Socially-Informed Timeline Generation for Complex Events

Lu Wang, **Claire Cardie**, and **Galen Marchetti**
Department of Computer Science
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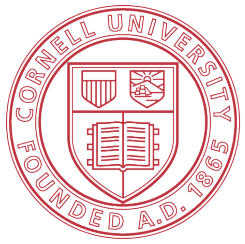
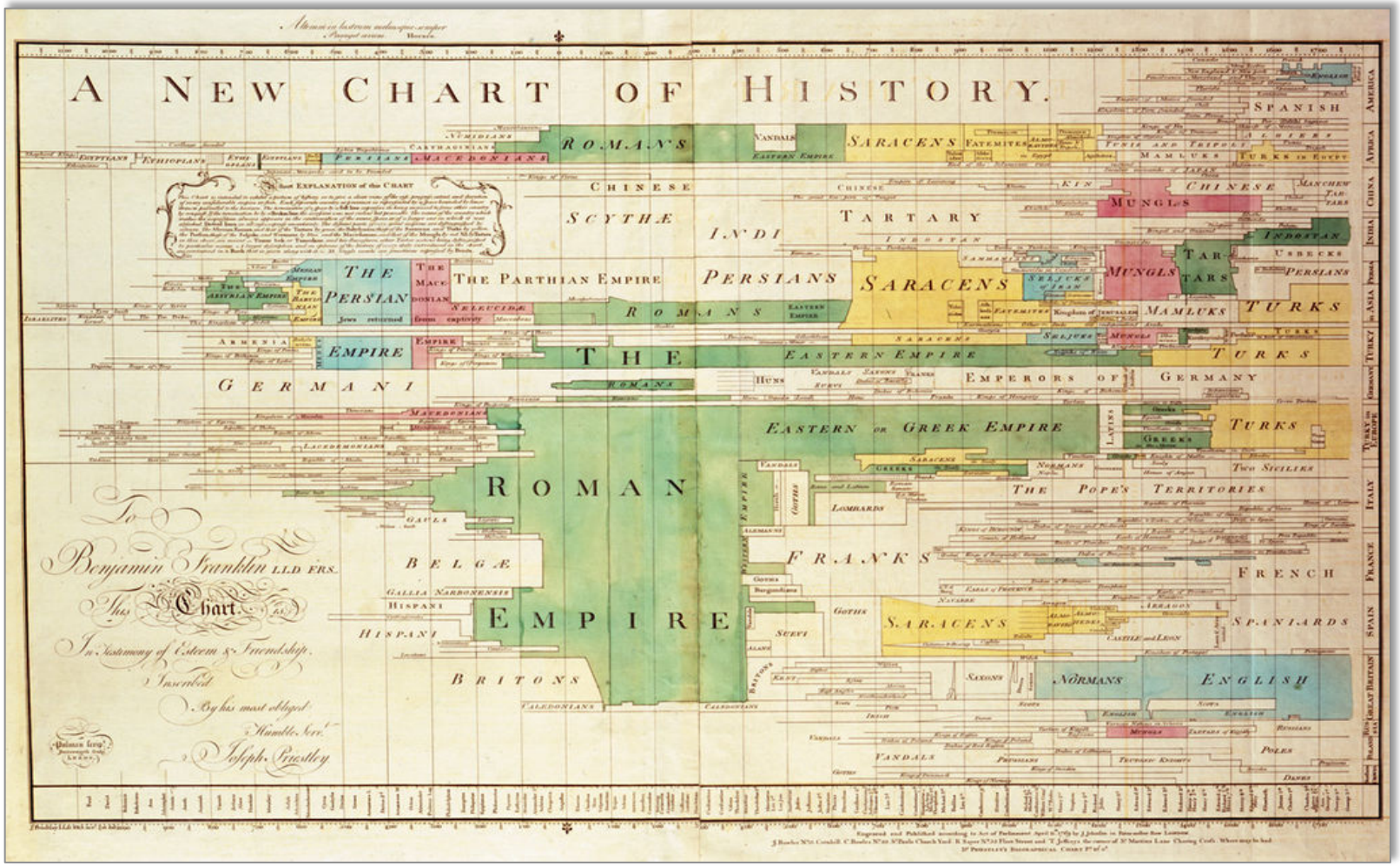


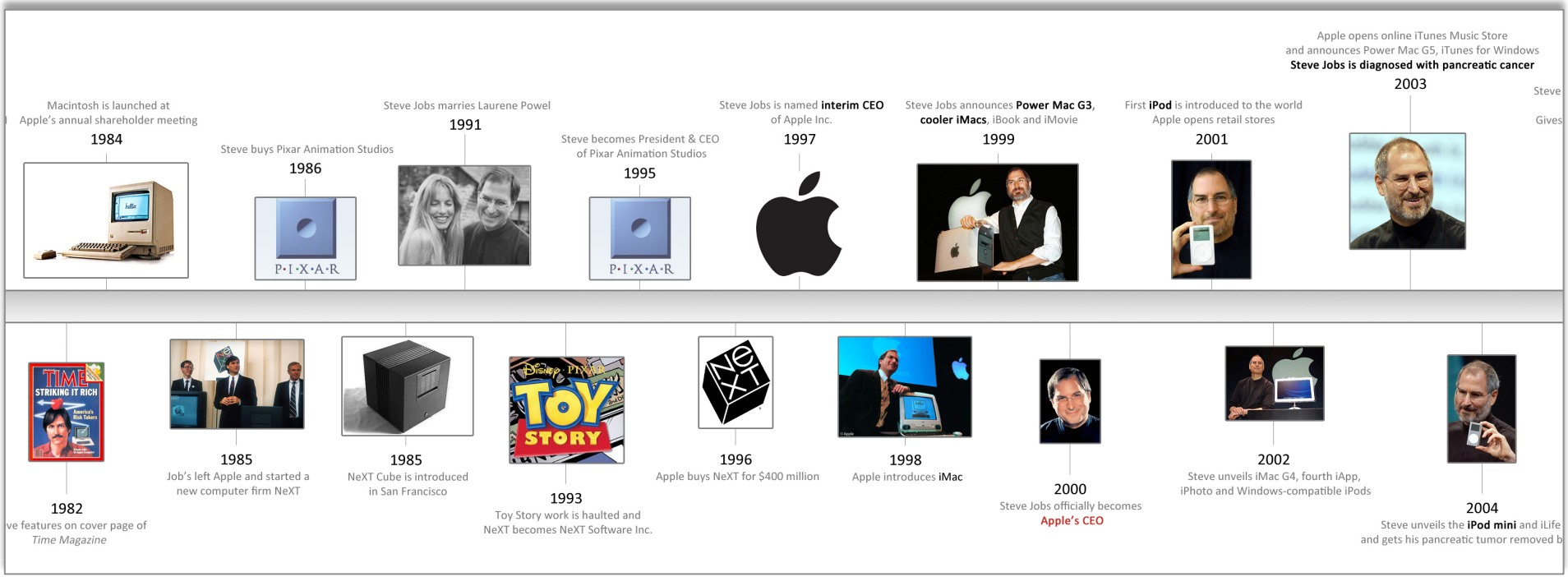
Cornell University

Timelines



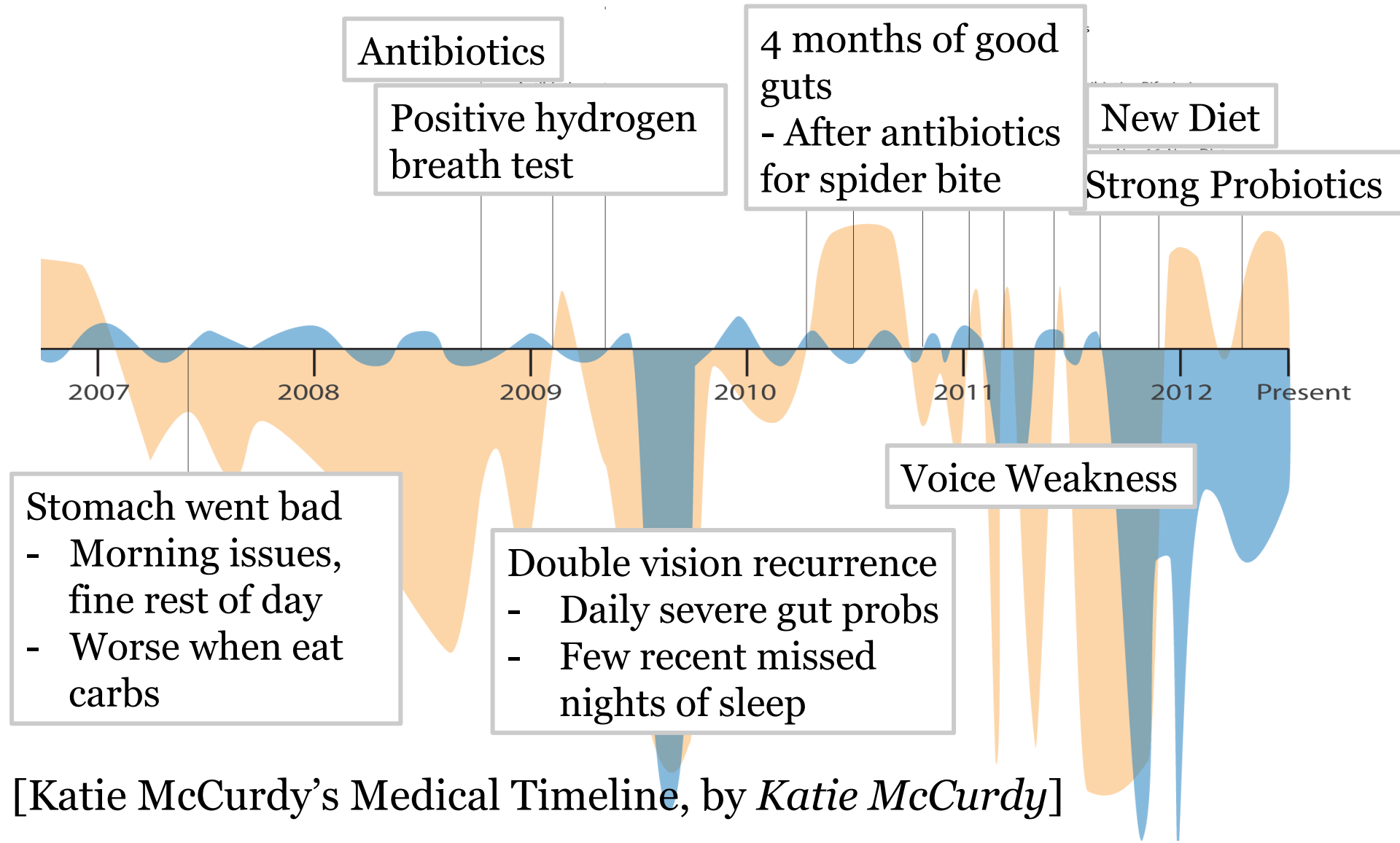
[Joseph Priestley's *A New Chart of History*, 1765]

Timelines



[Timeline of Steve Jobs, by *The Geeks Club*]

Timelines



[Katie McCurdy's Medical Timeline, by *Katie McCurdy*]

Timelines

[Timeline of political unrest in Ukraine, by *Global Times*]


Crimeans vote to rejoin Russia or return to its status under the 1992 constitution .
Obama declared sanctions on Russian officials.
President Obama warned Vladimir Putin that further provocations could isolate Russia.
March 16th, 2014
March 17th, 2014
March 18th, 2014

Crimeans vote to rejoin Russia or return to its status under the 1992 constitution .

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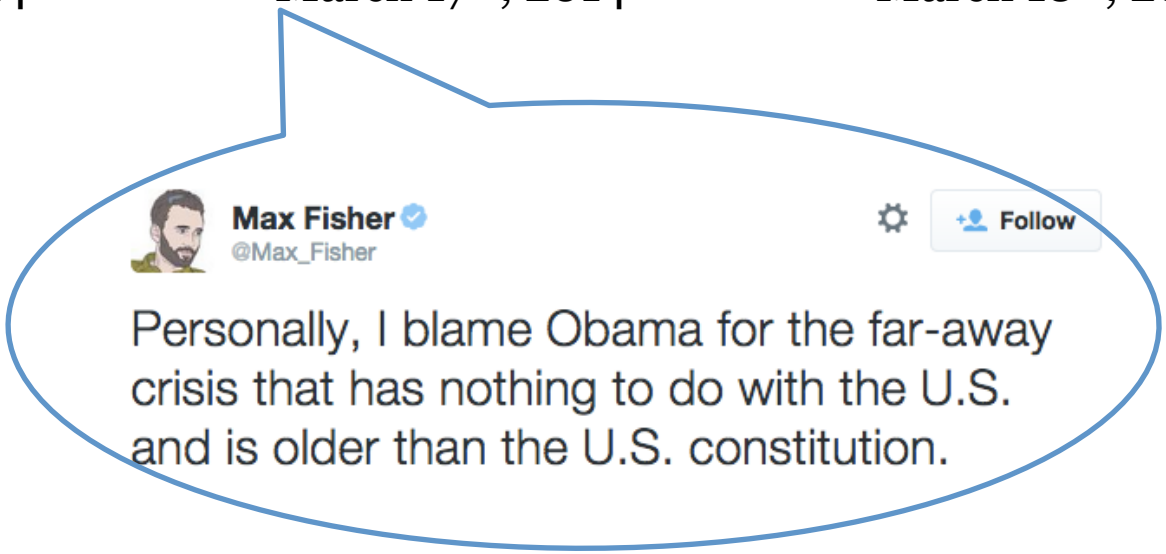
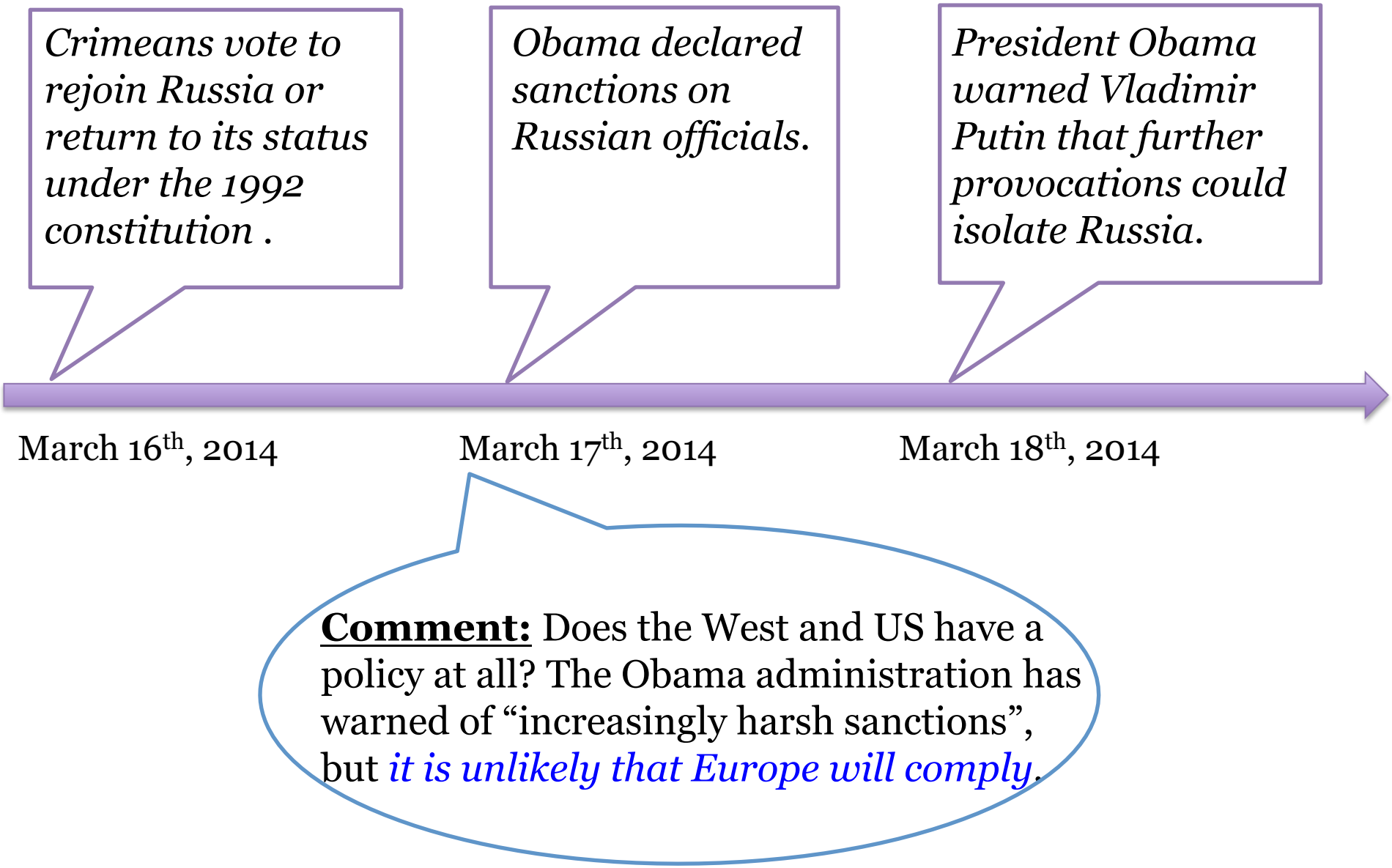
March 16th, 2014

March 17th, 2014

March 18th, 2014




Crimeans vote to rejoin Russia or return to its status under the 1992 constitution .
Obama declared sanctions on Russian officials.
President Obama warned Vladimir Putin that further provocations could isolate Russia.
March 16th, 2014
March 17th, 2014
March 18th, 2014
Comment: Does the West and US have a policy at all? The Obama administration has warned of "increasingly harsh sanctions", but *it is unlikely that Europe will comply*.

Socially-Informed Timeline Generation

Outline

- **Related Work**
- **Methodology**
  - *Socially-Informed Timeline Generation*
- **Experimental Setup**
  - *Data Collection*
- **Evaluation**
  - *Intrinsic and Extrinsic Evaluation*
- **Conclusion**

Outline

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Related Work: Summarization with Social Context

- Timeline generation from news articles and comment summarization have been studied as separate tasks. [Chieu and Lee, 2004][Yan et al., 2012][Ma et al., 2012]

Related Work: Timeline Generation

- Modeling the quality of timelines
  - "Burstiness" or "interestingness" [Chieu and Lee, 2004]
  - "Relevance", "coverage", "diversity", and "coherence" [Yan et al, 2011]
- Constructing the timeline
  - Greedy algorithm [Chieu and Lee, 2004]
  - Dynamic programming [Yan et al, 2011; Yan et al, 2012; Zhao et al, 2013]

Related Work: Topic detection and tracking

- Document-level link detection and topic tracking [Allan et al., 1998]
- Event threading [Nallapati et al., 2004]
- Coherent graph for news articles [Shahaf et al., 2012]

Related Work: Summarization with Social Context

- Article summaries informed by social context
  - Learning users' interests [Hu et al., 2008]
  - Improving the word importance estimation [Zhao et al., 2013]
- Joint summarization: article + tweet
  - Supervised learning based on factor graphs [Yang et al., 2011]
  - Unsupervised learning with topic modeling [Gao et al., 2012]

Socially-Informed Timeline Generation

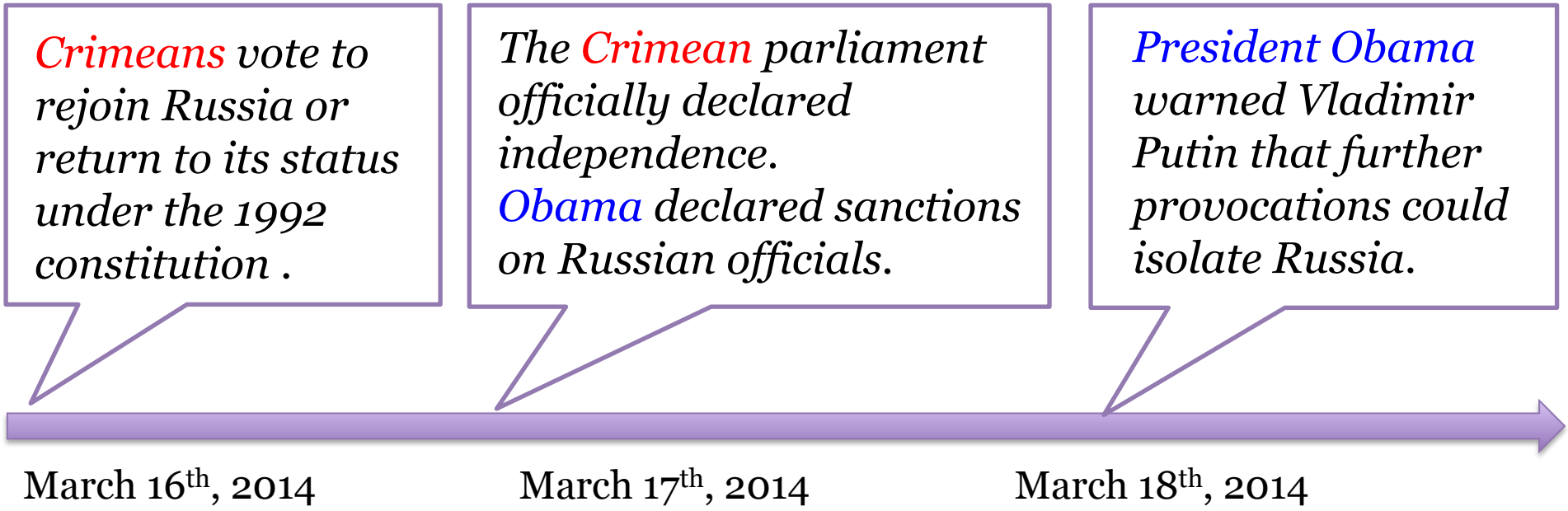
- A **socially-informed timeline generation system** jointly generates a *news article summary* and a *user comment summary* for each day of an ongoing complex event.

Challenges

- Importance estimation of article sentences and comments
  - Large volumes of comments

Challenges

- Enforcing continuity in the timeline for complex event
  - Different from document-level continuity [Shahaf et al., 2012]



Challenges

- Connection between article summary and comment summary

Challenges

Importance estimation of article sentences and comments

⟹ *Joint learning for importance estimation*

Enforcing continuity in the timeline for complex event

⟹ *Entity-centered event threading*

Connection between article summary and comment summary

⟹ *Bipartite matching*

Challenges

Joint Learning

Importance estimation of article sentences and comments

⟹ *Joint learning for importance estimation*

Enforcing continuity in the timeline for complex event

⟹ *Entity-centered event threading*

Connection between article summary and comment summary

⟹ *Bipartite matching*

Challenges

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Timeline Generation

Enforcing continuity in the timeline for complex event

⟹ *Entity-centered event threading*

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Outline

- **Related Work**
- **Methodology**
  - *Socially-Informed Timeline Generation*
- **Experimental Setup**
  - *Data Collection*
- **Evaluation**
  - *Intrinsic and Extrinsic Evaluation*
- **Conclusion**

Socially-Informed Timeline Generation

- How to find the salient sentences and user comments?
  - *Joint Learning for Importance Estimation*
- How to measure the quality of a timeline with social context?
  - *Summary Quality Measurement*
- How to construct the timeline?
  - *An Alternating Optimization framework*

Socially-Informed Timeline Generation

- How to find the salient sentences and user comments?
  - *Joint Learning for Importance Estimation*

- How to measure the quality of a timeline with social context?
  - *Summary Quality Measurement*

- How to construct the timeline?
  - *An Alternating Optimization framework*

Joint Learning for Importance Estimation

ECONOMY | NEWS ANALYSIS

Talk of Wealth Gap Prods the G.O.P. to Refoc

By JONATHAN WEISMAN and ASHLEY PARKER JAN. 21, 2015

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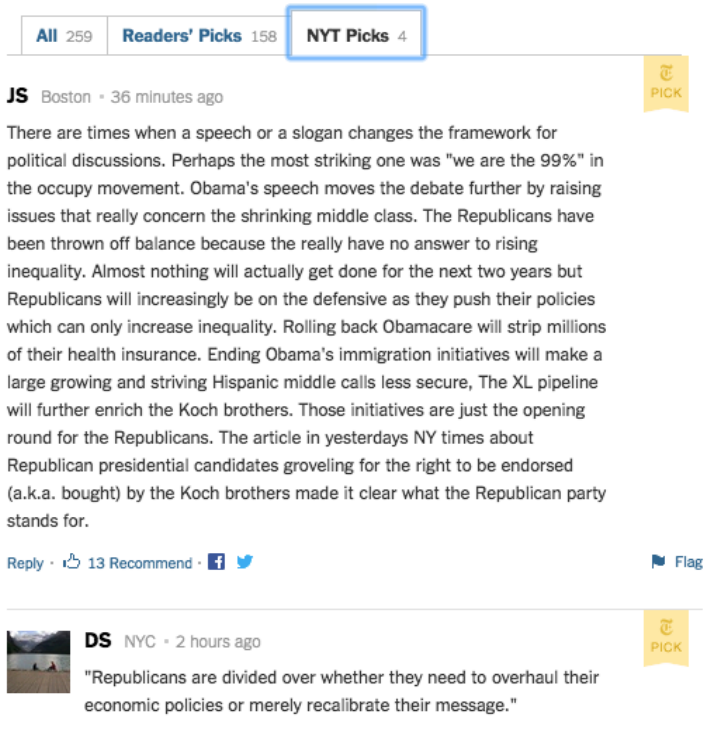
WASHINGTON — President Obama's push for a new "middle-class economics" may go nowhere in Congress, but his ambitious array of proposals to raise stagnant incomes and provide more government support for struggling working families will frame his last two years in office and help make the politics of rich and poor a central issue in the campaign to succeed him.

With the economy finally on more solid ground, even leading Republicans, on Capitol Hill and on the nascent 2016 presidential campaign front, are tempering complaints about overall economic growth and refocusing on the more intractable problem of income inequality.

The president laid the gro



All 259 | Readers' Picks 158 | NYT Picks 4

PICK

JS Boston · 36 minutes ago

There are times when a speech or a slogan changes the framework for political discussions. Perhaps the most striking one was "we are the 99%" in the occupy movement. Obama's speech moves the debate further by raising issues that really concern the shrinking middle class. The Republicans have been thrown off balance because the really have no answer to rising inequality. Almost nothing will actually get done for the next two years but Republicans will increasingly be on the defensive as they push their policies which can only increase inequality. Rolling back Obamacare will strip millions of their health insurance. Ending Obama's immigration initiatives will make a large growing and striving Hispanic middle calls less secure, The XL pipeline will further enrich the Koch brothers. Those initiatives are just the opening round for the Republicans. The article in yesterdays NY times about Republican presidential candidates groveling for the right to be endorsed (a.k.a. bought) by the Koch brothers made it clear what the Republican party stands for.

Reply · 13 Recommend · Flag

PICK

DS NYC · 2 hours ago

"Republicans are divided over whether they need to overhaul their economic policies or merely recalibrate their message."

Joint Learning for Importance Estimation

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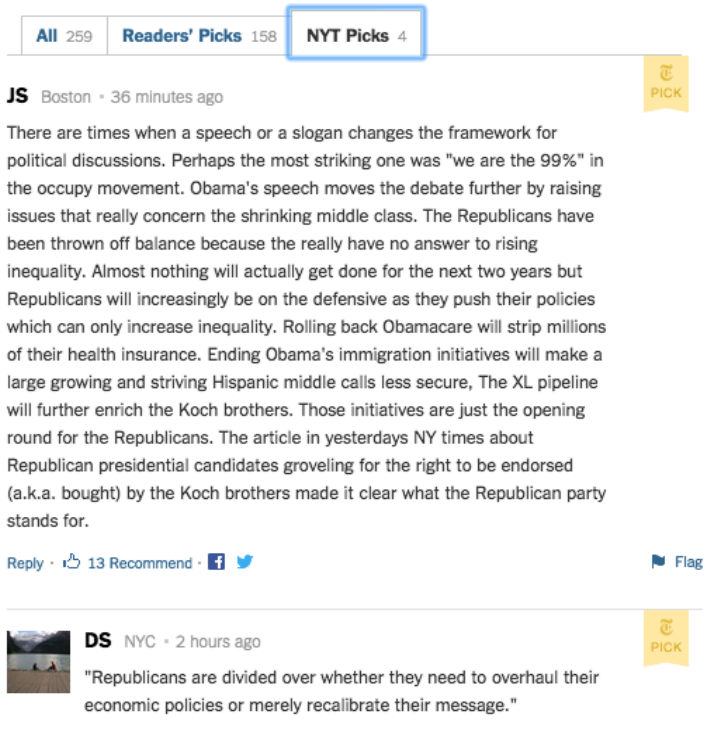

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Training data: New York Times 2013

- 3,863 articles – each article has a human-written abstract
- 833,032 comments – editor's-picks or not

Joint Learning for Importance Estimation

- **Training data**: a set of articles $D = \{d_i\}_{i=0}^{|D|-1}$
- Each article d_i contains a set of
  - Sentences
    - Gold-standard importance score: *ROUGE-2* [Lin and Hovy, 2003]
  - Comments
    - Gold-standard importance score: *editor's picks* are assigned 1.0; otherwise, 0.0

The Joint Learning Method

Article Sentence Scoring

(0.8) S_0: The Crimean parliament officially declared independence.

(0.9) S_1: Obama declared sanctions on Russian officials.

...

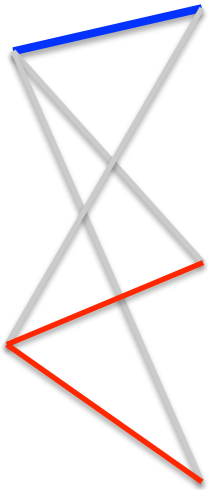
Comment Scoring

(1.0) C_0: The "Crimean Parliament", headed by an ethnic Russian separatist, has voted…

(1.0) C_1: The Obama administration has warned of "increasingly harsh sanctions", but it is unlikely that Europe will comply…

(1.0) C_2: Sanctions are effective and if done in unison with the EU…

...



Part I
Linear regression scorer

Part II
Linear regression scorer

Part III
graph-based regularization

The Joint Learning Method

Objective Function:

$$J(\mathbf{w_s}, \mathbf{w_c}) = J_s(\mathbf{w_s}) + J_c(\mathbf{w_c}) + J_{s,c}(\mathbf{w_s}, \mathbf{w_c})$$

Sentence **Comment**

The Joint Learning Method

Objective Function:

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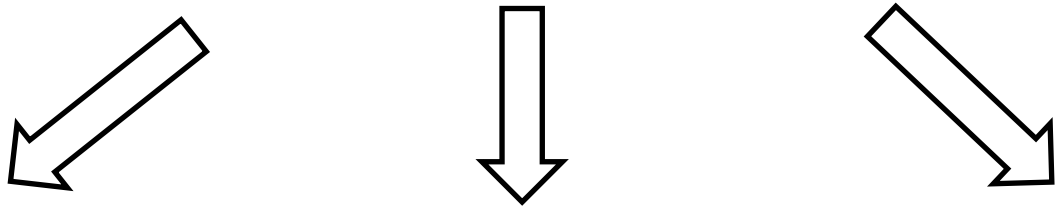

Part I: **Sentence importance only**
- Loss function

+ Regularization

Part II: **Comment importance only**
- Loss function

+ Regularization

Part III: **Interplay between sentences and comments**
- Regularization

The Joint Learning Method

Objective Function:

$$J(\mathbf{w_s}, \mathbf{w_c}) = J_s(\mathbf{w_s}) + J_c(\mathbf{w_c}) + J_{s,c}(\mathbf{w_s}, \mathbf{w_c})$$

$$\tilde{\mathbf{X}} = \begin{bmatrix} \tilde{\mathbf{X}}_\mathbf{s} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{X}}_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{X}}' = \begin{bmatrix} \tilde{\mathbf{X}}'_\mathbf{s} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{X}}'_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{Y}} = \begin{bmatrix} \tilde{\mathbf{Y}}_\mathbf{s} \\ \tilde{\mathbf{Y}}_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{Y}}' = \begin{bmatrix} \tilde{\mathbf{Y}}'_\mathbf{s} \\ \tilde{\mathbf{Y}}'_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{L}} = \begin{bmatrix} \lambda_{sc}\mathbf{I}_{|\mathbf{X_s}|} & -\lambda_{sc}\tilde{\mathbf{Q}} \\ -\lambda_{sc}\tilde{\mathbf{Q}}^\mathbf{T} & \lambda_{sc}\mathbf{I}_{|\mathbf{X_c}|} \end{bmatrix}$$

$$\tilde{\beta} = \begin{bmatrix} \beta_s\mathbf{I_k} & \mathbf{0} \\ \mathbf{0} & \beta_c\mathbf{I_l} \end{bmatrix} \quad \tilde{\lambda} = \begin{bmatrix} \lambda_s\mathbf{I}_{|\mathbf{X}'_\mathbf{s}|} & \mathbf{0} \\ \mathbf{0} & \lambda_c\mathbf{I}_{|\mathbf{X}'_\mathbf{c}|} \end{bmatrix}$$

$$\mathbf{w} = \begin{bmatrix} \mathbf{w_s} \\ \mathbf{w_c} \end{bmatrix}$$

Closed Form Solution:

$$\Rightarrow \quad \hat{\mathbf{w}} = (\tilde{\mathbf{X}}^\mathbf{T}\tilde{\mathbf{L}}\tilde{\mathbf{X}} + \tilde{\mathbf{X}}^\mathbf{T}\tilde{\mathbf{X}} + \tilde{\mathbf{X}}'^\mathbf{T}\tilde{\lambda}\tilde{\mathbf{X}}' + \tilde{\beta})^{-1}(\tilde{\mathbf{X}}^\mathbf{T}\tilde{\mathbf{Y}} + \tilde{\mathbf{X}}'^\mathbf{T}\tilde{\lambda}\tilde{\mathbf{Y}}')$$

The Joint Learning Method

Objective Function:

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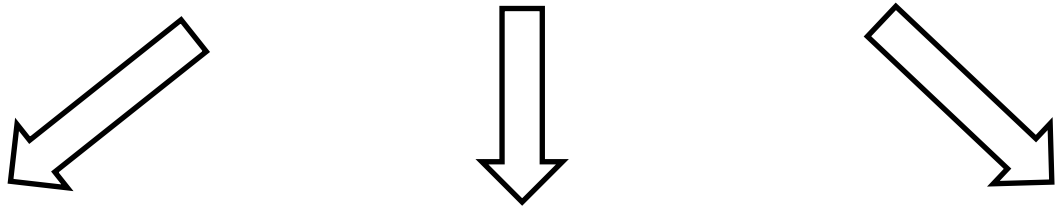

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Joint Learning: Start with Ridge Regression

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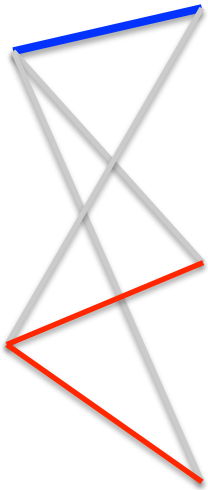

Part I
Linear regression scorer

Part II
Linear regression scorer

Part III
graph-based regularization

Joint Learning: Start with Ridge Regression

Article Sentence Scoring

- Sentence x_s : feature vector $\mathbf{x_s} \in \mathbf{R}^k$
- Training set: $\tilde{\mathbf{X}}_\mathbf{s}$ and $\tilde{\mathbf{Y}}_\mathbf{s}$
- Ridge regression:

  $f_s(x_s) = \mathbf{x_s} \cdot \mathbf{w_s}$
- Objective function:

$$\min_{\mathbf{w_s}} \underbrace{\left\| \tilde{\mathbf{X}}_\mathbf{s}\mathbf{w_s} - \tilde{\mathbf{Y}}_\mathbf{s} \right\|_2^2}_{\text{Label loss}} + \beta_s \cdot \underbrace{\left\| \mathbf{w_s} \right\|_2^2}_{\text{L}_2 \text{ regularization}}$$

Joint Learning: Start with Ridge Regression

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Basic Features
Length
Position
Number of named entities
Overlaps with the headline
Average/Sum TF-IDF

Social Features
Average/Sum frequency of content words appearing in comments
Average/Sum frequency of dependency relations appearing in comments

Joint Learning: Start with Ridge Regression

Article Sentence Scoring

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(0.9) S_1: Obama declared sanctions on Russian officials.

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Comment Scoring

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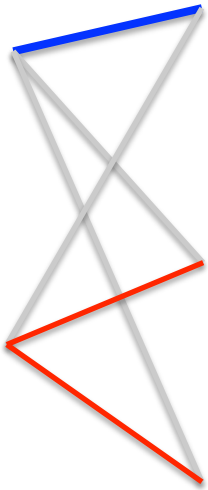

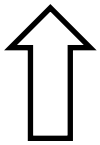

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Linear regression scorer

Part II
Linear regression scorer

Part III
graph-based regularization

Joint Learning: Start with Ridge Regression

Comment Scoring

- Comment x_c: feature vector $\mathbf{x_c} \in \mathbf{R}^l$
- Training set: $\tilde{\mathbf{X}}_\mathbf{c}$ and $\tilde{\mathbf{Y}}_\mathbf{c}$
- Ridge regression:

  $f_c(x_c) = \mathbf{x_c} \cdot \mathbf{w_c}$
- Objective function:

$$\min_{\mathbf{w_c}} \underbrace{\left\| \tilde{\mathbf{X}}_\mathbf{c}\mathbf{w}_\mathbf{c} - \tilde{\mathbf{Y}}_\mathbf{c} \right\|_2^2}_{\text{Label loss}} + \beta_\mathbf{c} \cdot \underbrace{\left\| \mathbf{w_c} \right\|_2^2}_{\text{L}_2\text{ regularization}}$$

Joint Learning: Start with Ridge Regression

Basic Features
Length
Number of named entities
Contains URL

Readability Features
Flesch-Kincaid Readability
Gunning-Fog Readability

Sentiment Features
Number of positive/negative words
Number of sentiment words (MPQA (Wilson et al., 2005), General Inquirer (stone et al., 1966))

Comment Scoring

- Comment x_c: feature vector $\mathbf{x_c} \in \mathbf{R}^l$
- Training set: $\tilde{\mathbf{X}}_\mathbf{c}$ and $\tilde{\mathbf{Y}}_\mathbf{c}$
- Ridge regression:

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Joint Learning: Graph-Based Regularization

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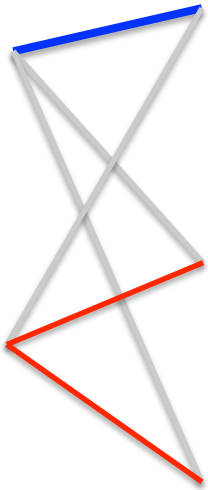

Comment Scoring

(1.0) C_0: The "Crimean Parliament", headed by an ethnic Russian separatist, has voted…

(1.0) C_1: The Obama administration has warned of "increasingly harsh sanctions", but it is unlikely that Europe will comply…

(1.0) C_2: Sanctions are effective and if done in unison with the EU…

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Part I
Linear regression scorer

Part II
Linear regression scorer

Part III
graph-based regularization

Joint Learning: Graph-Based Regularization

Graph-Based Regularization

- Adjacency (similarity) matrix $\tilde{\mathbf{A}} \in \mathbf{R}^{N \times M}$
- N, M are the numbers of sentences and comments

$$J_{s,c}(\mathbf{w_s}, \mathbf{w_c}) = \lambda_{sc} \cdot \sum_{d_i} \sum_{x_s \in x_{s_{d_i}}, x_c \in x_{c_{d_i}}} \tilde{A}_{x_s, x_c} \cdot (\mathbf{x_s} \cdot \mathbf{w_s} - \mathbf{x_c} \cdot \mathbf{w_c})^2$$

Similarity Sentence Comment

Joint Learning: Graph-Based Regularization

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(0.9) S_1: Obama declared sanctions on Russian officials.

(1.0) C_1: The Obama administration has warned of "increasingly harsh sanctions", but it is unlikely that Europe will comply…

(1.0) C_2: Sanctions are effective and if done in unison with the EU…

Joint Learning: Graph-Based Regularization

Objective Function:

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Part I: **Sentence importance only**
- Loss function

+ *Regularization*

Specialty of first sentence

Part II: **Comment importance only**
- Loss function

+ Regularization

Part III: **Interplay between sentences and comments**
- Regularization

Joint Learning: Graph-Based Regularization

Objective Function:

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Specialty of first sentence

Part II: **Comment importance only**
- Loss function

+ *Regularization*

Bias towards editor's picks comments

Part III: **Interplay between sentences and comments**
- Regularization

The Joint Learning Method

Objective Function:

$$J(\mathbf{w_s}, \mathbf{w_c}) = J_s(\mathbf{w_s}) + J_c(\mathbf{w_c}) + J_{s,c}(\mathbf{w_s}, \mathbf{w_c})$$

$$\tilde{\mathbf{X}} = \begin{bmatrix} \tilde{\mathbf{X}}_\mathbf{s} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{X}}_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{X}}' = \begin{bmatrix} \tilde{\mathbf{X}}'_\mathbf{s} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{X}}'_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{Y}} = \begin{bmatrix} \tilde{\mathbf{Y}}_\mathbf{s} \\ \tilde{\mathbf{Y}}_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{Y}}' = \begin{bmatrix} \tilde{\mathbf{Y}}'_\mathbf{s} \\ \tilde{\mathbf{Y}}'_\mathbf{c} \end{bmatrix} \quad \tilde{\mathbf{L}} = \begin{bmatrix} \lambda_{sc}\mathbf{I}_{|\mathbf{X_s}|} & -\lambda_{sc}\tilde{\mathbf{Q}} \\ -\lambda_{sc}\tilde{\mathbf{Q}}^\mathbf{T} & \lambda_{sc}\mathbf{I}_{|\mathbf{X_c}|} \end{bmatrix}$$

$$\tilde{\beta} = \begin{bmatrix} \beta_s\mathbf{I_k} & \mathbf{0} \\ \mathbf{0} & \beta_c\mathbf{I_l} \end{bmatrix} \quad \tilde{\lambda} = \begin{bmatrix} \lambda_s\mathbf{I}_{|\mathbf{X}'_\mathbf{s}|} & \mathbf{0} \\ \mathbf{0} & \lambda_c\mathbf{I}_{|\mathbf{X}'_\mathbf{c}|} \end{bmatrix}$$

$$\mathbf{w} = \begin{bmatrix} \mathbf{w_s} \\ \mathbf{w_c} \end{bmatrix}$$

Closed Form Solution:

$$\Rightarrow \quad \hat{\mathbf{w}} = (\tilde{\mathbf{X}}^\mathbf{T}\tilde{\mathbf{L}}\tilde{\mathbf{X}} + \tilde{\mathbf{X}}^\mathbf{T}\tilde{\mathbf{X}} + \tilde{\mathbf{X}}'^\mathbf{T}\tilde{\lambda}\tilde{\mathbf{X}}' + \tilde{\beta})^{-1}(\tilde{\mathbf{X}}^\mathbf{T}\tilde{\mathbf{Y}} + \tilde{\mathbf{X}}'^\mathbf{T}\tilde{\lambda}\tilde{\mathbf{Y}}')$$

Socially-Informed Timeline Generation

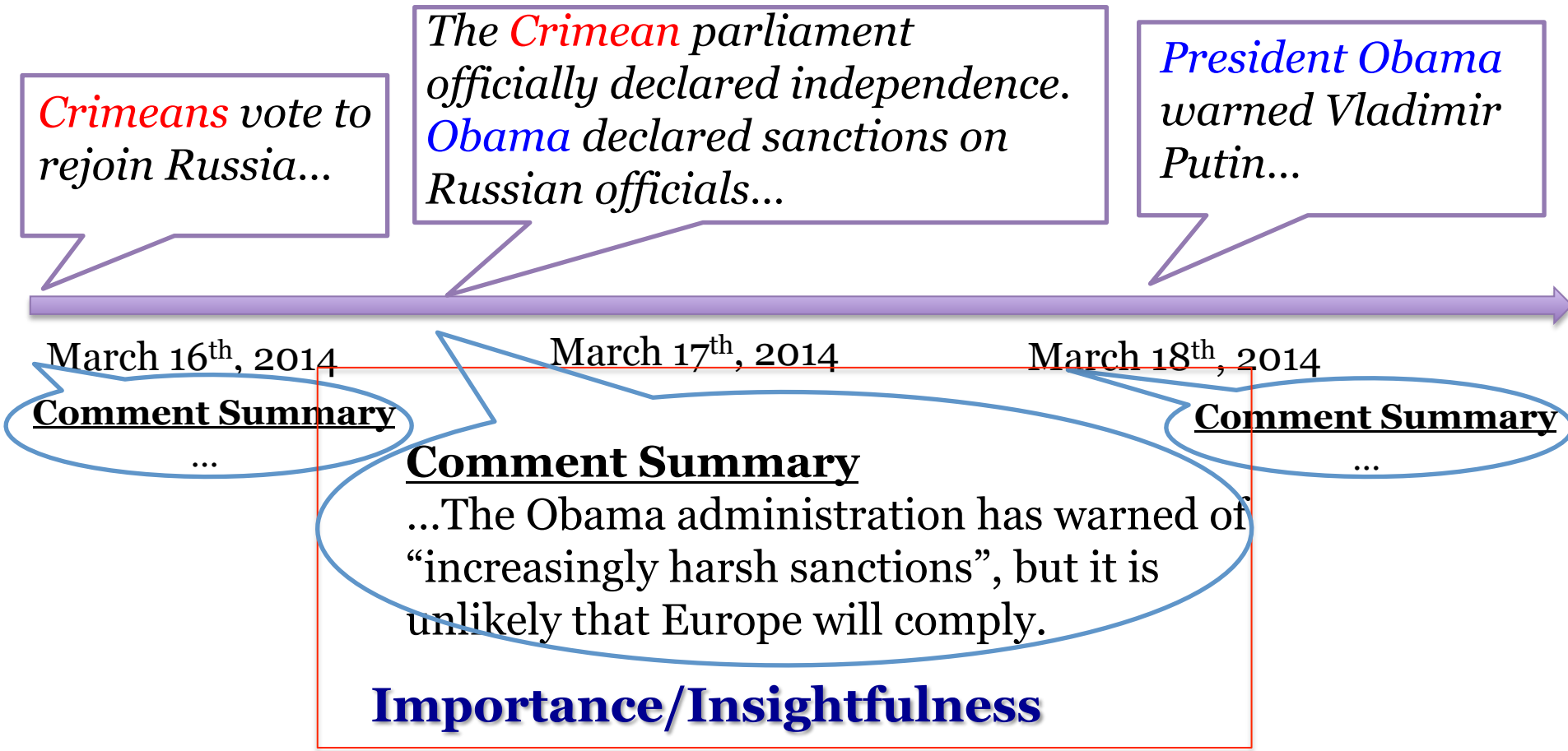
- A **socially-informed timeline generation system** jointly generates a *news article summary* and a *user comment summary* for each day of an ongoing complex event.
- For each day
  - **Input**: a set of articles with sentence set V_s and comment set V_c
  - **Output**: article summary $S \subseteq V_s$ and comment summary $C \subseteq V_c$

Socially-Informed Timeline Generation

- How to find the salient sentences and user comments?
  - *Joint Learning for Importance Estimation*
- How to measure the quality of a timeline with social context?
  - *Summary Quality Measurement*
- How to construct the timeline?
  - *An Alternating Optimization framework*

Socially-Informed Timeline Generation

Socially-Informed Timeline Generation



Socially-Informed Timeline Generation

Socially-Informed Timeline Generation

- An optimization framework

$$Z(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

S : *Article Summary*

C : *Comment Summary*

$\mathcal{T}$: *Event Threads*

Socially-Informed Timeline Generation

- An optimization framework

$$\mathcal{Z}(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

S : *Article Summary*

C : *Comment Summary*

$\mathcal{T}$: *Event Threads*

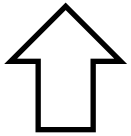
Constraints:

$$length(S) \leq \theta_s$$

$$size(C) \leq \theta_c$$

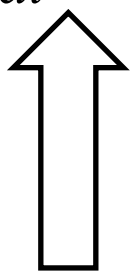
Summary Quality Measurement

$$Z(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$



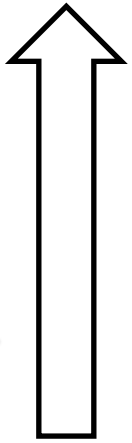
Article Summary

- **Importance**
- **Coverage**
- **Continuity**



Comment Summary

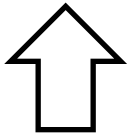
- **Importance**



Connectivity

Summary Quality Measurement: *Importance*

$$Z(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$



Article Summary

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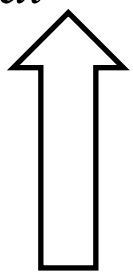
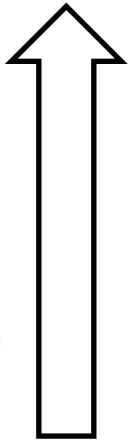


Comment Summary

- **Importance**



Connectivity

Summary Quality Measurement: *Importance*

$$Z(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

Article Summary

- **Importance**
- **Coverage**
- **Continuity**

Comment Summary

- **Importance**

Connectivity

⇨ *simply add up the importance scores*

Summary Quality Measurement: *Coverage*

$$\mathcal{Z}(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

Article Summary

- Importance
- **Coverage**
- Continuity

Comment Summary

- Importance

Connectivity

Summary Quality Measurement: *Coverage*

All Candidate Sentences

S_0: The Crimean declared independence.

S_1: Obama declared sanctions.

S_2: EU condemned Russia.

S_3: Russia recognized the independence.

Current Summary

The Crimean declared independence.
Obama declared sanctions.

Summary Quality Measurement: *Coverage*

All Candidate Sentences

S_0: The Crimean declared independence.

\+ S_1: Obama declared sanctions.

\+ S_2: EU condemned Russia.

\+ S_3: Russia recognized the independence.

Current Summary

The Crimean declared independence.
Obama declared sanctions.

$$\sum_{s' \in V_s} \sum_{s \in S} tfidf(s, s')$$

Each sentence s'

Coverage of s' by current summary S

Summary Quality Measurement: *Coverage*

All Candidate Sentences

S_0: The Crimean declared independence.

\+ S_1: Obama declared sanctions.

\+ S_2: EU condemned Russia.

\+ S_3: Russia recognized the independence.

Current Summary

The Crimean declared independence.
Obama declared sanctions.

$$\sum_{s' \in V_s} \min\left(\sum_{s \in S} tfidf(s, s'), \alpha \sum_{\hat{s} \in V_s} tfidf(\hat{s}, s')\right)$$

Each sentence *s'*

Coverage of *s'* by current summary *S*

Upper bound for encourage diversity

[Lin and Bilmes, 2011]

Summary Quality Measurement: *Continuity*

$$Z(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

Article Summary

- Importance
- Coverage
- **Continuity**

Comment Summary

- Importance

Connectivity

Summary Quality Measurement: *Continuity*

- An optimization framework

Event Threads

$$Z(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

Article Summary

- Importance
- Coverage
- **Continuity**

Comment Summary

- Importance

Connectivity

Entity-Centered Event Threading

Day 1:

1. Barack Obama pledges to stand with Ukraine.
2. Putin formally asked the federation council for permission to use the armed forces in Ukraine.

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1. Barack Obama pledges to stand with Ukraine.
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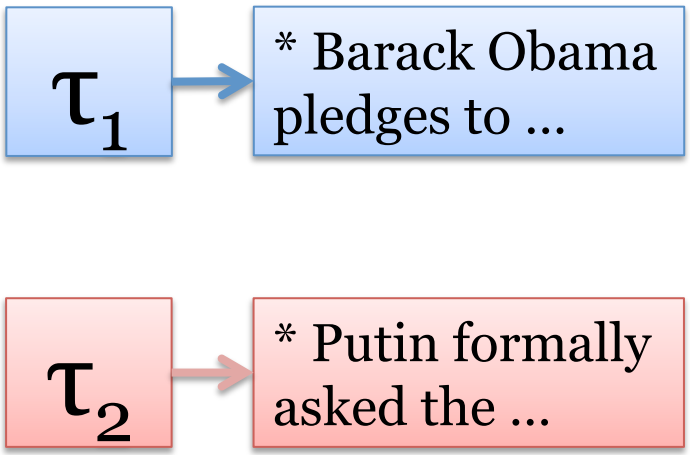
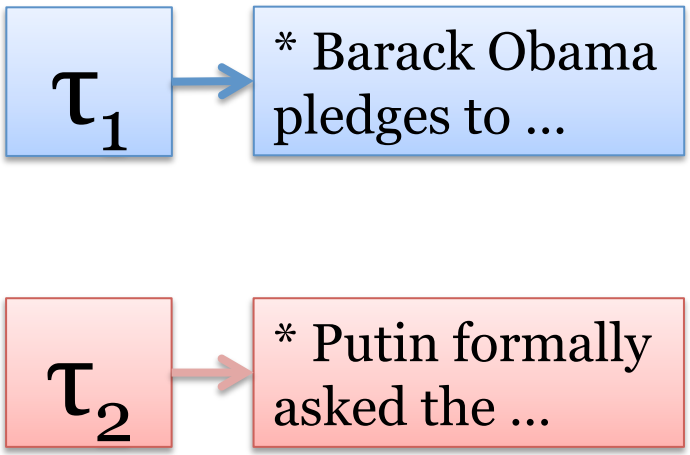


Day 2:

1. Obama declared sanctions on Russian officials.
2. US president Barack Obama urges Moscow to “move back its troops” and lower tensions .
3. Putin addresses parliament, defending Moscow’s actions on Crimea.



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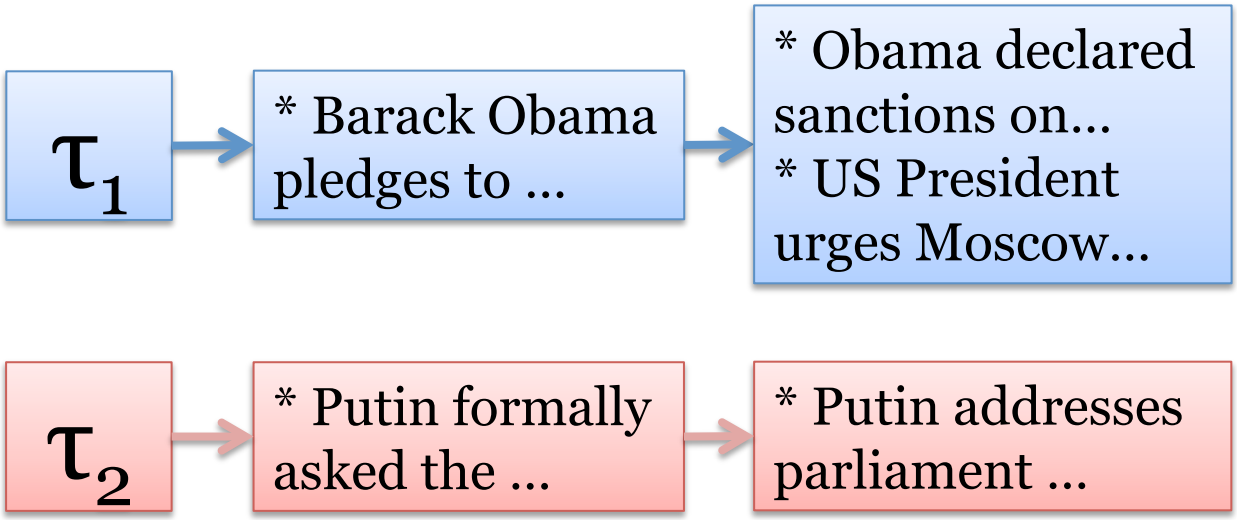
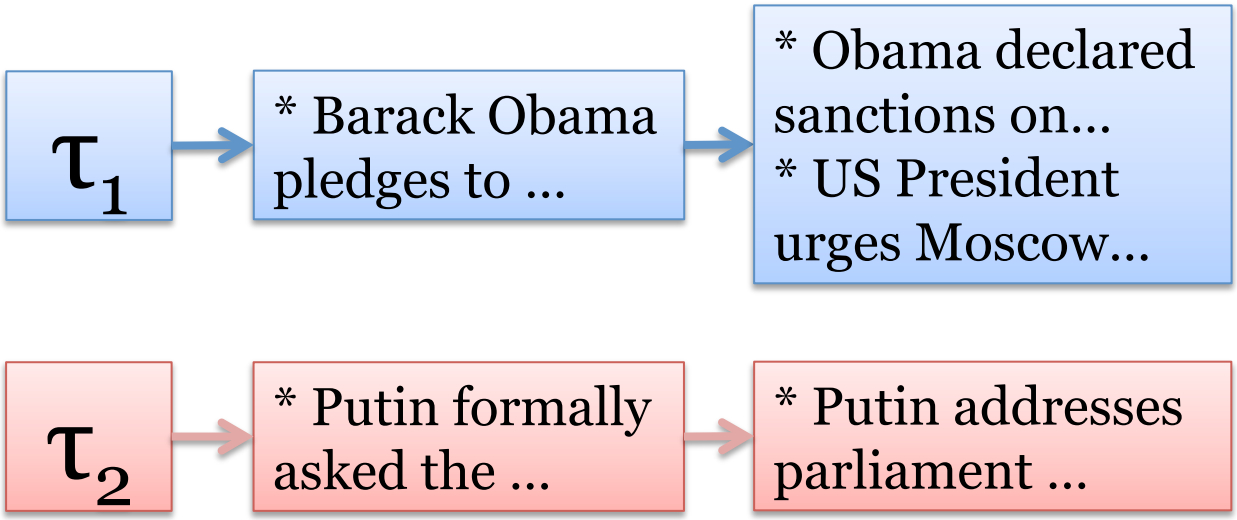


Day 3:

1. Russian president Vladimir Putin dismisses claims that Russian agents are acting in eastern Ukraine.
2. Barack Obama extends the list of individuals targeted for sanctions.
3. EU rejected the referendum on independence in Crimea.



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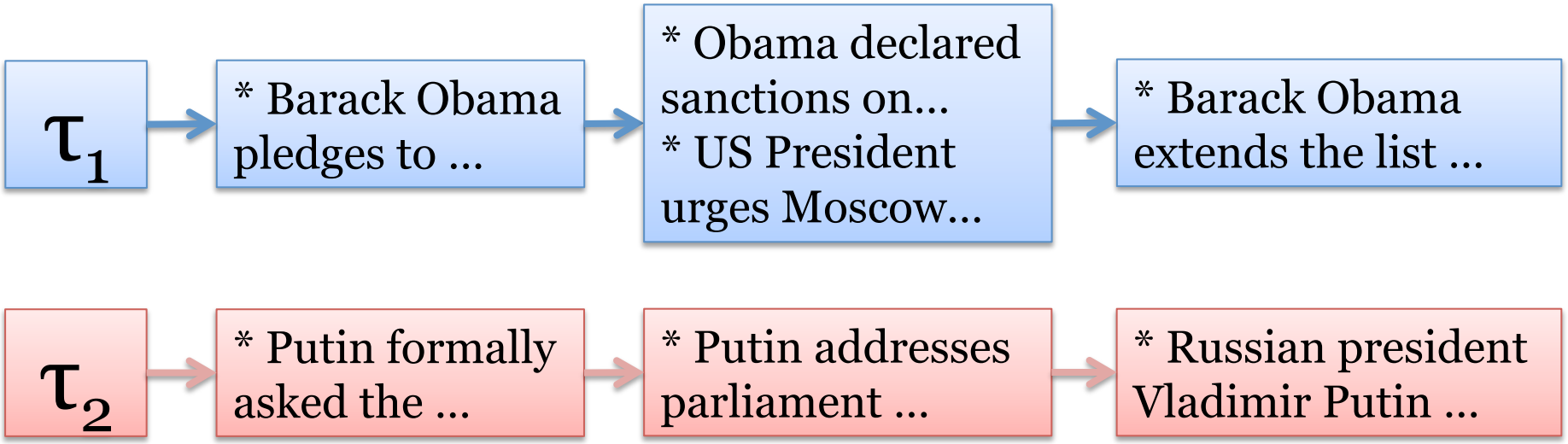

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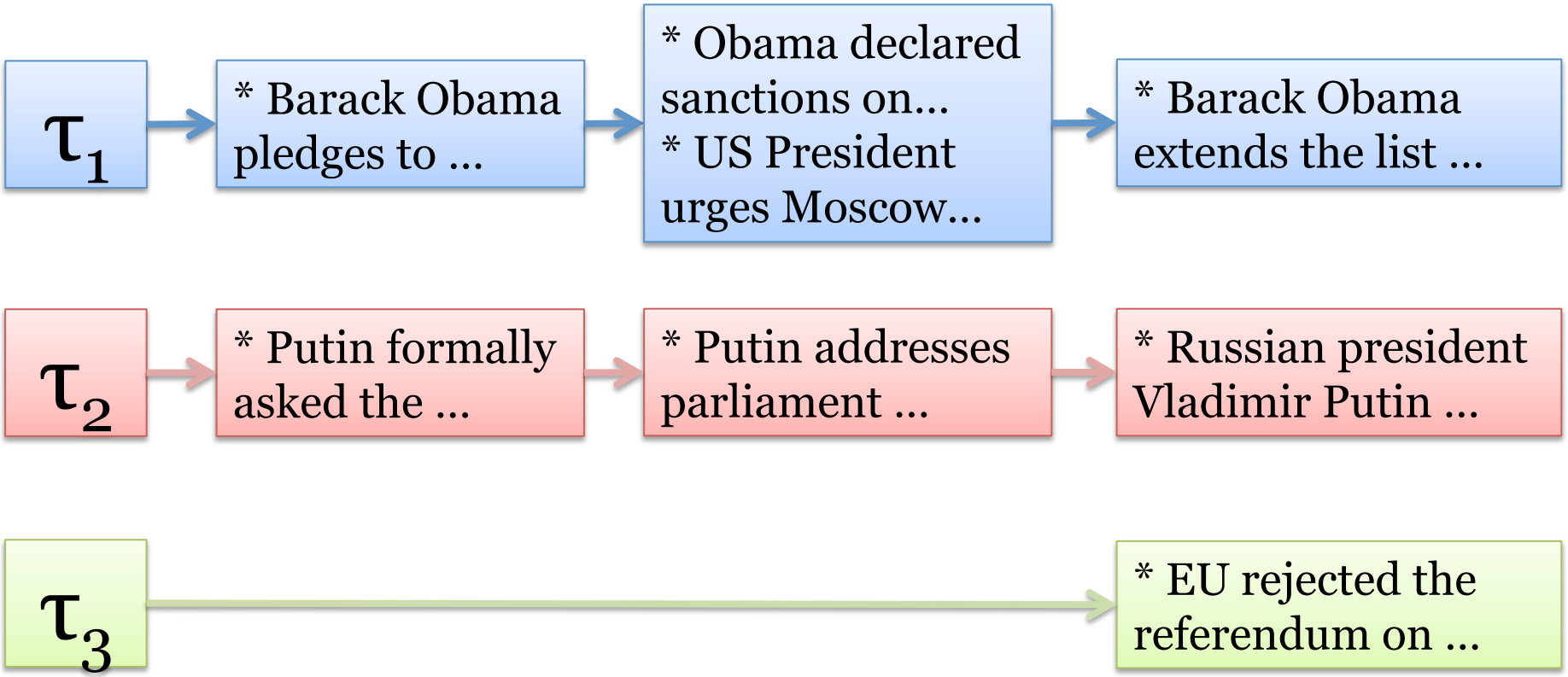
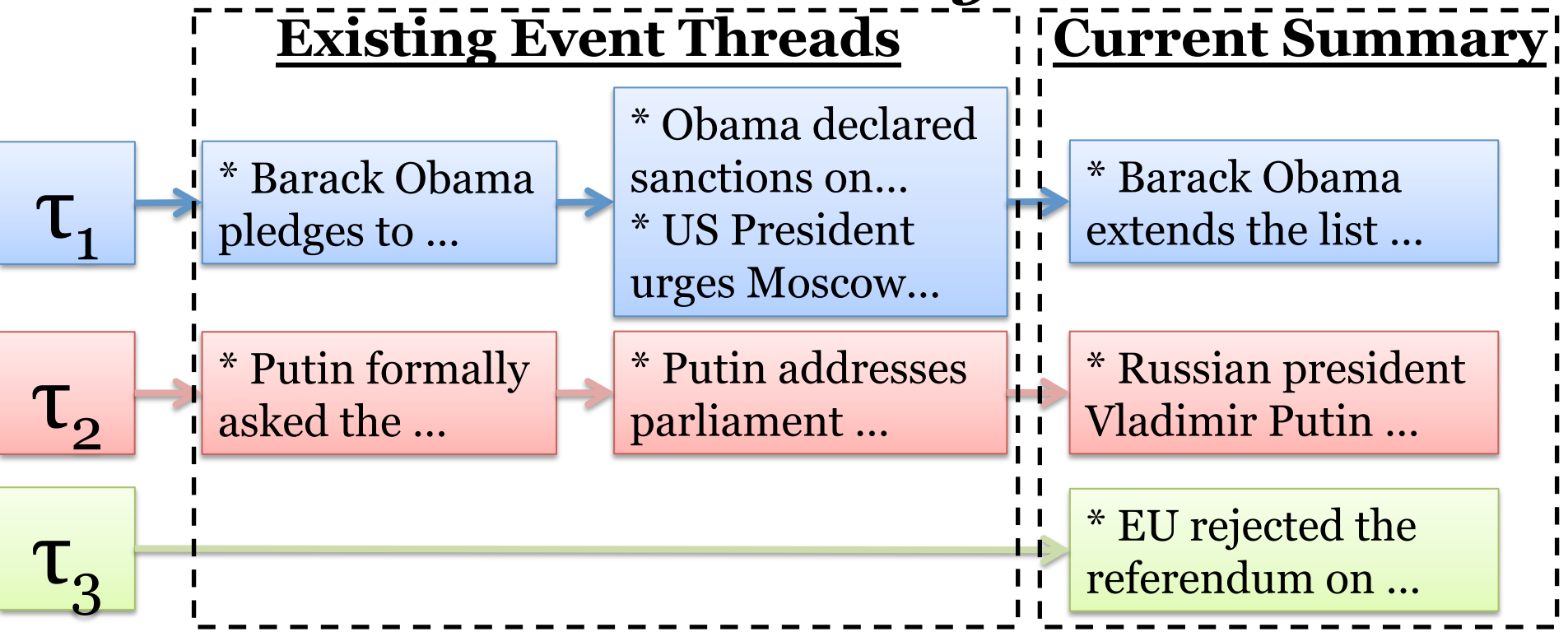


Summary Quality Measurement: *Continuity*

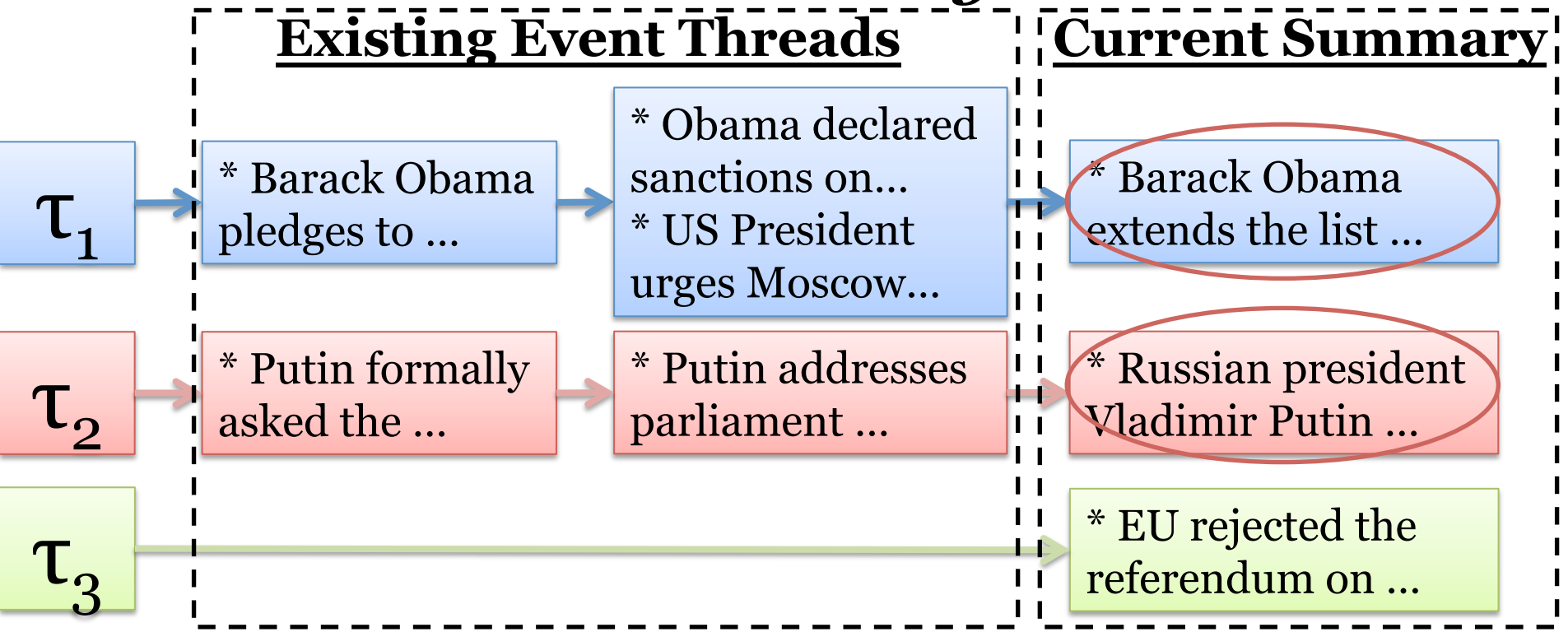


$$\sum_{\tau \in \mathcal{T}} \max_{s_k \in S} cohesion(s_k, \tau), \quad cohesion(s, \tau) = \min_{\mathbf{s_i} \in \tau, \mathbf{s_i} \neq \emptyset} tfsimi(\mathbf{s_i}, s)$$

Each thread

Continuity for τ: maximum cohesion of any sentence in current summary to thread

Summary Quality Measurement: *Continuity*



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Each thread

Continuity for τ: maximum cohesion of any sentence in current summary to thread

Summary Quality Measurement: *Connectivity*

$$Z(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

Article Summary

- **Importance**
- **Coverage**
- **Continuity**

Comment Summary

- **Importance**

Connectivity

Summary Quality Measurement: *Connectivity*

Goals:

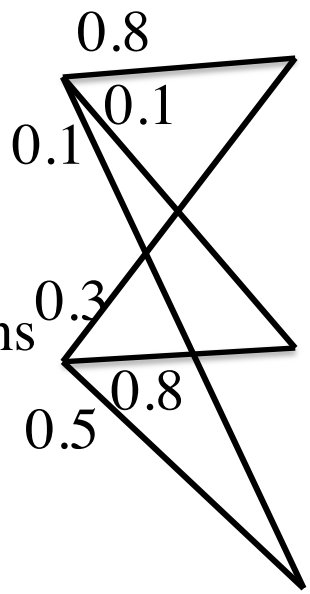
- Comments should be *on the topics* in article summary.
- Comments that cover *diversified events* are preferred.

Summary Quality Measurement: *Connectivity*

Article Summary ***S***

S_0: The Crimean parliament officially declared independence.

S_1: Obama declared sanctions on Russian officials.



Comment Summary ***C***

C_0: The "Crimean Parliament", headed by an ethnic Russian separatist, has voted…

C_1: The Obama administration has warned of "increasingly harsh sanctions"…

C_2: Sanctions are effective and if done in unison with the EU…

Step 1: construct a bipartite graph

Summary Quality Measurement: *Connectivity*

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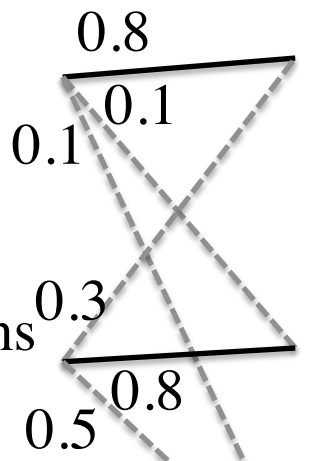

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Step 1: construct a bipartite graph
Step 2: find the best matching

Summary Quality Measurement: *Connectivity*

Article Summary ***S***

S_0: The Crimean parliament officially declared independence.

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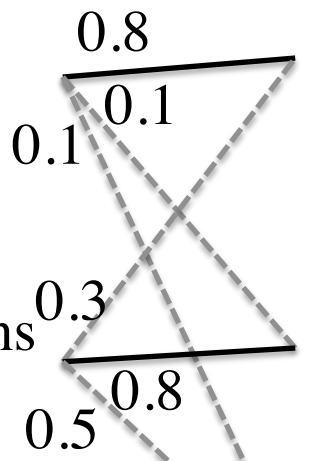

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Step 1: construct a bipartite graph
Step 2: find the best matching
Step 3: compute the connectivity

Socially-Informed Timeline Generation

$$\mathcal{Z}(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

Article Summary

- **Importance**
- **Coverage**
- **Continuity**

Comment Summary

- **Importance**

Connectivity

Socially-Informed Timeline Generation

- How to find the salient sentences and user comments?
  - *Joint Learning for Importance Estimation*
- How to measure the quality of a timeline with social context?
  - *Summary Quality Measurement*
- How to construct the timeline?
  - *An Alternating Optimization framework*

Socially-Informed Timeline Generation

- An Alternating Optimization Algorithm

$$\mathcal{Z}(S,C;\mathcal{T}) = S_{qual}(S;\mathcal{T}) + C_{qual}(C) + \delta\mathcal{X}(S,C)$$

- Idea: alternatively search for better S and C until convergence
- For each iteration
  - Fix C , find S with hill-climbing search
  - Fix S , find C with Ford-Fulkerson algorithm [Ford-fulkerson, 1956]
    - max-weight bipartite graph matching problem → max network flow problem [Kleinberg and Tardos, 2005]

Alternating Optimization Process

Initialization

- S_o by greedy algorithm
- C_o by Ford-Fulkerson algorithm

Article Summary

S1: The Crimean parliament declared independence.

S2: Barack Obama pledges to stand with Ukraine.

Comment Summary

C1: The "Crimean Parliament", headed by an ethnic Russian separatist, voted for Crimea to be annexed into Russia...

C2: Obama need to stick with America's domestic problems...

Alternating Optimization Process

Initialization

- S_o by greedy algorithm
- C_o by Ford-Fulkerson algorithm

Iterations

- S_t by Hill-climbing search

Article Summary

S1: The Crimean parliament declared independence.

~~**S2**: Barack Obama pledges to stand with Ukraine.~~

S2: EU rejected the referendum on independence in Crimea.

Comment Summary

C1: The "Crimean Parliament", headed by an ethnic Russian separatist, voted for Crimea to be annexed into Russia...

C2: Obama need to stick with America's domestic problems...

Alternating Optimization Process

Initialization

- S_o by greedy algorithm
- C_o by Ford-Fulkerson algorithm

Iterations

- S_t by Hill-climbing search

Article Summary

S1: The Crimean parliament declared independence.

S2: EU rejected the referendum on independence in Crimea.

Comment Summary

C1: The "Crimean Parliament", headed by an ethnic Russian separatist, voted for Crimea to be annexed into Russia...

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Alternating Optimization Process

Initialization

- S_o by greedy algorithm
- C_o by Ford-Fulkerson algorithm

Iterations

- S_t by Hill-climbing search
- C_t by Ford-Fulkerson algorithm

Article Summary

S1: The Crimean parliament declared independence.

S2: EU rejected the referendum on independence in Crimea.

Comment Summary

C1: The "Crimean Parliament", headed by an ethnic Russian separatist, voted for Crimea to be annexed into Russia...

~~**C2:** Obama need to stick with America's domestic problems...~~

C2: The Obama administration warned of "harsh sanctions", but it is unlikely that EU will comply...

Alternating Optimization Process

Initialization

- S_o by greedy algorithm
- C_o by Ford-Fulkerson algorithm

Article Summary

S1: The Crimean parliament declared independence.

S2: EU rejected the referendum on independence in Crimea.

Iterations

- S_t by Hill-climbing search
- C_t by Ford-Fulkerson algorithm

Comment Summary

C1: The "Crimean Parliament", headed by an ethnic Russian separatist, voted for Crimea to be annexed into Russia…

C2: The Obama administration warned of "harsh sanctions", but it is unlikely that EU will comply…

Outline

- **Related Work**
- **Methodology**
  - *Socially-Informed Timeline Generation*
- **Experimental Setup**
  - *Data Collection*
- **Evaluation**
  - *Intrinsic and Extrinsic Evaluation*
- **Conclusion**

Data

- Articles and User Comments
  - Sources
    - New York Times (NYT)
    - CNN
    - BBC
  - Events
    - Missing Malaysia Airlines flight MH370
    - Political unrest in Ukraine
    - Israel-Gaza conflict
    - NSA surveillance leaks

Data

	Time Span	# Articles	# Comments
Missing Flight MH370	03/08-06/30	955	406,646
Ukraine Crisis	03/08-06/30	3,779	646,961
Israel-Gaza Conflict	07/20-09/30	909	322,244
NSA surveillance leaks	03/23-06/30	145	60,481

Outline

- **Related Work**
- **Methodology**
  - *Socially-Informed Timeline Generation*
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  - *Data Collection*
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  - *Intrinsic and Extrinsic Evaluation*
- **Conclusion**

Experiments

- **Question 1: Article Summary Quality**

Do socially-informed timeline generation systems produce more informative summaries?

- **Question 2: Comment Summary Quality**

Do comment summaries provide additional insights?

- **Question 3: Event Thread Quality**

Can event threads allow users to easily locate and absorb information?

Experiment 1: Article Summary Quality

- Gold-standard timelines
  - Wikipedia pages
  - New York Times/BBC topic page
- Automatic evaluation metric
  - ROUGE scores [Lin and Hovy, 2003] : ngrams recall
- Comparisons
  - Chieu and Lee, 2004: "*burstiness*" or "*interestingness*"
  - Yan et al, 2011: "*coverage*", "*diversity*", and "*coherence*"
  - Single-article abstracts

Experiment 1: Article Summary Quality

	Missing Flight	Ukraine Crisis	Israel -Gaza	NSA
Comparisons: *no social context*				
• **Chieu and Lee**	10.89	8.87	**7.32**	9.73
• **Yan et al.**	10.35	8.67	5.78	7.73
• **Single-article abstract**	10.62	8.40	5.42	8.65
Our Systems				
• **No Alternating OPT**	10.86	9.75	6.16	10.09
• **With Alternating OPT**	**11.63**	**12.72**	6.38	**10.36**

ROUGE scores (×100): larger numbers → better performance

Experiment 2: Comment Summary Quality

- Amazon Mechanical Turk on ranking tasks
  - Informativeness
  - Insightfulness
- Comparisons:
  - Random
  - Users' picks (ranked by positive ratings)
  - Editors' picks
- 15 randomly selected timelines
  - Each is evaluated by four people

Experiment 2: Comment Summary Quality

	Informativeness		Insightfulness	
	% Best	Average Rank	% Best	Average Rank
Random	1.7%	3.67	3.3%	3.58
User's-picks	5.0%	2.83	15.0%	2.55
Editor's picks	26.7%	2.05	30.0%	2.22
Our system	**66.7%**	**1.45**	**51.7%**	**1.65**

Inter-annotator agreement by Krippendorff's α

- *Informativeness*: 0.63
- *Insightfulness*: 0.50

Experiment 3: Event Thread Quality

- 10-day timeline is randomly selected per dataset.
- Design one question
  - "*describe the activities for searching for the missing flight MH370*"
- 10 undergraduate and graduate students (native speakers of English):
  - Read the question and the timeline for 5 minutes
  - Write down an answer after removing the timeline
- For each student, 2 timelines are displayed with threads, and the other 2 are not.

Experiment 3: Event Thread Quality

- Amazon Mechanical Turk to evaluate the informativeness of students' answers
  - read all 10 answers for the same question
  - Rate informativeness on 1-to-5 scale

Answer Type	Mean ± STD	Rated 5 (%)	Rated 4 (%)
No Thread	2.6 ± 1.2	7%	23%
With Thread	**3.3** ± 1.3	17%	26%

Article Summary

March 17th, 2014
Obama administration froze the U.S. assets of seven Russian officials, while similar sanctions were imposed on four Ukrainian officials…

March 18th, 2014
Ukraine does not recognize a treaty signed in Moscow on Tuesday making its Crimean peninsula a part of Russia…

March 19th, 2014
The head of NATO warned on Wednesday that Russian President Vladimir Putin may not stop with the annexation of Crimea…

March 20th, 2014
The United States on Thursday expanded its sanctions on Russians…

Comment Summary

Theodore Roosevelt said that the worst possible thing you can do in diplomacy is "soft hitting". That is what the US and the EU are doing in these timid "sanctions"…

Though there were many in Crimea who supported annexation, there were certainly some who did not. What about those people?…

If you look at a real map , Crimea is an island and has always been more connected to Russia than to Ukraine…

The US and EU should follow up economic sanctions with concrete steps to strengthen NATO…

Conclusion

- We present a socially-informed timeline generation system.
- We describe a joint learning-based approach to identify important sentences and comments.
- We propose an alternating optimization framework to construct topic-relevant timelines.

Thank you! Questions?

Datasets:
http://www.cs.cornell.edu/~luwang