to improve interoperability with NFTs from various external sources. Second, this model also does not support users in importing smart contract addresses directly when wanting to access NFTs, so improvements in this area will allow users to access NFTs originating from various smart contracts on the blockchain more easily. Lastly, this model does not provide an option to cancel a transaction from either the user or system perspective,

which often requires repeated confirmations to confirm the desired transaction. Increasing flexibility in managing transactions would be a positive step towards improving user experience. Analysis of these shortcomings provides valuable insight into how the proposed NFT model can be improved to meet broader user needs and strengthen its position in the ever-evolving NFT ecosystem.

Table 1. Black box testing results

Testing	Scenario	Expected results	Results	Validity
Main menu	Select existing menu options	Displays the target menu page	Match	✓
Image menu	Create NFT image	Can make NFT	Match	✓
Video menu	Create NFT video	Can make NFT	Match	✓
Document menu	Create NFT document	Can make NFT	Match	✓
Domain menu	Create NFT domain	Can make NFT	Match	✓
Audio menu	Create NFT audio	Can make NFT	Match	✓
Assets menu	Create NFT assets	Can make NFT	Match	✓
Others menu	Create other NFT	Can display NFT in mint via the application	Match	✓

To ensure the reproducibility of this research, all necessary technical details for replication are provided. The code used to implement key processes, such as NFT creation, smart contract interactions, and IPFS uploads, is available in the supplementary materials. A critical section of the code, specifically the minting function, is outlined as follows: the program connects to the Ethereum network using Web3 and Infura, constructs a transaction to mint the NFT, signs it with the user's private key, and sends the transaction to the blockchain. The exact versions of the tools and libraries used in this study are: Python 3.9, Brownie v1.17.2, IPFS (ipfshttpclient v0.4.6), and the Infura API v3 for Ethereum. To further enhance reproducibility, sample transaction hashes generated during testing on the Ropsten testnet are provided. For example, the minting transaction hash “0x9c1e8927dbca99f6f1edb2bb99c7e4a1588a4bc4c5fe278bcefc4c1c47b6bcd1” and the smart contract deployment hash “0x34c9a87d3fd22d440ad5d12f322d9c3f4a37682f351e7b0290d3091da07dbba7” can be verified on the Ropsten Etherscan Explorer. This process is supported by full pseudocode in the supplementary materials, detailing the steps necessary for others to replicate the work. The exact versions of the tools used are Python 3.9, Brownie v1.17.2, IPFS (ipfshttpclient v0.4.6), and the Infura API v3 for Ethereum. In addition to the code and versions, a threat model has been outlined to assess potential risks associated with the application. The model identifies key assets, adversaries, attack vectors, and corresponding mitigation measures to secure the system and ensure that vulnerabilities are minimized during interactions on the blockchain. The model outlines the risks involved, such as man-in-the-middle (MITM) attacks targeting NFT data or phishing attacks aimed at user private keys. Mitigation measures, such as the use of hardware wallets for private key storage, contract upgradability, input sanitization, and rate-limiting, are implemented to minimize potential attack vectors, as detailed in Table 2.

Table 2. Threat model

Assets	Adversaries	Attack vectors	Mitigation measures
NFT data (metadata, files)	Malicious users	MITM attacks	Use of hardware wallets for private key storage
Smart contract interactions	Malicious smart contracts	Reentrancy attacks and overflow	Contract upgradability, input sanitization, and rate-limiting
User private keys	Phishing attacks	Keylogging and social engineering	Hardware wallets, multi-signature contracts

For experiments conducted during the research, several important metrics were measured to assess the performance and usability of the system. Gas cost per mint was measured by running the minting process 10 times, with the mean $\pm$ standard deviation (std) reported to evaluate the cost efficiency. IPFS upload and pin time via Infura was also measured, with results provided in the same format (mean $\pm$ std) to evaluate the performance of the IPFS upload process. Usability testing was carried out with a small group of 6-12 users using the system usability scale (SUS), providing quantitative feedback on the application's ease of use, clarity of instructions, and overall satisfaction. Additionally, the interoperability test involved importing and displaying two external NFTs, confirming that the system can effectively integrate and display NFTs from other sources. These experiments and their results ensure the technical reproducibility of the study, providing empirical data to evaluate the performance and usability of the system. By making these details available, other researchers can replicate the process, validate the results, and build upon the work in future studies.

4. CONCLUSION

Based on the extensive research findings in blockchain and NFTs, utilizing NFTs for personal digital assets and works within the blockchain ecosystem has demonstrated remarkable efficacy. The process of tokenizing a diverse array of file types while ensuring cross-format compatibility has exhibited robust functionality, affirming the application's capacity to create and manage NFTs seamlessly. Notably, this application showcases high interoperability by facilitating users to access and exhibit their NFTs through established channels such as the OpenSea NFT marketplace website. This integration broadens the exposure of digital assets and enhances their visibility to a broader audience, underpinning the platform's potential as a valuable tool for creators within the NFT landscape. Furthermore, users can exercise real-time oversight of their NFTs on the Ethereum blockchain through platforms like Etherscan, emphasizing the application's alignment with the blockchain's core principles of transparency and decentralization. The research outcomes underscore the NFT application's role in empowering creators to tokenize and manage their digital assets within blockchain technology. This development opens new avenues for creators to harness the benefits of NFTs, thus revolutionizing private asset management within DApps.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Yusuf Kurnia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rino		✓	✓	✓	✓					✓				
Edy		✓	✓	✓						✓				
Junaedi	✓				✓	✓				✓				
Aditiya Hermawan					✓					✓	✓			
Kevin			✓			✓				✓				

C : Conceptualization

M : Methodology

So : Software

Va : Validation

Fo : Formal analysis

I : Investigation

R : Resources

D : Data Curation

O : Writing - Original Draft

E : Writing - Review & Editing

Vi : Visualization

Su : Supervision

P : Project administration

Fu : Funding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no known financial or non-financial competing interests that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

The datasets generated and analyzed during the current study, including transaction logs, performance measurements, and usability evaluation results, are available from the corresponding author upon reasonable request. The source code, smart contract implementations, and supporting resources developed for this research are publicly accessible at the following repository: <https://github.com/QuertyCube/NFTFactory>. This repository contains all scripts, configuration files, and documentation necessary to reproduce the experimental procedures and system deployment described in the manuscript.

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Enhancing digital asset ownership through decentralized non-fungible token applications (Yusuf Kurnia)

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BIOGRAPHIES OF AUTHORS



Yusuf Kurnia    received a Master's degree in Computer Science from Budi Luhur University and is currently a lecturer in the Department of Informatics Engineering, Faculty of Sains and Technology, Universitas Buddhi Dharma, Tangerang, Indonesia. In his role, he teaches various information technology courses and actively engages in research focused on new technologies and their applications. His research interests include the internet of things (IoT) and automation systems. He can be contacted at email: yusuf.kurnia@ubd.ac.id.



Rino    received a Master's degree in Computer Engineering from STMIK Eresha and is currently a lecturer in the Department of Informatics Engineering, Faculty of Science and Technology, Universitas Buddhi Dharma, Tangerang, Indonesia. In his role, he teaches various information technology courses and actively engages in research focused on new technologies and their applications. His research interests include data mining, machine learning, and also internet of things. He can be contacted at email: rino@ubd.ac.id.



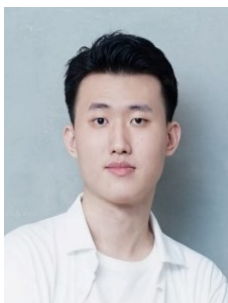
Edy    received a Master's degree in Computer Engineering from STMIK Eresha and is currently a lecturer in the Department of Software Engineering, Faculty of Science and Technology, Universitas Buddhi Dharma, Tangerang, Indonesia. In his role, he teaches various information technology courses and actively engages in research focused on new technologies and their applications. His research interests include software engineering and software quality assurance. He can be contacted at email: edy.edy@ubd.ac.id.



Junaedi    completed his studies in Computer Science and obtained a Master's degree (S2) from Budi Luhur University, and currently he is a lecturer in the Department of Information Systems, Faculty of Science and Technology, Buddhi Dharma University, Tangerang, Indonesia. In his roles, he taught various mathematics of information systems and is currently actively engaged in research focused on the latest technologies. His research interests include the internet of things, decision support systems, machine learning, and blockchain technology. He can be contacted at email: junaedi@ubd.ac.id.



Aditiya Hermawan    received a Master's degree in Computer Science from Budi Luhur University and is currently a lecturer in the Department of Informatics Engineering, Faculty of Science and Technology, Universitas Buddhi Dharma, Tangerang, Indonesia. In his role, he teaches various information technology courses and actively engages in research focused on new technologies and their applications. His research interests include data mining, machine learning, focusing on developing algorithms for data-driven predictions and decisions; database design, and blockchain technology. He can be contacted at email: aditiya.hermawan@ubd.ac.id.



Kevin    is a professional with a profound passion for emerging technologies, such as blockchain and cryptocurrency, stemming from his ambitious drive to continuously push the boundaries of what's possible within the technology sector. After obtaining a Bachelor's degree in Informatics Engineering from Buddhi Dharma University, he has successfully transformed his academic foundation into a successful career as a software engineer through numerous roles at multinational companies. Within these positions, his technical expertise and skilled problem-solving abilities enable him to effectively develop scalable automated solutions—significantly impacting projects despite complex and rapidly evolving environments. Energized by the sector's relentless progress, he pursues relentless self-driven learning and research, allowing him to stay ahead of industry changes and remain at the forefront of advancements within fields like Web3. He can be contacted at email: kevin@ubd.ac.id.