Leibniz Universität Hannover

Fakultät für Elektrotechnik und Informatik
Institut für Verteilte Systeme
Fachgebiet Wissensbasierte Systeme (KBS)

Seminar: Topics in Data Mining

Summer Semester 2016

STREAMCUBE: Hierarchical Spatio-temporal Hashtag Clustering for Event Exploration over the Twitter Stream

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M.Sc. ITIS

27th June 2016

Overview

- Introduction
- Event as a cluster of hashtags
- Data warehousing structure
- Hashtag clustering
- Event ranking
- Experimental study
- Conclusion

Introduction

- Twitter : Most famous microblogging website
- Over a billion tweets posted per week
- Each tweet: 140 characters
- Tweet composition:
  - Text
  - Link to author
  - Hashtags (words preceded by '#')
  - Usertags
  - Timestamp
  - Links to external resources
- Geo-tagging of tweets

Sample Tweet Record

Event as a Cluster of Hashtags

- Twitter Users: Post updates on ongoing events
- Detect events in real time
- Analyze long-term events
- Event as a cluster of hashtags
- Syrian Uprising of 2012[1]
  - #Bashar
  - #Assad
  - #AssadCrime
  - #GenocideInSyria
  - #RiseDamascus

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Data Warehousing Structure

- STREAMCUBE: Data Cube Structure[3] extension
- Explore events along
  - Time dimension
  - Space dimension
- Data arrangement in real time
- Rank events in real time using
  - Popularity
  - Burstiness
  - Localness

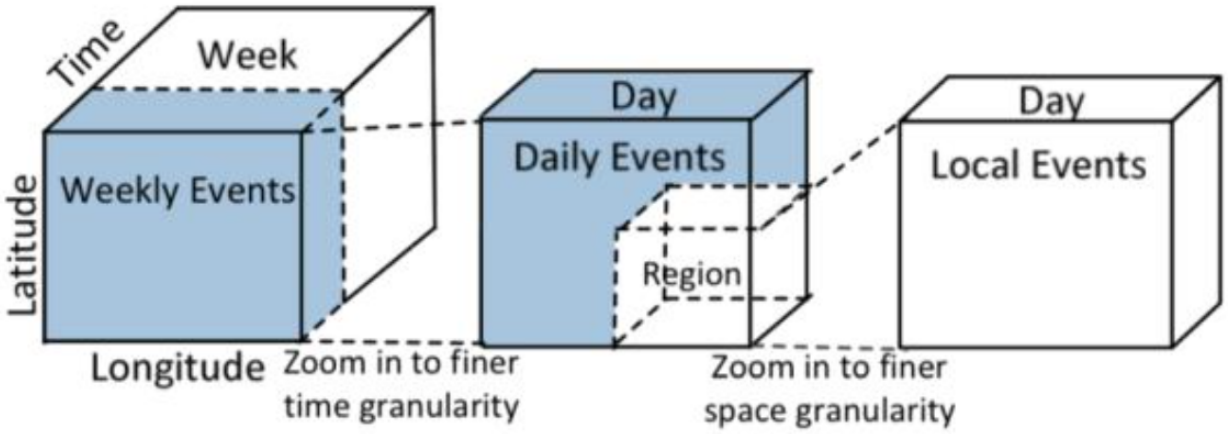

Fig. 1. Zoomable Event Cube[2]

Data Warehousing Structure

- Event Cube structure: Spatio-temporal aggregation
- Space Hierarchy
  - Entire global space
  - Quad Tree like hierarchy
  - Country, city and district
- Time Hierarchy
  - Coarsest granularity: 24 hrs
  - Finest granularity: 6 hrs
- Space Hierarchy embed in Time Hierarchy
- Current 6 hr frame: Main Memory
- Older frames: Disk Storage

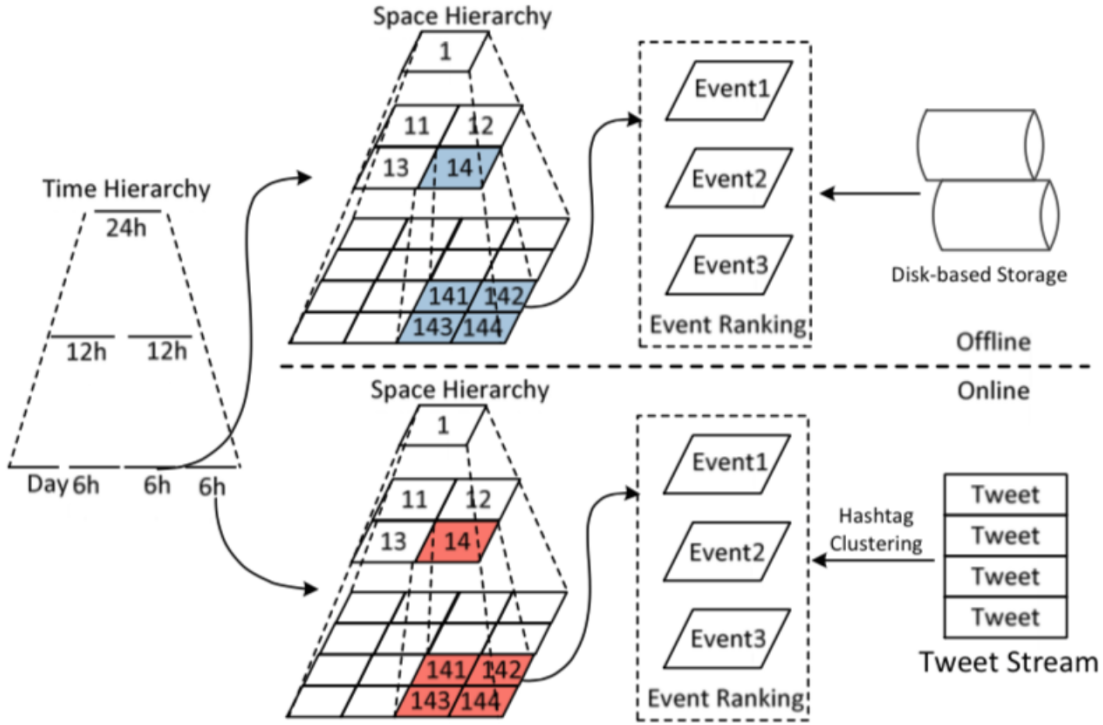

Fig. 2. Framework[2]

Data Warehousing Structure

- Connecting Space and Time Hierarchy
- Creating New Cubes
  - Assigning tweet to lowest hierarchy
  - Mapping to global snapshot in current time frame
  - Diff. tweets, diff. regions: Parallel Mapping
- Spatial Merge
  - All sub-regions combined into a region
  - Current as well as previous cube
- Temporal Merge
  - Matching same regions of current & previous 6 hr frame
  - Current 12 hr frame merged with previous 12 hr frame

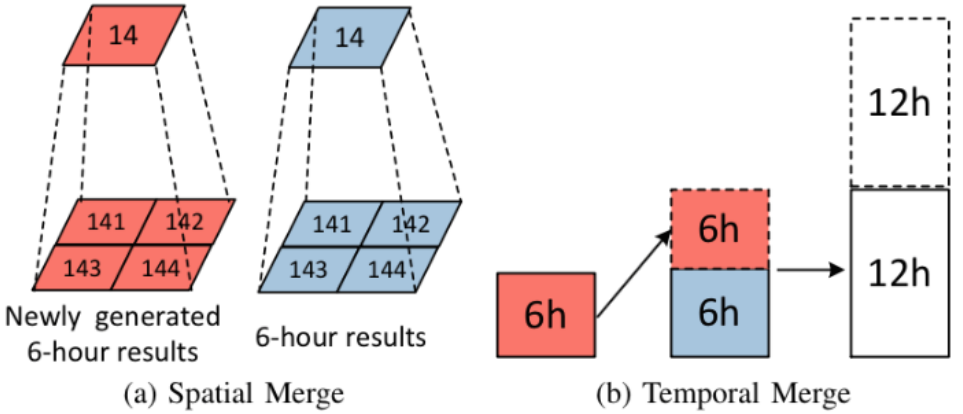

Fig. 3. Spatio-temporal aggregation[2]

Hashtag Clustering

- **Major Challenge**: Hashtags are not Static Data Points

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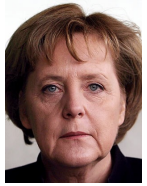
#merkel



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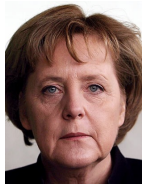

#hannovermesse

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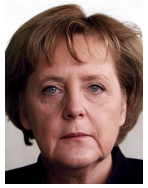

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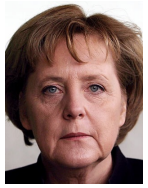

Merkel's Visit to Hannover Messe

Hashtag Clustering

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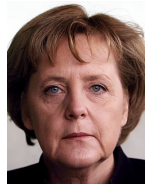
#merkel #hannovermesse



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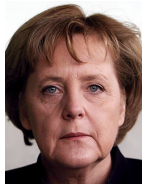

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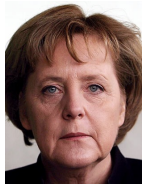


Angela Merkel on UK's exit from EU

#hannovermesse

Merkel's Visit to Hannover Messe

Hashtag Clustering

Other Challenges:

- Avoiding Iterative Computation
  - Single-Pass Algorithm
  - Little Cost for merging events
- Clear understanding of
  - Localness
  - Burstiness
  - Popularity
- Users interested in
  - Breaking News
  - Past Year's Events
  - Local News
  - Global News

Breaking News Vs. Past Year's Events

Global News Vs. Local News

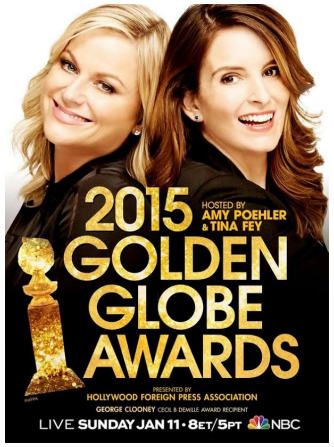
Hashtag Clustering

Hashtag Representation and Similarity:

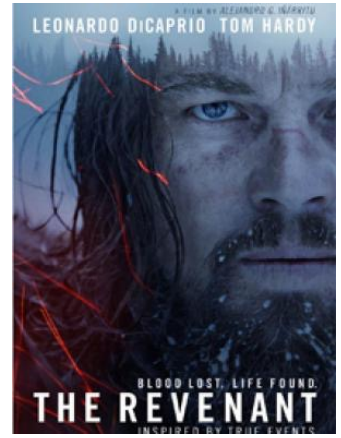
- Hashtag as a Bag of Words
  - Collect all tweets containing hashtag h
  - Identify words in tweets important for hashtag
  - Hashtag h as Normalized Weighted Vector

    $h_{word} = (w_1, w_2, \ldots, w_{|W|})$ & $||h_{word}|| = 1$

- #GoldenGlobes
  - Movies: The Revenant, The Martian
  - Actors: Leonardo DiCaprio, Matt Damon
  - Actresses: Brie Larson, Jennifer Lawrence



Golden Globes 2015

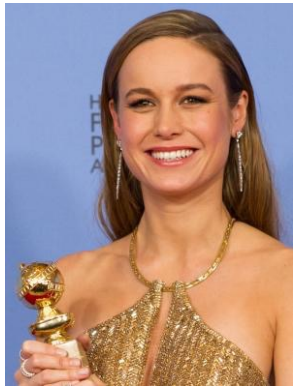


The Revenant

The Martian


Matt Damon


Leonardo DiCaprio


Brie Larson

Jennifer Lawrence

Hashtag Clustering

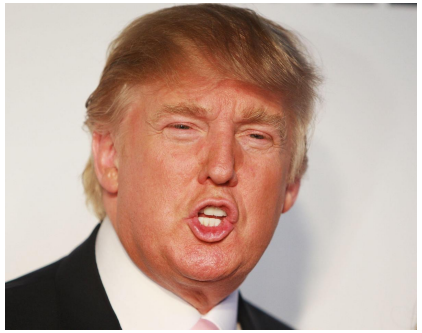
Hashtag Representation and Similarity:

- Hashtag as a Bag of Hashtags
  - Hashtag describing an event co-occur with each other
  - Hashtag set H and hashtag h

    $h_{tag} = (h_1, h_2, \ldots, h_{|H|})$ & $||h_{tag}|| = 1$

- US Presidential Elections 2016
  - #Trump2016
  - #Hillary2016
  - #Sanders
  - #USElections2016

US Presidential Elections 2016



Donald Trump

Bernie Sanders

Hillary Clinton

Hashtag Clustering

Hashtag Representation and Similarity: What to use ?

- Use Combination of both
  - Hashtag as bag of words
  - Hashtag as bag of hashtags
- Given two hashtags h_1 and h_2, their similarity can be calculated as follows
  - $\alpha + \beta = 1$
  - $\beta = 0.7$
  - System gives more weight to hashtags than extracted words

$$
\begin{aligned}
sim(\mathbf{h}_1, \mathbf{h}_2) &= \alpha \cdot cos(\mathbf{h}^1_{word}, \mathbf{h}^2_{word}) + \beta \cdot cos(\mathbf{h}^1_{tag}, \mathbf{h}^2_{tag}) \\
&= \alpha \frac{\mathbf{h}^1_{word}, \mathbf{h}^2_{word}}{||\mathbf{h}^1_{word}|| \cdot ||\mathbf{h}^2_{word}||} + \beta \frac{\mathbf{h}^1_{tag}, \mathbf{h}^2_{tag}}{||\mathbf{h}^1_{tag}|| \cdot ||\mathbf{h}^2_{tag}||} \\
&= \alpha \sum_{i=1}^{|W|} w^1_i w^2_i + \beta \sum_{i=1}^{|H|} h^1_i h^2_i \\
&= (\alpha^{\frac{1}{2}} \mathbf{h}^1_{word}, \beta^{\frac{1}{2}} \mathbf{h}^1_{tag}) \cdot (\alpha^{\frac{1}{2}} \mathbf{h}^2_{word}, \beta^{\frac{1}{2}} \mathbf{h}^2_{tag})
\end{aligned}
$$

Hashtag Clustering

Hashtag Representation and Similarity:

- What does the system do?
  - Normalized word weighted vector for hashtag **h**
  - Normalized hashtag weighted vector for hashtag **h**
  - Re-normalization using combination of both for finding similarity between hashtags
  - Hashtag can be finally represented as the vector:

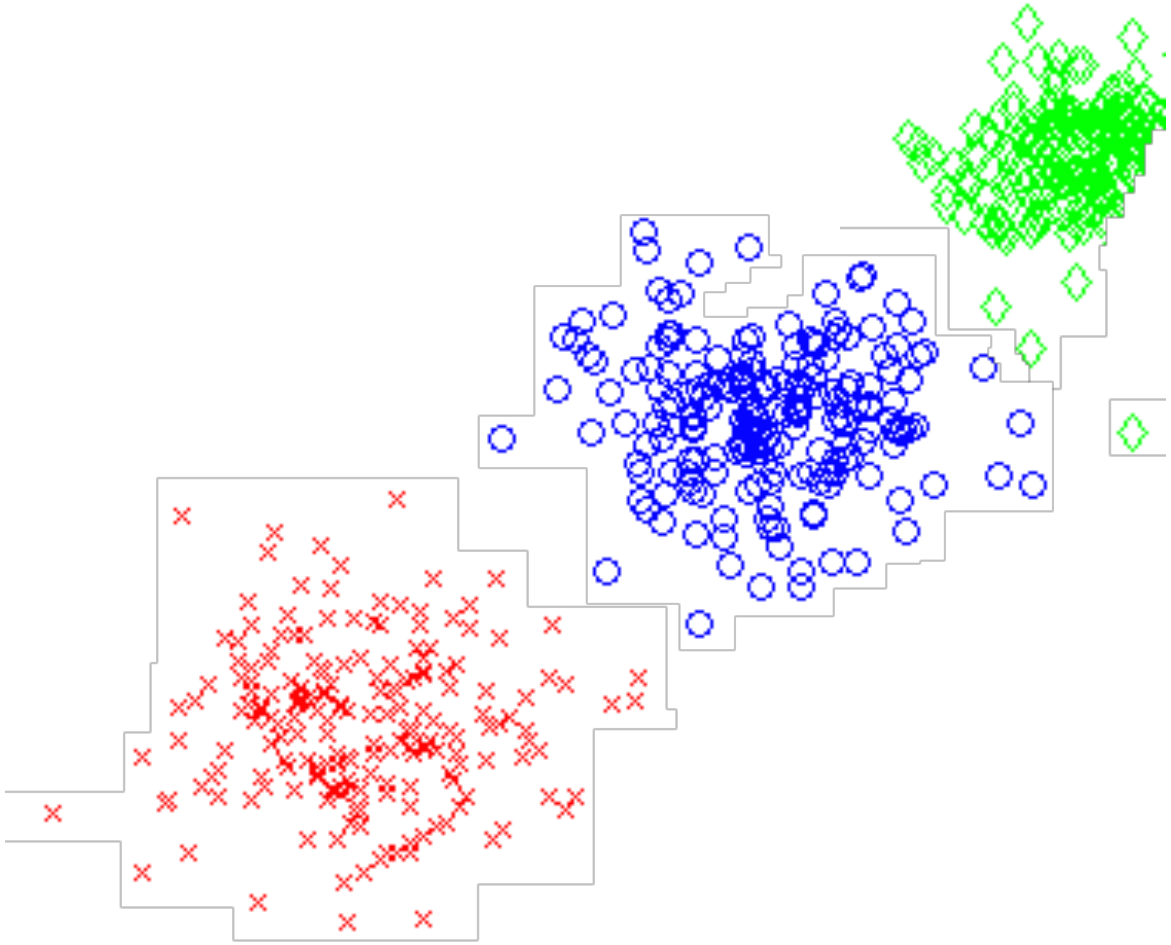
$$\mathbf{h} = (\alpha^{\frac{1}{2}}\mathbf{h}_{word}, \beta^{\frac{1}{2}}\mathbf{h}_{tag})$$

- Event Representation
  - Event: Group of Hashtags
  - Can be represented in the same way as hashtags, i.e.,

$$\mathbf{e} = (\alpha^{\frac{1}{2}}\mathbf{e}_{word}, \beta^{\frac{1}{2}}\mathbf{e}_{tag})$$

Hashtag Clustering

Part Of Vector Space (22-24. April 2016)



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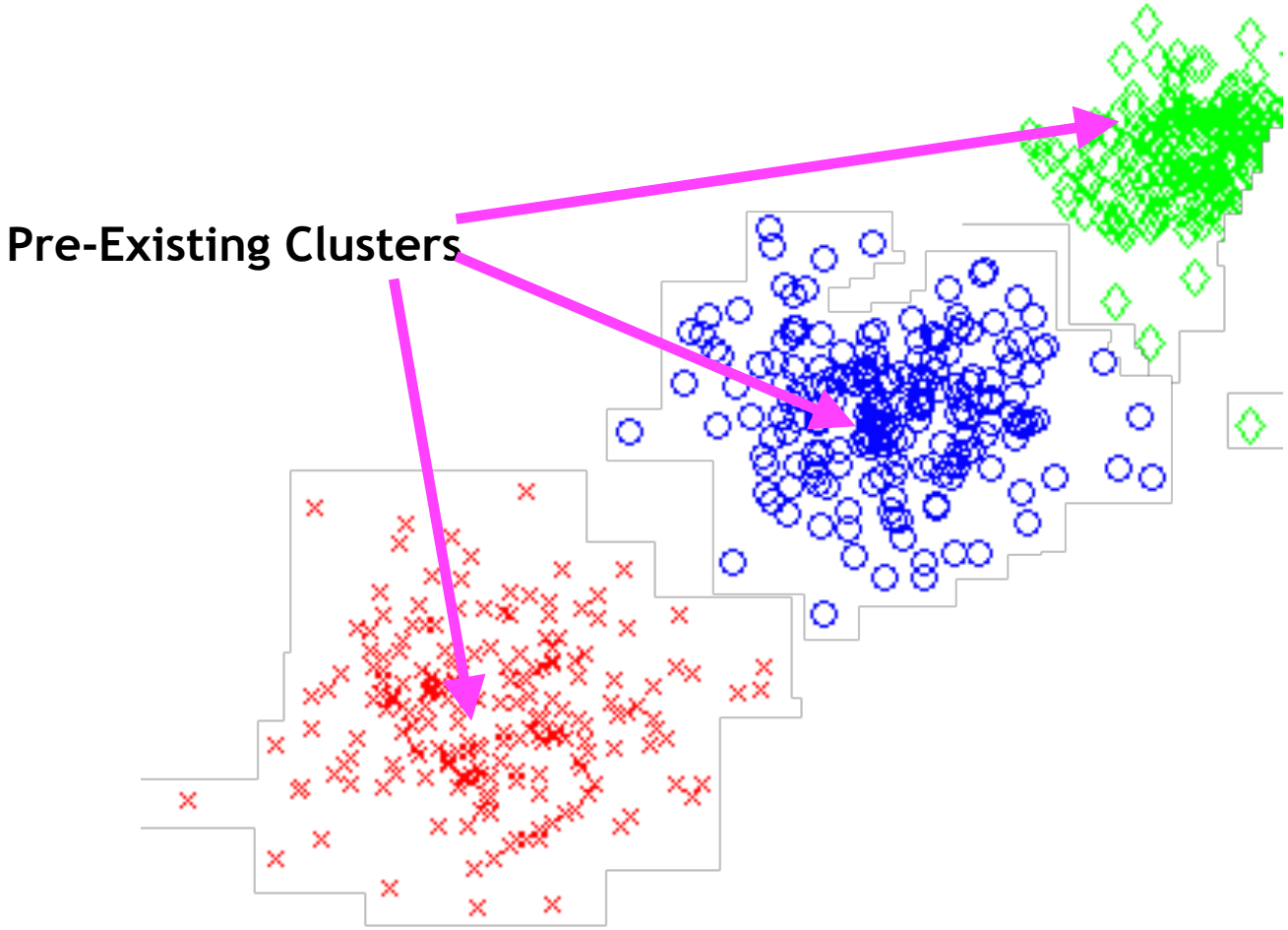

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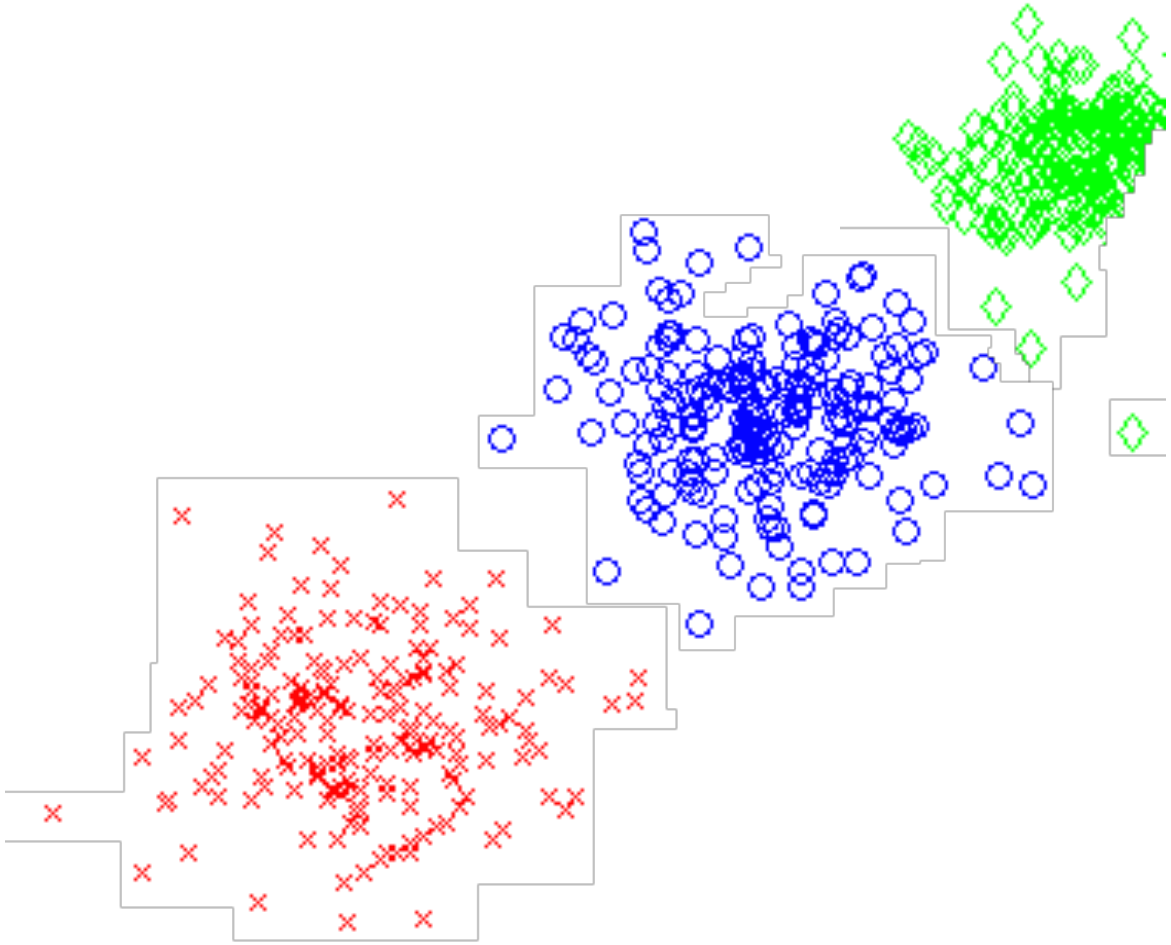

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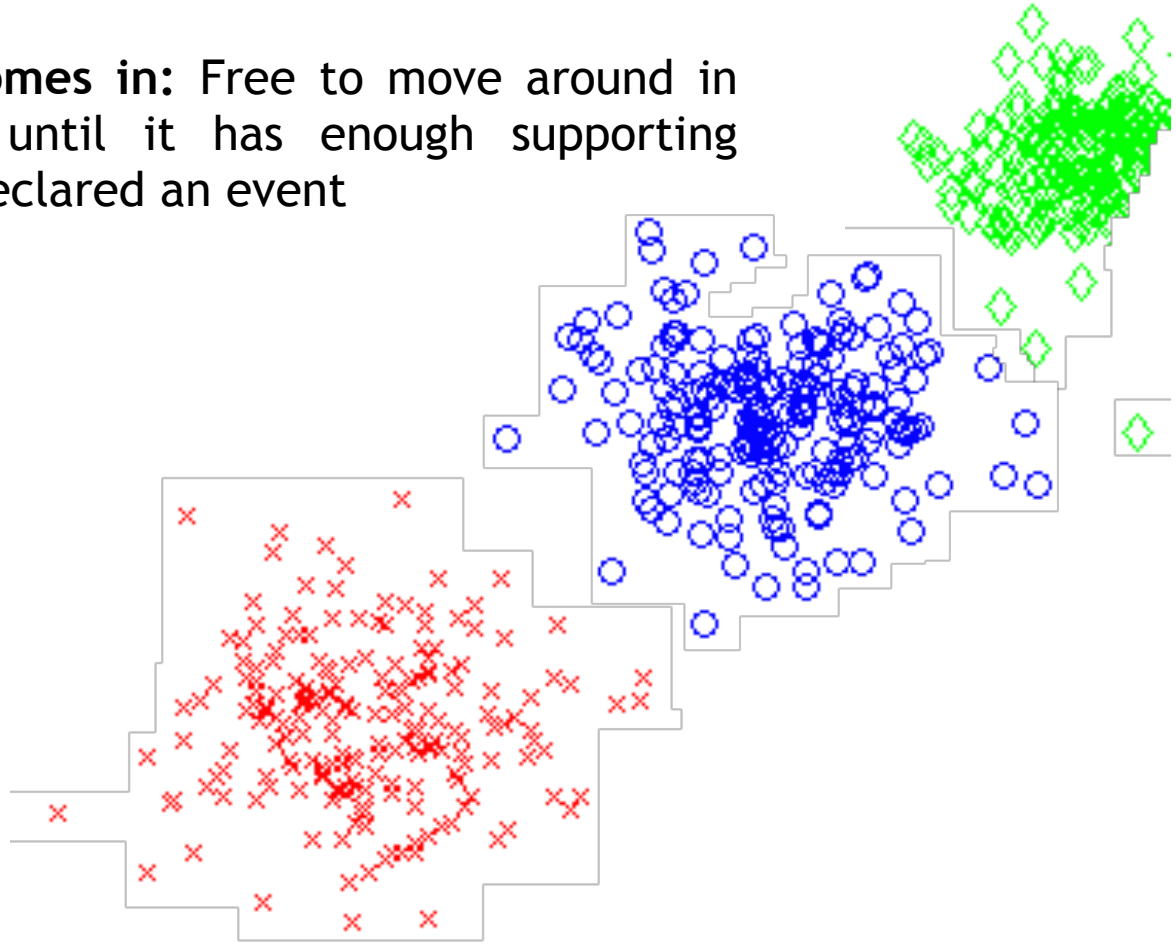

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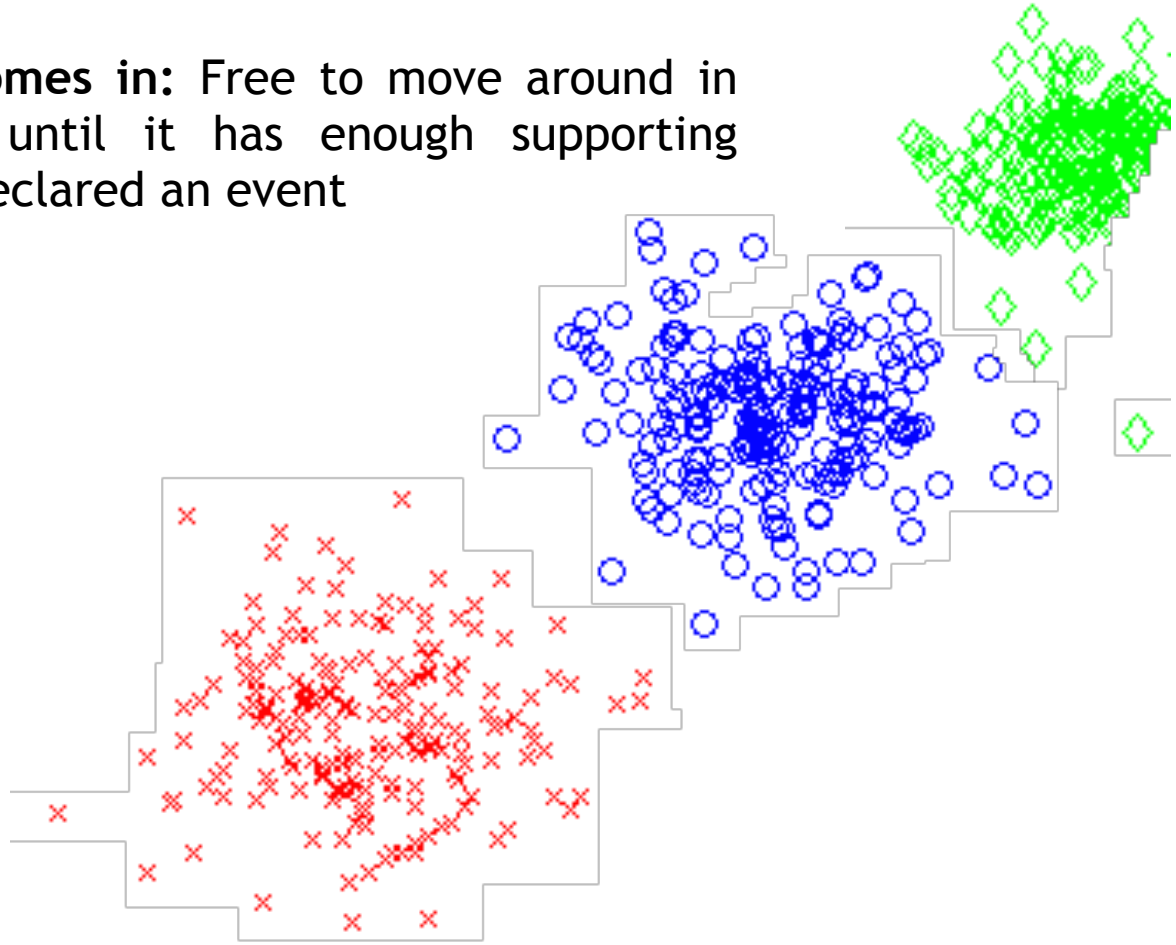

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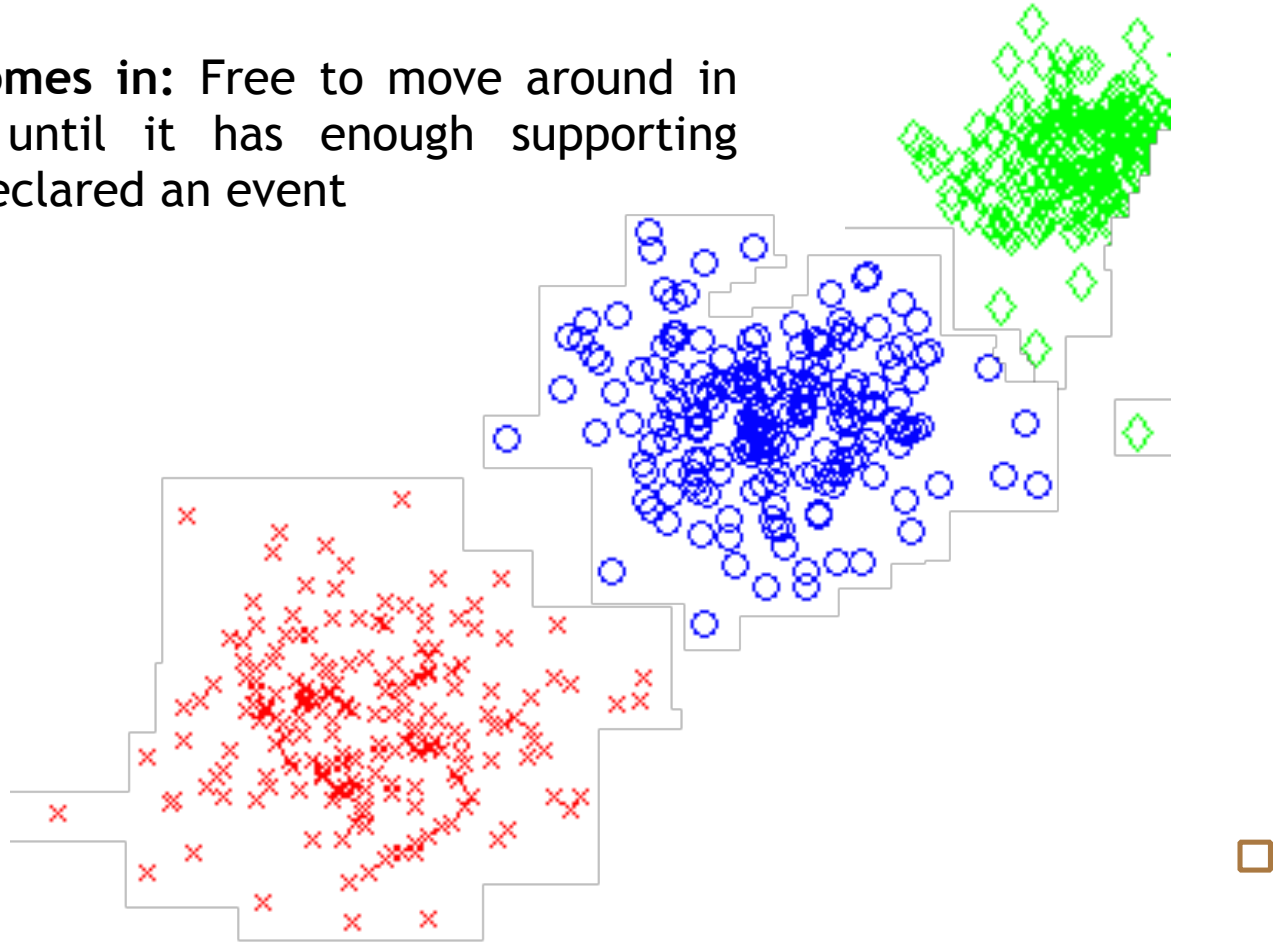

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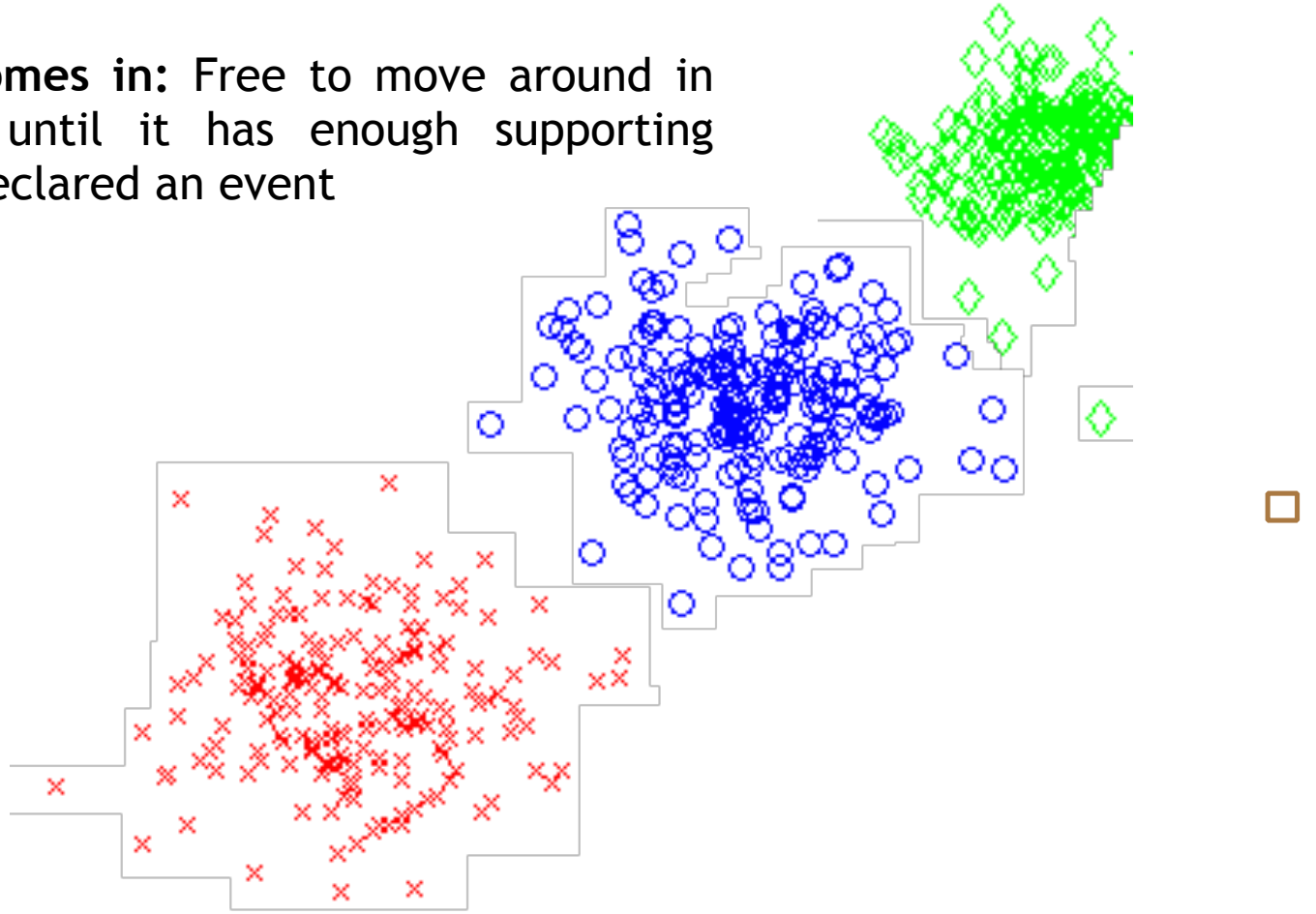

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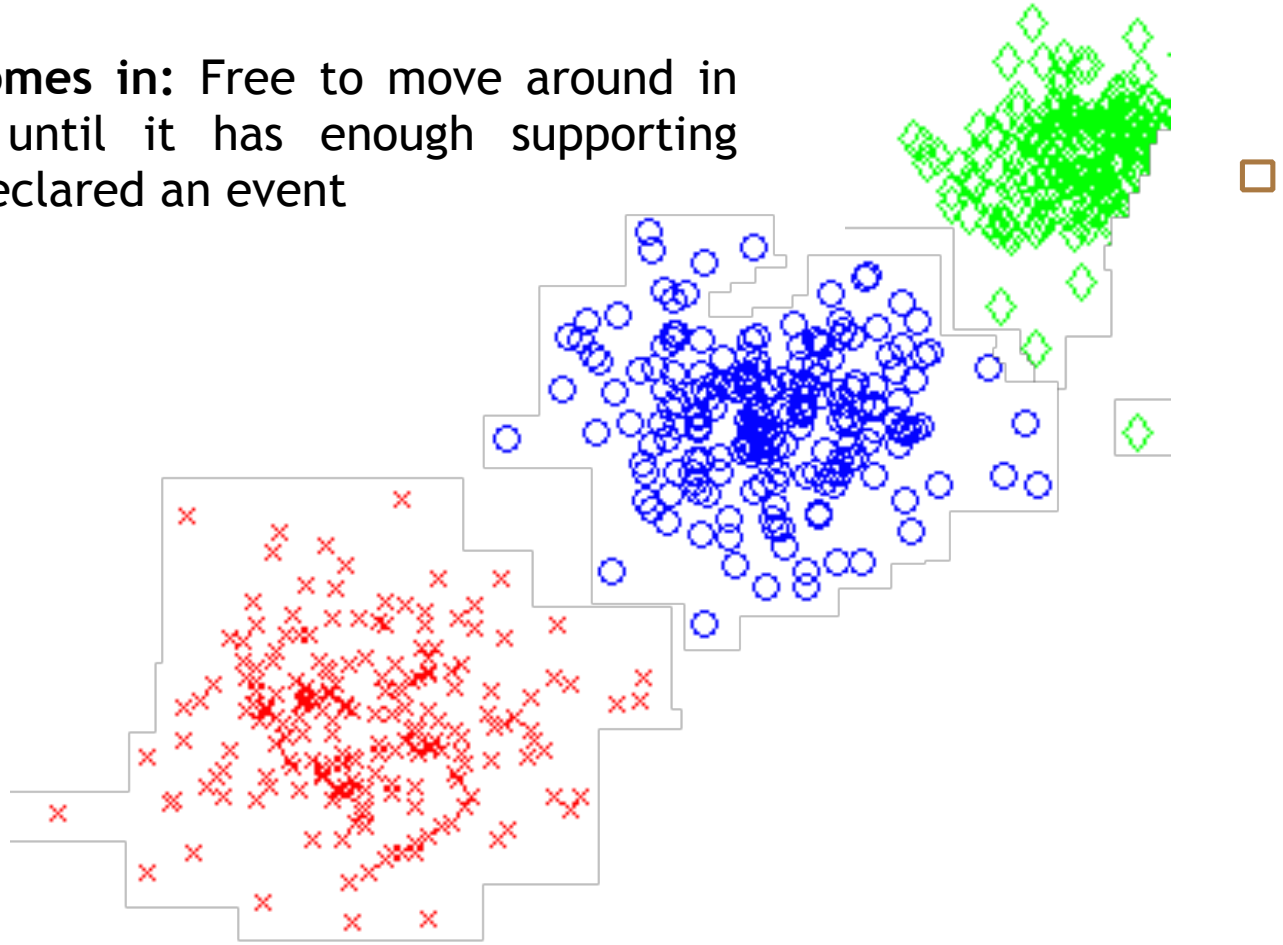

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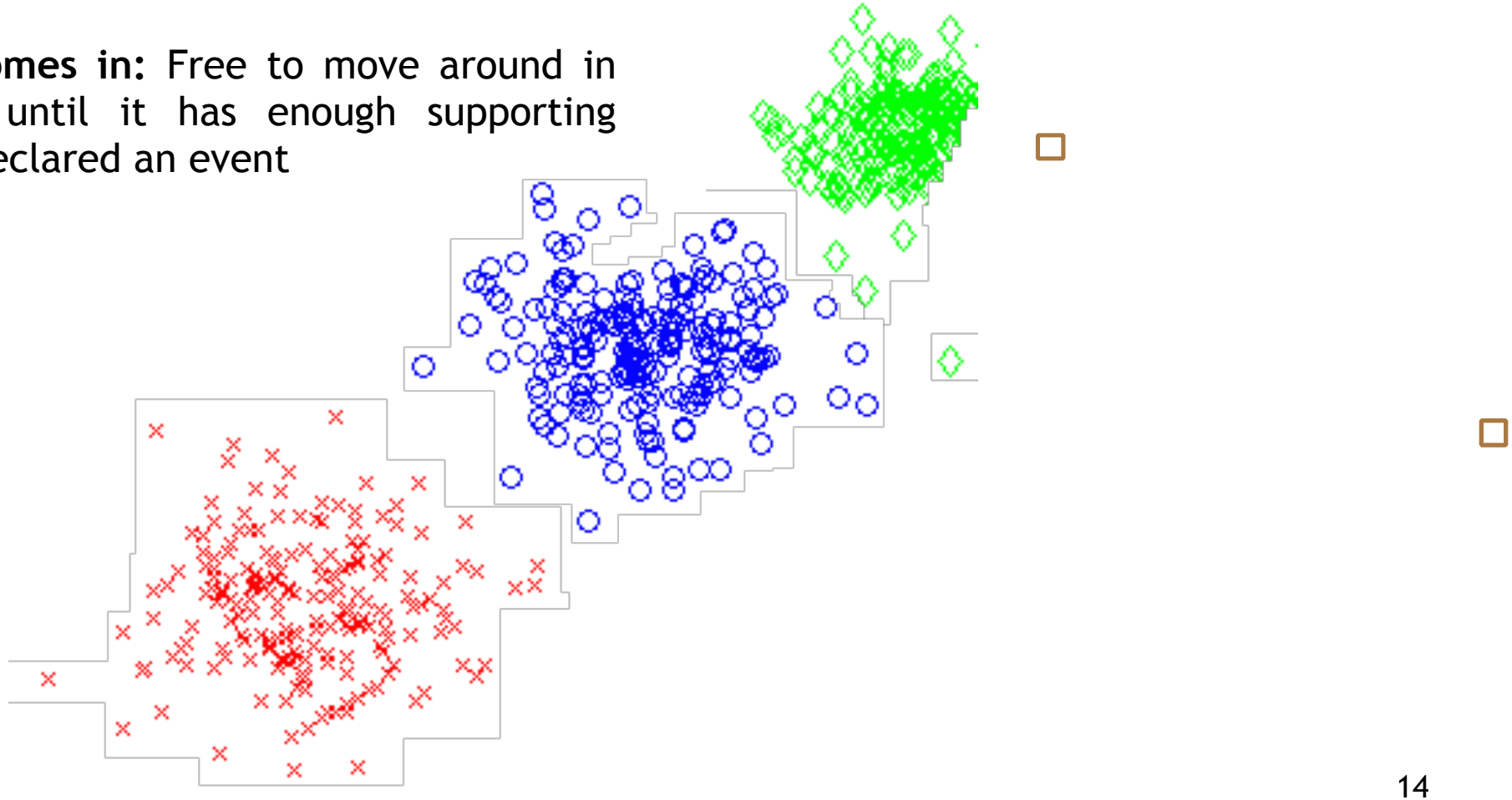

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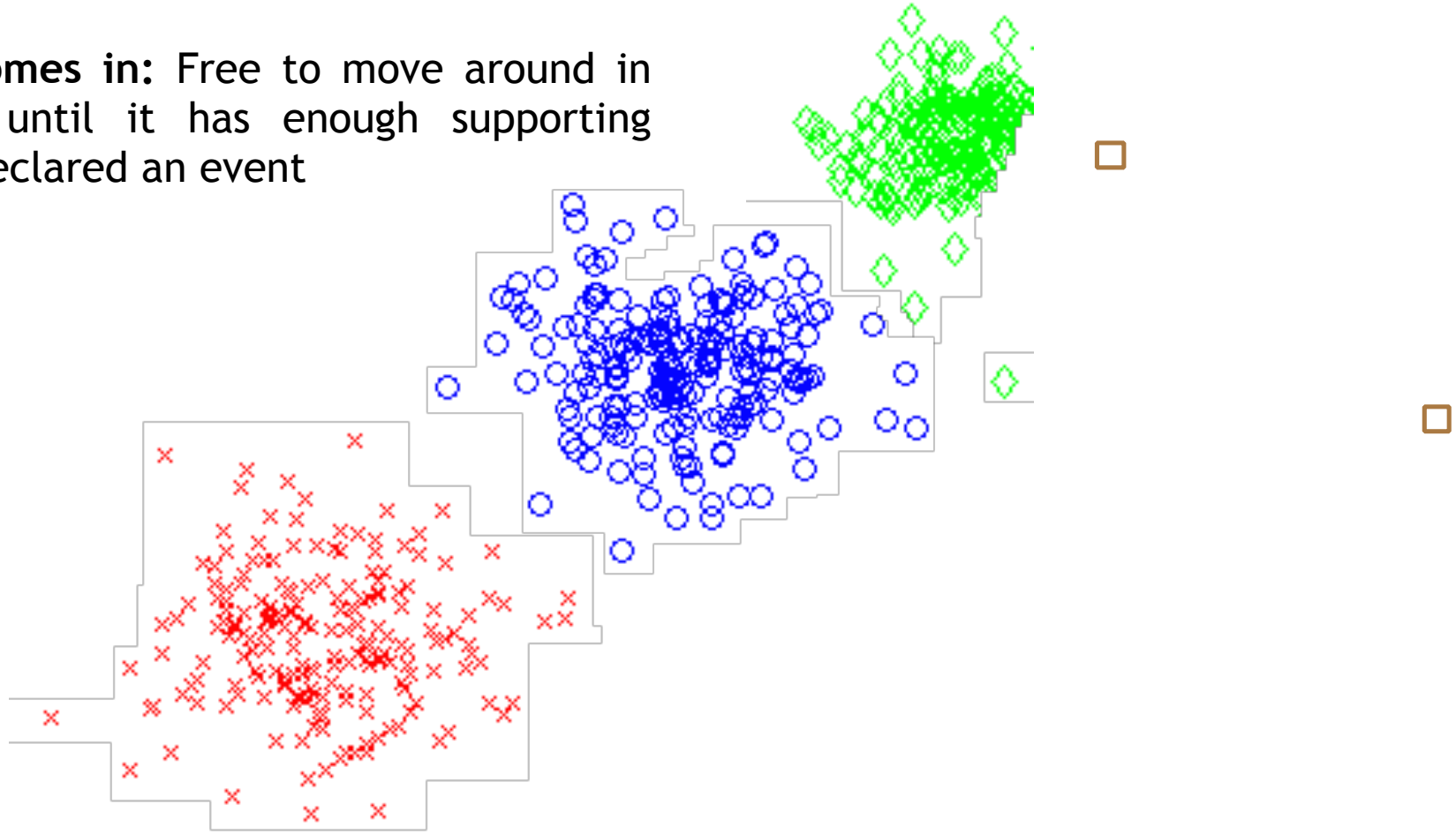

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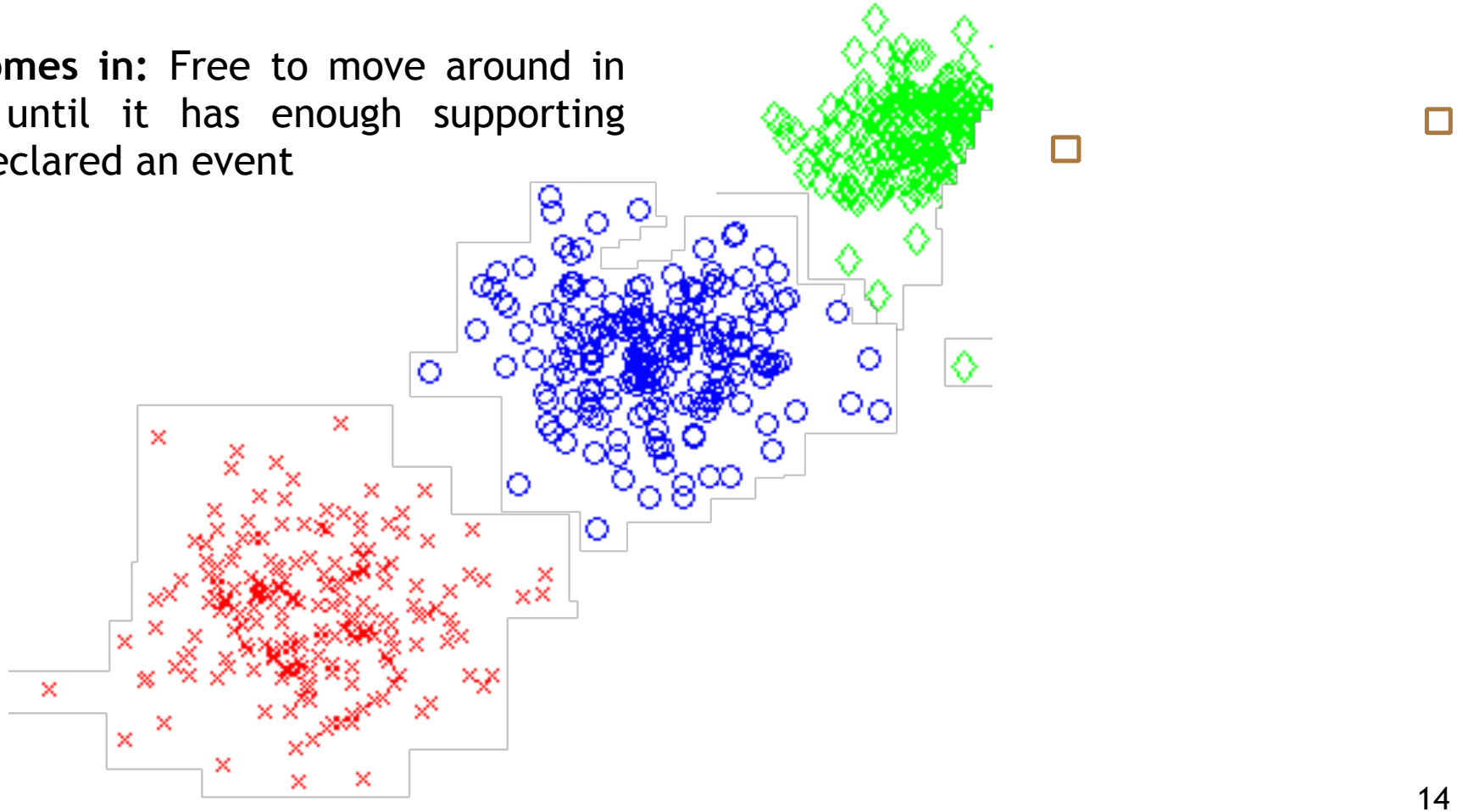

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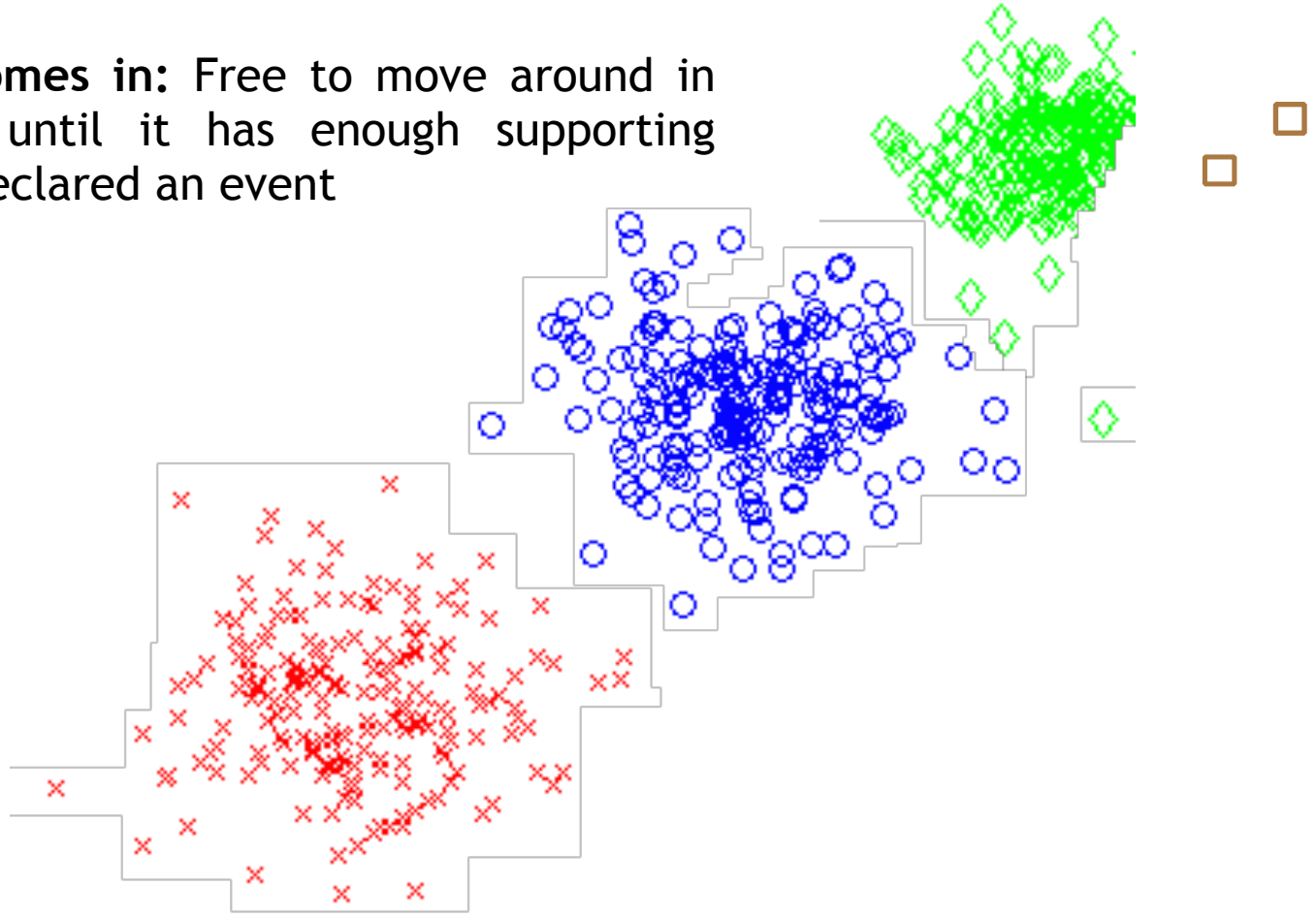

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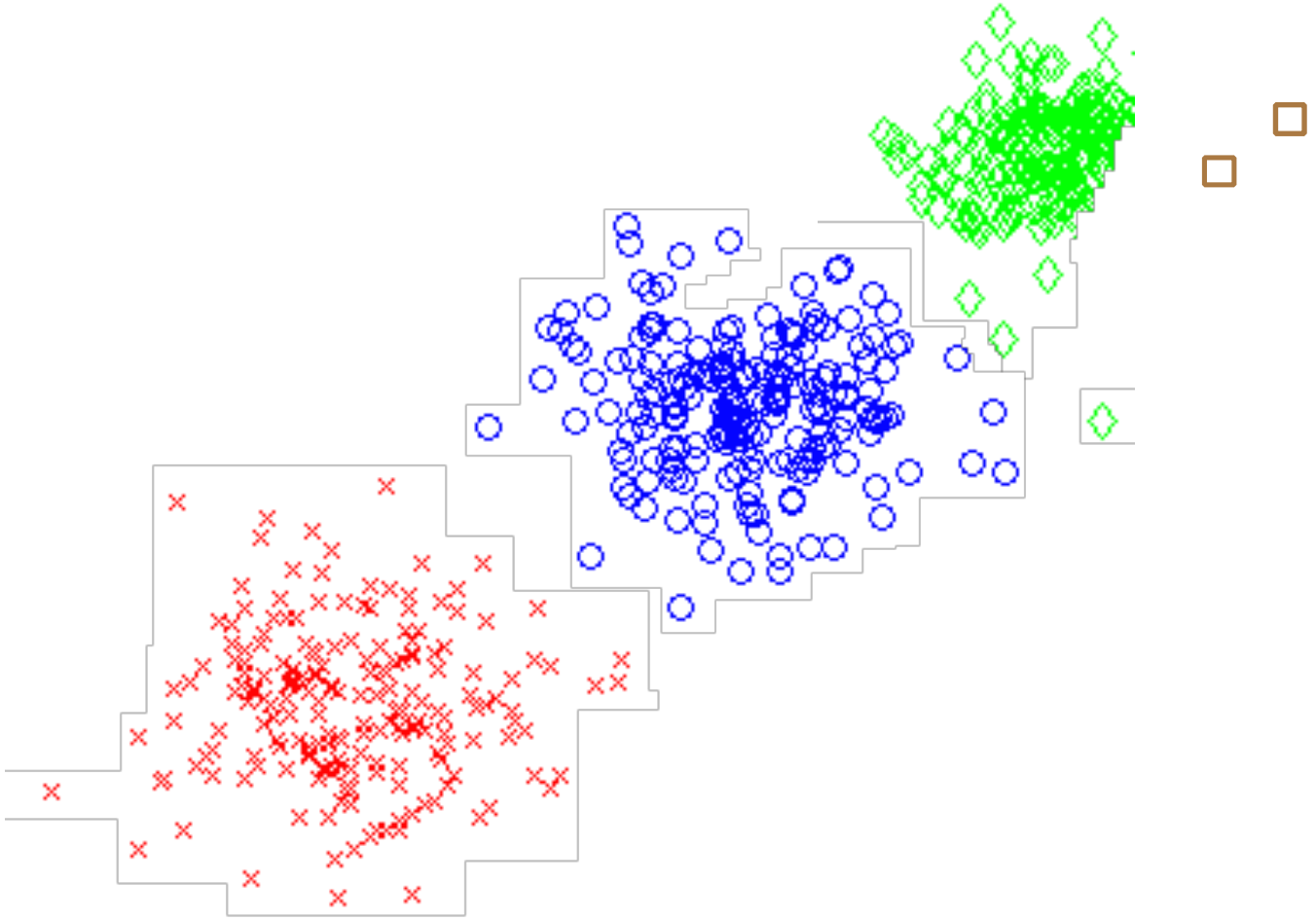

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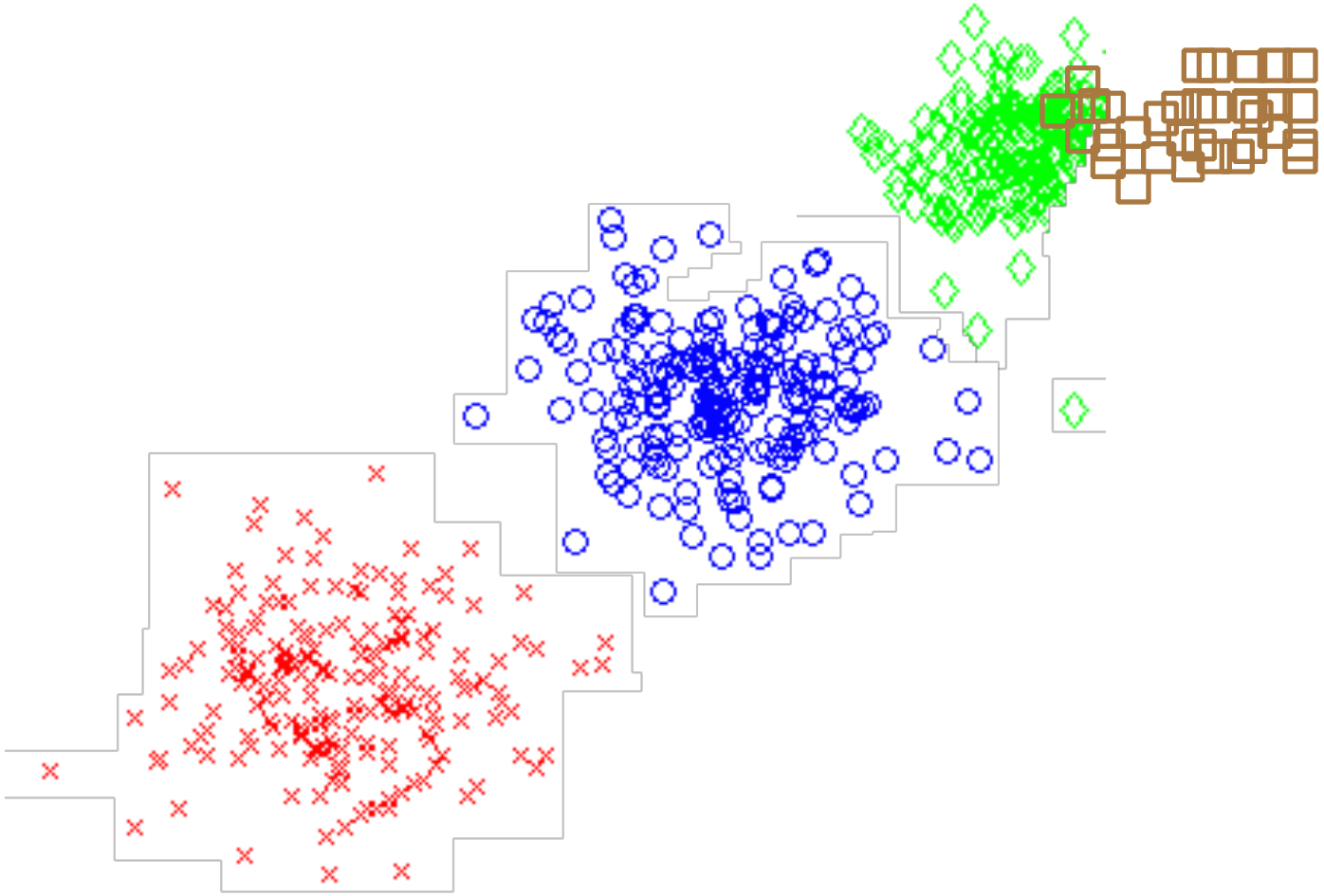

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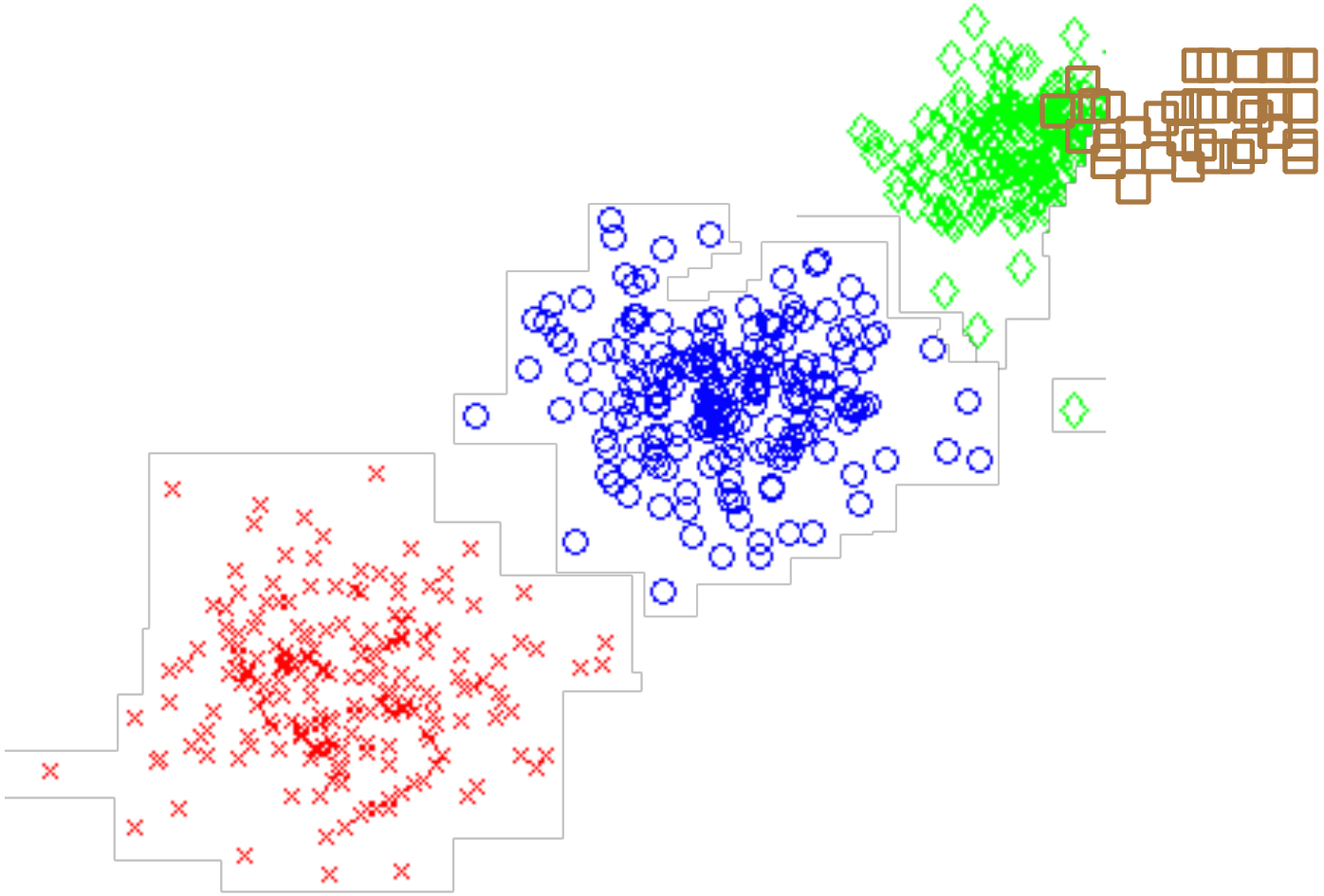

Event > 30 Tweets

Hashtag Clustering

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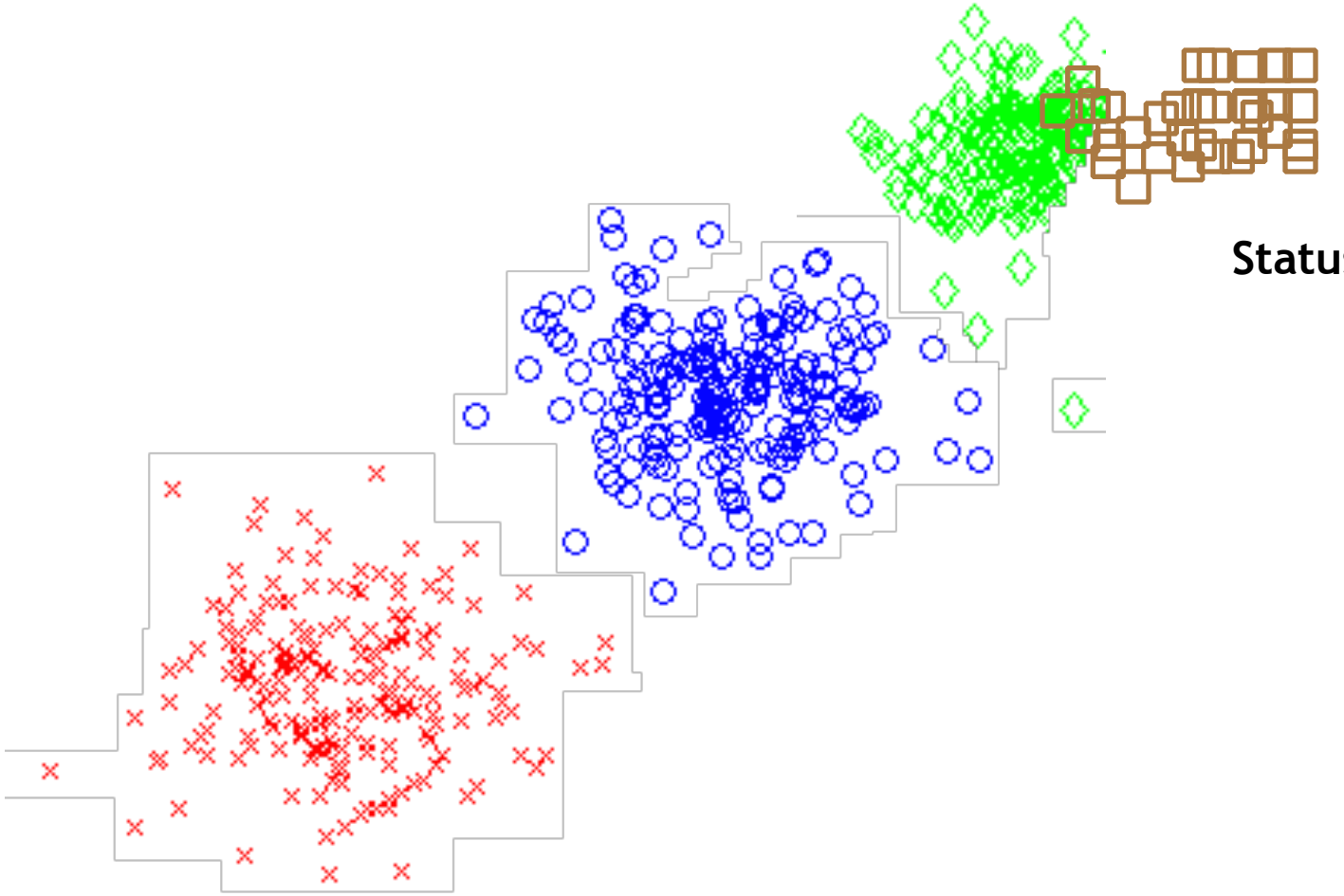

Event > 30 Tweets

Status Change: Inactive to Active

Hashtag Clustering

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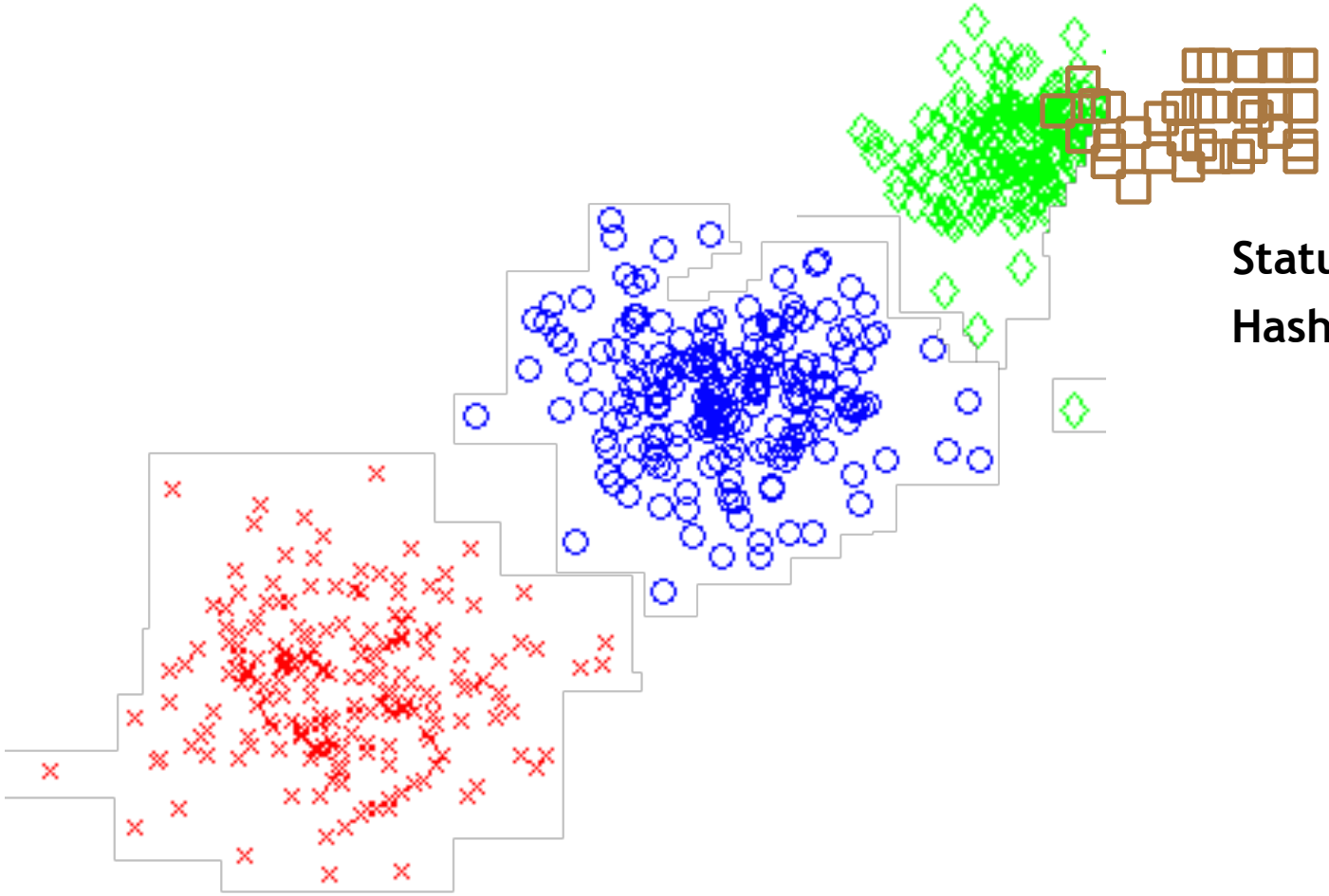


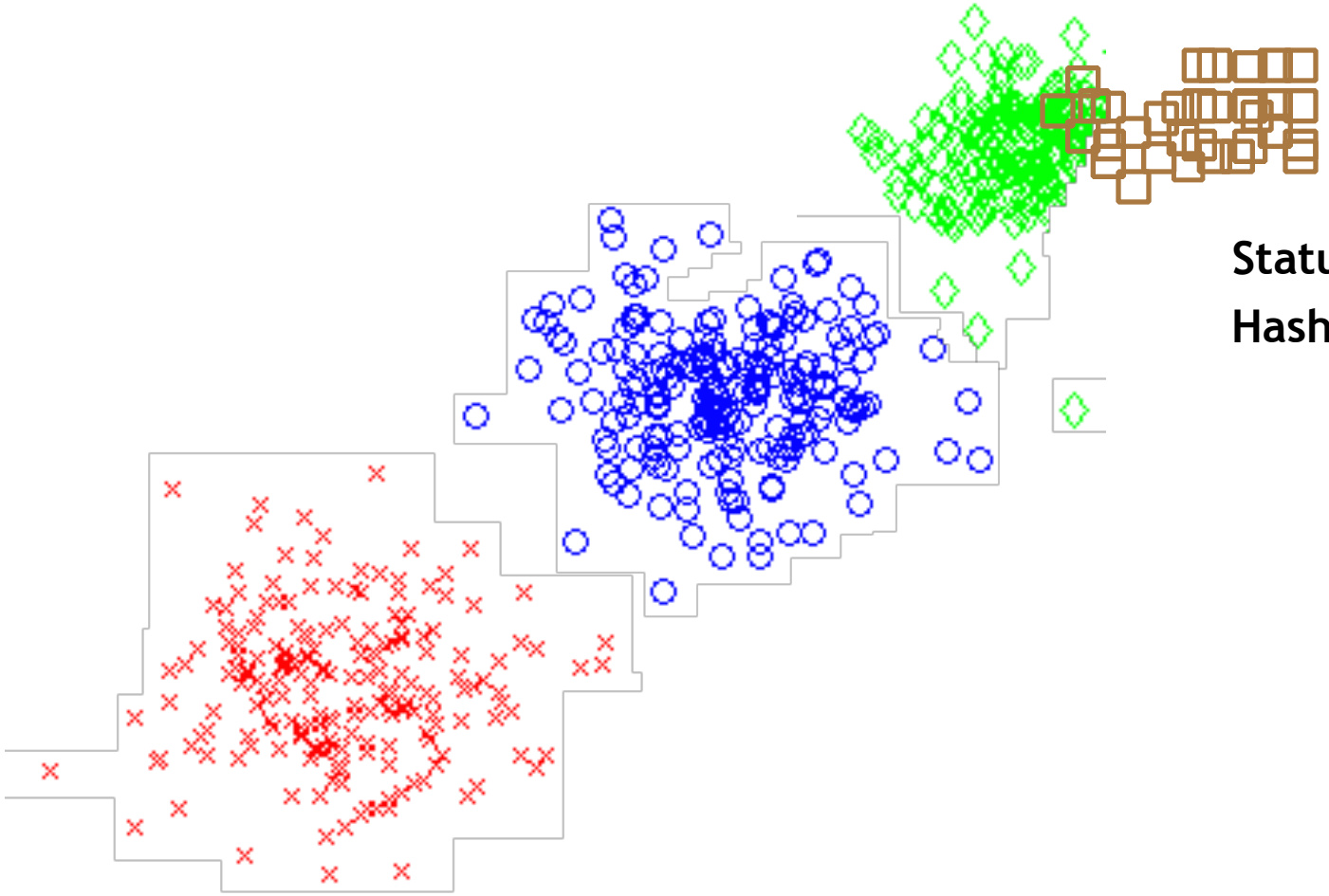
Event > 30 Tweets

Status Change: Inactive to Active

Hashtags: Dynamic to Static

Hashtag Clustering

Part Of Vector Space (22-24. April 2016)

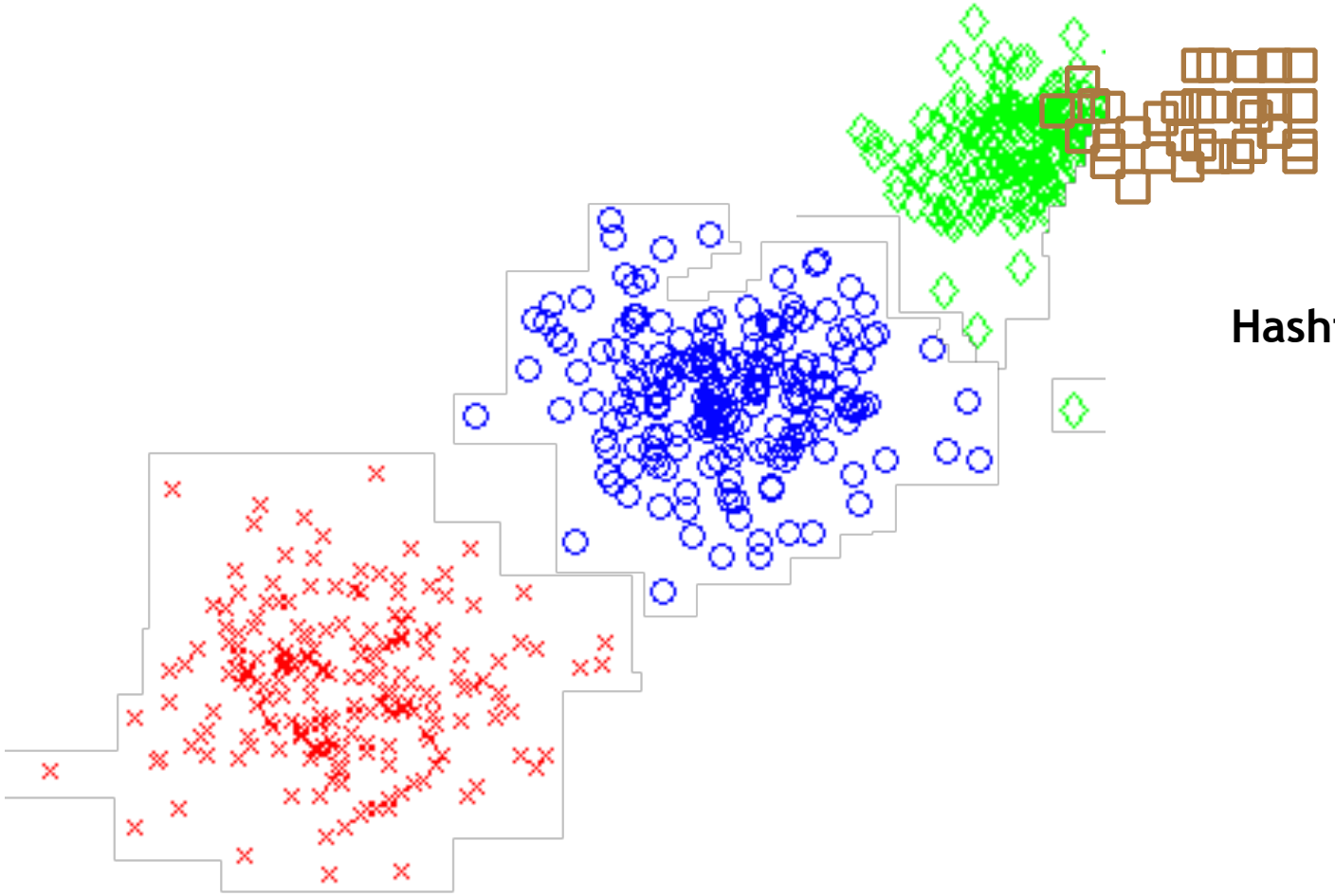


Status Change: Inactive to Active

Hashtags: Dynamic to Static

Hashtag Clustering

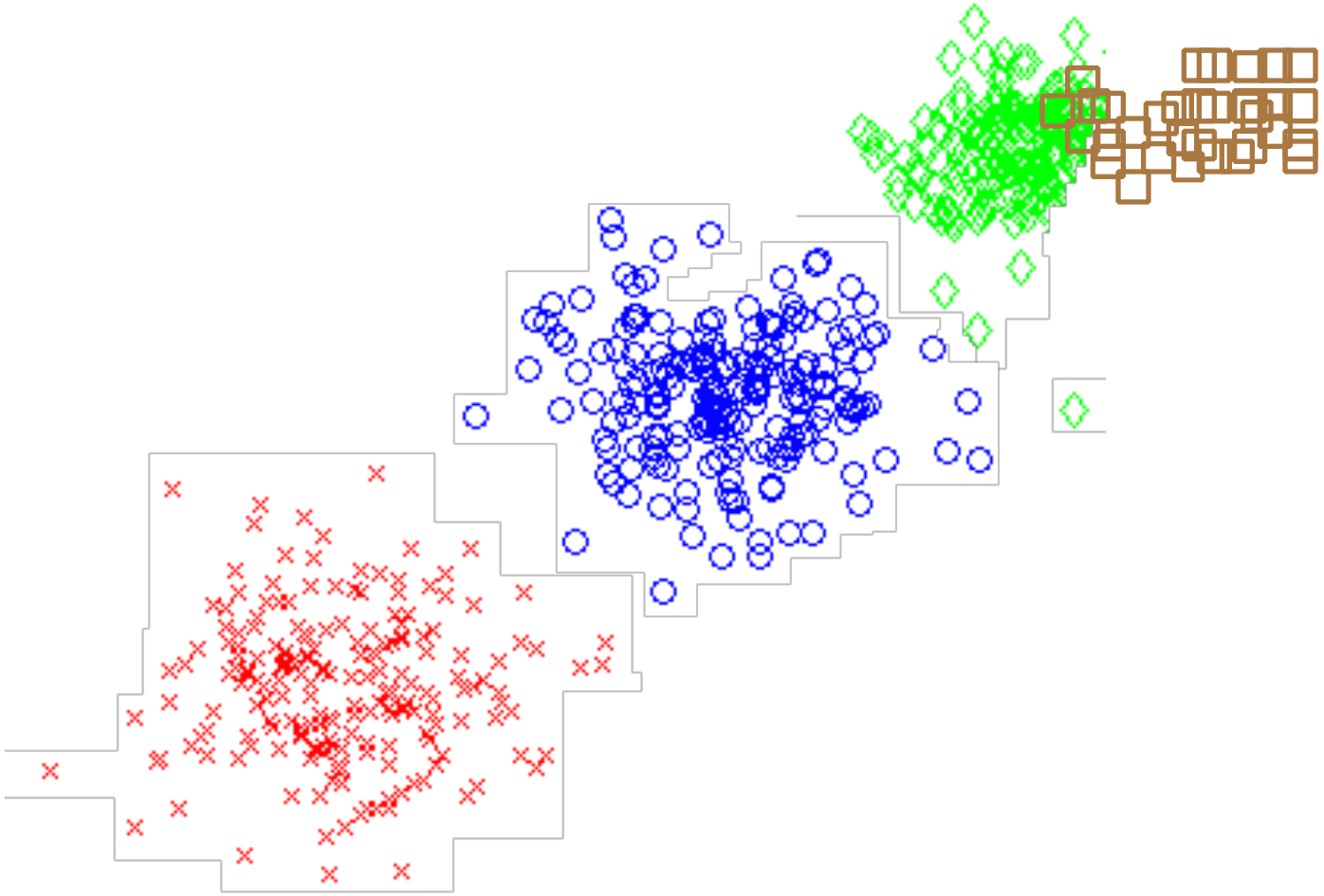
Part Of Vector Space (22-24. April 2016)



Hashtags: Dynamic to Static

Hashtag Clustering

Part Of Vector Space (22-24. April 2016)



Hashtag Clustering

Part Of Vector Space (22-24. April 2016)

St. George Day's Celebration (23. April)

Hashtag Clustering

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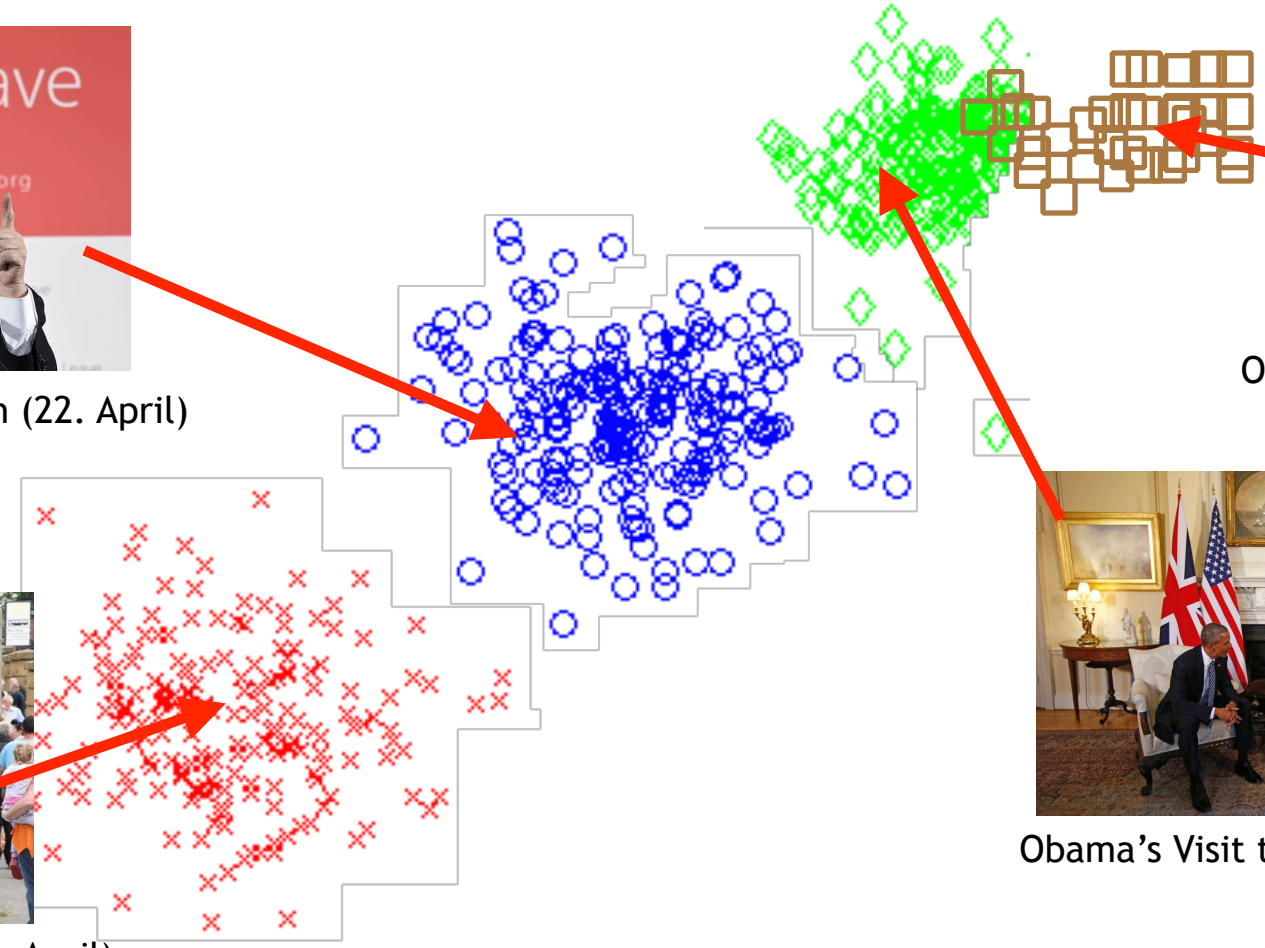

Nearest Neighbour Search

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Obama's Visit to UK (23. April)

Hashtag Clustering

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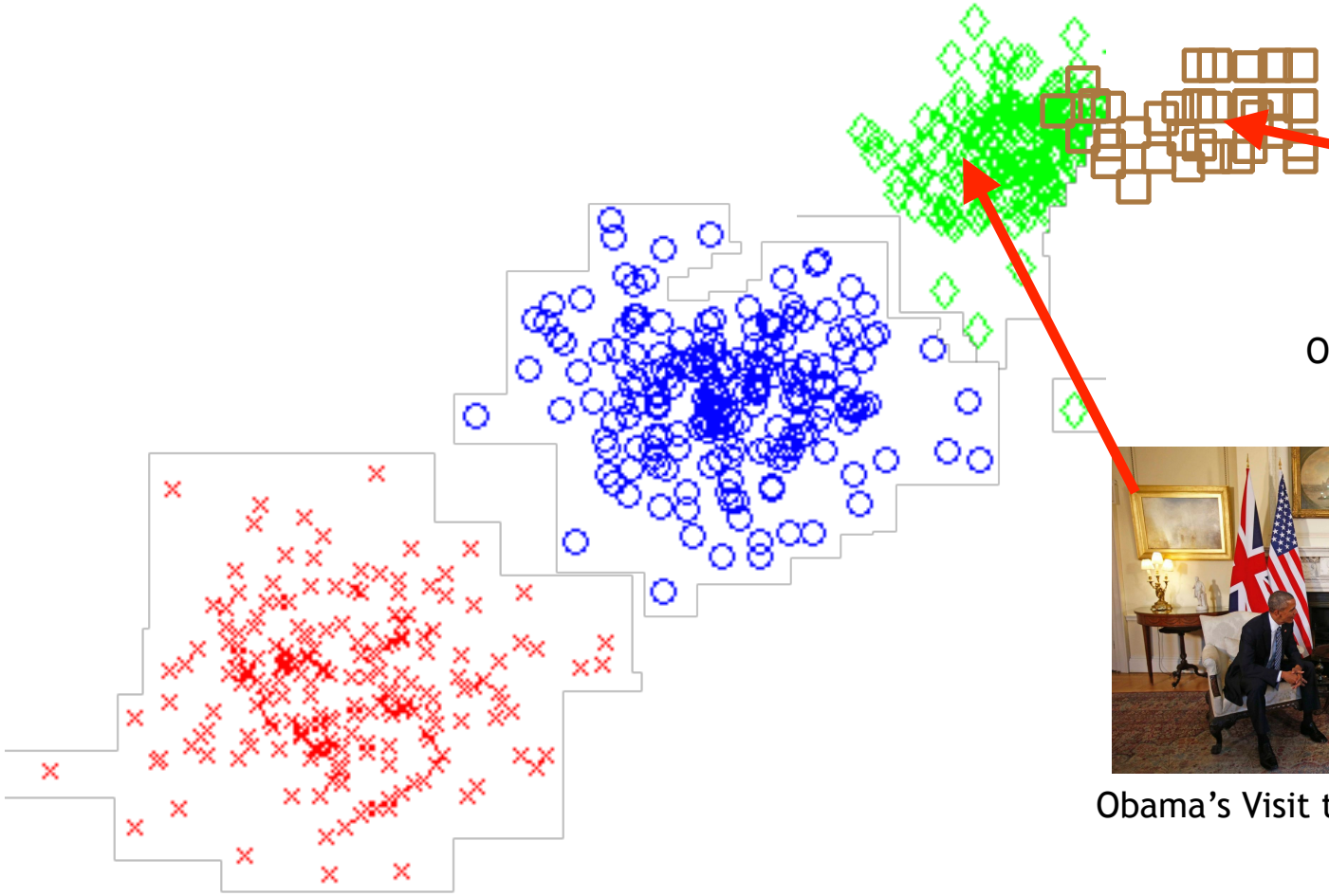

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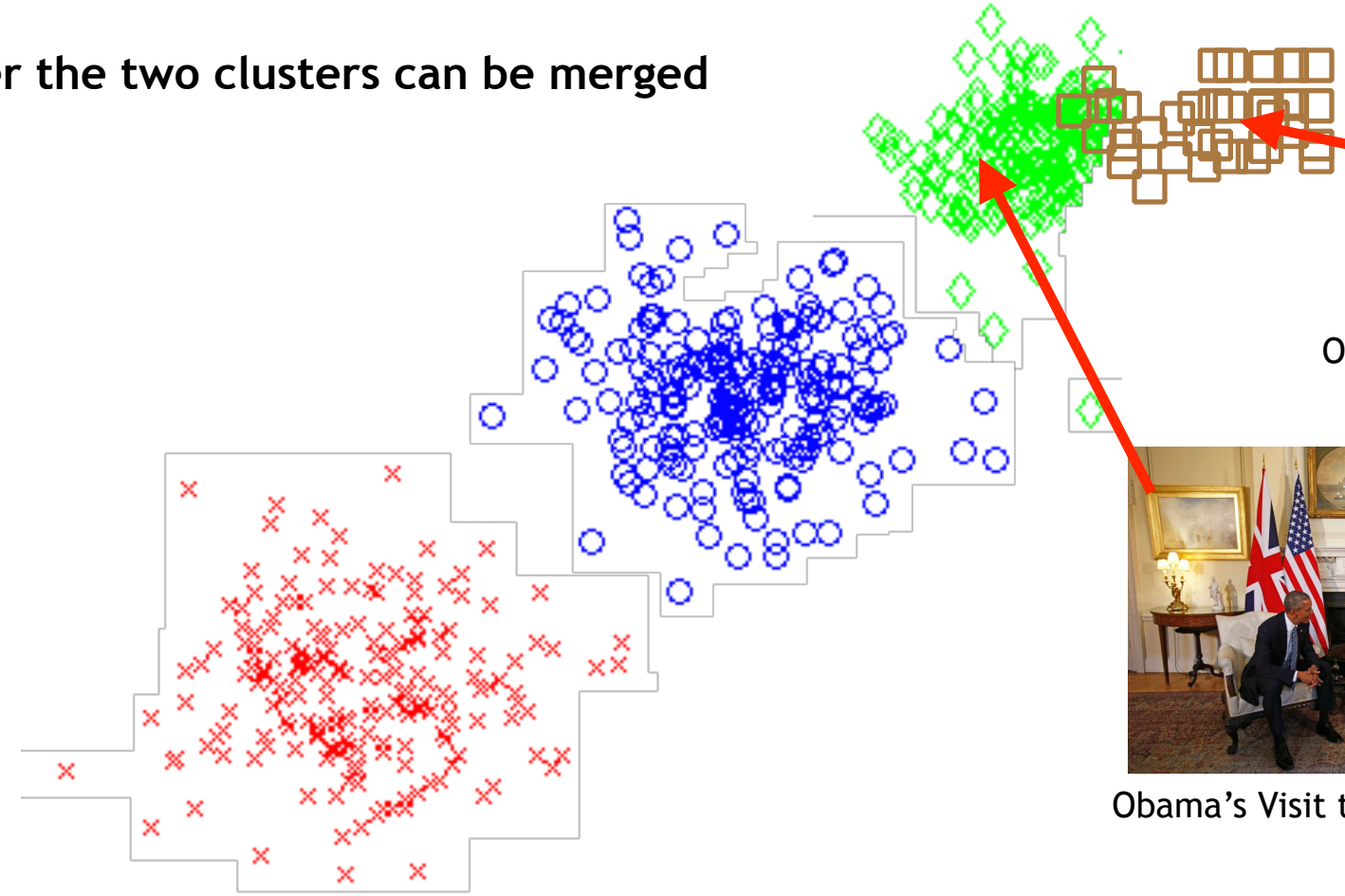

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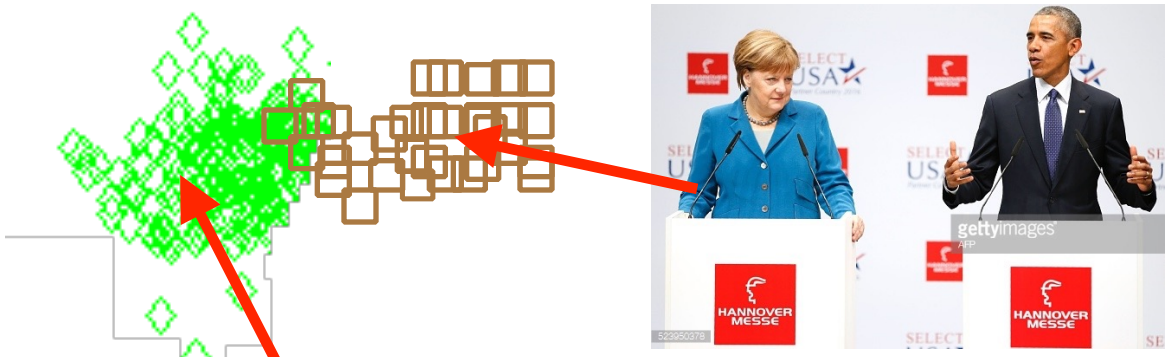

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Check whether the two clusters can be merged

- Check which hashtags are common

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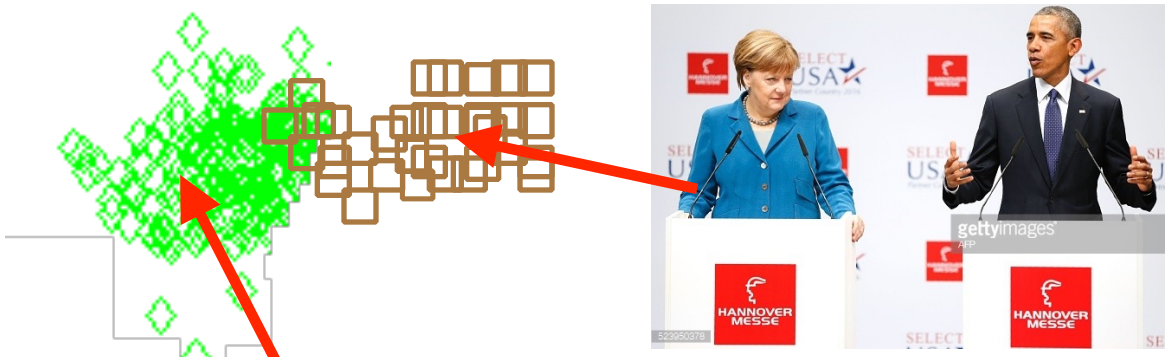

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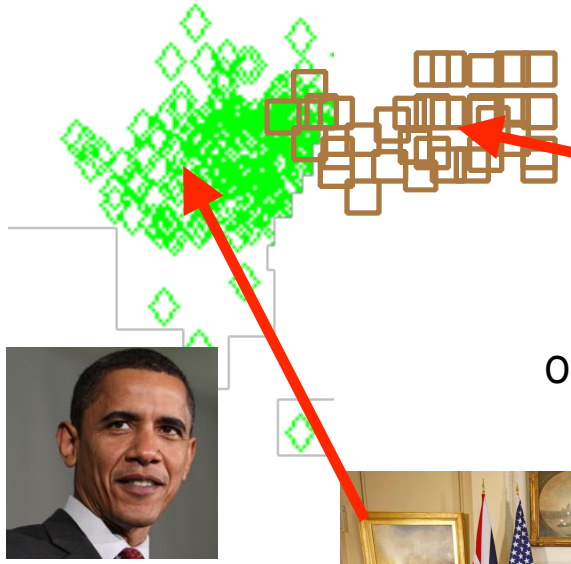

#obama

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Obama's Visit to UK (23. April)

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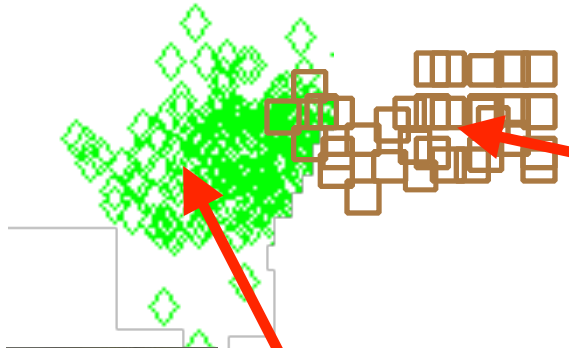


Nearest Neighbour Search

Obama's Visit to Hannover Messe (24. April)

#foreignvisit

#obama

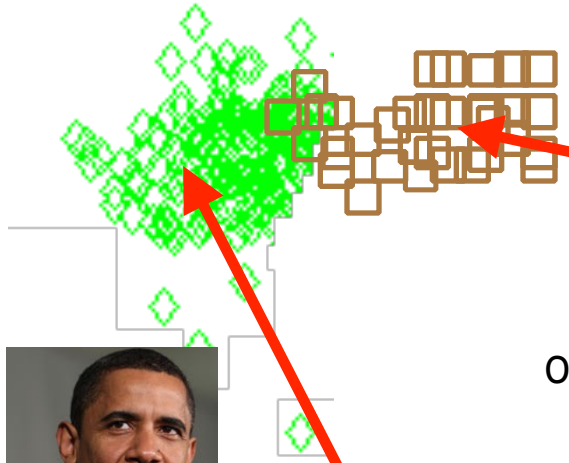
Obama's Visit to UK (23. April)

Hashtag Clustering

Part Of Vector Space (22-24. April 2016)

Check whether the two clusters can be merged

- Check which hashtags are common
- Common hashtags get absorbed



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Check whether the two clusters can be merged

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- Common hashtags get absorbed
- Check which hashtags are uncommon

#foreignvisit

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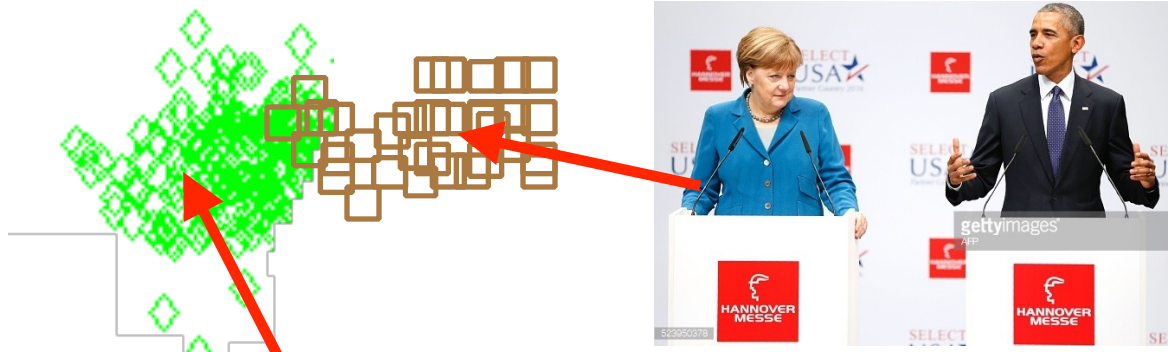

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- Check which hashtags are common
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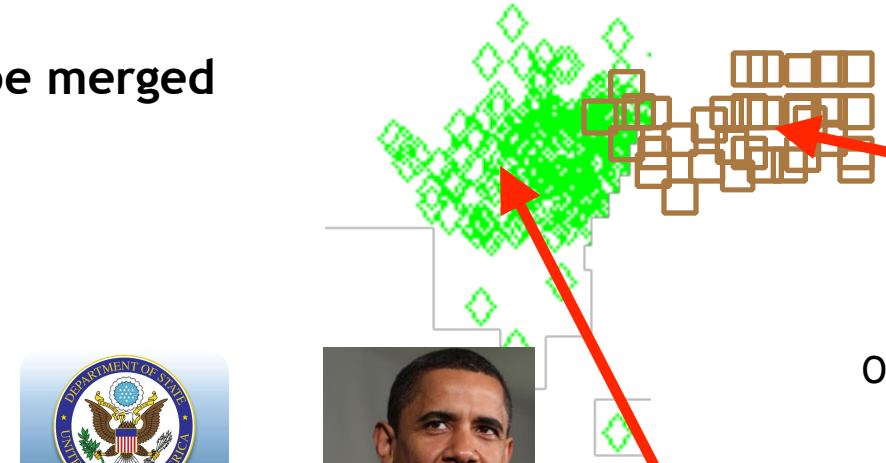
- Check which hashtags are uncommon
- If uncommon hashtags are within absorbance threshold: Merge Clusters



Nearest Neighbour Search

Obama's Visit to Hannover Messe (24. April)

#obama

Obama's Visit to UK (23. April)

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#brexit

#hannovermesse

HANNOVER MESSE

Hashtag Clustering

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- Check which hashtags are common
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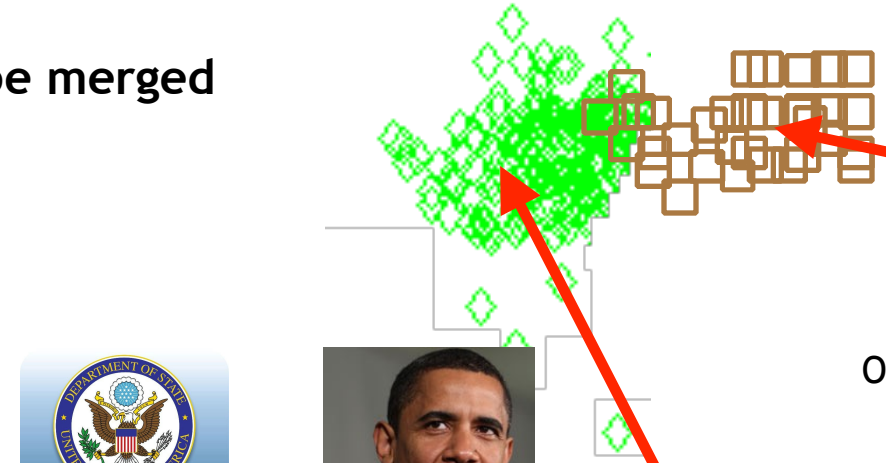
- Check which hashtags are uncommon
- If uncommon hashtags are within absorbance threshold: Merge Clusters
- Else: Keep clusters separate



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HANNOVER MESSE

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Separate Clusters ⇒ Separate Events

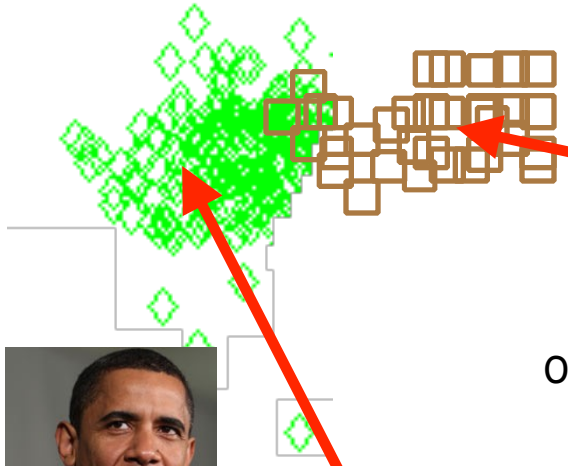
#foreignvisit

#obama

#brexit

#hannovermesse

Nearest Neighbour Search



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- Check which hashtags are uncommon
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- Else: Keep clusters separate

Separate Clusters ⇒ Separate Events

Same Cluster ⇒ Same Event

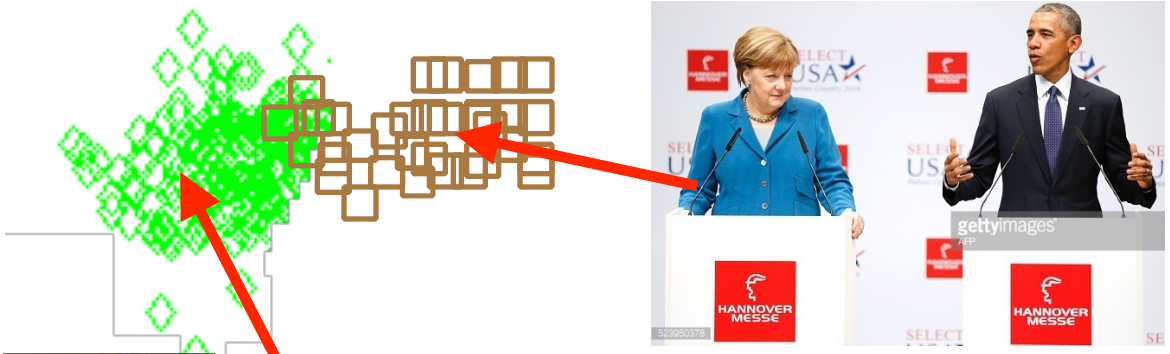
#foreignvisit

#obama

#brexit

#hannovermesse

Nearest Neighbour Search



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Event Ranking

Ranking Factors

- Burstiness

  - Burst Events: Events exhibiting high popularity during very short period of time

Event Ranking

Ranking Factors

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Kröpcke, Hannover

Event Ranking

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Event Ranking

Ranking Factors

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Shopping in Kröpcke

Demonstrations in Kröpcke

Event Ranking

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Event Ranking

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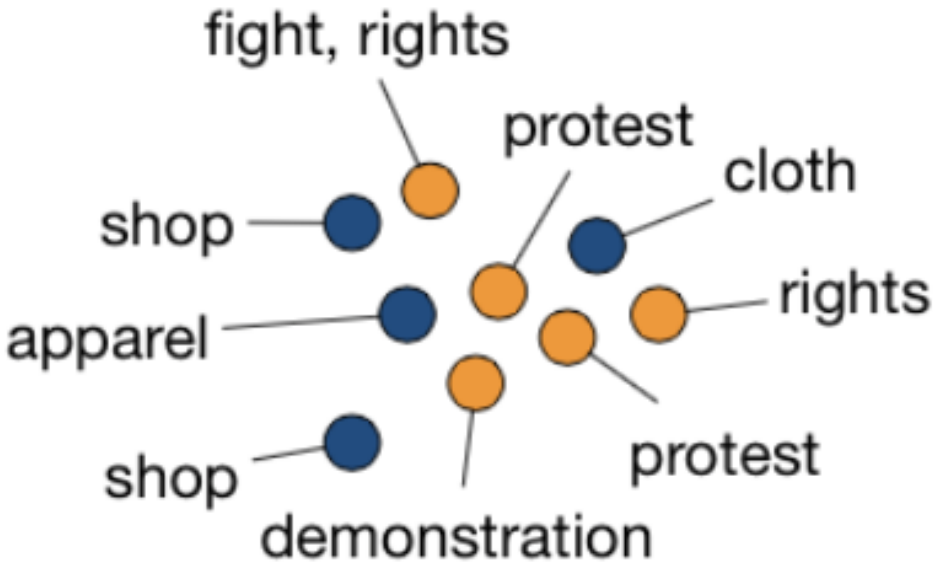


Tweets around Kröpcke, Hannover

Event Ranking

Ranking Factors

- Burstiness

  - Model historical popularity as Gaussian Distribution

  - p_t = popularity in time frame t, μ = mean, σ = standard deviation

$$burstiness(e) = \frac{p_t - \mu}{\sigma}$$

- Localness

  - Similar to Burstiness: Region instead of time

$$localness(e) = \frac{p_r - \mu}{\sigma}$$

- Popularity

  - freq(e) = frequency of event e, N= Total number of tweets

$$popularity(e) = \frac{freq(e)}{N}$$

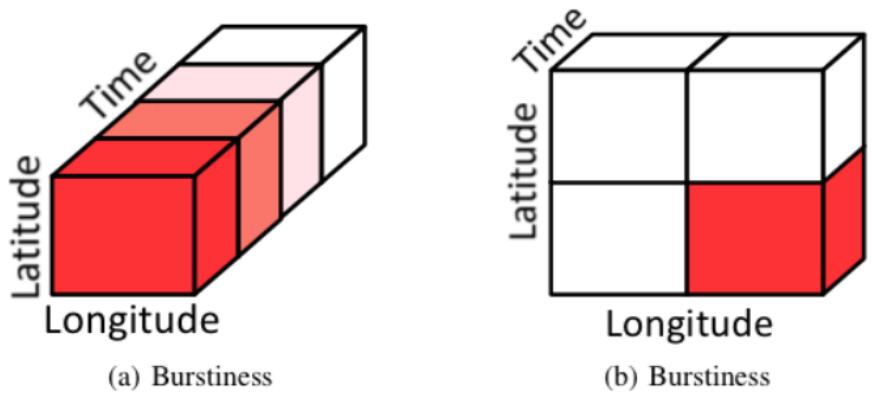


Fig. 4. Localness[2]

Event Ranking

Ranking Score

- Total Ranking Score

$$score(e) = \sum_{i=1}^{k} w_i score(h_i)$$
$$= \alpha \sum_{i=1}^{k} w_i pop(h_k) + \beta \sum_{i=1}^{k} w_i burst(h_k) + \gamma \sum_{i=1}^{k} w_i local(h_k)$$
$$= \alpha \cdot pop(e) + \beta \cdot burst(e) + \gamma \cdot local(e)$$

- Values of α, β, and γ varied according to the interest of the users

- For local events, higher value of γ when compared to α and β

- Popular events of an year: higher value of α when compared to β and γ

Experimental Study

Baselines

- TwitterMonitor[4]
  - Classify tweets on basis of important keywords
  - Finds events by clustering keywords with high burstiness
- SCMA[5]
  - Batch clustering of keywords : Offline mode
  - Incremental clustering of each new tweet that comes in on basis of keywords
- SUMBLR[6]
  - Batch clustering of tweets instead of keywords
  - Incremental clustering of each new tweet that comes in

Experimental Study

Qualitative Evaluation

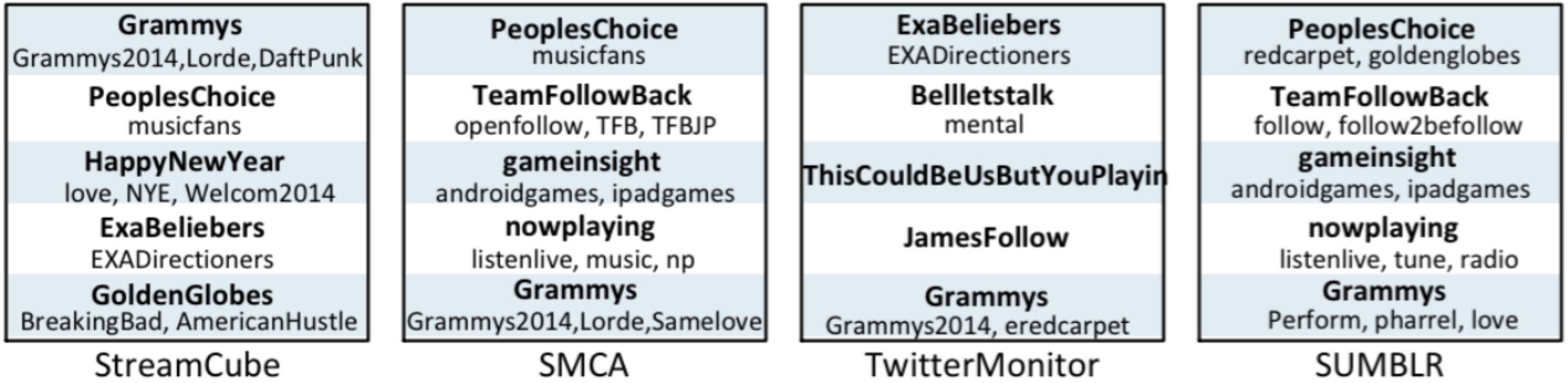
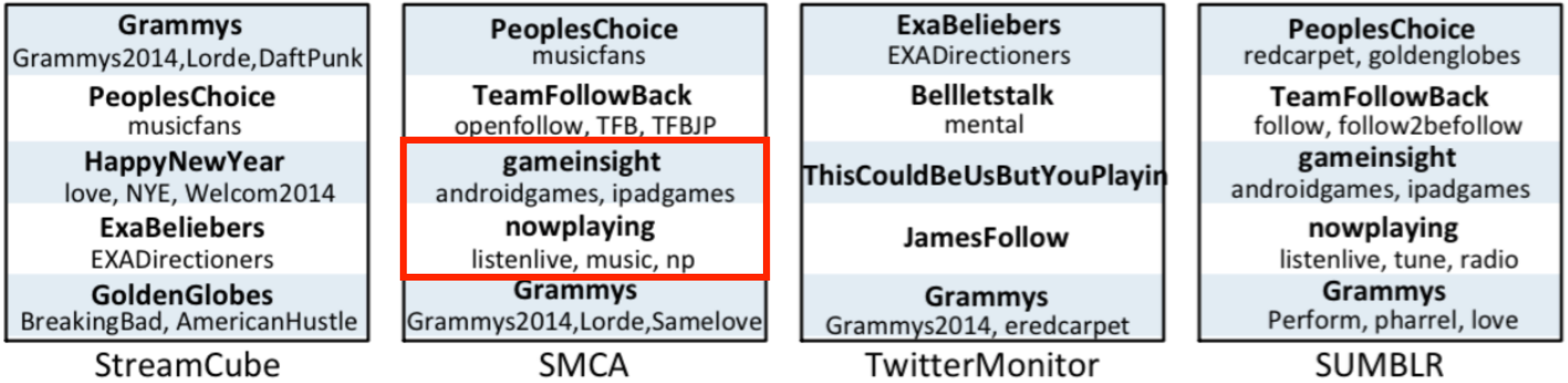


Fig. 5. Detected events by different methods in January 2014[2]

Experimental Study

Qualitative Evaluation



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Experimental Study

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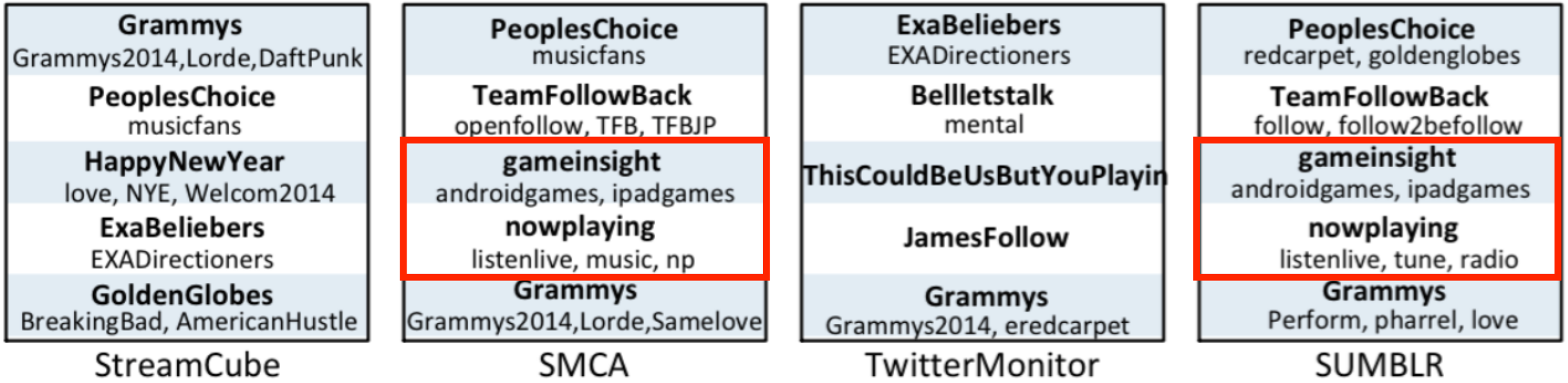

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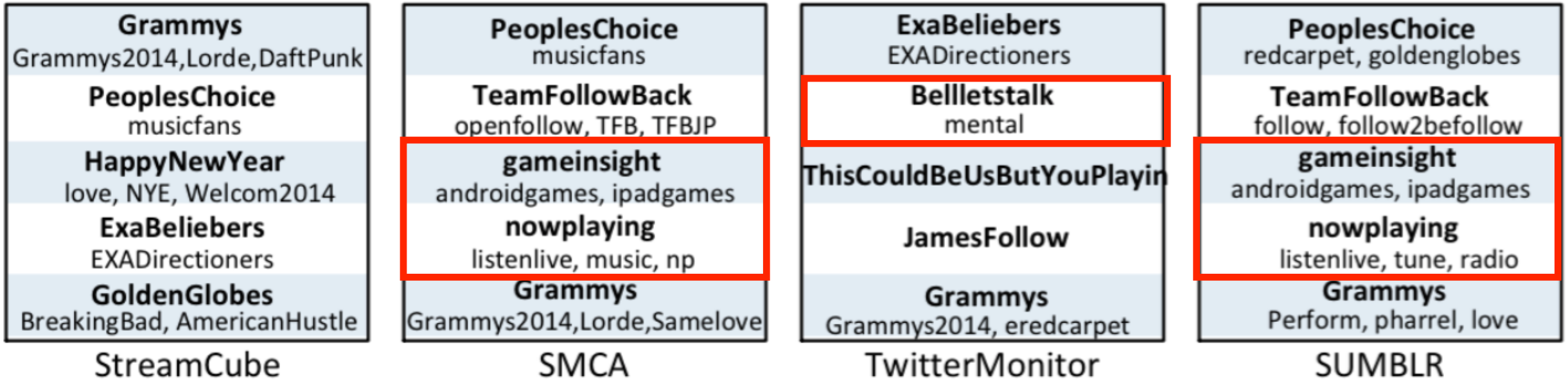

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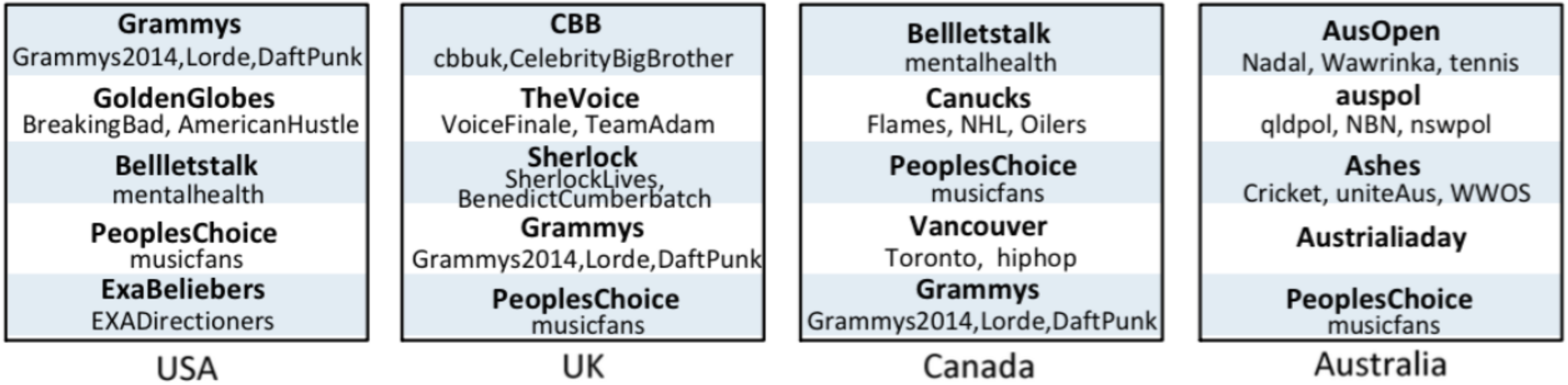
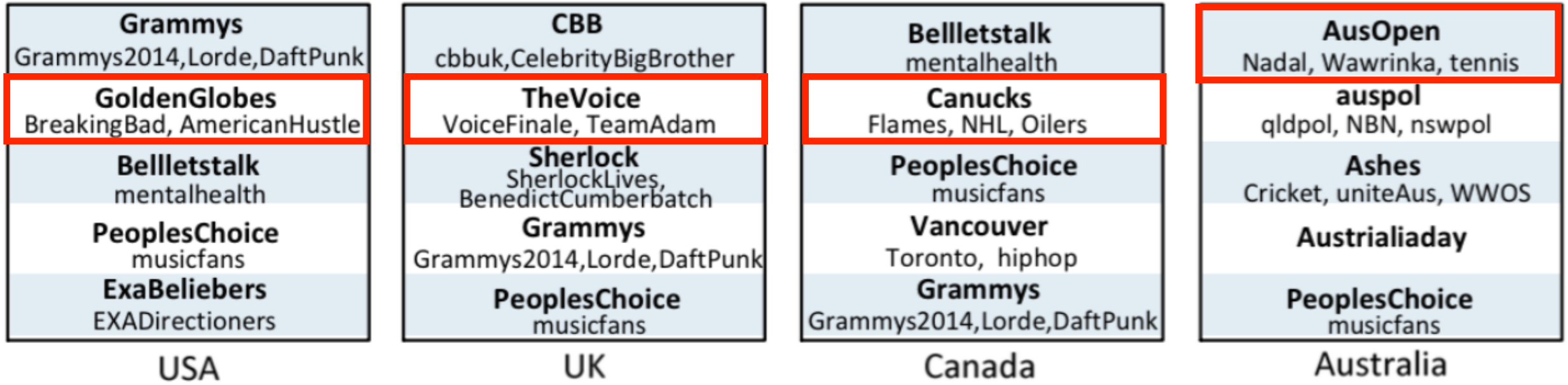


Fig. 6. Events in four different countries in January 2014[2]

Experimental Study

Qualitative Evaluation



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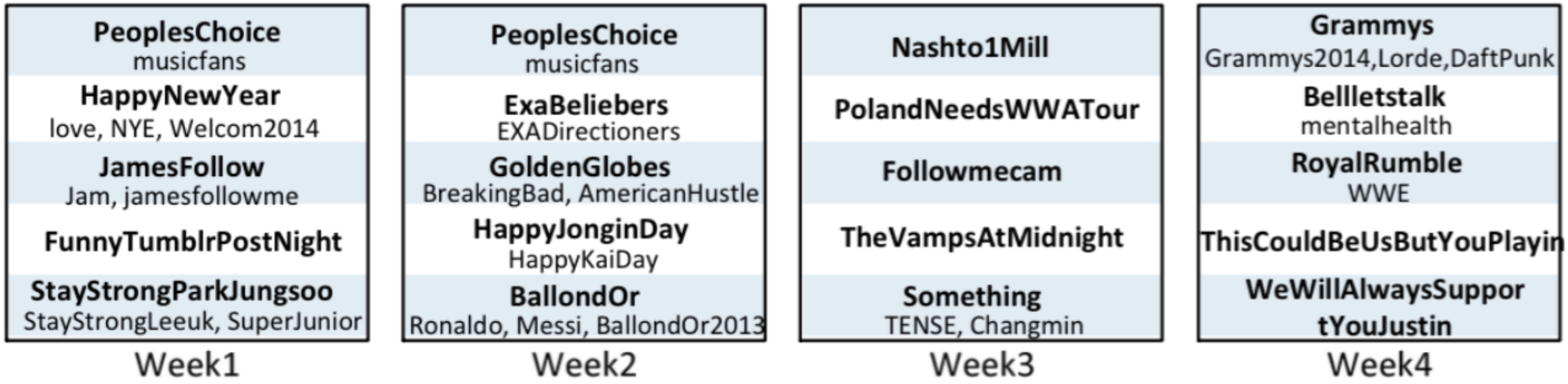

Fig. 7. Events in four weeks of January 2014[2]

Experimental Study

Qualitative Evaluation

Fig. 7. Events in four weeks of January 2014[2]

Experimental Study

Quantitative Evaluation

- Crowdsourcing: 10 People ranked top-10 events in each Candidate Set
- Average Precision (AP)

$$AP = \frac{\sum_{k=1}^{n} precision@k \times isTopEvent(e)}{the\ number\ of\ positive\ events}$$

- Mean Average Precision

$$MAP = \frac{\sum_{i=1}^{N} AP_i}{N}$$

Metric	SUMBLR	SMCA	TMONITOR	STREAMCUBE
MAP	0.511	0.523	0.608	**0.634**

Table 1. Ranking Quality[2]

Experimental Study

Scalability

- **TwitterMonitor:** Slowest as clusters keywords instead of hashtags
- **SCMA & SUMBLR:** Better as batch clustering of tweets performed initially followed by incremental clustering
- **STREAMCUBE:** Shortest running time due to single pass, nearest neighbour search algorithm

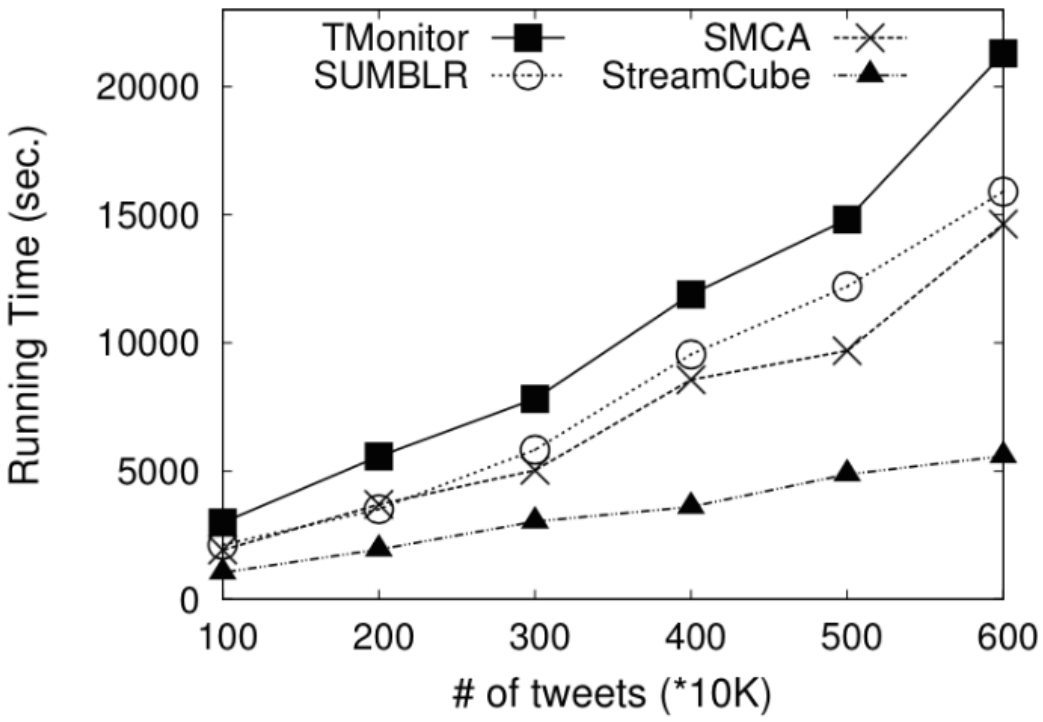

Fig. 8. Scalability[2]

Experimental Study

Memory Usage

- **TwitterMonitor:** Maintains similarity matrix for all pair of keywords, Consumes most memory
- **SCMA & SUMBLR:** SUMBLR performs better than SMCA as its able to remove outdated clusters
- **STREAMCUBE:** Least memory usage due to hashtag clustering performed at early stage and only current 6 hr time frame kept in Memory

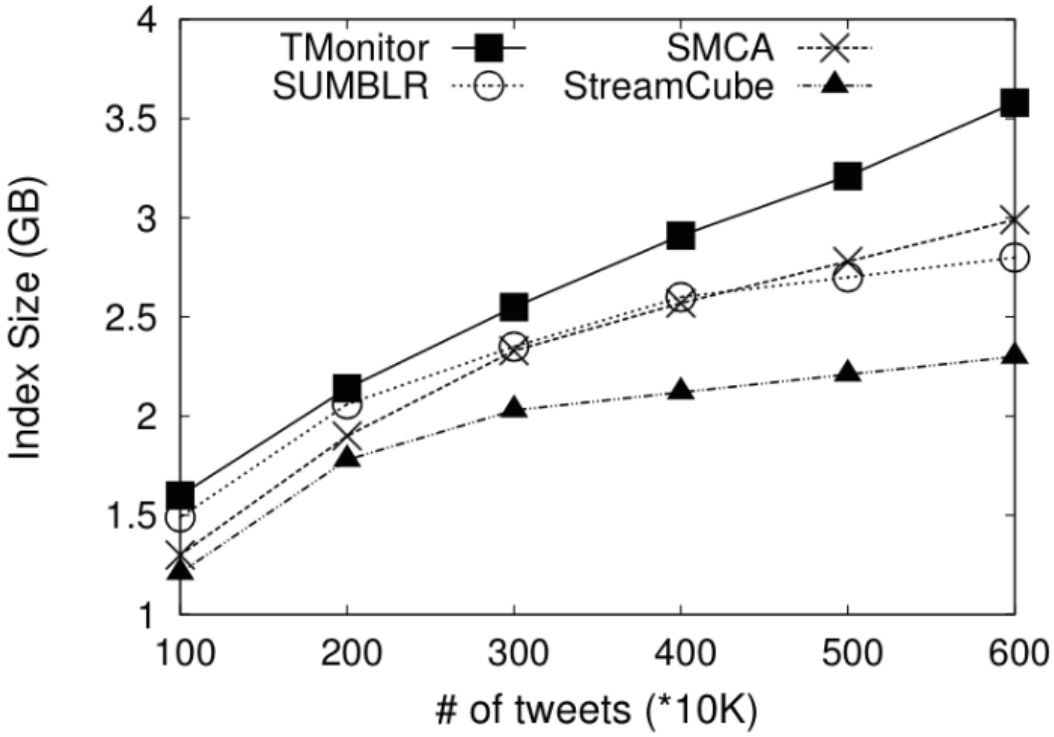

Fig. 9. Memory Usage[2]

Conclusion

- Explore events along different space and time granularity
- Takes into account dynamic nature of hashtags while hashtag clustering
- Considers all tweets, assigns geo-location to tweets not geo-tagged
- **Drawback 1:** Less than 2 per cent of tweets are geo-tagged
- **Solution 1:** Consider all tweets for hashtag clustering but only geo-tagged tweets for event ranking as done by EvenTweet[7] system
- **Drawback 2:** Uses complete global space
- **Solution 2:** Begin with local space (eg. USA) and gradually expand as tweets come in from new countries

Conclusion

- Finest granularity of space restricted to district
- **Possible Extension 1:** Allow any space granularity by specifying co-ordinates of the region in the form of bounding rectangle as done by EvenTweet[7] system

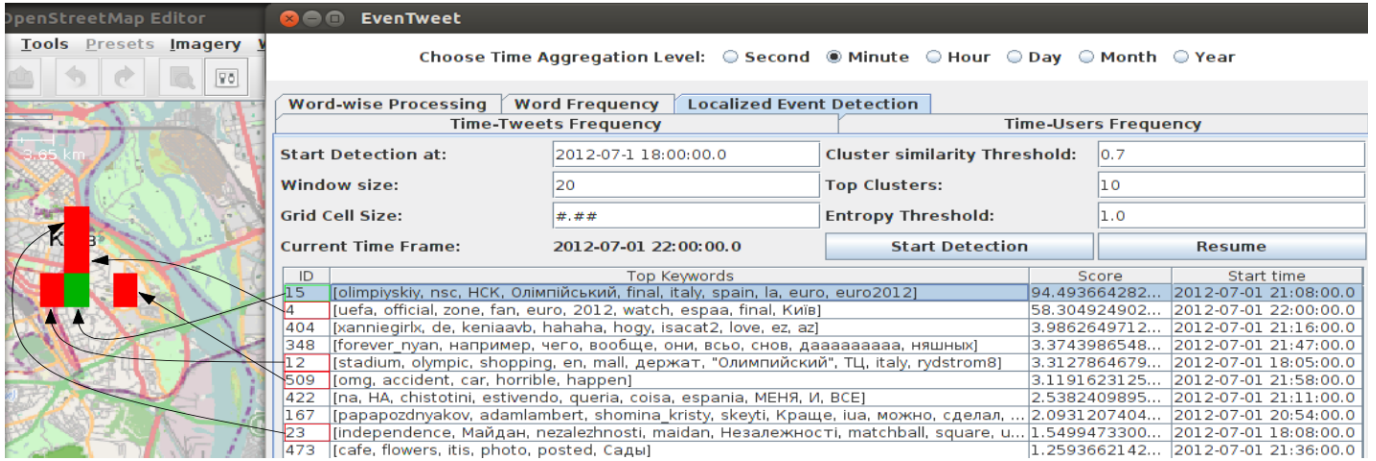

Fig. 10. EvenTweet Interface[7]

- **Possible Extension 2:** Allow users to explore events along Topic dimension
- **Possible Extension 3:** Alert mechanism to regularly push out event information to users

References

[1] Salaheldeen, H.; Nelson, M. L.: “Losing My Revolution: How Many Resources Shared on Social Media Have Been Lost?” JCDL, Washington, USA, 2012.

[2] W. Feng et al., "STREAMCUBE: Hierarchical Spatio- temporal hashtag clustering for event exploration over the Twitter stream," 2015 IEEE 31st International Conference on Data Engineering, Seoul, 2015, pp. 1561-1572.

[3] J. Han, Data Mining: Concepts and Techniques. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 2005.

[4] M. Mathioudakis and N. Koudas, “Twittermonitor: trend detection over the twitter stream,” in SIGMOD Conference, 2010, pp.1155–1158.

[5] O. Tsur, A. Littman, and A. Rappoport, “Efficient clustering of short messages into general domains.” in ICWSM, E. Kiciman, N. B. Ellison, B. Hogan, P. Resnick, and I. Soboroff, Eds.,2013.

[6] L. Shou, Z. Wang, K. Chen, and G. Chen, “Sumblr: continuous summarization of evolving tweet streams,” in SIGIR, 2013, pp. 533–542.

[7] Michael Gertz et. al. “EvenTweet: Online Localized Event Detection from Twitter” 39th International Conference on Very Large Data Bases, August 26-30th, Trento, Italy.

Discussion