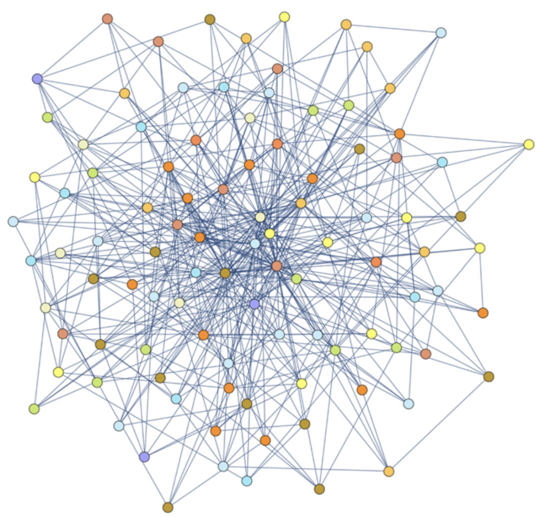
Simulating the Quality of Community Decisions
DF4B-RFP2
Simulation of Voting Methods
Milestone 4 Report



Principal Investigator: Kenric Nelson

Project Manager: Juana Attieh

Photrek, LLC

admin@photrek.io

28 June 2024

Milestone Description and Deliverables

Simulation of Voting Methods
Budget: $ 11,080

Milestone Description:

- Analysis of voting design modeling and simulation outputs utilizing careful statistical analysis including statistical moments (e.g. second moment kurtosis).
- Provide summary of the relative performance outcomes of quadratic and no-cost grading.
- Develop a proposal plan for how correlation measurements can be incorporated into the simulation for collusion mitigation.
- Community Engagement: Red team review of Photrek's M3 deliverables.

Deliverable Description:

- Extensive data for knowledge extraction conclusions and decision-making support for the SNET community.
- A comprehensive report featuring in-depth statistical analysis, valuable insights and conclusions along with a detailed examination of complex system statistics.
- A proposal plan for integrating correlation measurements into collusion mitigation simulations.
- Comprehensive evaluation by red team experts of the quadratic voting implementation and complete plural voting design as presented in Milestone 3.

Milestone Accomplishments

Voting Simulation Model: Getting insights from deep funding data

Agent's credit distribution

We reviewed the credit distribution of 182 users dataset and found an error in preprocessing the data. Here we show the correct distribution. The distribution is strongly unequal, with the top wallet holding 86% of the tokens! The top 5 wallets hold 95% of the tokens and the top 16 wallets hold 99% of the total balance.

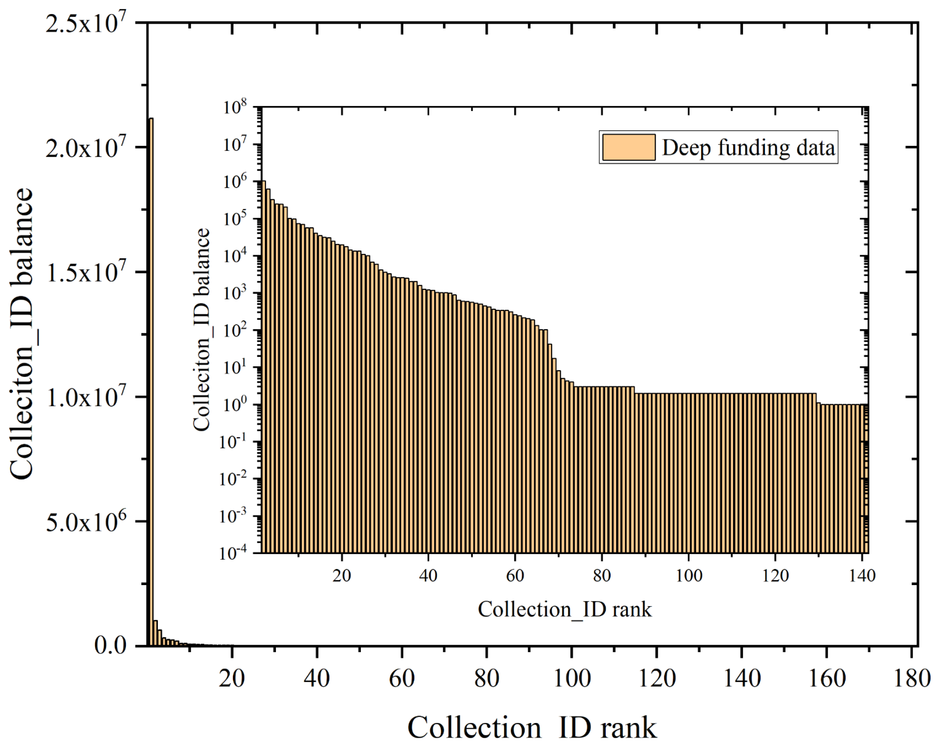


Figure 1. Distribution of user balances on the Deep Funding platform. The distribution is highly skewed, with the top wallet holding 86% of all tokens among the collection_ids. The inset shows the same plot with a logarithmic scale on the y-axis for better visualization.

The previous distribution of tokens balances appeared to be formed of 2 independent distributions, but the correct distribution can be fitted by a power law in monolog scale, which is a more natural distribution. The distribution has heavy tails and we used the fitted parameters to model the correct credit distribution of the users in the simulations.

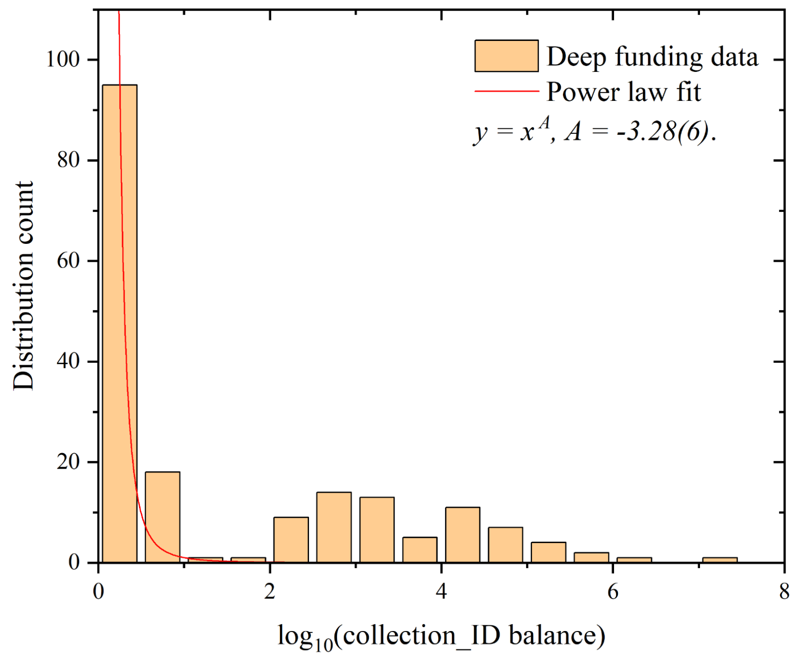


Figure 2. Distribution of the balance of each wallet holds using real-world data from the Deep funding platform. We executed a power law fit with this distribution and used the estimated parameters to model the credits distribution in the simulation.

Round Funding

To model the total funding of the round, we averaged the total funding of rounds 1, 2, 3, 4-beta and round 4 of deep funding. However, real rounds in general have hundreds of proposals and we are using 10 to 20 proposals in the simulations. We plotted the relationship between the total funding and the number of proposals in Deep Funding in Figure 3 using a linear fit.

Hence, to better model the ratio between the round budget and the number of proposals, we use the estimated parameters to calculate the total funding as a function of the number of proposals, making the simulation more realistic.

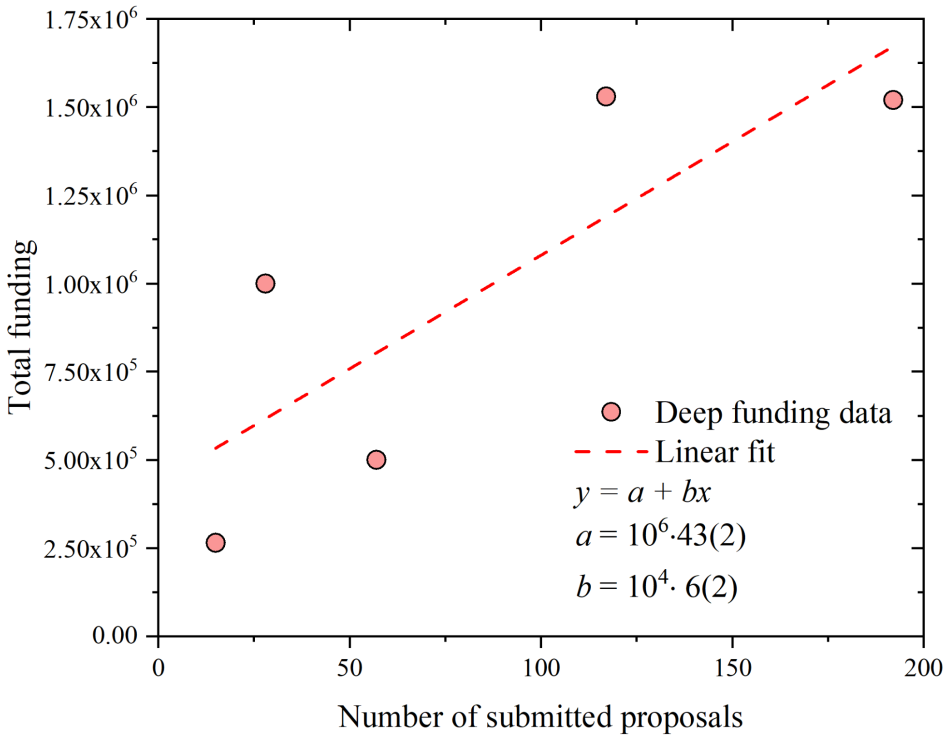


Figure 3. Relationship between round total funding and number of submitted proposals on the Deep Funding platform. We executed a linear fit with this distribution and used the estimated parameters to model the round budget in the simulation as a function of the number of proposals..

Voting Simulation Model: Modeling the social dynamics in proposals ratings

Previously, we considered the initial individual utility about the projects to be random between 1 and 5 stars. However, 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. 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:

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

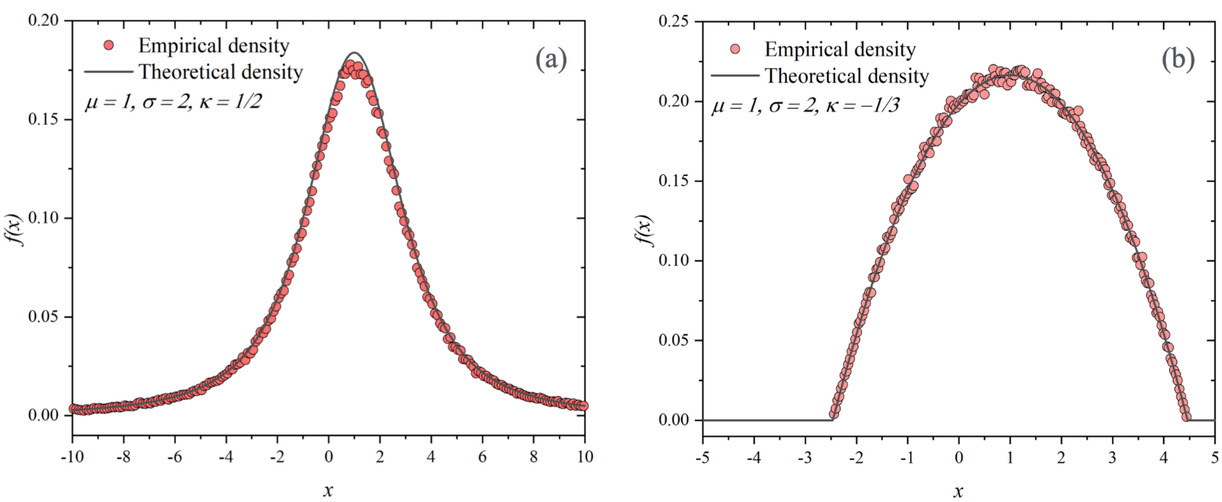


Figure 4. Empirical density of simulated data for a standard coupled-gaussian. In (a), the distribution is unbounded and in (b) it displays compact support. The empirical distribution has $5 \cdot 10^5$ samples. We use coupled gaussian with heavy tails to model the voters initial sentiment distribution.

In this context, the average value of the distribution μ represents the true quality of the proposal and the variance σ denotes the noise of the users in interpreting the proposal and the different value the same proposal has to users of different subpopulations.

Social effects

We consider a system of N individuals voting on Np proposals. 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 the agent i read the proposal p and form an opinion u(i, p)about the value of that proposal following 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) get closer to the average community review U(n, p), achieving the final opinion u'(i, p) given by

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

On the other hand, with probability I(i, n), the individual i disagree 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 Simulation Model: 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.

Plural 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 Unbounded Plural 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.

Voting Strategies

Sentiment voting

In opinion/sincere voting, the voters use grades aligned with their sentiments about the proposals. We make a linear mapping between the sentiments and the grades. In unbounded plural voting, the fraction of tokens the users allocate to the proposals is proportional to their sentiments. For example, Considering o'(i, p) the opinion about the set of proposals the agent i has a positive opinion, we model the tokens distributions on the proposals as

$$total\ votes(p) \ = \ \sum_i \sqrt{o'(i,p)b(i)/\sum_P o'(i,p)}.$$

So they allocate more tokens to proposals they like more. And to negative unbounded plurality voting, the total number of votes in the proposal is

$$total\ votes(p) \ = \ \sum_i \sqrt{|o(i,p)|b(i)/\sum_P |o(i,p)|}.$$

With the users concentrating their votes where they have more extreme opinions.

K Extreme voting

Here the individuals do not vote aligned with their sentiments, but use strategic voting. Here, the user votes with grade 10 in their top k preferred proposals and with grade 1 on the remaining proposals. For the purposes of plural voting, they vote with their maximum sentiment on their top k preferred proposals and with their minimum sentiment on the remaining proposals.

K Skip extreme voting

Similar to K extreme voting, but here the user votes with grade 10 in their top k preferred proposals and skip the remaining proposals. For the purposes of plural voting, they vote with their maximum sentiment on their top k preferred proposals and skip the remaining proposals.

Fully extreme voting

The fully extreme voter votes with grade 10 on every proposal he has a positive opinion, and with grade 1 on every proposal he has a negative opinion. This would be equivalent to the K extreme voter with K approaching infinity, so the voter votes with grade 10 on every proposal he likes, no matter the total number of proposals, and with grade 1 on the proposals he does not like). For the purposes of plural voting, they vote with their maximum sentiment on proposals he has a positive opinion and with their minimum sentiment on the remaining proposals.

Fully skip extreme voting

Similar to the fully extreme voter, but votes with grade 10 on every proposal he has a positive opinion, and skip the remaining proposals. This would be equivalent to the K Skip extreme voter with K approaching infinity, so the voter votes with grade 10 on every proposal he likes, no matter the total number of proposals, and skips the rest). For the purposes of plural voting, they vote with their maximum sentiment on proposals he has a positive opinion and skip the remaining proposals.

K Demanding voting

Here the individuals use grades aligned with their sentiments about the proposals, but only vote on their top k preferred proposals, skipping the remaining proposals.

K Extreme Demanding voting

Here, users only consider voting on their top k preferred proposals, and normalize their sentiments considering only these proposals they want to vote. So, Considering $\tilde{o}(i, p)$ the opinion about the set of their k preferred proposals, the normalized opinion is given by

$$o(i,p) = \tilde{o}(i,p)/\sum_{p}\tilde{o}(i,p).$$

Voting Simulation Model: 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 5 compares the impact of the SingularityNET method and several other voting systems on the aggregate voters’ welfare when all the voters are honest/sincere. All voting systems show a sharp decline in welfare from the zero inertia case; however, unbounded plurality consistently results in higher aggregate voter welfare than the other systems. It is important to note that the threshold of an average grade of at least 6.5 for a proposal to be eligible for funding might not be appropriate for voting systems that allow negative grades, which may be impacting their welfare. Analyzing the threshold impact can be a topic of future investigation.

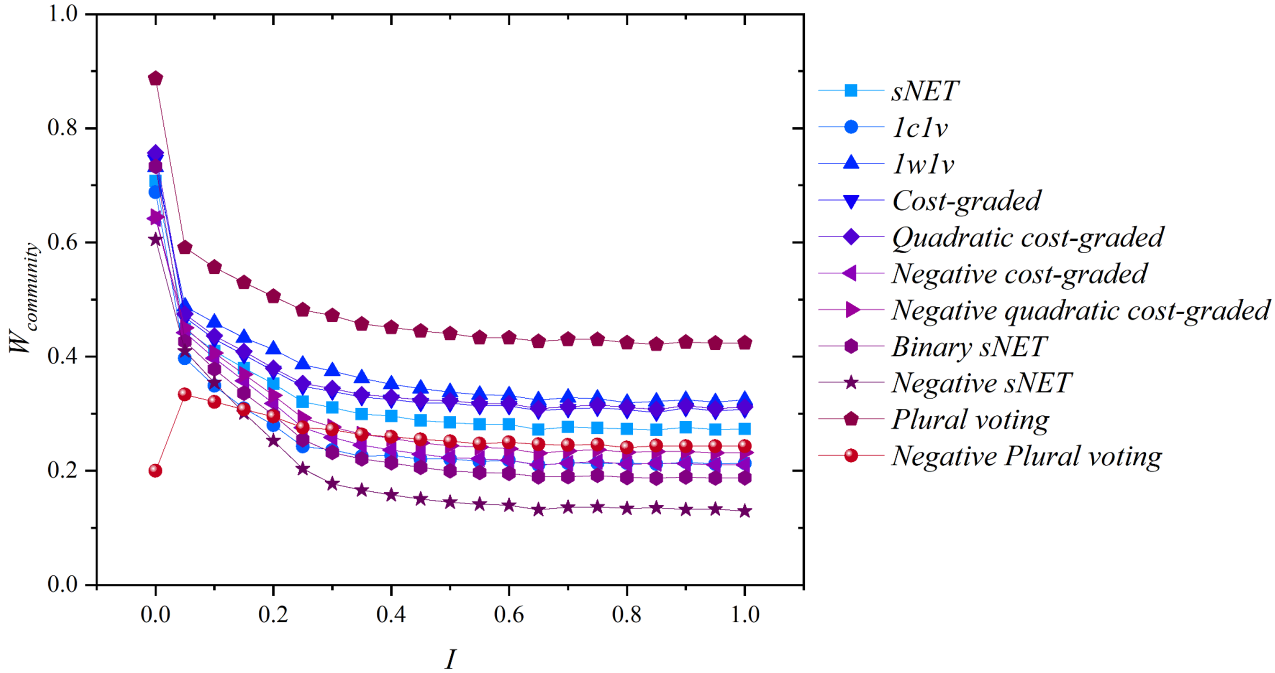


Figure 5. Here we show how the aggregate voters' welfare of several voting systems changes with the social inertia value of the voters. Here, all voters are honest/sincere and we used a community with 500 voters, 20 proposals, social pressure of 1%, Probability of posting of 40% and a probability of 5% of skipping a proposal.

In Figures 6 to 11, we examine the impact of strategic voting on the singularity NET voting system, 1c1v, Unbounded plural voting, 1w1v, cost-grading and negative unbounded plural voting over the fraction f of strategic voters.

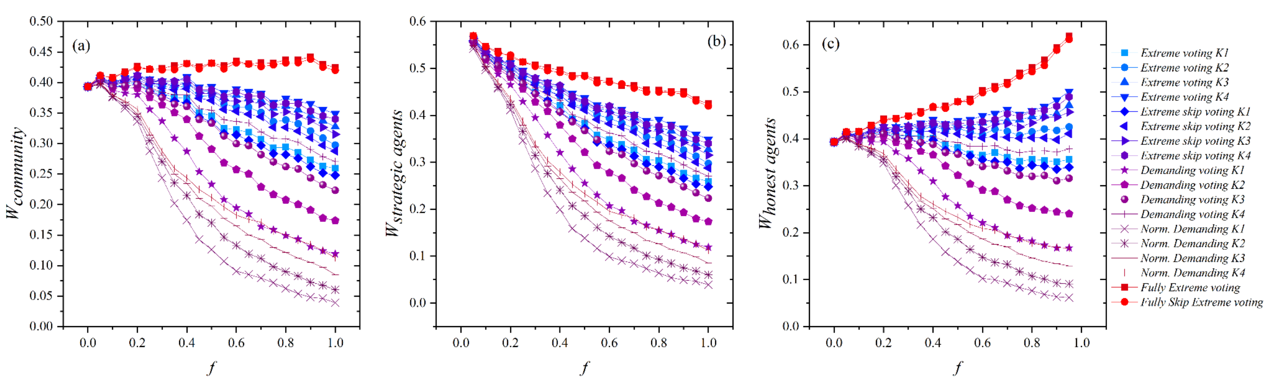


Figure 6. Here we show how the aggregate voters' welfare of the **Singularity NET** changes if we introduce voters using strategic voting Here we used a community with 500 voters, 20 proposals, Inertia I is set to 0.1, social pressure of 1%, Probability of posting of 40% and a probability of 5% of skipping a proposal. In (a), we have the welfare of the community, in (b) the welfare of the strategic agents and in (c) the welfare of the honest agents.

In general, strategic voting increases voter welfare at the expense of aggregate welfare. However, in Unbounded plural voting, strategic options do not impact the aggregate welfare. In this system, the welfare of the honest voters strictly increases with f. The Extreme demanding voting and Demanding voting are especially harmful to the voter's welfare, highlighting the importance of increasing the participation of users in voting in more proposals. On the other hand, the Fully extreme voting is the best strategy in almost all voting systems, except in cost-grade voting, negative plural voting and plural voting.

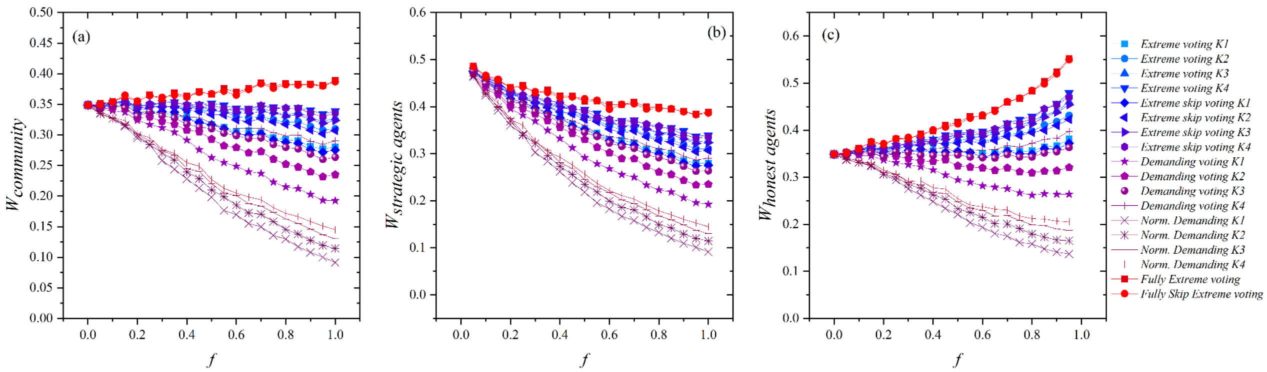


Figure 7. Here we show how the aggregate voters' welfare of the **One Coin, One Vote** changes if we introduce voters using strategic voting Here we used a community with 500 voters, 20 proposals, Inertia of 0.1, social pressure of 1%, Probability of posting of 40% and a probability of 5% of skipping a proposal. In (a), we have the welfare of the community, in (b) the welfare of the strategic agents and in (c) the welfare of the honest agents.

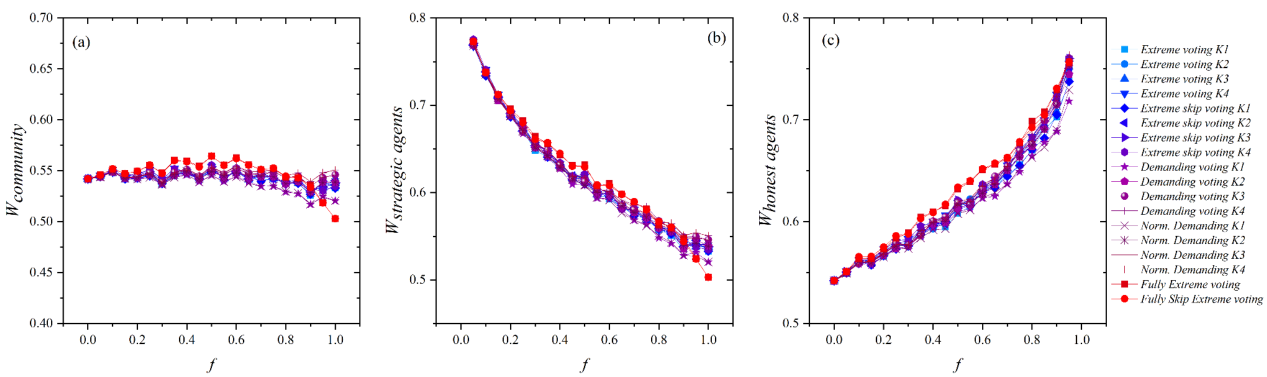


Figure 8. Here we show how the aggregate voters' welfare of the **Unbounded Plural voting** changes if we introduce voters using strategic voting Here we used a community with 500 voters, 20 proposals, Inertia of 0.1, social pressure of 1%, Probability of posting of 40% and a probability of 5% of skipping a proposal. In (a), we have the welfare of the community, in (b) the welfare of the strategic agents and in (c) the welfare of the honest agents.

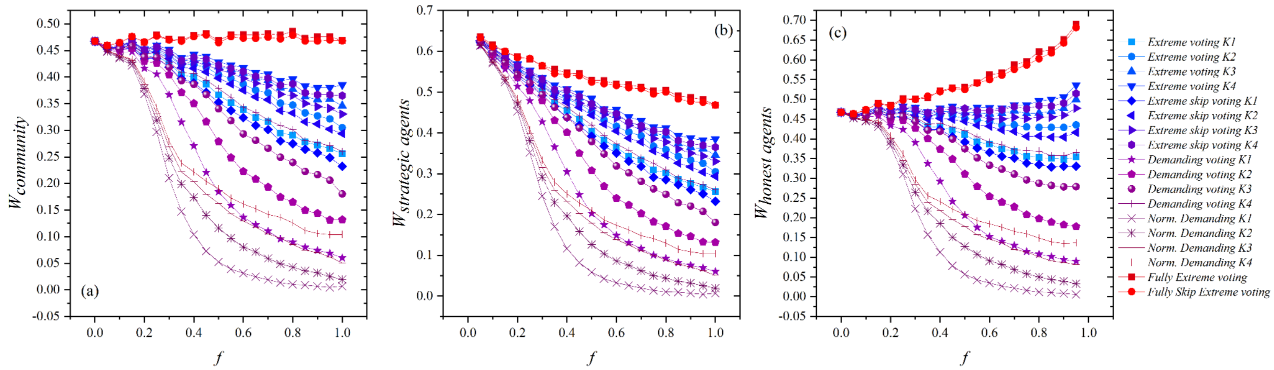


Figure 9. Here we show how the aggregate voters' welfare of the **One Wallet, One vote** changes if we introduce voters using strategic voting. Here we used a community with 500 voters, 20 proposals, Inertia of 0.1, social pressure of 1%, Probability of posting of 40% and a probability of 5% of skipping a proposal. In (a), we have the welfare of the community, in (b) the welfare of the strategic agents and in (c) the welfare of the honest agents.

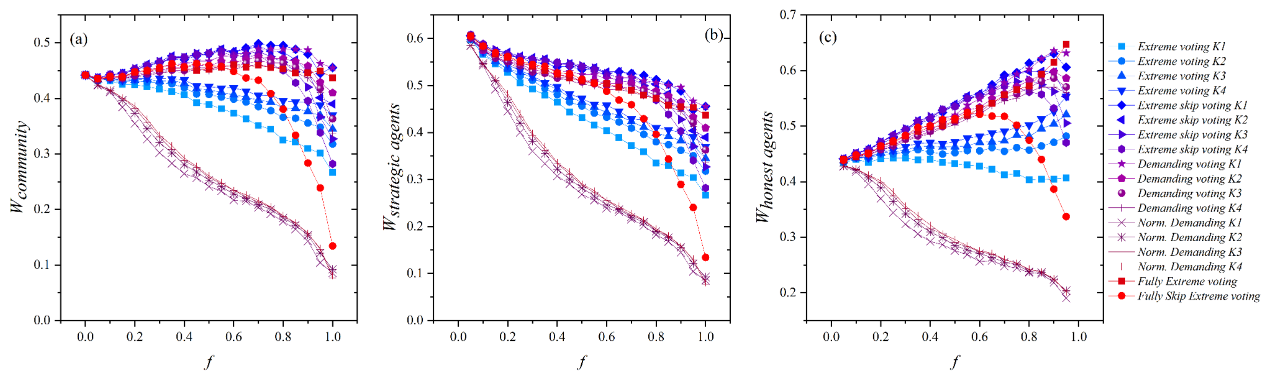


Figure 10. Here we show how the aggregate voters' welfare of the **Cost-graded voting** changes if we introduce voters using strategic voting Here we used a community with 500 voters, 20 proposals, Inertia of 0.1, social pressure of 1%, Probability of posting of 40% and a probability of 5% of skipping a proposal. In (a), we have the welfare of the community, in (b) the welfare of the strategic agents and in (c) the welfare of the honest agents.

Research Highlights

Unbounded plural voting has, by far, the better welfare across all voting systems, even in the presence of strategic voters. However, because the grades are unbounded in unbounded plural voting, this also increases the influence of extreme voters. In the simulation, the agents use their money in an extreme way to vote. However, in QV, the voters need to pay for a vote, limiting extreme voters' behavior.

One way to limit the impact of extreme voters and users who skip a lot of proposals is including a reputation system. In this context, the voting entropy is an efficient way to distinguish between responsible voters who thoroughly review proposals, to evaluate community benefits from individuals who opt for a simpler route, offering extreme high ratings to a select few projects while disregarding the rest. The voting entropy would consider the average behavior of the user across all pools, and would affect the user's voting power, penalizing extremal voting behavior and amplifying the voices of users who cast unbiased, responsible, and honest votes.

However, we could start by examining the effect of more proposals and including pools first. After all, the more a person benefits from voting on multiple proposals the less incentive there is to be extreme about one.

P.S. It was hard to find nonlinear functions that fit and could numerically converge on the token distributions. Although the power-law functions converge, the fit quality can be better. In the following report, we will try to use coupled functions such as the coupled exponential to fit the credit distributions.

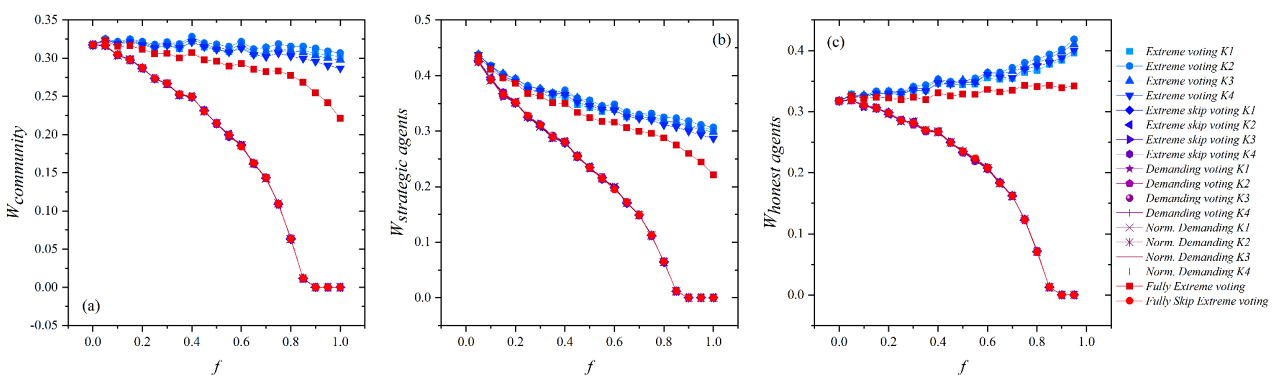


Figure 11. Here we show how the aggregate voters' welfare of the **Negative Unbounded Plural voting** changes if we introduce voters using strategic voting. Here we used a community with 500 voters, 20 proposals, Inertia of 0.1, social pressure of 1%, Probability of posting of 40% and a probability of 5% of skipping a proposal. In (a), we have the welfare of the community, in (b) the welfare of the strategic agents and in (c) the welfare of the honest agents.

Voting Simulation Code

The code is a simulation of a social voting and funding model. It simulates the behavior of individuals rating and voting on proposals under several voting systems with a variety of factors such as social inertia, social pressure, and funding distribution. The simulation aims to model how different voting mechanisms and social factors affect the funding and rating of proposals in a community. Additionally, the voters can follow different voting strategies, and the simulation measures the aggregate voter's welfare, and also the welfare of strategic and honest voters. The simulation uses a mix of predefined parameters and random distributions to simulate realistic variations in individual behavior, credit and funding distributions.

The code and his description can be accessed in the Community Decisions Simulation GitHub repository link by clicking here and accessing the folder "Milestone 4".

Below we reproduce a detailed description of the code and its functionalities:

Main Simulation Workflow
The overall simulation workflow involves:

- Initializing system parameters and distributions.
- The credit and funding distributions are generated based on real data.
- Simulating proposal dynamics and individual ratings.
- Attribute a voting strategy to each voter, considering a fraction f of strategic voters.
- Casting votes using different methods.
- Calculating results, determining the most voted and funded proposals and calculating the voters' aggregate welfare, and the welfare of honest and strategic voters.

System Parameters
The code defines several constants that are used throughout the simulation:

- Number of individuals (N).
- Fraction of strategic voters (f).
- Number of experiments (Nxps).
- Backup rate (backUpRate). (minimum number of experiments to write data in a text file)
- Number of stages for threading (Nstages).
- Social inertia parameters (AverageInertiai, AverageInertiaf, dAverageInertia).
- Inertia proportional constant (InertiaProp).
- Probability of posting a rating (Pposting).
- Social pressure parameter (socialPressure).
- Number of proposals available for voting (Nproposals).
- Probability of skipping a proposal (Pskip).
- Maximum number of proposals to vote on using plurality voting (NmaxProposalsToVote).

- Funding parameters (funding money, yoL, xc, w, AL, yo, A, xo, minFunding), variables fitted using real data to generate realistic distributions of credit and proposal funding requests.
- Coupled gaussian parameters (kappa, sigma, and the minimum and maximum true quality of each proposal muMin and muMax).

Random Number Generation

We write functions for generating power law and exponential distributions are defined to simulate randomness in the model using the Inverse Transform Sampling Method. These functions are used to generate the tokens distributions among users and the funding each proposal requests.

Proposal dynamics

The ProposalDynamics() function simulates the process of individuals rating proposals on the Deep Funding platform, socially influenced by previous ratings from other users. This influences how they will grade and vote on the proposals.

Voting Systems

Different methods of casting votes are implemented:

- sNET (CastVotesSqrtTokens())
- Binary sNET (CastBinaryVotesSqrtTokens())
- Negative sNET
- 1c1v (CastVotesOneCoinOneVote())
- 1w1v (CastVotesOneWalletOneVote())
- Cost-grading (CastVotesPluralityVoting())
- Quadratic Cost-grading (CastQuadraticVotesPluralityVoting())
- Negative Plural voting (CastVotesPluralityVotingWithNegatives())
- Quadratic negative plural voting (CastQuadraticVotesPluralityVotingWithNegatives())
- Unbounded plurality voting (CastVotesUnboundedPluralityVoting())
- Negative Unbounded plurality(CastVotesUnboundedPluralityVotingWithNegatives())

Voting Strategies

Different strategies of users casting votes are implemented:

- K Extreme voting (AgentsDistributionExtreme())
- Fully extreme voting (AgentsDistributionFullyExtreme())
- Fully Skip extreme voting (AgentsDistributionFullyExtremeSkip())
- K Skip Extreme voting (AgentsDistributionExtremeSkip())
- K demanding voting (AgentsDistributionEconomist())
- K Extreme demanding voting (AgentsDistributionEconomistExtreme())

Decision Making

Functions to determine which proposals to vote on and which are the most favored in plurality voting when there is a cost to grade the proposals:

void GetFavoriteProposals();
void DecideWichProjetcsToVote();

Results Calculation

Functions to get the most voted and awarded proposals:

void GetMostVotedProposals();
void GetAwardedProposals();
void GetPluralityAwardedProposals();

Functions to get the aggregate voter's welfare and the welfare of strategic and honest voters:

welfare();
welfareStrategicAgents();
welfareNonStrategicAgents();

Stage and Points

Structures and functions to manage simulation stage threads:

```
struct STAGE {
   float INITIAL;
   float FINAL;
};
struct STAGE POINTS(float initial_point, float final_point, float increment, int number_stages);
```

Red Team Reviews

Milestone 3 Review, Duong

Here are my red team comments on the milestone 3 project report, meant to be a "Devil's Advocate" to the simulation rather than a rating, meant to find weaknesses in time to address them. The first weakness I see in the stated design is in the way that utility is modeled. First of all, it is assumed that the person voted as was their utility, and that is a generally sound assumption, just not as applied in this simulation. That a person votes as is their utility is true regardless of how the aggregate utility is calculated. But then a weak social assumption is used to model how voting was done, that assumes that people's utility is random except for social pressure which convinces them to vote more towards the average vote. It is a weak assumption because it does not consider the networked nature of utility, including different utilities for different subnetworks and different interest groups. The weak assumption would result in a normal distribution, and the "non conformists" just make this a wider normal distribution, that isn't for example bimodal or reflective of the diverse utilities of social networks. It is important to correct this as it is the most likely reason that one coin one vote has such high aggregate utility in both ways that aggregate utility is calculated. It would be better to have access to the true distribution of individual's votes in the past, which is reasonable to have for the sake of improving the voting systems. Voters should be given the option of releasing their vote not to the public but to be used for improvement of voting systems and kept anonymous while doing so.

Developer Comments

We thank Deborah Duong for reviewing the project development. We appreciate your work as a Red team independent reviewer in finding the simulation and model weakness, which is extremely important so we can improve the project to make it as realistic and accurate as possible in analyzing voting systems to the Singularity NET (SNET) Deep Funding initiative.

We agree with you that assuming the initial individual utility about the projects is random is a weak assumption, even if we consider the social pressure and nonconformism effect afterwards. After all, the initial individual utility should depend on both the proposal features and the agent interest in the proposal, which is typically not random. Randomness is chosen by design to obtain initial insights of the effects of rating in welfare estimations. Indeed, 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.

Another problem is that we are considering the people's utility to be bounded between one and five stars. However, 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 can 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. 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, the voters are moderate, in contrast, within the heavy tail regime, coupled gaussian distributions are able to represent the average perception regarding the quality of a proposal, but at the same time allow extreme opinions to be present.

It is a good idea to examine the true distribution of an individual's votes in the past, which can also help understand empirical voting strategies.

The thing wrong with assuming the way they vote is their utility is that the simulation was sort of chasing its own tail in that its real purpose is to compare how the singularity net way of voting and the plurality quadratic voting way compare to each other in terms of aggregate utility. But the quadratic voting group had a more restricted distribution for their votes, and thus more restricted and less comparable utilities, if utilities are votes. A fair way to compare utilities across different voting methods would be to model utility before the voting system, and then have the voter vote the most rationally according to their view of their utilities. Note that voting rationally would mean what you mean by "voting dishonestly".

Why not design a voting system to be honest given that voters will maximize utility, which is what game theory including the theory behind quadratic voting assumes. When you assume a biased responder, that would vote like (10, 1, 1, 1) has another true utility, you are ignoring the fact that the reason he is biased is that it has the most utility to him as an individual. You may consider, for example, just voting yay or nay, and allowing the voter to weigh their vote according to how much they care about it, using their voting credits. This may in fact turn out to be the same thing as making extreme votes cost more.

Developer Comments

That's correct. In milestone 3, the utility we considered was aligned with the SingularityNET method, which isn't suitable for making proper comparisons with other voting systems. We now agree that it's better to model utility independently of the voting system. Currently, we consider individual sentiments drawn from the coupled Gaussian distribution, incorporating social pressure and nonconformity effects to calculate utility. This allows us to calculate the aggregate utility of all voting systems in a fair and standardized manner, enabling proper comparisons.

We are also investigating various voting strategies to determine the optimal strategy for each voting system. This way, we can consider each individual's vote rationally according to the voting system and utilities. Additionally, we've incorporated your suggestion of a voting system where participants vote "yay" or "nay" and weigh their votes using voting credits, which is an exciting approach.

Regarding biased or extreme responses, these often represent strategic positions rather than true individual utility. For example, a user might vote with a grade of 10 for every proposal they feel positively about and a grade of 1 for every proposal they think negatively about, regardless of the sentiment's magnitude. Note that that this strategy doesn't align with the voter's true utility; instead, it reflects an individual voting strategy. However, not all extreme voters are strategic; it's possible for a user's true utility set to naturally be extreme (e.g., (10, 1, 1, 1)), which our simulation with heavy-tailed coupled Gaussians can accommodate.

Additionally, there may be no sense in letting only extreme values, above 7, count, because sometimes one might have strong feelings towards not having something succeed that is against their values. Also, there is no reason why voting at lukewarm values is against the idea of quadratic voting, in fact the idea of quadratic voting is that you have to pay to concentrate your vote on an issue by not voting on another issue, and thus not concentrating your vote, in lukewarm votes should cost less and thus be worth more, My recommendation is to just accept the quadratic penalty on big wallets because the disparity is too great. How much to discount it is a dark art, there is no objective criteria. Then test quadratic voting further by limiting the weight of votes quadratically, so that they would have more power if they divided their votes across than if they concentrated their votes on single issues, in accordance with quadratic voting theory. However, have an objective utility, that is less known by some than others, to simulate expertise, and then test the further quadratic penalty.

Developer Comments

We agree with you and excluded the threshold in plurality voting of only voting in proposals with grade above 7. Some people's strategies indeed may include voting against proposals that do not align with their values. The average value of the coupled gaussian now makes the role of the proposal objective utility and the sigma of the distribution simulates the lack of expertise of some agents in correctly evaluating the project's true utility.

Walter Karshat
Review of Milestone 3.
Designation

Granting Agency: Singularity NET Deep Funding
Funding Round: 4-Beta
Pool: RFP
Proposal: **Simulating The Quality Of Community Decisions**
Proposer: Photrek
Code: DFR4B-RFP2

Earlier Rounds

Deep Funding rules and guidance on proposals and their rating have been changing from round to round. The size of the participant community increased manyfold and the composition likely changed as well. We are on a different platform now and approach public reviews and comments in a new way. I suggest that for the voting analysis, we focus exclusively on the outcomes of Round 4 and look for more nuance between subpopulations and within pools, rather than immediately averaging all votes across all the rounds.

Developer Comments

We thank you for the suggestions. Indeed, the way the platform approaches reviews and comments substantially changed. We agree it would be good to focus on Round 4 and also include the pools in our analysis, which can turn the simulation even more realistic.

Reviewer Segments

I suspect that we will need to look at the subpopulations to uncover the relationships between recorded scores and individually perceived utility. One may also be able to validate whether there is any merit to the hypothesis that reviewers adjust their scores toward some disclosed *community score,* even if individual propensity differs.

We have three sets of scores:
Experts [5 stars]
Community [5 stars]
Votes [1-10 rating]

Expert identities are known to DF staff. Community members tend to include some identity information when leaving extensive reviews. These constitute two distinct groups of individuals and their respective scoring processes are different. Experts individually scored a list of [some initial] projects, without knowing how others did. By comparison, Community members filed their reviews for public viewing and could see all the reviews already filed, with all the explanations and individual scores per 5 categories. Any effects due to external social pressures or a desire to conform to the social consensus would be the strongest among the Community scores and would not be present in Expert scores.

On-chain voting during Round 4 presented a web page per pool, with an averaged Expert value expressed as 1.0-5.0, and no reference to the Community score. With the rating on a 1-10 scale, I expect hardly any effect from the Expert value.

Developer Comments

You are correct that external social pressures would be more evident in the community score and not in the expert reviews since the experts individually write their reviews. While the number of experts is low, they can significantly influence other users' opinions, and including them in the simulation would be important. We agree that the difference between the 1-5 stars scales and the grades from 1-10 can confuse some individuals. It is an excellent suggestion for deep funding to use the same scale to avoid confusion. Nonetheless, we can also simulate user confusion and uncertainty with noisy voting.

Proposal Value

I venture that in total the Experts and the Community have the best insight into the proposal value for the ecosystem due to prolonged exposure and consistent engagement. With identities known or at least suggested, they would express reasonable behaviors. Plenty of them may not have proposals submitted, or at least not in the same pool, and have no direct material benefit in the outcomes.

For the subset of the proposals that have been covered by the Experts, one may observe slightly higher scores than from the Community. Yet, they all bunch around 4 out of 5, somewhere between 7.5 and 8.5 on the 10 scale. The distribution of the on-chain votes is notably lower, perhaps centered closer to 6, which is around 3 stars.

Likely, most of the Expert and Community reviewers have also cast votes, but perhaps constitute only a minority of the Voters. Meanwhile, with 210 submitted and over 190 allowed proposals in Round 4, a large fraction of Voters are on one or several proposals. Further investigation is suggested for the voting patterns at the intersection between Expert/Community reviewers, Voters, and Proposers.

Developer Comments

We thank you for your suggestions about looking further in the Deep Funding data. This can reveal more insights and patterns about the system and the voters. We shall investigate the voting patterns and the effect of the Expert and community reviewers.

Distinct Pools

The competition on scores and the allocation of amounts happen entirely within individual pools. The ratio of the maximum proposal size to the pool total varies from 1 to 15. A large fraction of proposals are at the maximum amount for the pool, so the ratio of the proposals funded also varies. Any dependency of the scores on the proposal amount should be looked at separately within each pool.

Anywhere between 20 and 50 on-chain scores for each proposal are cast by some of well over a hundred unique voters. Though which proposals each voter subpopulation has chosen to rate and how is TBD. There appears a slight pattern within some pools, where proposals with more votes get higher scores.

The score distributions vary notably between the pools, with Ideation and Marketing getting significantly lower average scores and Community RFP notably higher. A much weaker version of this pattern can be seen in Expert and in Community ratings, its cause TBD.

Developer Comments

We acknowledge the importance in including the pools in the simulation since the competition happens in individual pools and the score changes significantly between pools. The pattern that more voted proposals would also have higher scores is interesting and may be investigated. This can reveal more insights in the community voter dynamics.

Expected Distribution

We need better guidance on what constitutes a proper or at least acceptable distribution of ratings submitted. Giving mostly 1 or 10 is so frowned upon that it would damage one's reputation. Yet this gives your votes the most impact, which is exactly the rational approach. Is there then an expectation for giving mostly 5 and 6? Maybe an even usage of values between 1 and 10, or some bell curve centered around 5.5 or around 6.5?

The 6.5 score needs a better justification or explanation, as the cutoff resulted in only 20% of the Ideation pool amount getting awarded this Round Only 5 proposals out of some 40 submitted scored 6.5 or higher. Quite likely individual voters did not actually think that so few should be even considered for funding.

Developer Comments

We believe the best way the users can vote is aligned with their true sentiments regarding the proposals, so people do not need to consider strategic voting. We want to analyze the claim that unbounded plural voting incentivizes users to be honest about their opinions when voting. We agree with you that the threshold of 6.5 is somewhat arbitrary, and we can investigate the effect of the thresholds in the simulations, to better understand the threshold impact on the community.

Suggestions for Future Rounds

Mental and algorithmic conversion between 1-5 stars and a 1-10 rating introduces additional confusion or ambiguity, as in actuality we convert 4 to 9 intervals. Let's switch to 1-10 throughout.

Developer Comments

We totally agree with you and may give this suggestion do Deep Funding, which can simplify the voting process.

Budget & Schedule

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

Future Plans & Change

Notifications

Project References

[1] Moe, Wendy W., and Michael Trusov. "The value of social dynamics in online product ratings forums." *Journal of marketing research* 48.3 (2011): 444-456.

[2] Mubarok, Mohamad Syahrul, Adiwijaya Adiwijaya, and Muhammad Dwi Aldhi. "Aspect-based sentiment analysis to review products using Naïve Bayes." *AIP conference proceedings*. Vol. 1867. No. 1. AIP Publishing, 2017.

[3] Sahoo, Nachiketa, Chrysanthos Dellarocas, and Shuba Srinivasan. "The impact of online product reviews on product returns." *Information Systems Research* 29.3 (2018): 723-738.

[4] Constantinides, Efthymios, and Nina Isabel Holleschovsky. "Impact of online product reviews on purchasing decisions." *12th International Conference on Web Information Systems and Technologies, WEBIST 2016*. SCITEPRESS, 2016.

[5] Baccianella, Stefano, Andrea Esuli, and Fabrizio Sebastiani. "Multi-facet rating of product reviews." *Advances in Information Retrieval: 31th European Conference on IR Research, ECIR 2009, Toulouse, France, April 6-9, 2009. Proceedings 31*. Springer Berlin Heidelberg, 2009.

[6] Network Science. Albert-Lazló Barabási. Cambridge University Press, 2016.

[7] Reyhani, Reyhaneh, Mark C. Wilson, and Javad Khazaei. "Coordination via polling in plurality voting games under inertia." *Proceedings of COMSOC* (2012): 359-370.

[8] "Deep Funding Round 1 Voting Analysis - Part 1: Number Crunching." Deep Funding, deepfunding.ai/deep-funding-round-1-voting-analysis-part-1-number-crunching/. Accessed 17 June 2024.

[9]Benhaim, Alon, Brett Hemenway Falk, and Gerry Tsoukalas. "Balancing Power in Decentralized Governance: Quadratic Voting under Imperfect Information." SSRN Scholarly Paper. Rochester, NY, April 3, 2023. https://doi.org/10.2139/ssrn.4416748.

[10] Kelter, Jacob, Andreas Bugler, and Uri Wilensky. "Agent-Based Models of Quadratic Voting." In *Proceedings of the 2020 Conference of The Computational Social Science Society of the Americas*, edited by Zining Yang and Elizabeth Von Briesen, 131–42. Springer Proceedings in Complexity. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-83418-0_8.

[11] Lalley, Steven P., and E. Glen Weyl. "Quadratic Voting." Available at SSRN, 2016. https://www.aeaweb.org/conference/2015/retrieve.php?pdfid=3009&tk=BHDG8H2E.

[12] Lalley, Steven P., and E. Glen Weyl. “Quadratic Voting: How Mechanism Design Can Radicalize Democracy.” AEA Papers and Proceedings 108 (May 2018): 33–37. https://doi.org/10.1257/pandp.20181002.