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

Vaibhav Kasturia

M.Sc. ITIS

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# 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
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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

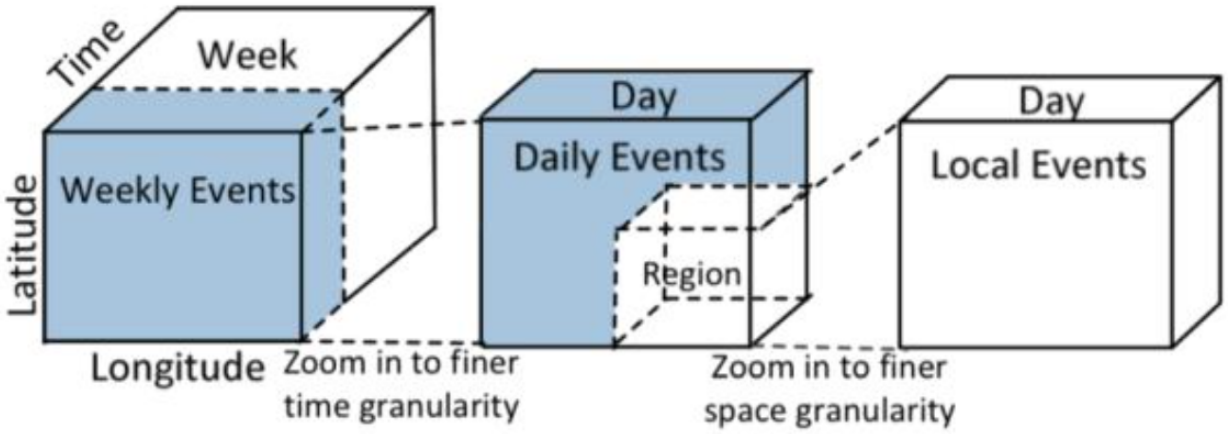


Fig. 1. Zoomable Event Cube[2]

# 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
- Time Hierarchy embed in Space Hierarchy
- Current 6 Hr Frame: Main Memory
- Older Frames: Disk Storage

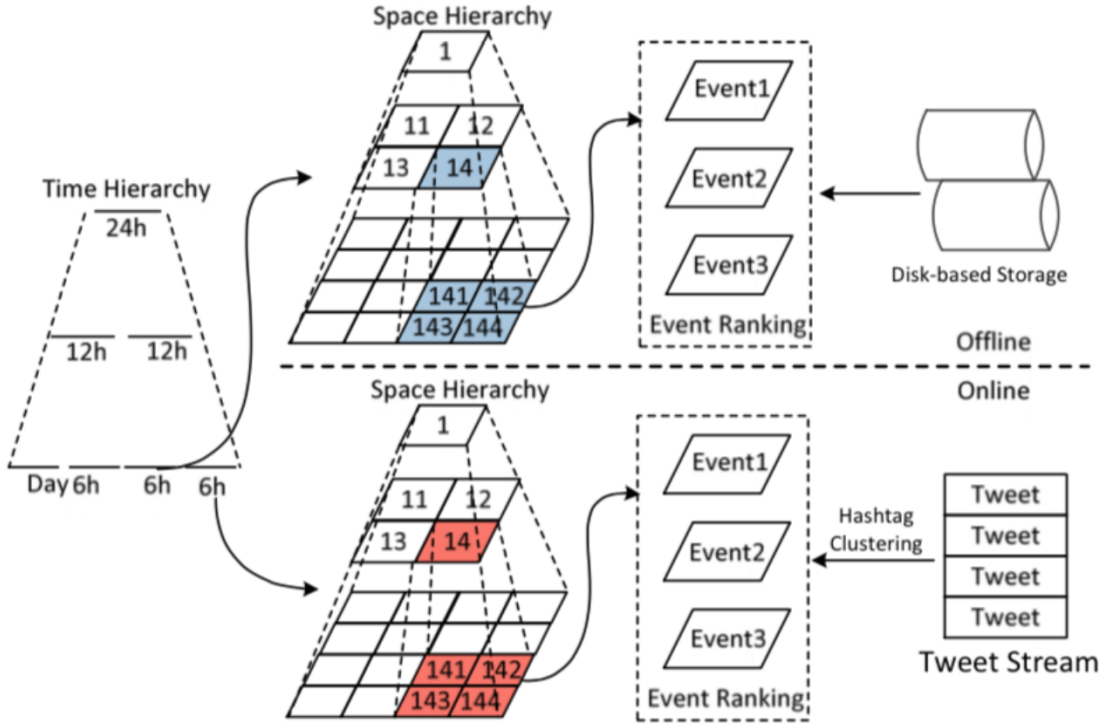


Fig. 2. Framework[2]

# 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

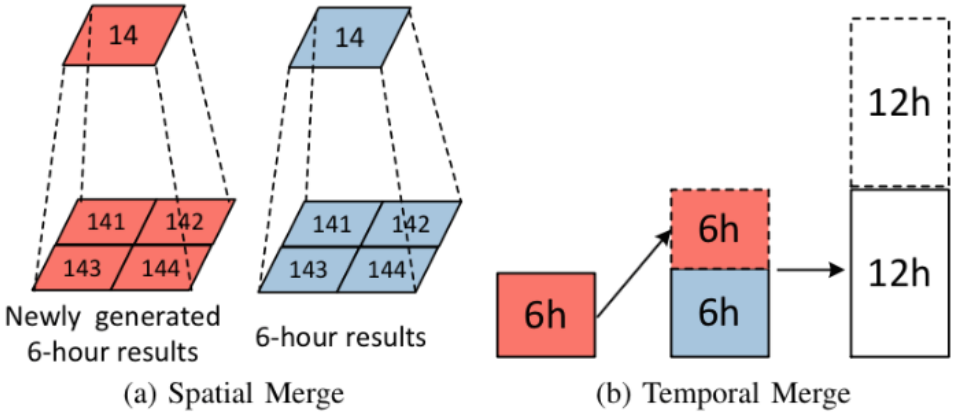


Fig. 3. Spatio-temporal aggregation[2]

# Hashtag Clustering

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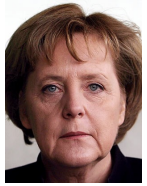
#merkel



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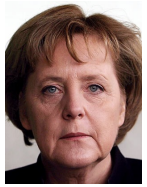

#hannovermesse

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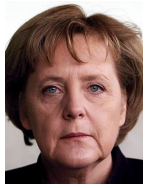

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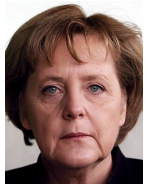



Merkel's Visit to Hannover Messe

# Hashtag Clustering

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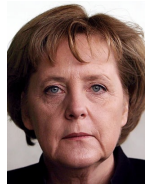
#merkel #hannovermesse





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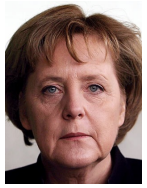

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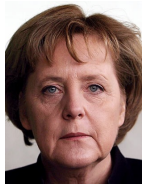


Angela Merkel on UK's exit from EU

#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

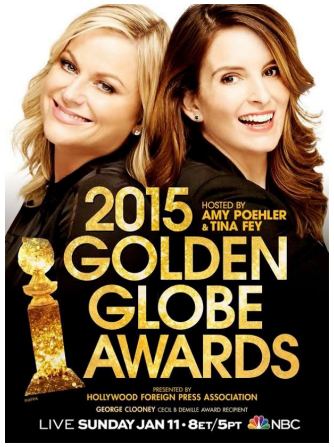
# Hashtag Clustering

**Hashtag Representation and Similarity:**

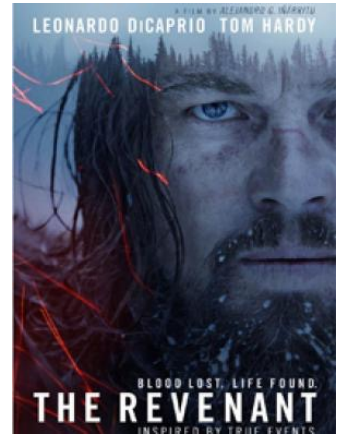
- Hashtag as a Bag of Words
  - Collect all tweets containing hashtag h
  - Identify words in tweets important for hashtag
  - Hashtag h as Normalized Weighted Vector

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

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



Golden Globes 2015

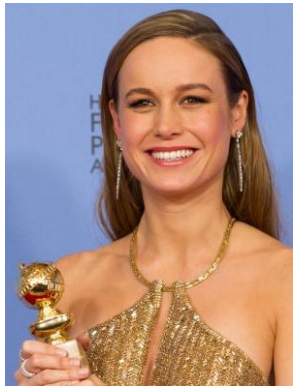


The Revenant

The Martian


Matt Damon


Leonardo DiCaprio


Brie Larson

Jennifer Lawrence

# Hashtag Clustering

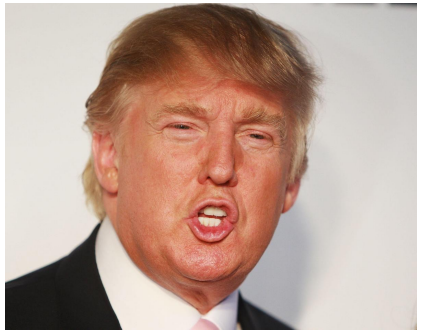
**Hashtag Representation and Similarity:**

- 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:

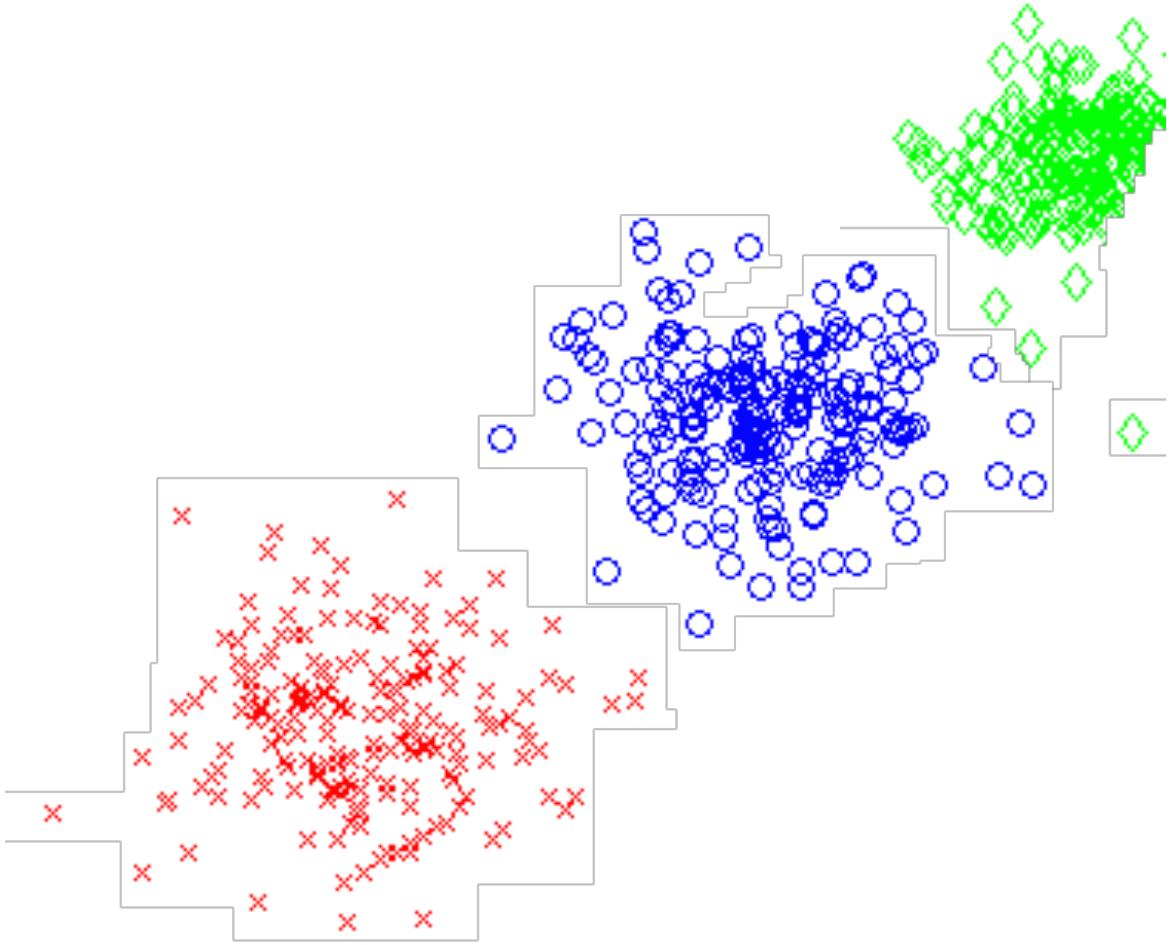
$$\mathbf{h} = (\alpha^{\frac{1}{2}}\mathbf{h}_{word}, \beta^{\frac{1}{2}}\mathbf{h}_{tag})$$

- 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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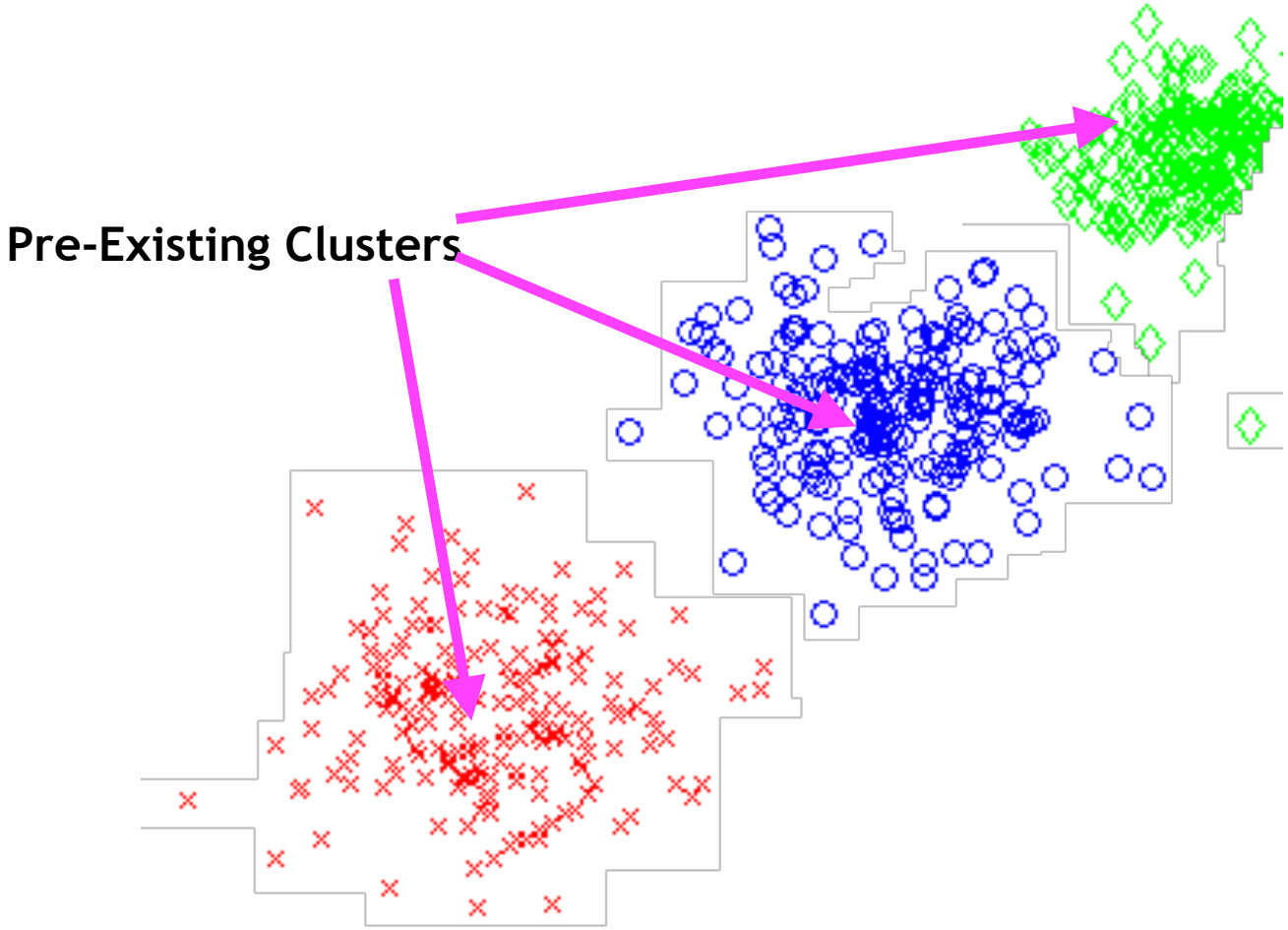

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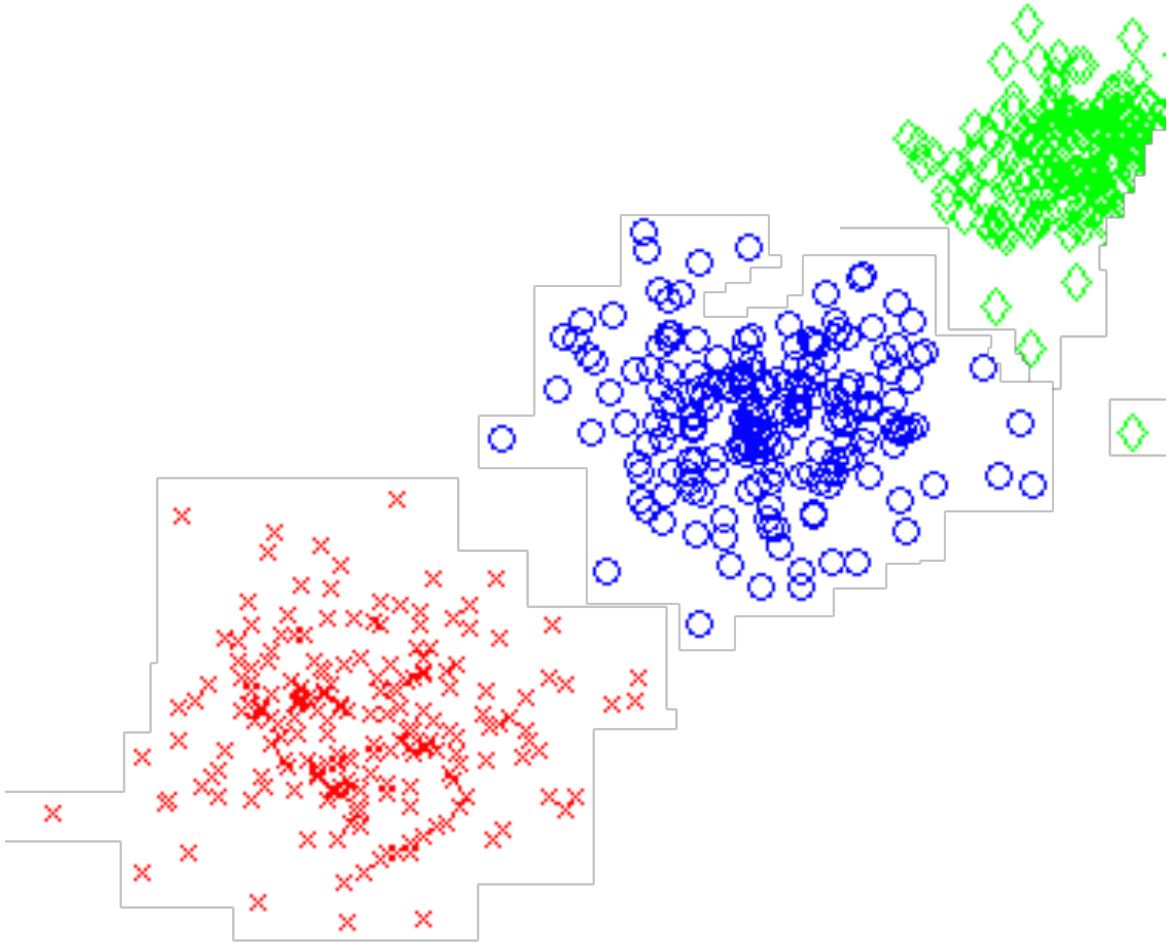

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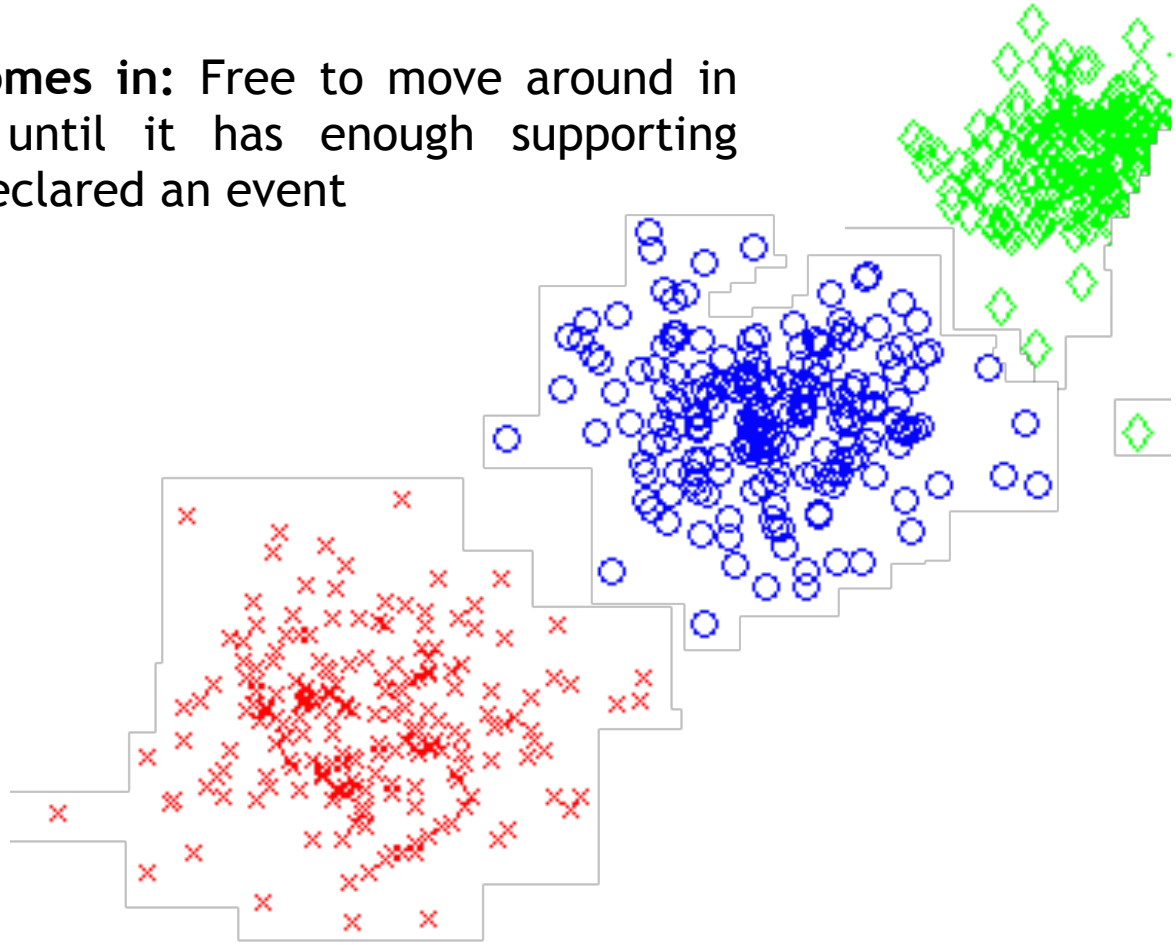

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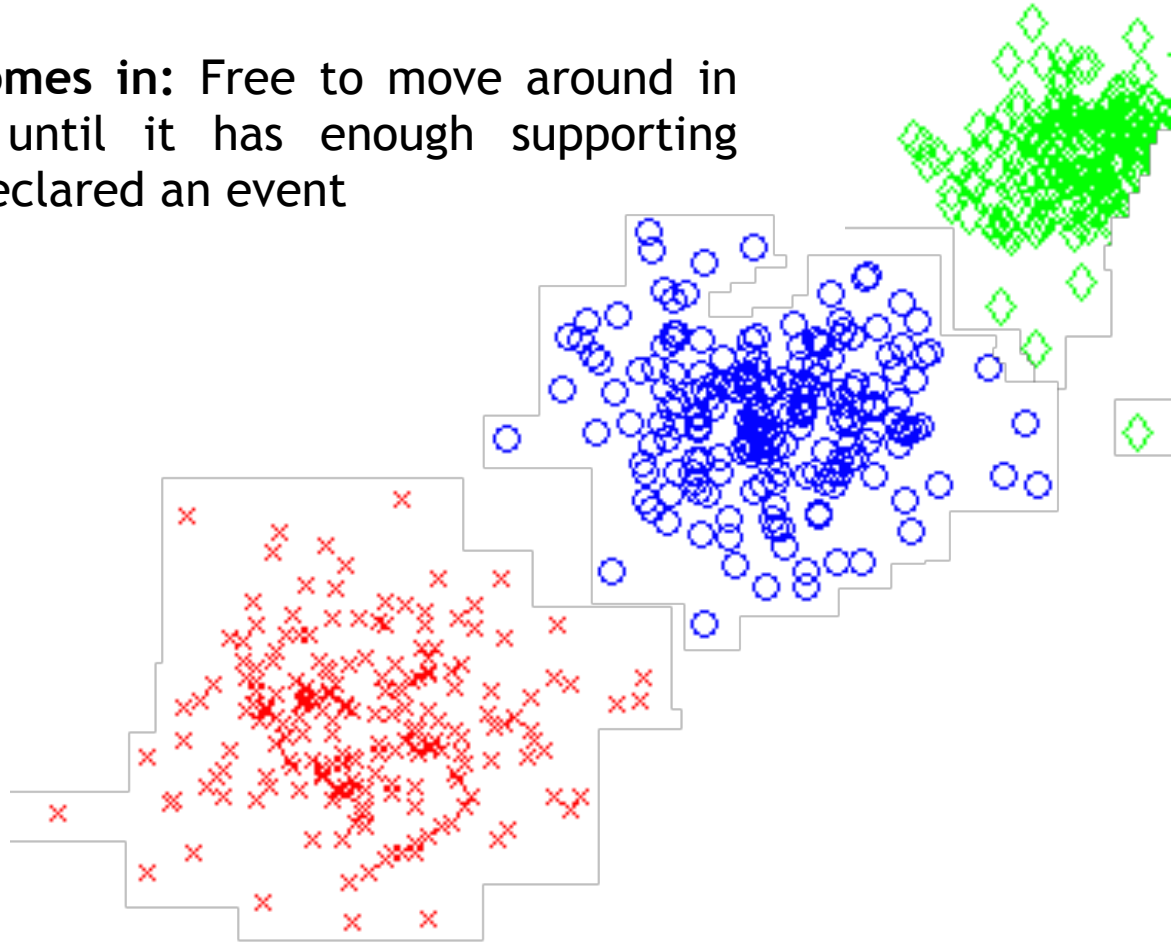

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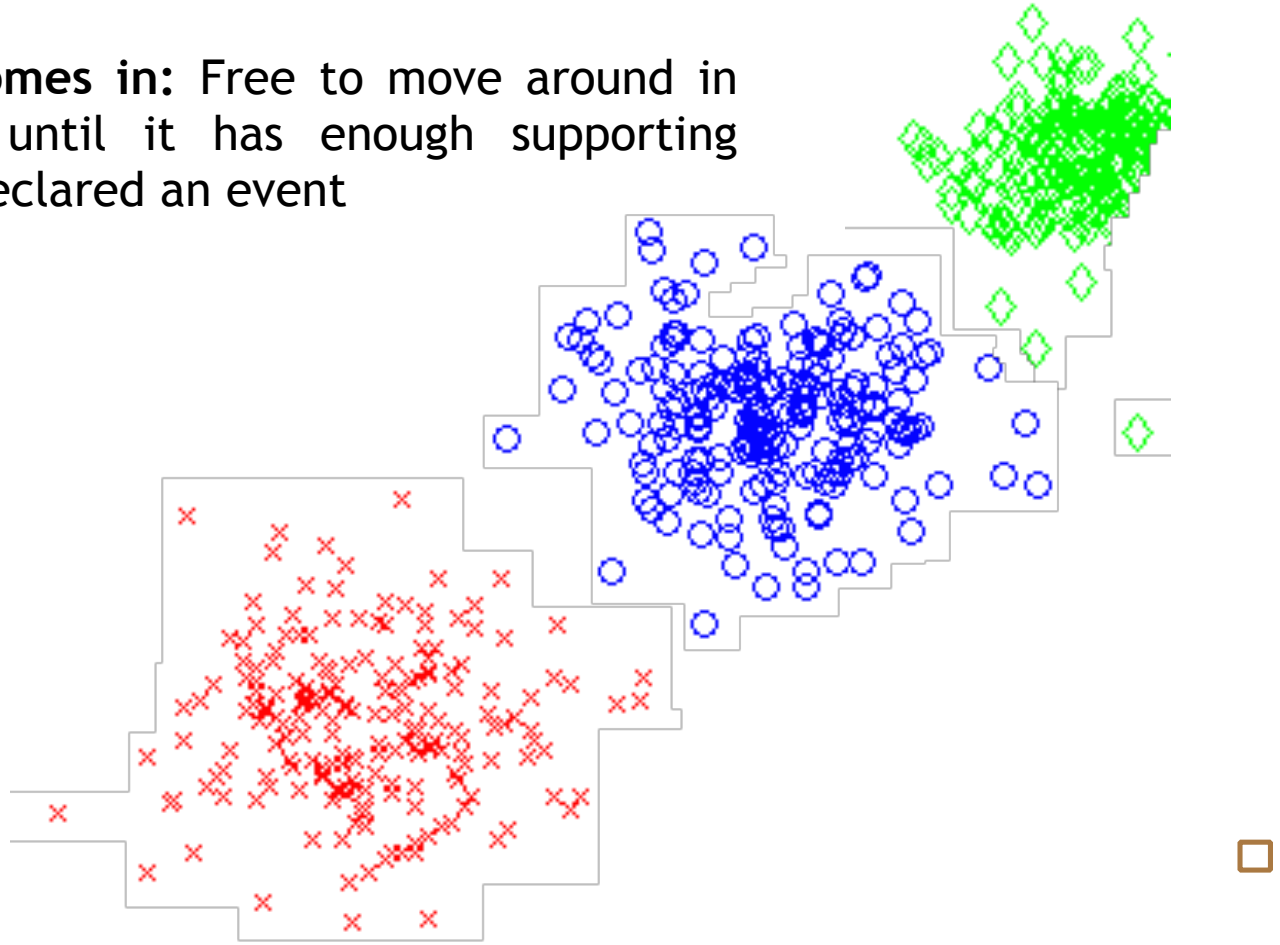

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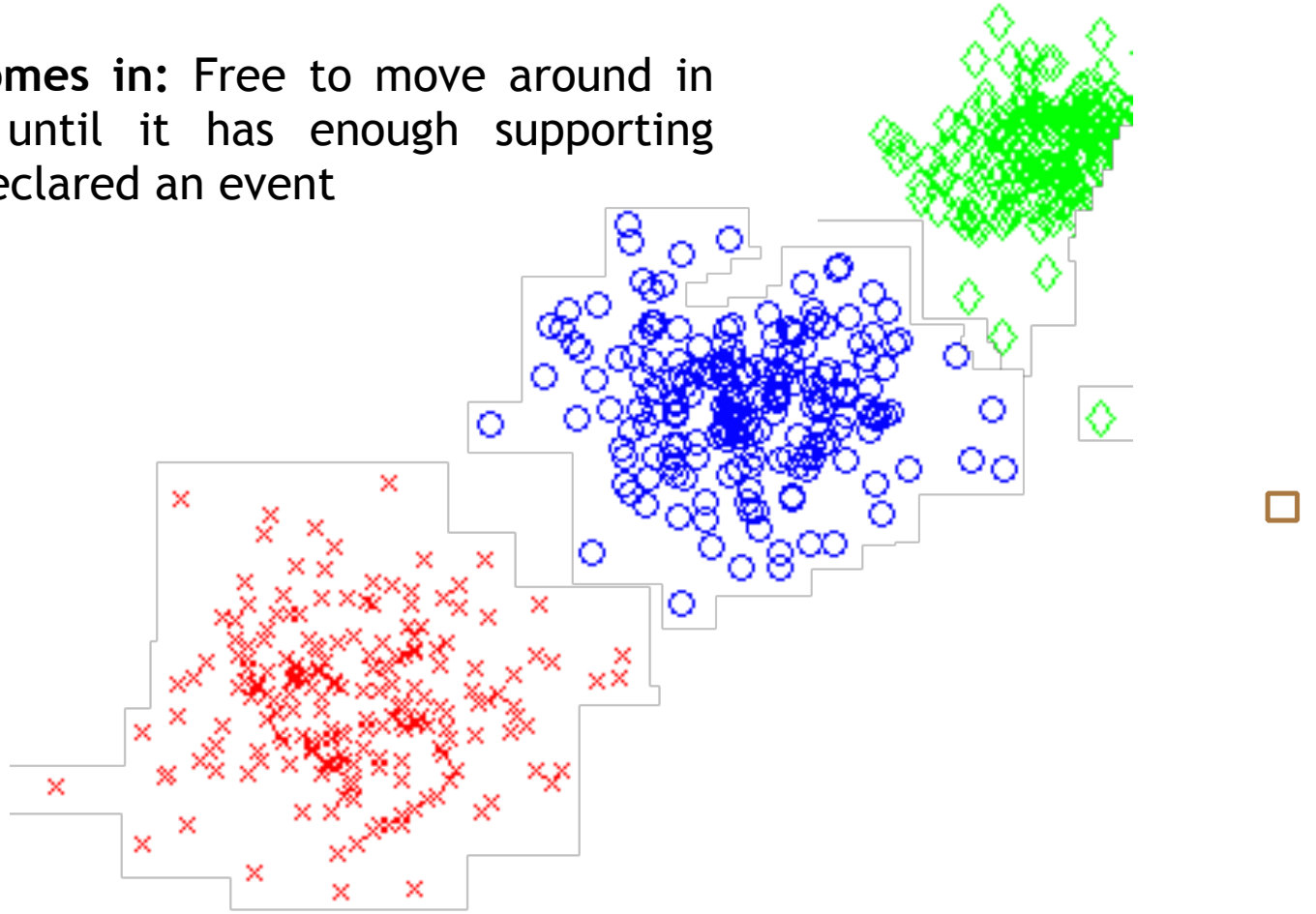

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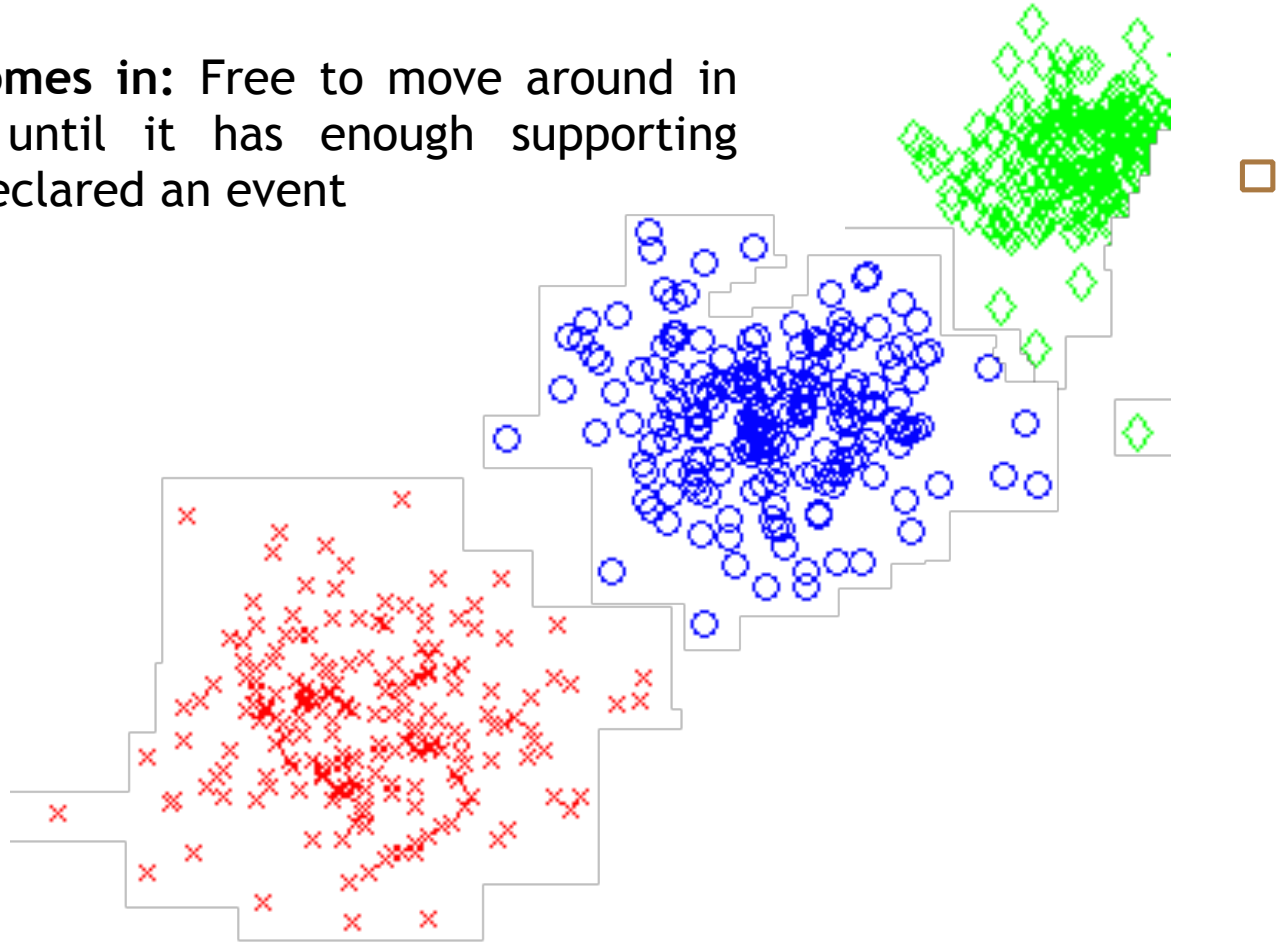

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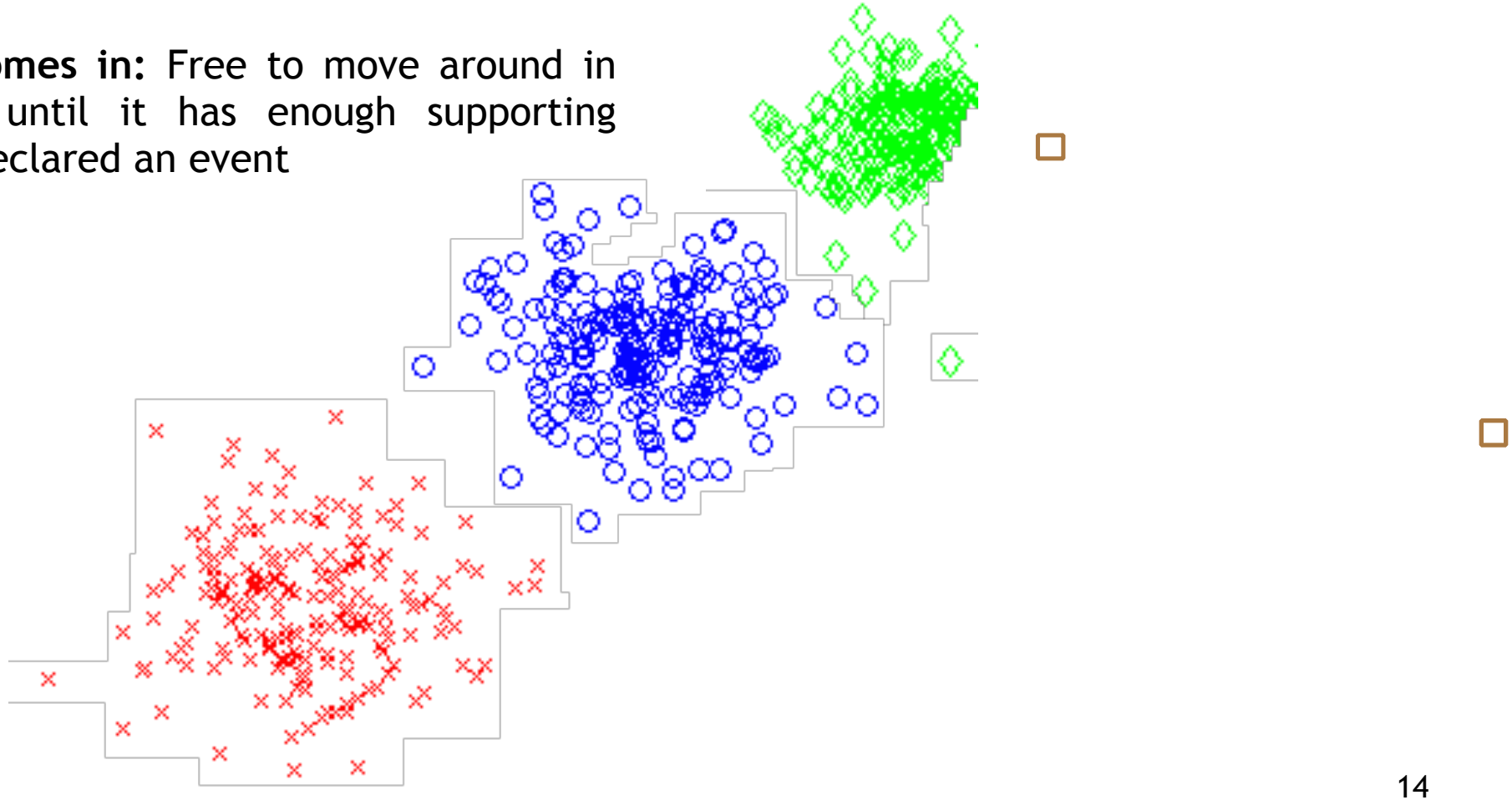

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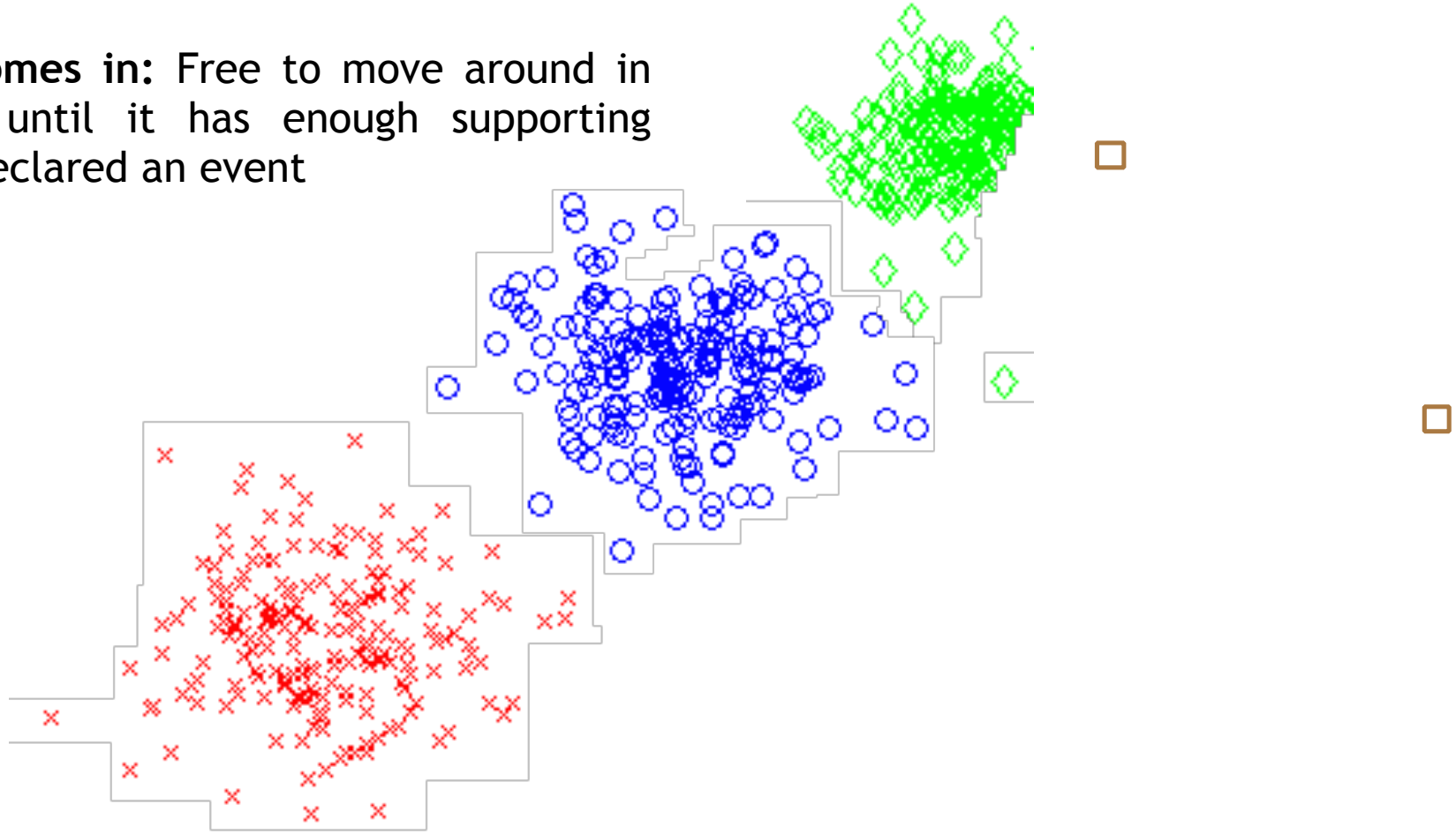

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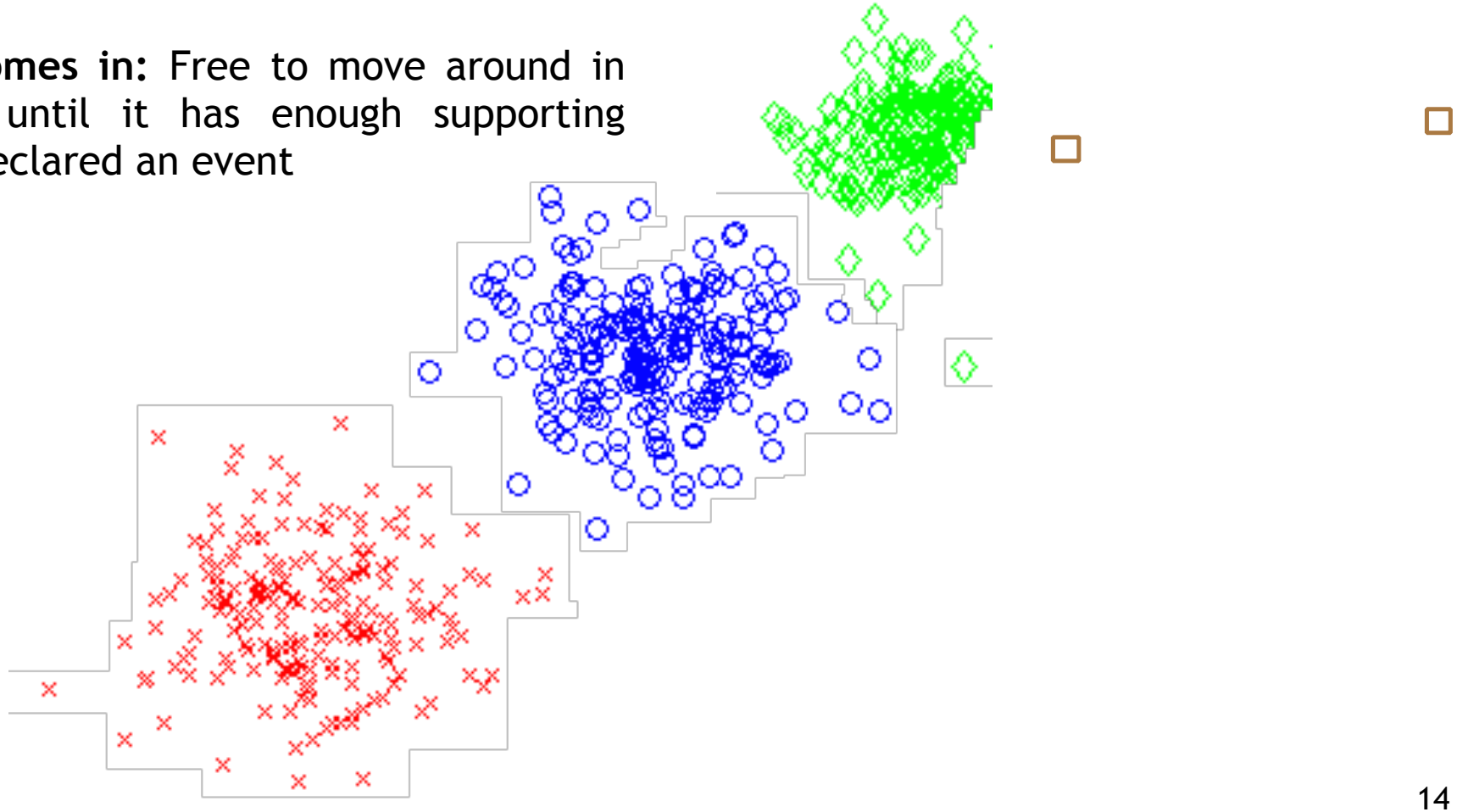

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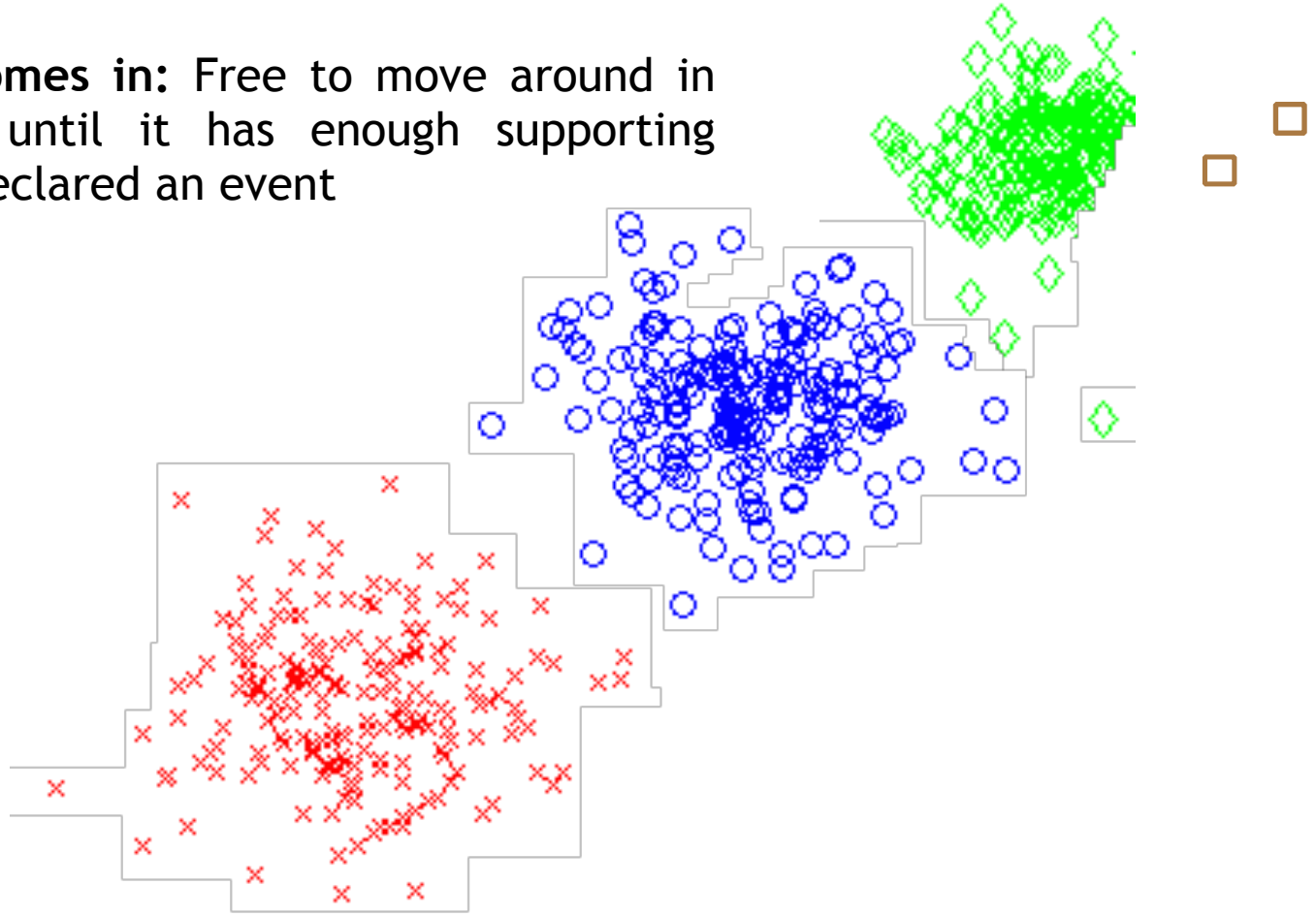

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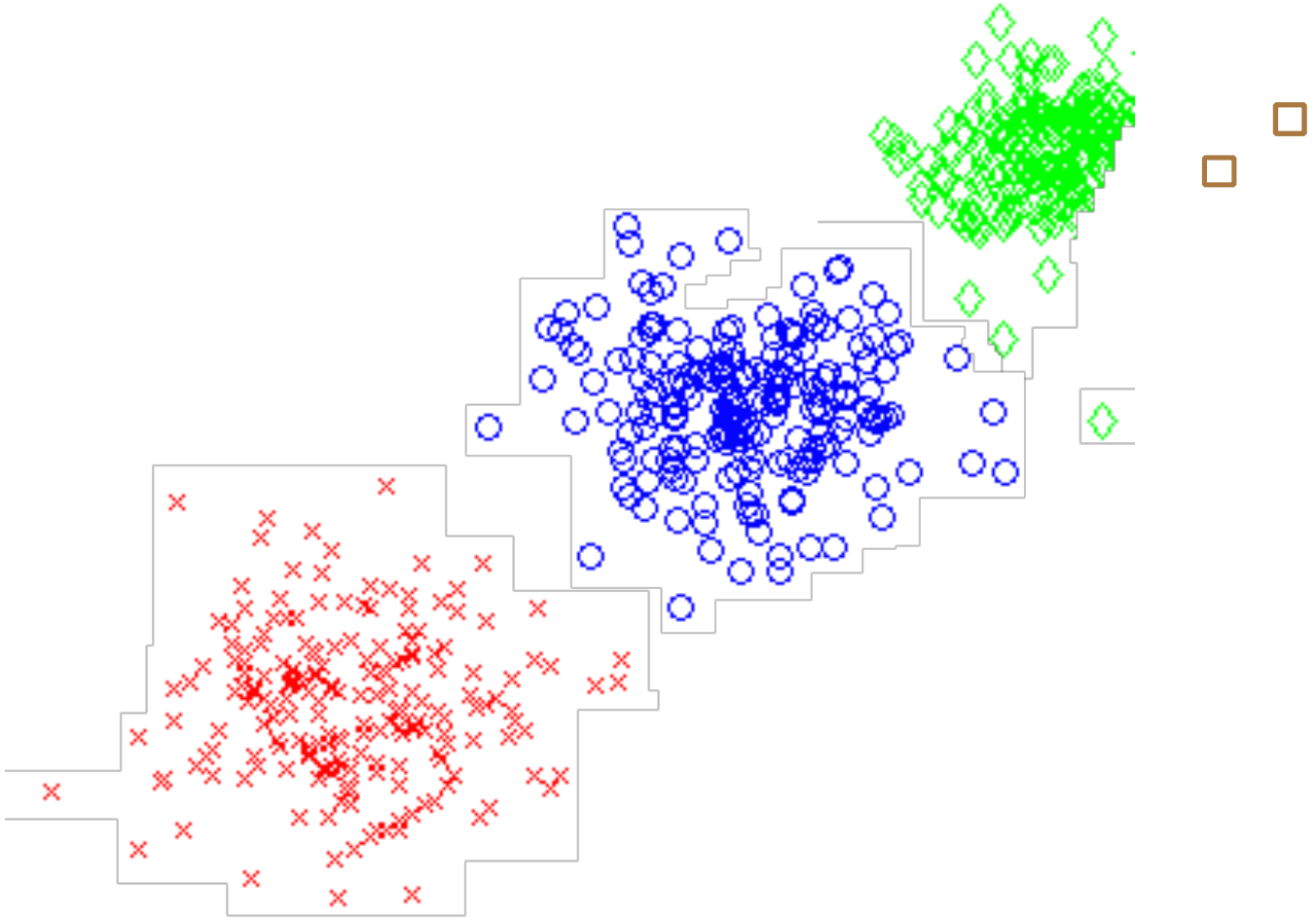

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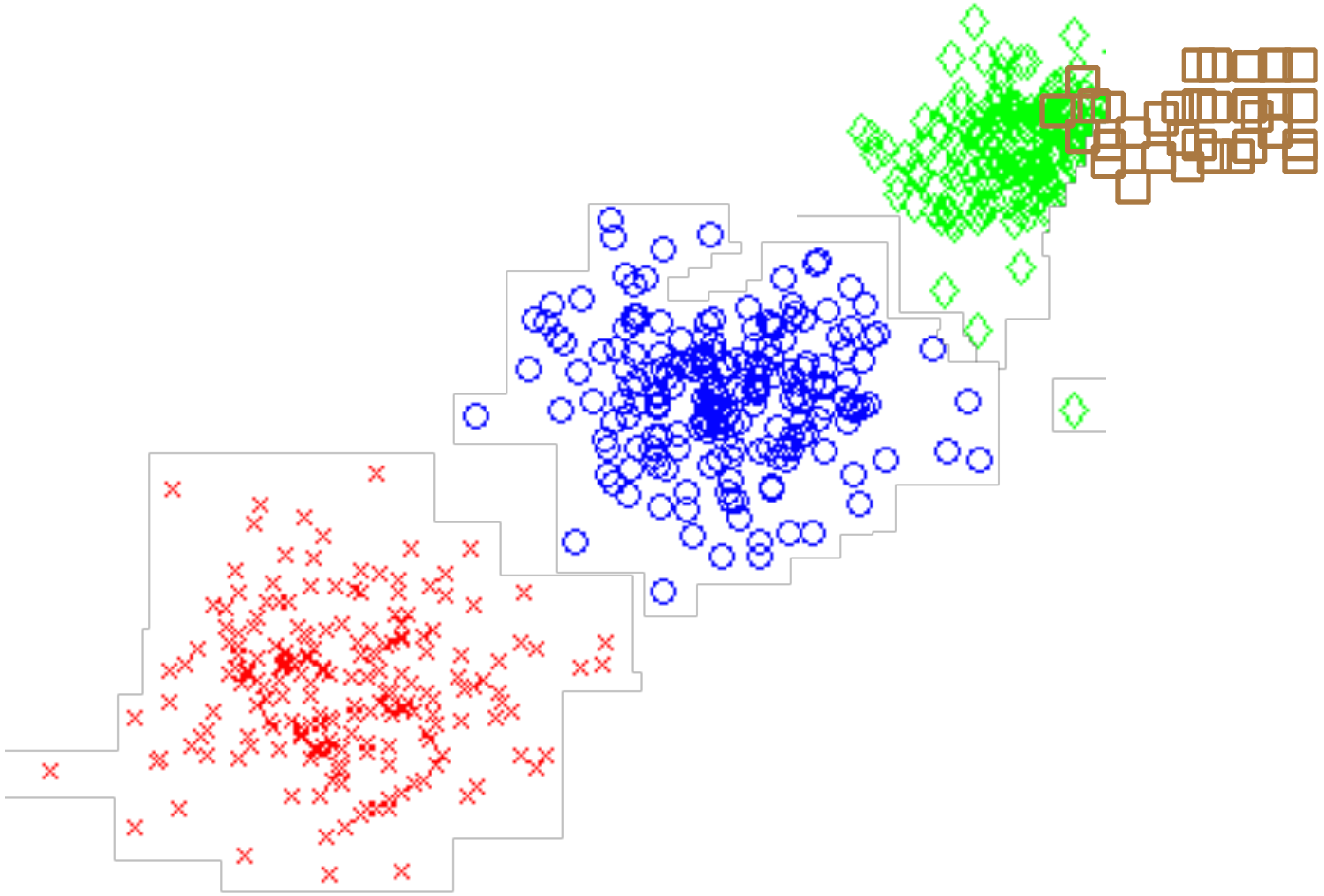

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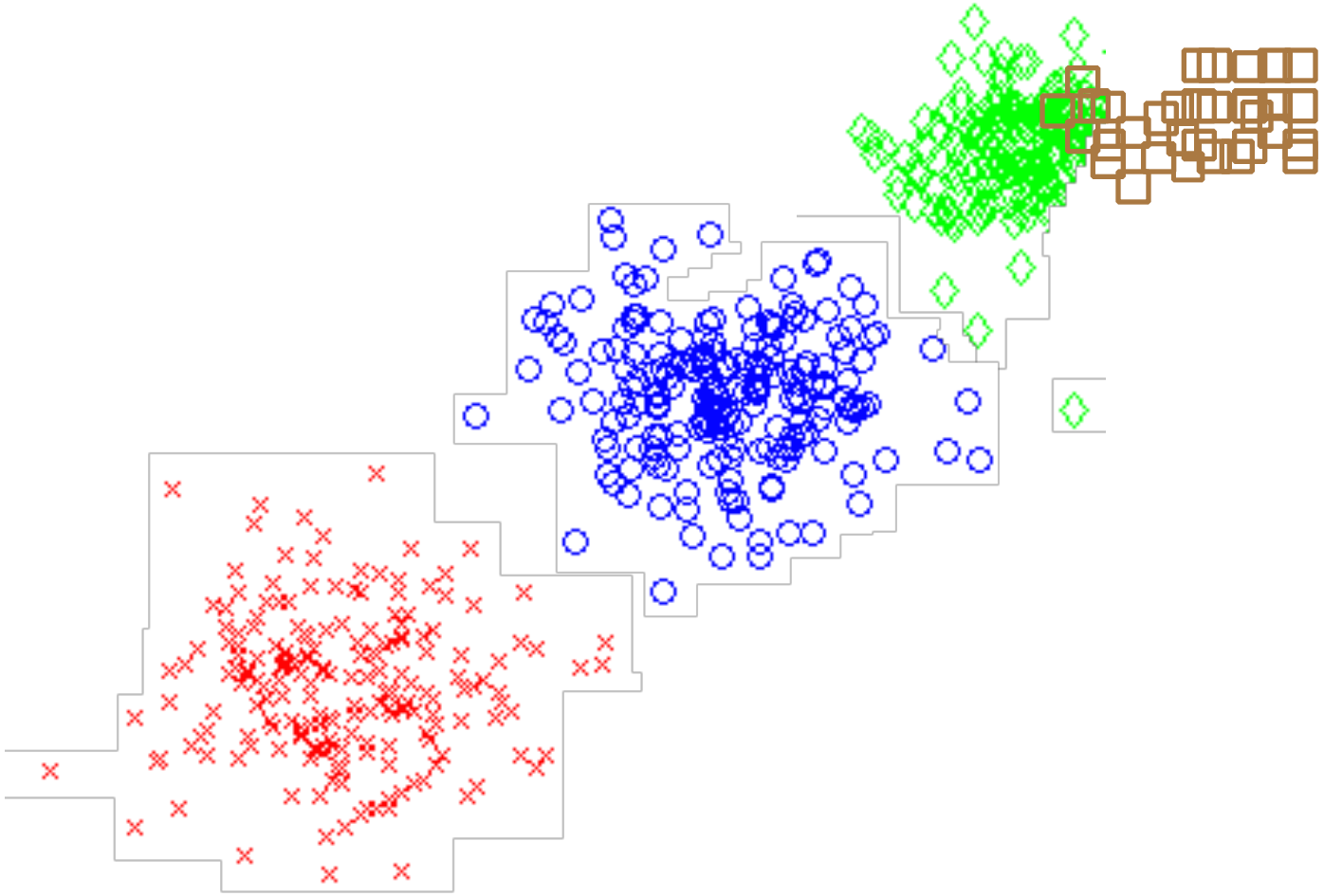

Event > 30 Tweets

# Hashtag Clustering

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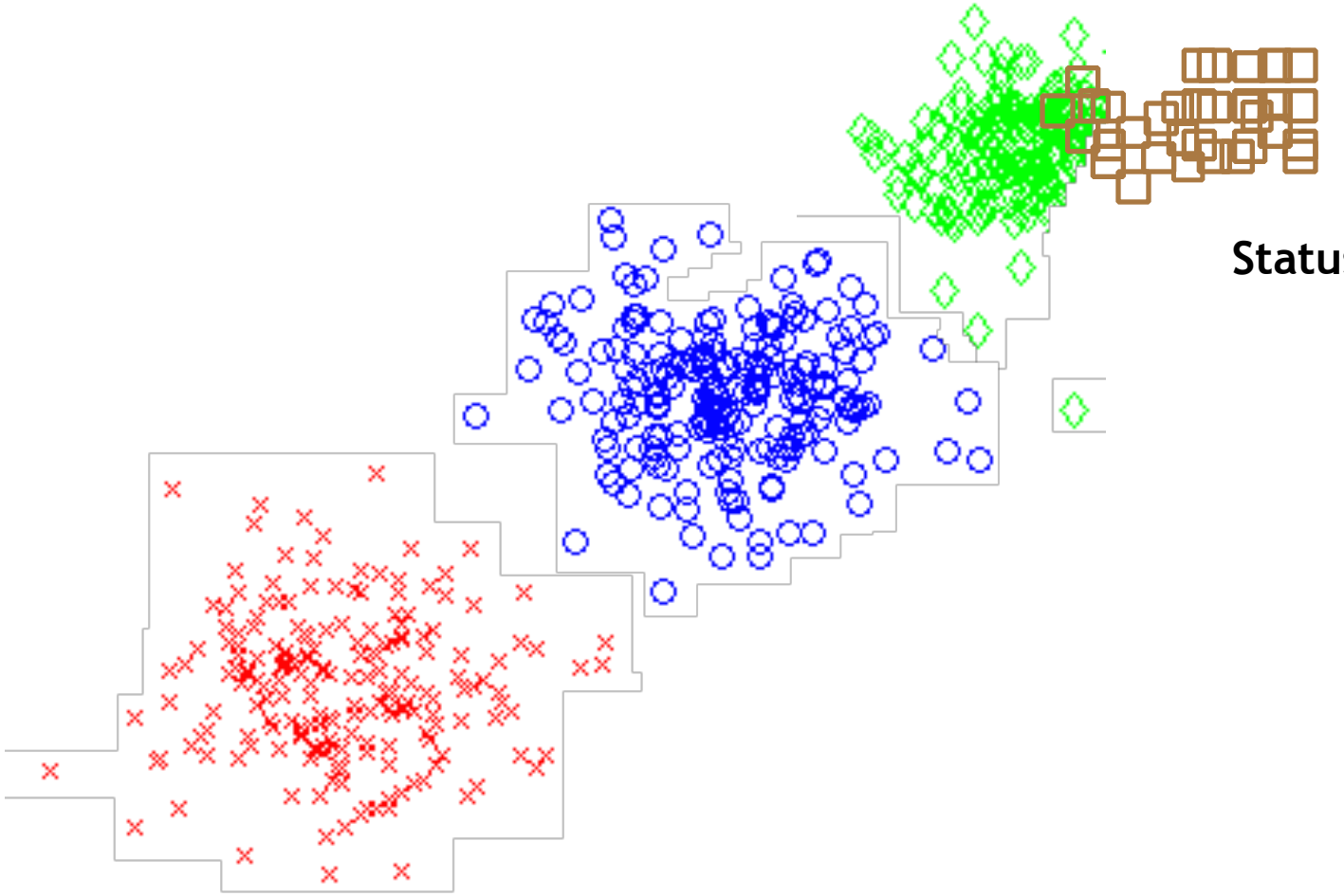

**Event > 30 Tweets**

**Status Change:** Inactive to Active

# Hashtag Clustering

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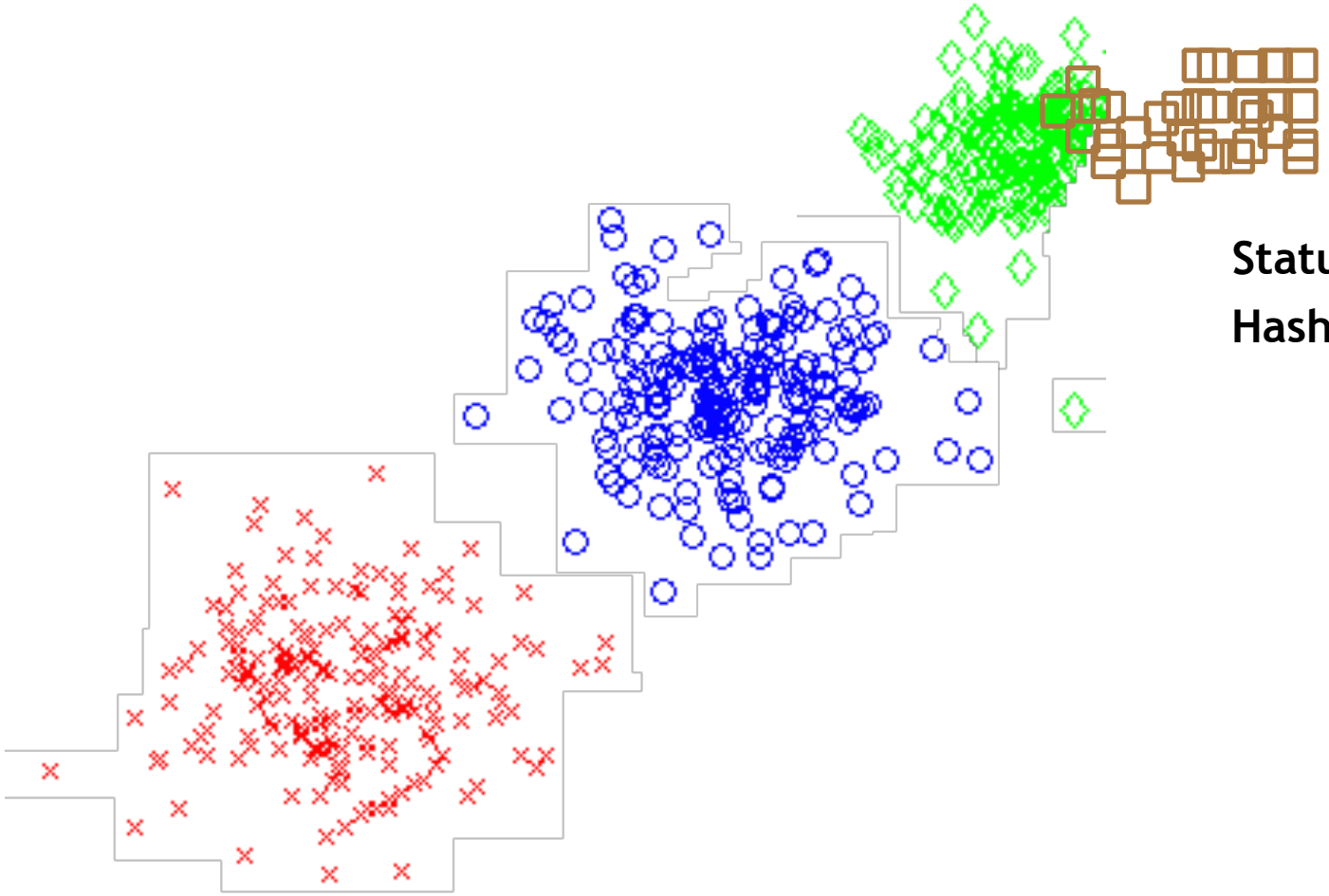

**Event > 30 Tweets**

**Status Change:** Inactive to Active

**Hashtags:** Dynamic to Static

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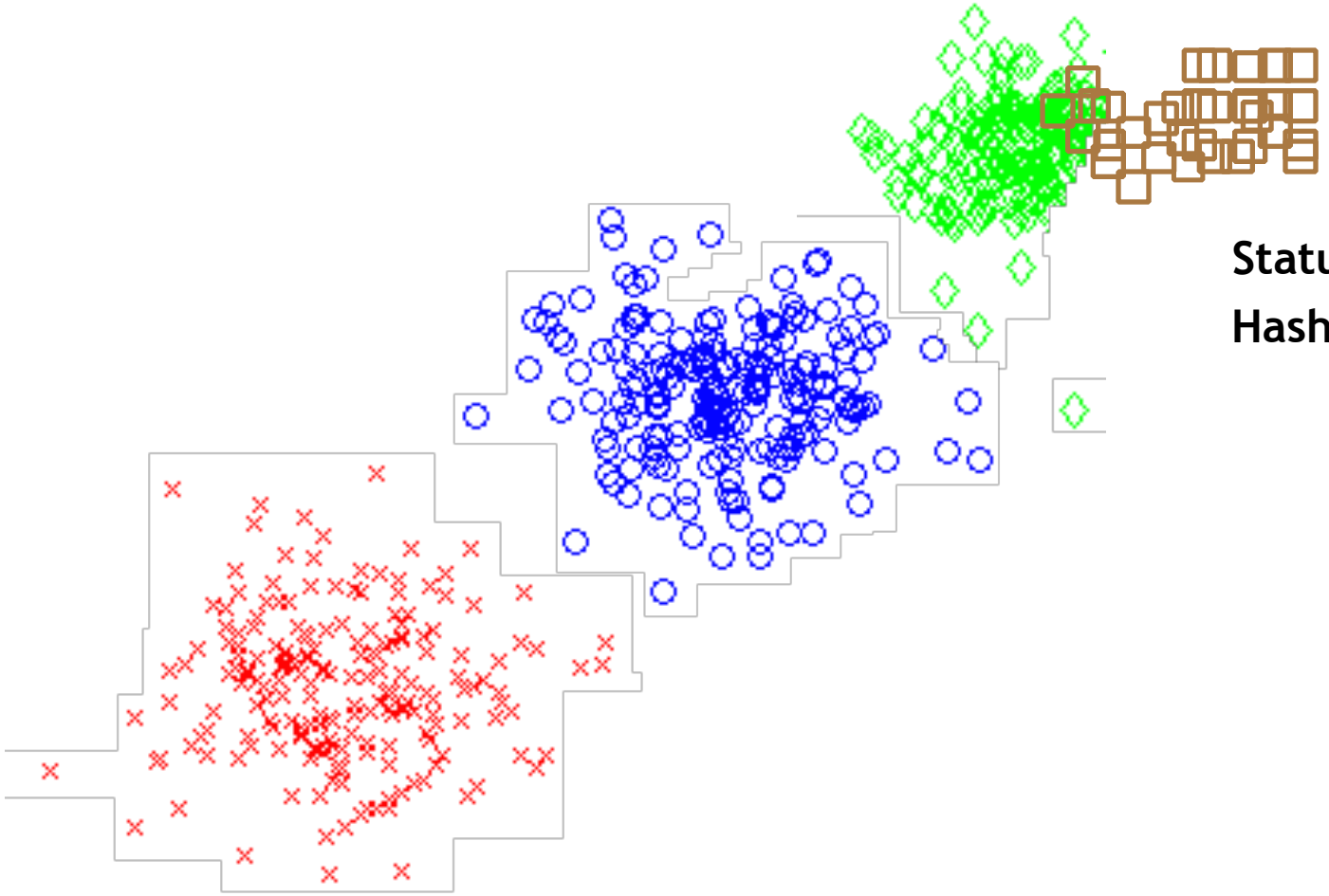

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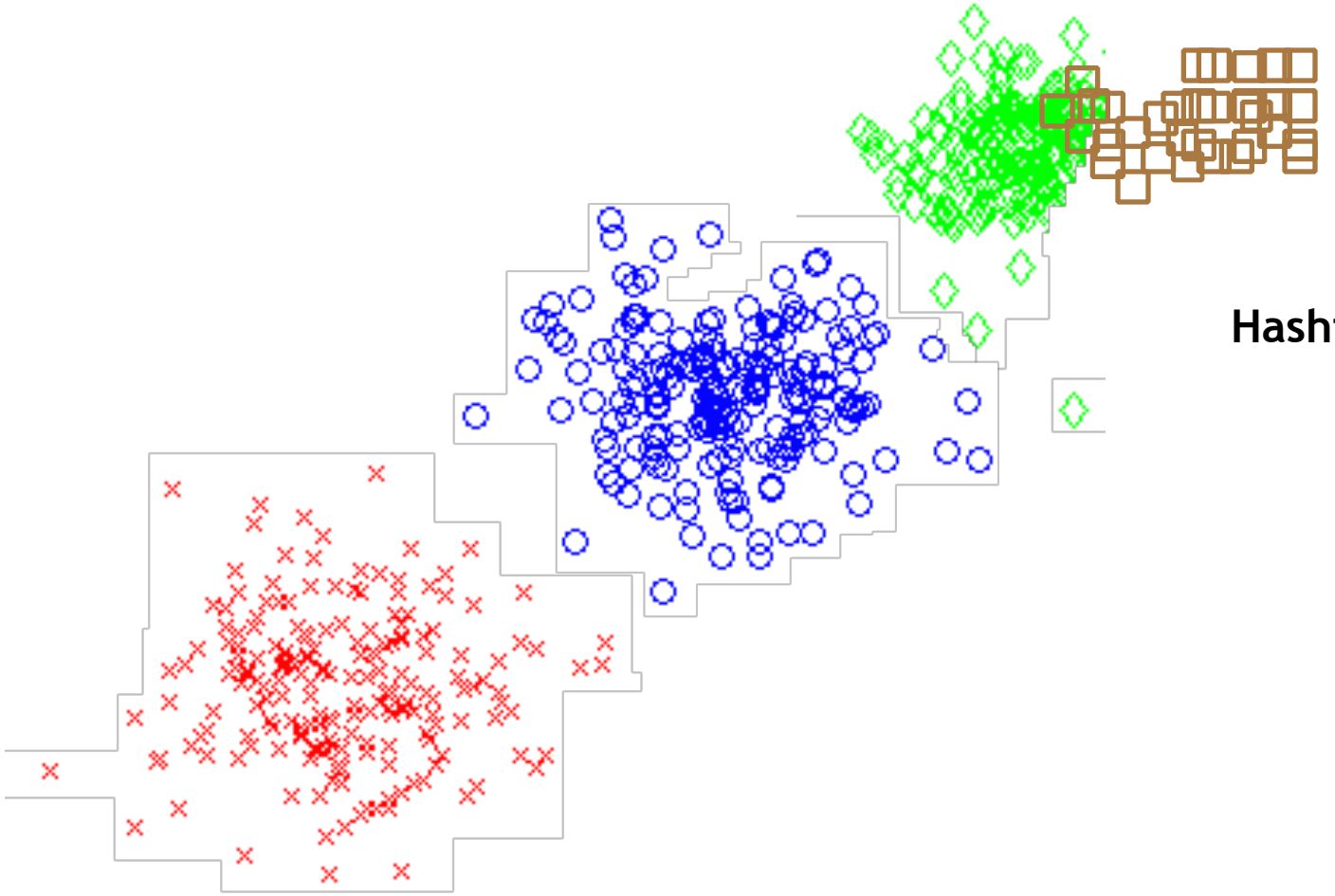

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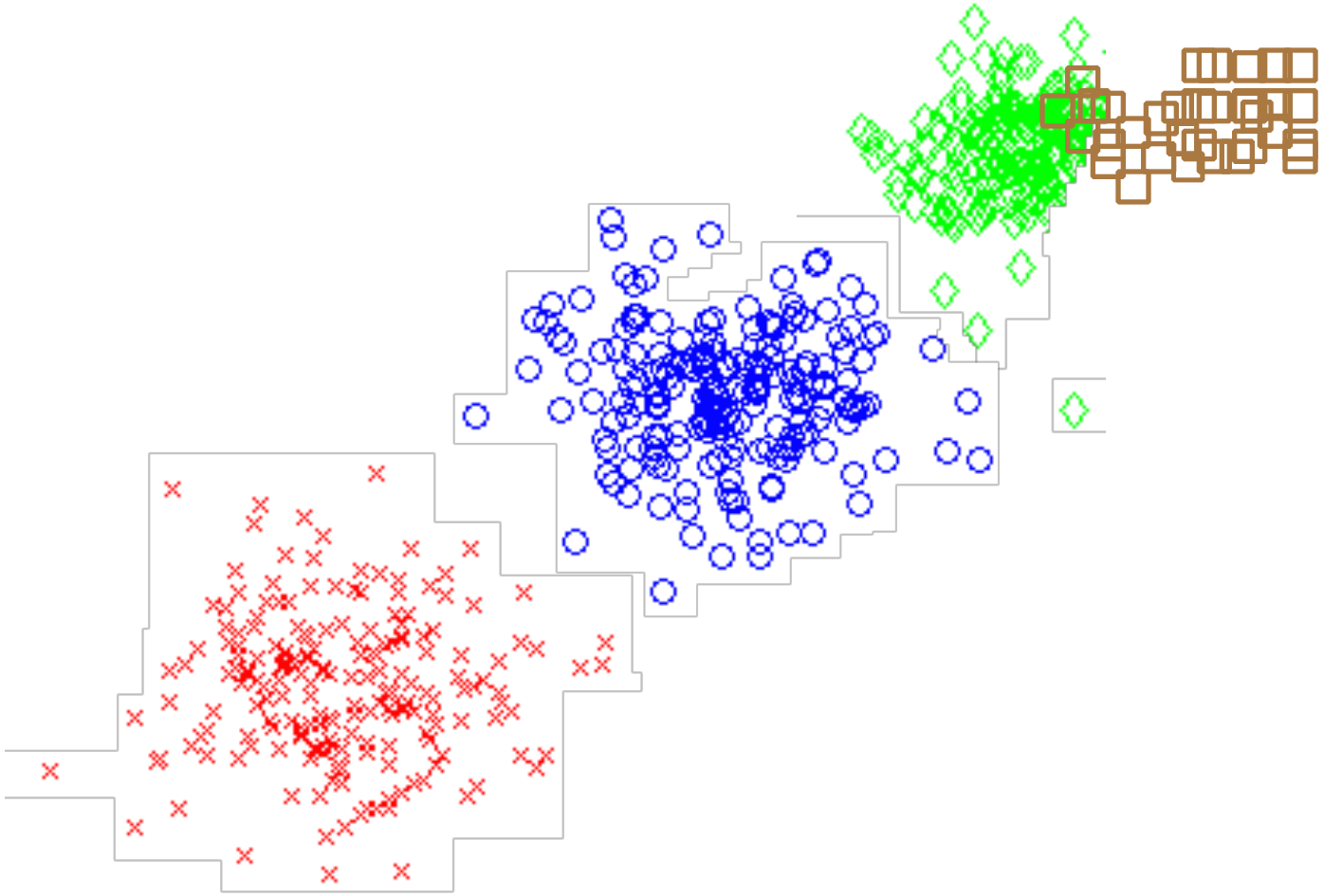

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## Part Of Vector Space (22-24. April 2016)

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

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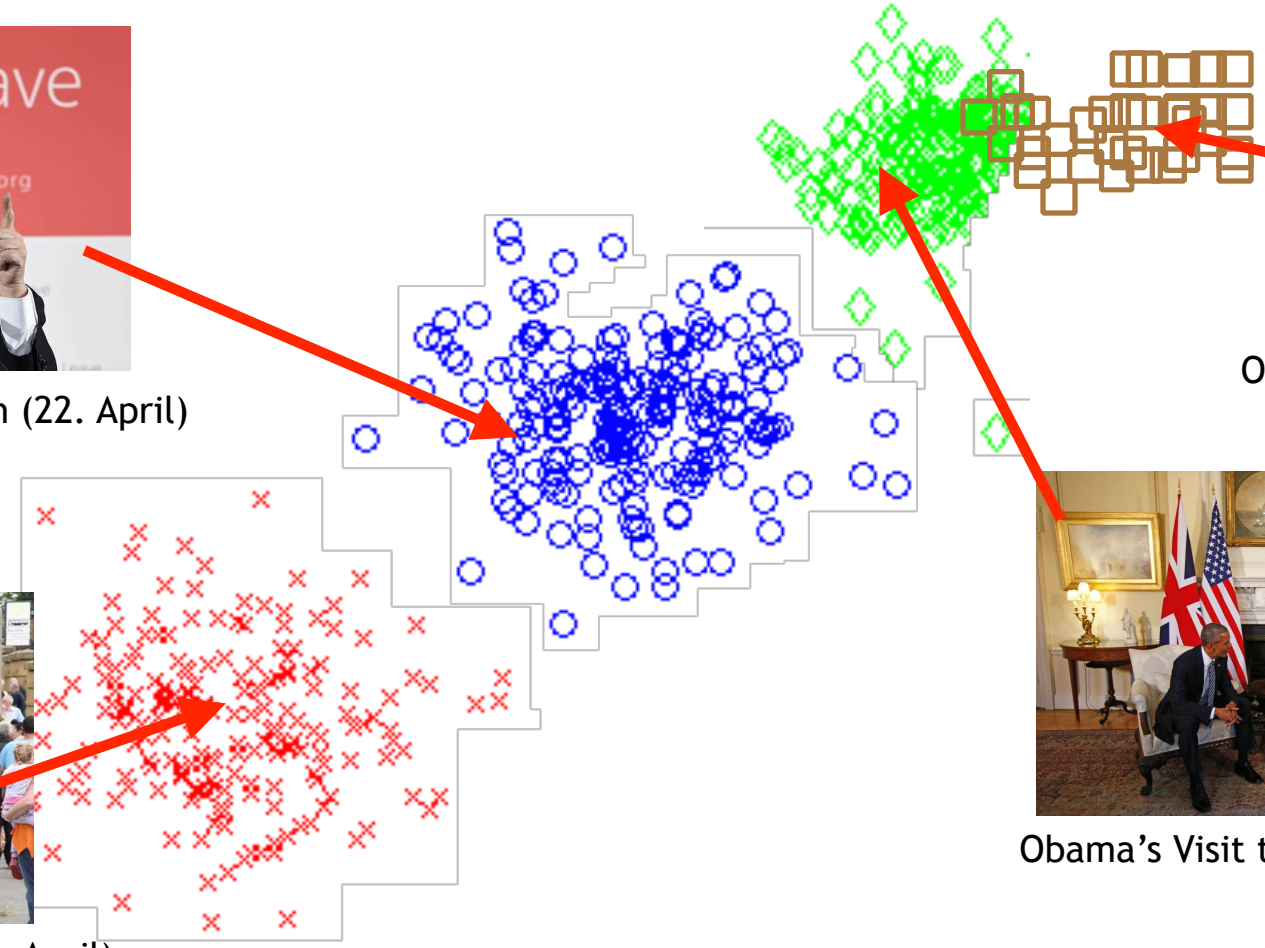

## Nearest Neighbour Search


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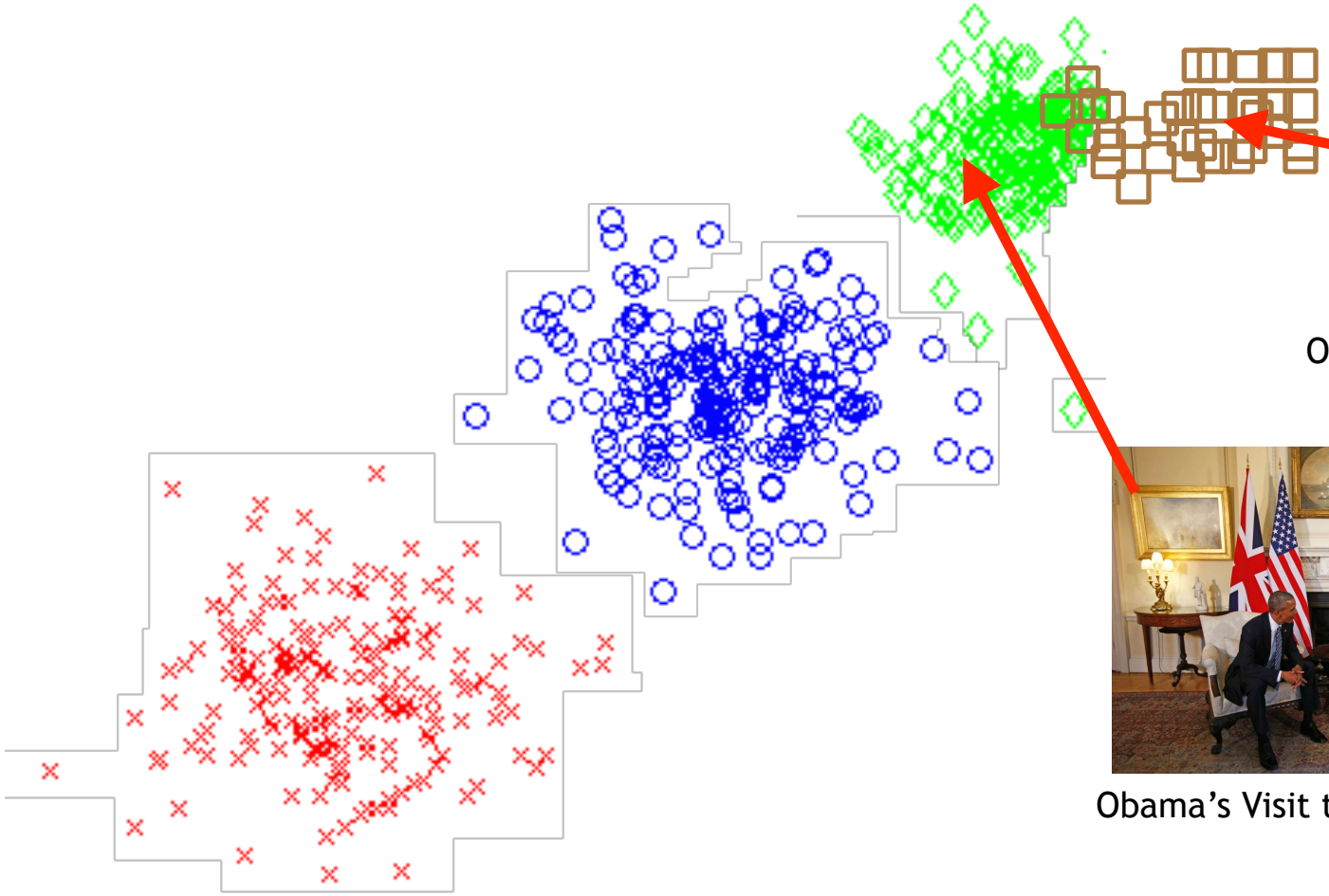

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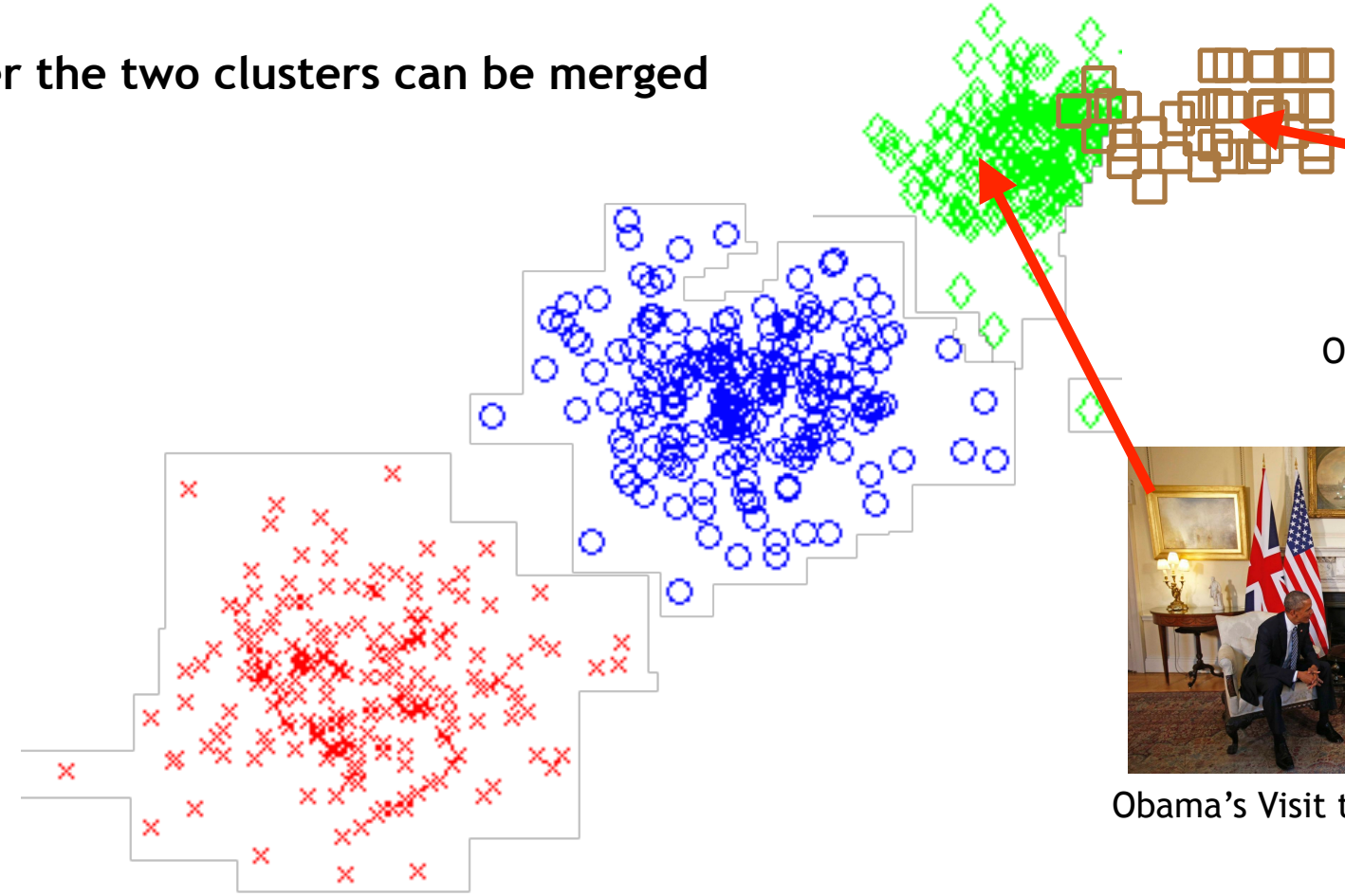

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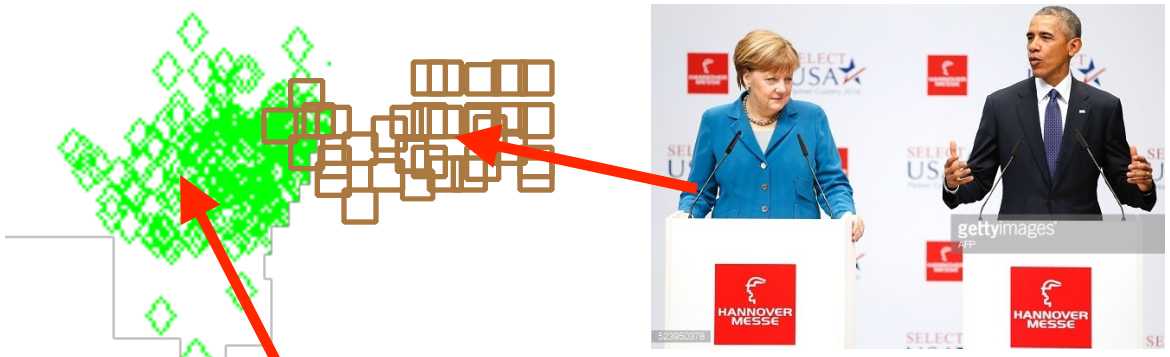


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**Check whether the two clusters can be merged**

- Check which hashtags are common

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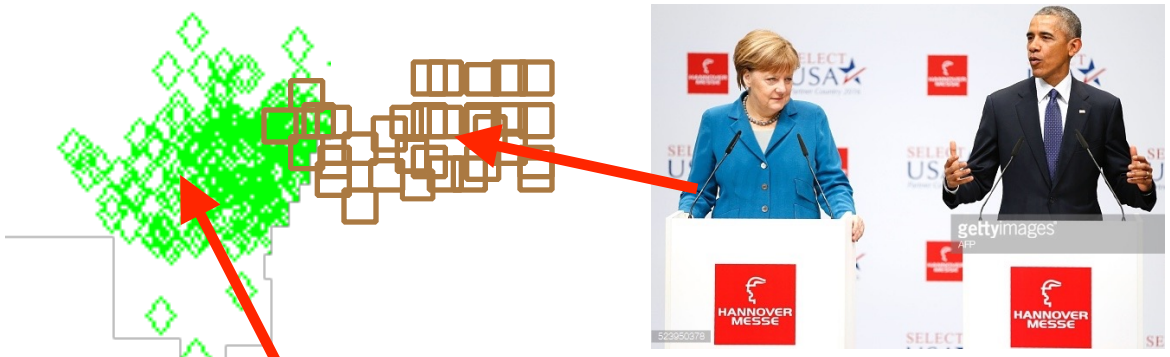


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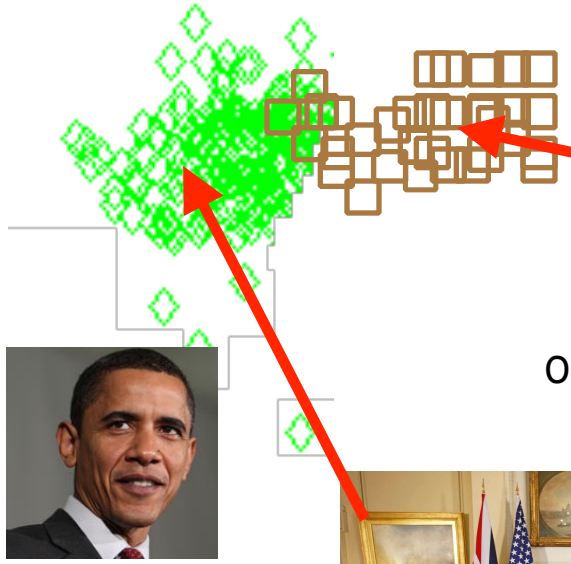

#obama


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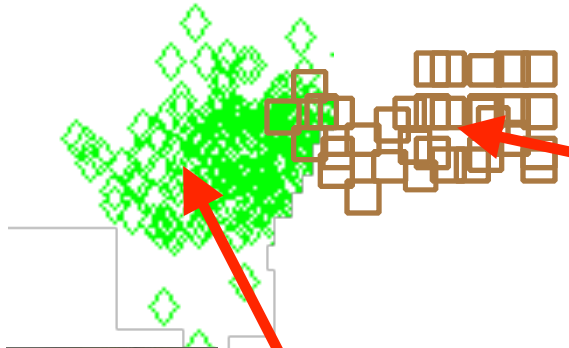

**Nearest Neighbour Search**


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

#foreignvisit

#obama

Obama's Visit to UK (23. April)

# Hashtag Clustering

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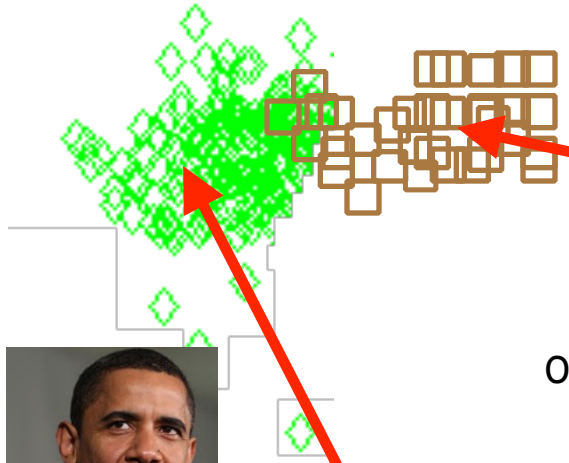
**Check whether the two clusters can be merged**

- Check which hashtags are common
- Common hashtags get absorbed



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#foreignvisit



#obama

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#foreignvisit

#obama

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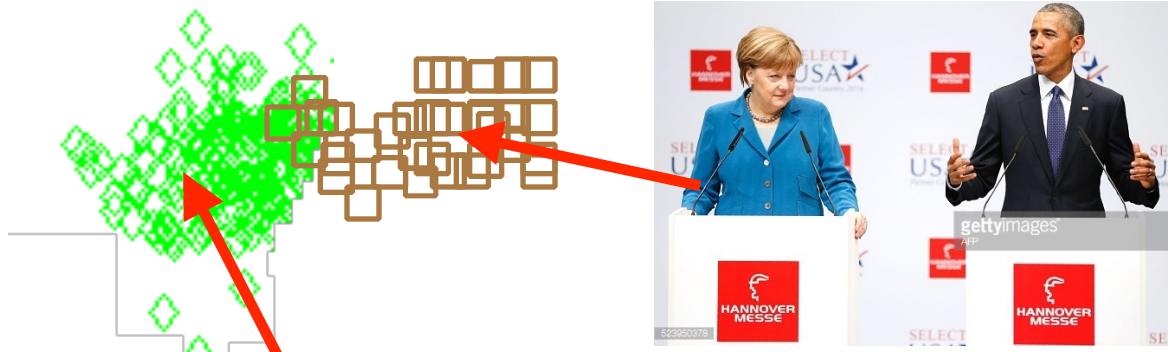


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#brexit

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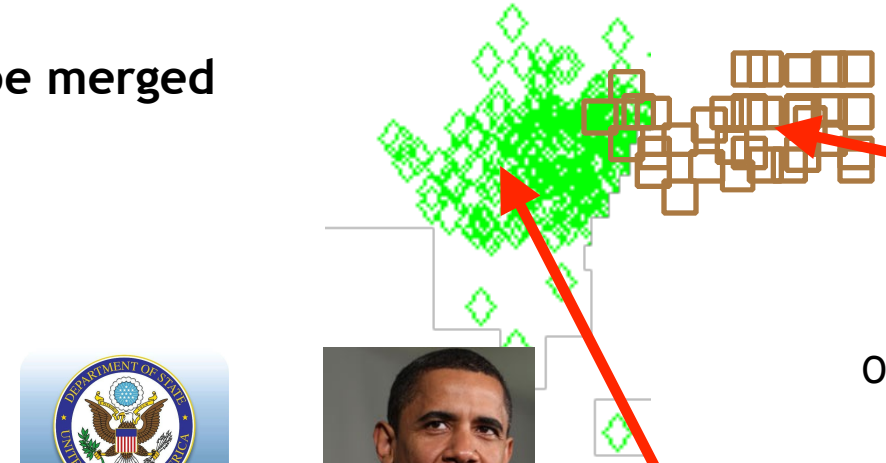

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#obama

Obama's Visit to UK (23. April)

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- Else: Keep clusters separate

#foreignvisit

#obama

#brexit

#hannovermesse

HANNOVER MESSE

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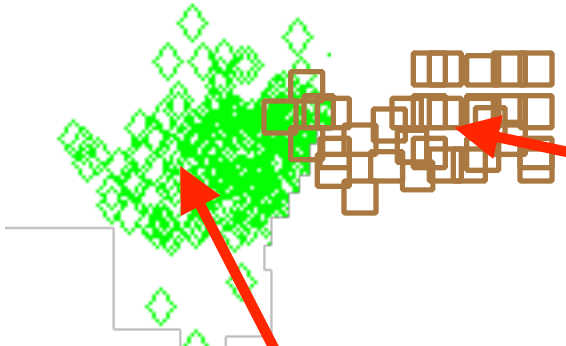


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**Separate Clusters ⇒ Separate Events**

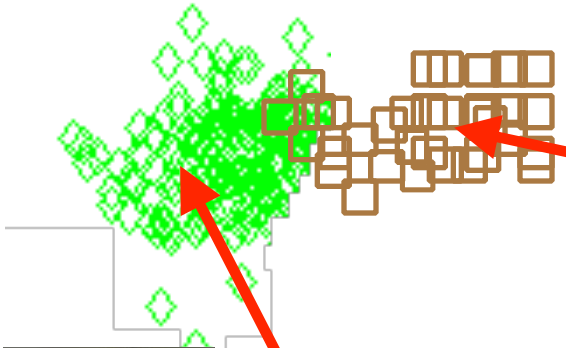
#foreignvisit

#obama

#brexit

#hannovermesse

**Nearest Neighbour Search**

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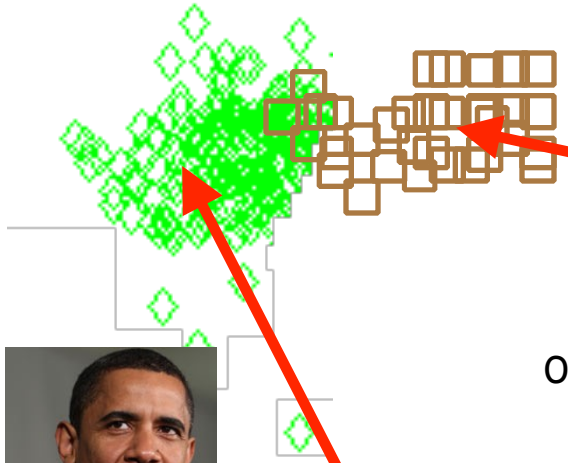
- Else: Keep clusters separate

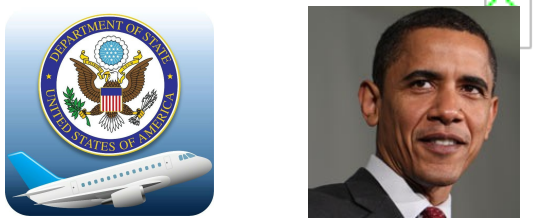
**Separate Clusters ⇒ Separate Events**

**Same Cluster ⇒ Same Event**



**Nearest Neighbour Search**


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



#obama

Obama's Visit to UK (23. April)

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#hannovermesse

HANNOVER MESSE

# Event Ranking

## Ranking Factors

- Burstiness

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

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Kröpcke, Hannover

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Shopping in Kröpcke


Demonstrations in Kröpcke

# Event Ranking

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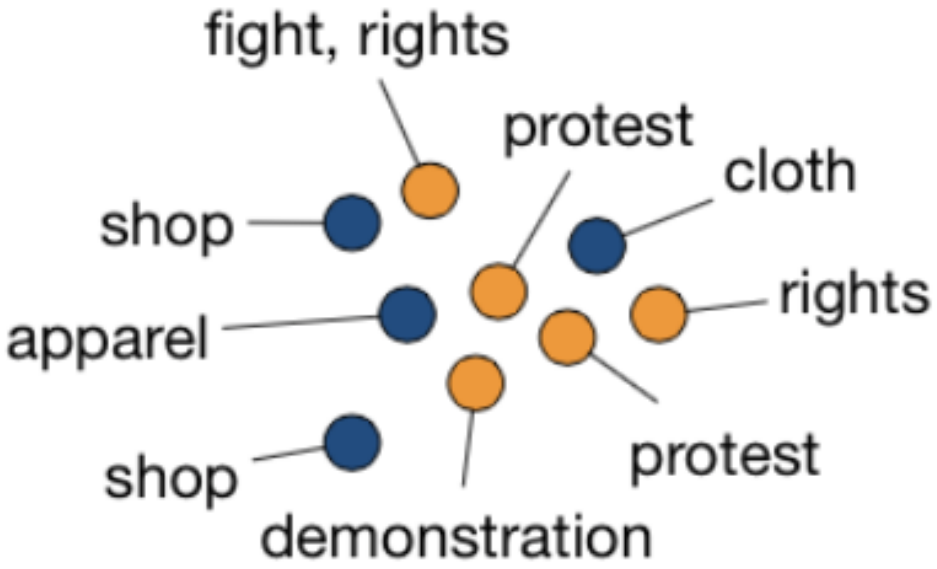


Tweets around Kröpcke, Hannover

# 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

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

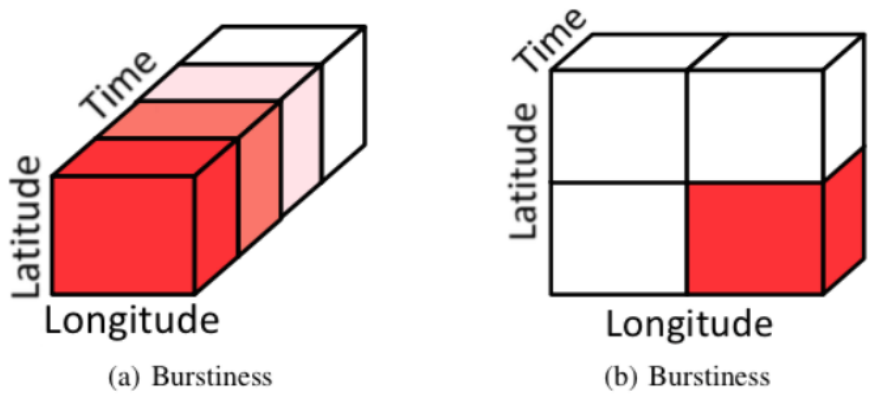


Fig. 4. Localness[2]

# 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 $\alpha$, $\beta$, and $\gamma$ varied according to the interest of the users

- For local events, higher value of $\gamma$ when compared to $\alpha$ and $\beta$

- Popular events of an year: higher value of $\alpha$ when compared to $\beta$ and $\gamma$

# 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

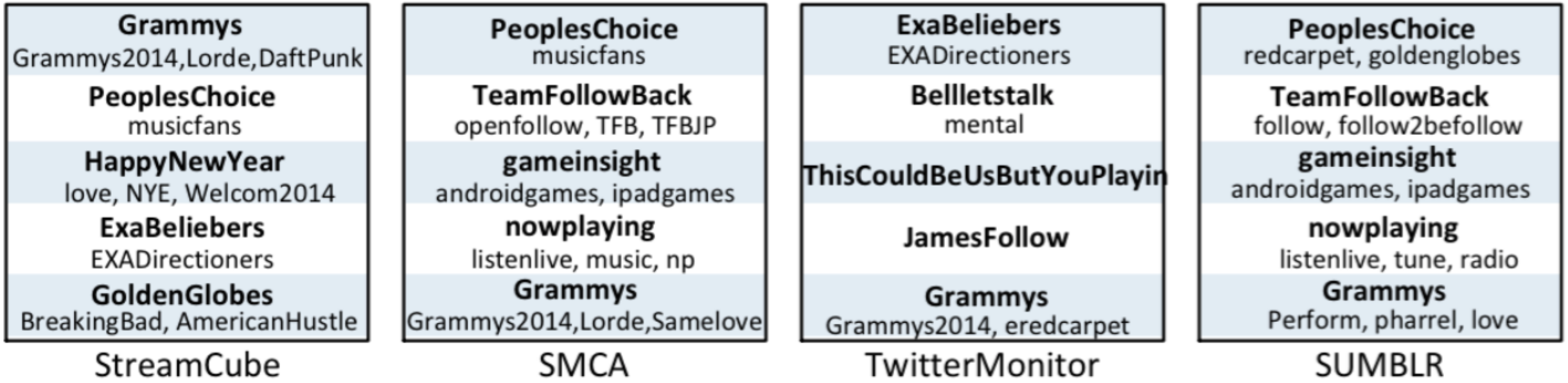


Fig. 5. Detected Events by Different Methods in January 2014[2]

# Experimental Study

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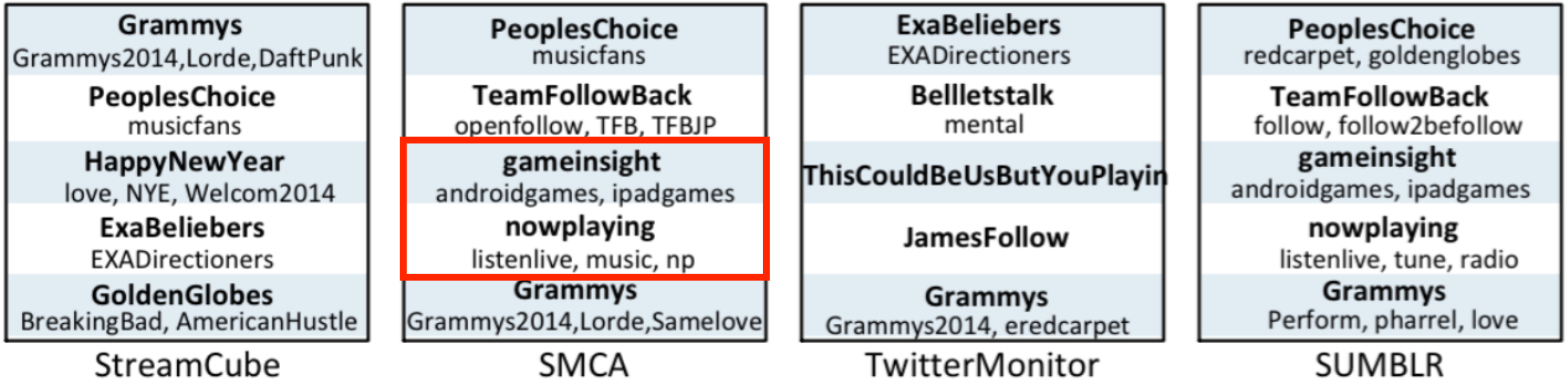


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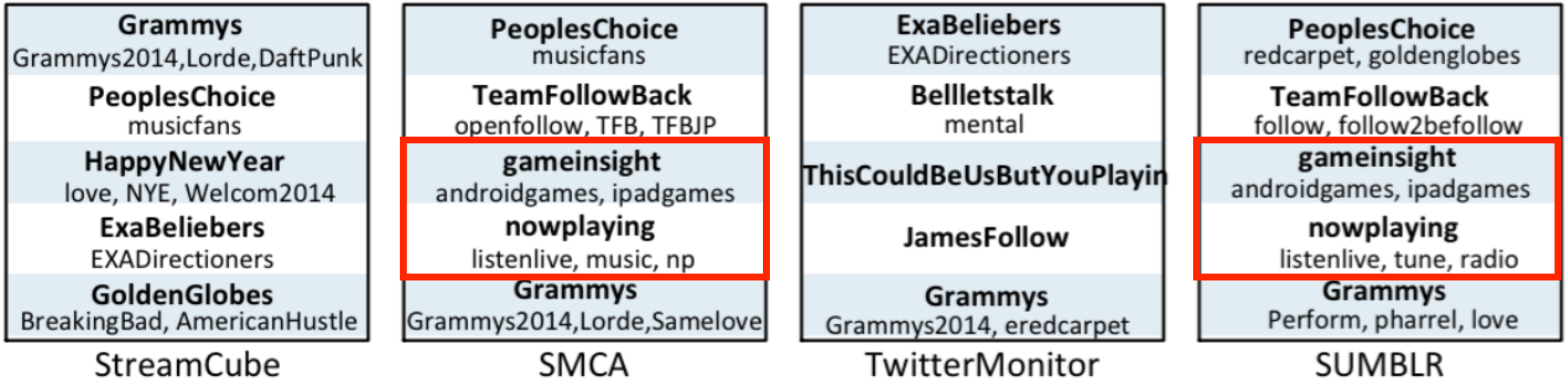


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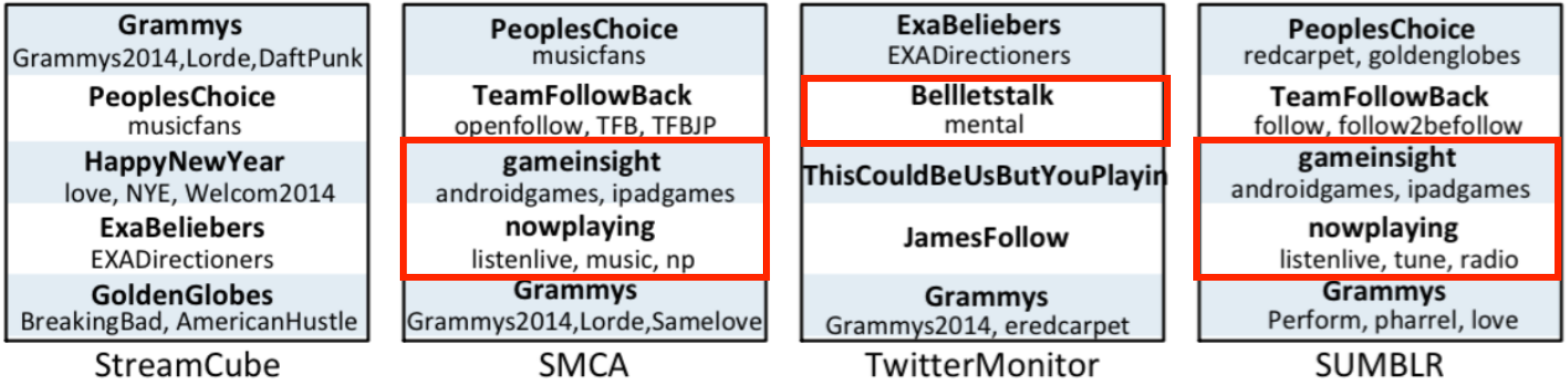


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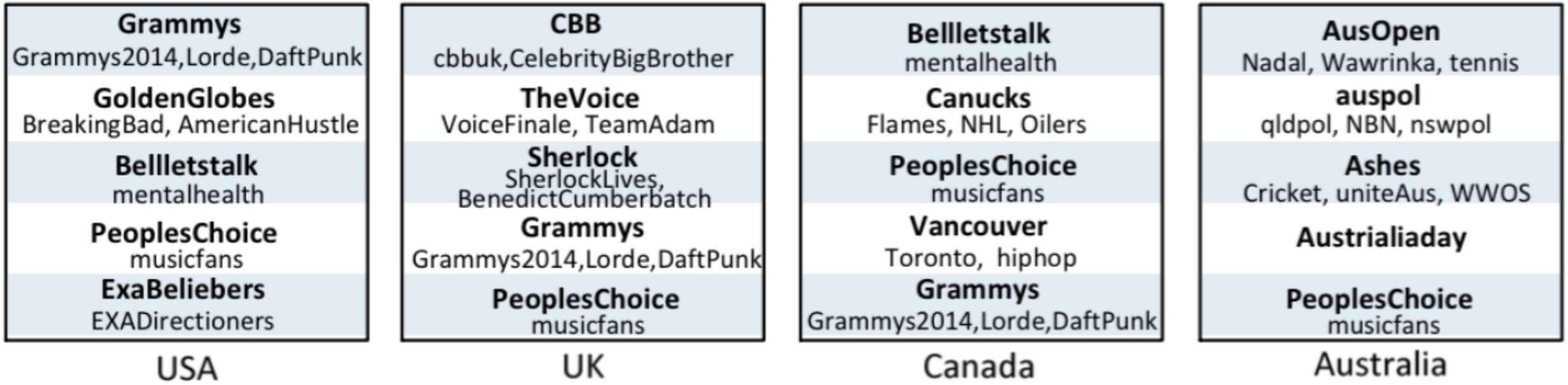


Fig. 6. Events in Four Different Countries in January 2014[2]

# Experimental Study

## Qualitative Evaluation

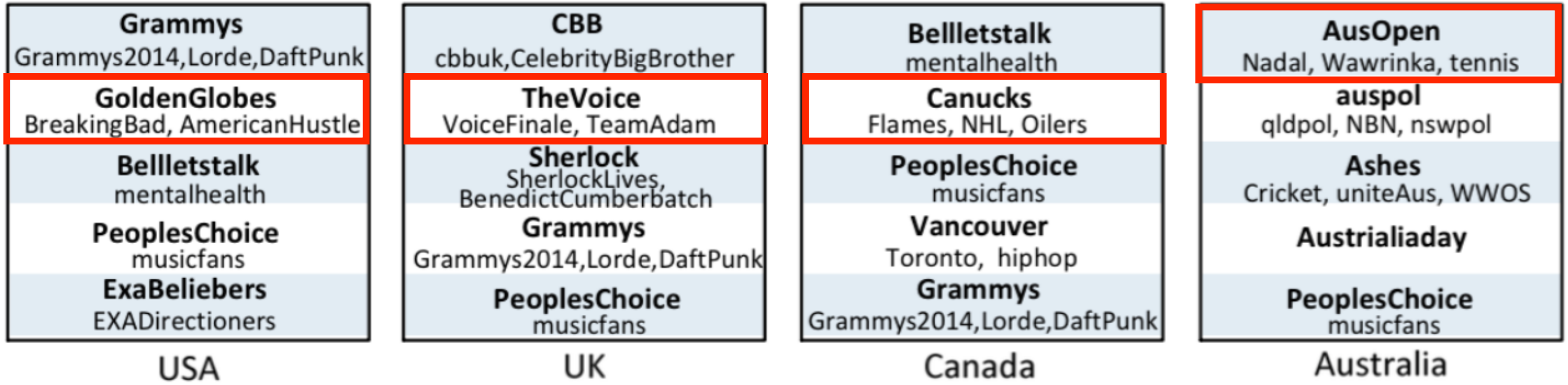


Fig. 6. Events in Four Different Countries in January 2014[2]

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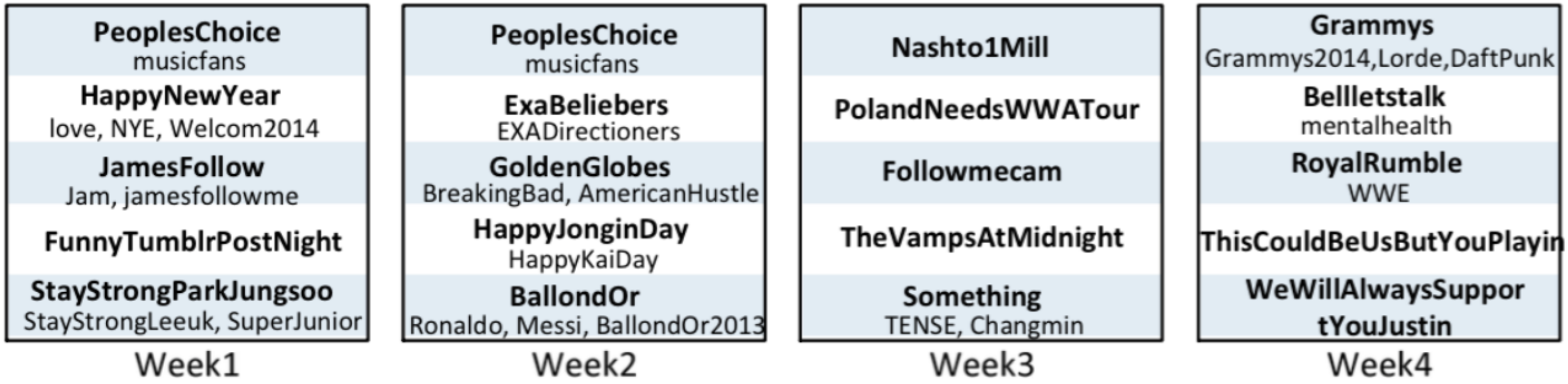


Fig. 7. Events in four weeks of January 2014[2]

# 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

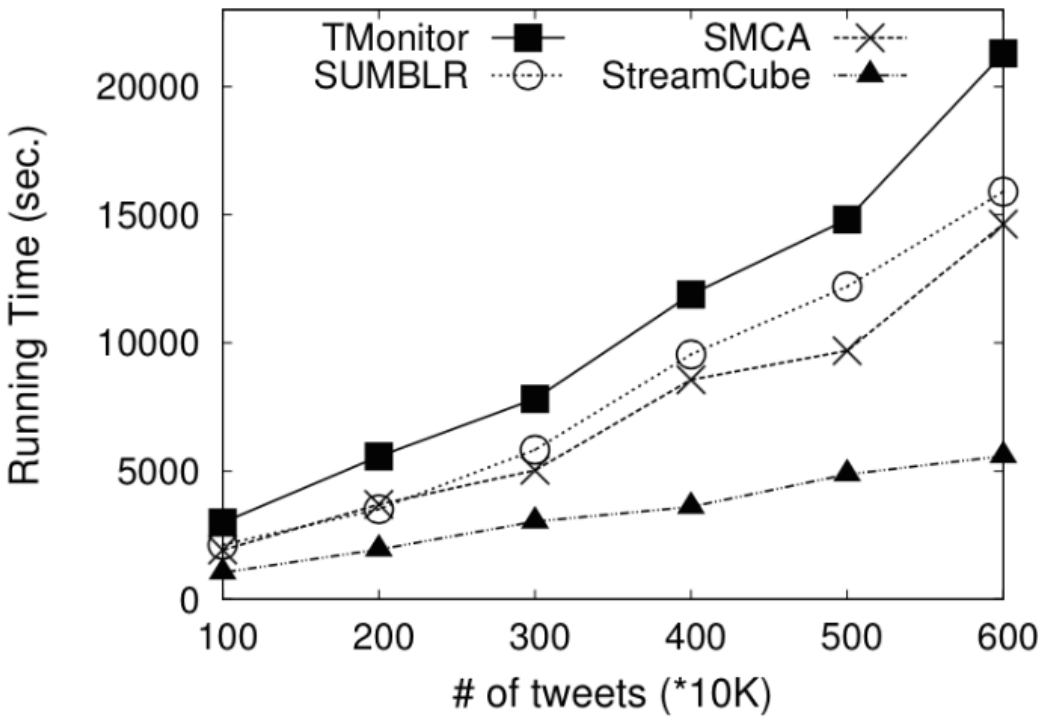


Fig. 8. Scalability[2]

# 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

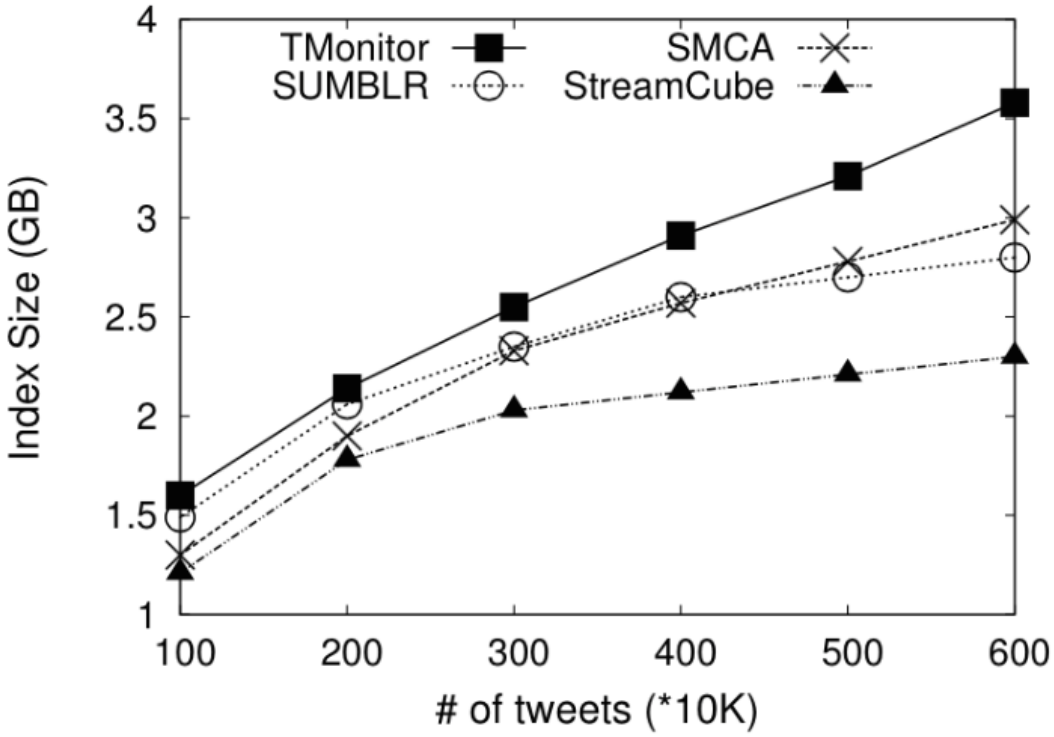


Fig. 9. Memory Usage[2]

# 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 space 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

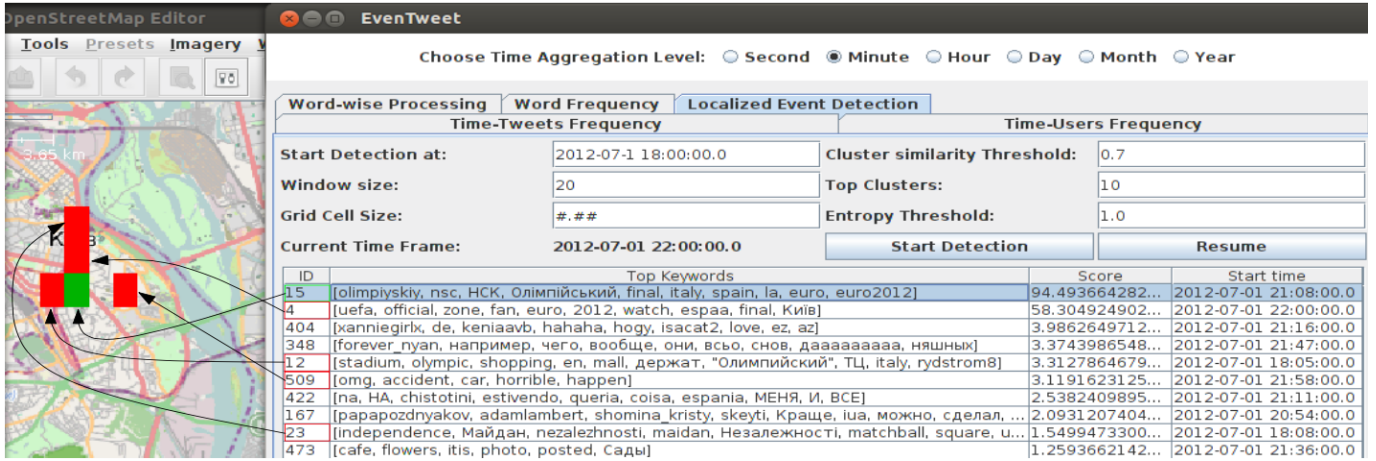


Fig. 10. EvenTweet Interface[7]

- **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


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# Discussion