ICDM 2015
IEEE International Conference on Data Mining

A GENERAL **SUSPICIOUSNESS** METRIC FOR **DENSE BLOCKS** IN **MULTIMODAL** DATA

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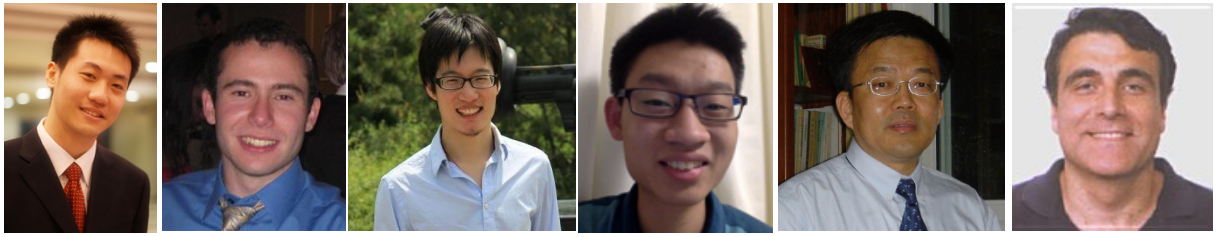
Joint work with
Alex Beutel (CMU), Peng Cui (Tsinghua), Bryan Hooi (CMU),
Shiqiang Yang (Tsinghua), Christos Faloutsos (CMU)



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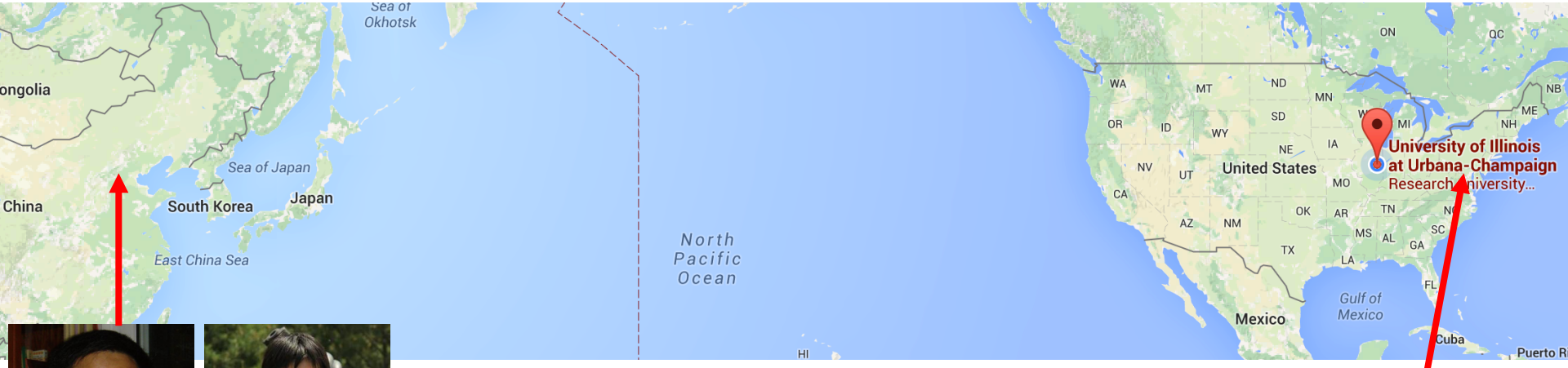

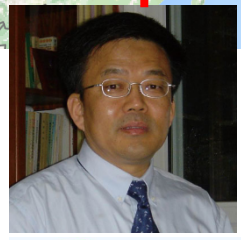

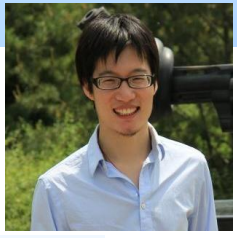

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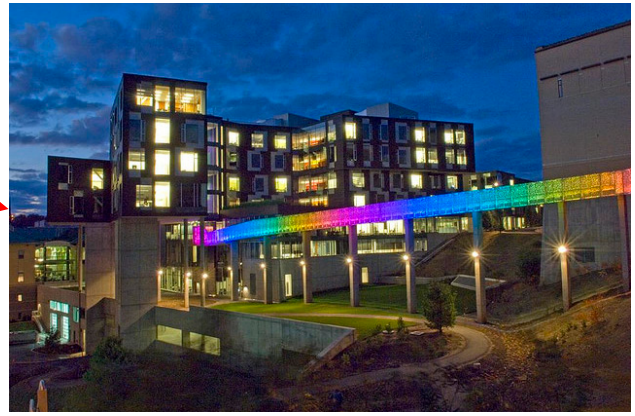
2012-2013



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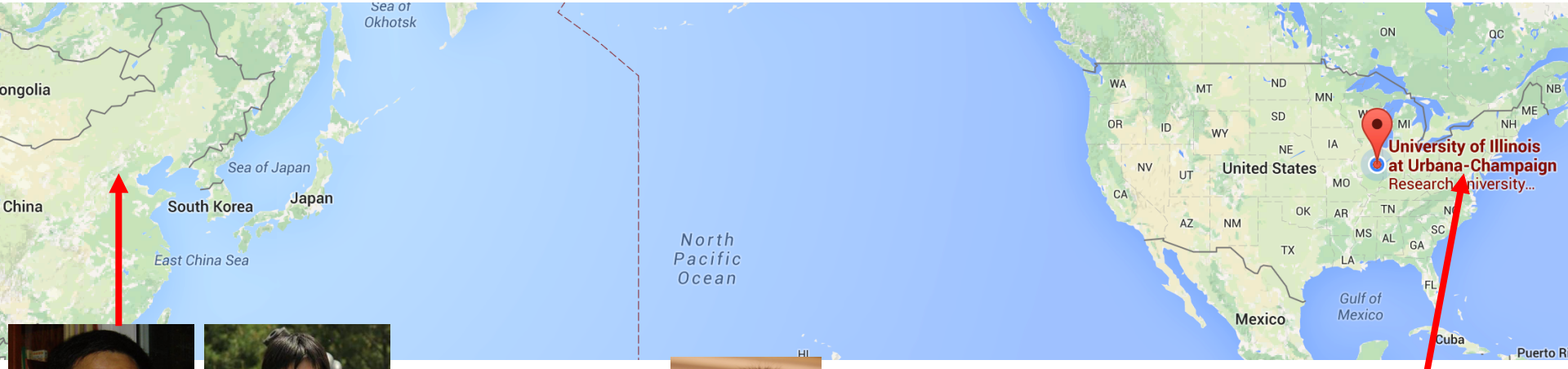

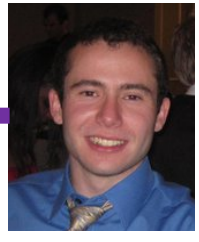

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KDD 2014
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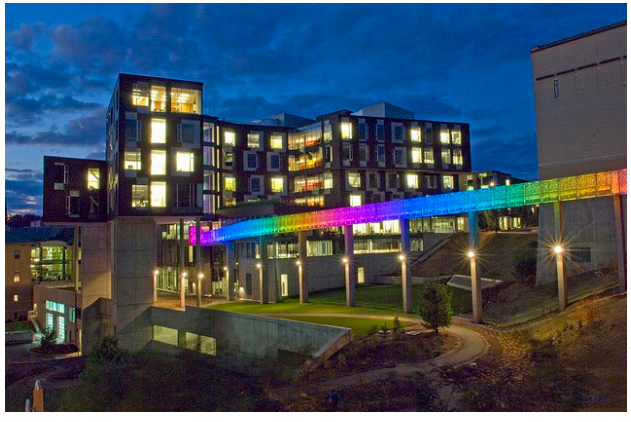

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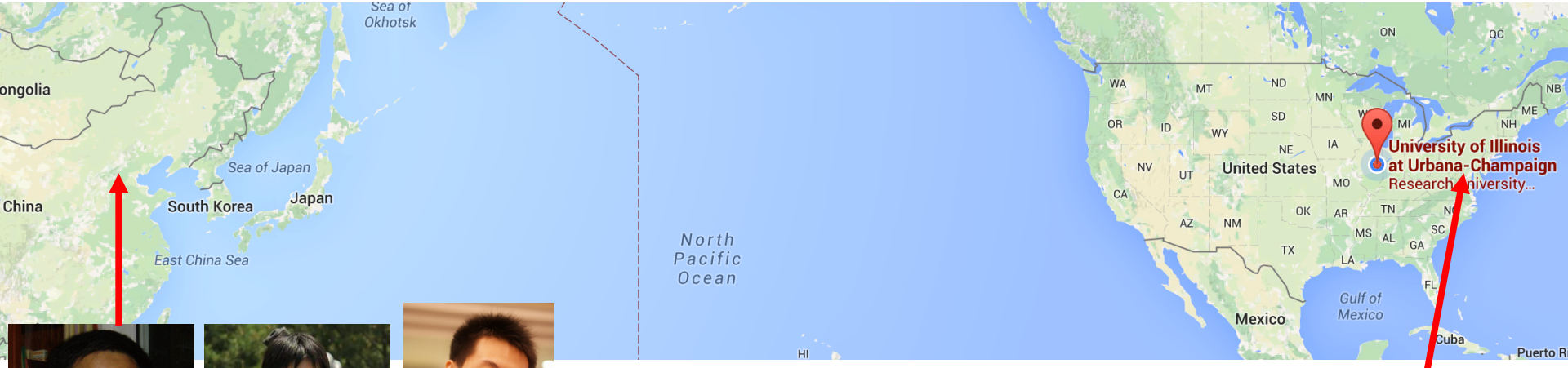

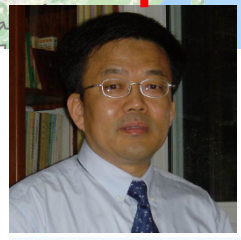

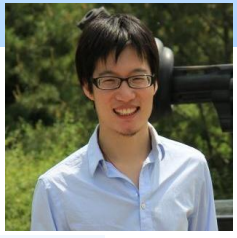

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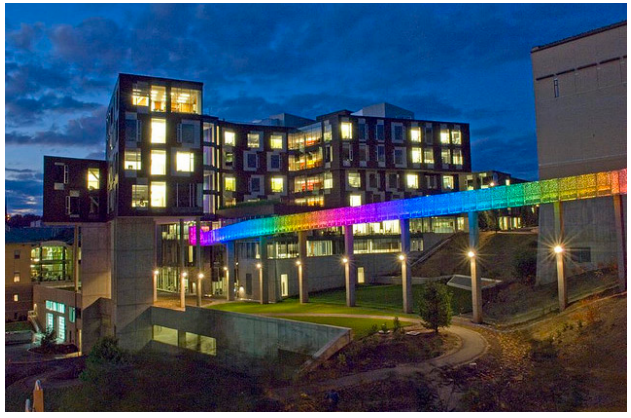
ICDM paper

May, 2015



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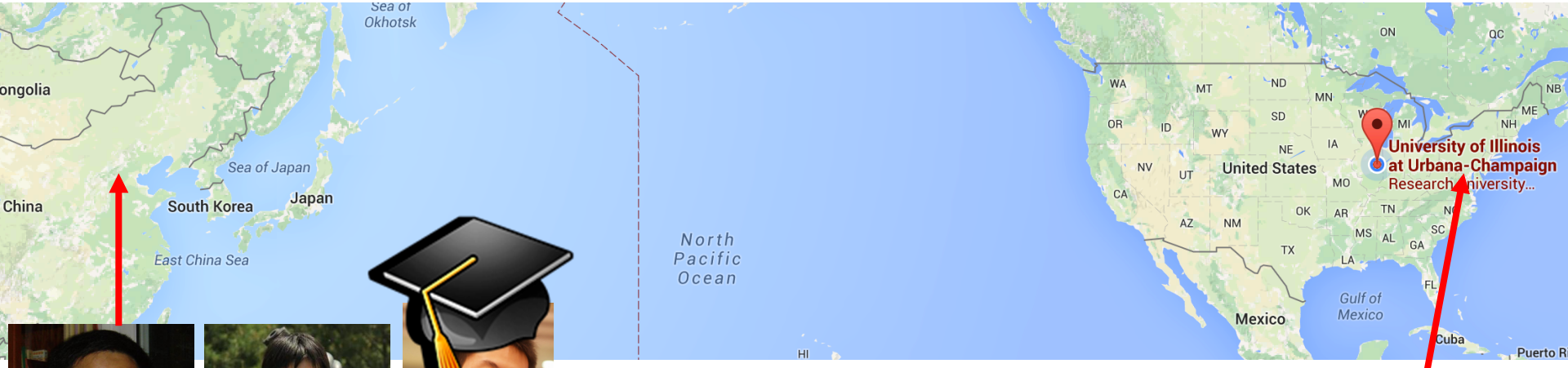

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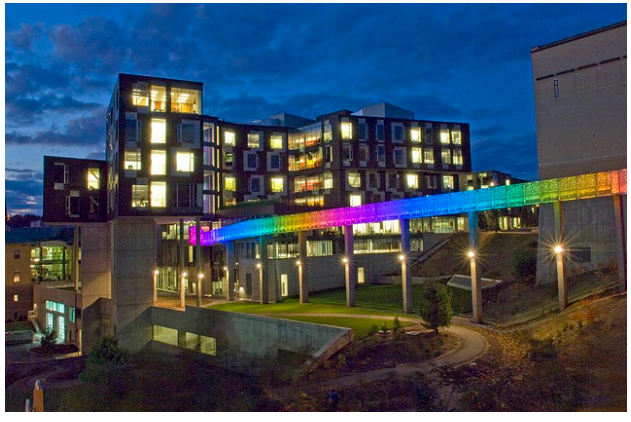
Ph.D.,Tsinghua

June, 2015



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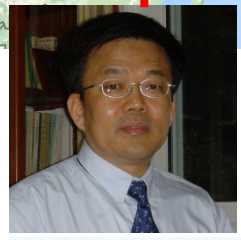

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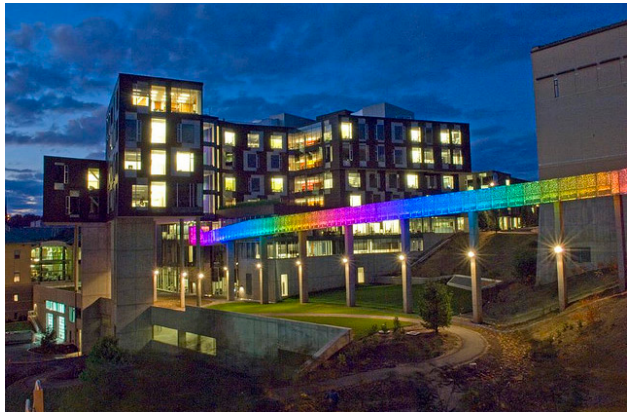
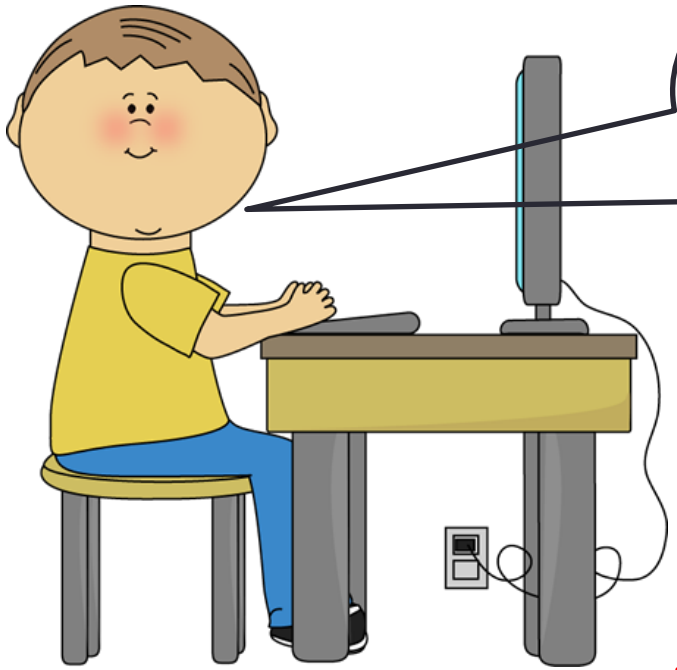
Postdoc, UIUC

August, 2015



Suppose You Work in Twitter



My boss wants me to **catch fraud** in such a big table – **billions of records, tens of columns**!!! How?!

	ID	USER_NAME	CREATED_AT	TEXT	HASH_TAGS
1	251	SpiritSofts	Dec 14, 2013	SAP HANA ONLINE TRAINING COURSE CONTENT http://t.co/2DefOMC0Vi	
2	252	Blue net studiO	Dec 14, 2013	sap hana online training and placenet 2 http://t.co/S1wGh8n5Kk	
3	253	Hana Kingham	Dec 14, 2013	Right film fest today: love actually, elf, gravity, training day. #dayyym	dayyym,
4	254	Nora Apnila J...	Dec 14, 2013	Alhamdulilaaahhhh...selesai ikutin kelanjutan training dadakan mb Hana ...	
5	255	ZaranTech	Dec 14, 2013	I added a video to a @YouTube playlist http://t.co/O3qD9wfi8K SAP BUSI...	
6	256	ZaranTech	Dec 14, 2013	I added a video to a @YouTube playlist http://t.co/XxrfuCUqAS SAP BUSI...	
7	257	Helmich op t...	Dec 14, 2013	Reserveer alvast 15 januari 2014 training HANA Essentials #SAP #HANA	SAP,HANA,
8	258	Social News	Dec 13, 2013	sap hana online training and placenet 2 http://t.co/JlaA41IdnV	
9	259	Nurjanah	Dec 13, 2013	Baca notif fb .. ada training dadakaann dari eyang kita.... ayo wara wiri ca...	
10	260	Nora Apnila J...	Dec 13, 2013	lanjutt di rumaah dulu ikutan trainingnyaaa..mau buru buru pulang see u...	
11	261	madhu	Dec 13, 2013	SAP HANA TRAINING	SAP HANA PLACEMENT	SAP HANA INSTITUTE I...	
12	262	Hana O'Neill	Dec 13, 2013	@sarahsilvanator no I have life guard training Saturday and my final test t...	
13	263	arjun	Dec 13, 2013	sap grc online training |sap hana sap security online training@YEKTEK - A...	

fraud

Suspicious Behaviors in **Multi-Modal** Data

Wholesalebargain2015 Retweeted

Real Time Deals @ebayrt · 2h

Seattle Mariners Mlb #Majestic Authentic Diamond Blue Stitched 2 Xl M... (Sanford) USD 25 ebayrt.co/sports-mem-car… #eBay #eBayUS via @wil30225

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Real Time Deals @ebayrt · 2h

Embroidered Navy Blue Aztec Mexican Top/ Long Sleeve Ethnic Mod... USD 35 ebayrt.co/clothing-shoes… #Handmade #eBay #eBayUS via @smilingbluedog

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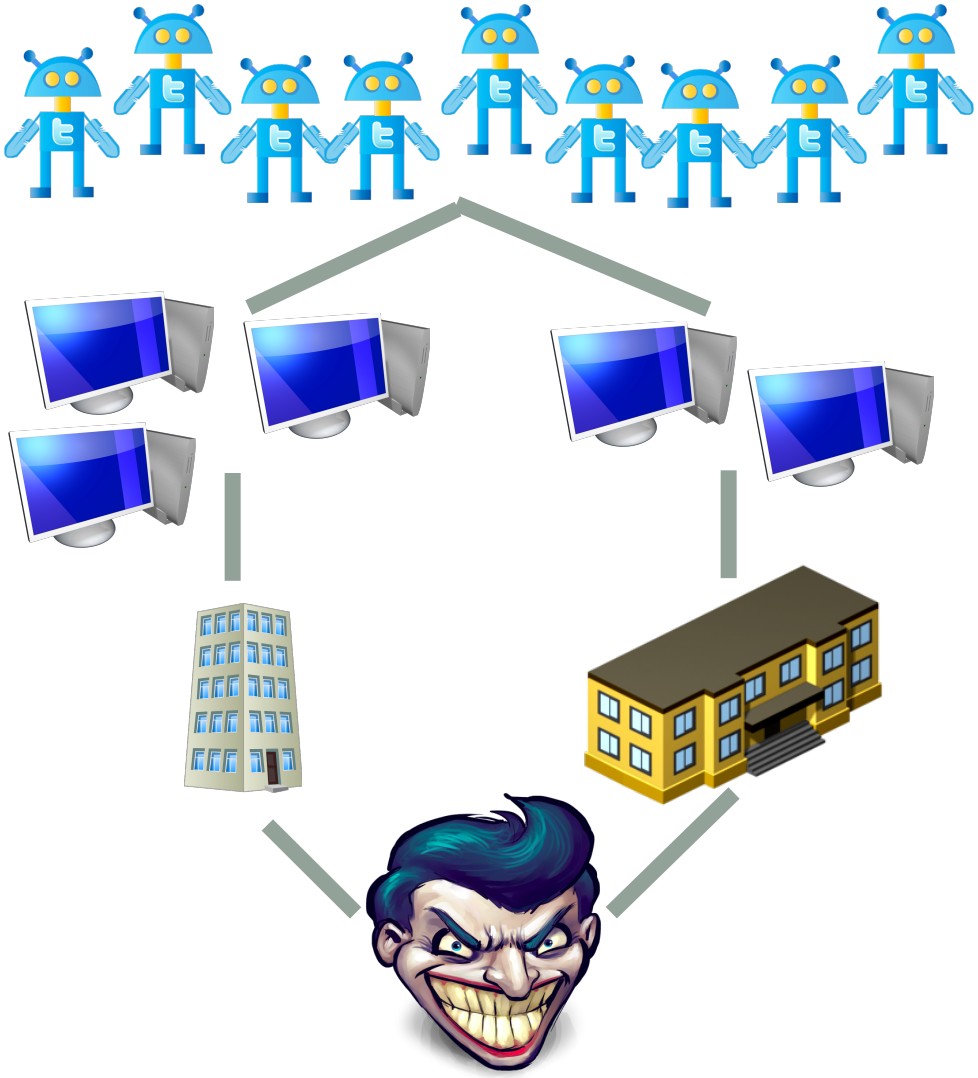
Contractubex Children Cartoon Boxing Gloves Red (Bloomington) USD 21.78 ebayrt.co/sporting-goods… #eBay #eBayUS via @GaroldFrenz

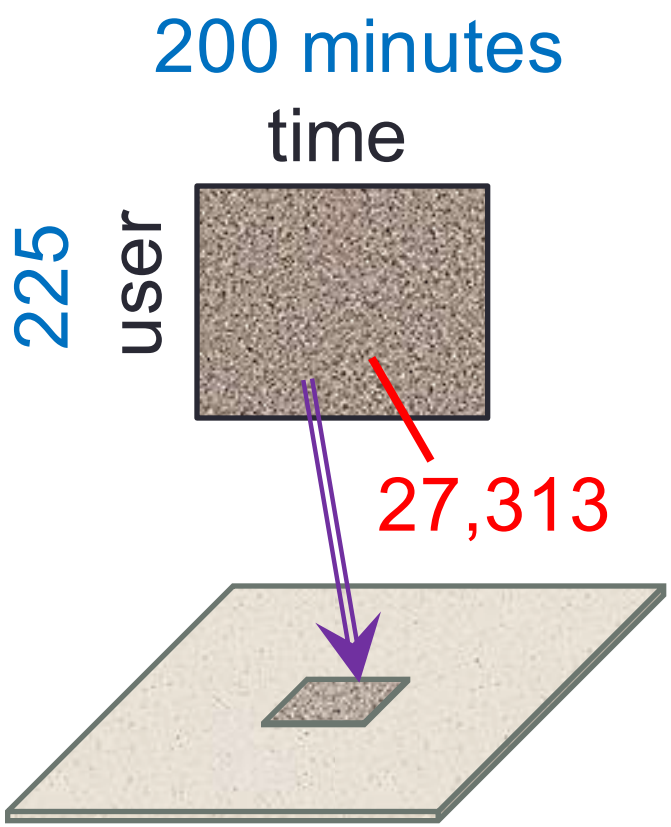
4



Massive **Multi-Modal** Data: Lines & Columns (Modes)

Dataset	Mode				Mass
Retweeting	**User**	**Root ID**	**IP**	**Time (min)**	**#retweet**
	29.5M	19.8M	27.8M	56.9K	211.7M
Trending (Hashtag)	**User**	**Hashtag**	**IP**	**Time (min)**	**#tweet**
	81.2M	1.6M	47.7M	56.9K	276.9M
Network attacks (LBNL)	**Src-IP**	**Dest-IP**	**Port**	**Time (sec)**	**#packet**
	2,345	2,355	6,055	3,610	230,836

Dense Blocks Indicates **Suspiciousness**



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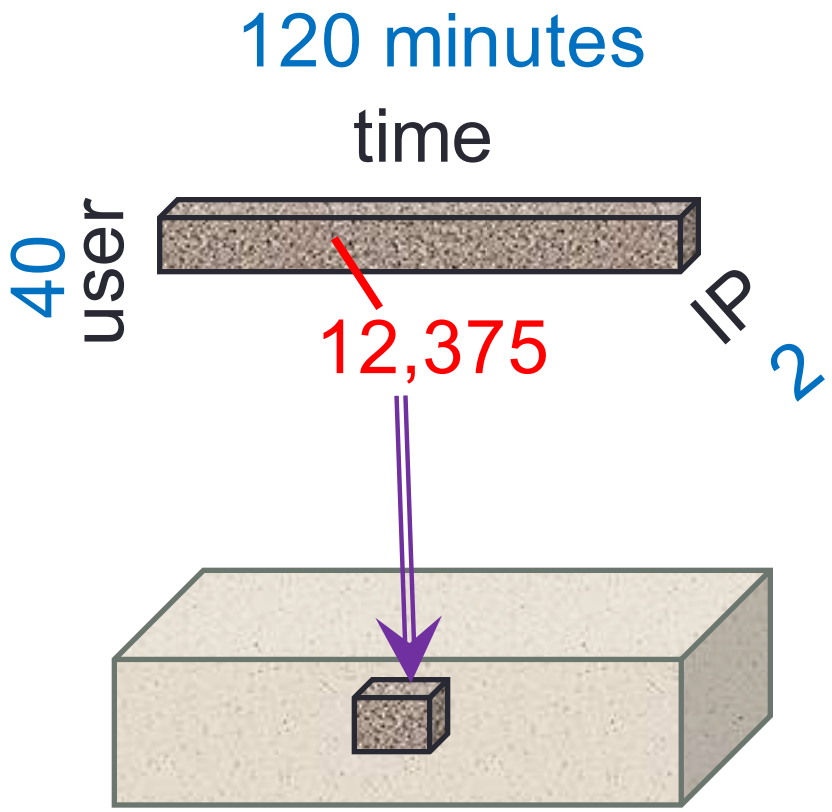
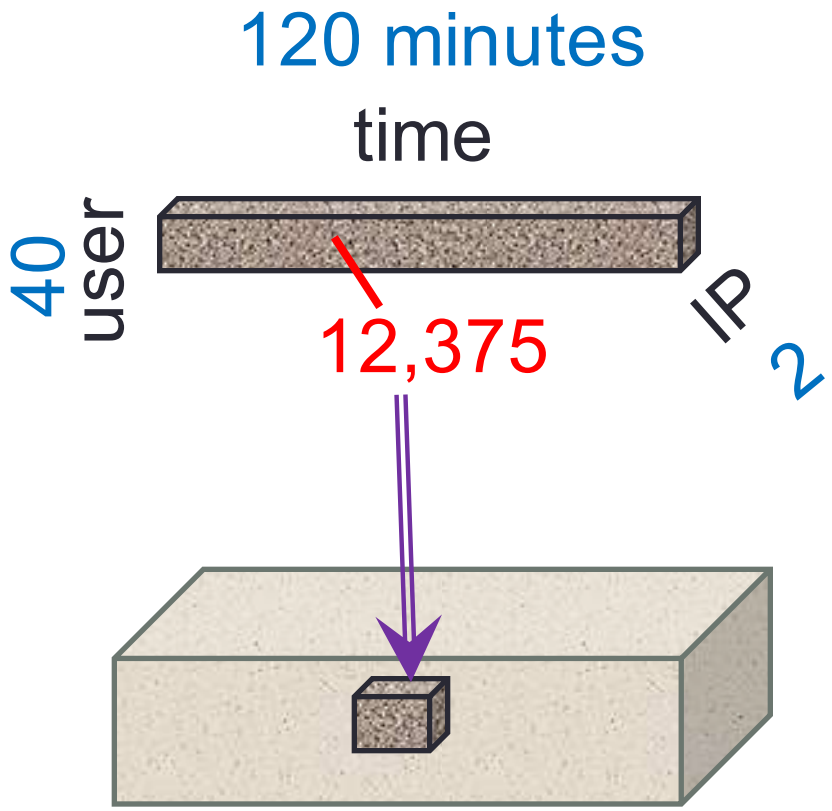
4

Dense Blocks Indicates **Suspiciousness**

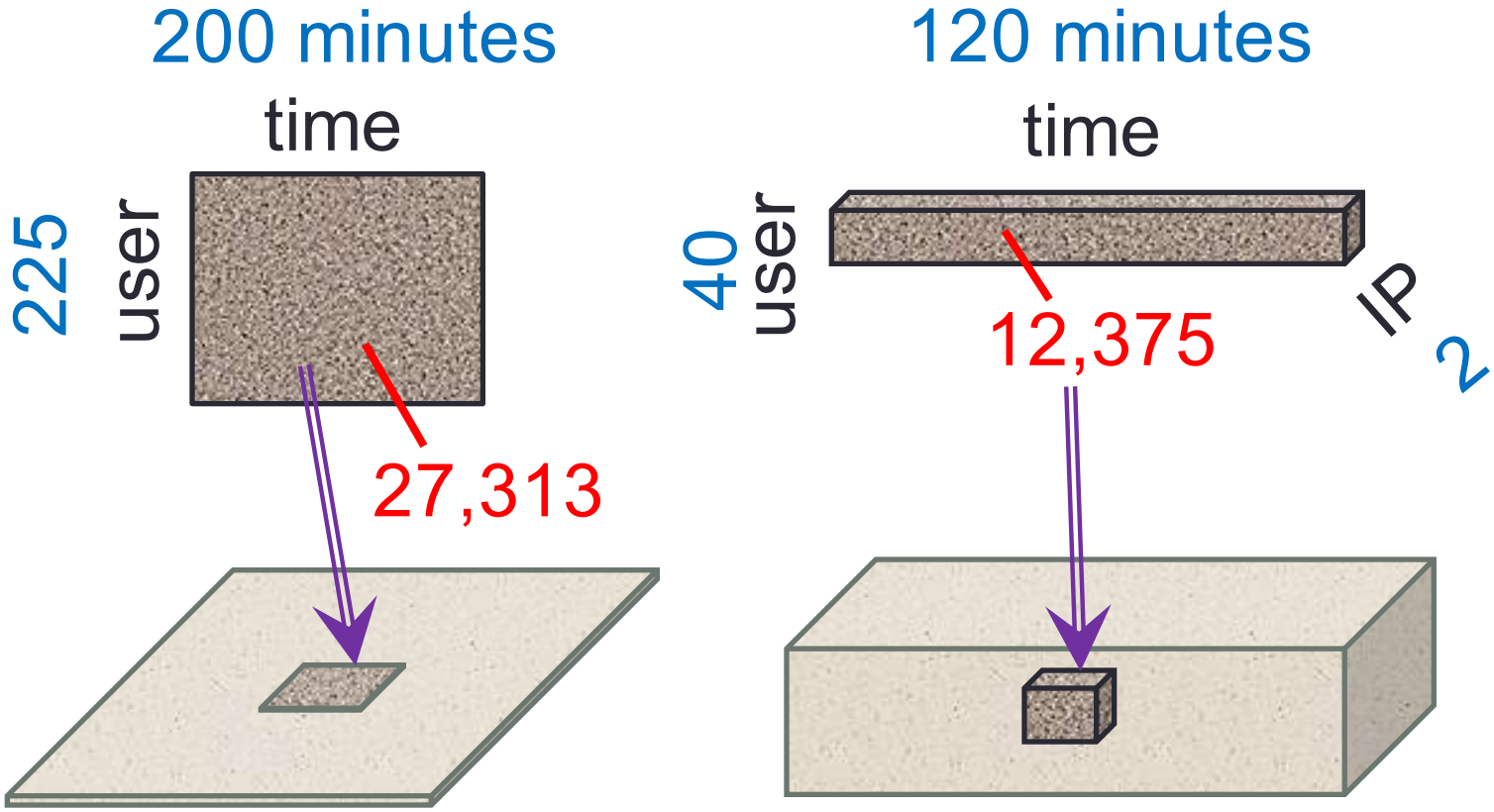


Dense Blocks Indicates **Suspiciousness**



+Hashtag
+Item
+Product
+Location
+…

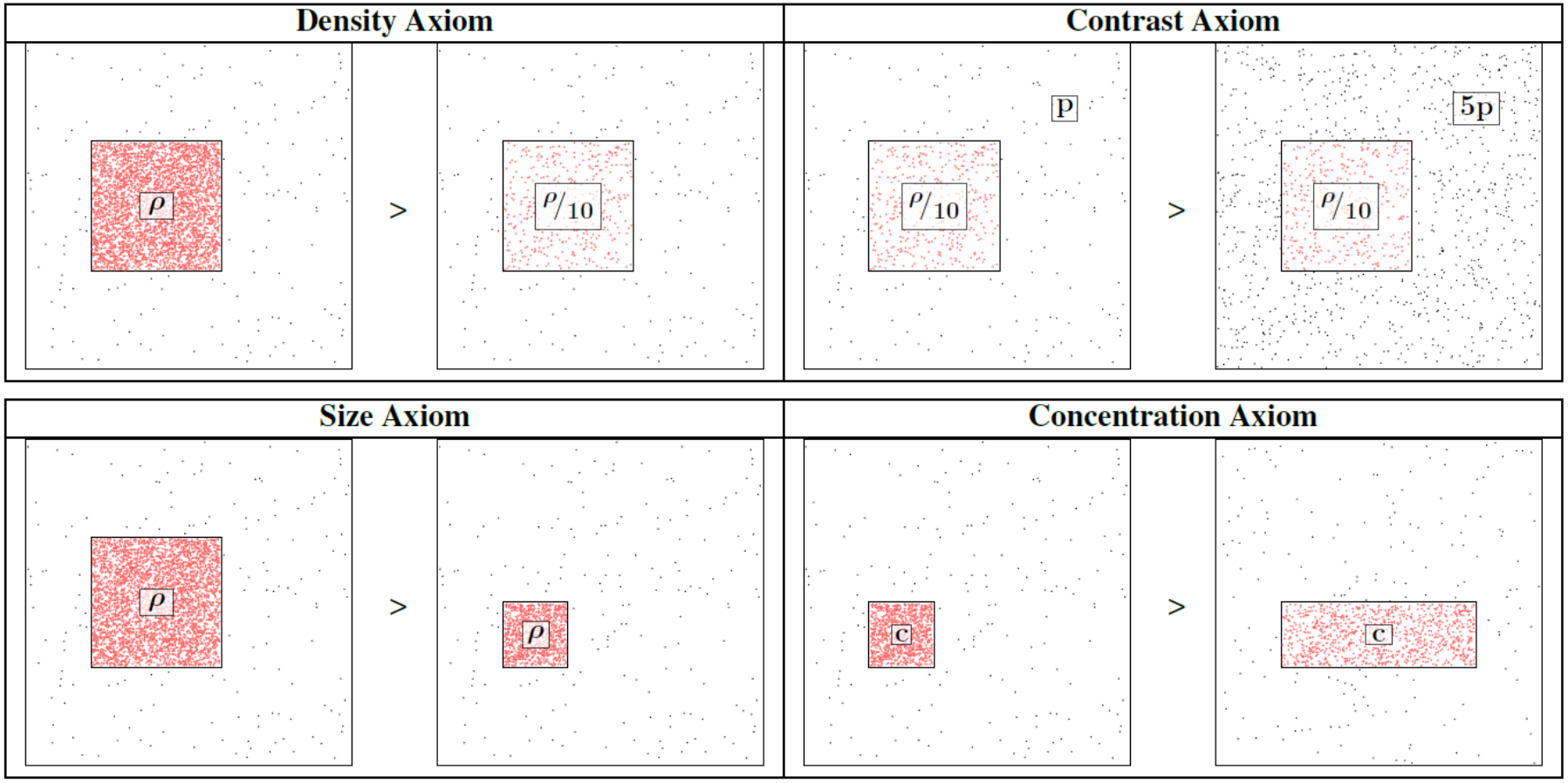
Dense Blocks Indicates **Suspiciousness**



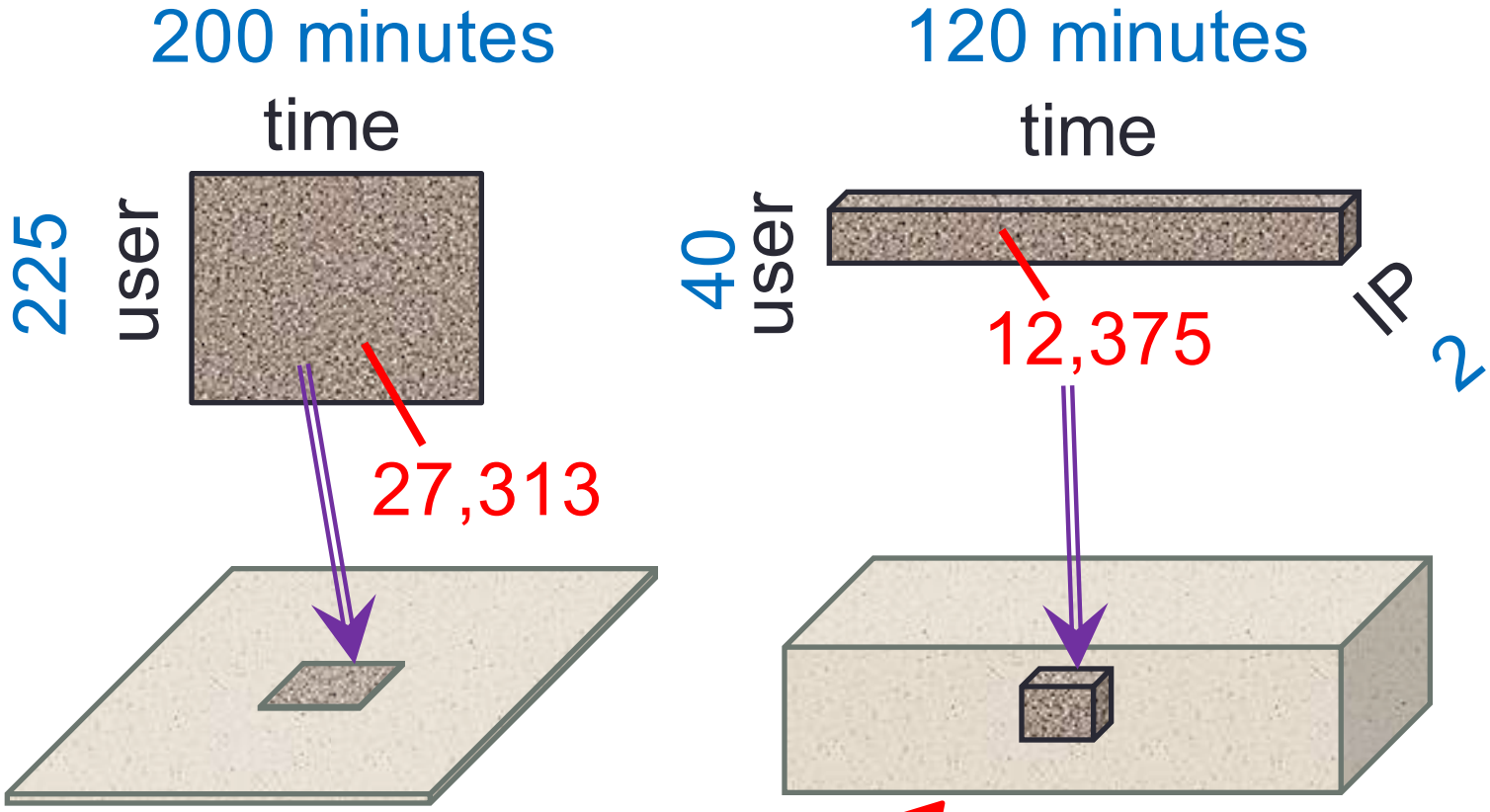
Question: Which is more suspicious?

- Before we search, we should be able to rank.

Axioms


Density Axiom
ρ
>
ρ/10
Contrast Axiom
p
ρ/10
>
5p
ρ/10
Size Axiom
ρ
>
ρ
Concentration Axiom
c
>
c

A General Idea to **Quantify Suspiciousness**



0.9% **Probability** 0.05%

A General **Suspiciousness** Metric

- Negative log likelihood of block's probability

$$f(n, c, N, C) = -\log\left[Pr(Y_n = c)\right]$$

Lemma *Given an $n_1 \times \cdots \times n_K$ block of mass c in $N_1 \times \cdots \times N_K$ data of total mass C, the suspiciousness function is*

$$f(\mathbf{n}, c, \mathbf{N}, C) = c(\log \frac{c}{C} - 1) + C \prod_{i=1}^{K} \frac{n_i}{N_i} - c \sum_{i=1}^{K} \log \frac{n_i}{N_i}$$

Using ρ as the block's density and p is the data's density, we have the simpler formulation

$$\hat{f}(\mathbf{n}, \rho, \mathbf{N}, p) = \left(\prod_{i=1}^{K} n_i\right) D_{KL}(\rho||p)$$

- CrossSpot: Local search

Advantage: "Suspiciousness"+CrossSpot

- Scoring dense blocks
- Targeting multi-modal data
- Satisfying axioms

	Method	Scores Blocks	Axioms: Density 1	Size 2	Concentration 3	Contrast 4	Multi-modal 5
Metrics	**SUSPICIOUSNESS**	✔	✔	✔	✔	✔	✔
	Mass	✓	✓	✗	✗	✗	✓
	Density	✓	✓	✗	✓	✗	✗
	Average Degree [9]	✓	✓	✗	✗	✗	N/A
	Singular Value [10]	✓	✓	✓	✓	✗	✗
Methods	**CROSSSPOT**	✔	✔	✔	✔	✔	✔
	Subgraph [30, 10, 36]	✓	✓	✓	✓	✗	N/A
	CopyCatch [6]	✓	✓	✓	✓	✗	N/A
	EigenSpokes [31]	✗	N/A				
	TrustRank [14, 8]	✗	N/A				
	BP [28, 1]	✗	N/A				

Performance: Synthetic Data

- Experiments: Synthetic data
  - 1,000 × 1,000 × 1,000 of 10,000 random data
  - Block#1: 30 × 30 × 30 of 512 — 3 modes
  - Block#2: 30 × 30 × 1,000 of 512 — 2 modes
  - Block#3: 30 × 1,000 × 30 of 512 — 2 modes
  - Block#4: 1,000 × 30 × 30 of 512 — 2 modes

	Recall				Overall Evaluation		
	Block #1	Block #2	Block #3	Block #4	Precision	Recall	F1 score
HOSVD (r=20)	93.7%	29.5%	23.7%	21.3%	**0.983**	0.407	0.576
HOSVD (r=10)	91.3%	24.4%	18.5%	19.2%	0.972	0.317	0.478
HOSVD (r=5)	85.7%	10.0%	9.5%	11.4%	0.952	0.195	0.324
CrossSpot	**100%**	**99.9%**	**94.9%**	**95.4%**	0.978	**0.967**	**0.972**

Performance: Manipulating Trends

User × hashtag × IP × minute	Mass c	Suspiciousness
582 × 3 × 294 × **56,940**	5,941,821	111,799,948
188 × 1 × 313 × **56,943**	2,344,614	47,013,868
75 × 1 × 2 × 2,061	689,179	19,378,403

User ID	Time	IP address (city, province)	Tweet text with hashtag
USER-D	11-18 12:12:51	IP-1 (Deyang, Shandong)	**#Snow#** the Samsung GALAXY SII QQ Service customized version...
USER-E	11-18 12:12:53	IP-1 (Deyang, Shandong)	**#Snow#** the Samsung GALAXY SII QQ Service customized version...
USER-F	11-18 12:12:54	IP-2 (Zaozhuang, Shandong)	**#Snow#** the Samsung GALAXY SII QQ Service customized version...
USER-E	11-18 12:17:55	IP-1 (Deyang, Shandong)	**#Li Ning - a weapon with a hero#** good support activities!
USER-F	11-18 12:17:56	IP-2 (Zaozhuang, Shandong)	**#Li Ning - a weapon with a hero#** good support activities!
USER-D	11-18 12:18:40	IP-1 (Deyang, Shandong)	**#Toshiba Bright Daren#** color personality test to find out your sense...
USER-E	11-18 17:00:31	IP-2 (Zaozhuang, Shandong)	**#Snow#** the Samsung GALAXY SII QQ Service customized version...
USER-D	11-18 17:00:49	IP-2 (Zaozhuang, Shandong)	**#Toshiba Bright Daren#** color personality test to find out your sense...
USER-F	11-18 17:00:56	IP-2 (Zaozhuang, Shandong)	**#Li Ning - a weapon with a hero#** good support activities!

Conclusion

- Proposed a general “suspiciousness” metric based on **probability** for multi-modal behaviors
- CrossSpot: Proposed a local search algorithm for catching suspicious behaviors

Thank you!

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- www.meng-jiang.com