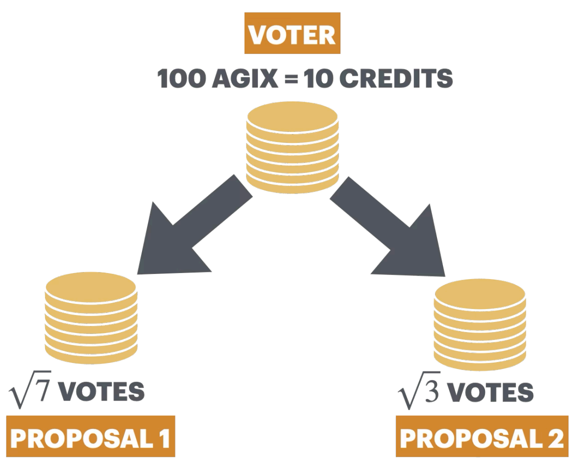
Simulating the Quality of Community Decisions
DF4B-RFP2
Simulation of Voting Methods
Milestone 5
Final Report



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Milestone Description and Deliverables

Milestone Description:

- Present a combination of visual, analytical, and statistical analyses.
- Communicate key aspects of our design and research findings to the SNET community.
- Offer insights and a potential roadmap for voting design improvements based on the simulation results.
- Create a strategy that involves incorporating reputation scores into the simulation framework.
- Red team will provide independent recommendations based on the simulation results.

Deliverable Description:

- Presentation of visual, analytical, and statistical research conclusions, engaging the SingularityNET community with key findings and a roadmap for enhancements to SingularityNET voting platform.
- Presentation of independent evaluations and recommendations from the red team.

Final Report

Executive Summary

This report investigates how different voting systems affect decision-making within SingularityNET's Deep Funding program, particularly focusing on addressing concerns about fairness, community engagement, and optimal resource allocation. One key finding is that **SingularityNET's Deep Fund program is not currently operating as a fully decentralized ecosystem**, with one wallet holding 86% of the voters' AGIX tokens and 1.75% of the AGIX circulation supply. Applying the square root to the wallets to compute voting credits, the largest wallet has 34% of the voting credits, which is sufficient to retain disproportionate influence over the outcomes. Additionally, considering non-zero wallets who voted, 3% of wallets have 52% of the voting credits and 19% of the wallets have 90% of the voting credits. Further investigation is needed to understand how this centralization occurred and its implications for governance.

Despite this concern, **simulation results provide preliminary evidence that Preferential Quadratic Voting (PQV) could significantly improve decision-making**, leading to higher average community welfare and thus more efficient outcomes. The phase *preferential quadratic voting* is used to emphasize the voters ability to express the strength of their preference and to contrast with applying the square-root to the wallet holdings but is functionally just the QV method. Based on these findings, we recommend conducting a **beta round** in which the current 1-10 ranking system is replaced with **preference weighting using quadratic voting**, allowing for more effective outcomes in decision-making in the funding process.

Report Organization

In the main body of the report, we explain the main results obtained from a broader perspective, focusing only on the main voting systems and voting strategies. Then, we show the main necessary definitions as a context to help the reader understand the main results. After explaining the simulation design and results, we discuss the project's next steps and future recommendations.

For readers interested in the simulation details, Deep Funding statistical analysis, and the model mathematical description, please see the appendix. The simulation codes can also be accessed in the [Project's GitHub]() and the Town Hall presentation is on the Deep Funding [website]().

Introduction

The purpose of this project is to investigate how different voting systems impact decision-making quality in decentralized communities, specifically within SingularityNET's Deep Funding program. Effective decision-making is crucial for ensuring that valuable projects receive the necessary funding and that the community's resources are allocated efficiently. Poorly designed voting mechanisms can lead to divisive factionalism, funding of low-impact projects, or the misallocation of community resources, ultimately undermining the goals of SingularityNET and its commitment to decentralized governance.

Deep Funding, as a core component of the SingularityNET ecosystem, relies on the active participation and judgment of its community to select, prioritize, and fund projects that will advance AI and decentralized technologies. However, as participation grows, ensuring fairness and optimization of the voting mechanisms become increasingly challenging. The community must be able to express preferences in a way that promotes high-quality outcomes while avoiding the risk of domination by any one group.

We investigate how twelve distinct voting systems affect the quality of decision-making by simulating the opinions and voting strategies of multiple individuals interacting in a complex social ecosystem. These simulations aim to model real-world behavior on the Deep Funding platform, helping us understand how factors like social effects and strategic voting influence funding decisions. We simulate the opinions and several possible voting strategies of multiple individuals interacting in a complex social community though Deep Funding platform using a data-driven approach. By doing so, we provide insights into how decentralized governance within SingularityNET can be improved to enhance community welfare, fairness, and decision process quality.

Main Results

In Figure 1, we analyze the balance of 182 wallets of Deep Funding using the available data from Round 3 [19], where we have 39 zero wallets and 143 non-zero wallets. The distribution is strongly skewed, with the top wallet holding 86% of the voters' AGIX and 1.75% of all the AGIX circulation supply, estimated at 1.2 billion [21]. Since there are 8.96k wallets holding at minimum 10 AGIX [20], that means 0.0001% of the wallets have almost 2% of the total AGIX circulation.

Additionally, following the application of the square-root to compute voting credits, the four top wallets alone hold 51.2% of the voting credits, and the top 27 wallets have 90% of the voting credits. In percentage terms, considering only non-zero wallets, that means 0.7% of the wallets have 34% of the voting credits, 3% of wallets have 52% of the voting credits and 19% of the wallets have 90% of the voting credits.

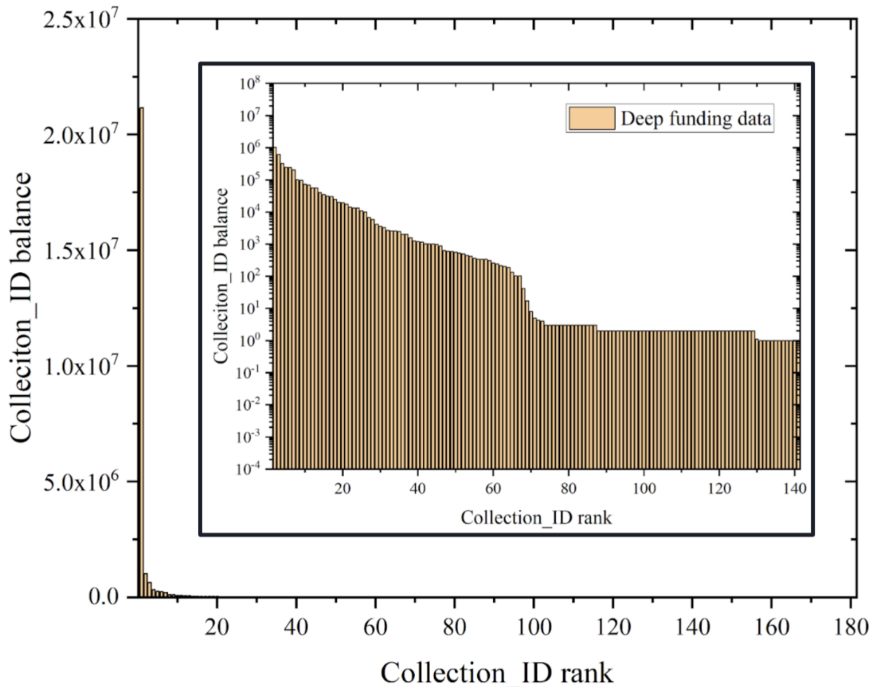

Figure 1. Distribution of user balances on the Deep Funding platform. The distribution is highly skewed, with the top wallet holding 86% of all tokens among the collection_ids. The inset shows the same plot with a logarithmic scale on the y-axis for better visualization.

This data from the voter's balance provides concerns that SingularityNET's Deep Fund program is not currently operating as a fully decentralized ecosystem. However, we do not aim to resolve this issue in this project, instead we analyzed this data to generate a realistic balance distribution of the voters in the simulation. Nonetheless, we notified Jan Horlings, the Chief Deep Funding Officer at SingularityNET, who has tasked the Deep Funding Analytics Circle to further investigate this issue.

Besides the voter's balance data, we also analyzed how much funding each proposal requested for each voting pool/category and the total funding each pool has available to fund the projects. We used this information to generate distributions based on real-world data, so the simulation is accurate and realistic.

In figure 2, we show the simulation results about how four main voting systems impact the voter's welfare as the voter's inertia/nonconformity changes. The voting systems we consider here include: the current SNET method, One Coin-One Vote (1c1v), the SNET method with binary grades and preferential quadratic voting. The voters' welfare is a metric of how satisfied the average voter is with the voting outcomes. In that way, a higher voters' welfare indicates the funding decisions are more aligned with the global preference of the voters. In this study welfare was measured per wallet, though in future studies we recommend adding measures of wealth per coin and also global impact. Observe that the welfare is normalized here, so for example, a welfare of 0.6 means the welfare is 60% of his maximum possible value. Therefore, we aim for a voting system that can maximize the voter's welfare.

On the other hand, the inertia models the intensity of the users' nonconformity as they interact with other users through the Deep Funding platform. An user with a low inertia is more likely to agree with the reviews other users made about a proposal, while a voter with a higher inertia will disagree more often. But 10 positive ratings are far more convincing than 2 positive ratings. Hence, we introduce a social pressure parameter to model the decayment of the agent's i initial inertia. For example, if the social pressure is 1%, then the inertia of agent i decreases 1% for each new posted rating, increasing the social validation phenomena intensity.

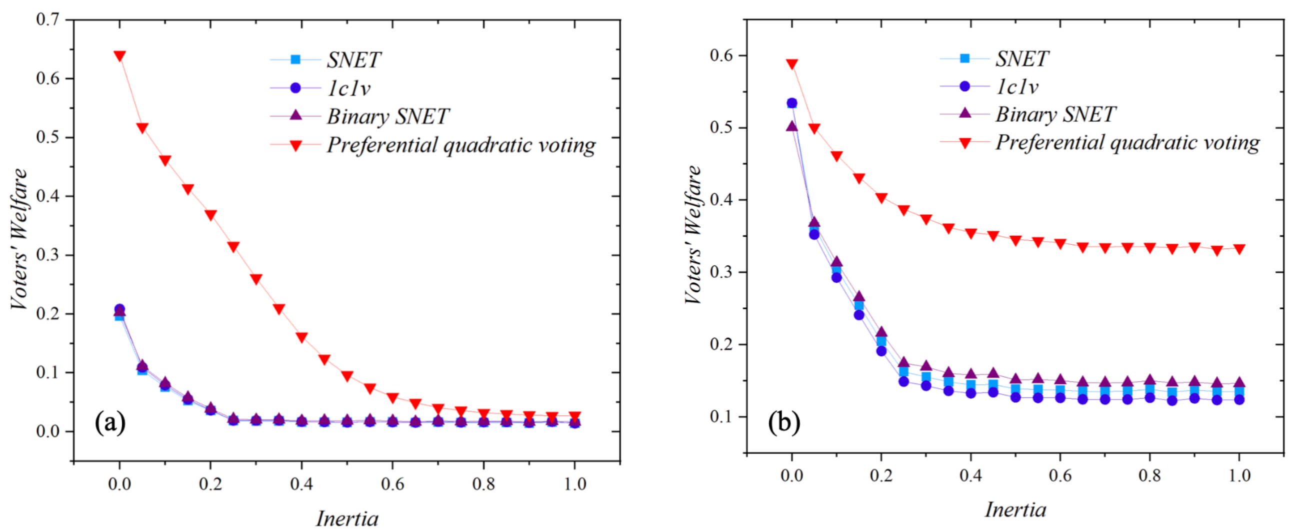

Figure 2. Here we show how the aggregate voters' welfare of several voting systems changes with the social inertia value of the voters. Here, all voters express their strength of opinion. In (a), we used a community with 150 voters, 198 proposals, 6 voting pools, social pressure of 1%, probability of posting of 40% and a probability of 2/3 of skipping a proposal, mimicking the current Deep Funding environment. In (b), we show the effects of increasing the voter's participation, using 500 voters.

Figure 2 (a) shows a voting environment similar to what we have in Deep Funding, with 150 voters, approximately 200 proposals, 6 voting pools/categories, and used a probability of skipping a proposal of ⅔, so each proposal receives on average 50 votes. Empirical evidence from several studies [1-5, 14-16] suggest people are susceptible to the herd effect, even without noticing. At the same time, we also have some individuals with higher social nonconformity. Thus, the simulation is more realistic to low to moderate values of the inertia parameter.

The figure shows that the preferential quadratic voting method significantly improves the average voters' welfare. In figure 2 (b) we show another possible scenario where the participation of the voters increased, considering 500 voters, which amplifies even more the benefits of the preferential quadratic voting for the voting community.

Observe that the welfare of the voters increases as the inertia decreases to all voting systems. That means that as users interact more with each other and are influenced by the opinions of their peers, they can better estimate the true utility of the proposals as they change information and personal views, and ultimately can make better voting decisions, favoring everybody.

Voting Methods Investigated

Here we focus on explaining the mechanisms behind the four main voting systems. A detailed overview of all twelve voting systems considered can be seen in the appendix. These methods allow us to explore the influence of wealth, sentiment, and participation on decision-making.

1. **SingularityNET Method:** In this voting system, the user's voting credits is equal to the square-root of their AGIX holdings. Each user ranks proposals with a score of 1-10 and the weighted grade of a proposal is the weighted arithmetic mean of the scores.

2. **One Coin, One Vote (1C1V)**: The user's voting credits are equal to their AGIX holdings, amplifying the influence of wealthier voters. The voter still applies a score of 1-10.

3. **Binary SingularityNET Method:** SNET method, but each user only approves or disapproves a proposal, instead of using scores of 1-10.

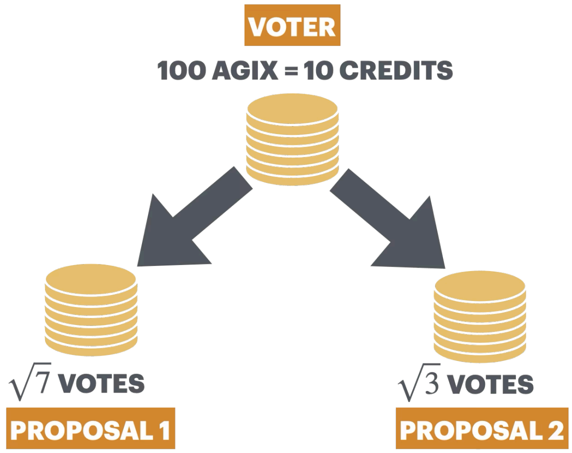

Figure 3. In Preferential Quadratic Voting, a user with 100 AGIX has 10 voting credits. (The square root of 100). He can then freely distribute his credits between the proposals. For example, he can give 7 credits to proposal 1 and 3 credits to proposal 3. (Using his 10 credits). The number of voters the proposal receives is the square root of the credits, so proposal 1 receives sqrt(7) votes and proposal 2 receives sqrt(3) votes.

4. **Preferential Quadratic Voting**: Each user has a number of voting credits given by the square root of their total holdings. The users then distribute their credits between the proposals rather than having the full credits applied to each proposal. To incentivize the users to vote across more proposals rather than consolidating their credits toward a few proposals, the credits are also square rooted. An example is provided in Figure 3. This method is called quadratic voting in the scientific literature; here we had preferential contrast to the method with square-root voting, which SingularityNET currently uses.

Simulation Design

The simulation modeled real-world behavior on the Deep Funding platform by analyzing user balance distributions, proposal reviews, proposal funding requests, pools available funding and the social dynamics of voting. **Credit distribution** among users was based on actual token balances from Deep Funding data, with a Weibull fit used to represent the distribution of tokens.

Additionally, **pool funding and proposal submissions** were modeled by analyzing Deep Funding round 4 data, establishing relationships between the number of proposals and the total funding allocated for each pool. We used several distributions to model the proposal funding request of each voting pool/category. This allowed the simulation to adjust round funding based on the number of proposals, ensuring more accurate decision-making scenarios and incentivizing competition between the proposals. Below is a detailed breakdown of the simulation structure and its components:

1. **Agent-Based Modeling:**

The core of the simulation relied on agent-based modeling, where each agent represented an individual voter. Agents were assigned various attributes, including their **token balance**, **preferences**, and **voting strategies**. These agents interacted with a set of **proposals**, each having distinct attributes such as **requested funding** and **community sentiment**.

- **Example:** Each agent was initialized with a random token balance drawn from a Weibull distribution to reflect real-world token distribution. This disparity in token holdings allowed the simulation to capture the potential dominance of wealthier participants in voting outcomes.

2. **Proposal Evaluation and Social dynamics:**

Each proposal in the simulation had an inherent quality score, which represented its objective value to the community. Agents, based on their preferences and interests, evaluated these proposals and generated personal sentiment scores. The sentiment was then translated into **voting decisions**.

- **Initial Utility Distribution:** The initial sentiment of the users about the proposals follow a **coupled Gaussian distribution** that allows a small but non-negligible probability to generate **extreme opinions** (because of the distribution's heavy tails). For instance, a proposal might receive very high sentiment scores from a certain subset of voters (those passionate about the topic), while the majority gave moderate or even negative feedback due to differing interests. See Figure 4.
- **Example:** If a proposal aimed to enhance decentralized AI governance, agents with a strong interest in governance might rate the proposal highly. Meanwhile, agents with little interest in governance would have lower sentiment.

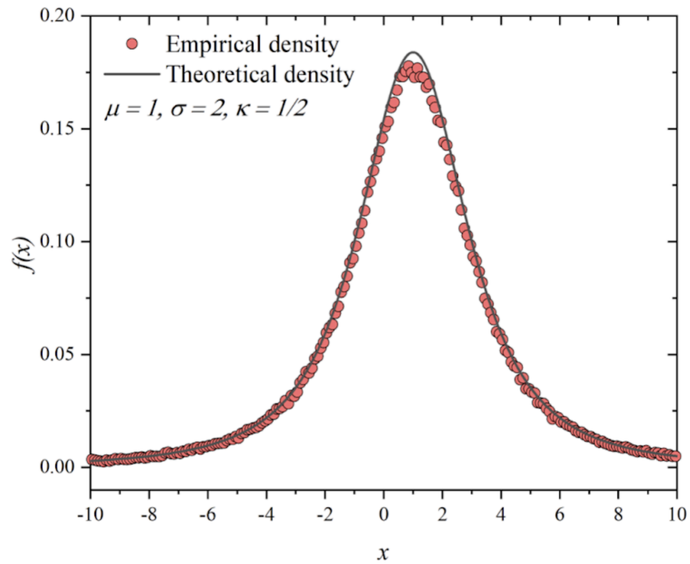

Figure 4. Example of the user's initial utility distribution regarding a specific proposal. The mean μ stands for the true quality of the proposal, the scale σ models the proposal interpretation noise and the Coupling $\varkappa$ controls the shape of the tail decay, allowing for extreme opinions..

To capture the **social influence** within a decentralized community, the simulation incorporated **herd behavior**. As more agents rated a proposal in Deep Funding, subsequent voters were more likely to be influenced by the overall sentiment of the reviews, either positively or negatively, adapting their sentiments regarding the proposals.. However, agents were also given varying levels of **inertia** to simulate **nonconformity**, where some agents deliberately went against the majority opinion.

- **Example:** If a proposal received many positive reviews early on, other agents might feel compelled to vote positively due to **social pressure**. However, agents with high inertia resisted this pressure and voted based on their own independent judgment, potentially giving the proposal a low score despite the community's positive consensus.
- **Social Pressure Parameter (Sp):** The influence of previous users was modeled using a **social pressure parameter**, where each new rating on a proposal reduced the inertia of the next agent by a fixed percentage, making them more likely to conform to the majority.
    - **Example:** If the **Sp** was set to 1%, and 50 agents had already reviewed positively on a proposal, the next agent would have their inertia reduced by $(0.99)^{50} = 60.5\%$, making them more likely to align with the group's opinion.

3. **Voting Strategies:**

In each voting system, agents can decide to vote tactically or to vote based on their utilities about the proposals. Strategic agents aim to increase their influence or the likelihood of their preferred outcomes.

The main voting strategies include:

- **Sentiment/Honest Voting:** Voters align their score (or voting credits in preferential quadratic voting) with their true opinions regarding the proposals.
- **K Extreme Voting:** Voters assign the most extreme possible ratings (e.g., 10 out of 10 for their top K preferences and 1 out of 10 for others) to maximize the impact of their favorite proposals.
- **K skip Extreme Voting:** Similar to K Extreme Voting, but users skip the remaining proposals and only votes extremely on their top K favorite proposals. .
- **K Exigent Voting:** Sentiment voting, but voters only engage with their top K favorite proposals, skipping those that fall outside their primary interests.
- **Total Extreme Voting:** User votes with maximum rating in every proposal they like and with minimum rating on the remaining proposals. In preferential quadratic voting, they concentrate their credits uniformly in every proposal they like.
- **Total skip Extreme Voting:** Similar to total extreme voting, but users skips all proposals they do not like.

Example: In **Extreme Voting with K = 3**, agents assigned the highest possible score to their top 3 proposals and the lowest score to all others, in an attempt to optmize the chances of their favorites being funded. This strategic approach was contrasted with more balanced voting behaviors, such as **Sentiment Voting**, to assess its impact on overall community welfare.

4. **Aggregate Community Welfare:**

To evaluate the effectiveness of each voting mechanism, the simulation calculated the **aggregate voters' welfare**, which represented the total satisfaction of the voters with the funded proposals. **Welfare scores** were calculated based on how closely the funded proposals aligned with the global preferences of the agents.

- **Example:** If a proposal that received strong support from the majority of agents was funded, the welfare score increased. However, if a niche or unpopular proposal was funded due to a few high-token-holding agents, the welfare score decreased, reflecting lower overall satisfaction within the community.

5. **Proposal Funding Criteria:**

To mimic real-world constraints, the simulation included criteria for proposals to receive funding, such as reaching a **minimum average score** and fitting within the total available budget after higher voted proposals were funded.

- **Example:** Proposals needed to receive an average grade of at least 6.5 and could only be funded if the total funding did not exceed the round's budget.

In preferential quadratic voting, as the votes do not have a default upper boundary, we cannot use the minimum average grade of 6.5 as a threshold to funding proposals. Instead, we consider that if the average percentage of the balance the individuals invested in the proposal is at least 5 percent, then the proposal is eligible to be funded. Not voting or skipping a proposal is equivalent to investing 0 percent of the user balance.

- **Example:** If one user invests 50% of his money on a proposal, but the other 199 users only invested 1% of their tokens on that proposal, the average balance invested per user would be approximately 1.5% and the proposal would not be eligible to be funded.

Simulation Results with Strategic Voting

Here we investigate how several different kinds of possible strategic voting affect the aggregate voters' welfare. These results provided valuable insights into the robustness and effectiveness of the voting mechanisms.

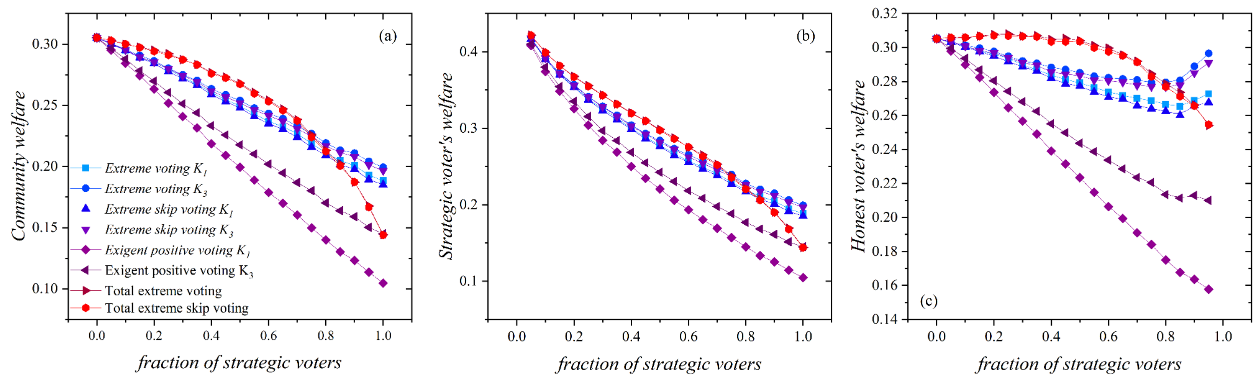

Figure 5. How the voters' welfare using the **SNET method** changes with the fraction of strategic voters. Here we used a community with 500 voters, 198 proposals, 6 pools, social pressure of 1%, posting probability of 40%, proposal skipping probability of 5% and Inertia of 0.1.

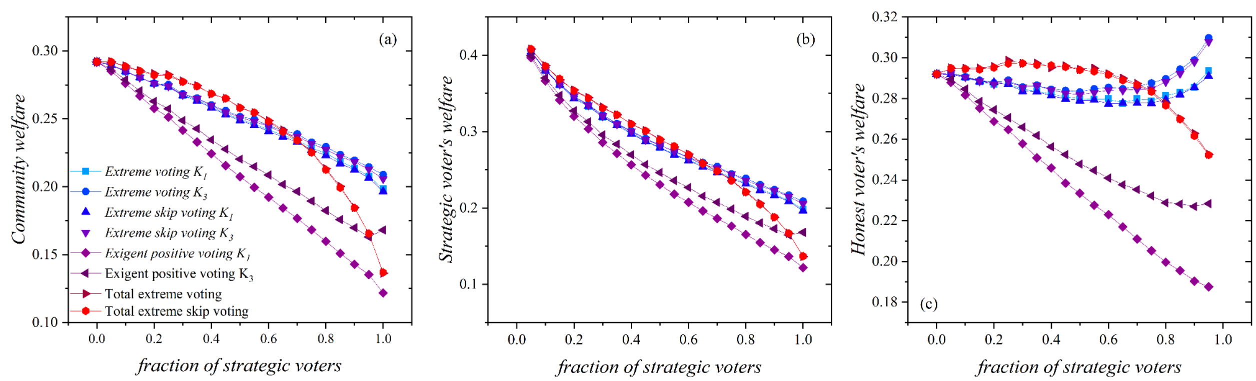

Figure 6 How the voters' welfare using the **1c1v** changes with the fraction of strategic voters. Here we used a community with 500 voters, 198 proposals, 6 pools, social pressure of 1%, posting probability of 40%, proposal skipping probability of 5% and Inertia of 0.1.

From Figures 4-6, we see the fraction of users adopting strategic voting significantly impacts the global voters' welfare for the SNET method, 1c1v and binary SNET. Note that, while some isolated strategic voters get personal benefits, as more voters act strategically, they harm each other, decreasing the welfare of both honest and strategic agents.

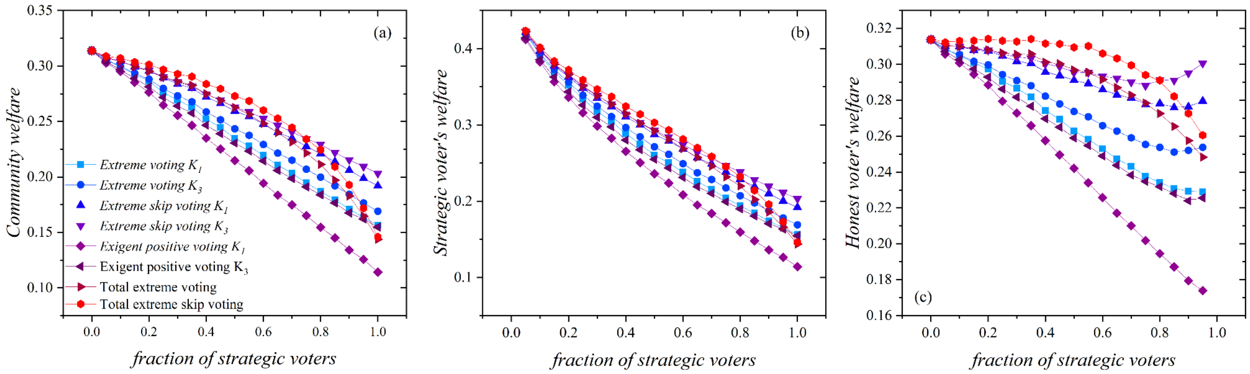

Figure 7. How the voters' welfare using the **binary SNET method** changes with the fraction of strategic voters. Here we used a community with 500 voters, 198 proposals, 6 pools, social pressure of 1%, posting probability of 40%, proposal skipping probability of 5% and Inertia of 0.1

On the other hand, Figure 7 shows that Preferential Quadratic Voting showed higher resilience to strategic manipulation, maintaining high welfare even with a significant fraction of strategic voters. Additionally, it was the only voting system in which the welfare of the honest voters increased as more agents acted strategically. However, it is also important to realize isolated strategic agents still get higher personal benefit in this voting system.

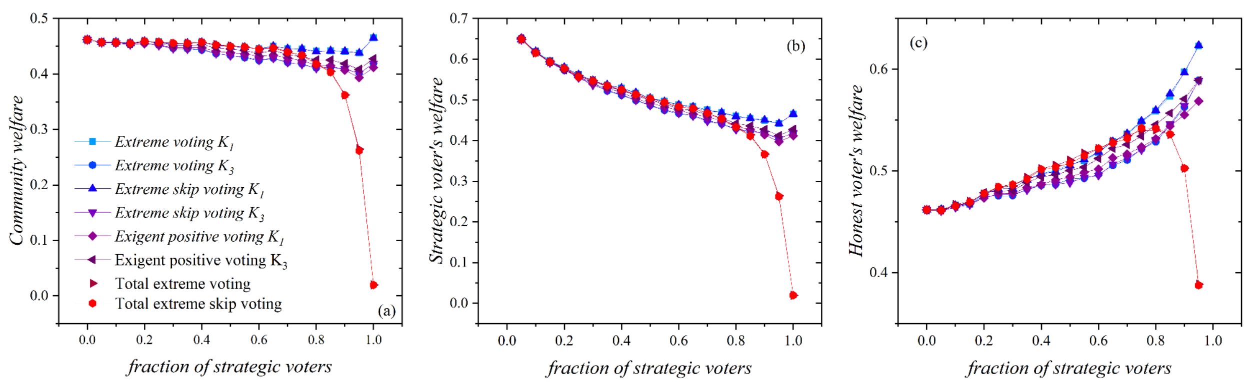

Figure 8. How the voters' welfare using the **Preferential Quadratic Voting** changes with the fraction of strategic voters. Here we used a community with 500 voters, 198 proposals, 6 pools, social pressure of 1%, posting probability of 40%, proposal skipping probability of 5% and Inertia of 0.1.

We also simulated other scenarios, such as changing the number of voters and proposals, and verified that preferential quadratic voting still displays higher voters' welfare when compared to other voting systems, even in the presence of strategic agents.

Conclusion

This report demonstrates that advanced voting mechanisms, particularly **Preferential Quadratic Voting (PQV)**, can significantly enhance decision-making within SingularityNET's Deep Funding program. Our simulations show that PQV consistently produced higher community welfare even in the presence of strategic voting, by enabling passionate minorities to concentrate their influence on preferred projects, leading to more equitable outcomes. The simulations underscore the importance of properly pricing influence in community decisions.

Despite the positive initial results, we emphasize that simulations are limited in the complexities they are able to model. For this reason, we recommend a beta round to further investigate the impact PQV would have on making quality decisions. We have also recommended further simulation studies that could refine the measurement of community decision-making.

Additionally, the proposed enhancements to the voting portal's UI/UX, including more transparent credit allocation and a proposal shortlisting feature, are key to ensuring voters can make informed decisions with ease. Future implementation of a two-tier token system and recommender system can further incentivize thoughtful voting and diversify the range of supported proposals.

As Deep Funding evolves, these updates will be critical to maintaining a fair, transparent, and community-driven funding process that continues to fund high-quality projects in AI and decentralized technologies.

Simulation Next Steps

As the simulation evolves, the next phase will focus on deeper insights into critical factors that impact the effectiveness of voting mechanisms. These steps include investigating the role of reputation and correlation in voting behavior, detecting collusion, investigating the impact of wallet splitting and analyzing the broader economic welfare derived from funded proposals. By exploring these areas, the simulation aims to optimize community decision-making processes, ensuring that proposals benefit not only individual users but also the entire ecosystem across social, economic, and environmental dimensions.

Investigate the Effects of Reputation:

- Explore how integrating **reputation scores** with Preferential Quadratic Voting affects voter influence and outcomes. The simulation should measure how users with higher engagement, expertise, or positive contributions can sway decisions differently from low-reputation users.
- Test different **weighting mechanisms** for reputation to find an optimal balance between empowering trusted community members and preventing undue concentration of influence. The impact of sybil-resistant reputation metrics on reducing the influence of bots or malicious actors can also be modeled.
- Refine the social dynamics model to describe more precisely subpopulations in Deep Funding and how reputation affects the social effects.

Investigate Collusion and Correlation Detection:

- Simulate **collusion detection mechanisms** to see how well the system identifies and mitigates coordinated voting by groups with similar interests. For instance, use **correlation analysis** to detect patterns of votes that indicate collusion.
- Implement and assess different correlation-detection algorithms to ensure that votes reflect **independent, diverse opinions** and prevent small groups from dominating outcomes.
- Consider the role of **penalties** for detected collusion and evaluate how this affects community trust, participation, and voting behaviors.

Investigating Economic Welfare and the Benefits of Proposals:

The economic welfare derived from voting outcomes needs to be analyzed across three dimensions: **People, Profit, and Planet**. In the current simulation, the primary focus has been on **people** described as community members that own a wallet in the ecosystem. Future iterations of the simulation aim to optimize for the welfare of all three dimensions simultaneously:

- **People**: Simulate how community-wide decisions impact individual well-being, engagement, and satisfaction. Analyze the effectiveness of different voting mechanisms in maximizing benefits for the community, ensuring that proposals reflect the needs and preferences of the users. This includes understanding how the distribution of resources influences long-term community cohesion and participation.
- **Profit**: Explore how **Preferential Quadratic Voting** affects overall economic efficiency, particularly in terms of cost-effectiveness and the optimal use of treasury funds but also the increase in value of the ecosystem's token. Evaluate whether the allocation of resources supports projects that deliver tangible economic returns for the SingularityNET ecosystem, fostering both financial sustainability and ecosystem growth.
- **Planet**: Integrate **environmental impact metrics** into the simulation to measure how voting decisions and funded proposals contribute to the broader ecosystem's sustainability. This includes evaluating whether proposals that promote environmental sustainability, ethical AI, and long-term planetary welfare are receiving adequate support. The goal is to optimize the voting process so that it prioritizes projects that address critical beneficial AI challenges while promoting holistic, long-term impacts.

Implementation in Deep Funding

To effectively integrate Preferential Quadratic Voting into Deep Funding, we propose issuing a **Request for Proposal (RFP)** to enhance the existing voting portal's UX/UI, with a specific focus on incorporating this voting mechanism into a future **Deep Funding Round**. This initiative will include both technical updates and community education efforts, ensuring a smooth rollout and widespread understanding of the new voting system.

Testing Phase

We recommend **testing Preferential Quadratic Voting** in a **beta round** of Deep Funding to assess its functionality and gather user feedback. This trial phase will help refine the system before full deployment.

UX/UI Enhancements for Voting Portal

1. **Clear Explanation of Preferential Quadratic Voting:** The interface should be updated to explain that not only are the total credits derived from the square root of the user's AGIX holdings, but that the **final weight** of a vote is also **based on the square root of the credits allocated to each proposal**. This must be clearly communicated with visual aids or tooltips. See Figure 3.
2. **Voting Credits Display:**
   - **Total Credits Available:** The UI will clearly show the total voting credits a user has, calculated by the square root of their AGIX holdings.
   - **Live Credit Counter:** As users allocate credits to proposals using a slider or input field, the **square-rooted weight** of the vote for each proposal should be displayed in real time. This preview should dynamically update to show the final impact of the user's credit allocation on each proposal, reinforcing the quadratic effect.
3. **Proposal Shortlisting Feature:** Introduce a pool/proposal shortlisting feature, enabling users to **pre-select** their preferred pools and proposals before assigning credits. This functionality will display the user's top choices at the top of the voting page, facilitating easier credit distribution.
4. **Credit Distribution Slider:** A **slider or input field** will allow users to assign credits to each proposal. The UI will visually represent how much of the user's total voting influence has been allocated to each proposal, helping users manage their credits efficiently..

Updating Calculations and Eligibility Criteria

To accommodate Preferential Quadratic Voting, the backend algorithms that handle voting calculations will be updated. This will ensure that the **voting weight** and **eligibility criteria** for funding proposals are correctly aligned with the new system, maintaining fairness and transparency.

External Communication and Community Education

The success of Preferential Quadratic Voting will depend on clear **communication and education** efforts aimed at the community. This will include tutorials, FAQ sections, and community workshops to ensure all users understand the new voting process and its benefits for Deep Funding decision-making.

Future Recommendations

Enhancing Voter Engagement with Data-Driven Insights and enhanced UX/UI

Through these UI enhancements, more granular data about voter behavior, proposal preferences, and pool engagement will be collected. This data can be analyzed to gain insights into voting patterns, user decision-making, and proposal popularity. Such data collection paves the way for the potential development of a **recommender system** that would encourage more efficient credit allocation by voters.

In particular, many users may leave credits unallocated either due to indecision or uncertainty about additional proposals. To address this, a **recommender system** could be designed that leverages data gathered during the voting process, including:

- **User Voting History**: Based on the user's previous voting patterns, the system could suggest similar proposals or those that align with the user's preferences.
- **Proposal Similarities**: Using metrics such as proposal category, theme, or impact area (e.g., ethical AI, climate change, community engagement), the system can recommend proposals that are aligned with the user's values and interests.

Key Features of the Recommender System:

1. **Remaining Credit Notification**: A prompt that notifies users of unallocated credits and encourages them to explore more proposals.
2. **Personalized Recommendations**:
    - After a user allocates credits to their top proposals, the system could suggest other proposals of interest based on past voting behavior, proposals they've viewed, or popular choices among similar voters.
    - The recommendations would be dynamic, factoring in the user's available credits and showing how distributing them across suggested proposals can influence the final outcome.
3. **Proposal Discovery**:
    - A "**Discover More Proposals**" section can be added at the bottom of the voting page, using AI and machine learning models to highlight lesser-known but promising proposals.
    - This would ensure that proposals with less visibility also receive consideration, which can result in more equitable distribution of credits and broader community engagement.

Simulating a two-tier token system

One approach to enhancing governance mechanisms is the implementation of a two-tier token system to incentivize high-quality contributions and foster more effective decision-making. This system would divide reputation tokens into fungible and non-fungible types, rewarding community members based on the quality of their contributions. Fungible tokens could be spent or traded, while non-fungible tokens would represent long-term reputation and influence within the community.

This system could be integrated with preferential quadratic voting, where voters pay for their votes using these earned reputation tokens rather than their own financial resources. By tying voting behavior to reputation, this system would encourage participants to make more thoughtful and high-quality contributions, as they would prefer to use earned reputation rather than spend economic tokens.

To evaluate the effectiveness of this two-tier token system, simulations can be applied to model various scenarios. For instance, the simulation can track how different distributions of fungible and non-fungible reputation tokens affect proposal funding, community engagement, and overall decision-making quality. The models can test if the system results in better project outcomes, increased long-term community welfare, and enhanced alignment with SingularityNET's core goals. Additionally, simulations can help identify potential imbalances, such as the concentration of voting power, and explore the system’s effect on reducing collusion or strategic voting.

Appendix

Analysis of deep Funding data for the data-driven simulation

In Figure 8 we show the distributions of proposal funding requests to each voting pool using data from Deep Funding round 4. We modeled the distributions using several functions to improve the simulation accuracy. Note that for the ideation phase voting pool, almost all the proposals asked for 5000 USD. Therefore, for simulation purposes, we just assumed all the proposals in the ideation phase category asked for 5000 USD to be funded.

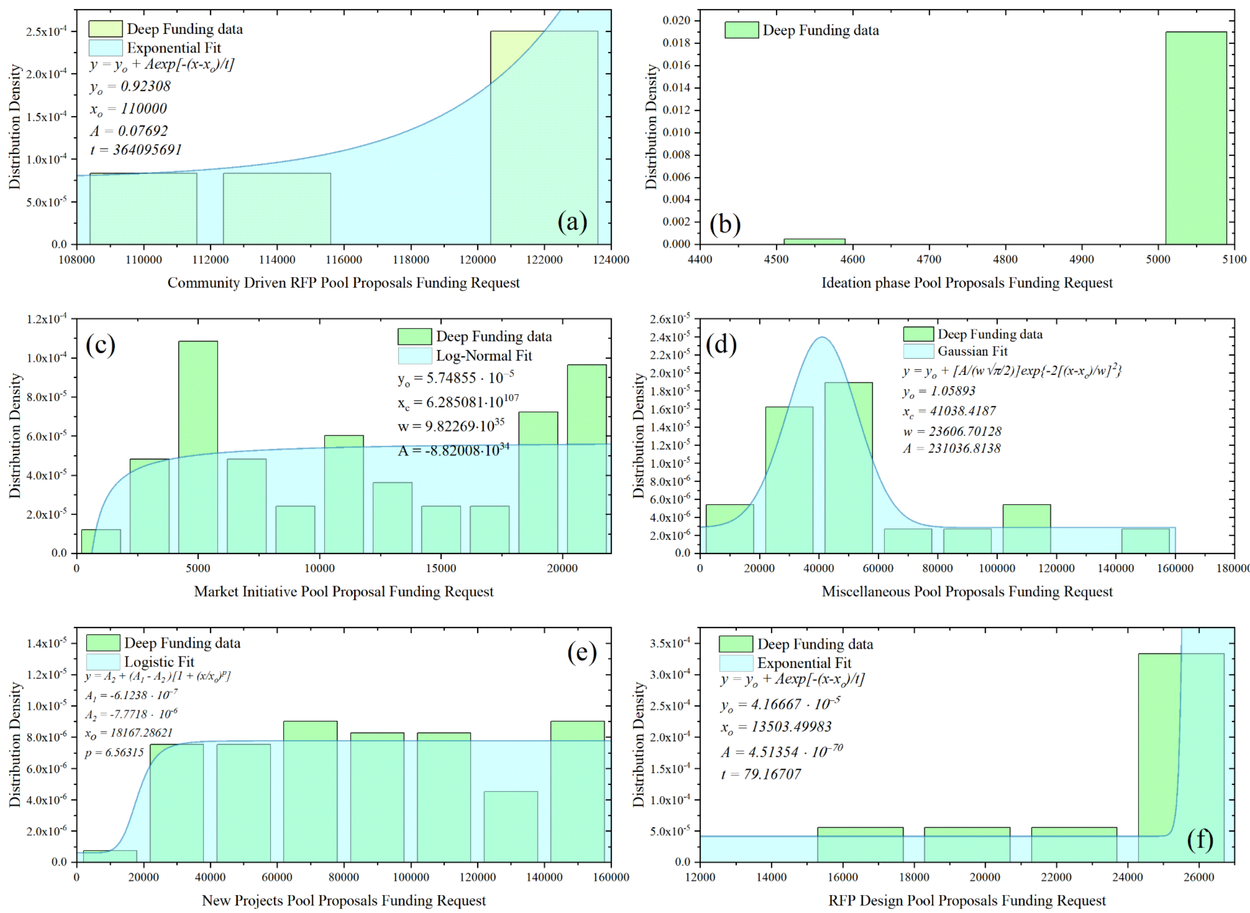

Figure 9. Distributions fit how much funding each proposal asks for in each voting pool/category, based on data from Deep Funding round 4. We use this data to generate random variables to set the funding of the proposals.

In table 1, we calculated the ratio between the total funding requested for the proposals of each pool and the pool total funding,based on the round 4 results. In the simulation, we set the number of proposals of each pool, generate the funding each proposal asks for in each pool using the information and distributions from Figure 8 and calculate each pool funding using the pool ratio between total proposals funding request and the pool funding of Table 1. This ensures the pool funding in the simulation is consistent with each pool and that not all proposals will be funded, incentivizing the competition between different proposals.

	Community RFP	Ideation Phase	Marketing initiatives	Miscellaneous	New projects	RFP Design
proposals funding request (FR)	\$585.000	\$194.500	\$529.916	\$1.039.500	\$6.116.000	\$204.450
Pool Funding (PF)	\$120.000	\$75.000	\$100.000	\$150.000	\$1.000.000	\$75.000
FR/PF	0.2051	0.3856	0.1887	0.1443	0.1635	0.3668

Table 1. How much funding the proposals asked in each voting pool versus the available funding of each pool. We use the same ratio in the simulation to emulate the competition between the proposals.

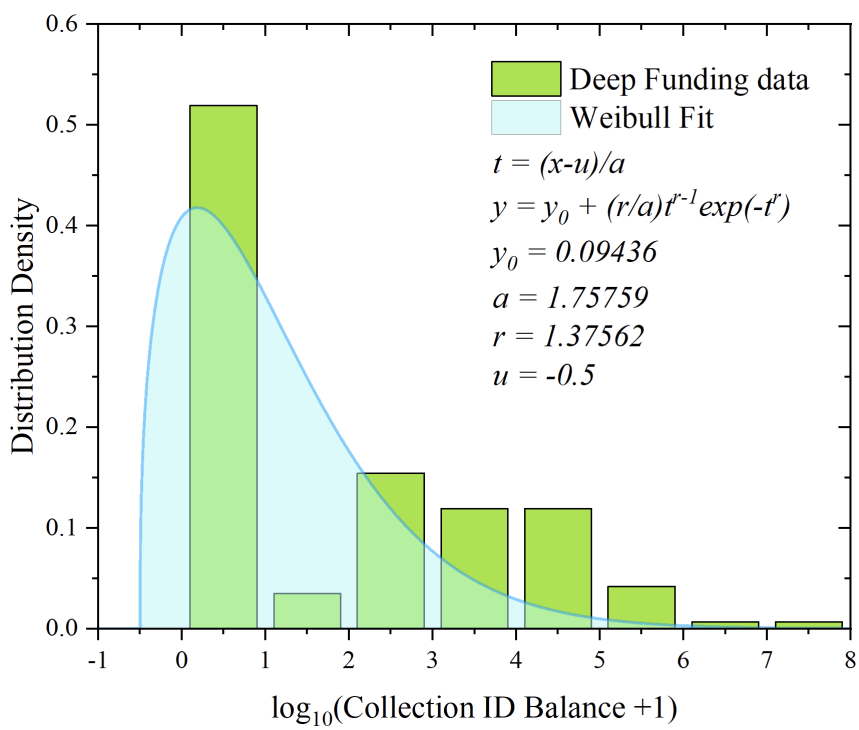

Figure 10. Weibull fit of the user balances distribution on Deep Funding on the log domain. We use this fit to generate random weibull variables to set the balance of the users in the simulation.

Similarly, In Figure 9, we model the balance distribution of 182 voters of deep funding using a Weibull fit. The distribution has heavy tails and we used the fitted parameters to model the credit distribution of the users in the simulations.

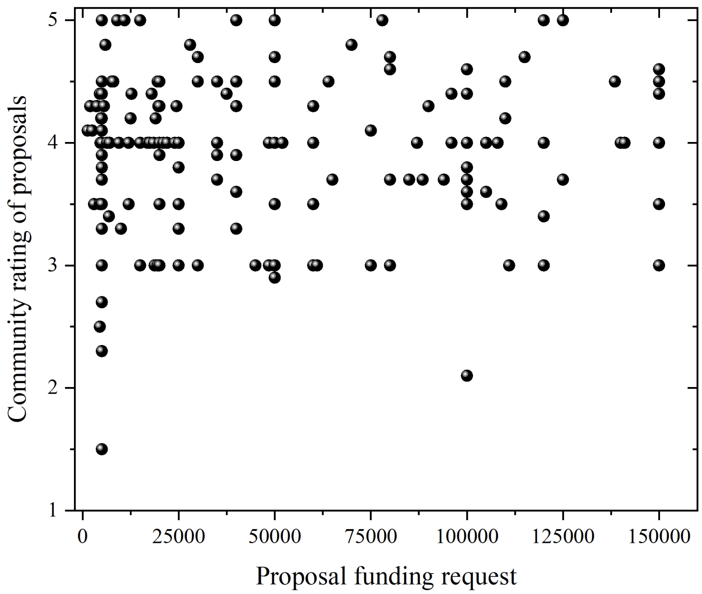

Figure 11. We show that, in general, the proposal's funding request does not affect the average community review of the proposals. Therefore, in our simulations, the proposal's funding request does not influence how people will vote.

How does the funding request the proposal asks affect the community rating on these proposals? The figure 10 shows that, in general, there is no correlation between the proposal funding request and the community average rating. We see that the majority of the ratings below 3 stars are concentrated on proposals with low funding requests. However, this effect is weak and overall, the proposal funding request does not affect the community review on the proposals.

Using the Deep Funding round 4 data [22, 23], we calculate the correlation between the community score of the proposal and the proposal average grade and the percentage of users who voted on the proposal in 192 proposals from 6 different voting pools. Figure 11 shows that the Pearson’s r coefficient indicates moderate positive correlation between the community score and the percentage of users who voted on the proposal and a weak to moderate correlation between the community score and the proposal average grade. These results indicate there is significant nonconformity between the users, and that only the average community score is not sufficient to predict the final grade of the proposals. Therefore, the distribution of user's sentiment about the proposal is wide. This motivates using the coupled gaussian to model the initial utility of the users about the proposals, and the construction of a social model with nonconformity where individuals interacting in a complex social community to better describe how the users vote.

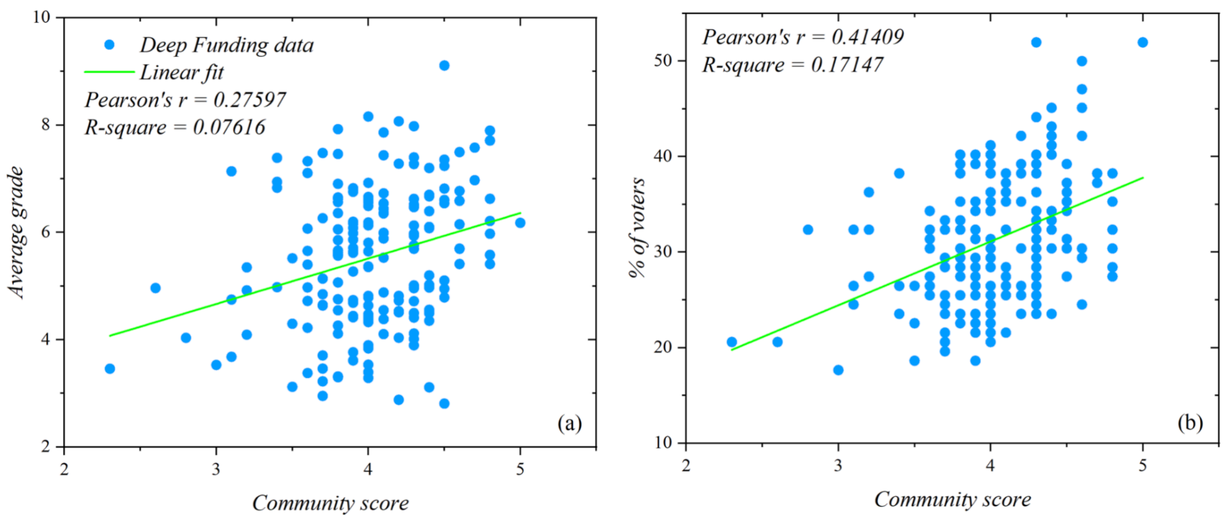

Figure 12. Correlation measures between the community score and the average grade and percentage of users who voted on a proposal, based on data from Deep Funding round 4.

Voting Simulation Model: Modeling the social dynamics in proposals ratings

When people analyze one proposal, only a small fraction of them publicly record their opinion and ratings. We do not have access to the rating of all users. However, we can construct a model to simulate the interaction between community members and the sentiments of the individuals and their strength of opinions on the projects.

We consider a system of N individuals voting on Np proposals. When one proposal is created on deep funding, it has no reviews. One individual may read the proposal with probability 1 - Pskip, and will get a sentiment regarding the proposal. The initial individual utility should depend on both the proposal features and the agent interest in the proposal, which is typically not random. People may tend to have higher initial sentiment about high quality proposals and lower initial opinions about low-quality proposals. Yet, different interest groups can still have different opinions about the same project.

Additionally, two reviews with five stars and different comments can communicate very different sentiments about the proposals. For instance, a more enthusiastic and engaged five star review with several compliments may transmit a higher sentiment about the proposal than a more moderate 5-star review. Hence, we may consider the sentiments of the individuals about the projects to be unbounded, so we can capture extreme opinions and the subjective nature of the comments. Note also the inertia here plays a crucial role since people can have different understandings about the comments someone wrote.

To address these problems, we now model the initial utility distribution of the individual using a coupled gaussian. The coupled gaussian is a robust distribution from nonextensive statistical mechanics (NSM) which can have heavy tails and compact support. This distribution maximizes the generalized entropy function and is suitable to model nonlinear dynamics systems. The distribution includes a mean, a scale, which is the standard deviation when the coupling is zero, and a shape or coupling parameter that determines the rate of decay of the tail. Using the coupled gaussian, it is possible to simulate the average quality of a proposal for a user without 5-star limitations. In compact support ($-1 < \kappa < 0$), the voter's utility is bound to a finite domain, while in the heavy tail regime ($\kappa > 0$), coupled gaussian distributions the utility is over an infinite domain and includes a higher probability of extreme opinions than for a Gaussian distribution.

In Figure 4, we display the empirical density simulated making a comparison with the analytical expression for the 1D coupled Gaussian for (a) heavy-tails domain and (b) compact support regime:

$f(x) = C[1 + \kappa(x - \mu)^2/\sigma^2]^{-(1 + 1/\kappa)/2}$

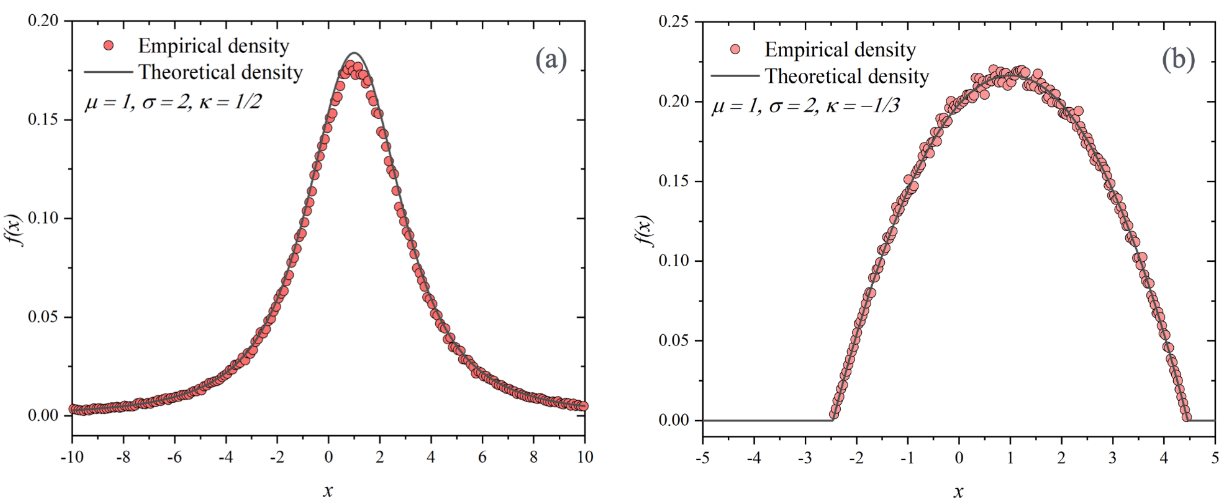

Figure 13. Empirical density of simulated data for a standard coupled-gaussian. In (a), the distribution is unbounded and in (b) it displays compact support. The empirical distribution has $5 \cdot 10^5$ samples. We use coupled gaussian with heavy tails to model the voters initial sentiment distribution.

In this context, the mean value of the distribution μ represents the true quality of the proposal, the scale σ denotes the noise of the users in interpreting the proposal and the different value the same proposal has to users of different subpopulations and the Coupling $\varkappa$ controls the shape of the tail decay, allowing for extreme opinions.

The true quality of each proposal is selected at random from and each user has a probability $1 - P_{skip}$ of reading a proposal. If the user reads the proposal, he obtain a sentiment about the proposal following the coupled gaussian distribution of the proposal and with probability $P_{posting}$, he posts his rating with a comment so the whole community can see his opinion.

After the first individual posts his opinion regarding the proposal, his opinion will affect the opinion of the next agents that will read the proposal. The next individuals will have a tendency to shift their opinions closer to the average community review due to the herd effect. However, some individuals can have a stronger opinion and display social nonconformity, disagreeing with the community review. To capture that effect, we introduce the concept of the agent's inertia to model the individual nonconformism or uncertainty about the average community review [7].

For example, consider that agent i read the proposal p and formed an opinion u(i, p) about the proposal value drawn from the coupled gaussian distribution. However, he sees that there is an average community review U(n, p) of n individuals of that proposal p. Then, with probability 1- I(i, n), the user i conforms with the average community review, and his opinion u(i, p) gets closer to the average community review U(n, p), achieving the final opinion u'(i, p) given by

$$u'(i,\ p)\ =\ u(i,\ p)\ +\ [1\ -I(i,\ n)][U(n,\ p)\ -u(i,p)].$$

If the user does not conform, he disagrees with the average community, and his opinion u(i, p) goes away from the average community review U(n, p), achieving a final opinion u'(i, p) given by

$$u'(i,\ p)\ =\ u(i,\ p)-\ I(i,\ n)/[U(n,\ p)\ -u(i,p)].$$

Note that if the inertia of the individual i is 1, the agent ignores the average community review. On the other hand, if the inertia of the agent is 0, the agent ultimately consents to the previously posted opinions and his final opinion will be equal to the average community rating U(n, p). Most agents might have an inertia between 0 and 1 and will stochastically agree or disagree with the community in each proposal.

Now, 10 positive ratings are far more convincing than 2 positive ratings. To simulate this effect, we introduce a social pressure parameter Sp and model the decayment of the agent's i initial inertia I_o in function of the quantity n of ratings:

$$I(i, n) = I_o(i)(1 - S_p)^n.$$

For example, if the social pressure is 1%, then the inertia of agent i decreases 1% for each new posted rating, increasing the social validation phenomena.

Voting mechanisms

Unless explicitly said otherwise, eligible proposals to be funded must have received votes from at least 1% the total number of wallets and the project needs a minimum average grade of 6.5 and must fit the pool's remaining budget after higher voted proposals are funded.

SingularityNET square root weight

In the singularityNET system, the grade each user gives to each proposal has a weight given by the square root of the user balance. The average grade of one proposal p is then calculated by a weighted arithmetic mean:

$$weighted\ grade(p) = \sum_i grade(i, p)\sqrt{b(i)} / \sum_i \sqrt{b(i)}.$$

Binary SingularityNET square root weight

Similar to the SingualirityNet voting system, it only allows approving or disapproving a proposal, i.e., grades can be +1 or -1.

Observation: Here we need to adjust the minimum average grade to be funded from 6.5 to 0.65.

Negative SingularityNET square root weight

SingualirityNet voting system allowing negative grades. Each user can select an integer grade from -10 to 10 to each proposal.

Observation: Here still use the minimum average grade to be funded as 6.5, however, it is possible this may be adjusted because of the negative grades. The proper threshold needs to be investigated.

One Wallet, One vote (1W1V)

In this voting mechanism, each user has the same weight and the average grade of the proposal p is simply the arithmetic mean of the grades of the users:

$$average\ grade(p) \ = \ \sum_i grade(i,\ p)/N.$$

One coin, One vote (1C1V)

This system is similar to the SingularityNet voting rule, but without the square root:

$$average\ grade(p) \ = \ \sum_i grade(i,\ p)b(i)/\ \sum_i b(i).$$

cost-graded voting

In this system, the users pay a quadratic cost to vote on each proposal. We consider each agent to invest a fraction of his tokens in each proposal that is proportional to the cost of the grade the user gives to that proposal. We consider grades to cost more as they become more extreme. For instance, the set of grades {1, 2, 3, 4, 5, 6, 7, 8, 9, 10} has a cost {5, 4, 3, 2, 1, 1, 2, 3, 4, 5}. Hence, the total number of votes of a proposal p is given by

$$weighted\ cost\ -\ grade(p) \ = \ \frac{\sum_i grade(i,p)\sqrt{Cost\ grade(i,p)b(i)/\sum_P Cost\ grade(i,P)}}{\sum_i \sqrt{Cost\ grade(i,p)b(i)/\sum_P Cost\ grade(i,P)}}$$

Where $Cost\ grade(i,\ p)$ is the cost of the grade the user i gave to proposal p.

Negative cost-graded voting

Plurality voting with negative grades. Here, the users have the set of grades {-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10} with cost {10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10}.

Observation: Here still use the minimum average grade to be funded as 6.5, however, it is possible this may be adjusted because of the negative grades. The proper threshold needs to be investigated.

quadratic-cost-graded voting

Similar to plural voting, but with quadratic costs on the grades. For instance, the set of grades {1, 2, 3, 4, 5, 6, 7, 8, 9, 10} has a cost {25, 16, 9, 4, 1, 1, 4, 9, 16, 25}.

Negative quadratic-cost-graded voting

Plurality voting with negative grades with quadratic costs.. Here, the users have the set of grades {-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10} with cost {100, 81, 64, 49, 36, 25, 16, 9, 4, 1, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100}.

Observation: Here still use the minimum average grade to be funded as 6.5, however, it is possible this may be adjusted because of the negative grades. The proper threshold needs to be investigated.

Preferential Quadratic Voting (Unbounded Quadratic Cost on Preferences)

In this method, the voters can distribute their money in the proposal in the way they find most adequate. Considering b(i, p) the amount of tokens the agent i gave to proposal p, then the total number of votes is

$$total\ votes(p) \ = \ \sum_i \sqrt{b(i,\ p))}$$

Where $b(i) \ = \ \sum_p b(i, p)$.

Observation: Note that here we cannot use the minimum average grade of 6.5 as a threshold to funding proposals. Instead, we consider that if the average percentage of the balance the individuals invested in the proposal is at least 5 percent, then the proposal is eligible to be funded. Not voting or skipping a proposal is equivalent to investing 0 percent of the user balance.

Note that, if one user invests 50% of his money on a proposal, but the other 199 users only invested 1% of their tokens on that proposal, the average balance invested per user would be approximately 1.5% and the proposal would not be eligible to be funded.

Negative Preferential Quadratic voting

Similar to the unbounded plurality voting, but enabling negative votes. Each user can approve or disapprove a proposal and distribute their tokens along the proposals to weigh their decisions. Considering A(i, p) = +1 if the voter i approved proposal p and A(i,p) = -1 otherwise, then the total number of votes is

$$total\ votes(p) \ = A(i,p) \sum_{i} \sqrt{b(i,\ p))}$$

Observation: Here we also cannot use the minimum average grade of 6.5 as a threshold to funding proposals and instead we consider that if the average percentage of the balance the individuals invested in the proposal is at least 5 percent, then the proposal is eligible to be funded. However, we only consider the percentage balance of users who voted positively to the proposal. Not voting, skipping a proposal or voting against a proposal is equivalent to investing 0 percent of the user balance for the purposes of the eligible criteria.

Voters' Aggregate welfare

To measure if the voting results are good for the overall voter, we calculate the aggregate voters' welfare of the system as the sum of sentiments of voters about the proposals [9-12]. To capture the level of satisfaction of an individual i with a proposal p, we consider his sentiment about the proposal and if the proposal was funded or not:

$$w_{ip} \ = \ \{o(i,p),\ if\ proposal\ p\ was\ funded\}.$$
$$w_{ip} \ = \ \{-\ o(i,p),\ if\ proposal\ p\ was\ not\ funded\}.$$
$$w_{ip} \ = \ \{0,\ if\ i\ skipped\ the\ proposal\ p\}.$$

To compute the aggregate voters' welfare, we can calculate the arithmetic mean of the individual welfares:

$$W \ = \sum_{p=1}^{Np} \sum_{i=1}^{N} w_{ip} \,/ \sum_{p=1}^{Np} \sum_{i=1}^{N} |w_{ip}|.$$

Where $\sum_{p=1}^{Np}$ and $\sum_{i=1}^{N}$ runs along the proposals and the agents, respectively. Since the individual welfare is unbounded, this metric is sensible to the worst individual welfare and can capture minorities with strong sentiments.

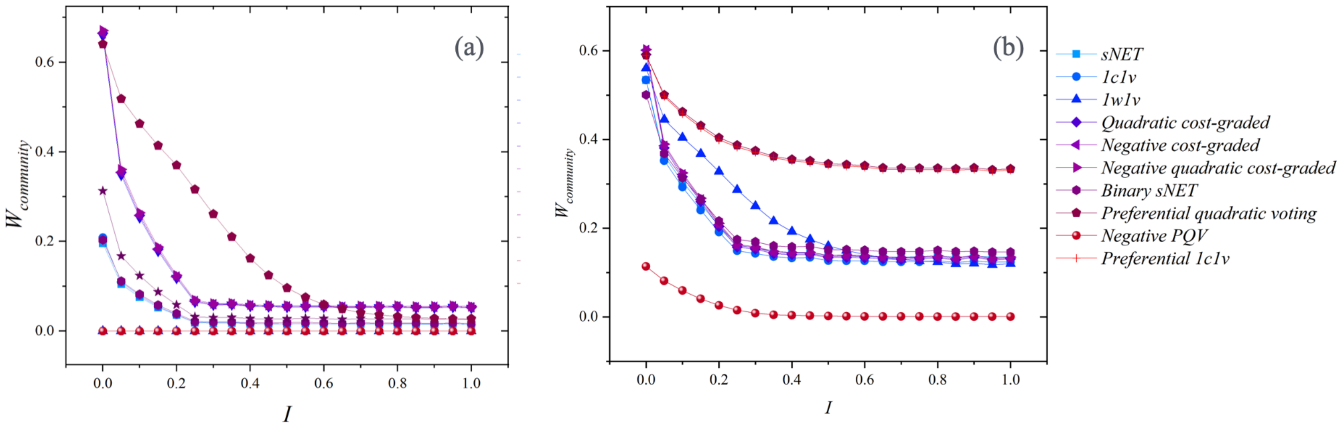

Figure 14. Here we show how the aggregate voters' welfare of several voting systems changes with the social inertia value of the voters. Here, all voters are honest. In (a), we used a community with 150 voters, 198 proposals, 6 voting pools, social pressure of 1%, Probability of posting of 40% and a probability of 2/3 of skipping a proposal, mimicking the current Deep Funding environment. In (b), we show the effects of increasing the voter's participation, using 500 voters.

In figure 14, we show the simulation results using all the twelve voting mechanisms considered. Subfigure (a) shows a voting environment similar to what we have in Deep Funding, with 150 voters, approximately 200 proposals, 6 voting pools/categories, and used a probability of skipping a proposal of ⅔, so each proposal receives on average 50 votes, while in (b) we have a scenario with more participation and 500 voters. Based on this, we chose to deepen the results on the current SNET method, One Coin-One Vote (1c1v), the SNET method with binary grades and Preferential quadratic voting, investigating their robustness to strategic voting, which was presented in the main body of the report.

In Figures 15 and 16, we show a preliminary analysis of how the threshold value impacts the welfare of the voting systems. For example, for the SNET method, welfare is maximized with a threshold value of approximately 6, while voting systems with negative grades seem to need no threshold at all. We did a separate threshold analysis for the voting system with unbounded scores, because the relevant scales are different. Simulation suggests that using an average percentage of the balance the individuals invested in the proposal is at least 5 percent, as we used in the simulations, maximizes the welfare of preferential quadratic voting.

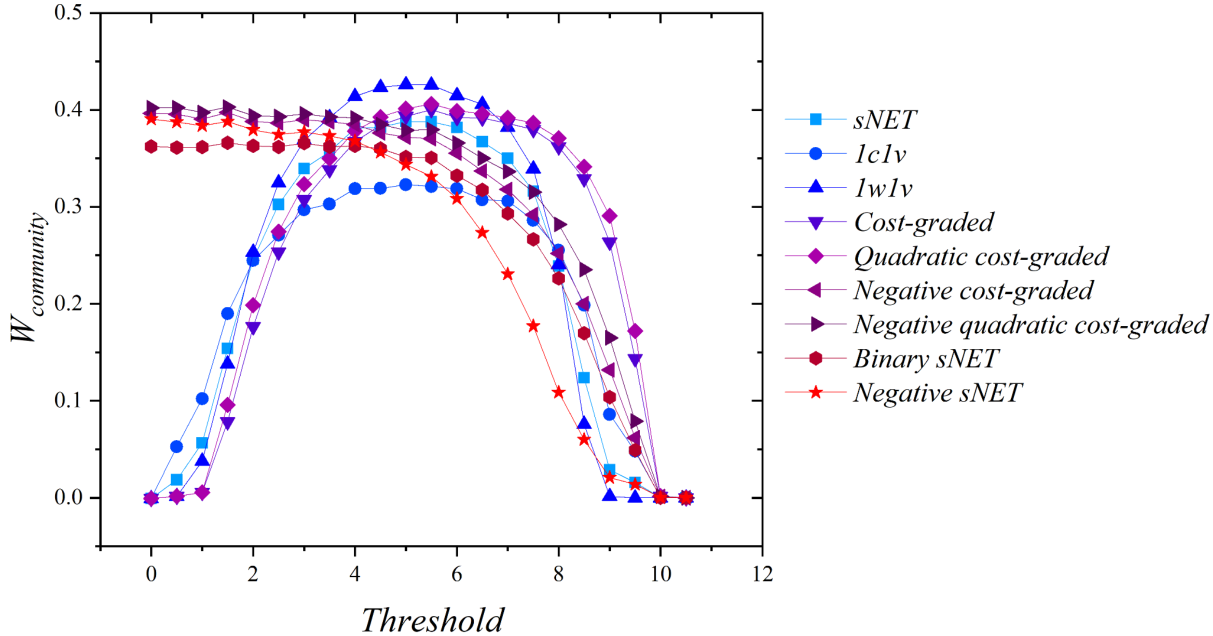

Figure 15. Here we show how the threshold impacts the aggregate voters' welfare of the bounded voting systems. Here, all voters are honest. We used a community with 150 voters, 198 proposals, 6 voting pools, social pressure of 1%, Probability of posting of 40% and a probability of 2/3 of skipping a proposal, mimicking the current Deep Funding environment.

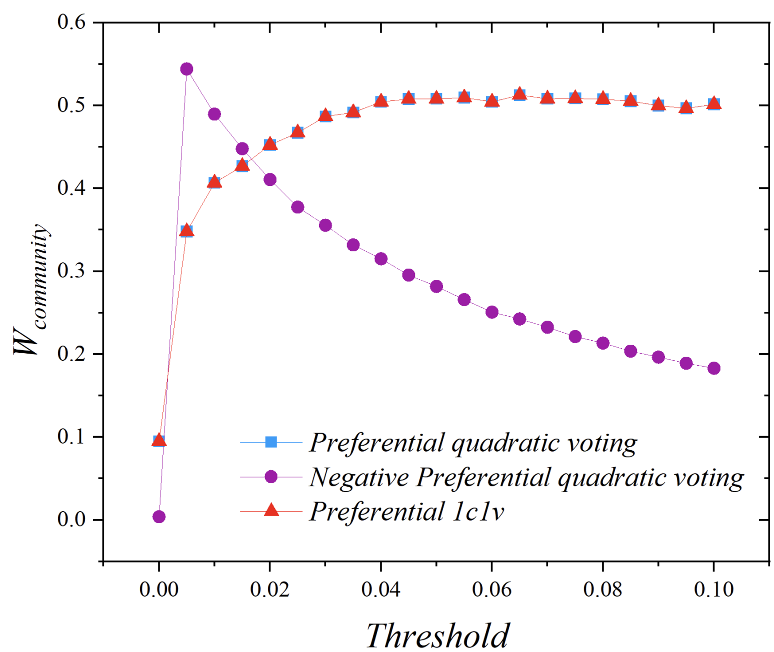

Figure 16. Here we show how the threshold impacts the aggregate voters' welfare of the unbounded voting systems. Here, all voters are honest. We used a community with 150 voters, 198 proposals, 6 voting pools, social

pressure of 1%, Probability of posting of 40% and a probability of 2/3 of skipping a proposal, mimicking the current Deep Funding environment.

Red Team Reviews of the Milestone 4 Report

Deborah Duong

My first impression is some doubt in the conclusion, that unbounded plurality voting yields the highest aggregate utility, due to concerns that the results could be an artifact of the methodology. For example, a distribution with heavy tails was used to model sentiment, with inadequate empirical support for its use. This matters because sentiment is the main factor in the computation of aggregate utility. While the report recognized that the unbounded pluralism increases the influence of extreme voters, it did not state that unbounded pluralism shows up as the highest aggregate utility because the extreme voters had extreme sentiments which came to be more important to aggregate utility than those with more normal sentiment. This is significant because humans do not tend towards any measurements that are "unbounded" in nature, as true unboundedness is alien to day to day life. It would be best to try still more models of the sentiment of voters, and further to compare them apples to apples, only making comparisons in groups where sentiment is considered in the same way.

Developer Comments

We thank Deborah Duong for your work as an independent expert reviewer dedicated to finding the simulation weakness. This is crucial to enhance the model to make it as realistic and accurate as possible in analyzing voting systems to improve the SNET Deep Funding governance.

In public opinion pools, it is typical to ask the opinion of individuals about issues using discretized categories such as "Strongly agree," "Agree," Neutral," "Disagree," and "Strongly disagree." This categorization facilitates the pool evaluation and simplifies the process for the general public. However, the underlying sentiments of the individuals can have a continuum of intensities, and different individuals can also have different thresholds to adopt an extreme opinion. Several studies have measured how strongly people hold their opinions using self-reported measures and behavioral indicators and pointed to social polarization's rise [13-16]. These studies also show that extreme views are constrained by social pressure and group dynamics, limiting how far an individual's opinions can shift.

Therefore, using the coupled Gaussian to model the initial utility of the individuals about the proposals enables the users to express a broad range of sentiments, including a small but non-negligible probability of extreme opinions. These extreme opinions, however, are bounded by the social validation effects, modeled here by the inertia or nonconformity parameter.

Note that the computation of the aggregate utility considers the voters' preferential intensity in the same way for all the voting systems considered. Additionally, the sentiment used in calculating the aggregate utility is the final sentiment after social interactions, not the initial sentiment drawn from the coupled Gaussian. As the sentiment distribution and aggregate utility computation method are the same for all voting systems, the higher aggregate utility from preferential quadratic voting results from the higher flexibility in distributing the user's voting credits among the proposals that preferential quadratic voting provides compared to other voting systems.

Second, I would recommend to represent the scenarios in which quadratic voting is meant to alleviate unfairness in both 1w1v and 1c1v. This is the case when one of the proposals matters a lot more to some classes of persons than other proposals, and it seems fair that one should have an avenue to use ones influence in proportion to ones needs. Therefore, one has a limited number of credits in which they can distribute rationally. The quadratic is taken because it is proportional to the chance that the plurality would flip when those votes are applied, and in this scenario is proven to maximize aggregate utility. Of course, when you make assumptions like everything over a threshold gets funded, this chance of flipping the vote is no longer true and another strategy should be taken. So to represent such a scenario, there should be clusters of voters that find utility in different proposals, and are allowed to allocate their voting power or not. This is not simulated in your present scenario, where all the social pressures tend towards a mean rather than clusters.

Developer Comments

Observe that, since the initial user utility about the proposal is drawn from the coupled gaussian distribution, in general the utility distribution is wide, and the proposals will matter a lot more to some users than to others. In sentiment voting, we consider the individuals using grades or voting credits (depending on the voting system) in proportion to their utility about the proposals. For example, in the current method of SNET, sentiment voters give higher grades to proposals they have a higher utility and in preferential quadratic voting, sentiment voters give more of their voting credits to proposals they like more.

We also consider other voting strategies, in which the users can distribute their voting credits strategically. In particular, observe that in the K exigent voting strategy, users only allocate their voting power on their top K preferred proposals, using grades and/or voting credits proportionally to their utilities on this subset of proposals. Similarly, in K extreme exigent voting, they use an extreme ranking on only a subset of proposals and do not vote on the other proposals. Therefore, user's can distribute their tokens rationally and decide if they want to allocate their voting power or not. Hence, the higher aggregate welfare of preferential quadratic voting may also be seen as balancing the user's sentiments and alleviating unfairness.

However, we agree with your statement that in our model, "all the social pressures tend towards a mean rather than clusters". While we made a lot of progress to model this complex social problem, we recognize there is still significant room for improvement. Despite the users reading (and therefore being influenced) by a different set of comments, because a user only is influenced by comments made before he/she read the proposal, the model still assumes the users read all the comments posted before them and that these reviews have the same weight for all users. We also ignored likes in comments and the expert reviews.

Hence, the social dynamics can be refined by considering different user's would give different weights to different reviews. For example, user's can give higher weights to reviews with sentiments similar to them (confirmation bias) and to reviewers with more likes (peer pressure). In that way, each user is socially influenced in a different way, generating the emergence of sentiment clusters or subcommunities, instead of all the social pressures tending toward the same mean.

Third, I would abandon the distinction between "honest" voting and "strategic" voting, as this distinction is only the result of a voting system that does not align incentives, and rather come up with voting systems in which the most "honest" is also the most "strategic". Since your purpose is to present evidence for the utility of voting systems, the only metric of this would be to assume rationality, that is, the most strategic thing to do would also be the highest utility both for the individual and the aggregate. I doubt the conclusion that strategic individuals benefit themselves at the cost of the group, because there is no mechanism given by which the aggregate would be separated from the group as the number of voters approaches infinity, in other words, with no mechanism, it is just a statistical anomaly that they are separated. It is important to look at why such statistical anomalies occur, and the main thing that would skew low numbers of voters away from a better average utility is how much one or a few voters matter despite the existing quadratic mitigations. If one person has 220 M tokens, then even if the square root is taken, that persons vote is still worth over 10k times the vote of a person with a single token. Any distance between this persons and the average utility coming from the random variates will skew the results.

It is important to note that the skew of the results couples with a skew of the real results, that the utility of the whale is satisfied 10K times more than the utility of the single token holder, which is autocratic and not democratic (yes, a problem). This could be mitigated by putting a lid on the number of extra votes one gets for tokens, or taking a cube root or higher first.

Developer Comments

We agree with you about coming up with a voting system in which the most "honest" is also the most "strategic". Evidently, honesty is also a voting strategy. The separation here between "honest" and "strategic" is indeed to measure how well the voting system aligns incentives and incentivizes or not strategic voting such as extreme voting.

Indeed, the aggregate utility considers the utility from both "honest" and "strategic" voters. The problem with strategic voters is that it can lead to funding of low impact projects or of low aggregate popularity. Strategic voters do not only conflict with honest voters but also with each other. For example, strategic voters who use extreme voting on their favorite proposals can conflict with each other because they have different favorite proposals. As a result, the outcome is not representative of the voters' aggregate, decreasing the voter's aggregate welfare.

The problem of the skew in the results is complex; Putting a lid on the number of extra votes one gets for tokens can incentivize wallet splitting. Using a cube root or higher is worth investigating. As you said, "The quadratic is taken because it is proportional to the chance that the plurality would flip when those votes are applied, and in this scenario is proven to maximize aggregate utility. Of course, when you make assumptions like everything over a threshold gets funded, this chance of flipping the vote is no longer true and another strategy should be taken.". In this context, it is possible that the choice of the best exponent is some function of the threshold, something not yet investigated.

Walter Karshat

Token Distribution

The finding that the wallet balance distribution is so lopsided on the high end is troubling, putting in question whether the quadratic [square root] adjustment is sufficient, or a higher exponent is in order. The influence of the score from the dominant wallet is worth a separate study, evaluating how far it moved the combined score and whether it often shifted the outcome of the proposal being accepted or rejected.

The log plot confirms that a large portion of wallets have 0 balance, and many others have a balance of only a few tokens, though likely representing different scenarios. Somewhat surprising to me is the particularly low count of wallets with balances between log values of 1 and 2, and we should confirm this. I'd run the fit across the counts of wallets with at least 100 tokens, to look at how the distribution of voting wallets with non-trivial balances compares with the trends across all the wallets holding the token.

Developer Comments

We appreciate the suggestions from Walter Karshat and his work as part of the Red team in providing an independent expert review to improve this project. This is essential to enhance the SNET Deep Funding governance. We agree with your suggestion of investigating the influence of the dominant wallet. In this case, it would be better to use the exact number of voters and use the exact wallet balance distribution, instead of generating similar communities using the simulation. Then we could simulate with and without the dominant wallet and how far it moved or not the outcomes. This could also show if some voting systems are more "whale resistant". Following your suggestions, more analysis of the balance distribution is provided in this milestone report and Jan Horlings has tasked the Deep Funding Analytics Circle to further investigate this issue.

Round Funding

To study the dynamics of the number of proposals and the causality of the funding amount, I'd look at a ratio of the number of filed proposals to those awarded, as a time series. I'd expect the ratio to increase over time, as the DF program gains more notoriety and improves the distribution of its round announcements. For example, in DF4 we saw 210 proposals filed, 191 accepted, and 29 awarded.

One can also calculate the sum of maximum size awards [MSA] possible per-pool. One divides the total pool amount by the pool proposal maximum. In DF4 MSA happened to be 31.7 A proposer reviews the pool rules when deciding whether to extend the effort to draft a proposal. The ratio of the total proposals filed to MSA is 6.62 for DFR4.

I am somewhat surprised that the simulations are being run for 20 proposals, while our actuals are closer to 200. The duration of the run is a consideration, but then why 20 and not 10? Any experimental proof or justification that the outcomes are largely the same would help here. We have some 150 voters, not 500, and with most proposals receiving 20 to 50 scores, a large majority of voters skip most of the proposals. Simulation parameters can be adjusted as needed, but without clear reasoning for doing otherwise, one should approximate the environment being modeled.

Developer Comments

We are following your suggestions from the previous milestone review, and we are focusing on the outcomes of Round 4 and integrating the voting pools/categories in the simulation. This is important because we are on a different platform now and approach public reviews and comments in a new way. Additionally, the voting pools changed from previous rounds to Round 4.

Based on the round 4 results, we calculated the ratio between the total funding requested for the proposals of each pool and the pool total funding. Additionally, we modeled the distribution of how much funding each proposal asks for in each pool. In the simulation, we set the number of proposals of each pool, generate the funding each proposal asks for in each pool and calculate the pool funding using the ratio based on Deep Funding data from round 4. This ensures the pool funding in the simulation is consistent with each pool and that not all proposals will be funded, incentivizing the competition between different proposals.

We agree with your suggestion in using parameters in the simulation to approximate the environment of Deep Funding. We executed the simulations with 150 voters, approximately 200 proposals, 6 voting pools/categories, and used a probability of skipping a proposal of ⅔, so each proposal receives on average 50 votes, mimicking the Deep Funding environment.

Social Dynamics and Effects

The model of voters examining already filed reviews before drafting their own does not reflect what actually happens during on-chain voting, as participants without specialized knowledge and tooling cannot access those records. Community Expert reviews likewise scored a subset of proposals independently. Community Expert star rating is visible during on-chain voting, but not the participant reviews, text, stars, or total numbers. I'd like some evidence that the effect actually exists before including the computation in the model.

There may well be correlations, clustering, and small-world effects across the voter and reviewer populations, which are well worth investigating, if one cares about the possibility of buying or swapping votes, etc.

Developer Comments

The voting process has two phases: first, the users should review the proposals and then vote on them. For example, some practices from the guide for voting on Deep Funding round 4 [17] include using the Deep Funding Portal to Review the proposals on the Open Projects & Proposals page. Consult Comments and Reports: Read the community comments and the curated recommendations by the decentralized Deep Funding Experts group. These can provide insights into which experts have positively evaluated proposals. Engage with Proposal Teams: Reach out to the proposal teams for more information if needed. This can be done through the proposal pages or Deep Funding's social media channels.

These practices are central to the opinion formation of the users about the proposals, which in turn is vital in how they will vote on the proposals. The social influence of comments and reviews from other users on the opinions of the individuals was also investigated in other studies [15, 16, 18]. Now, while the voter's opinion is formed and influenced when the user reviews the proposals, comments, and interacts with other users and/or proposals teams, the voting is done in a second moment. When voting, they may follow the opinion they constructed about the proposal but may not vote perfectly according to it due to memory constraints and human errors. One way to simulate this would be to introduce noisy voting. We would have a slight noise in the final voting process, potentially shifting the votes from the user.

To provide further evidence, we analyzed the effect of the community review and the expert review on the final average grade of the proposals. This indicates the social impact on the user's final voting decisions.

Indeed, the social dynamics can be refined by considering that users can give higher weights to reviews with similar sentiments (confirmation bias) and reviewers with more likes (peer pressure). Hence, we can model the relationships between users liking or disliking comments as a network, generating correlations and clustering effects between the users. In this context, this network can also be used to buy votes and collusion, which will be investigated in future work.

Voting

We already covered the arbitrary nature of the 6.5 cutoff on a 1 to 10 scale. However, we can linearly map it to the other proposed scales, as 0.3 on a -1 to +1 scale and 3 on a -10 to 10 scale. I'm not convinced that excluding 0 in those two proposed scales has the desired effect.

There appears an implication that voting with various scales produces different proposal prioritization outcomes. Some proposed scales have finer resolution but are all discrete, some are positive while others center around 0. So far I lack the intuition to support the expectation of different outcomes.

Using the Morals terms *honest* and *sincere* in the strategy discussion is suboptimal, as ill-defined and not externally observable. *Extreme* and *strategic* terminology best be rigorously defined or at least parameterized, as their usage does not appear to reference the opposite of *commonplace* and *tactical*.

Developer Comments

Thanks for your questions. To clarify the impact of the thresholds on different voting systems and scales, we simulated how the threshold value impacts the aggregate voter's welfare in several voting systems.

In the context of this work, the term "honest" means a user that behaves in a way that aligns with their true preferences or beliefs, using grades or voting credits proportional to their sentiments about the proposals. Indeed, It can be difficult to measure whether a voter is being honest without directly asking them, so this is not externally observable. However, we do not aim to measure how many honest voters are in Deep Funding. Instead, we separate the voters between honest and strategic in simulation to see whether the voting system incentivizes strategic voting or not and by how much.

Thus, strategic voting would mean voting misaligned with the user's true sentiments about the proposals, using grades and voting credits that are not proportional to their utilities. We provided a rigorous definition of the voting strategies, and they are parametrized. For example, the "K Extreme voting" strategy is parametrized by the positive integer K, meaning that the users vote with grade 10 in their top K preferred proposals and grade 1 on the remaining proposals. They distribute their voting credits uniformly on their top K preferred proposals in preferential quadratic voting.

Welfare

Defining total Welfare as a sum of individual [wallet or voter] Welfare scores is simple to compute, but does not align with any voting power method involving tokens, whether counted quadratically or otherwise. A typical reason given for assigning more voting power to those with a larger investment [number of tokens] is that they have more at stake, have taken the time to understand the ecosystem, and are more aligned with its long-term success. This outlook can be interpreted as indicating that their individual Welfare largely matches the global one.

Is there a central assumption of tension between optimizing individual Welfare or the global one, and we label *strategic* or *honest* the votes striving for one or the other? Perhaps being more definitive can bring clarity to the discussion.

DF already invested a bit of effort to produce aggregate assessments via Community Expert Reviews, intended to optimize for the ecosystem benefit. 47 preselected community members reviewed 40 good proposals, some 16 proposals each. Comparing the Expert scores with the outcomes of various computations applied to on-chain votes will permit tuning the computation.

Developer Comments

The Welfare is meant to calculate the aggregate utility of the voters with the voting outcomes. Note that the voting power (and therefore the tokens) already impacts the welfare calculation because they influence which proposals are funded or not. Thus, users with more voting power/tokens have a higher probability of determining the funded proposals, increasing their Welfare. Therefore, considering the tokens in the expression for the welfare calculation would mean considering the token's effects twice in the welfare computation.

As the simulation shows, some users can maximize their individual Welfare by voting strategically, which can decrease global Welfare. However, strategic voters also conflict with each other. For example, extreme voters who vote extremely on their favorite proposals in general have different favorite proposals. This can lead to outcomes that do not represent the community. Thus, extreme voters can harm honest voters and each other, significantly decreasing global Welfare.

Simulation

Personally, I am not convinced that considering ten vote counting approaches that variously permute several largely hypothetical methods is the best way to tease out the tendencies. For example, paying to vote is unlikely to be adopted.

Approaches that provide flexibility in allocating the number of votes per proposal invite *sniping* tactics. If one can monitor the state of the votes already cast, they would monitor the proposals they care about and apply the number of votes barely necessary to sway the outcome to the ones that can be won. Of course, waiting till the very last moment provides the most leverage, and once many people are waiting till the last second, the outcomes are divergent.

Developer Comments

While some of these methods might seem hypothetical, the rationale behind exploring a wide range of approaches is to understand how different voting mechanisms handle various real-world complexities (e.g., voter inequality and vote concentration). Each method tested, even if unlikely to be adopted, offers insights into how variations in vote counting can impact overall welfare, fairness, and voter influence. By exploring this wide range, we aim to find the most optimal system or identify key patterns across systems. For example, the binary SNET method was also tested as a useful baseline, but we do not expect to adopt this voting system.

Once these tendencies and patterns are observed, we can refine the analysis to focus on a smaller subset of the most promising and practical voting methods. This would allow us to discard those with minimal advantages or critical flaws. The goal is to iterate towards more refined and empirically supported recommendations.

Sniping, in which a voter uses information about prior votes, may be an issue; however, presently SingularityNET does not publish information about voting in progress. Further protections could be introduced using cryptographic security; this would eliminate the ability for administrators to leverage in progress voting information.

Conclusions

I am impressed by the broad research and detailed development work that Photrek has performed during several iterative stages of the project. It would now make sense to pare the findings to the aspects relevant and actionable for the Singularity NET Deep Funding initiative. The main body of the report should not assume high sophistication in Math and Stat and should present fewer but larger and more readable graphs. Heavy mathematical notation and numerical details can be contained in an Appendix.

Developer Comments

We thank you for your support and help in criticizing the project development and for offering suggestions along all the milestones of this proposal. We agree with you on simplifying the proposal description in the report's main body and leaving the details and mathematical notations in the appendix.

Budget & Schedule

Milestone	Description	Budget	Status
1	Contract Signing & Management Reserve	$2,400	Submitted - Approved
	Prototyping of Monte Carlo Simulations	$10,970	Submitted - 20 May; Approved
3	Simulation of Voting Methods	$11,080	Submitted - 28 June; Approved
4	Analysis of the Voting Dynamics	$11,660	Submitted - 12 Aug; Approved
5	Final Report & Roadmap	$13,890	Submitted 2 Oct

Project Resources

Town hall presentation: TH presentation Sim Project
Deep Funding Town Hall 05/09/2024 - Development Outreach Circle and Photrek Sim…
Previous reports: DF4B Sim Public
Simulation GitHub: [Community decisions simulation project]

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