

Vote-and-Comment: Modeling the Coevolution of User Interactions in Social Voting Web Sites

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1. Introduction

2. Model

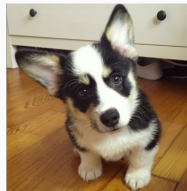
3. Experiments

4. VnC: Applications

5. Conclusions

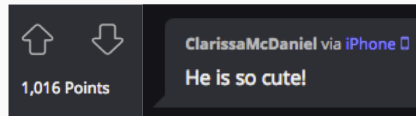
Social Voting Web Sites

In social voting web sites, users can submit **content** (e.g. pictures, news articles)



And other users can:

- **Up-vote** (like)
- **Down-vote** (dislike)
- Post **comments**



Examples of social voting web sites: Reddit, Imgur, Hacker-News

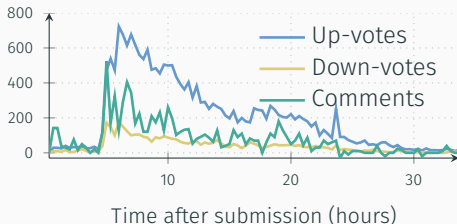
Coevolution of User Interactions

For a submission, we have 3 time-series: up-votes $v_+(t)$, down-votes $v_-(t)$ and comments $c(t)$:

Submission



Time-Series



Problem

Can we explain how $v_+(t)$, $v_-(t)$ and $c(t)$ evolve over time?

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Vote-and-Comment (VnC) Model

VnC: mathematical model that describes how the volume of up-votes, down-votes and comments changes over time

VnC is composed of 3 submodels that describe the following relationships:

1. Up-votes over time
2. Up-votes vs. down-votes
3. Comments vs. votes

VnC: Up-votes Over Time

The number $v_+(t)$ of up-votes received by a submission at time t is a function of:

1. $P(t)$: probability of a user up-voting at time t
2. N_+ : population of potential voters
3. $V_+(t)$: number of votes *accumulated* at time t

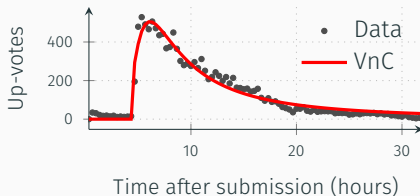
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Up-votes over Time

$$v_+(t+1) = \underbrace{[N_+ - V_+(t)]}_{\text{users that can vote}} \cdot P(t)$$

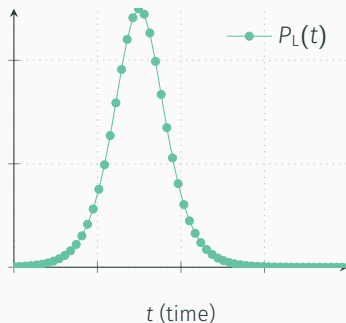


Next Step: How can we model the probability $P(t)$?

VnC: Modeling the Up-voting Probability

$P_L(t; \beta_+, \xi_+)$: Probability that a user likes a submission

- **Cascading Mechanism:**
submission popularity affects voting probability
- $P_L(t) = \xi_+ + \beta_+ \cdot V_+(t)/N_+$



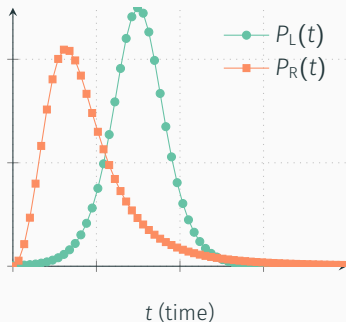
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$P_R(t; \mu, s)$: Probability that a user reacts at time t

- Log-logistic with parameters μ and s [Details](#)



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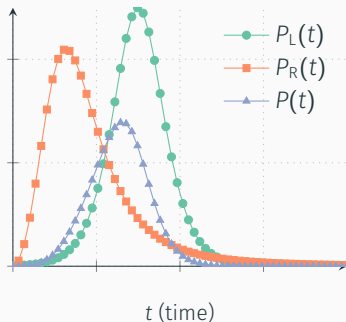
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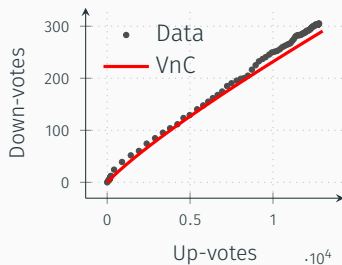
$P(t)$: Probability of a user up-voting at time t

- $P(t) = P_L(t) \cdot P_R(t)$



VnC: Up-votes vs. Down-votes

$$v_{-}(t+1) = [N_{-} - V_{-}(t)] \cdot P_L(t; \beta_{-}, \xi_{-}) \cdot P_R(t; \mu, s)$$



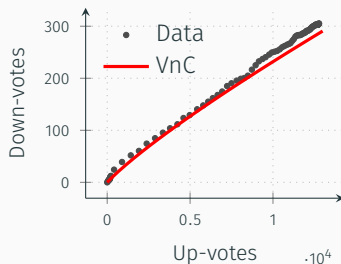
VnC: Up-votes vs. Down-votes

$$v_{-}(t+1) = [N_{-} - V_{-}(t)] \cdot \overbrace{P_L(t; \beta_{-}, \xi_{-})}^{\text{Cascading}} \cdot \overbrace{P_R(t; \mu, s)}^{\text{Reaction Times}}$$

The down-vote time-series

$v_{-}(t)$ also follows:

1. A cascading mechanism
2. Log-logistic reaction times



VnC: Up-votes vs. Down-votes

$$v_{-}(t+1) = \underbrace{[N_{-} - V_{-}(t)]}_{\text{Not-shared Parameters}} \cdot \underbrace{P_L(t; \beta_{-}, \xi_{-})}_{\text{Cascading}} \cdot \underbrace{P_R(t; \mu, s)}_{\text{Reaction Times, Shared}}$$

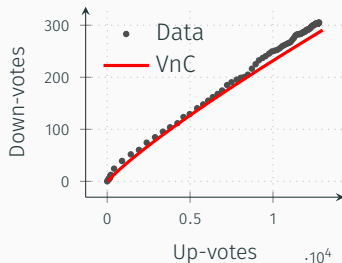
The down-vote time-series

$v_{-}(t)$ also follows:

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Sharing parameters with the up-vote time-series:

1. Shared: μ and s
2. Not shared: N_{-} , β_{-} and ξ_{-}

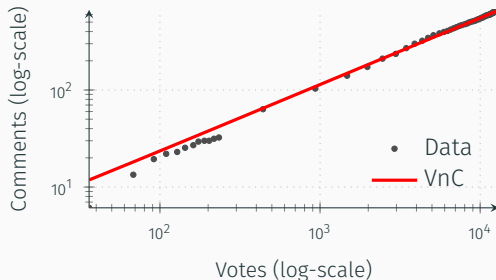


VnC: Comments vs. Votes

VnC models the number of comments $C(t)$ as a **power law** on the number of votes:

$$C(t) = k \cdot [V_+(t) + V_-(t)]^\alpha$$

The power-law — matches the data



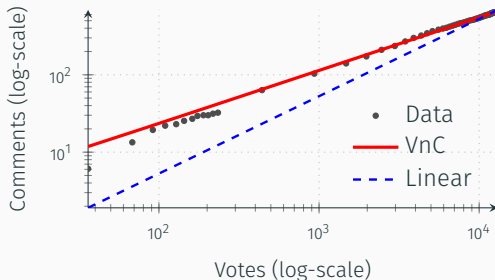
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The power-law — matches the data

- The linear relationship fails to match the data



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Our goal is to answer the following questions:

- **Q1 – Fit Accuracy:** Is VNC more accurate than existing models when fitting social voting data?
- **Q2 – Popularity Decay:** Can VNC model the popularity decay of submissions?
- **Q3 – Coevolution:** Can VNC model the coevolution of up-votes, down-votes and comments time-series?

Our crawler tracked Reddit and Imgur submissions:

- Collected the number of votes and comments every 20 minutes
- Submissions were tracked for 33 hours after their creation
- Submissions with less than 100 up-votes were discarded

Digg dataset publicly available (Lerman and Ghosh, 2010):

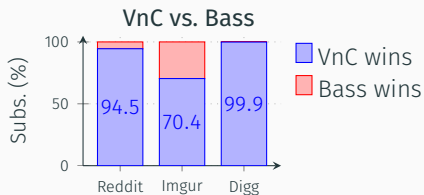
- Only up-votes (no down-votes and comments data)

Dataset	# Submissions	# User Interactions
Reddit	17,205	113,331,266
Imgur	724	2,107,576
Digg	3,553	5,149,170

Q1 – Fit Accuracy

Percentage of up-vote time-series that were best fit by each model

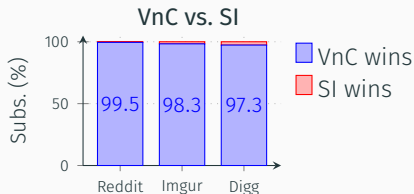
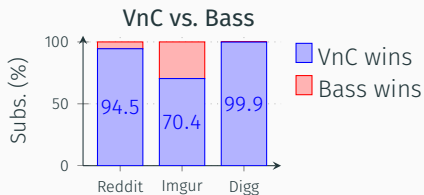
- Best fit determined by smaller root-mean-square error [Details](#)



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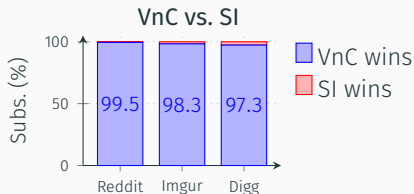
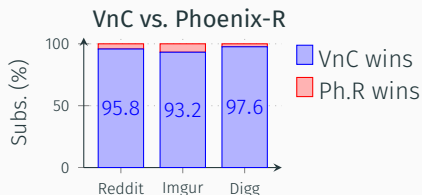
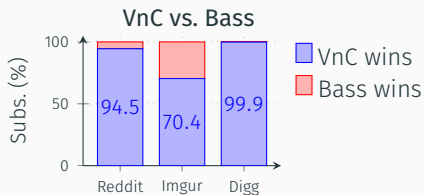
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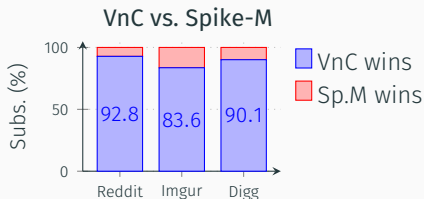
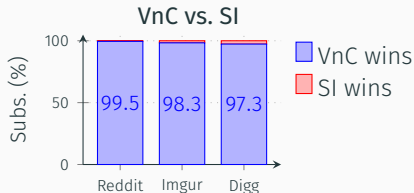
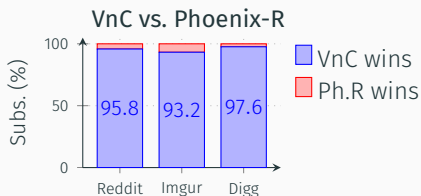
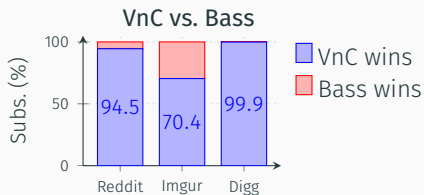
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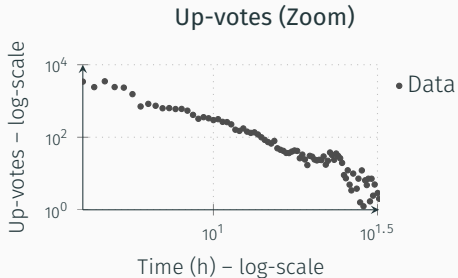
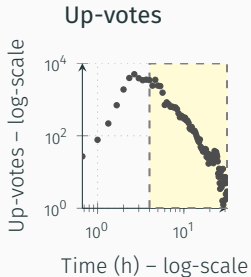
Percentage of up-vote time-series that were best fit by each model

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Q2 – Popularity Decay

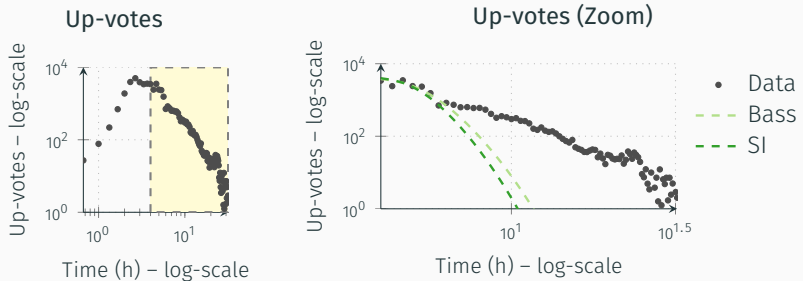
Up-vote time-series have a heavy-tail decay



Q2 – Popularity Decay

Up-vote time-series have a heavy-tail decay

Bass and SI models generate unrealistic exponential decays

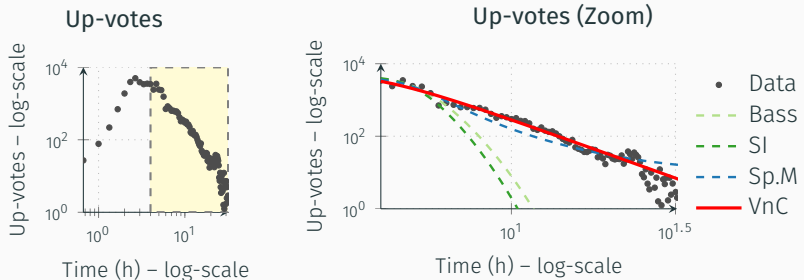


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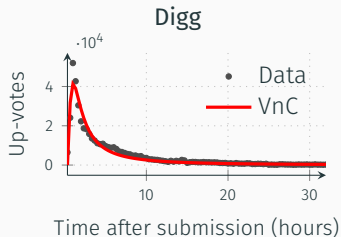
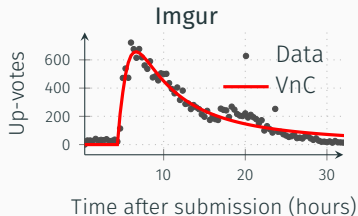
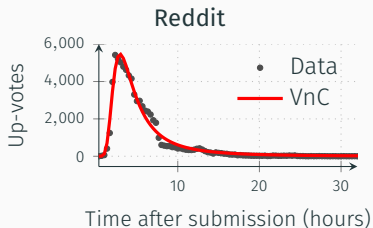
Bass and SI models generate unrealistic exponential decays

VnC and Spike-M are able to match the heavy tail decay



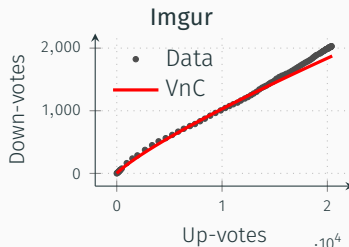
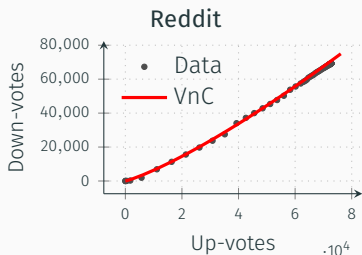
Q3 – Coevolution: Up-votes over Time

VnC up-vote time-series fits for the most voted submissions in each dataset



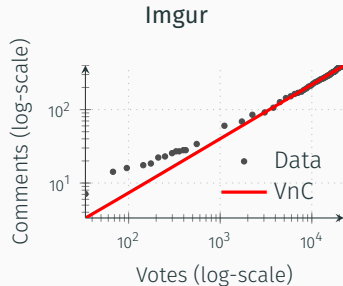
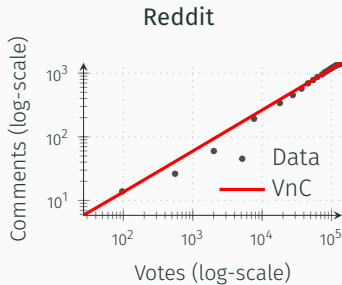
Q3 – Coevolution: Up-votes vs. Down-votes

VnC fit for the relationship between up-votes and down-votes received by a submission



Q3 – Coevolution: Votes vs. Comments

VnC fit for the relationship between total votes (up-votes + down-votes) and comments received by a submission

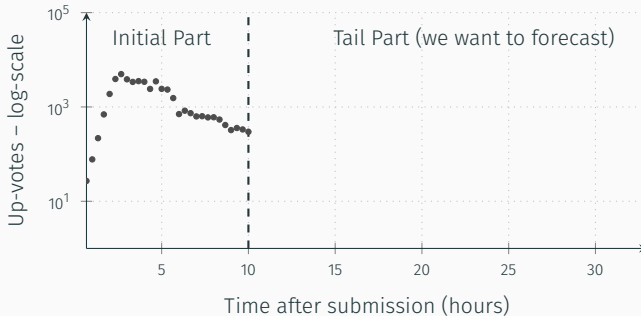


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Forecasting

Problem: Given the initial part of a social voting time-series, predict the tail part

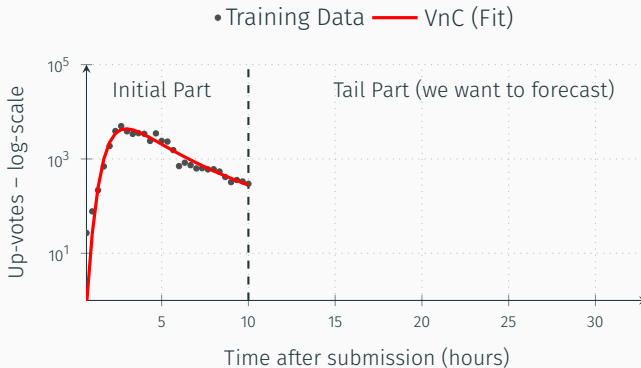
• Training Data



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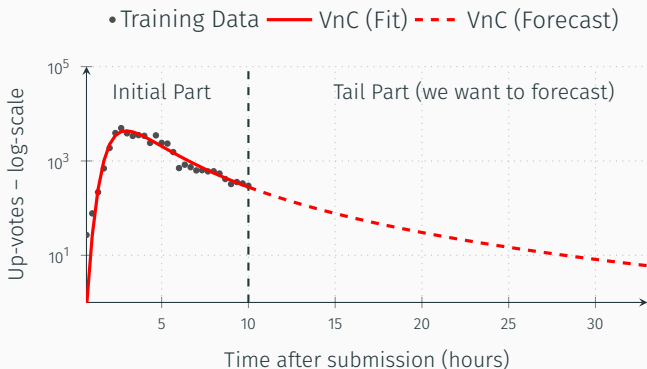
1. Estimate VnC parameters using the initial part



Forecasting

Problem: Given the initial part of a social voting time-series, predict the tail part

1. Estimate VnC parameters using the initial part
2. Use the parameters to forecast the tail part

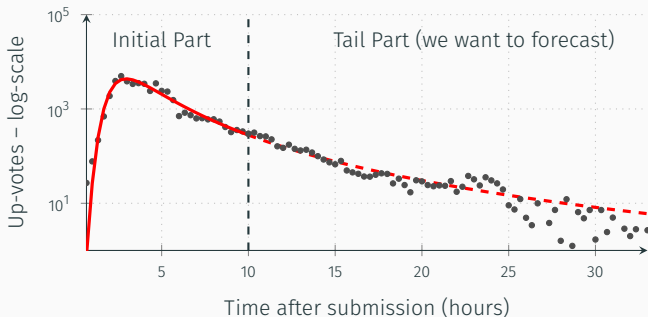


Forecasting

Problem: Given the initial part of a social voting time-series, predict the tail part

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• Training Data — VnC (Fit) - - - VnC (Forecast) • Tail Data



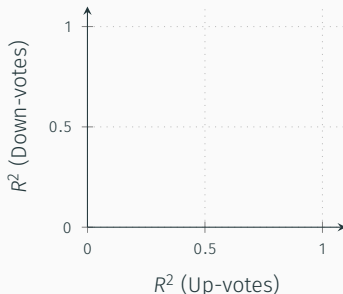
Outlier Detection

To detect outliers we use

VNC's R^2

- R^2 measures fit accuracy
- R^2 values closer to 1 indicate better fits

R^2 vs. R^2 plot:



Outlier Detection

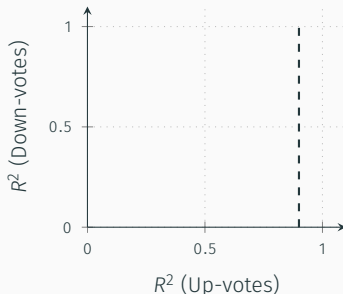
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R^2 vs. R^2 plot:

1. Compute R^2 for the up-vote time-series



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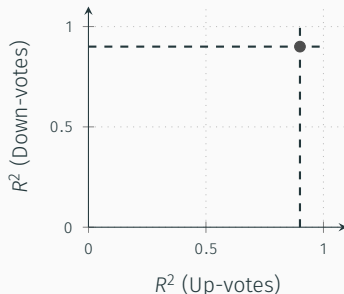
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R^2 vs. R^2 plot:

1. Compute R^2 for the up-vote time-series
2. Compute R^2 for the down-vote time-series



Outlier Detection

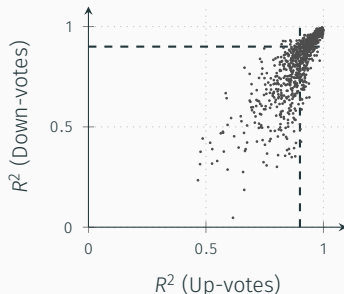
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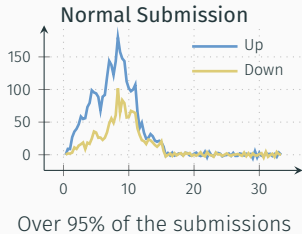
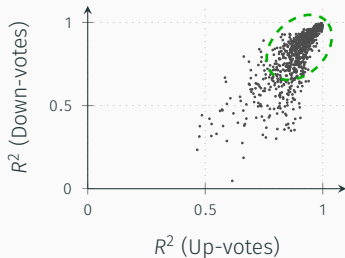
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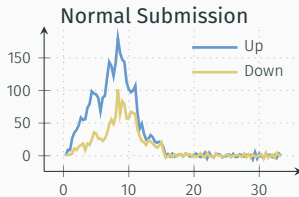
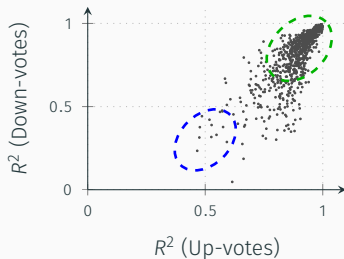
1. Compute R^2 for the up-vote time-series
2. Compute R^2 for the down-vote time-series
3. Repeat for all submissions



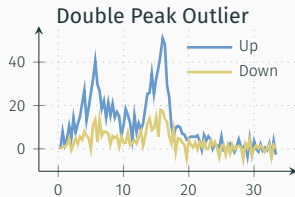
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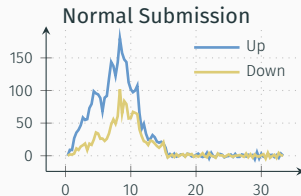
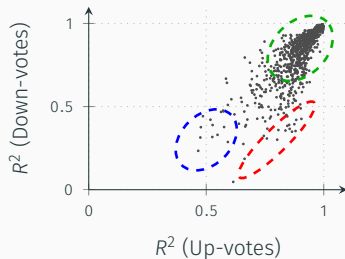


Over 95% of the submissions

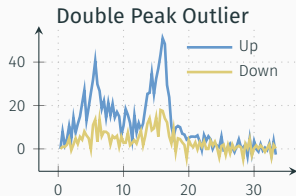


Late-night submissions: 1st peak at night, 2nd peak at morning

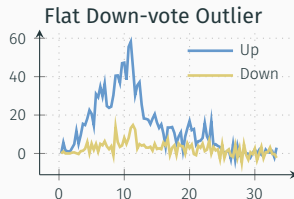
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Most are pictures of animals

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VNC has the following advantages:

- **Coevolution Modeling:** Describes up-vote, down-vote and comments time-series
- **Practicality:** Matches data from several social voting web sites
- **Usefulness:** Forecasting and outlier detection

Questions?

Vote-and-Comment: Modeling the Coevolution of User Interactions in Social Voting Web Sites

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Agma Juci Machado Traina

Christos Faloutsos

Dataset and Code: https://github.com/alceufc/vnc_model

Email: alceufc@icmc.usp.br

Funding:



Reaction Probability (Details)

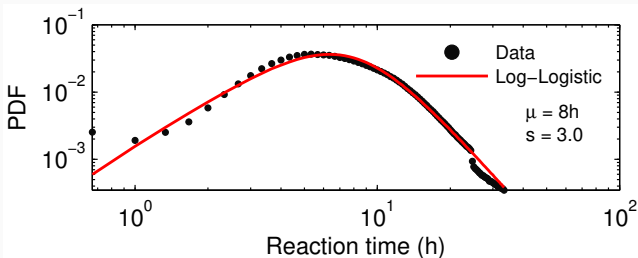
Definition (Reaction Time)

The reaction time corresponds to the time interval between the instant in which a submission is created and the instant in which an interaction (vote or comment) occurs.

Data: Reaction times of up-votes, down-votes and comments from the Reddit, Imgur and Digg datasets.

Log-Logistic PDF

$$f(x) = \frac{(s/\mu)(x/\mu)^{s-1}}{(1 + (x/\mu)^s)^2}$$



Parameter Estimation (Details)

To fit the up-vote time-series, VNC uses a set of 6 parameters denoted by $\theta = \{N, \beta_+, \xi_+, \mu, s, t_s\}$:

- N_+ : Population
- β_+ and ξ_+ : Cascading and independent coefficients
- μ and s : Log-logistic scale and shape parameters
- t_s : Share time

Given:

- A time-series $v_+(t)$ of real data
- The VNC estimated values $\hat{v}_+(t; \theta)$

We learn the parameters by minimizing the sum of squared errors between:

$$\min_{\theta} \sum_{t=1}^N [v_+(t) - \hat{v}_+(t; \theta)]^2$$

Delayed Up-voting

Some social voting Web sites allow users to create a submission at time $t = 1$ but only share it later at time $t = t_s$

VNC models this as follows:

- $P(t) = 0$ if $t \leq t_s$
- $P(t) = P_L(t) \cdot P_R(t - t_s)$ if $t > t_s$

Fit Accuracy (Details)

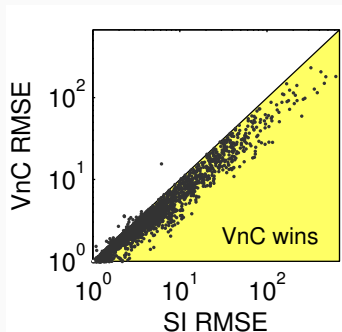
Root-Mean-Square Error

- Lower RMSE indicates a better fit
- Points below the diagonal: time-series that were best fit by VnC

Is VnC more accurate than:

- SI Model? **Yes**
- Bass Model?
- Phoenix-R?
- Spike-M?

VnC vs. SI Model



VnC is more accurate than SI model for 99% of the submissions

Fit Accuracy (Details)

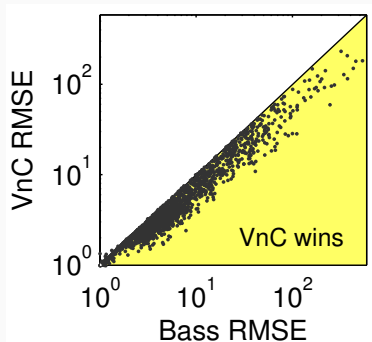
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of the submissions

Fit Accuracy (Details)

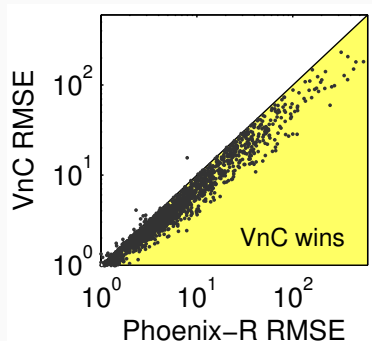
Root-Mean-Square Error

- Lower RMSE indicates a better fit
- Points below the diagonal: time-series that were best fit by VnC

Is VnC more accurate than:

- SI Model? **Yes**
- Bass Model? **Yes**
- Phoenix-R? **Yes**
- Spike-M?

VnC vs. Phoenix-R



VnC is more accurate than Phoenix-R for 96% of the submissions

Fit Accuracy (Details)

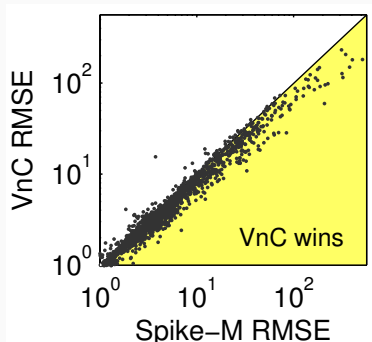
Root-Mean-Square Error

- Lower RMSE indicates a better fit
- Points below the diagonal: time-series that were best fit by VnC

Is VnC more accurate than:

- SI Model? **Yes**
- Bass Model? **Yes**
- Phoenix-R? **Yes**
- Spike-M? **Yes**

VnC vs. Spike-M



VnC is more accurate than Spike-M for 90% of the submissions