On the impact of social cost in opinion dynamics

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Algorithmic Game Theory Athens
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Formation of opinions in a social context

- intrinsic belief + friends’ expressed opinions

expressed opinion
Motivation

exponential growth of online social networks
\[\Downarrow\]
ever-increasing amount of social activity information available
\[\Downarrow\]
ability to analyze user behavior and interpret sociological phenomena at a large scale [AKM08]
\[\Downarrow\]

Investigating game theoretic models of networks against real data

We consider the phenomenon of opinion formation under social influence. Given a network dataset, we want to be able to:

- verify the existence of influence among users
- build a model that describes user behavior in the network.
Our contributions:

1. We analyze user activity in digg and verify that social interaction results in influence on opinions among the participants.

2. We initialize a sociological model using real data. Based on the Game Theory framework, we experimentally show that the repeated averaging process results to Nash equilibria which are illustrative of how users really behave.
digg is a news aggregator with a curated front page, aiming to select stories specifically for the Internet audience such as science, trending political issues, and viral Internet issues.
digg lets you:

- Submit stories.
- **Digg** (give a thumbs-up/positive vote to) a story you want other people to see.
- Follow users you consider interesting to get informed about their diggs in your news feed.
The *digg* dataset is appropriate for our study because:

- *digg* was very popular at the time the dataset was collected [LGS12]
- *digging* a story has a sense of opinion expression and an urge to influence
- both *diggs* and *follower links* are timestamped
The model: Basic notions

We use:

a variation of the DeGroot model due to Friedkin and Johnsen [FJ90] and the corresponding game of [BKO11].

Each user $i$ maintains:

- An intrinsic belief $s_i$ remains constant
- An expressed opinion $z_i$ updated iteratively through averaging

The cost a user suffers emanates from:

- Suppressing her intrinsic belief
- Disagreeing with her friends
The model: Repeated Averaging

Repeated Averaging
At each time step user $i$ updates $z_i$ to minimize her cost:

$$z_i = \frac{s_i + \sum_{j \in N(i)} w_{ij} z_j}{1 + \sum_{j \in N(i)} w_{ij}}$$

$N(i)$: the set of nodes that $i$ follows
$w_{ij}$: the strength of the influence of $j$ on $i$

The averaging process terminates when $z$ converges to the unique Nash equilibrium, where the social cost is minimized.
The model: Determining the influence strength

Our intuition:
The influence of $j$ on $i$ regarding a specific matter depends on:

- The impact $a_{ij}$ of $j$ on $i$
- The expertise $b_j$ of $j$

Does $i$ respect $j$’s opinion in general? Is $j$ authoritative on this matter?

We define:

$$w_{ij} = a_{ij}b_j$$
### Top-20 Cascade Patterns

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<td>15</td>
<td><img src="image19" alt="Pattern 15" /></td>
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the total *infections* were less than the initial *seeders* in more than 92% of the stories of digg
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A few users caused many cascades while most were unable to cause any.
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a few users caused many cascades while most were unable to cause any

even the most *authoritative* users were not effective in all stories
Our Experiments and Assumptions

- We performed repeated averaging in our model for stories of digg until the opinions, expressed by votes, converged to the unique Nash equilibrium.
- We compared against predictions obtained using a Neural Network classifier.

Model initialization assumptions

<table>
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<tr>
<th>Intrinsic belief $s_i$</th>
<th>Influential strength $w_{ij}$</th>
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| $s_i = \begin{cases} 
1 & \text{if } i \text{ voted a story before any user she follows} \\
0 & \text{otherwise} 
\end{cases}$ | Two variants: |
| \(a_{ij} = b_j = 1 \Rightarrow w_{ij} = 1\) | i) $a_{ij} = \frac{\# \text{ times } i \text{ is influenced by } j}{\# \text{ votes of } j}$ |
| ii) $a_{ij} = \frac{\# \text{ users influenced by } j \text{ in this story}}{\# \text{ followers of } j}$ | $b_j$ = \# users influenced by $j$ in this story |
Results

The fraction of predicted votes that were actually casted against the fraction of casted votes that are predicted:
The fraction of *predicted* votes that were actually *casted* against the fraction of *casted* votes that are *predicted*:

Our 2nd variant closely mimics the original social activity.
The fraction of *predicted* votes that were actually *casted* against the fraction of *casted* votes that are *predicted*:

```
           Precision          Recall
585 votes  0.4             0.6
335 seeders

271 votes  0.4             0.6
145 seeders

Repeated Averaging $(w_{ij} = 1)$
Repeated Averaging $(w_{ij} = a_{ij} b_j)$
Neural Network
```

- Our 2nd variant closely mimics the original social activity.
- The simplistic variant behaves poorly as expected.

The impact of social cost in opinion dynamics - Experimental Part
The fraction of *predicted* votes that were actually *casted* against the fraction of *casted* votes that are *predicted*:

- **Repeated Averaging** ($w_{ij} = 1$)
- **Repeated Averaging** ($w_{ij} = a_{ij}b_j$)
- **Neural Network**

*Our 2nd variant closely mimics the original social activity.*

*The simplistic variant behaves poorly as expected.*

*We consistently outperform the Neural Network classifier.*
The fraction of *predicted* votes that were actually *casted* against the fraction of *casted* votes that are *predicted*:

- **Repeated Averaging** ($w_{ij}=1$)
- **Repeated Averaging** ($w_{ij}=a_{ij}b_{j}$)
- **Neural Network**

24.46 percentage points, on average, higher precision for 90% recall!

Our 2nd variant closely mimics the original social activity.

The simplistic variant behaves poorly as expected.

We consistently outperform the Neural Network classifier.
The fraction of *predicted* votes that were actually *casted* against the fraction of *casted* votes that are *predicted*:

The repeated averaging process, combined with proper influence weights, results to Nash equilibria which are illustrative of how users really behave.

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On the impact of social cost in opinion dynamics • Experimental Part
References


We can estimate the price of anarchy in such a network, by comparing the social cost of the Nash equilibrium we computed here with the cost of the optimal setting of this network.

We can investigate approaches that may reduce the cost of such networks.
thank you!

for further details visit: http://hive.di.uoa.gr/network-analysis/

or email me at: katia@di.uoa.gr