Predictability of User Behavior in Social Media:
Bottom-Up v. Top-Down Modeling

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in collaboration with
Bill Rand and Michelle Girvan

Predictability of User Behavior in Social Media

Social Media

Twitter, Facebook, Google+, Instagram, Path

Unprecedented access to

millions of people's behavior

at second-level resolution.

Predictability of User Behavior in Social Media

Individual as a Computational Unit

Treat individuals as information processing units.

Not a new idea:

Claude Shannon (1948)

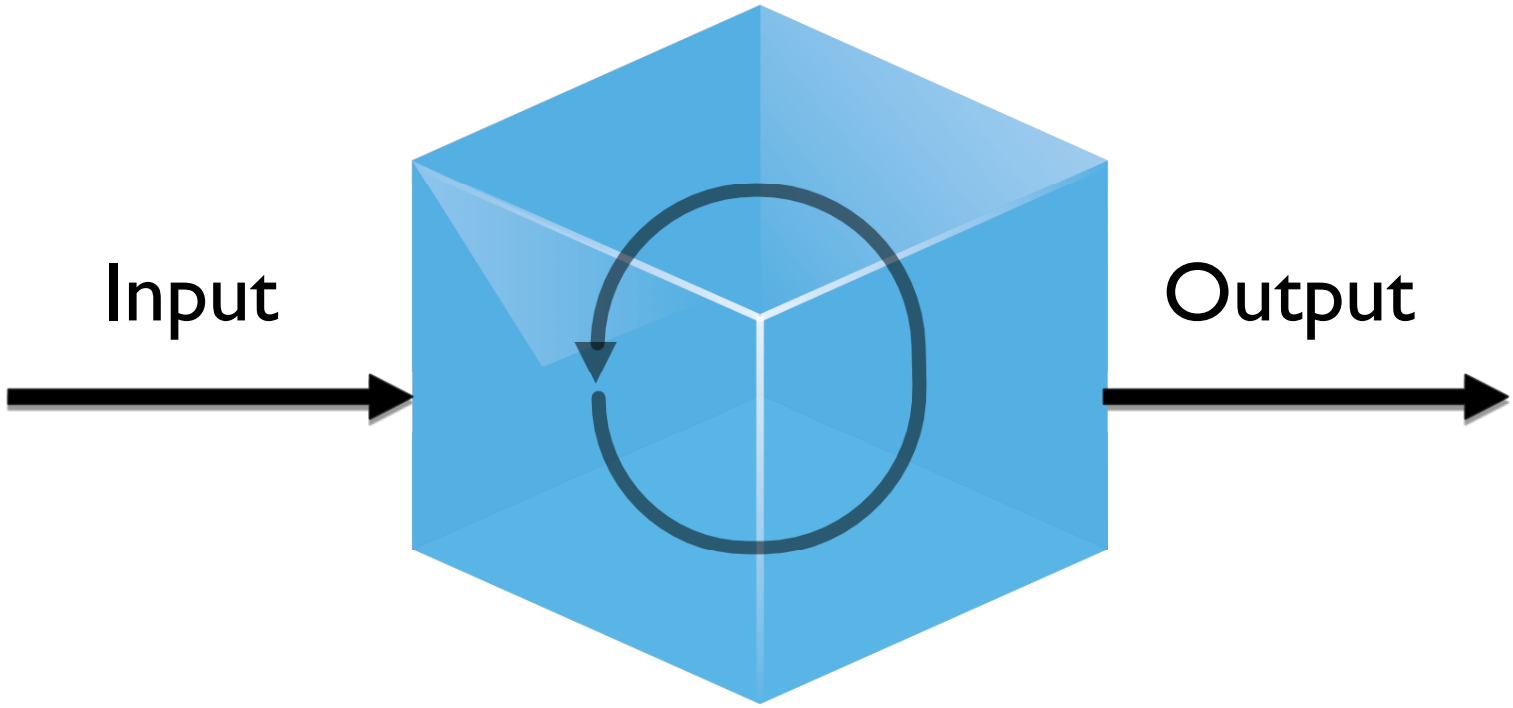
Information Theory and Channels

Simon DeDeo (2012)

Markov Models of Wikipedia Activity

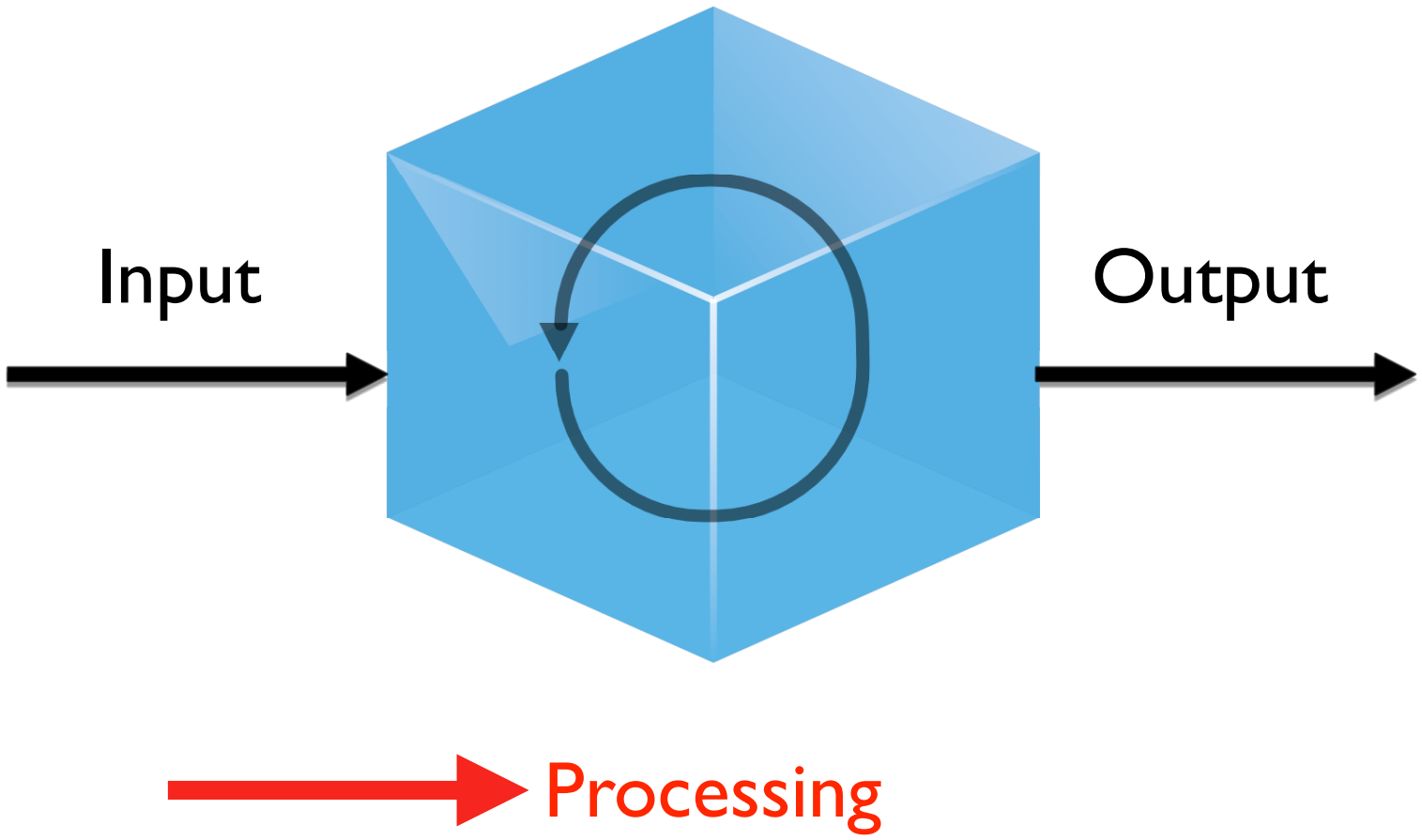
Predictability of User Behavior in Social Media

Individual as a Computational Unit



Predictability of User Behavior in Social Media

Individual as a Computational Unit



The Setup

Predictability of User Behavior in Social Media

The Setup

Timestamp	Tweet Text
2013-08-22 12:54:06	Is Your Gmail Social? How to Use
2013-08-22 13:11:22	Facebook's Embedded Posts Now
2013-08-22 13:14:06	The Credible Hulk http://t.co/q1
2013-08-22 13:29:02	25 Things You Didn't Know About
2013-08-22 13:32:59	Twitter Users: Revoke and Reestab
2013-08-22 13:48:46	10 Brilliant Facebook Marketing Tac
2013-08-22 14:17:11	Google Now Adds Cards for NCA
2013-08-22 15:18:03	What is the NSA Really Up To? [C
2013-08-22 15:39:04	6 Things Every Good Business Blog

User: DanielZeevi

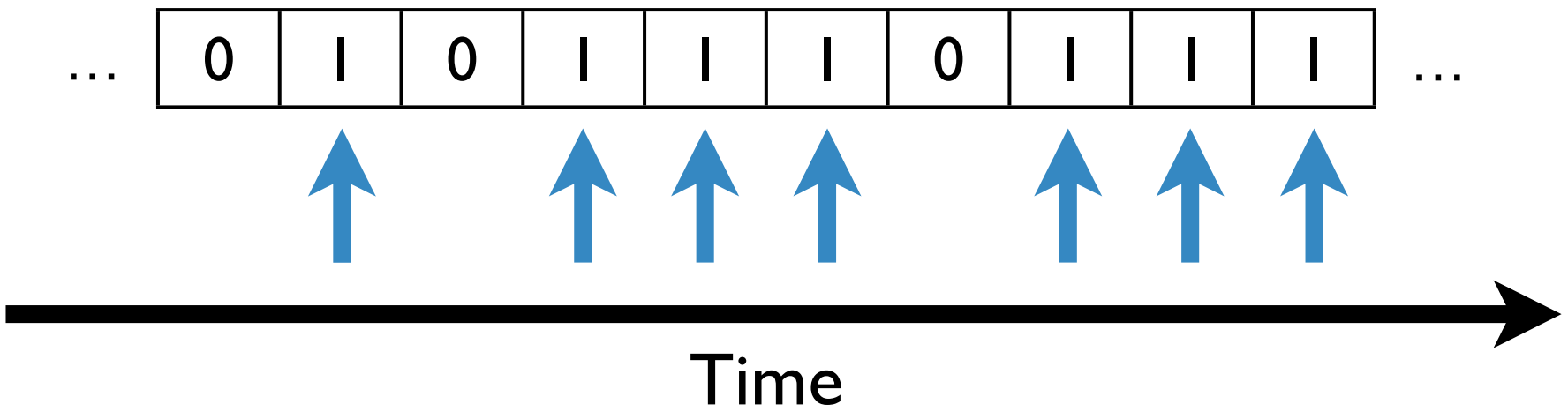
Predictability of User Behavior in Social Media

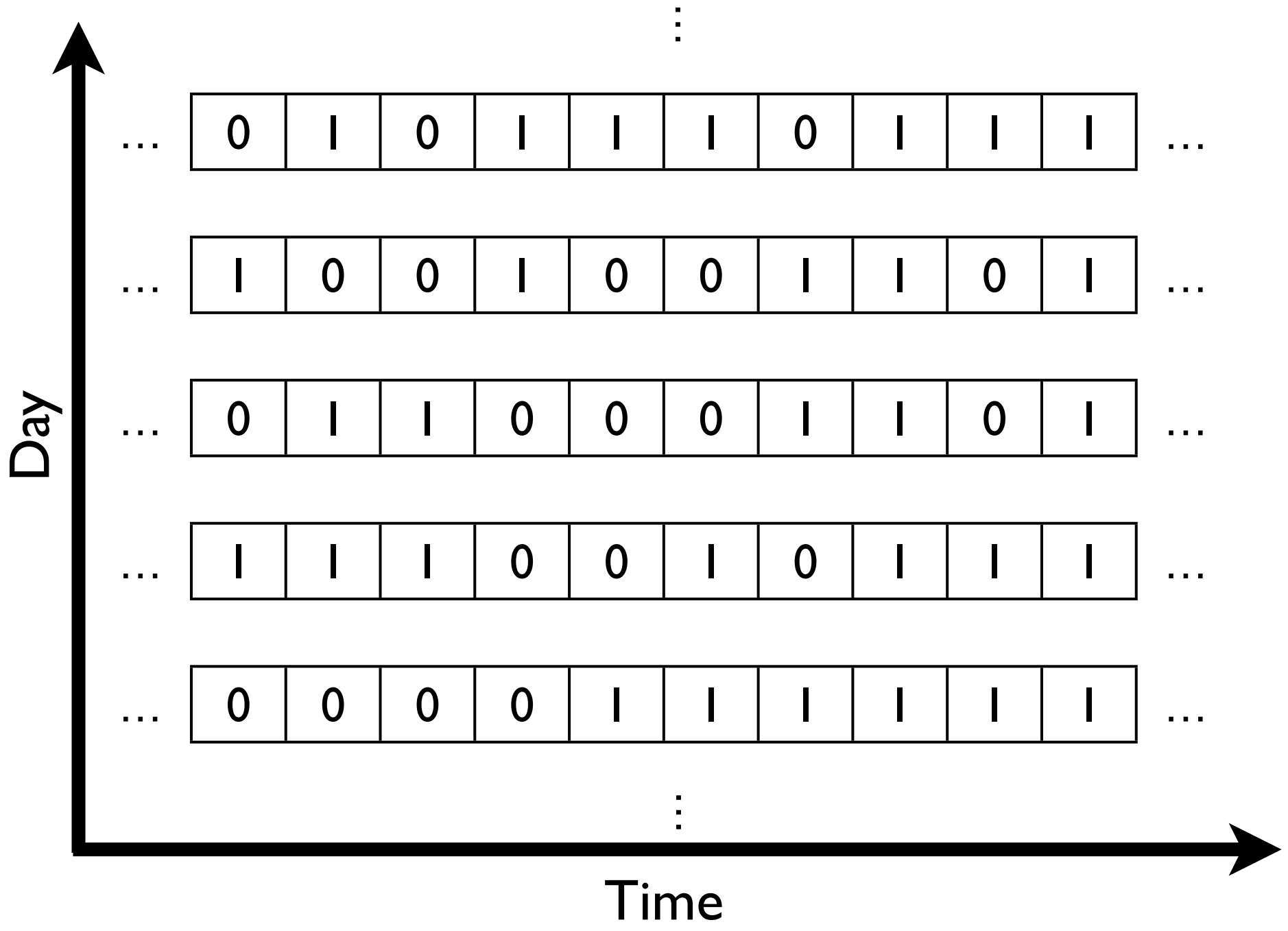
The Setup

Bin (in time) Twitter data, giving a discrete time series for each user *v* at time *t*:

$X(v,t) = 0$ — user *v* doesn't tweet

$X(v,t) = 1$ — user *v* tweets




Day
Time
... 0 1 0 1 1 1 0 1 1 1 ...
... 1 0 0 1 0 0 1 1 0 1 ...
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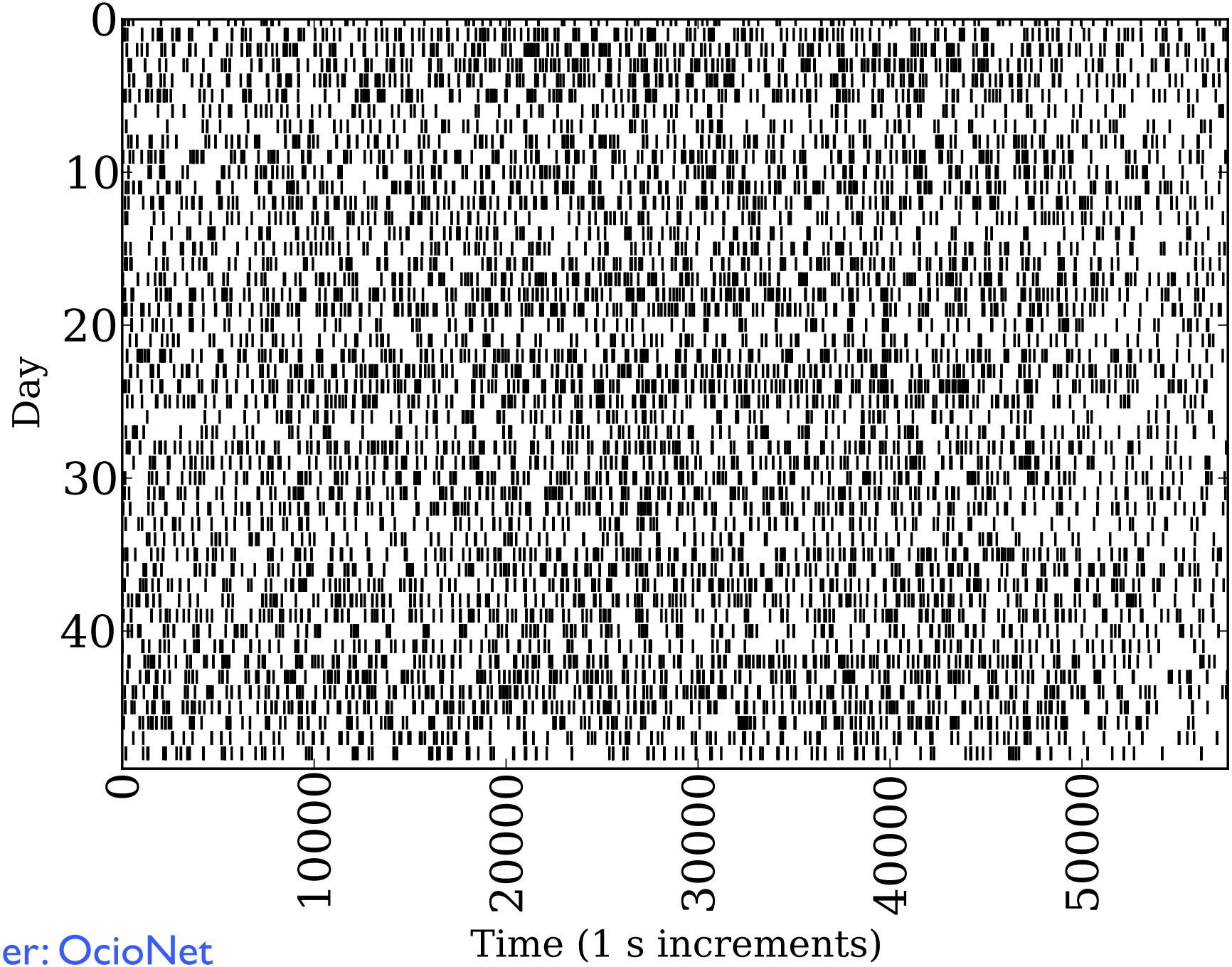
0
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Day
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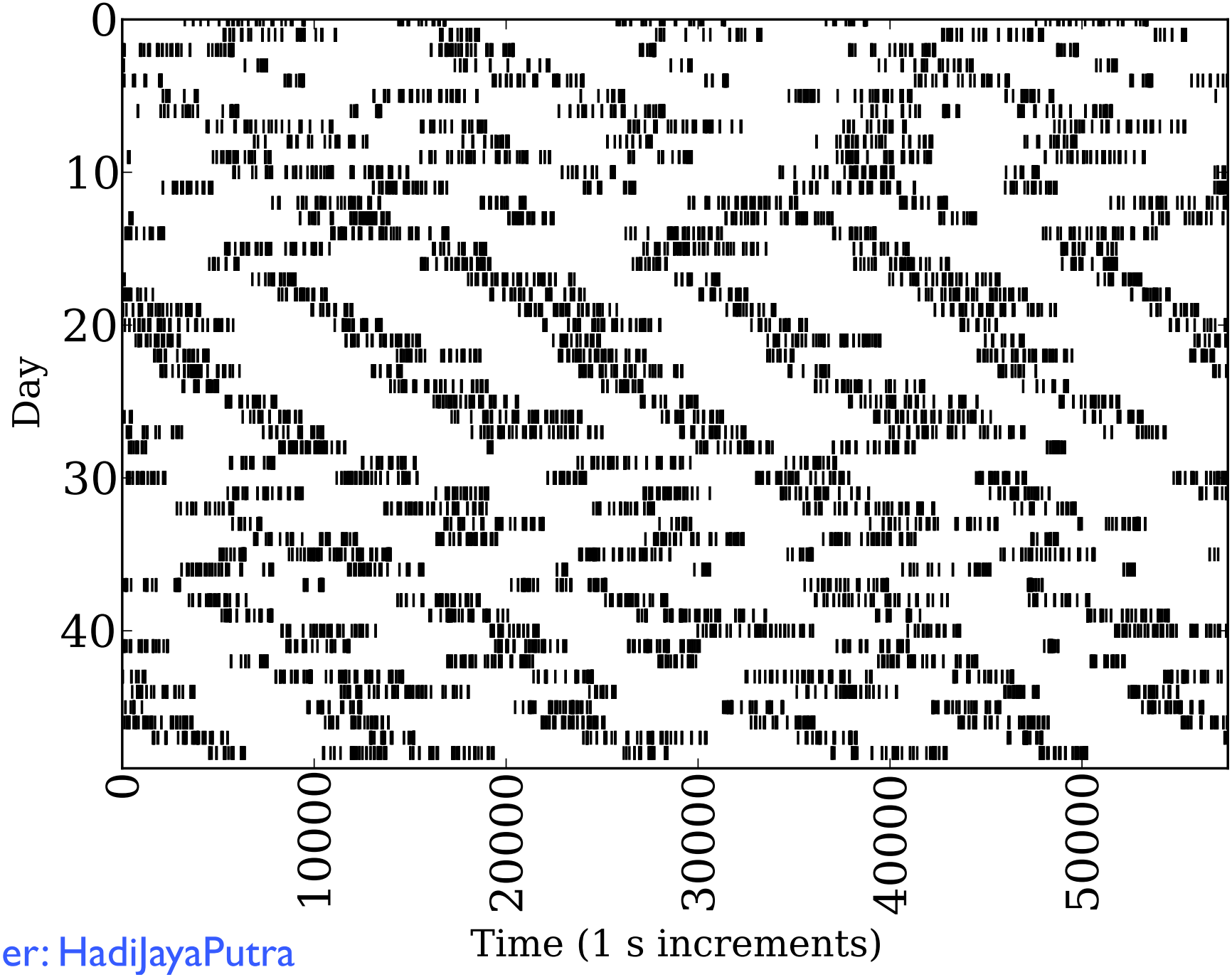
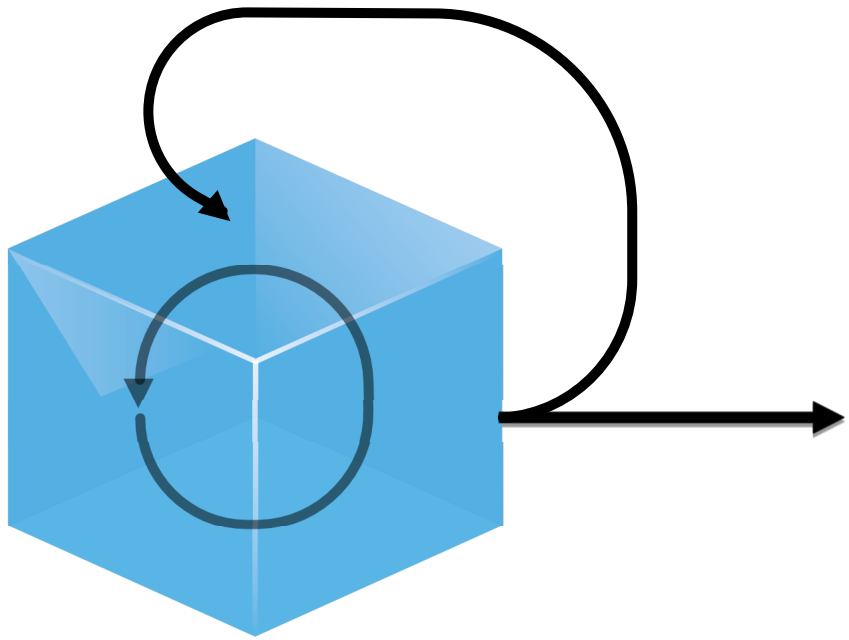
10000
20000
30000
40000
50000
Time (1 s increments)
User: OcioNet



User: HadiJayaPutra

Models



Predictability of User Behavior in Social Media

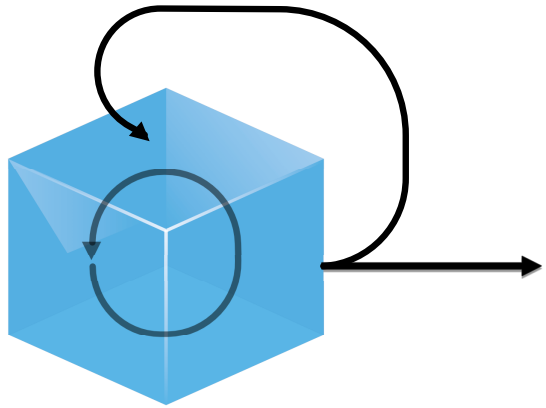
Modeling Framework — A Predictive View

A model that predicts well captures something about the computational capabilities of a user.

Necessary but not sufficient.

Predictability of User Behavior in Social Media

Modeling Framework — A Predictive View



Simplifying assumption: a process with self-feedback.

Observe: $X_{i-L}^{i-1} = (X_{i-L}, \ldots, X_{i-2}, X_{i-1})$.

Predict: $\hat{X}_i = \underset{x \in \{0,1\}}{\arg\max}\ r(x; X_{i-L}^{i-1})$.

Predictability of User Behavior in Social Media

Modeling Framework — A Predictive View

Our goal: Learn r.

Learn the function mapping us from the **past** to the **future**.

In essence, a problem in autoregression.

Observe: $X_{i-L}^{i-1} = (X_{i-L}, \ldots, X_{i-2}, X_{i-1})$.

Predict: $\hat{X}_i = \underset{x \in \{0,1\}}{\arg\max}\ r(x; X_{i-L}^{i-1})$.

Predictability of User Behavior in Social Media

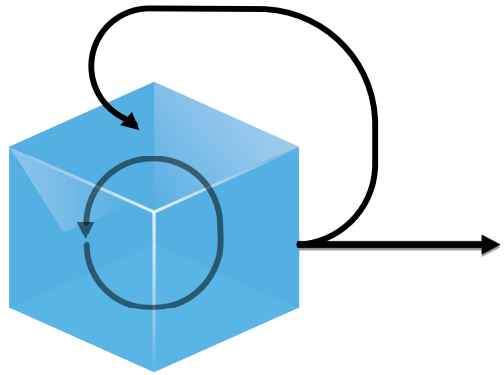
Modeling Framework — A Predictive View

Two approaches to learning r :

Computational Mechanics
"Bottom Up"

Reservoir Computing
"Top Down"

Models



Computational Mechanics

Predictability of User Behavior in Social Media

Computational Mechanics

Assume $\{X_i\}_{i=1}^{N}$ was generated by a *conditionally stationary* stochastic process.

Explicitly learn the predictive distribution

$$P(X_i | X_{i-L}^{i-1} = x)$$

by grouping together pasts x that give equivalent predictions.

Predictability of User Behavior in Social Media

Computational Mechanics

The sets of equivalent pasts induce an auxiliary (hidden) process $\{S_i\}_{i=1}^{N}$ that is:

Markov

Prescient for prediction

We only need to know that hidden state to perform prediction.

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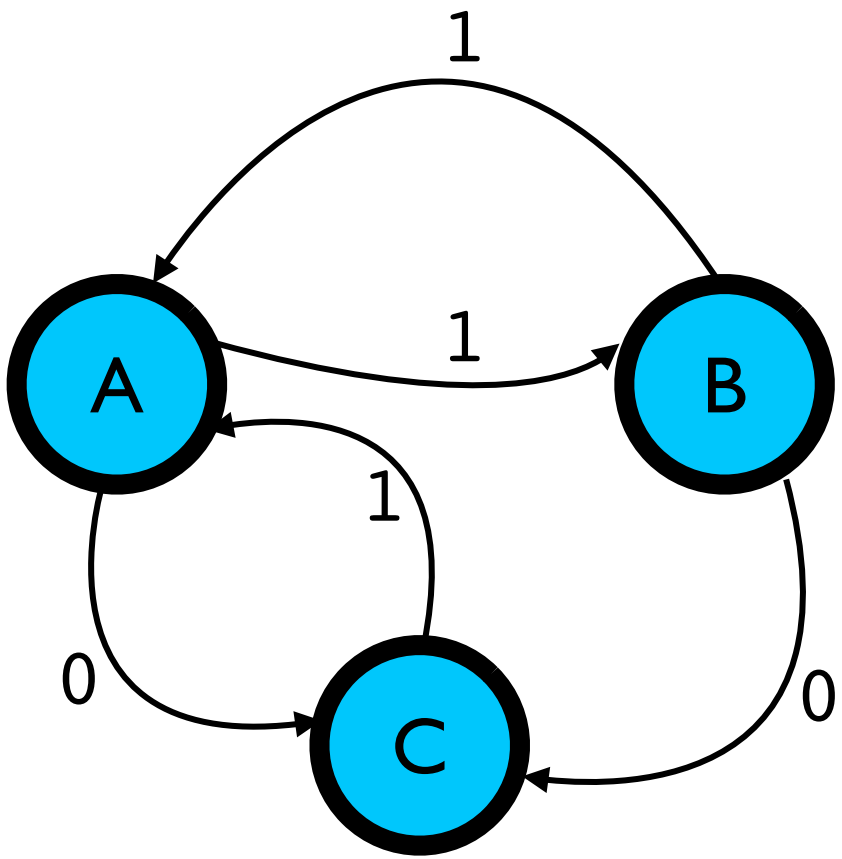
Computational Mechanics



— state

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Computational Mechanics

Call the model learned the

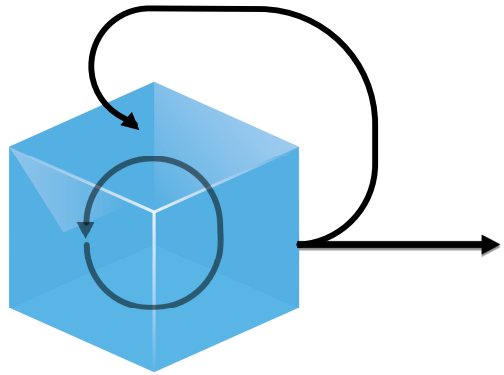
causal state model (CSM)

for each user.

Learn this state-space representation of the process using

Causal State Splitting Reconstruction (CSSR).

Models

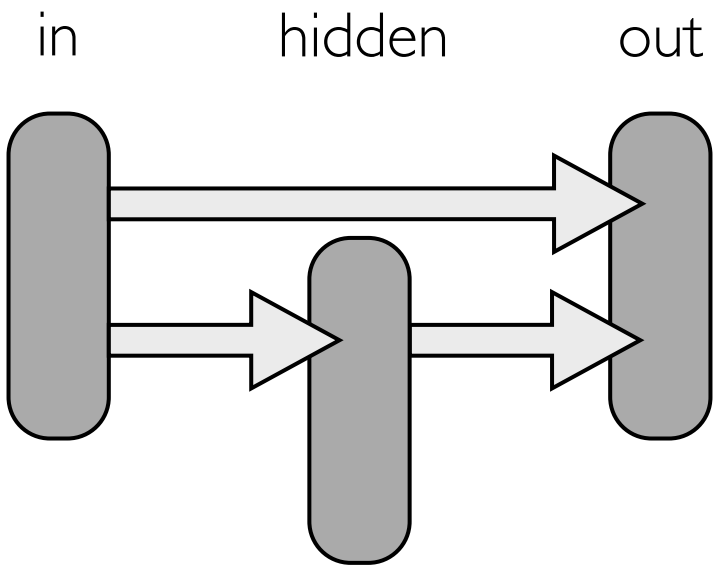


Echo State Networks

Predictability of User Behavior in Social Media

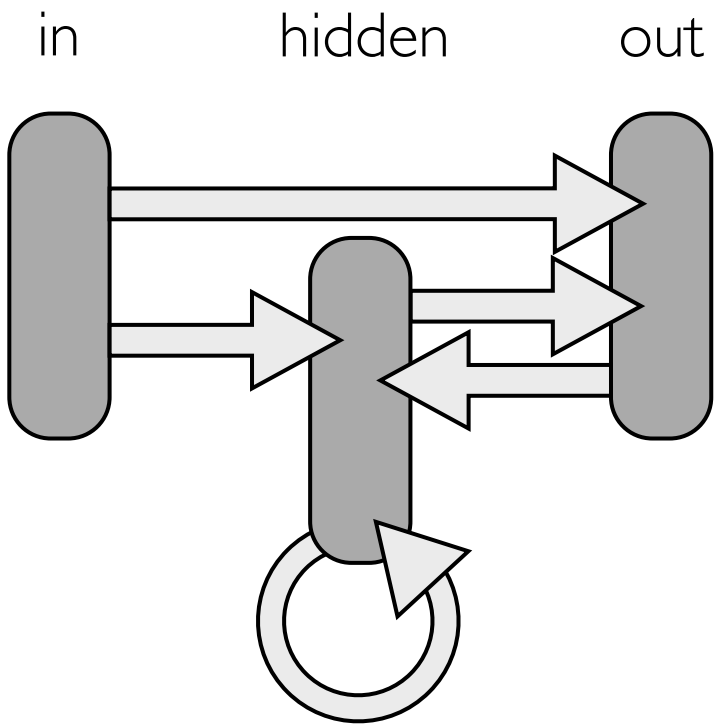
Feedforward Nets

Easy learning rules



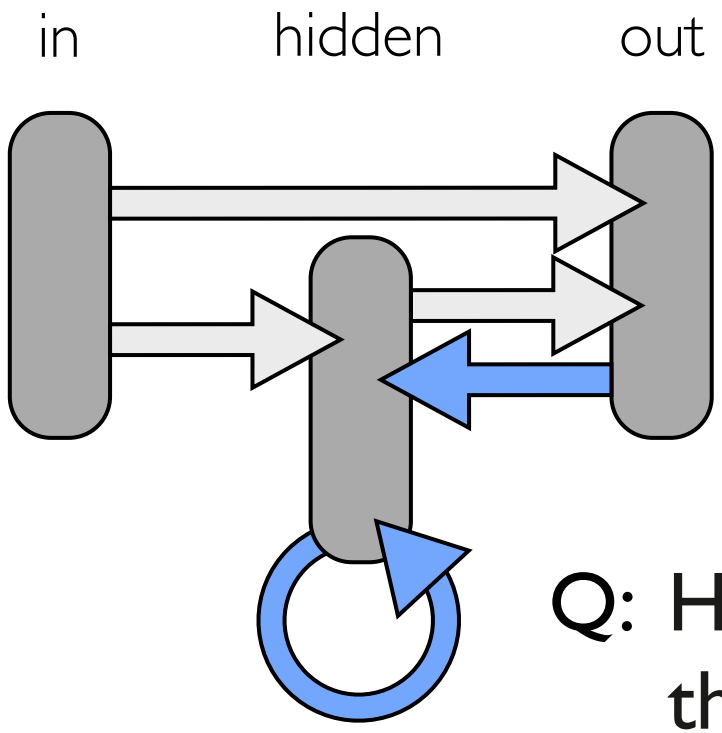
Recurrent Nets

Good with sequences



Predictability of User Behavior in Social Media

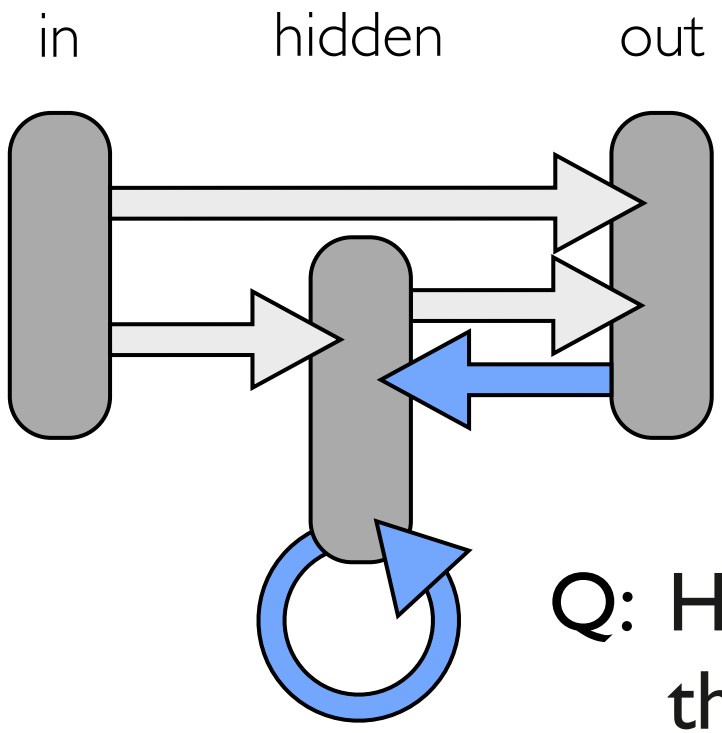
Echo State Networks



Q: How do we learn these weights?

Predictability of User Behavior in Social Media

Echo State Networks

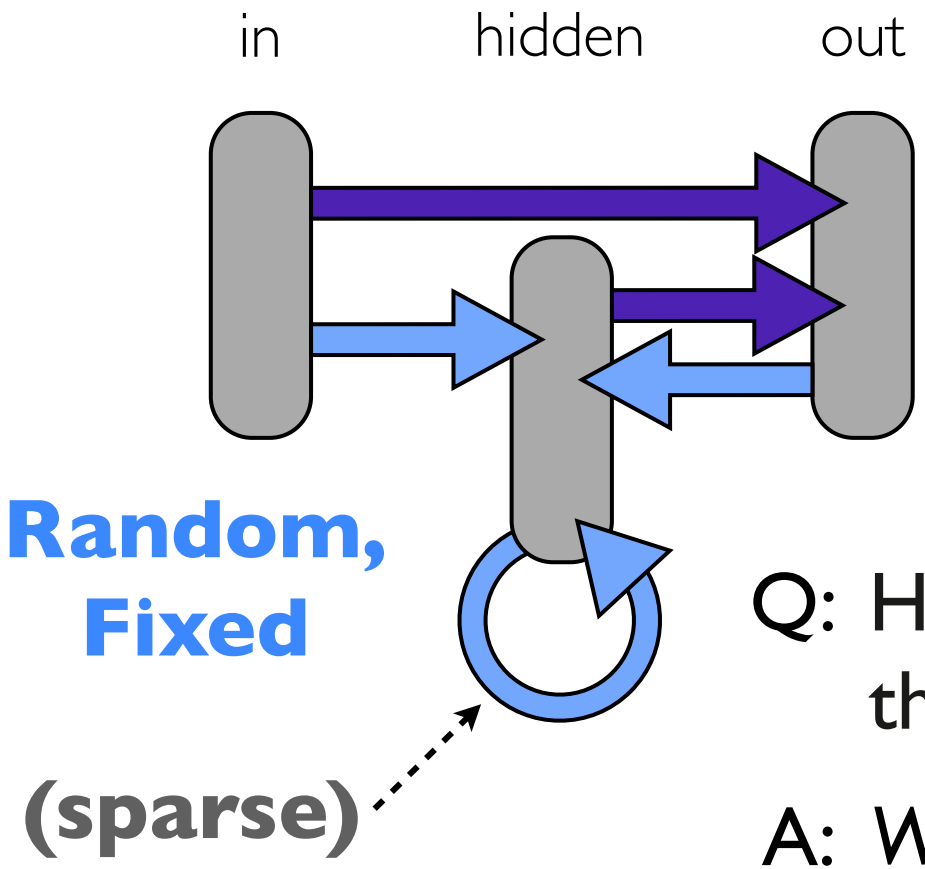


Q: How do we learn these weights?

A: *We don't.*

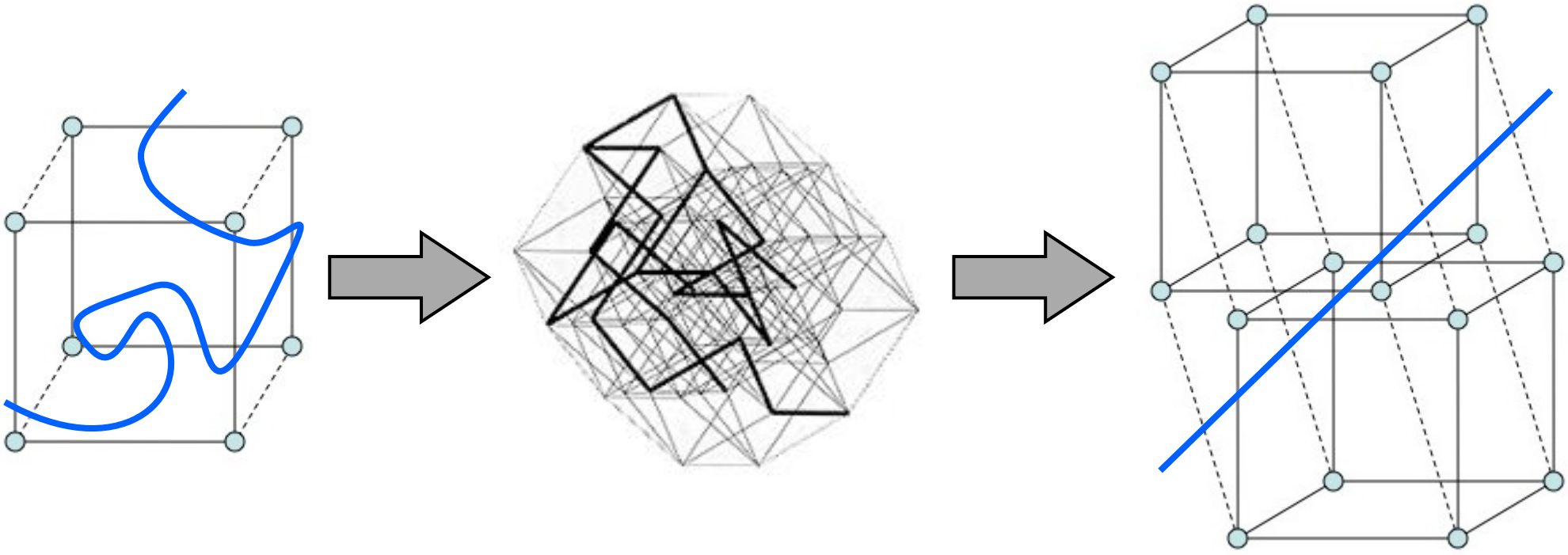
Predictability of User Behavior in Social Media

Echo State Networks



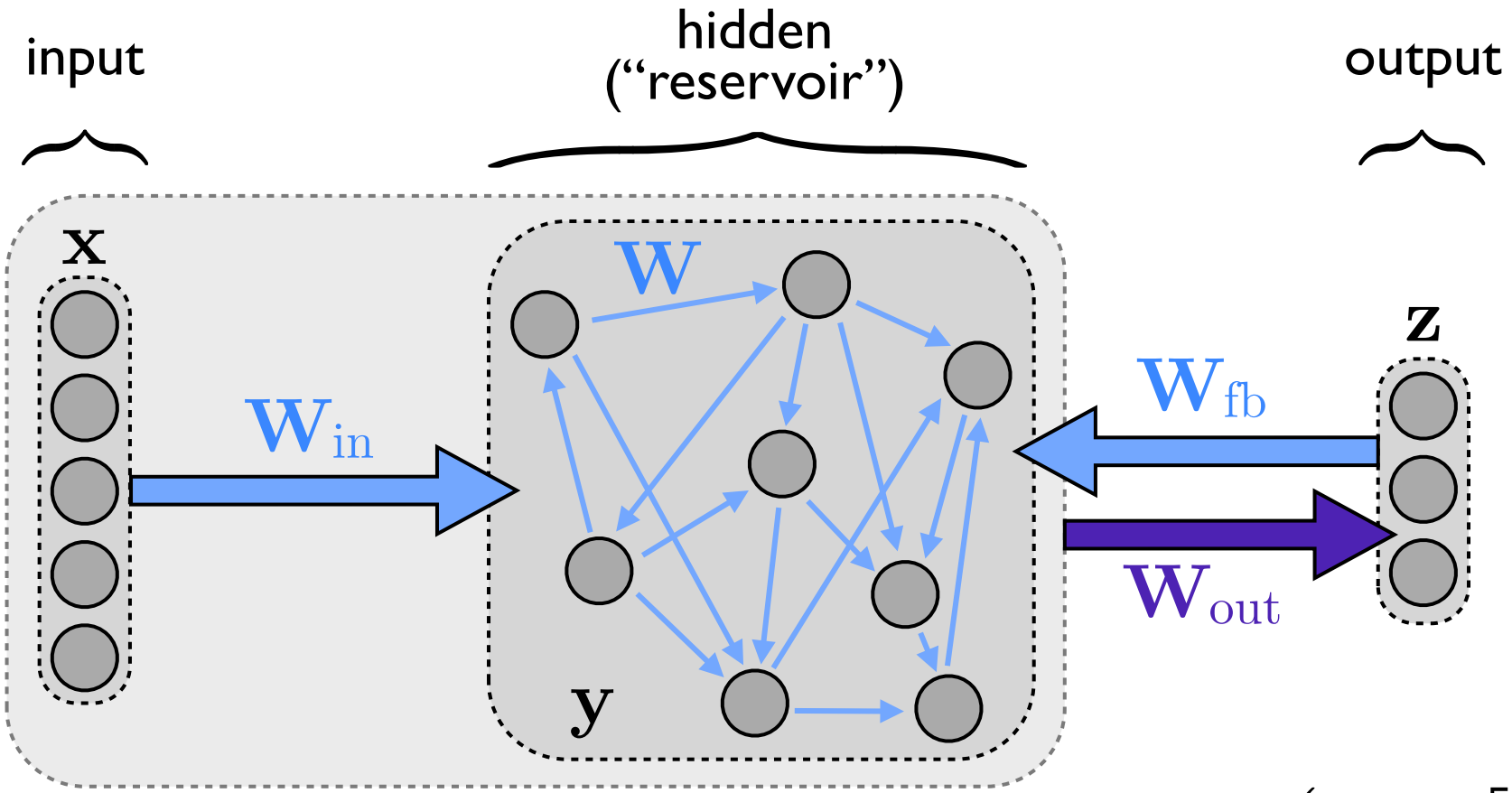
Q: How do we learn these weights?

A: *We don't.*



Predictability of User Behavior in Social Media

Echo State Networks



$$\mathbf{y}_t = \sigma(\mathbf{W}_{\text{in}}\mathbf{x}_t + \mathbf{W}\mathbf{y}_{t-1} + \mathbf{W}_{\text{fb}}\mathbf{z}_{t-1})$$

$$\mathbf{z}_t = \sigma\left(\mathbf{W}_{\text{out}}\begin{bmatrix}\mathbf{x}_t \\ \mathbf{y}_t\end{bmatrix}\right)$$

Data Collection and Processing

Predictability of User Behavior in Social Media

The Dataset

Twitter users embedded in a 15k user follower network.

Statuses of all users collected over 7 weeks.

Select 3k subset of most frequently tweeting users.

Predictability of User Behavior in Social Media

The Dataset — Coarsening

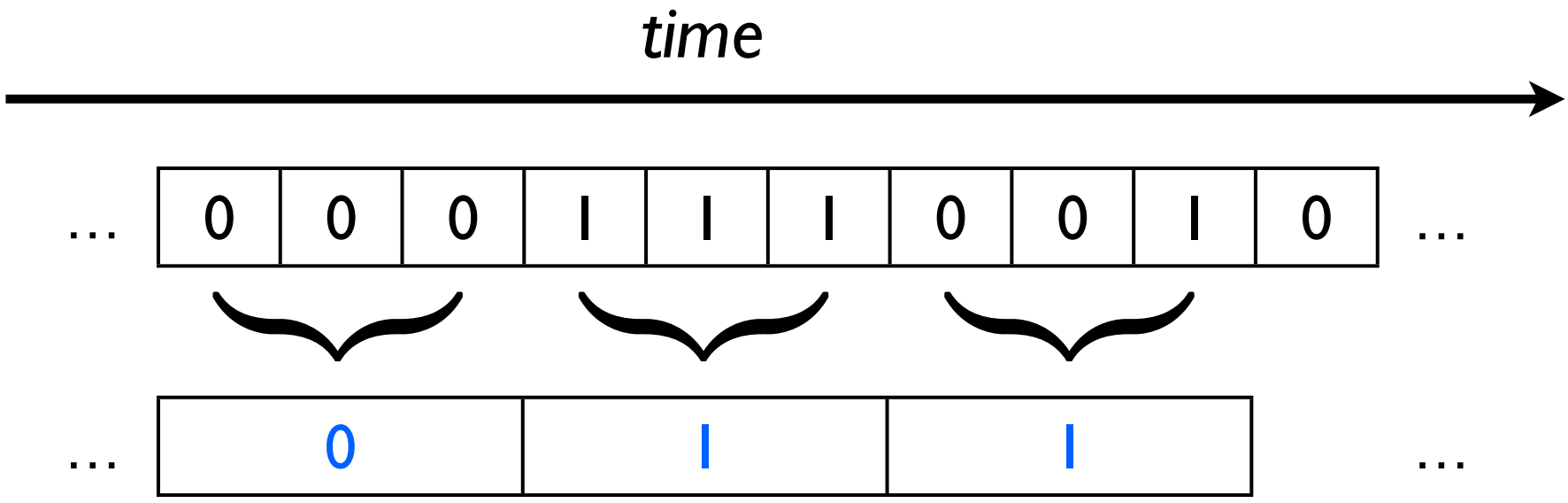
Need to looking L steps back in time.

Dimensionality of predictive space grows like 2^L.

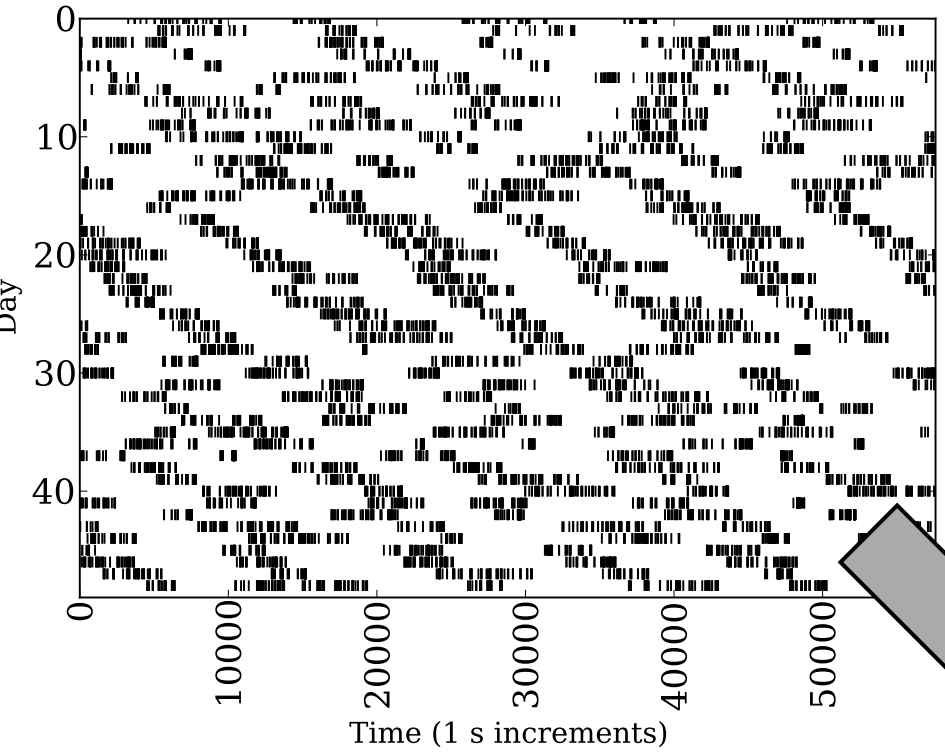
To deal with this limitation:
coarsen users' time series.

Predictability of User Behavior in Social Media

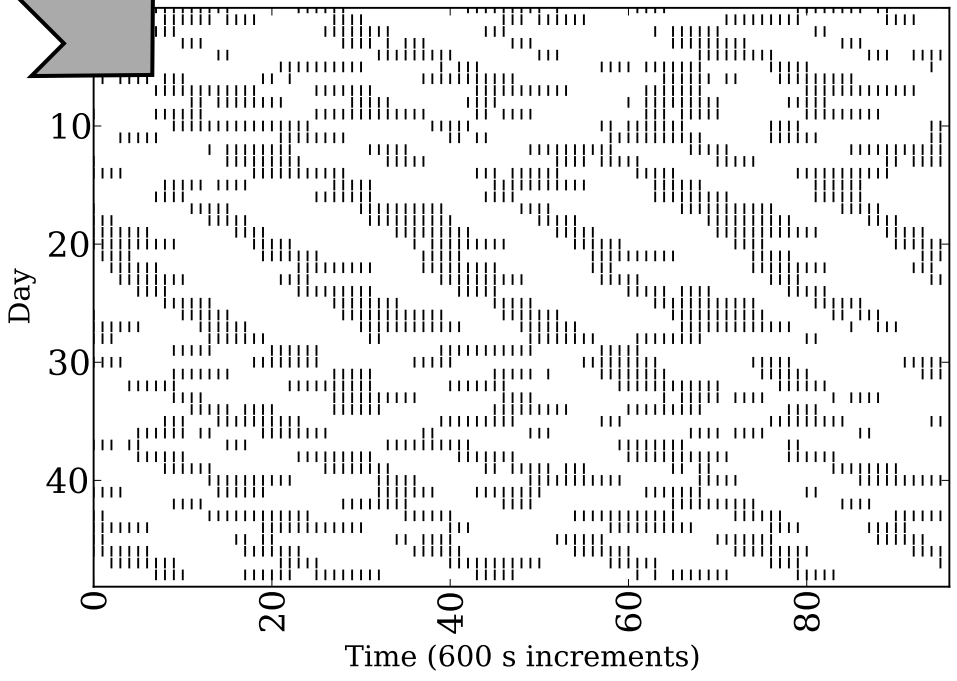
Example



"Does the user tweet during each binning?"



bin size = 600 s = 10 min

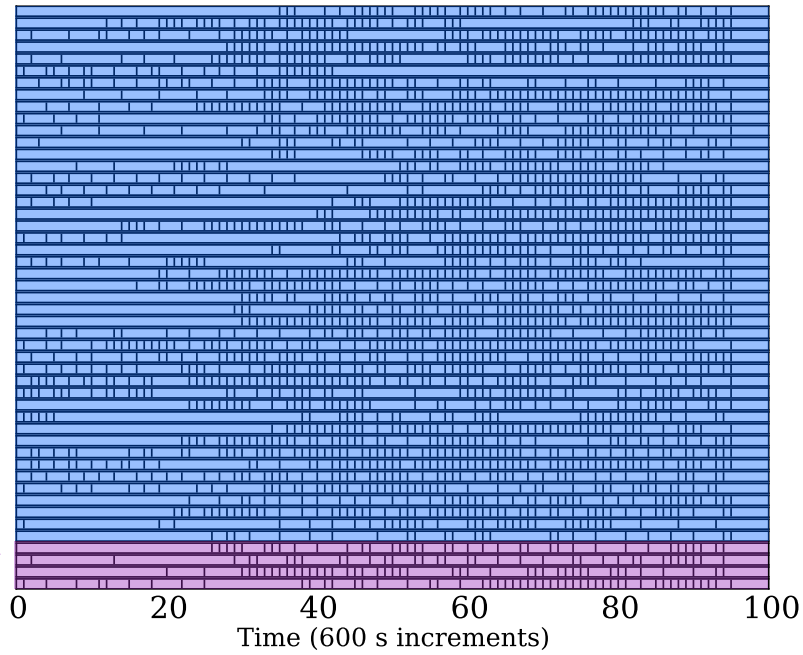


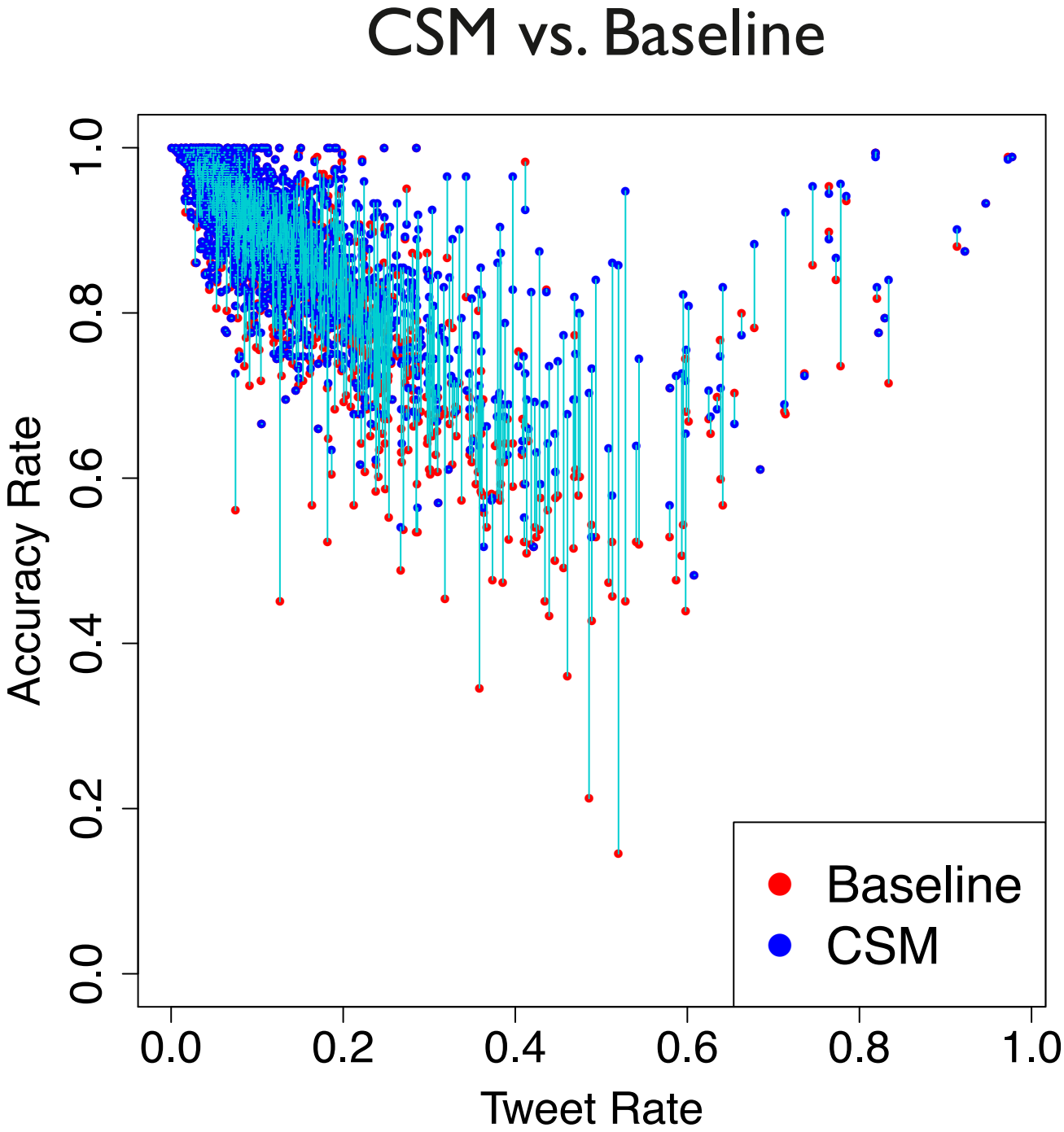
Results

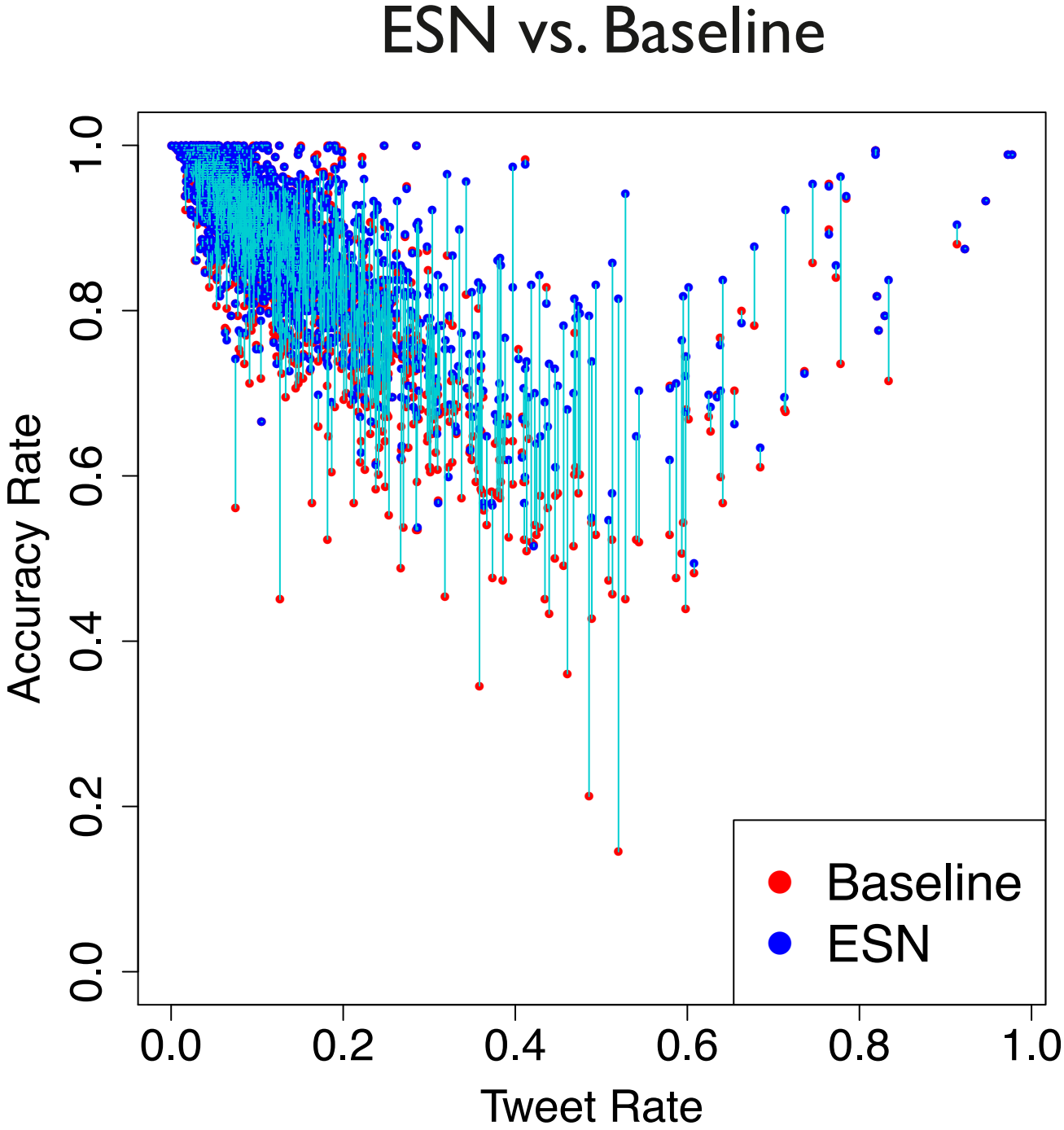
Predictability of User Behavior in Social Media

Testing Procedure

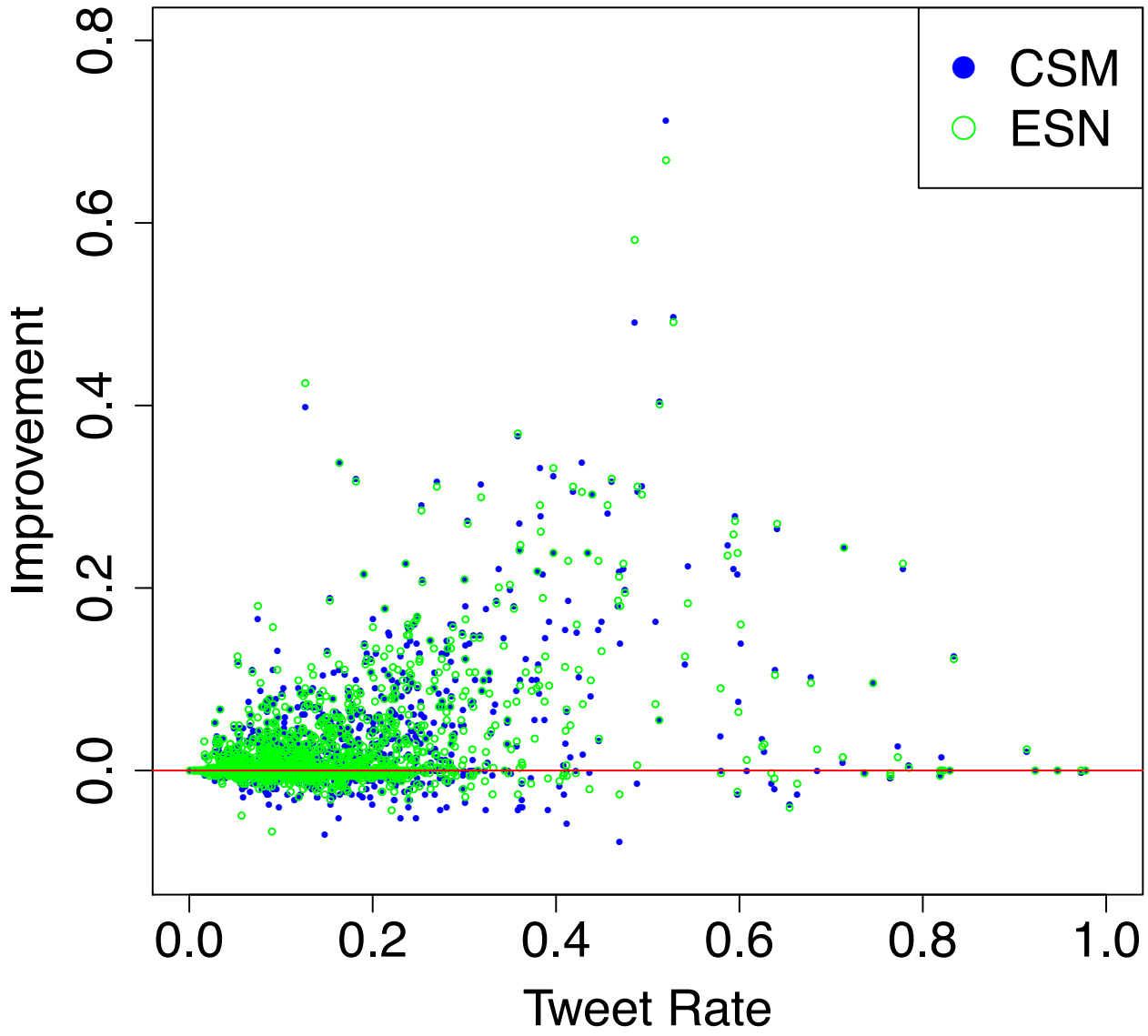
- Build model for each user separately
- Training: 45 days
- Testing: 4 days
- Look back 10 steps
- Predict ahead 1 step
- 0-1 Loss
- Compare to “majority vote” baseline



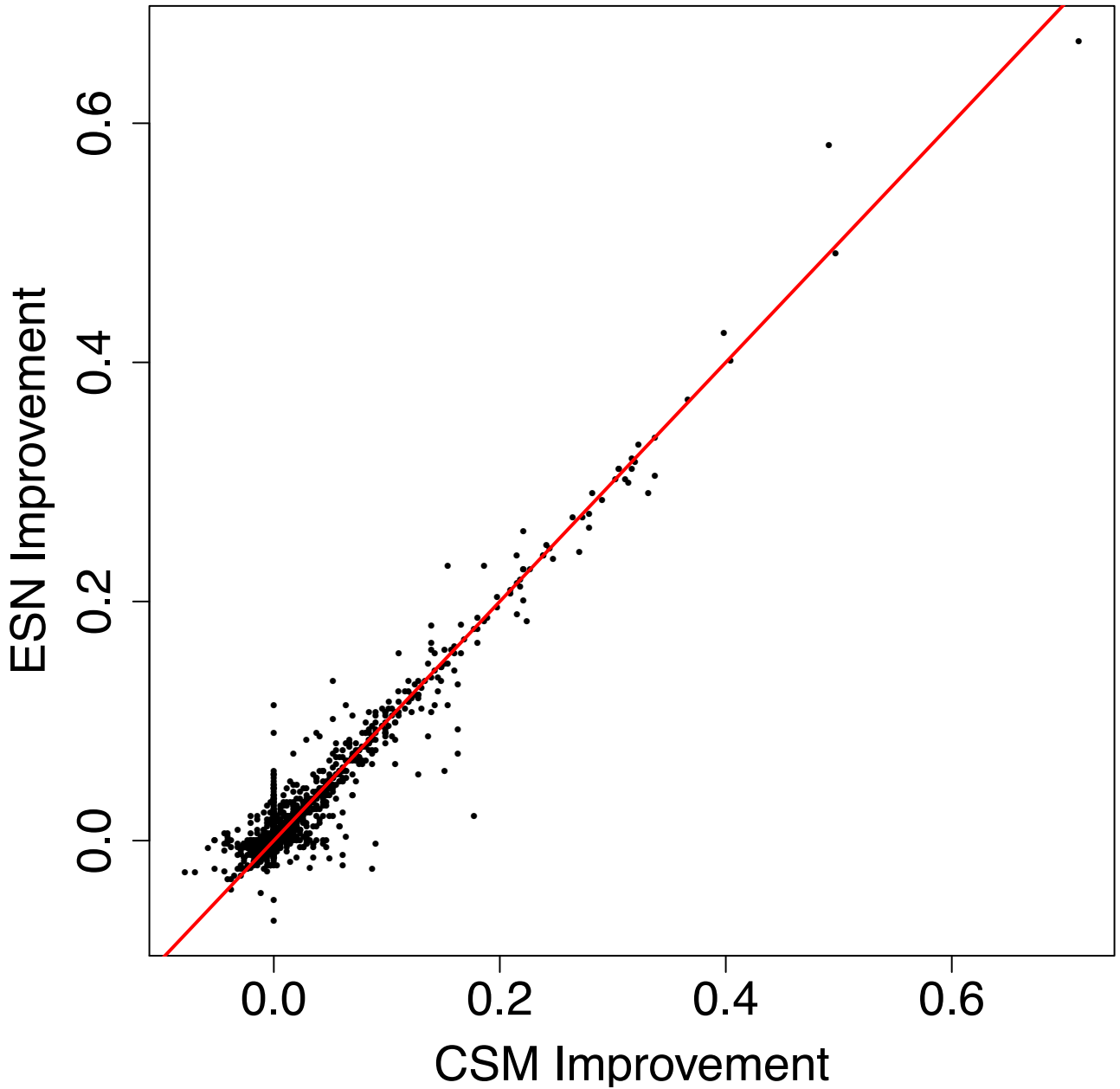

CSM vs. Baseline
Accuracy Rate
0.0
0.2
0.4
0.6
0.8
1.0
Tweet Rate
0.0
0.2
0.4
0.6
0.8
1.0
Baseline
CSM


ESN vs. Baseline
Accuracy Rate
0.0
0.2
0.4
0.6
0.8
1.0
Tweet Rate
0.0
0.2
0.4
0.6
0.8
1.0
Baseline
ESN

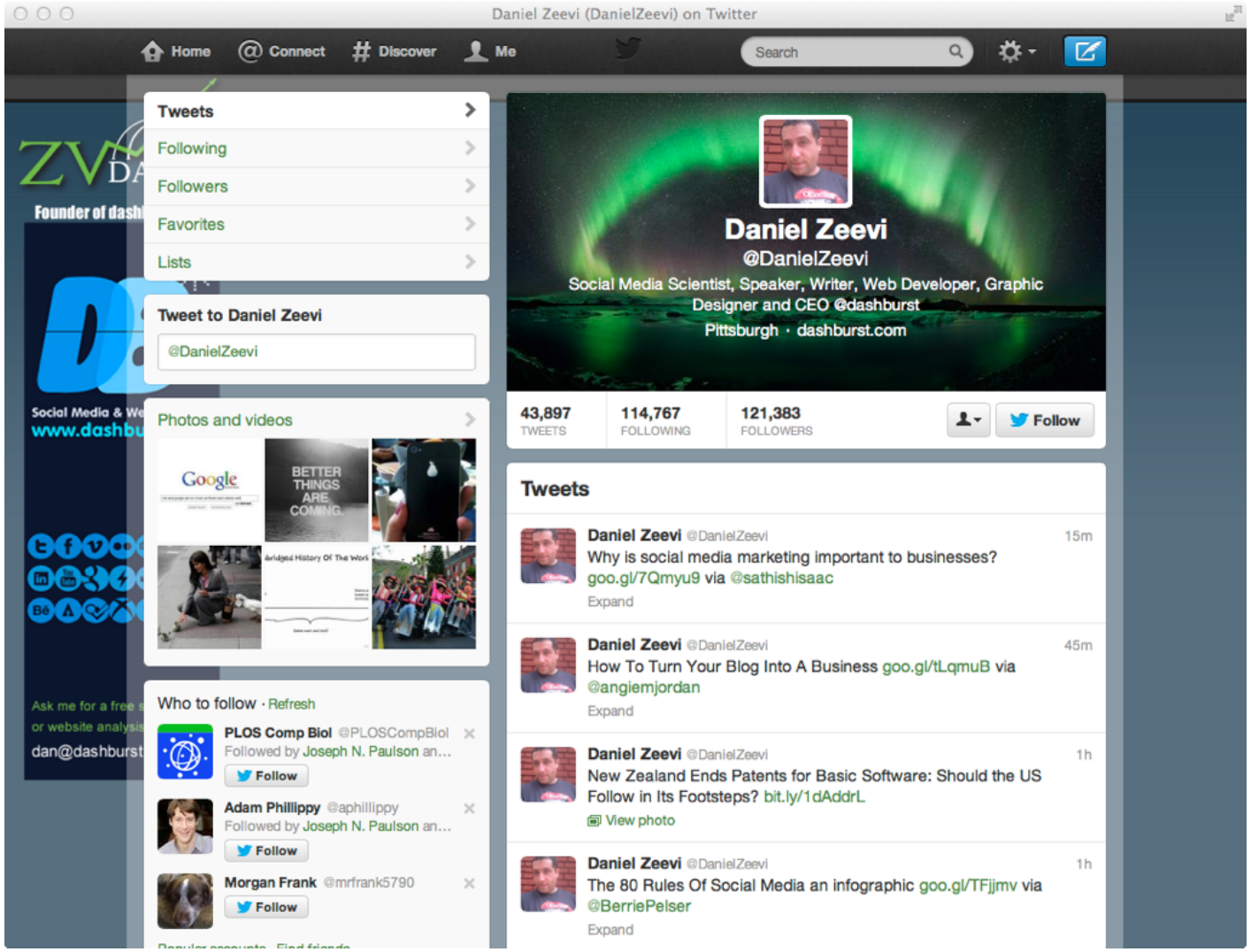
CSM vs. ESN



CSM vs. ESN

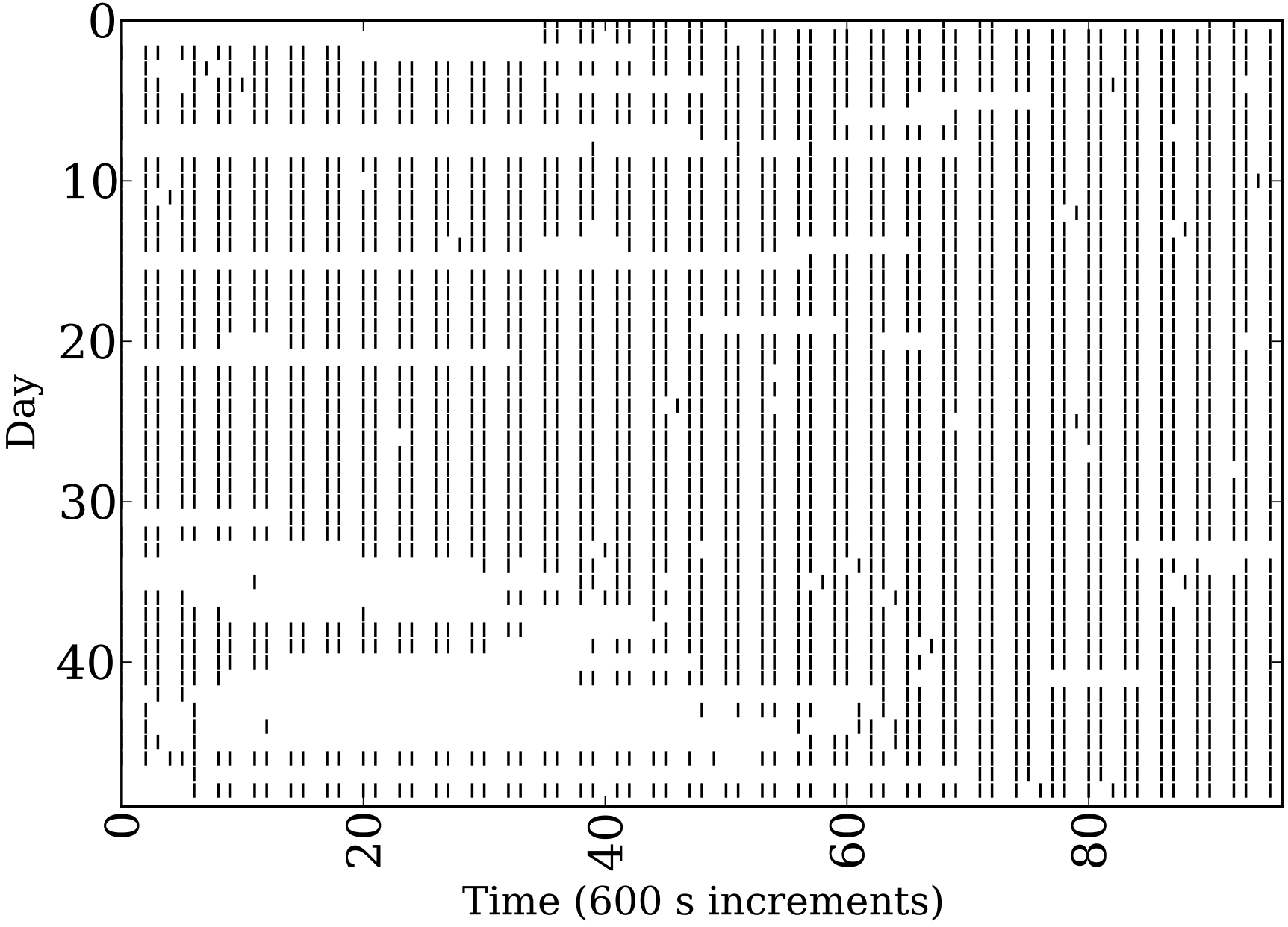


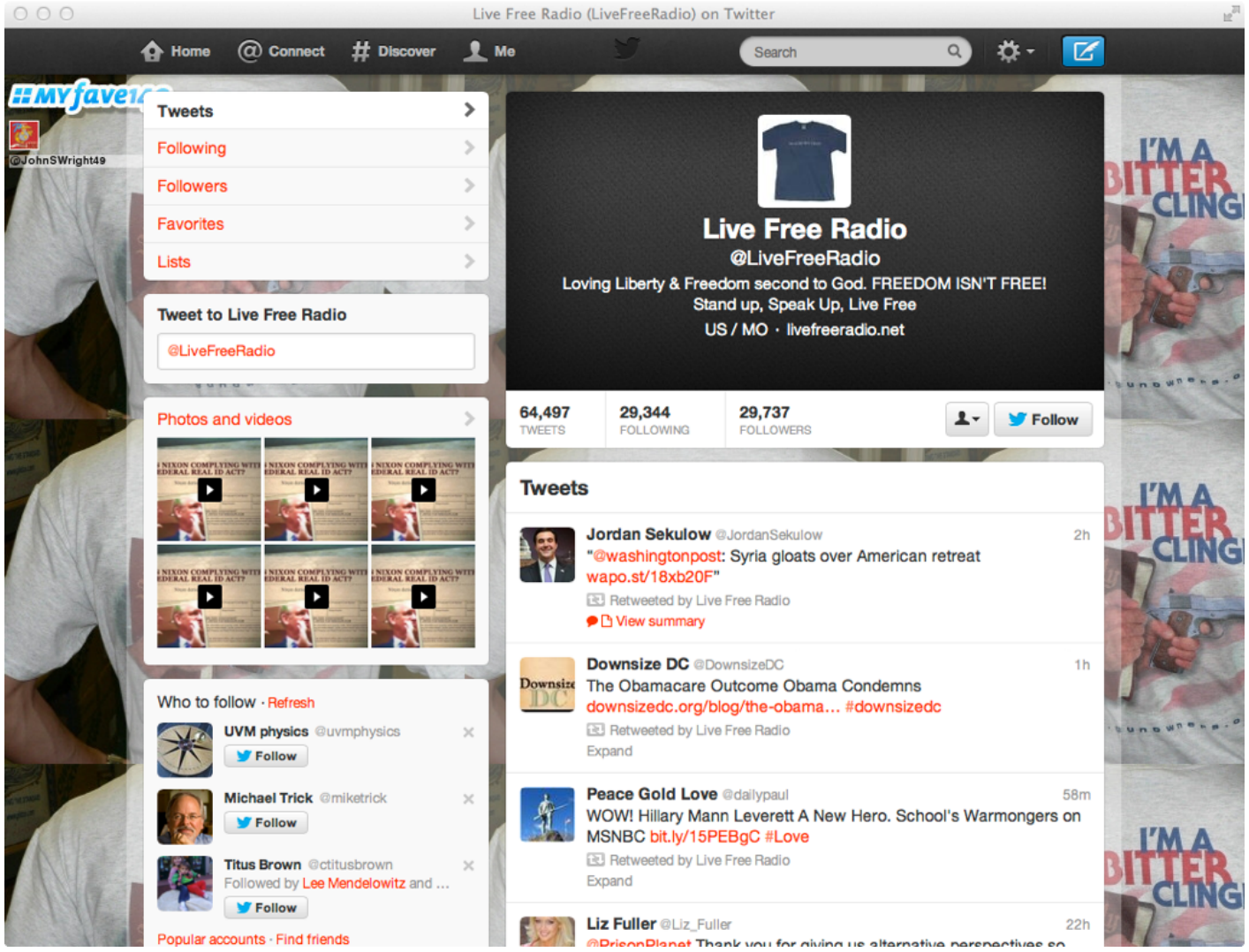
Case Studies



Base Rate:	0.4506
CSM Rate:	0.9477
ESN Rate:	0.9419

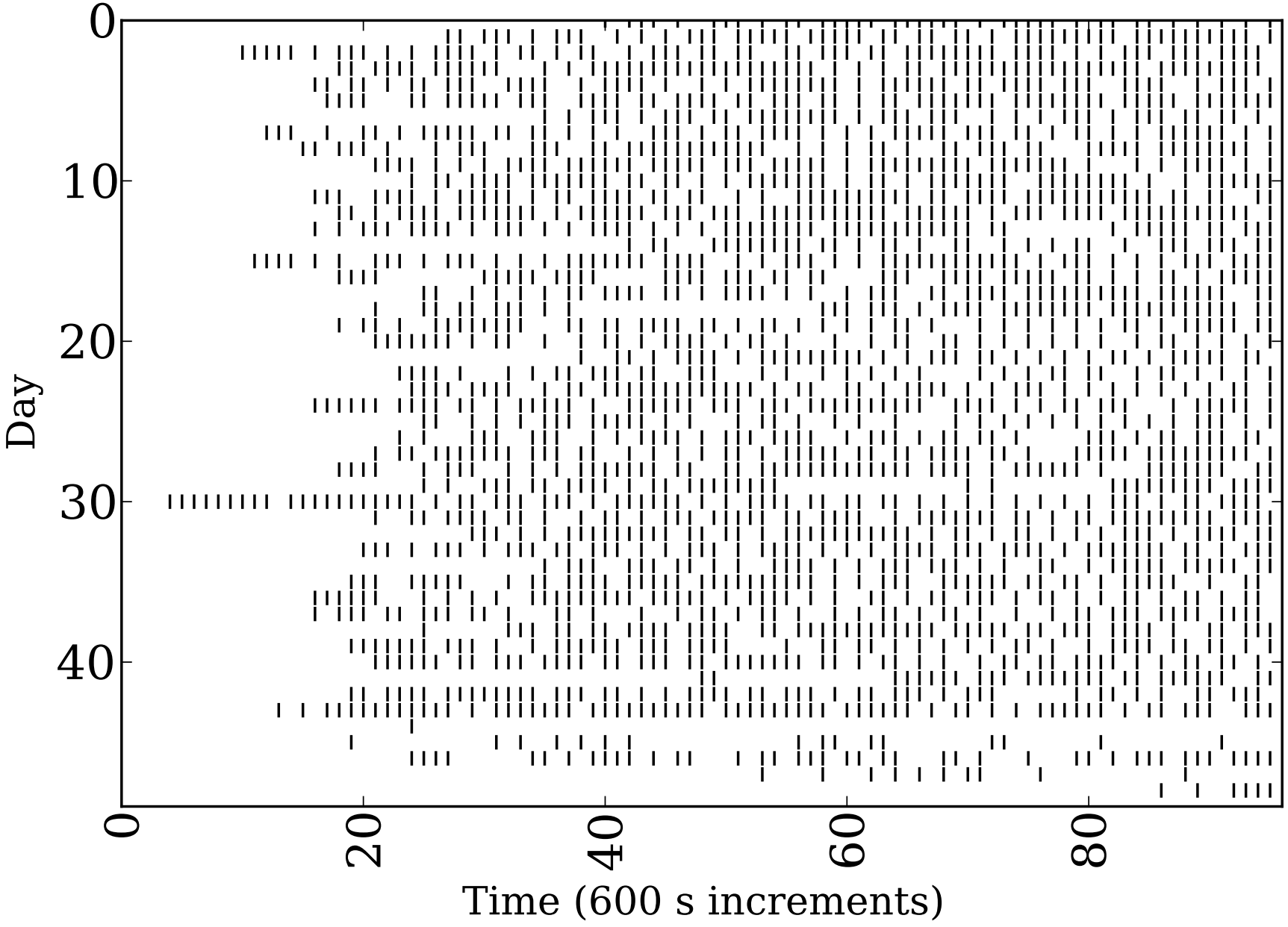
User: DanielZeevi


0
10
20
30
40
Day
0
20
40
60
80
Time (600 s increments)



Base Rate:	0.2122
CSM Rate:	0.7035
ESN Rate:	0.7936

User: LiveFreeRadio


0
10
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Day
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60
80
Time (600 s increments)

Conclusions
and
Future Directions

Predictability of User Behavior in Social Media

Conclusions

Many users on Twitter are well-modeled as processes with self-feedback.

Didn't need social information.

Computational Mechanics and Echo State Networks performed similarly on a large proportion of users.

Despite very dissimilar modeling paradigms.

Predictability of User Behavior in Social Media

Future Work

Consider:

- Network effects
  - Explicitly consider *social dynamics*
- Content from Tweets
  - Sentiment, etc.
- Longitudinal studies
  - Do users change over time?

Thanks!

Questions?