Artificial Intelligence-driven Decentralized Finance

Mohamed El-dosuky

Faculty of Computers and Information, Mansoura University, Egypt
Arab East Colleges, Saudi Arabia

ABSTRACT

Decentralized Finance, or DeFi, is a disruptive force in the financial industry, using blockchain technology to provide financial services that are accessible, open and transparent. Technologies of Artificial Intelligence (AI), particularly deep learning, are utilized in various financial tasks such as algorithmic trading, fraud detection, and risk assessment. Artificial Intelligence-driven Decentralized Finance (AI-DeFi) aims to enhance efficiency, security, and accessibility of decentralized financial systems by integrating AI technologies. This paper proposes a framework that combines AI and DeFi which contains the layers of Automated Market Makers (AMMs), yield farming and lending, and portfolio management. The AMM layer offers liquidity, asset pricing, swap execution, fee collection, and impermanent loss mitigation. Yield farming provides liquidity to decentralized exchanges or lending protocols, while lending platforms lock collateral for security and manage credit risks. DeFi portfolio management involves asset selection, risk management, and performance tracking.. This paper also provides implementation details to increase reproducibility of the proposed framework.

General Terms

Decentralized Finance, Blockchain, Artificial Intelligence

Keywords

Decentralized Finance, Blockchain, Artificial Intelligence

1. INTRODUCTION

Decentralized Finance, or DeFi for short, is a disruptive force in the financial industry, using blockchain technology to provide financial services that are accessible, open and transparent [1]. As the name suggests, DeFi eliminates the need for centralized intermediaries like banks, enabling the creation and execution of financial applications through smart contracts [2].

Figure 1 shows the DeFi stack. It has five layers: settlement, assets, protocols, aggregation and interfaces [1, 3]. Settlement allows consensus, replication, and transactions. Cryptoassets can be Non-Fungible Tokens or Fungible Tokens. DeFi protocols include lending, exchange, and derivatives. Aggregations provide compositions such as for DEX and yield. Interface provides graphical interfaces for DeFi users.

DeFi's growth is fueled by the widespread use of blockchain technology, particularly Ethereum, which offers a secure, programmable, and decentralized infrastructure for financial applications [4].
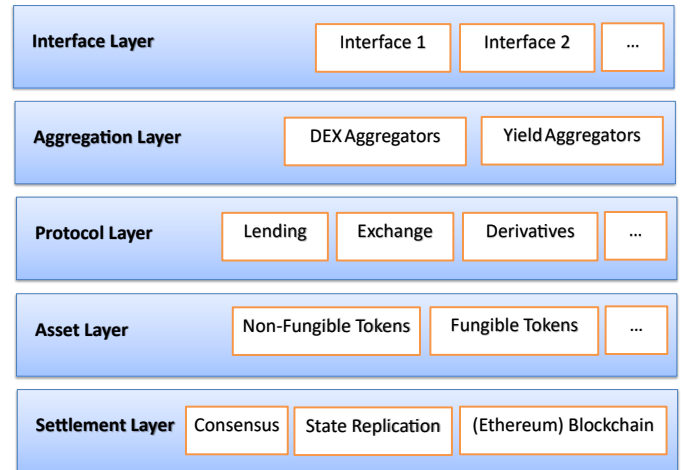

Fig. 1. DeFi Stack [1, 3]

Figure 2 shows DeFi challenges. DeFi cryptocurrencies face safety issues, fraud, privacy concerns, usability issues and limited decision-making as it is not clear who is responsible for errors.
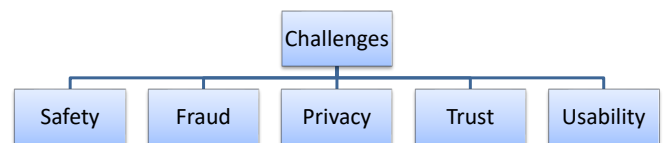

Fig. 2. Challenges Facing DeFi [5]

Technologies of Artificial Intelligence (AI), particularly deep learning, are utilized in various financial tasks such as algorithmic trading, fraud detection, and risk assessment [6].

The integration of AI in traditional finance is revolutionizing various aspects of the industry such as:

—Fraud detection and risk management [7, 8]

—Algorithmic trading [9, 10]

—Portfolio optimization [11]

—Robo-advising [12]

Integrating AI in traditional finance poses certain challenges that need to be handled such as:

—AI models can be biased, causing discriminatory outcomes [13].

—Deep learning models' lack of interpretability makes decision-making difficult [14].

—AI systems are vulnerable to adversarial attacks and data privacy concerns [15].

—AI deployment in finance raises ethical and regulatory challenges [16].

The synergy of AI and DeFi could be advantageous for both industries. The first direction of integrating AI in DeFi platforms can improve:

—market efficiency and liquidity [17],

—financial inclusion and accessibility [18],

—personalized and tailored financial services [19],

—credit assessment and risk management [20], and

—fraud detection [21].

The second direction of integrating DeFi in AI, or what can be called decentralized AI, can address data privacy and bias, promoting more accountability and trust in finance [22].

1.1 Problem Statement

Artificial Intelligence-driven Decentralized Finance (AI-DeFi) aims to enhance efficiency, security, and accessibility of decentralized financial systems by integrating AI technologies. By optimizing processes, reducing costs, and identifying malicious behavior, DeFi can revolutionize traditional financial services, simplify user interfaces, and automate compliance processes.

1.2 Contributions

The contributions of this paper are as follows:

—Exploring the potential synergies, opportunities, and challenges of combining DeFi and AI

—Proposing a framework that combines DeFi and AI, hereafter will be denoted as AI-DeFi

1.3 Paper Structure

The rest of this paper provides a background on DeFi platforms and applications in Section 2, the previous work review in Section 3, the proposed framework in Section 4, implementation in Section 5, and conclusion and future work in Section 6.

2. BACKGROUND ON DEFI PLATFORMS AND APPLICATIONS

Decentralized exchanges (DEXs) allow users to trade cryptocurrencies and tokens directly from their wallets, using automated market maker (AMM) protocols for efficient and trustless trading [23]. The famous DEXs are:

—**Uniswap v3** introduces concentrated liquidity, multiple fee tiers, and non-fungible tokens to enhance trading.

—**SushiSwap** offers features like yield farming, staking, and governance.

—**Balancer** allows for customizable liquidity pools with multiple tokens, enabling portfolio management, token trading, arbitrage opportunities, and liquidity mining.

DeFi lending platforms enable users to lend crypto assets, earn interest, or borrow funds using smart contracts, supply and demand calculations, and collateral liquidation [24]. Popular DeFi lending platforms are:

—**Aave** is a decentralized liquidity market protocol on the Ethereum blockchain, allowing users to lend and borrow crypto assets.

—**MakerDAO** stabilizes the Ethereum crypto economy using a stablecoin mechanism and governance token.

—**Compound** is a DeFi lending protocol with an algorithmic autonomous interest rate protocol, allowing users to vote on protocol changes and develop it.

Yield farming and liquidity mining involve users providing DeFi protocols with tokens or transaction fees, earning passive income and supporting market stability [25]. Reputable yield farming DeFis are:

—**Curve Finance** is a decentralized exchange for stablecoin trading, offering low slippage and fees.

—**Bancor Network** automates token conversions, utilizing an AMM mechanism.

—**Yearn Finance** optimizes yield farming strategies across DeFi protocols, reallocating funds to maximize returns.

Stablecoins maintain a stable value relative to the US dollar typically as a reference asset [26], crucial in DeFi for reducing volatility [27], while synthetic assets like Synthetix track real-world assets on blockchain [28]. **USDT**, **USDC**, and **DAI** are stablecoins pegged to the US dollar, with USDT and USDC centralized and DAI decentralized, over-collateralized by cryptocurrencies.

3. PREVIOUS WORK

3.1 Automated Market Makers (AMMs)

AI can enhance the fairness and efficiency of AMMs which are the backbone of DEXs [29]. This is achievable by dynamically adjusting liquidity pool parameters and incentives.
The formulization of constant product market maker model [30] is denoted by the equation 1:

$$x \cdot y = k \tag{1}$$

where x is the quantity of token X, y is the quantity of token Y, and k is a constant.
The price of token X in terms of token Y is given by equation 2:

$$p_x = \frac{dy}{dx} = \frac{y}{x} \tag{2}$$

When a user wants to swap an amount Δx of token X for token Y, the new quantities x' and y') after the swap must satisfy the condition in equation 3:

$$(x + \Delta x)(y - \Delta y) = k \tag{3}$$

Solving for Δy gives the equation 4:

$$\Delta y = y - \frac{k}{x + \Delta x} \tag{4}$$

3.2 Lending and credit scoring

AI can enhance DeFi lending platforms by providing accurate, inclusive credit scoring based on borrower data [19].
A simple way to model credit scoring may be presented as equation 5:

$$\text{Credit Score} = f(\text{RH}, \text{CD}, \text{C}) \qquad (5)$$

where RH denotes Repayment History, CD denotes Current Debt, and C denotes Collateral.

3.3 Yield farming

Yield farming is a method where a DeFi protocol is rewarded for providing liquidity in exchange for annual percentage yield (APY) [25]. The reward for yield farming can be computed using equation 6:

$$\text{Reward} = \text{Liquidity Provided} \times \left(1 + \frac{\text{APY}}{100}\right)^{\frac{\text{Time}}{\text{Year}}} \qquad (6)$$

where: Liquidity Provided is the amount of funds provided as liquidity, APY is the annual percentage yield, and Time is the time period the liquidity is provided for, in years.
AI optimization techniques can enhance yield farming in DeFi by scrutinizing protocol risks, fluctuations in token price , and market trends[31].
AI-powered yield aggregators can automatically rebalance portfolios and adjust staking strategies [32].

3.4 Intelligent portfolio management

AI can help users manage DeFi portfolios by providing personalized investment advice and automation, analyzing risk tolerance, investment goals, and market sentiment [33], and integrating AI-powered robo-advisors into DeFi platforms [34].

4. PROPOSED FRAMEWORK

Figure 3 shows proposed framework as an onion. At the core lies the Defi stack. Then comes the AMM layer that provides liquidity, asset pricing, swap execution, fee collection, impermanent loss mitigation, and governance and tokenomics. They allow users to contribute funds to liquidity pools by depositing equal amounts of assets, with liquidity providers earning fees proportional to their share. Asset prices are determined by a constant product formula, and swap prices are adjusted based on the pool's balances. Fees are charged for swaps, and impermanent loss is mitigated using strategies like liquidity bootstrapping pools or dynamic fee models. Governance tokens allow token holders to participate in decision-making processes and potentially provide additional benefits.
Yield farming is a method of providing liquidity to decentralized exchanges or lending protocols by depositing assets into liquidity pools. Users contribute their funds and receive token rewards, which can be used to claim rewards. Some protocols allow users to stake their tokens for additional rewards. Harvesting rewards involves regularly claiming and withdrawing them from the protocol. Yield farming exposes funds to potential impermanent loss, which can be mitigated using strategies like algorithmic stablecoin pairs or dynamic fee models. Risk assessment is crucial, considering factors like smart contract security, audit reports, tokenomics, and project reputation. Yield optimization strategies are often employed to maximize returns

Lending platforms allow users to borrow digital assets by locking collateral, providing security and mitigating risk for lenders. Borrowers can choose loan amount, duration, and interest rate. Platforms require collateral, typically digital assets, with a minimum collateralization ratio. Interest rates are determined in a decentralized marketplace, and borrowers must repay loans within a specified period. If collateral value falls below a threshold, platforms may liquidate it to recover borrowed funds and protect lenders.
Lending platforms use credit scoring functions to assess borrowers' creditworthiness, delegate lending decisions, implement reputation systems to track borrowers' performance, and manage credit risks. These functions include credit assessment, credit delegation, reputation systems, and risk management mechanisms. These functions help lenders make informed decisions about lending to specific borrowers, protect them from defaults, and minimize credit risks.
At the outer perimeter lies DeFi portfolio management which involves asset selection, risk management, yield optimization, portfolio rebalancing, performance tracking, due diligence, risk assessment, and reporting. Portfolio managers select assets based on risk tolerance, investment goals, and market conditions. They use risk management strategies to mitigate potential risks, such as diversification and regular performance evaluations. They aim to maximize yield by strategically allocating funds across various DeFi opportunities. Portfolio managers also periodically rebalance the portfolio to maintain its risk-return profile and align with investment objectives. They conduct thorough research on DeFi protocols, projects, and assets, staying updated with industry news and regulatory considerations. They assess risks, implement mitigation strategies, and maintain accurate records, providing periodic reports to stakeholders and investors.
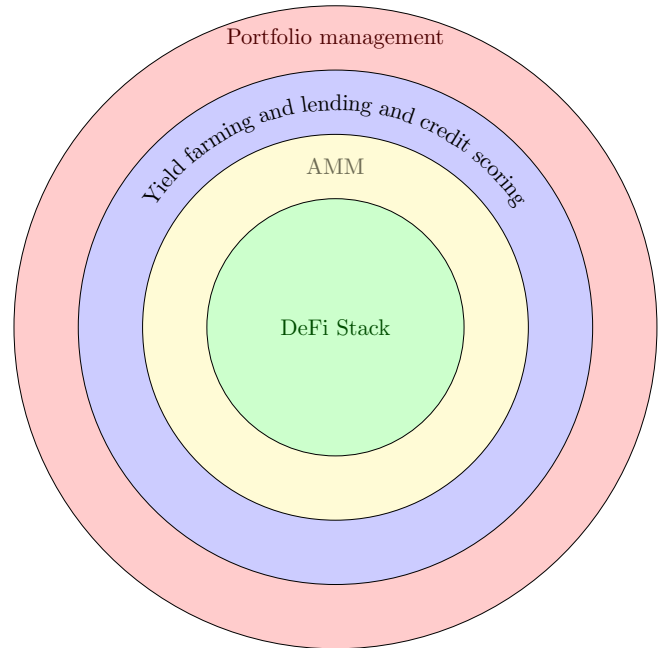

Fig. 3. Proposed Framework

Figure 4 shows flowchart for AMM. First, establish connection to Ethereum network using Web3. Second, load AMM contract us-

ing address and ABI. Third, define functions like get-token-price, swap-tokens, and add-liquidity to interact with AMM contract.
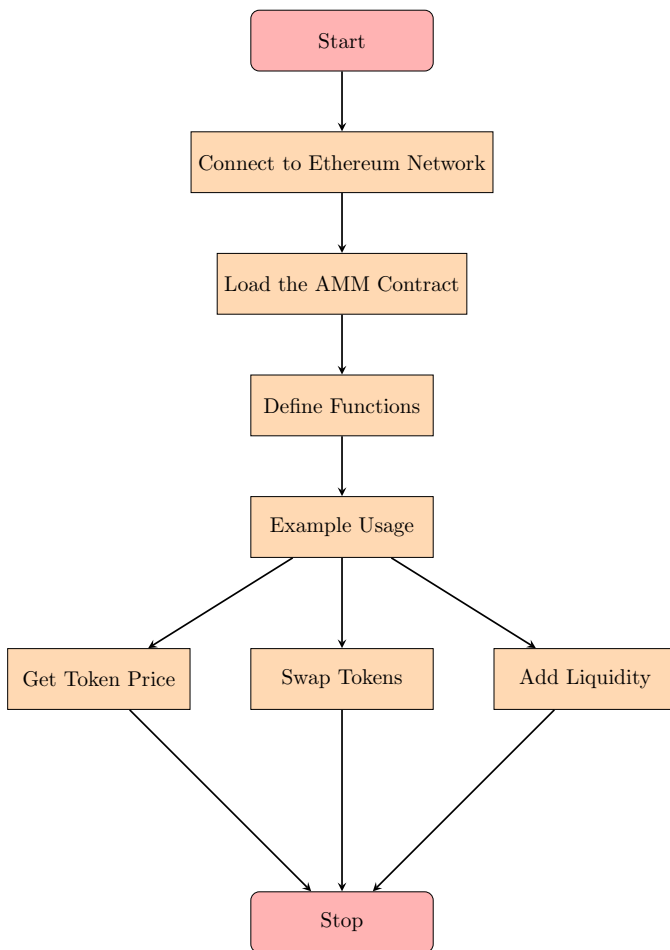

Fig. 4. AMM Flowchart

Figure 5 shows flowchart for portfolio management. Initially, ensure that necessary libraries are installed such as pandas, requests, and web3. Then, connect to Ethereum Network using web3. After that, you can fetch data from DeFi protocols using the Coingecko API. You can track portfolio by storing and updating balances and prices of assets. Tracking yield farming and staking activities is possible in this stage. For example, using Aave's API to get data on your deposits. Tracking and visualizing portfolio performance is also possible. Implementing basic security measures is necessary by ensuring secure handling of private keys and sensitive data. Finally, advanced features are integrated such as automated trading, rebalancing, etc.

5. IMPLEMENTATION

Implementation is performed on an HP ENVY x360 2-in-1 laptop with AMD Ryzen 7 5825U and Radeon Graphics, running Windows 11 Home 64-bit operating system. All codes are in Python, while smart contracts are in Solidity.

Web3 is a Python library that enables developers to interact with the Ethereum blockchain, manage accounts, send transactions, and
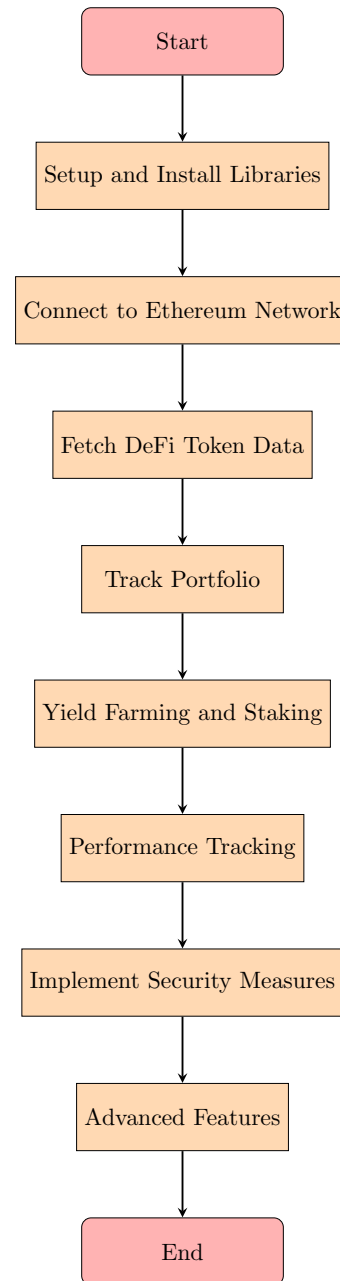

Fig. 5. Portfolio Management Flowchart

query blockchain data with ease. Web3 is easily installed using *pip install web3*. Then, the process involves library importation, connection to Ethereum network, account checking, working with accounts, loading accounts, retrieving balances, interacting with smart contracts, sending transactions, and handling receipts. Note that you need to sign up for an account at https://infura.io/ and provide your new project ID.

AI-DeFi portfolio management provides many useful reports with visualization. Figure 6 shows an example portfolio data over time.
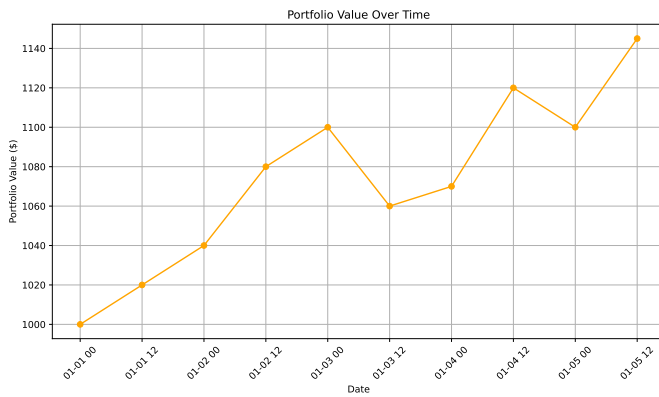
Fig. 6. Example Portfolio Data Over Time

6. CONCLUSION AND FUTURE WORK

This paper explores the potential synergies, opportunities, and challenges of combining DeFi and AI disruptive technologies. Then the paper proposes a framework that combines AI and DeFi which contains the layers of Automated Market Makers (AMMs), yield farming and lending, and portfolio management. This paper also provides implementation details to increase reproducibility of the proposed framework.

One possible future direction is to enhance DeFi portfolio management layer by integrating with additional DeFi protocols, automating trades, and setting up alerts for significant portfolio changes. Another possible future direction is to integrate Explainable AI (XAI) which is a promising research field that aims to enhance the transparency, interpretability, and accountability of AI models [35]. A promising future direction is to integrate IoT devices and real-world assets with AI-DeFi systems that offers promising prospects for developing innovative financial services and products [36]. Another promising research direction is to establish protocols and standards for cross-platform interoperability to promote adoption of AI-DeFi solutions [37]. Last but not least, privacy-preserving AI-DeFi solutions require advanced cryptographic techniques like homomorphic encryption and zero-knowledge proofs [38].

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