Mining and Forecasting of Big Time-series Data

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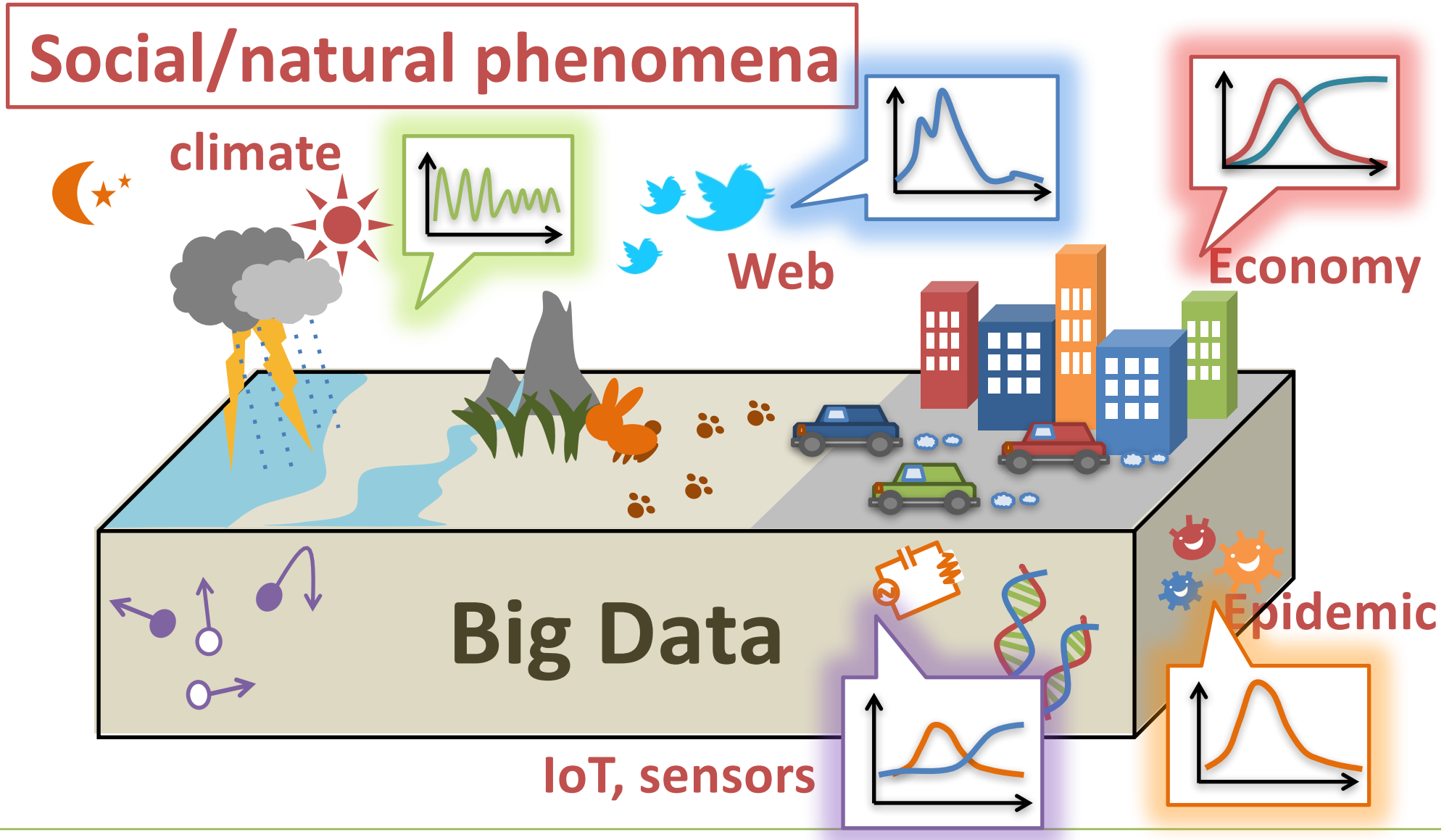
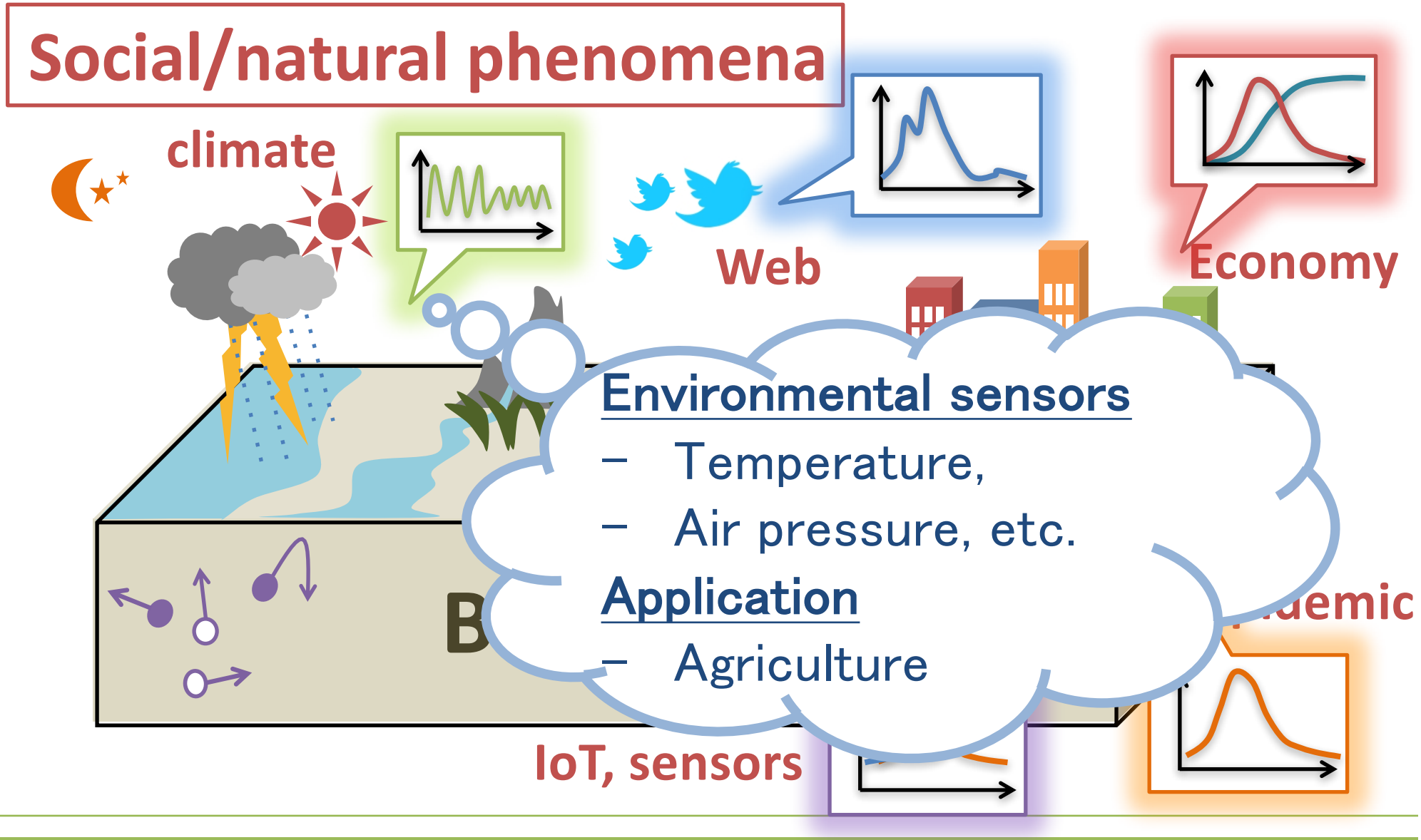
Big time-series data

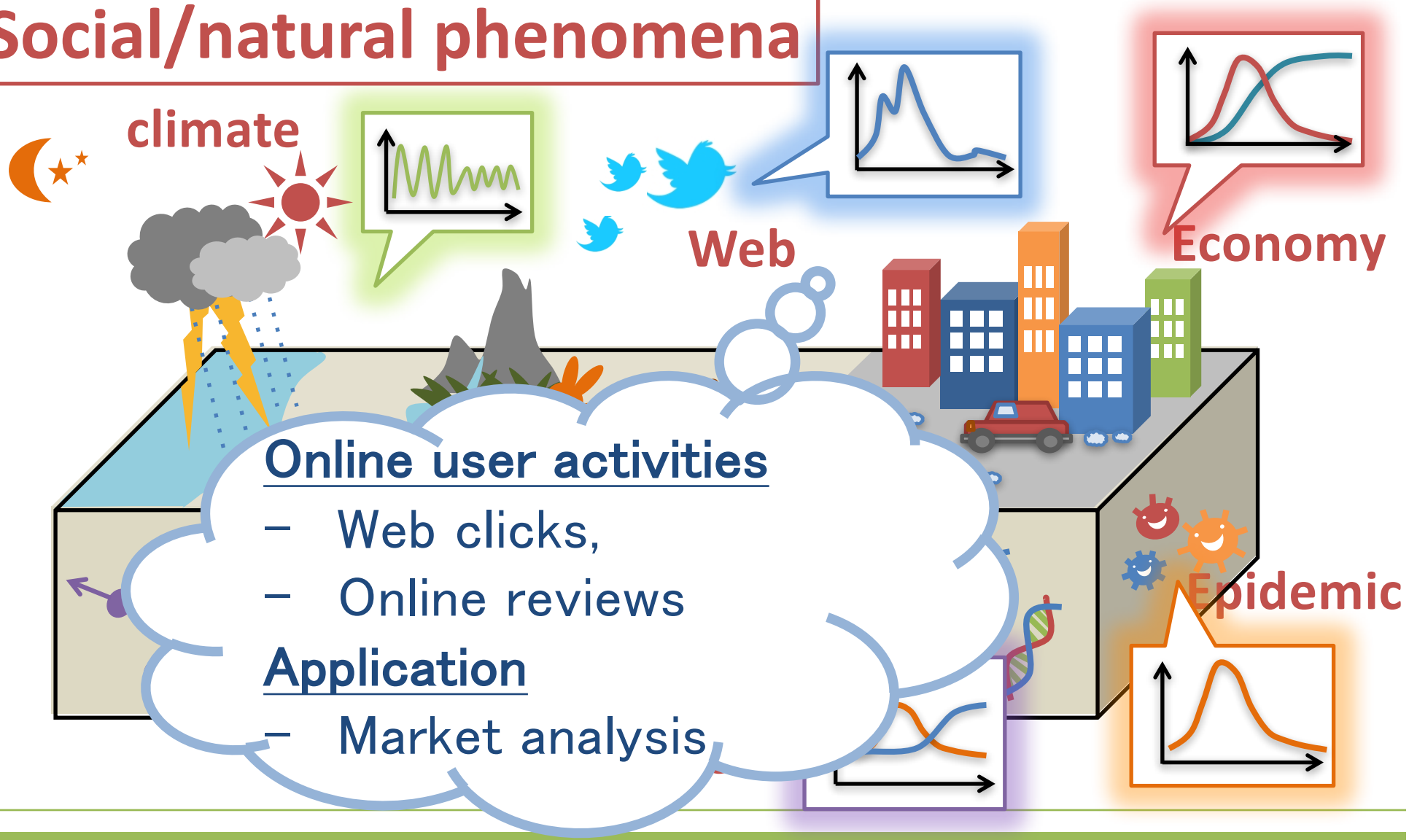


Big time-series data



Big time-series data

Social/natural phenomena



Online user activities

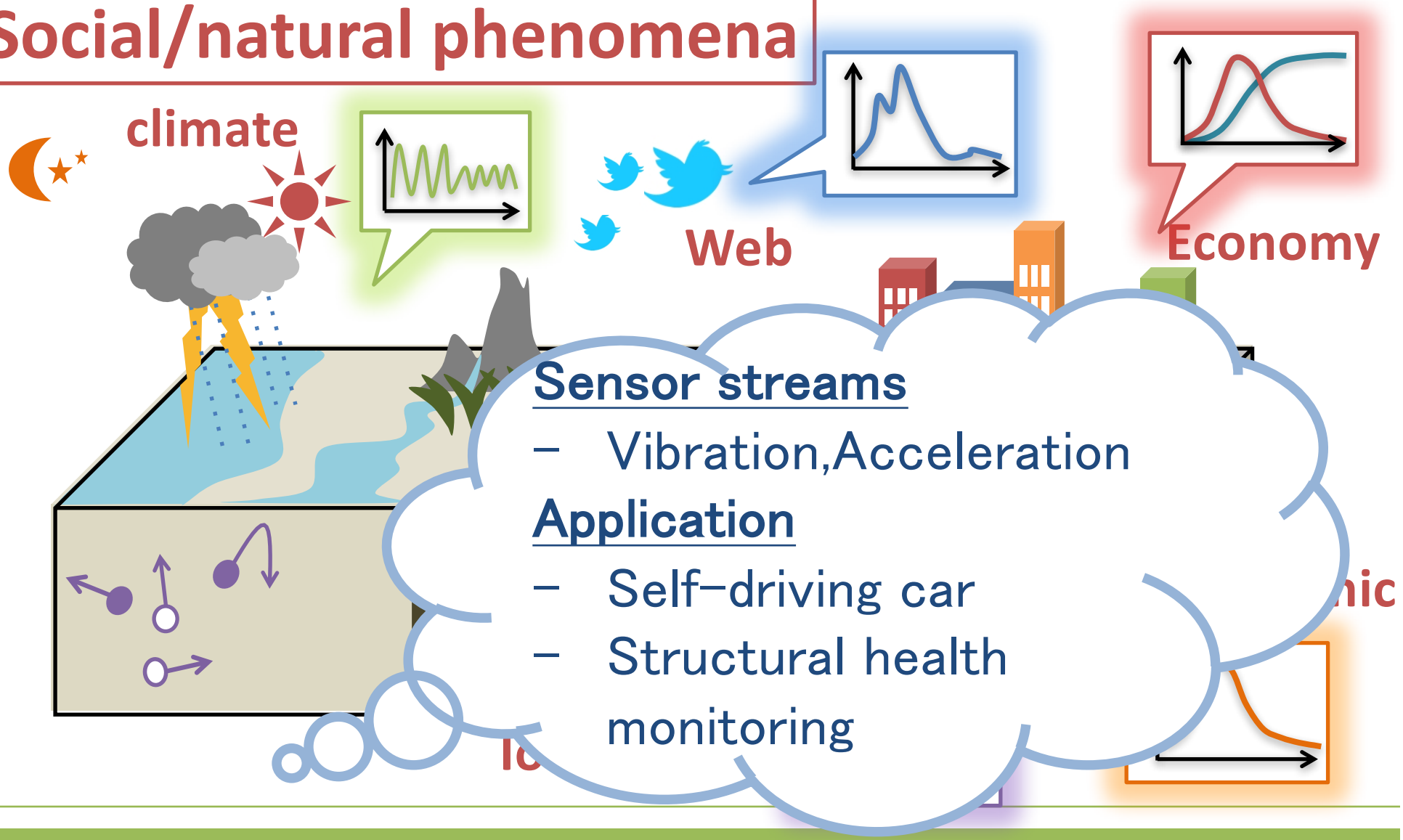
- Web clicks,
- Online reviews

Application

- Market analysis

Big time-series data

Social/natural phenomena



Sensor streams

- Vibration,Acceleration

Application

- Self-driving car
- Structural health monitoring

Motivation

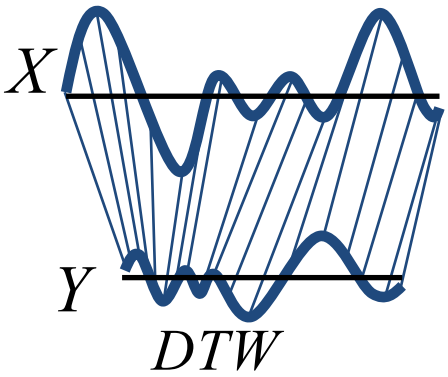
- **Given: Big time-series data**
  - Sensor data
  - Web, online activities
  - Medical data

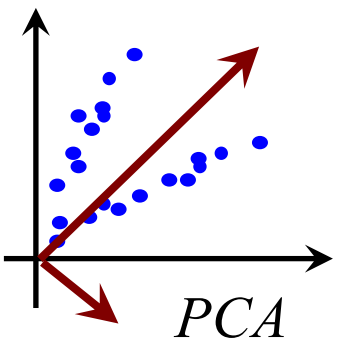
- **Goal: Real-time forecasting**
- **At-work:**
  - Online marketing
  - Sensor monitoring
  - Forecasting future epidemics

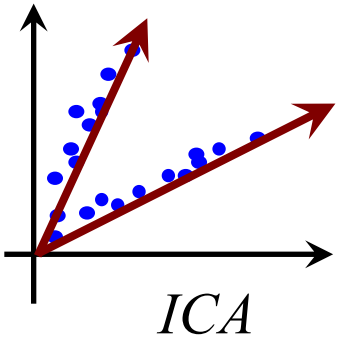
New challenges

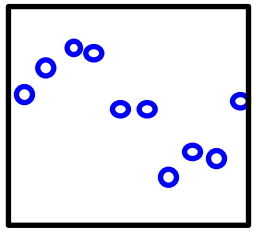
Time-series data analysis

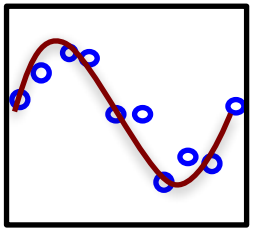
Indexing, Similarity search	Feature extraction	Linear-modeling	Data stream
ED, DTW, SAM	DFT, DWT, SVD, ICA	AR, LDS, ARIMA	Correlation monitoring etc.





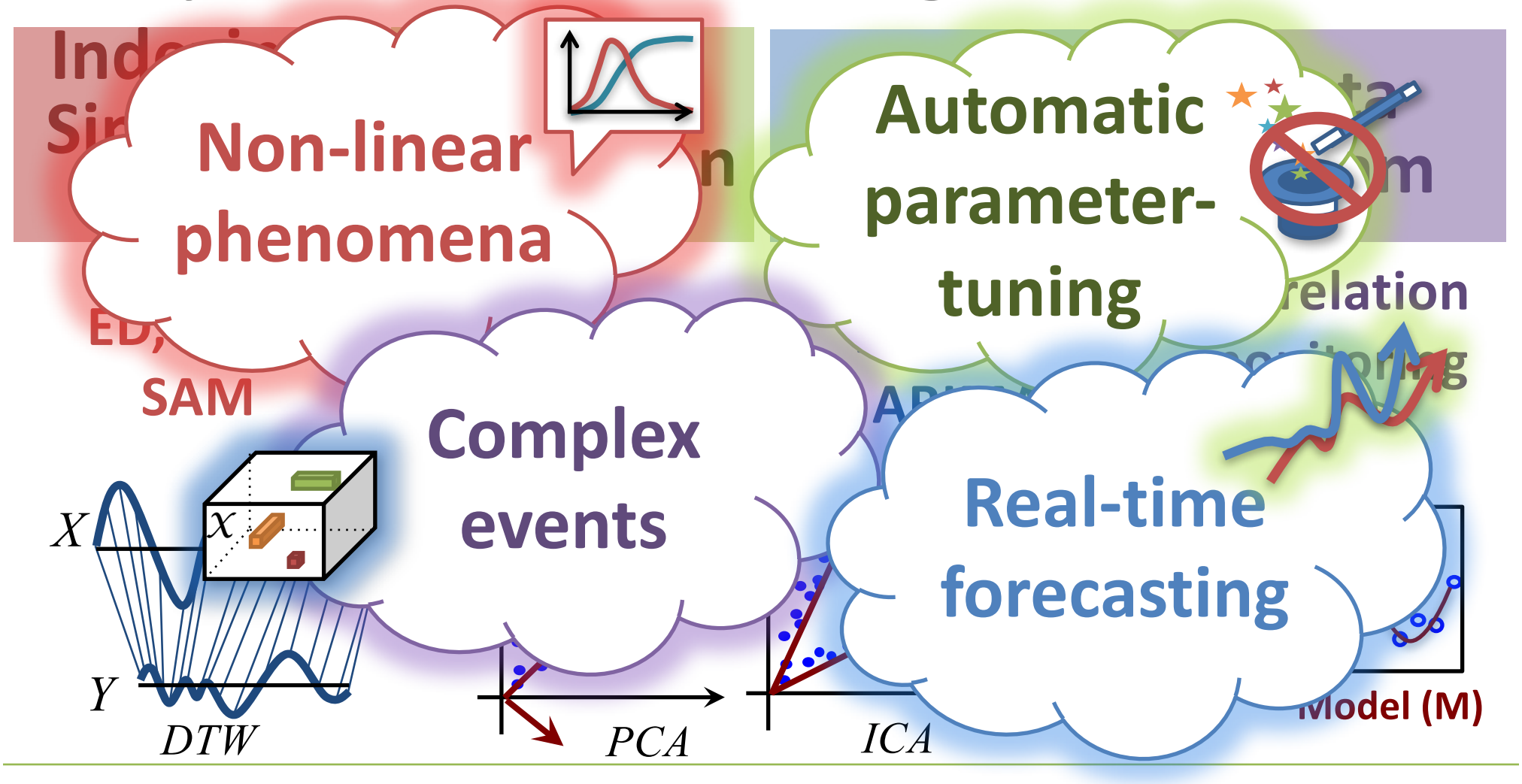






New challenges

They cannot handle "Big" data, i.e.,



New challenges

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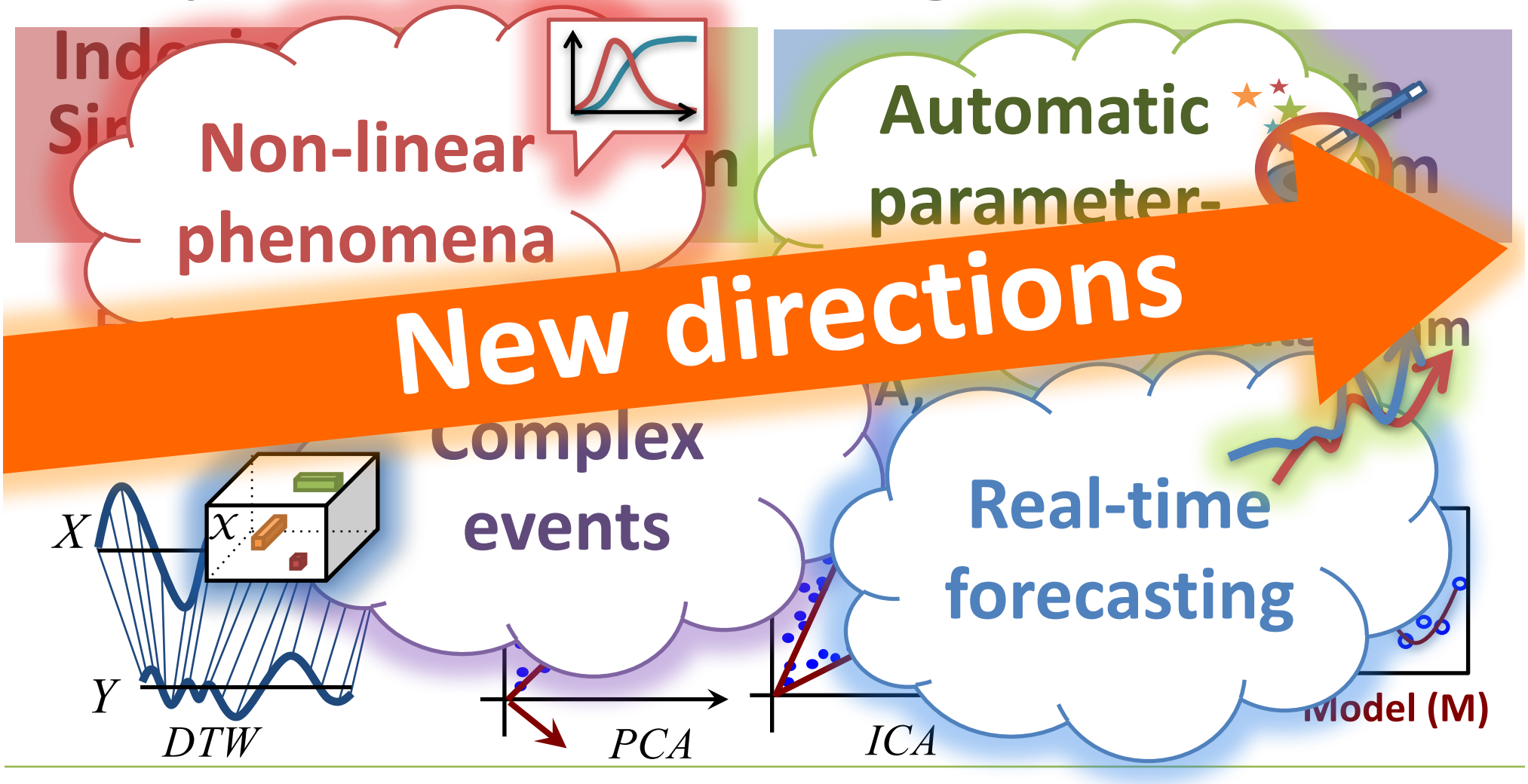
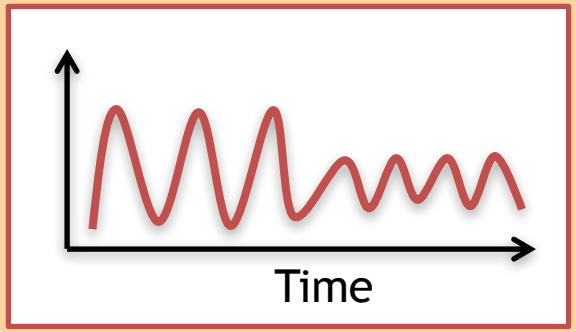
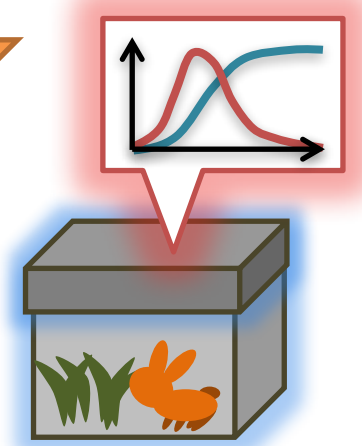
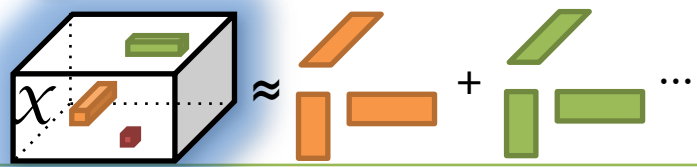


New research directions

- **Time-series data analysis**
  - Indexing and fast searching
  - Sequence matching
  - Clustering
  - etc.
- **New research directions**
  1. Automatic mining
  2. Non-linear modeling
  3. Large-scale tensor analysis







(R1) Automatic mining

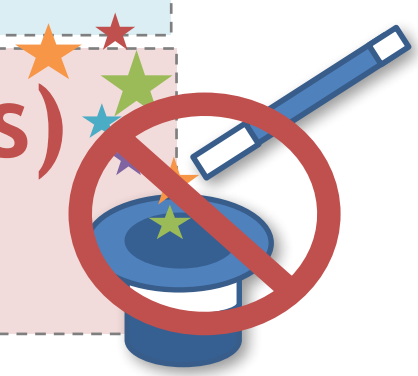
No magic numbers! … because,

Manual

- sensitive to the parameter tuning
- long tuning steps (hours, days, …)

Automatic (no magic numbers)

- no expert tuning required



Big data mining:

-> we cannot afford human intervention!!

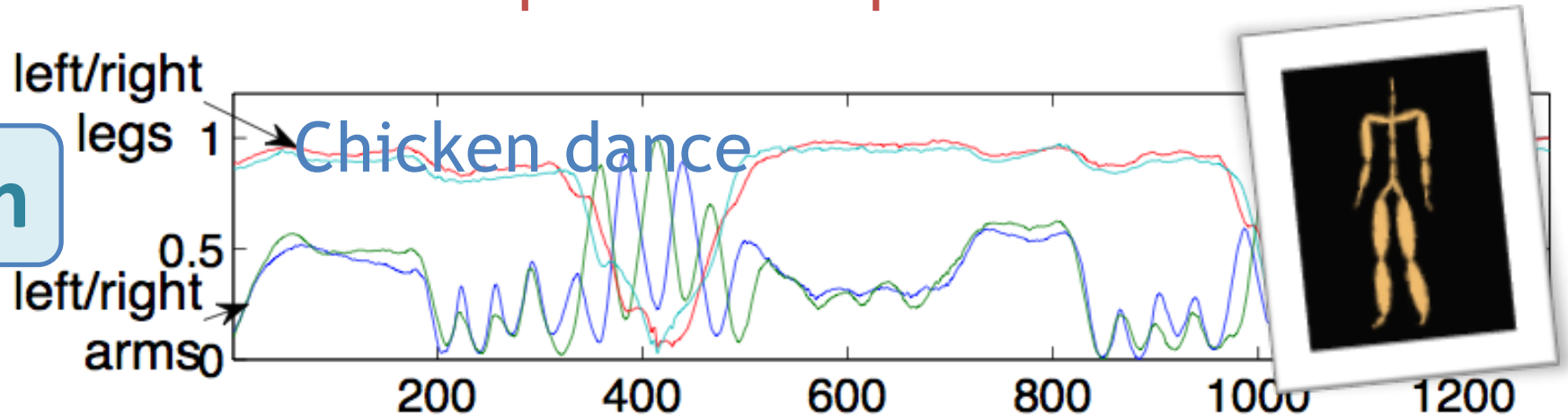
(R1) Automatic mining

AutoPlait
SIGMOD'14

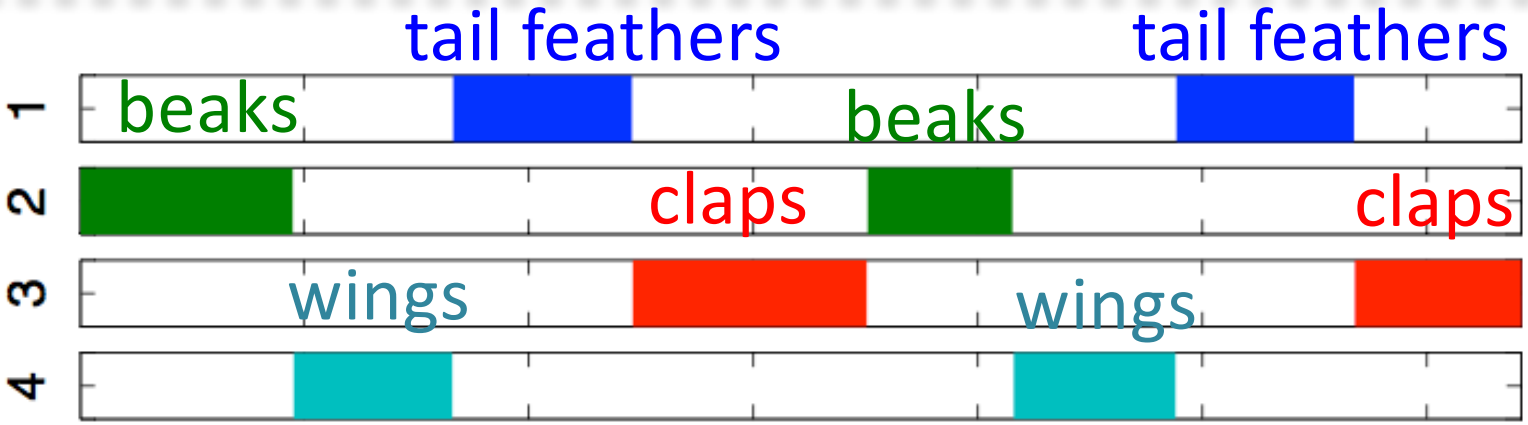
"Automatic" mining algorithm

Find: compact description of data X

Given



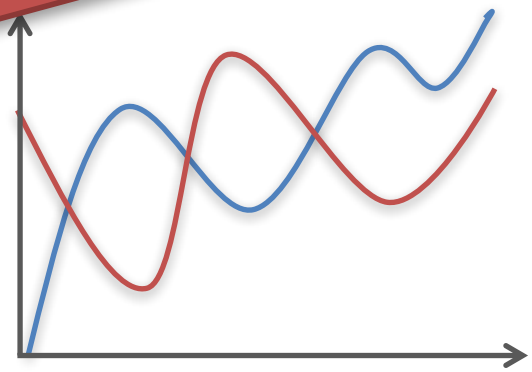
Find



(R1) Automatic mining

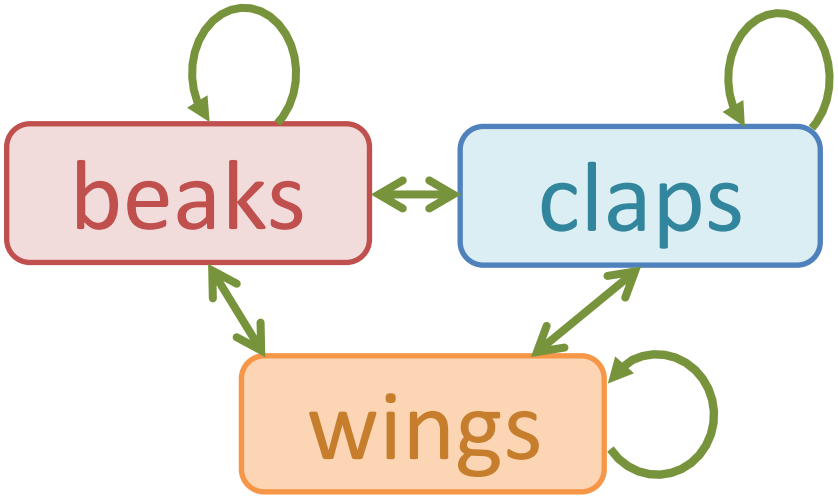
AutoPlait
SIGMOD'14

"Automatic" mining algorithm



Sequences

Model



Regimes

Idea (1): Multi-level chain model

–HMM-based probabilistic model

–with "across-regime" transitions

(R1) Automatic mining

AutoPlait
SIGMOD'14

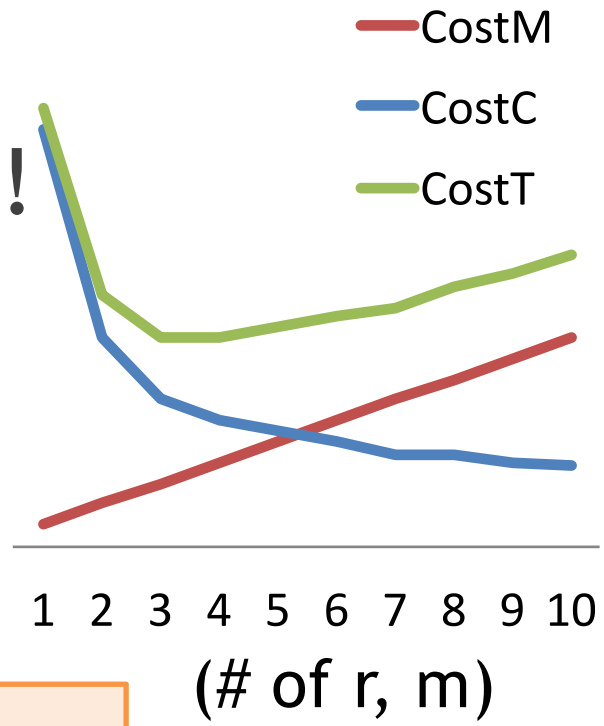
"Automatic" mining algorithm

Idea(2): Minimize encoding cost!

$$\min \left(\boxed{\mathrm{Cost}_M(M)} + \boxed{\mathrm{Cost}_c(X \mid M)} \right)$$

Model cost

Coding cost



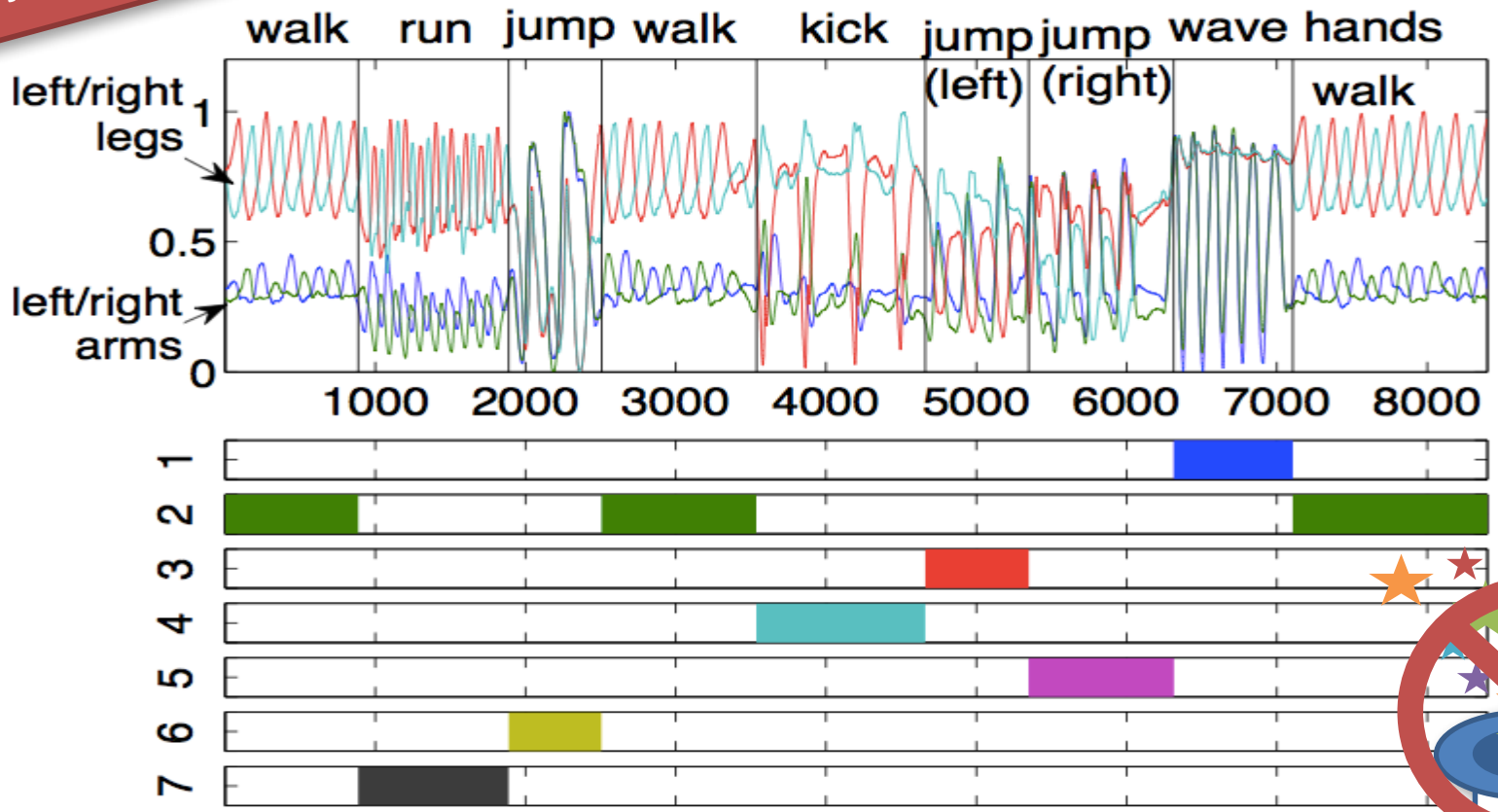
Good compression

Good description

(R1) Automatic mining

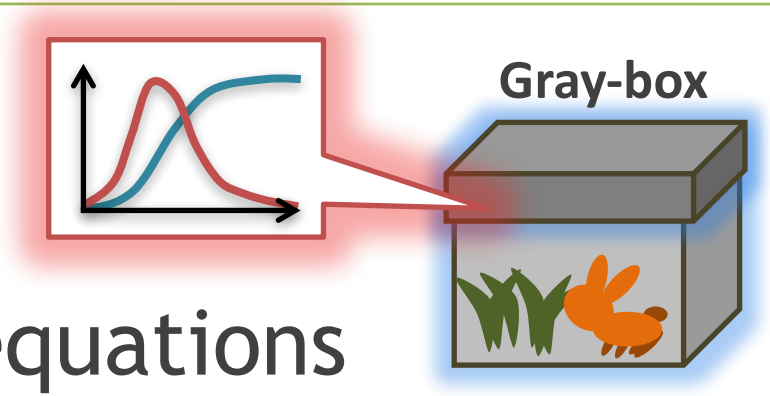
AutoPlait
SIGMOD'14

"Automatic" mining algorithm

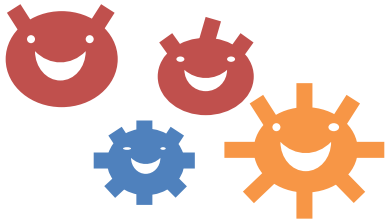


AutoPlait (**NO** magic numbers)

(R2) Non-linear (gray-box) modeling



- Gray-box mining
  - If we know the equations
- Non-linear (differential) equations
  - Epidemic
  - Biology
  - Physics, Economics, etc.



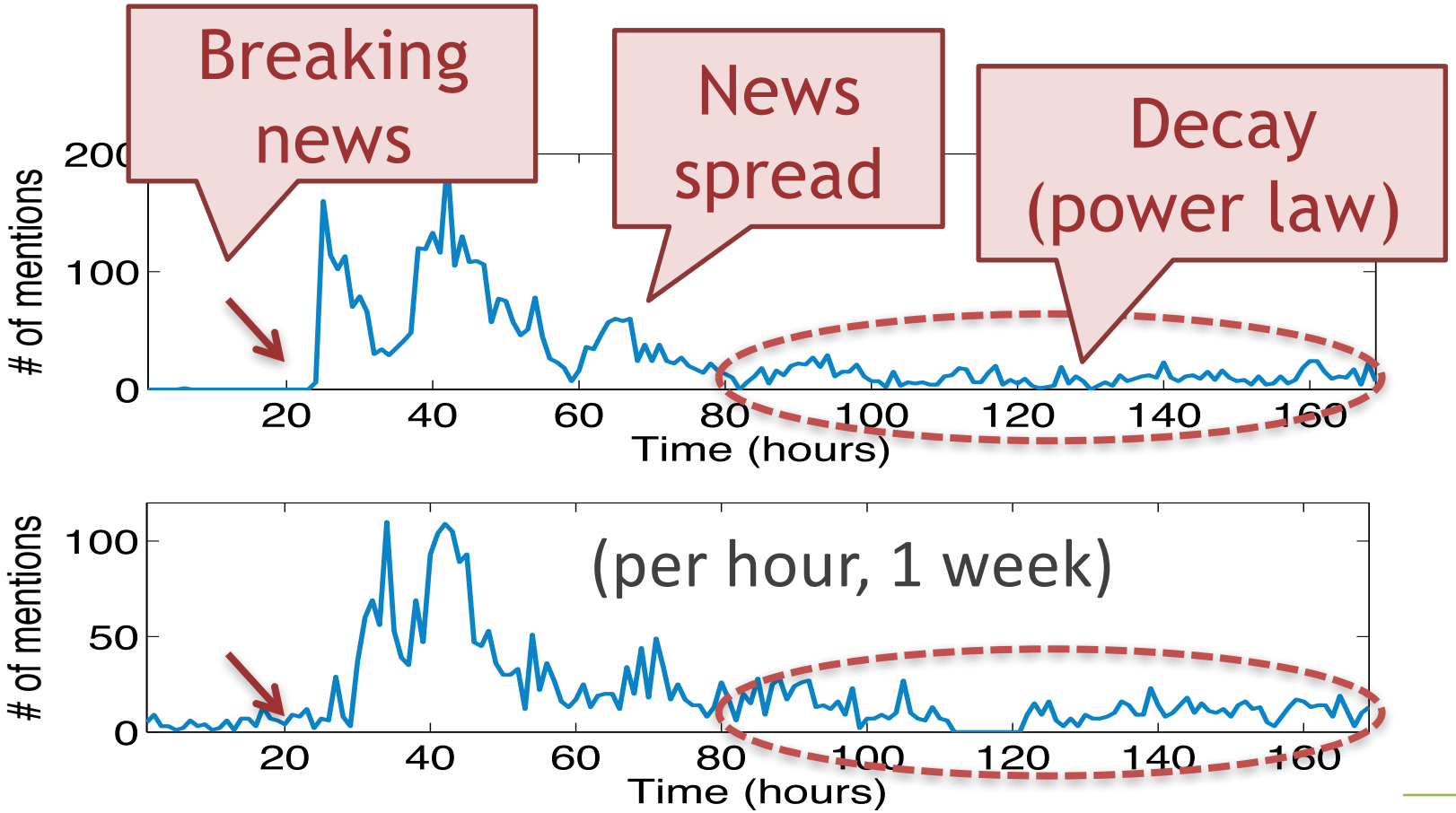
- Modeling non-linear social phenomena
  - Non-linear analysis for Web online activities (e.g., information diffusion, interaction)

(R2) Non-linear (gray-box) modeling

SpikeM
KDD'12

News spread in social media

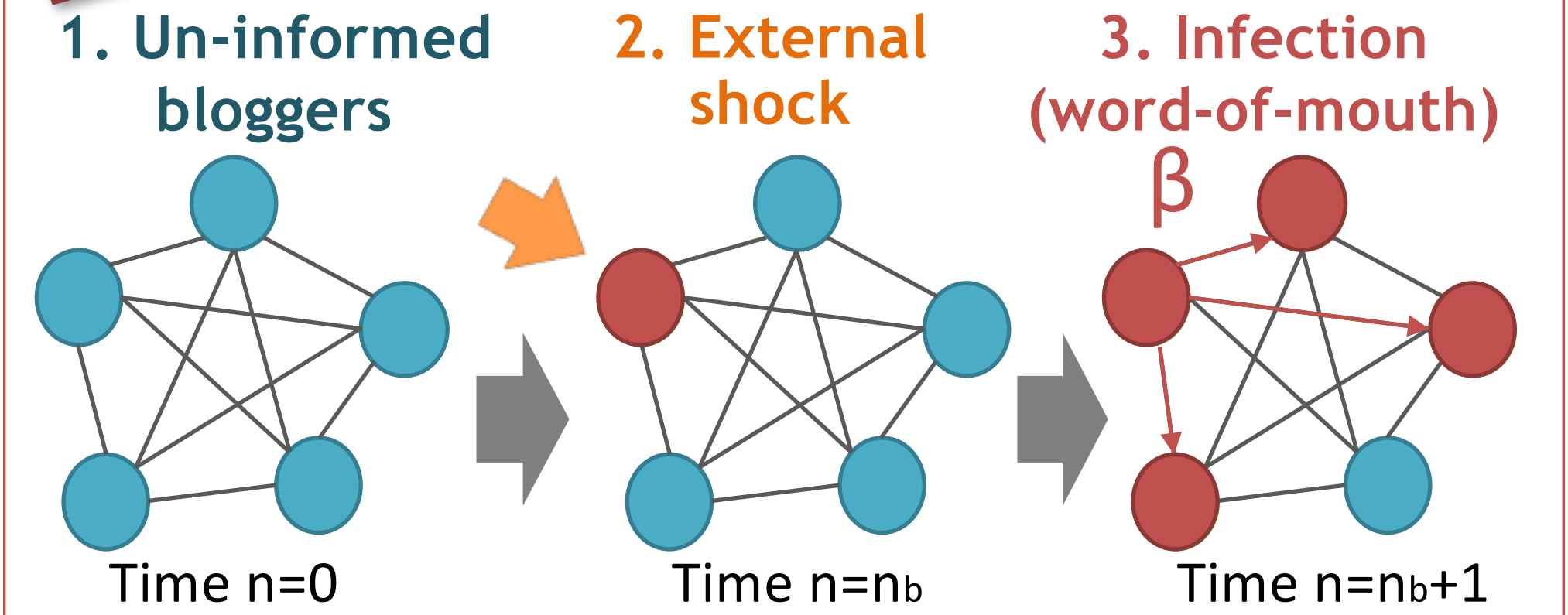
Number of mentions in blogs/Twitter



(R2) Non-linear (gray-box) modeling

SpikeM
KDD'12

News spread in social media



(R2) Non-linear (gray-box) modeling

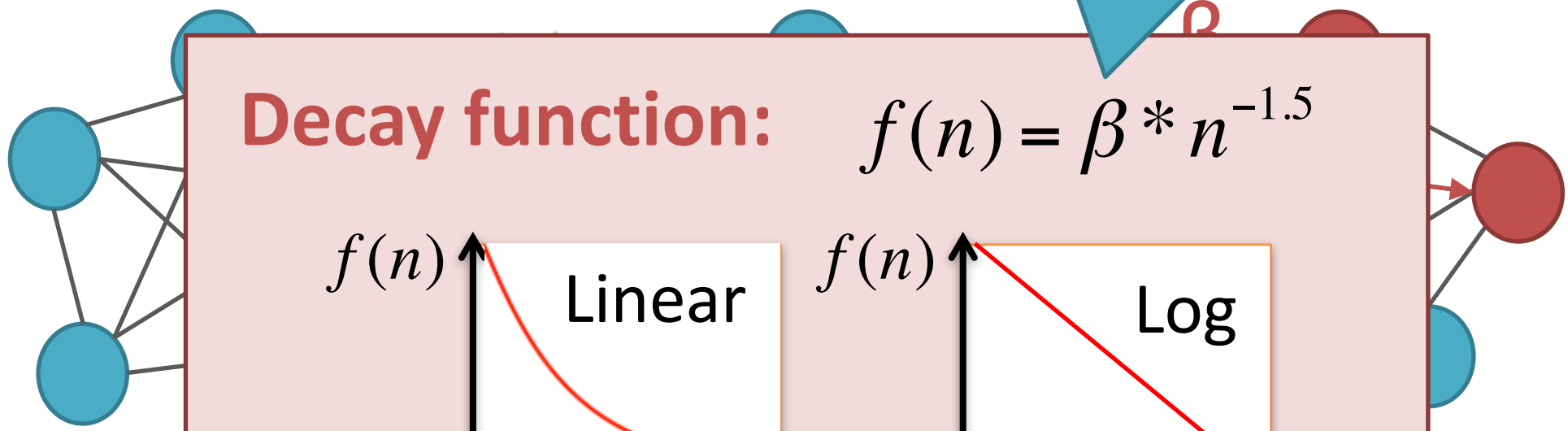
SpikeM
KDD'12

News spread in social media

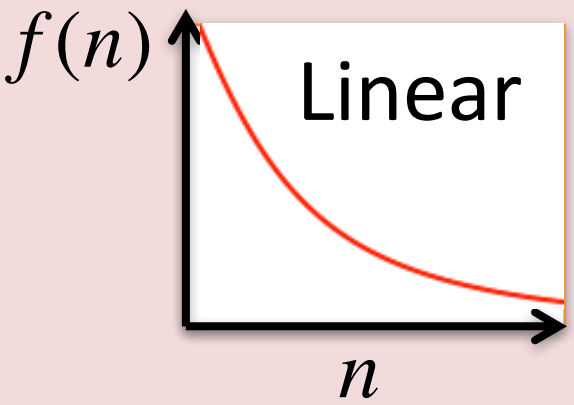
1. Un-informed bloggers

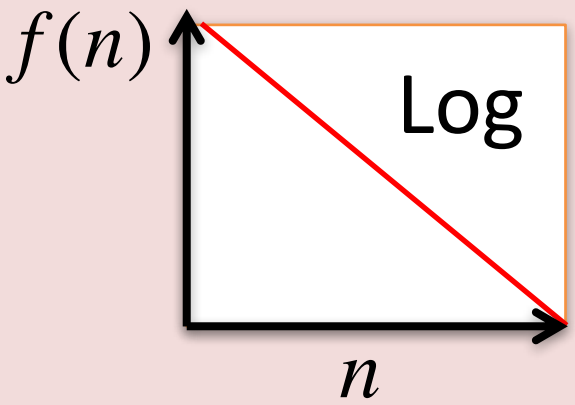
2. External shock

Power law



Decay function: $f(n) = \beta * n^{-1.5}$



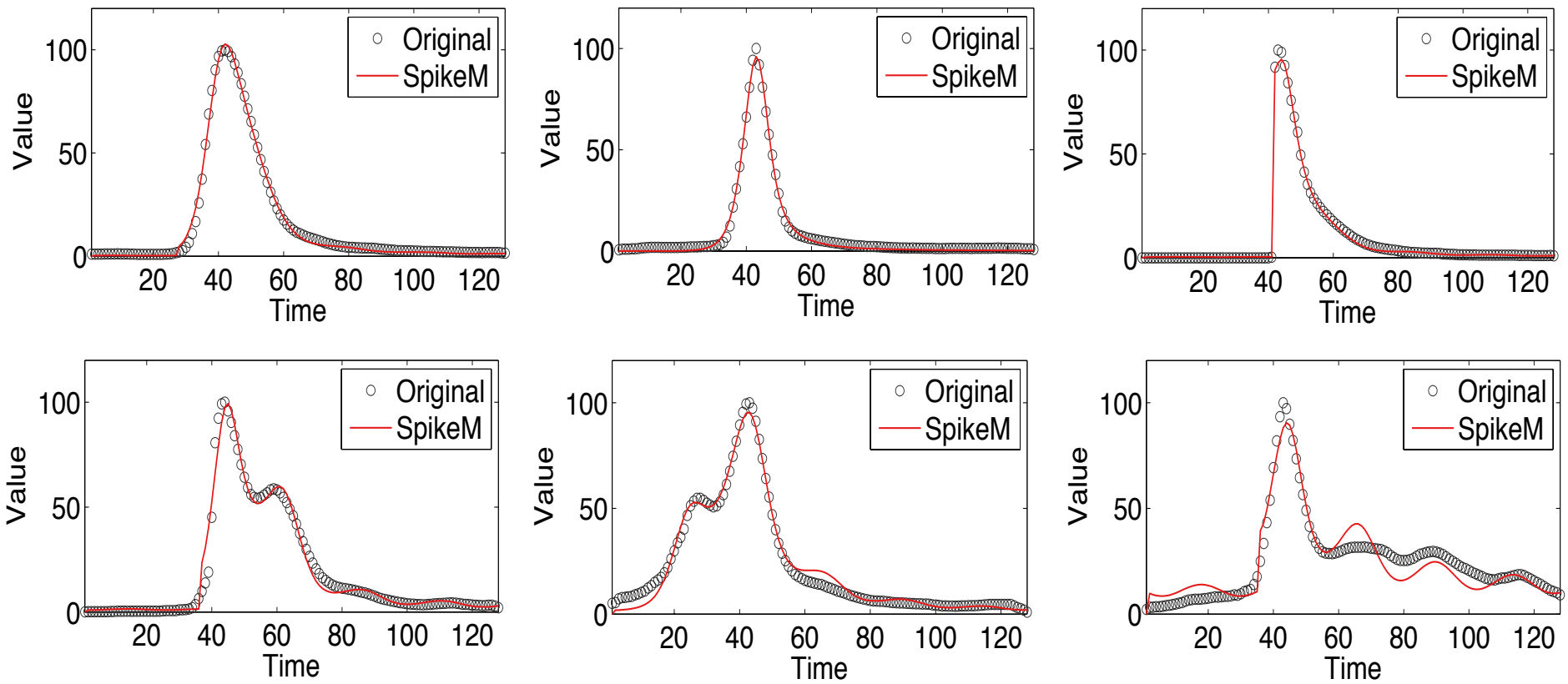


(R2) Non-linear (gray-box) modeling

SpikeM
KDD'12

News spread in social media

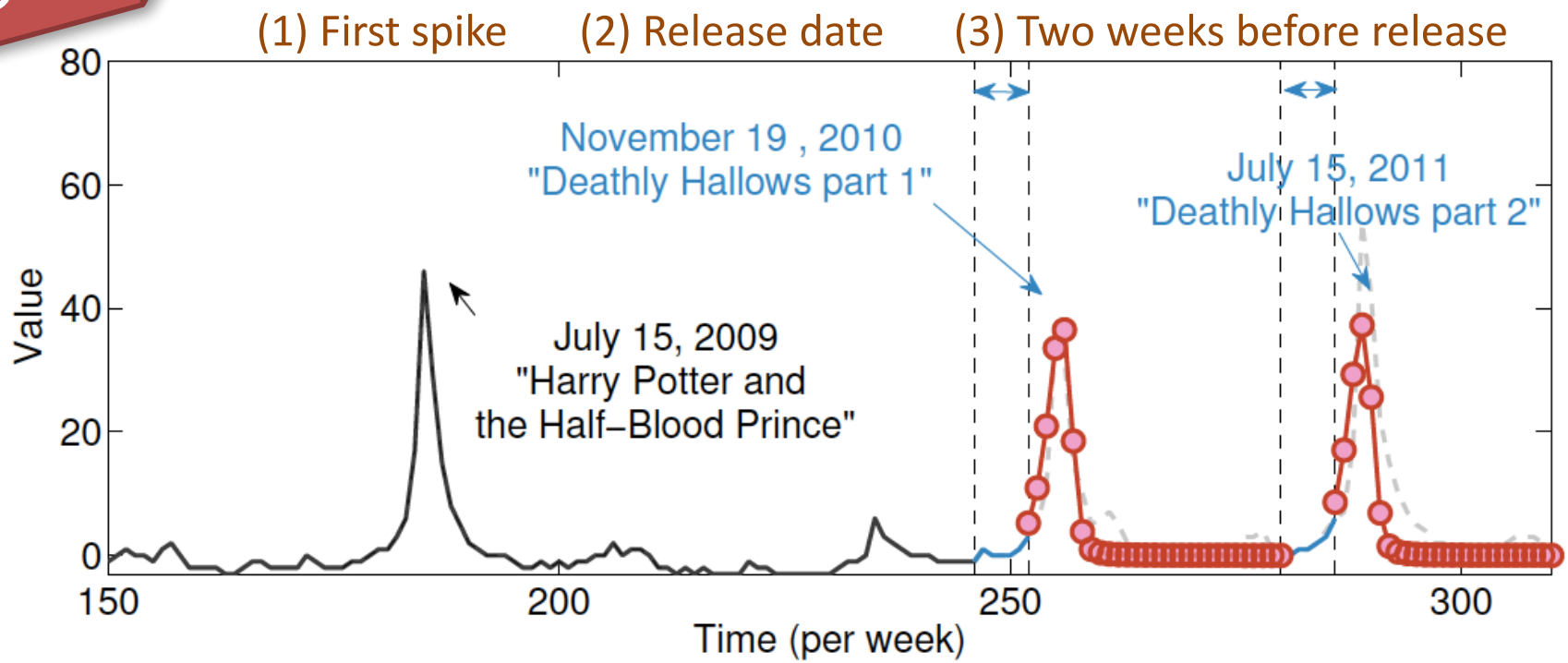
Memes in social media/blogs



(R2) Non-linear (gray-box) modeling

SpikeM
KDD'12

Forecast tail-part and **rise-part**!

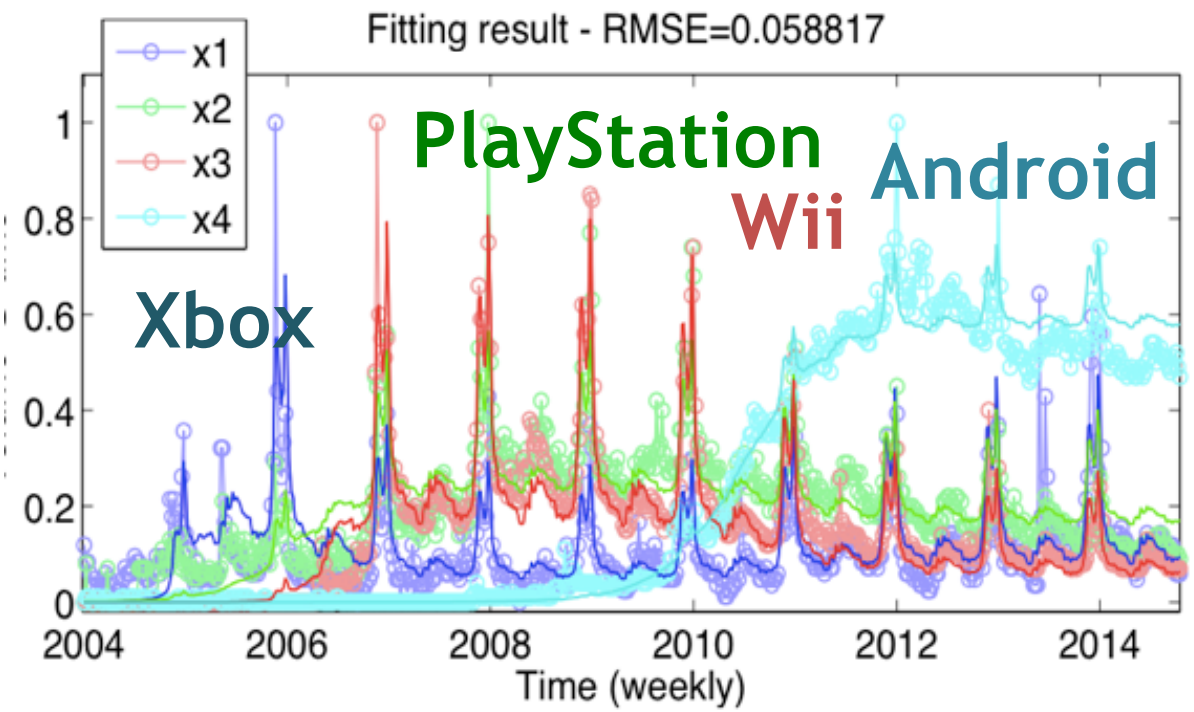


Given (1) first spike,
(2) release date of two sequel movies
(3) access volume before the release date

(R2) Non-linear (gray-box) modeling

EcoWeb
WWW'15

Online competition



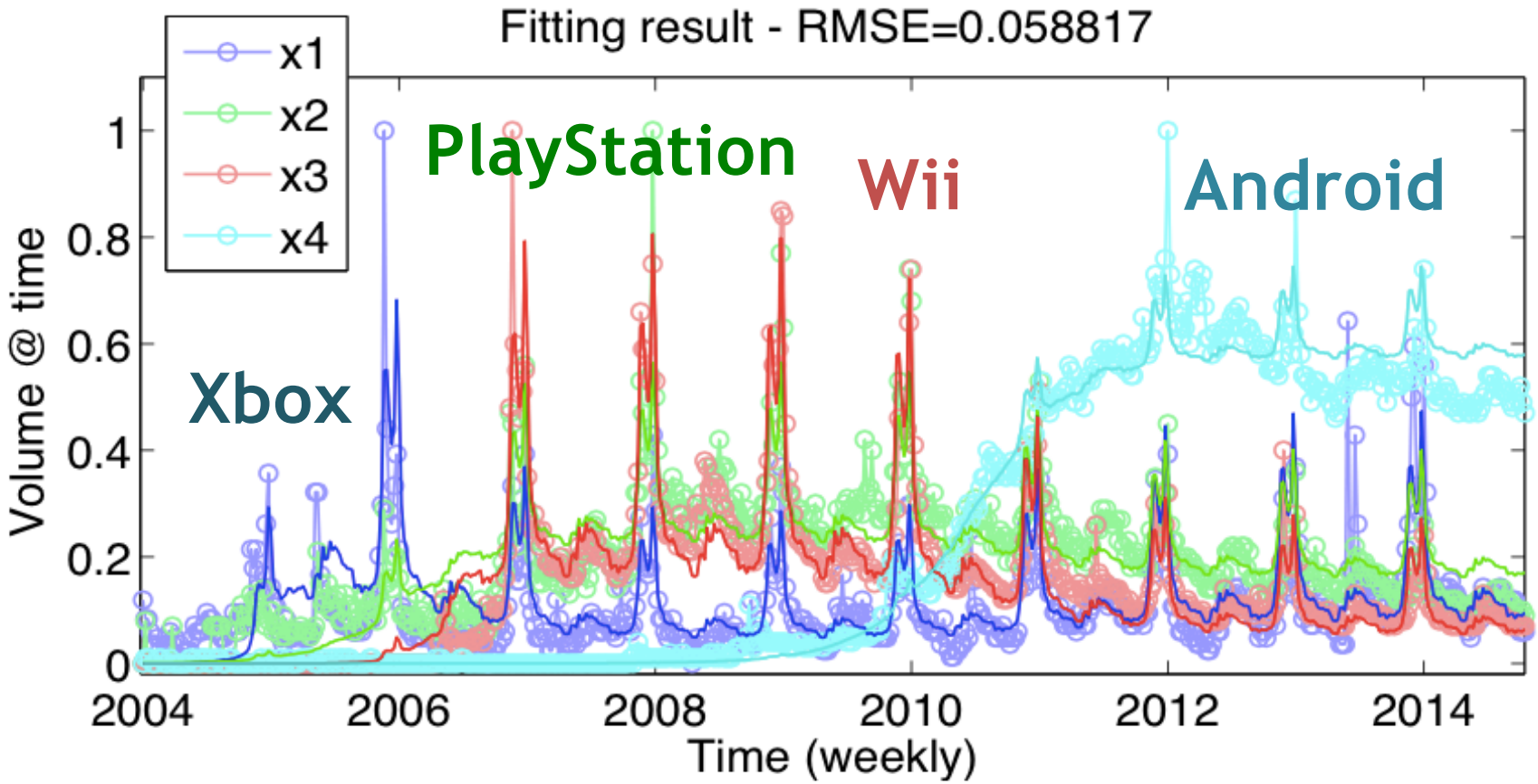
Interactions between keywords

(R2) Non-linear (gray-box) modeling

EcoWeb WWW'15

Online competition

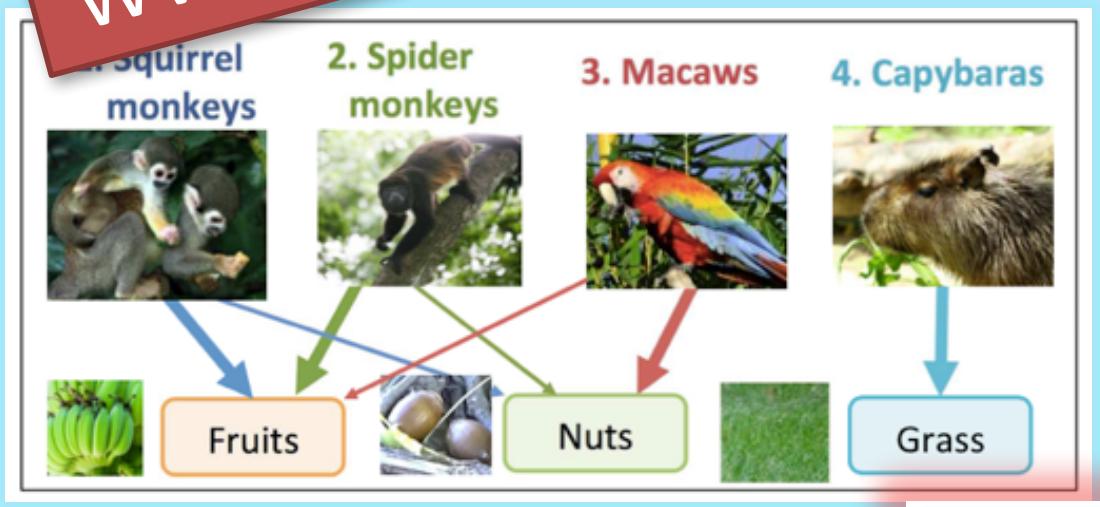
(*Google* Search volume)



(R2) Non-linear (gray-box) modeling

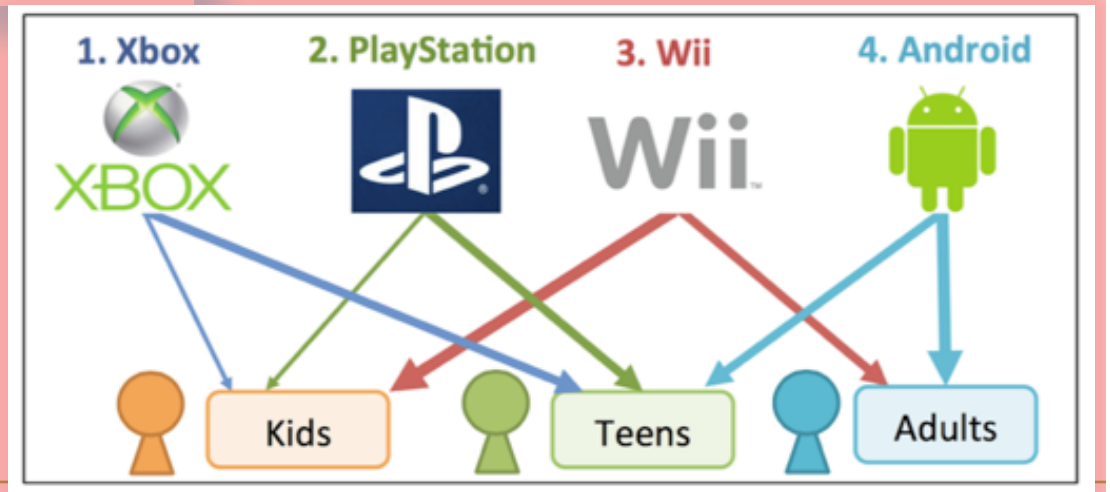
EcoWeb
WWW'15

The Web as a Jungle !



Ecosystem on the **Web**

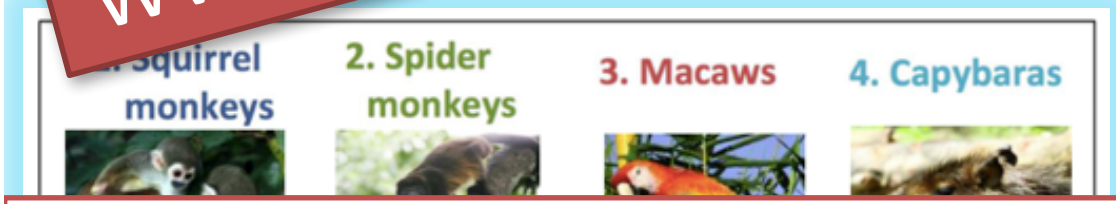
Ecosystem in the **Jungle**



(R2) Non-linear (gray-box) modeling

EcoWeb WWW'15

The Web as a Jungle !

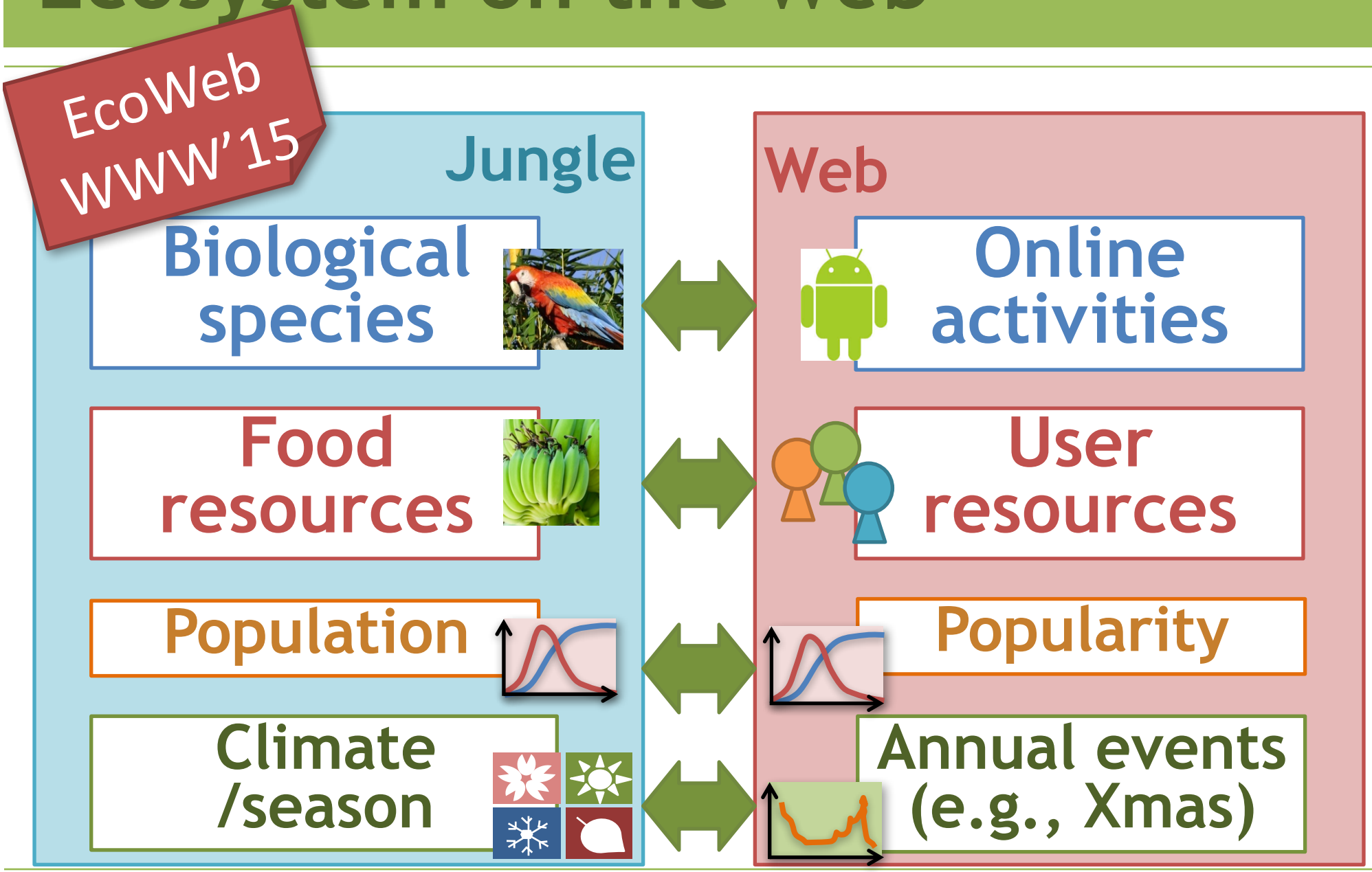


Ecosystem

--- Non-Linear equations ---

$$P_i(t+1) = P_i(t)\left[1 + \mathrm{r}_i\left(1 - \frac{\sum_{j=1}^{d} a_{ij} P_i(t)}{K_i}\right)\right]$$

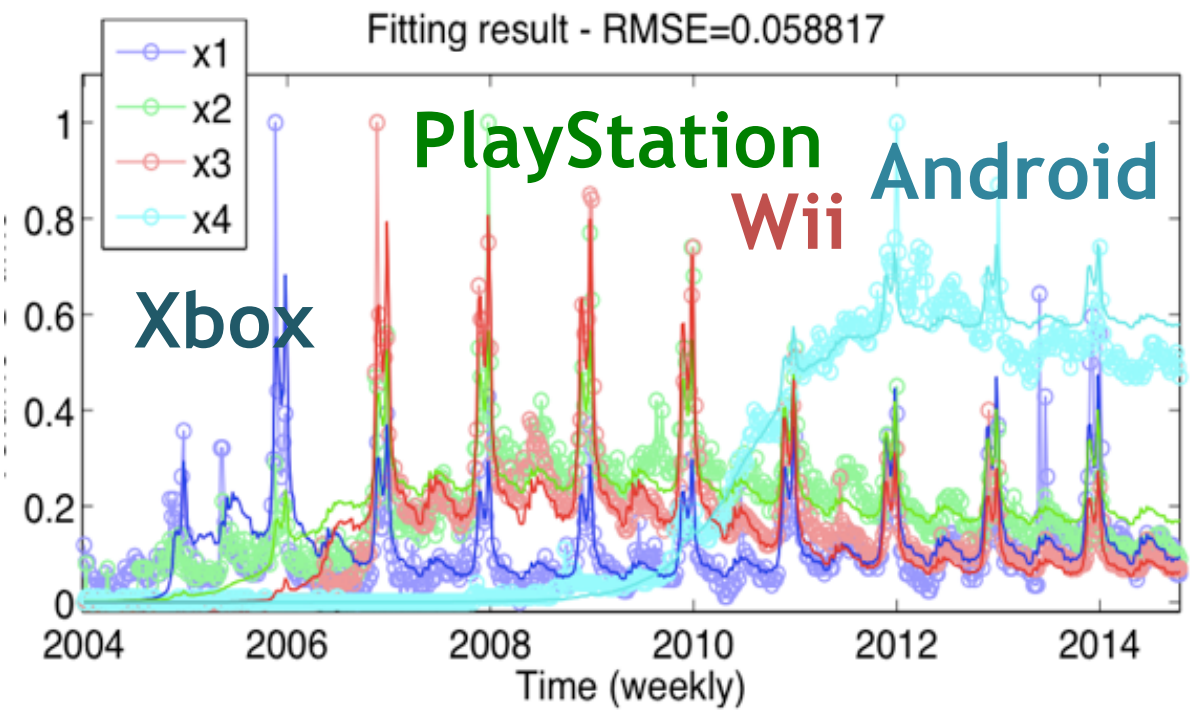
Ecosystem on the Web



(R2) Non-linear (gray-box) modeling

EcoWeb
WWW'15

The Web as a Jungle !

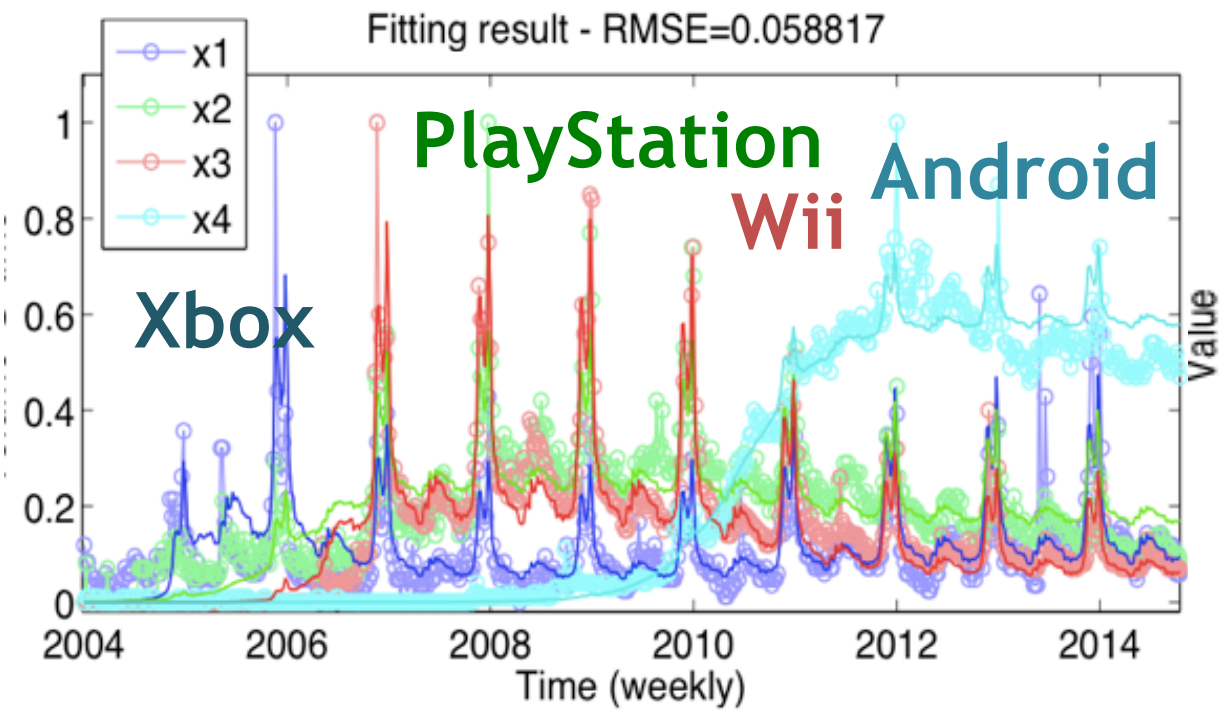


Interactions between keywords

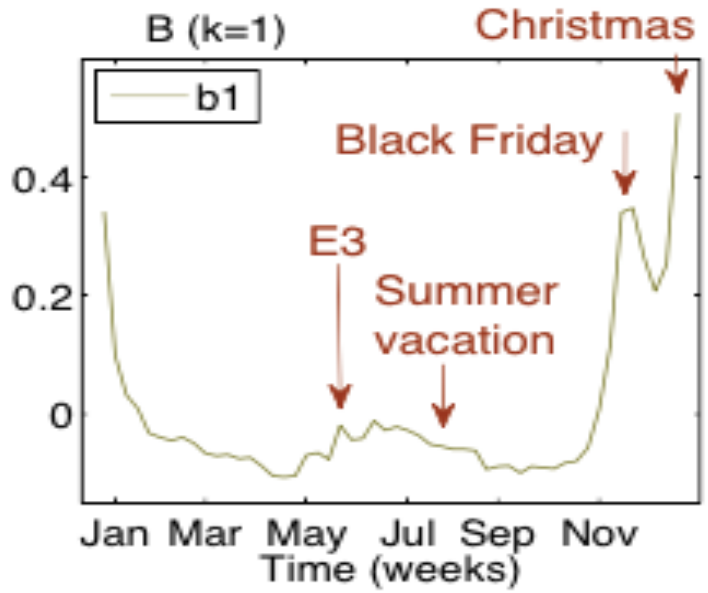
(R2) Non-linear (gray-box) modeling

EcoWeb
WWW'15

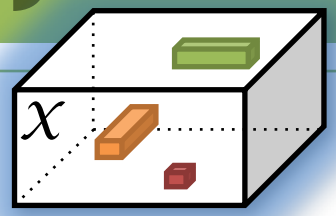
The Web as a Jungle !



Seasonality

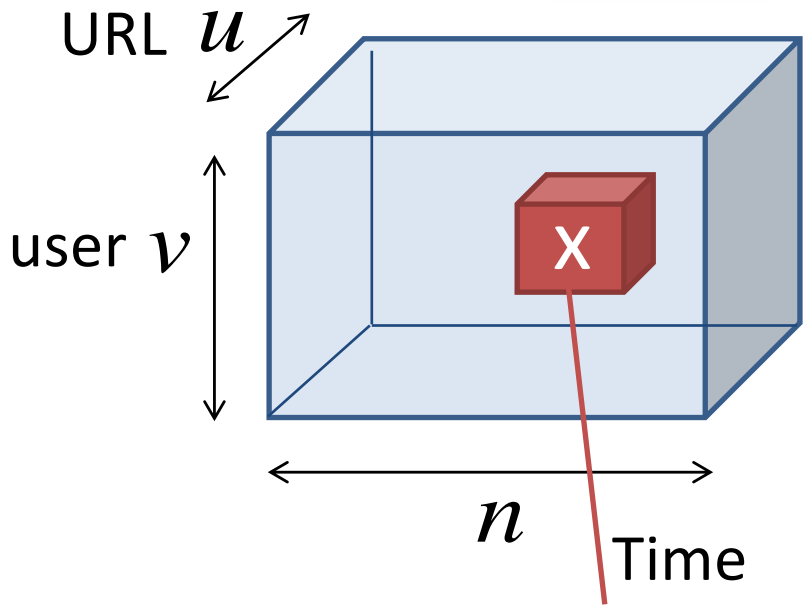


(R3) Large-scale tensor analysis



- Time-stamped events
  - *e.g., web clicks*

Time	URL	User
08-01-12:00	CNN.com	Smith
08-02-15:00	YouTube.com	Brown
08-02-19:00	CNET.com	Smith
08-03-11:00	CNN.com	Johnson
…	…	…



Represent as
Mth order tensor (M=3)

$$\mathcal{X} \in \mathbb{N}^{u \times v \times n}$$

Element x: # of events

e.g., 'Smith', 'CNN.com', 'Aug 1, 10pm'; 21 times

(R3) Large-scale tensor analysis

TriMine
KDD'12

Complex time-stamped events

{time, URL, user ID, access devices, http referrer,…}

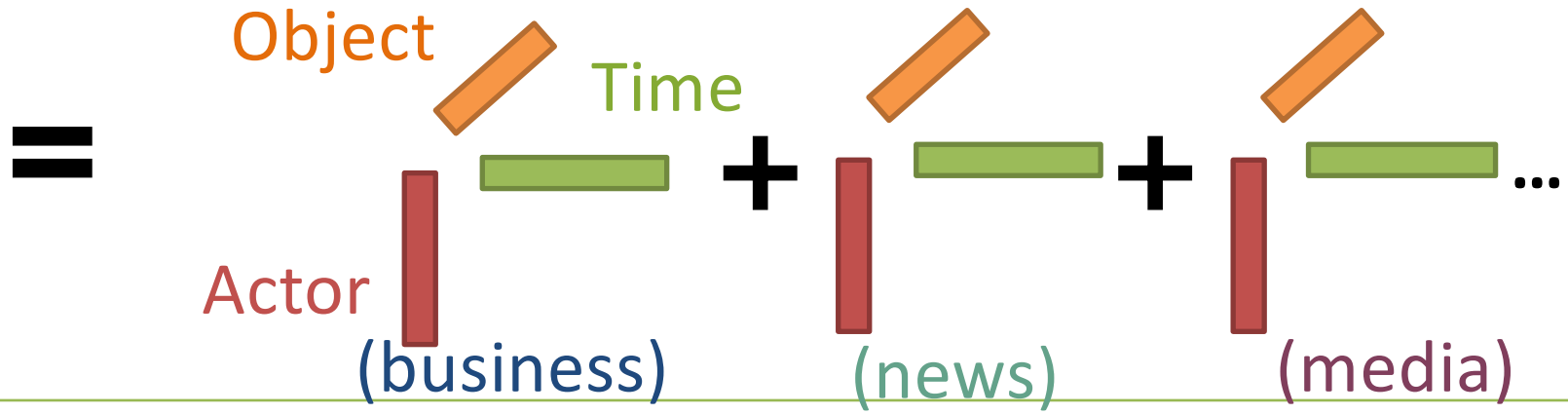
Forecast

Timestamp	URL	User	Device
2012-08-01-12:00	CNN.com	Smith	iphone
12-08-02-15:00	YouTube.com	Brown	iphone
12-08-02-19:00	CNET.com	Smith	mac
2012-08-03-11:00	CNN.com	Johnson	ipad
…	…	…	…
2012-08-05-12:00	CNN.com	Smith	iphone
2012-08-05-19:00	CNET.com	Smith	iphone

(R3) Large-scale tensor analysis

TriMine
KDD'12

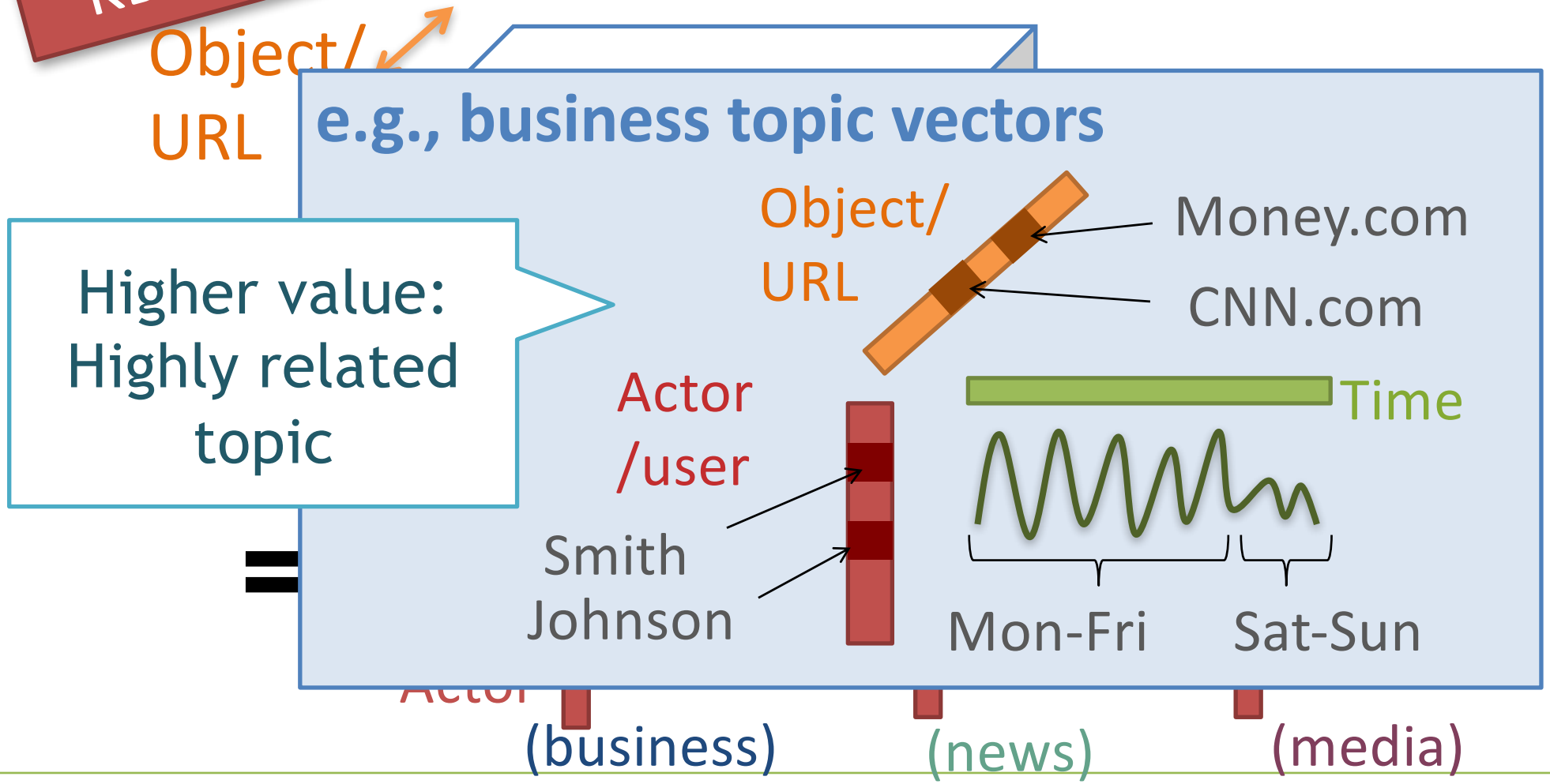
Complex time-stamped events



(R3) Large-scale tensor analysis

TriMine
KDD'12

Complex time-stamped events

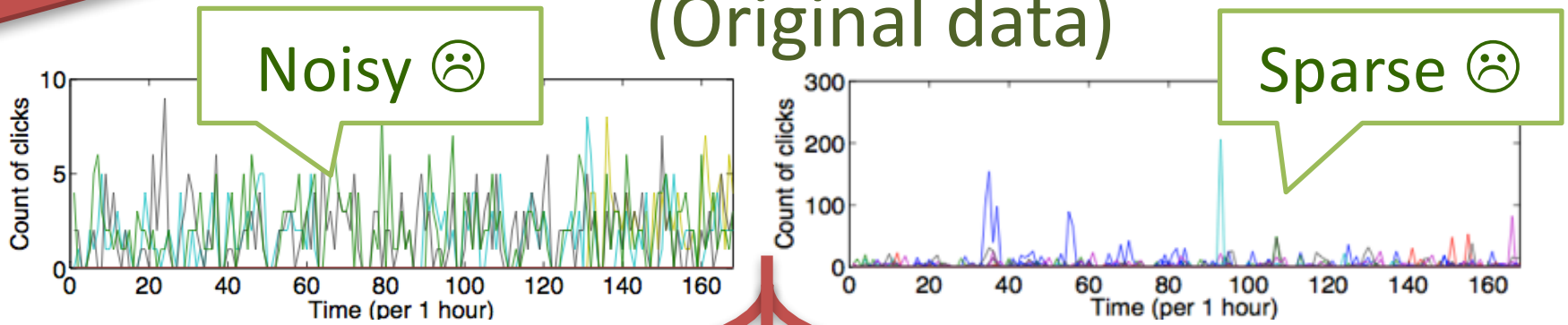


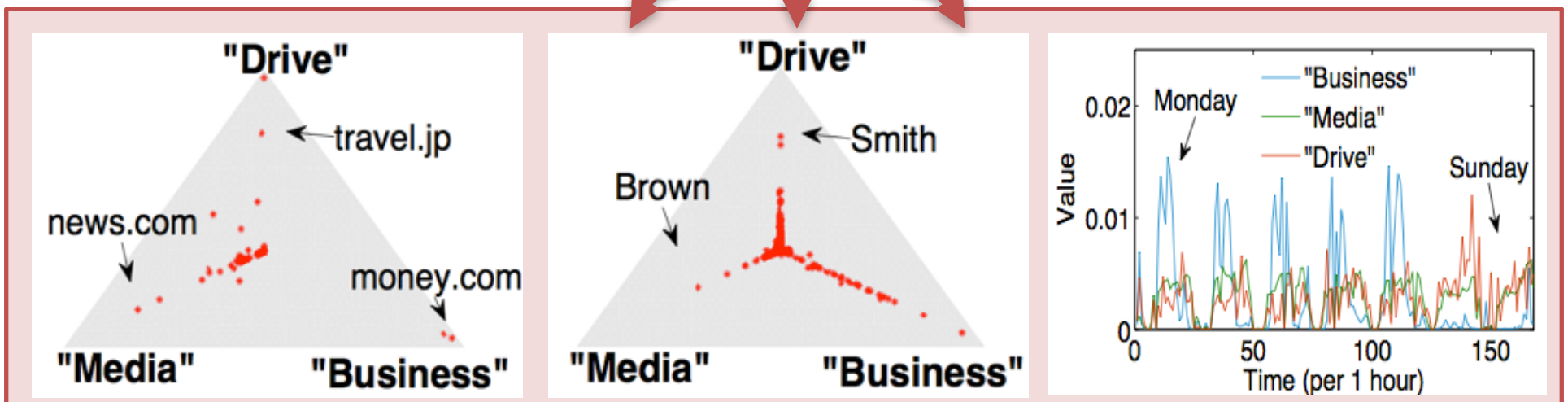
(R3) Large-scale tensor analysis

TriMine KDD'12

Complex time-stamped events

(Original data)





URL matrix | User matrix | Time matrix

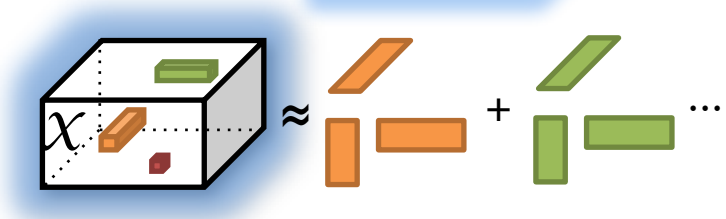
Putting it all together

3h-Tutorials
SIGMOD'15
WWW'16

New research directions

1. Automatic mining
2. Non-linear (gray-box) modeling
3. Large-scale tensor analysis

Put all together



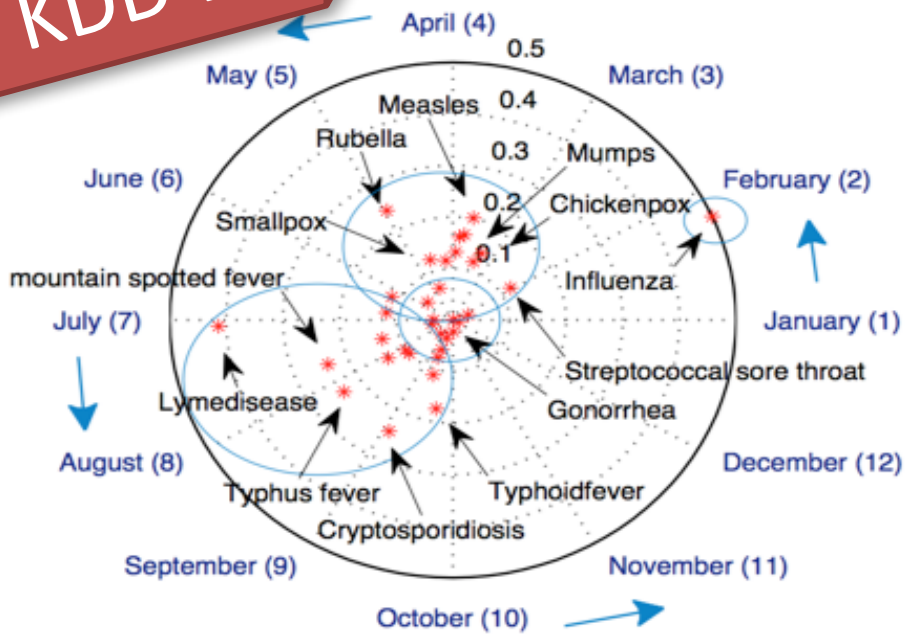
New challenge: MANT analysis

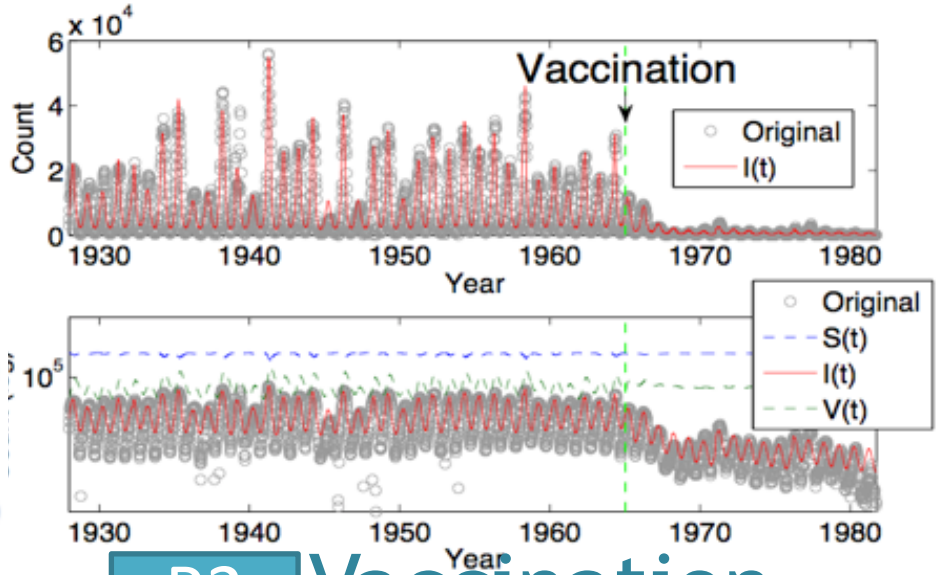
Multi-Aspect Non-linear Time-series

New challenge: MANT analysis

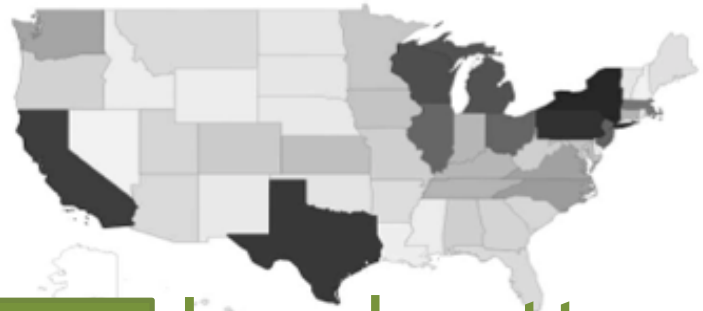
FUNNEL
KDD'14

Non-Linear tensor analysis





P2 Vaccination



s

P1 Seasonality

P4 External shocks

P5 Mistakes, errors

P3 Local patterns

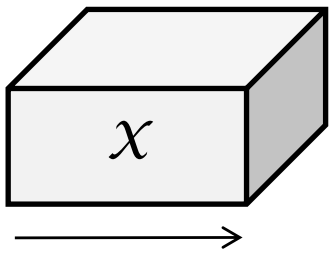
New challenge: MANT analysis

FUNNEL
KDD'14

Non-Linear tensor analysis

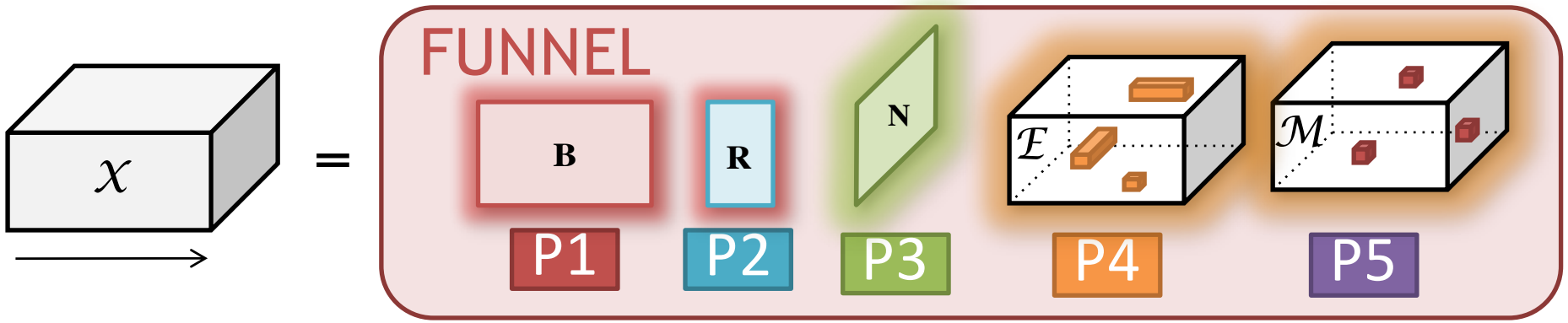
Given:

Tensor $\mathcal{X}$ (disease x location x time)



Find:

Compact description of $\mathcal{X}$, ***"automatically"***



New challenge: MANT analysis

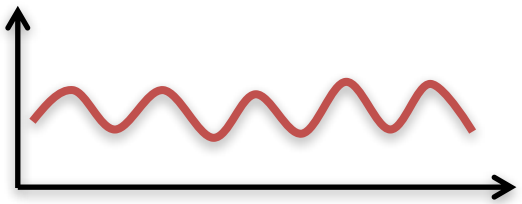
FUNNEL
KDD'14

Non-Linear tensor analysis

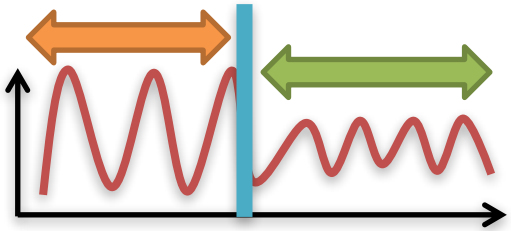
Given:

Ten ocatio

Seasonality

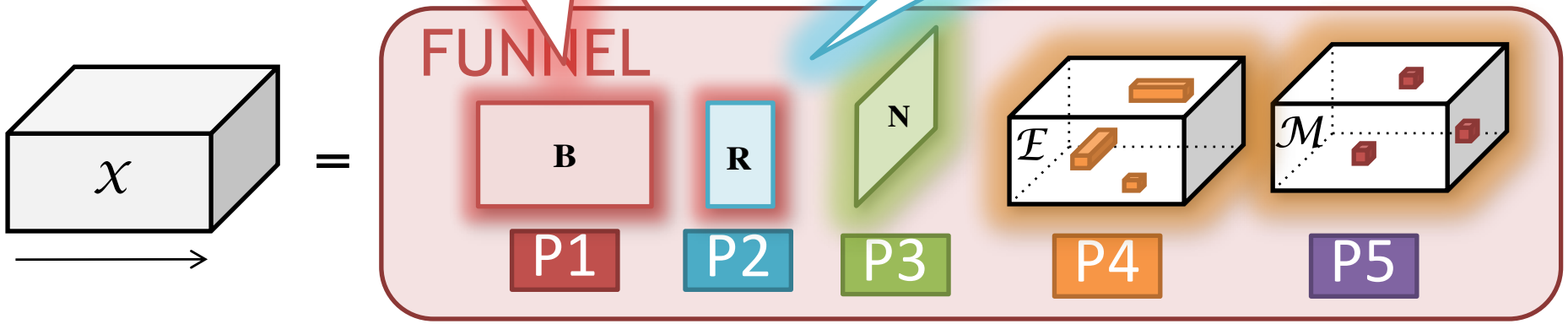


Discontinuities



Fin

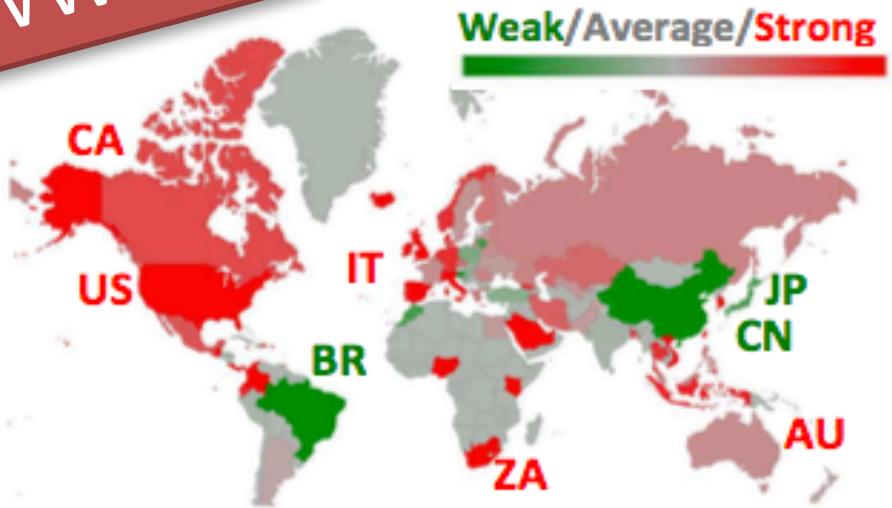
Compact desc ion of $\mathcal{X}$, "*omatically*"



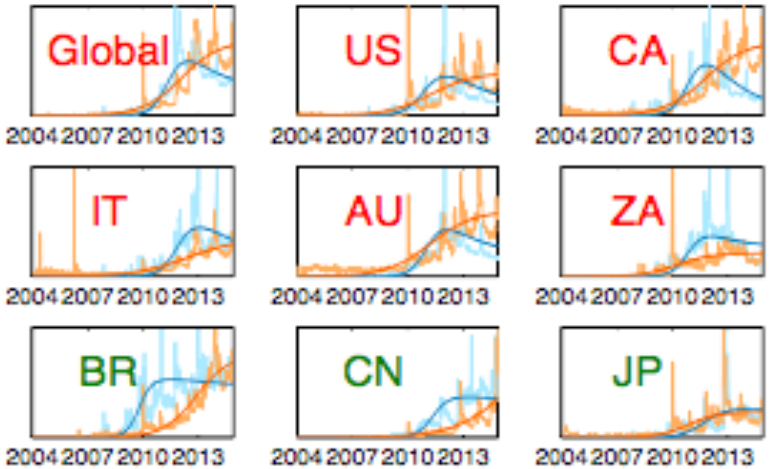
New challenge: MANT analysis

CompCube WWW'16

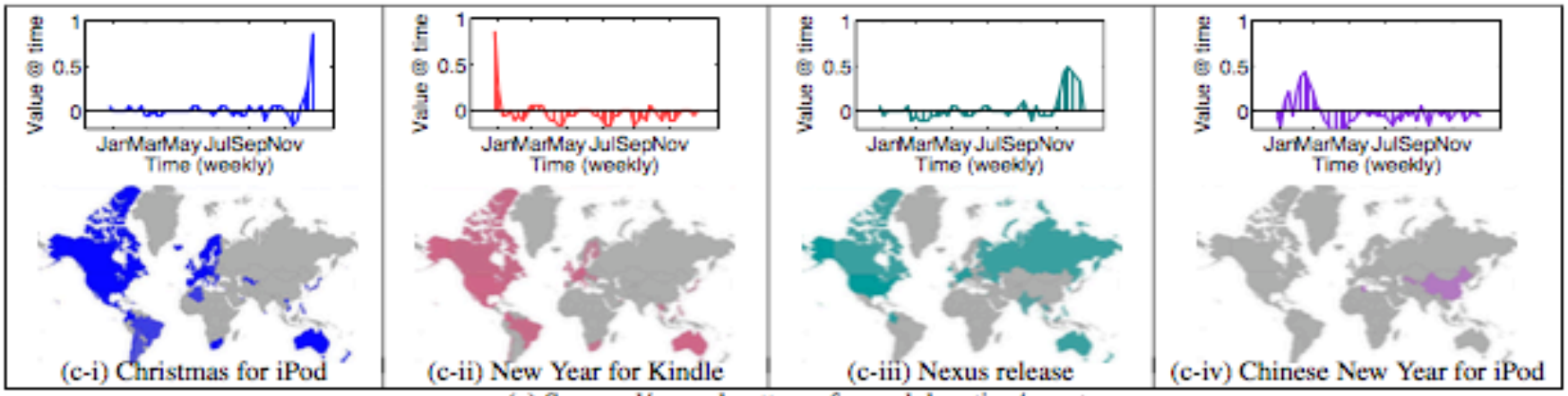
Non-Linear mining & forecasting of local competition



(a) Local competition strength between Kindle and Nexus



(b) Original/fitted search volumes for Kindle and Nexus



(c-i) Christmas for iPod (c-ii) New Year for Kindle (c-iii) Nexus release (c-iv) Chinese New Year for iPod

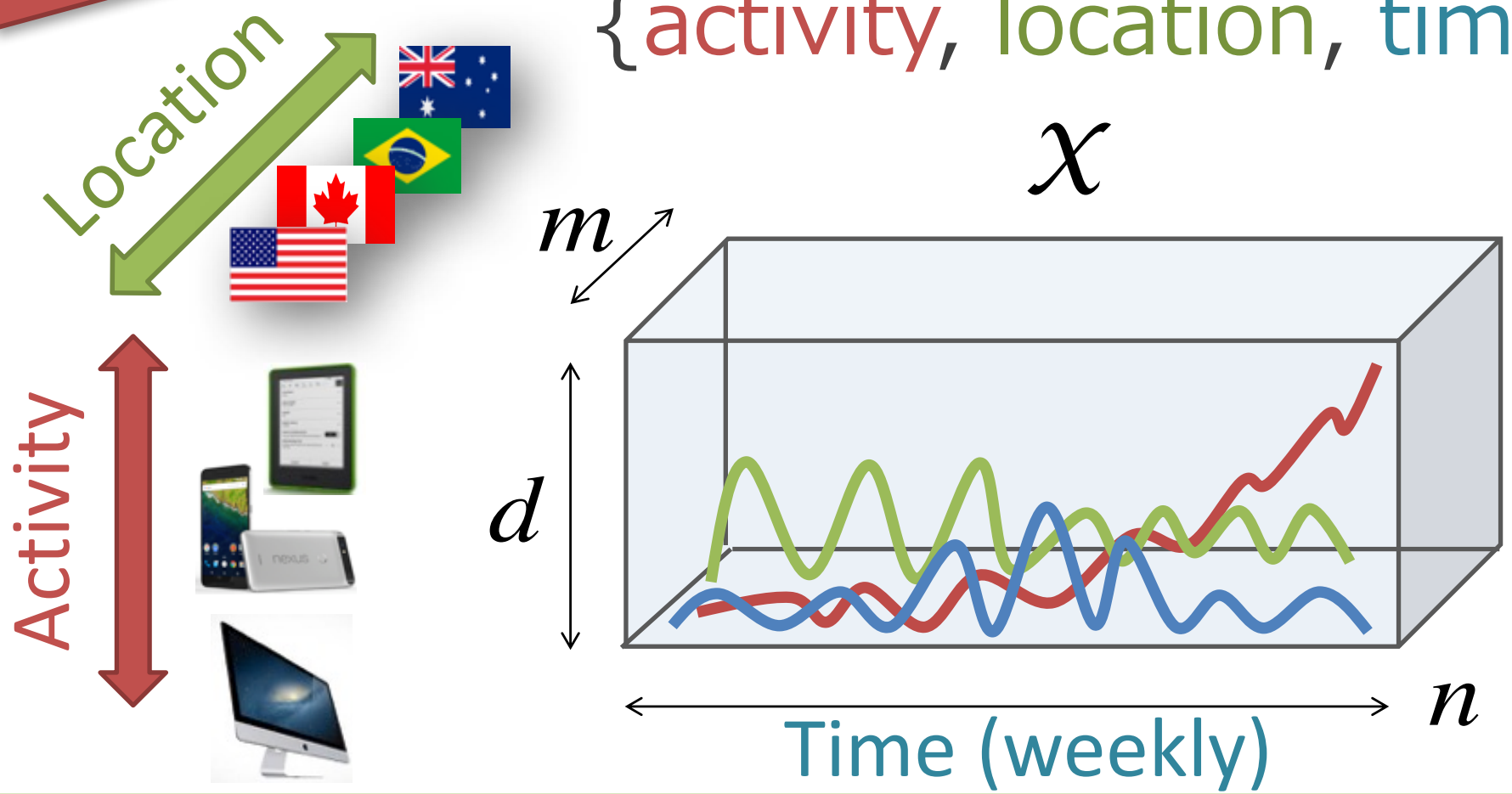
(c) Seasonal/annual patterns for each location/country

New challenge: MANT analysis

CompCube
WWW'16

Time-stamped events:

{activity, location, time}

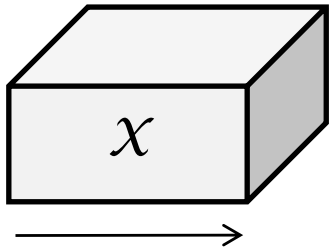


New challenge: MANT analysis

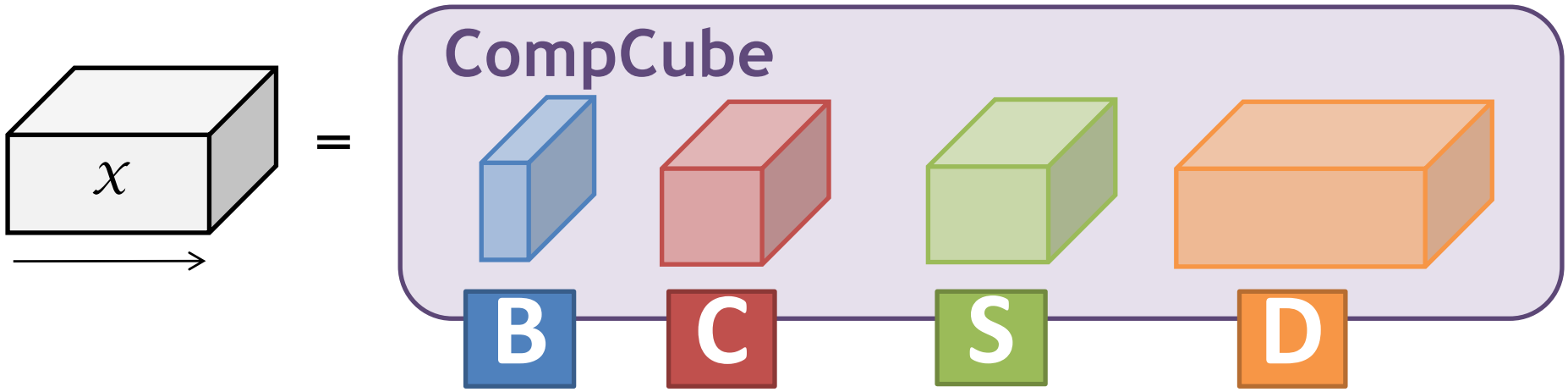
CompCube
WWW'16

Given: Tensor $\mathcal{X}$

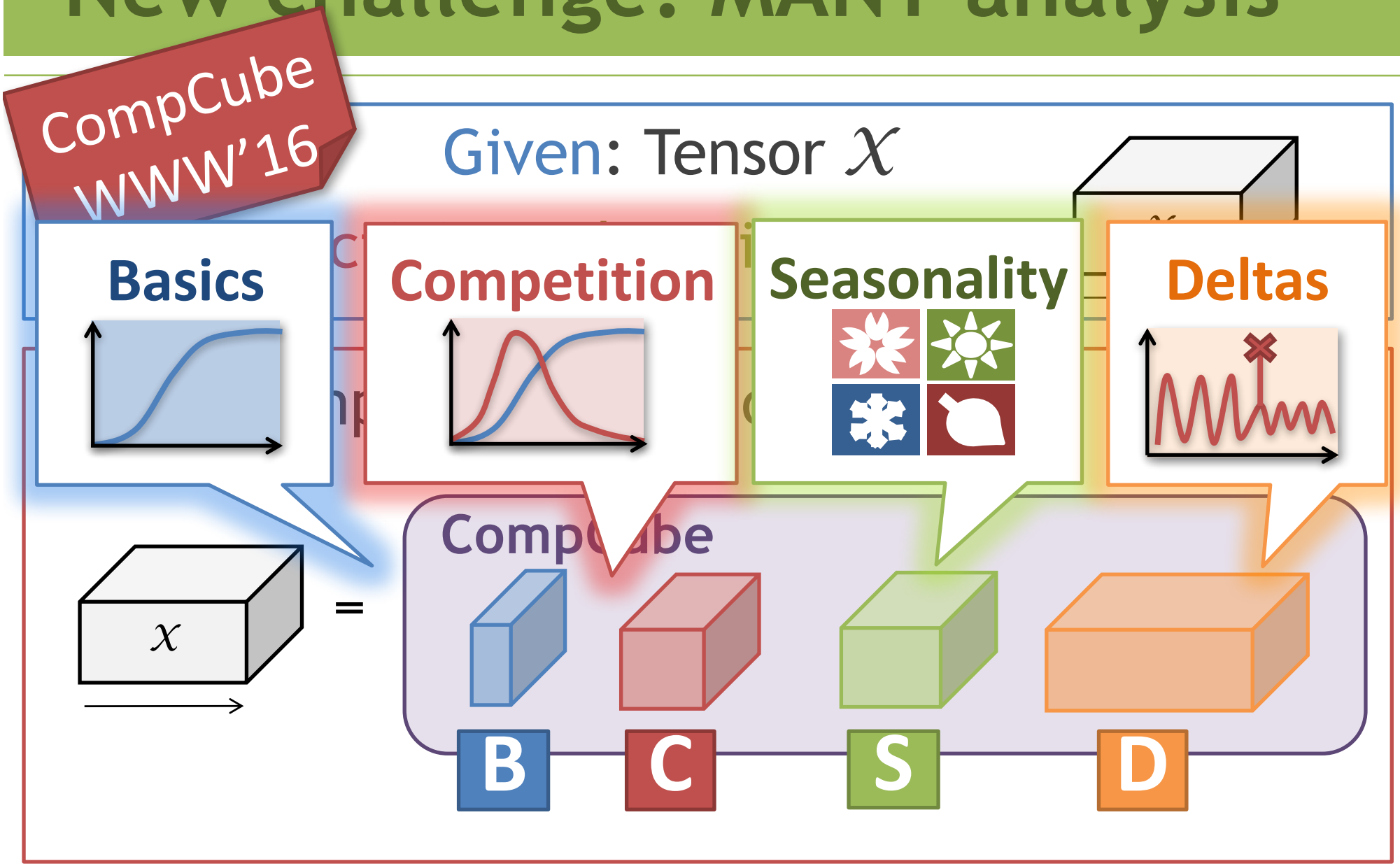
(activity x location x time)



Find: Compact description of $\mathcal{X}$



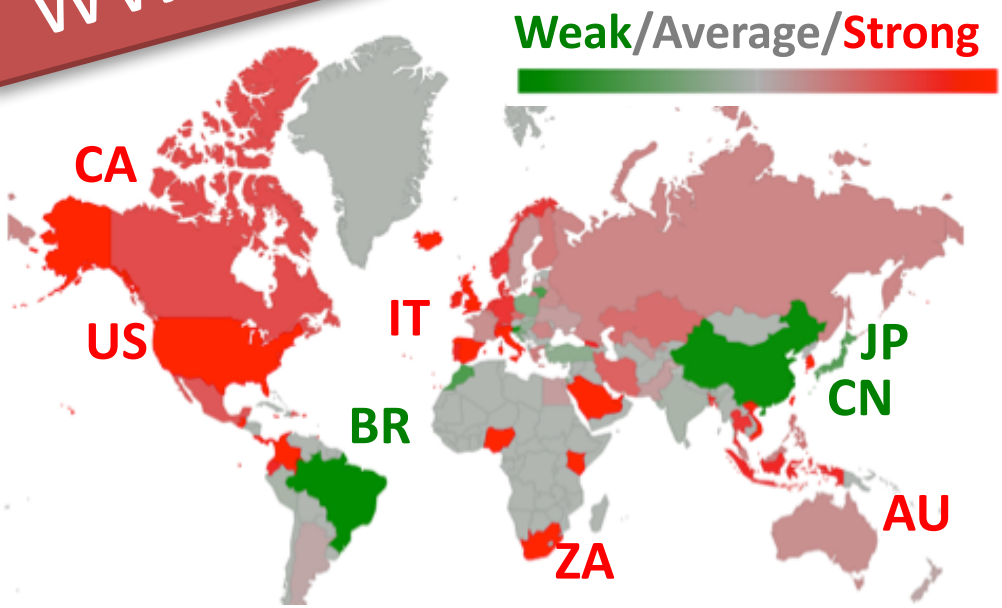
New challenge: MANT analysis

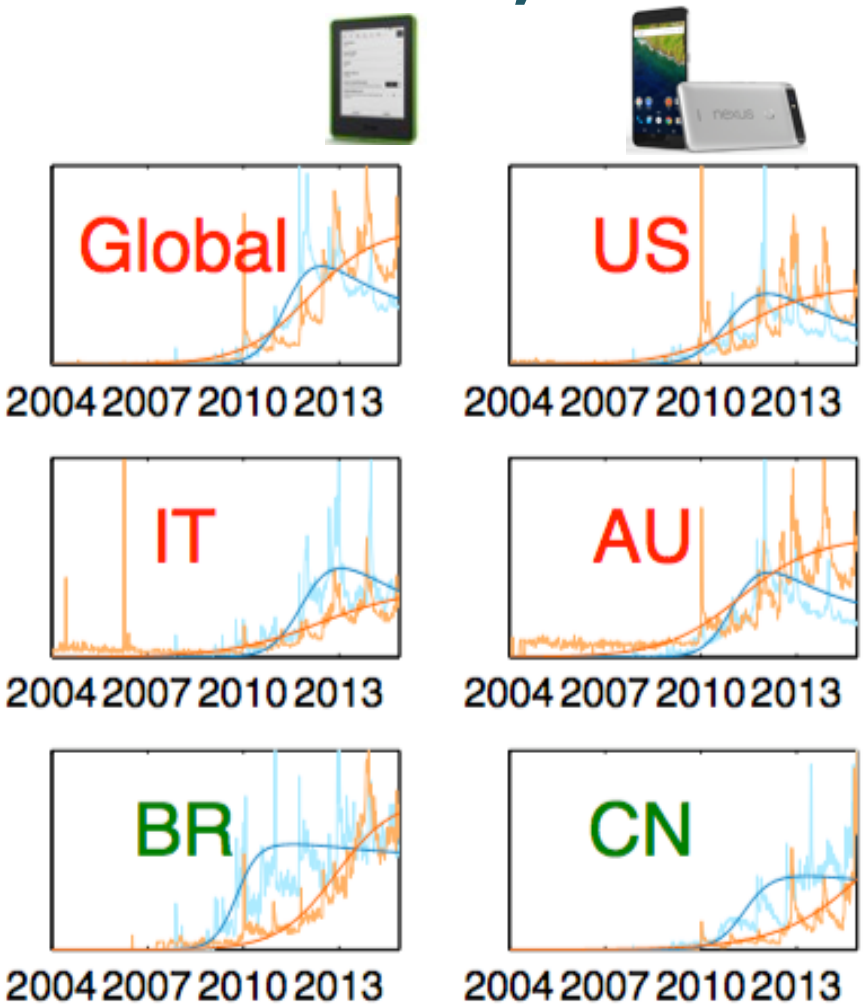


Modeling power of CompCube

CompCube WWW'16

Google search for **Kindle, Nexus**



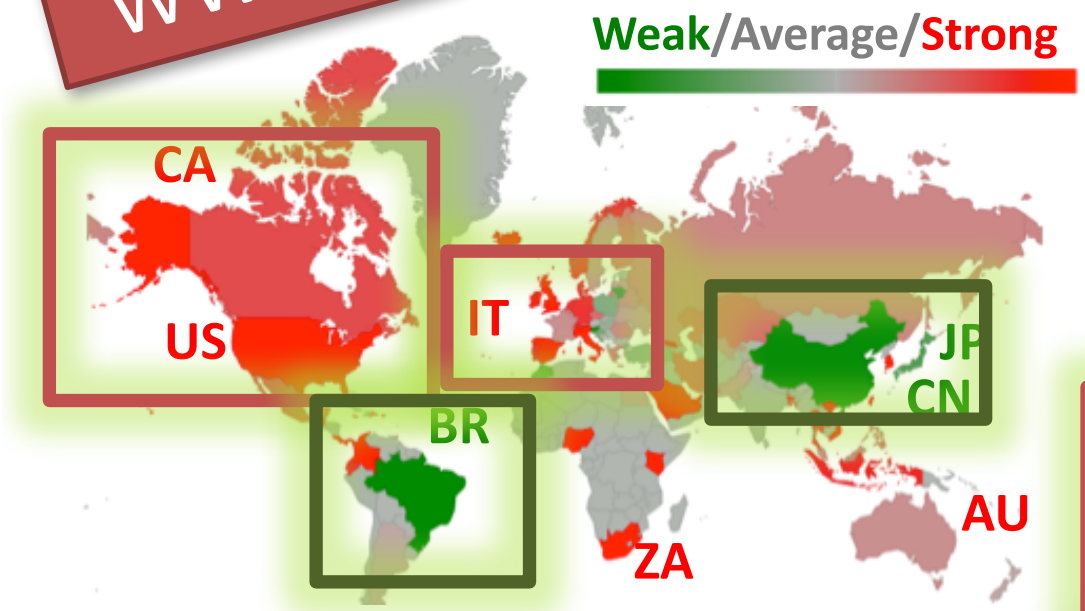


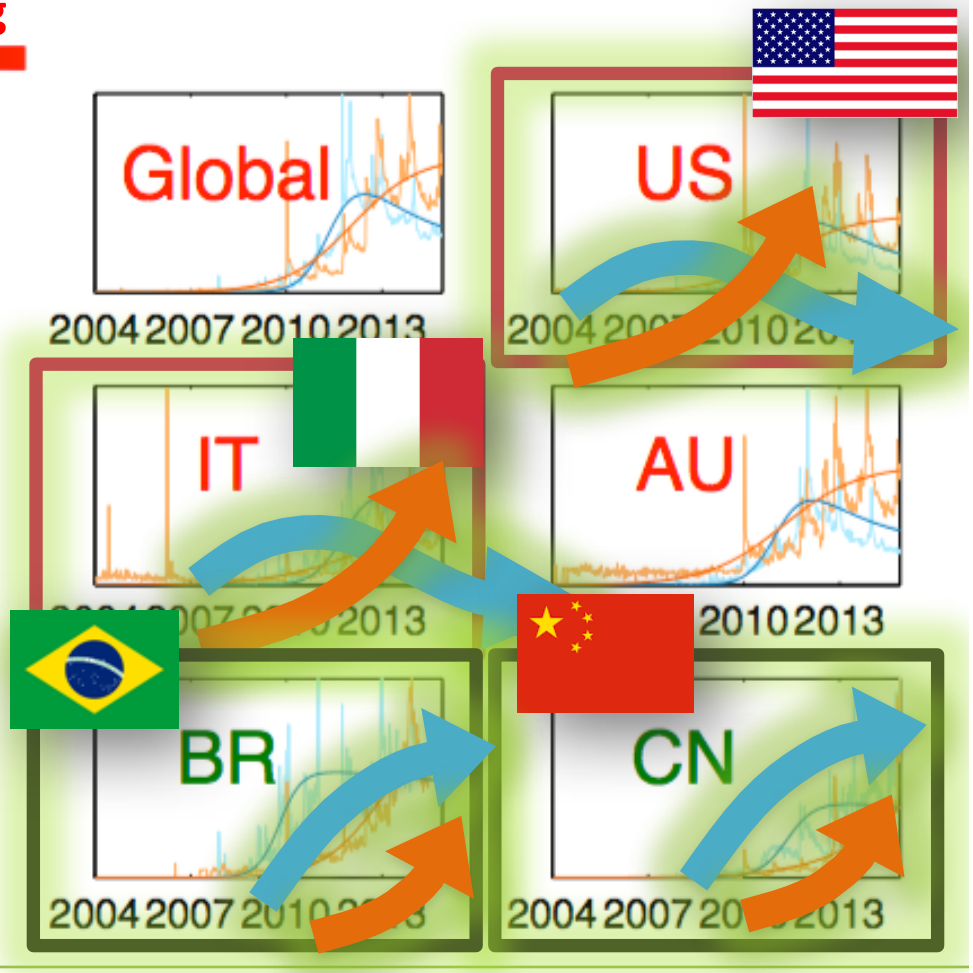
Local Competition strength

Modeling power of CompCube

CompCube WWW'16

Google search for **Kindle, Nexus**



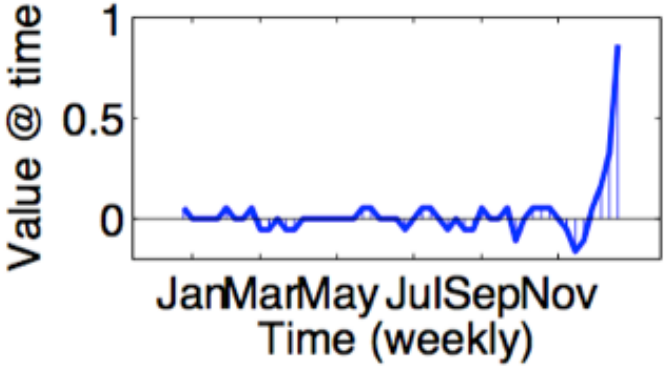


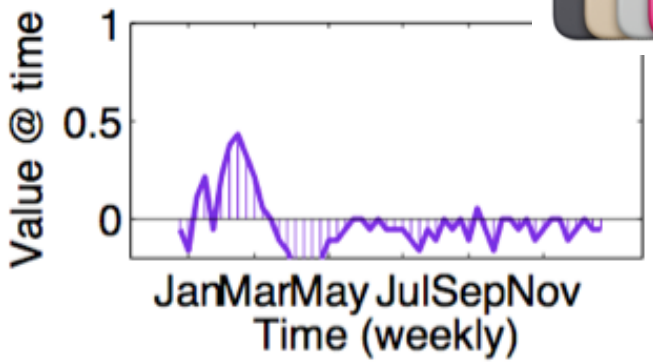
Local Competition strength

Modeling power of CompCube

CompCube WWW'16

Local seasonality for **iPod**





Component #1

Component #2

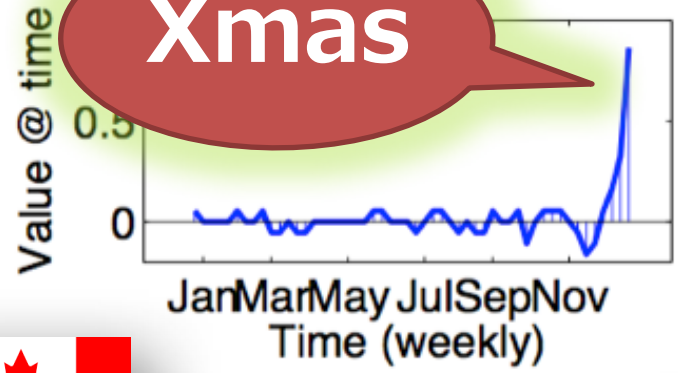
Modeling power of CompCube

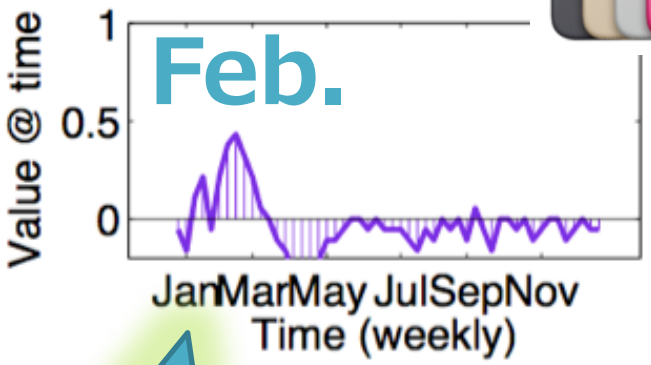
CompCube WWW'16

Local seasonality for **iPod**

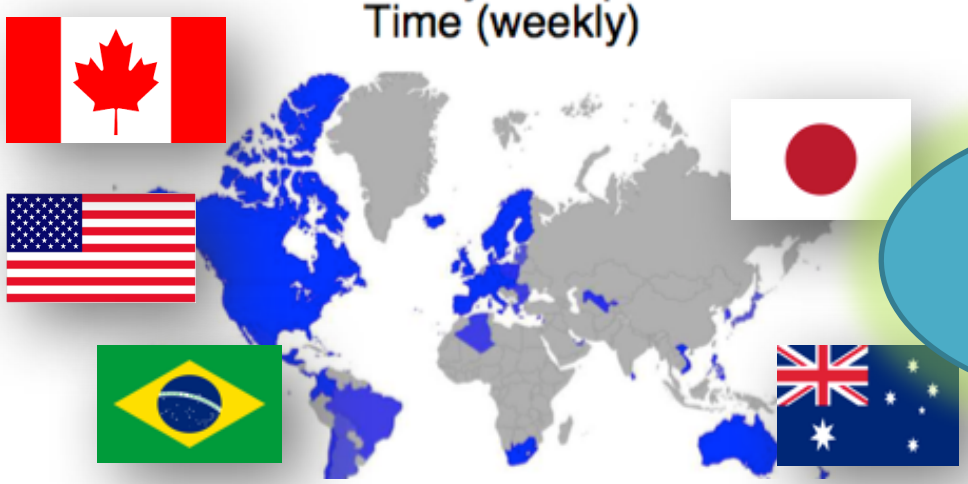
Dec.

Xmas





Feb.



Chinese New Year

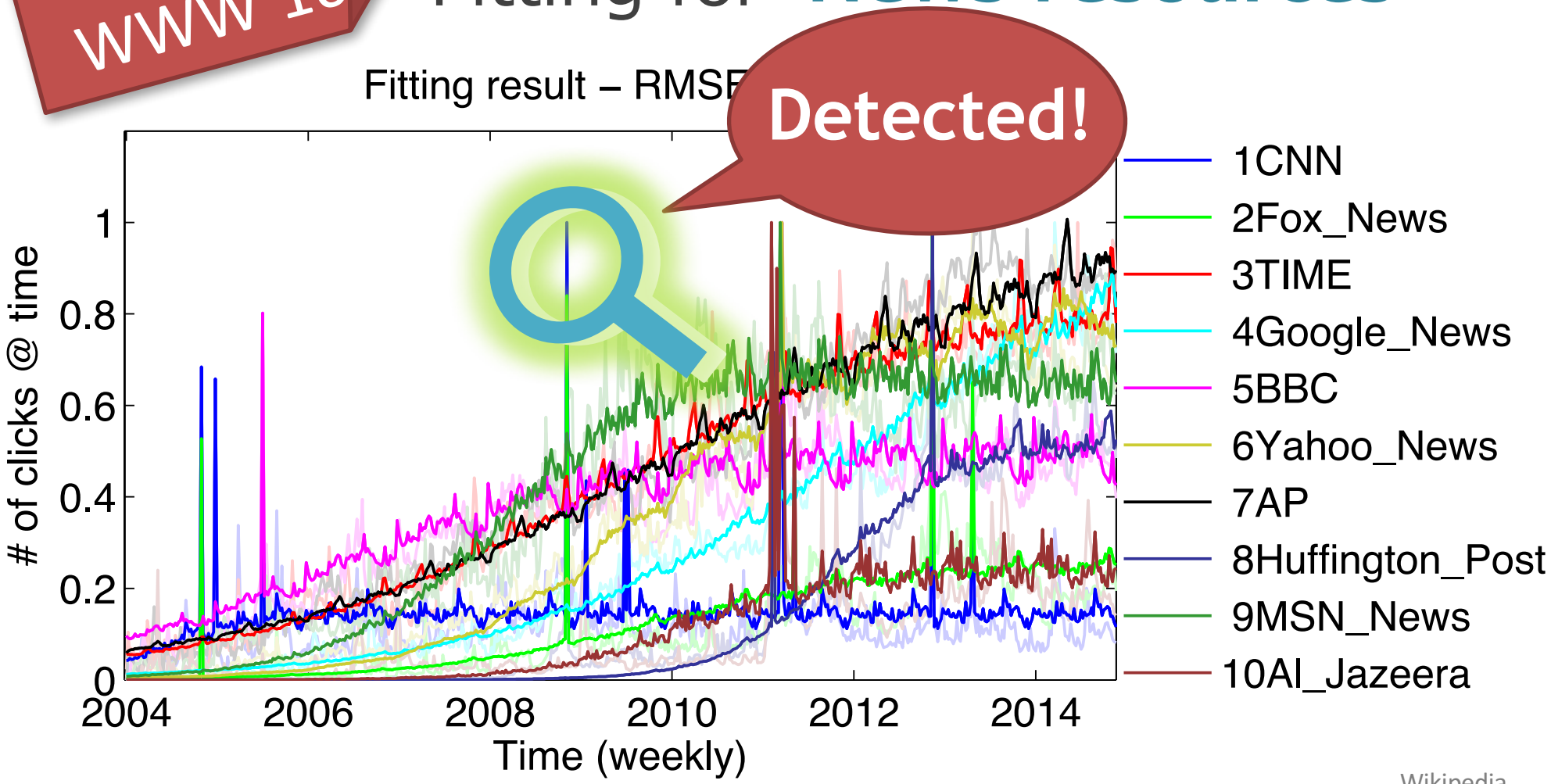
Component #1

Component #2

Modeling power of CompCube

CompCube WWW'16

Fitting for **News resources**



Wikipedia

Modeling power of CompCube

CompCube WWW'16

Fitting for **News resources**

Weak/**Strong**

Local attention to US election

US election Nov. 2008

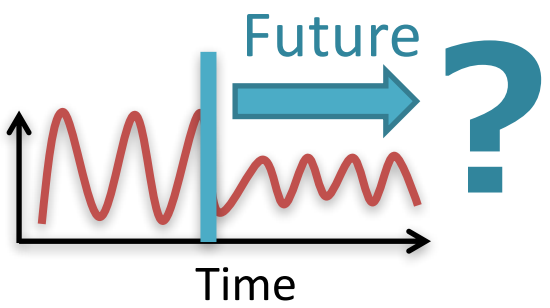
Wikipedia

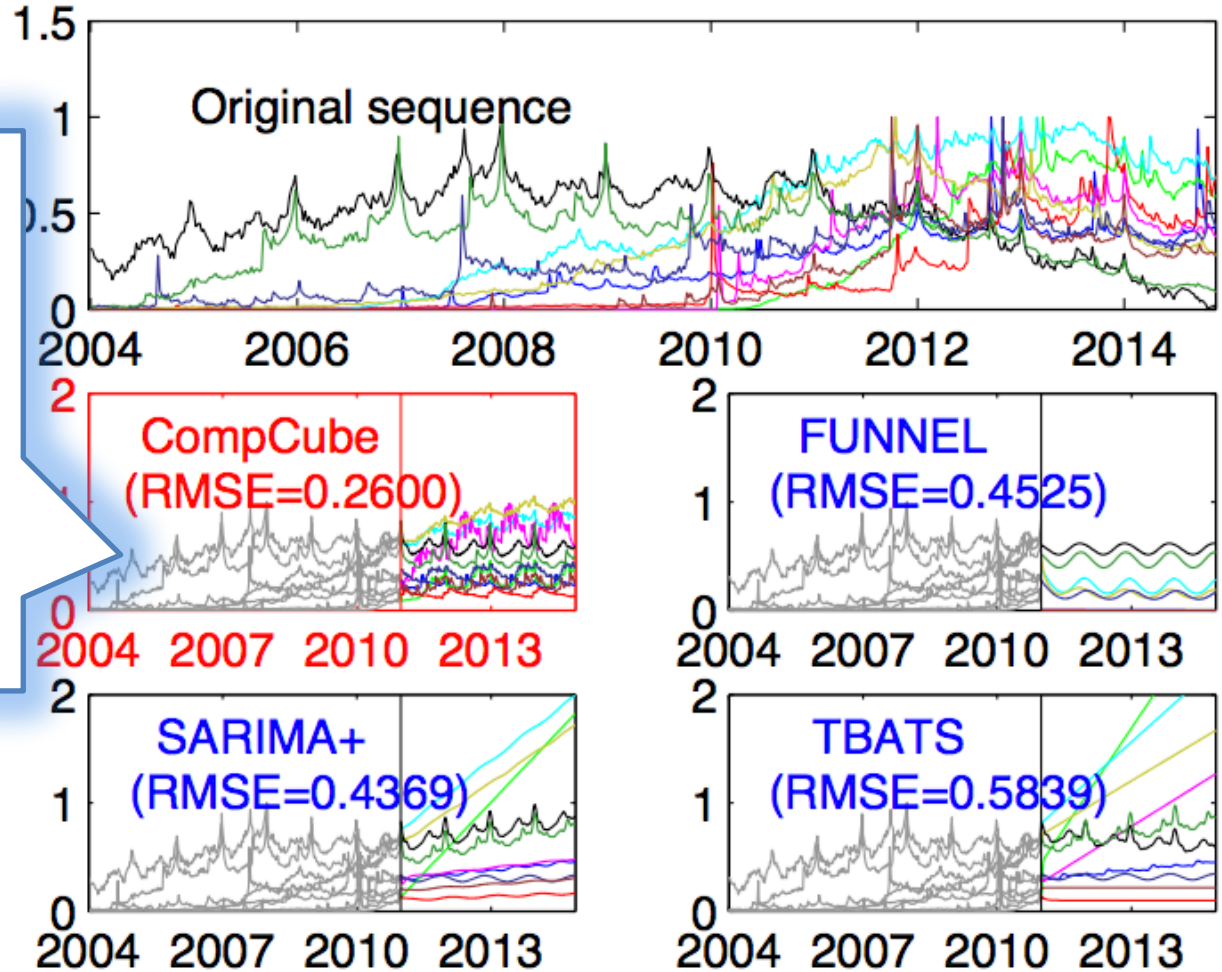
New challenge: MANT analysis

CompCube WWW'16

Non-Linear mining & forecasting of local competition

3. Forecast future activities





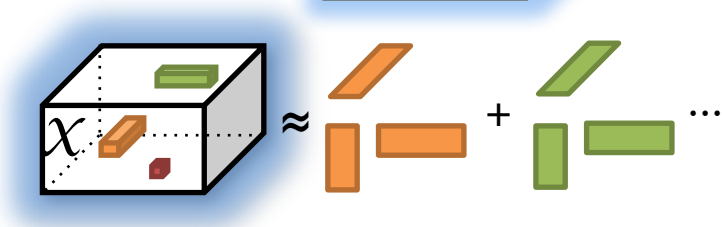
Putting it all together

3h-Tutorials
SIGMOD'15
WWW'16

New research directions

1. Automatic mining
2. Non-linear (gray-box) modeling
3. Large-scale tensor analysis

Put all together



M A N T

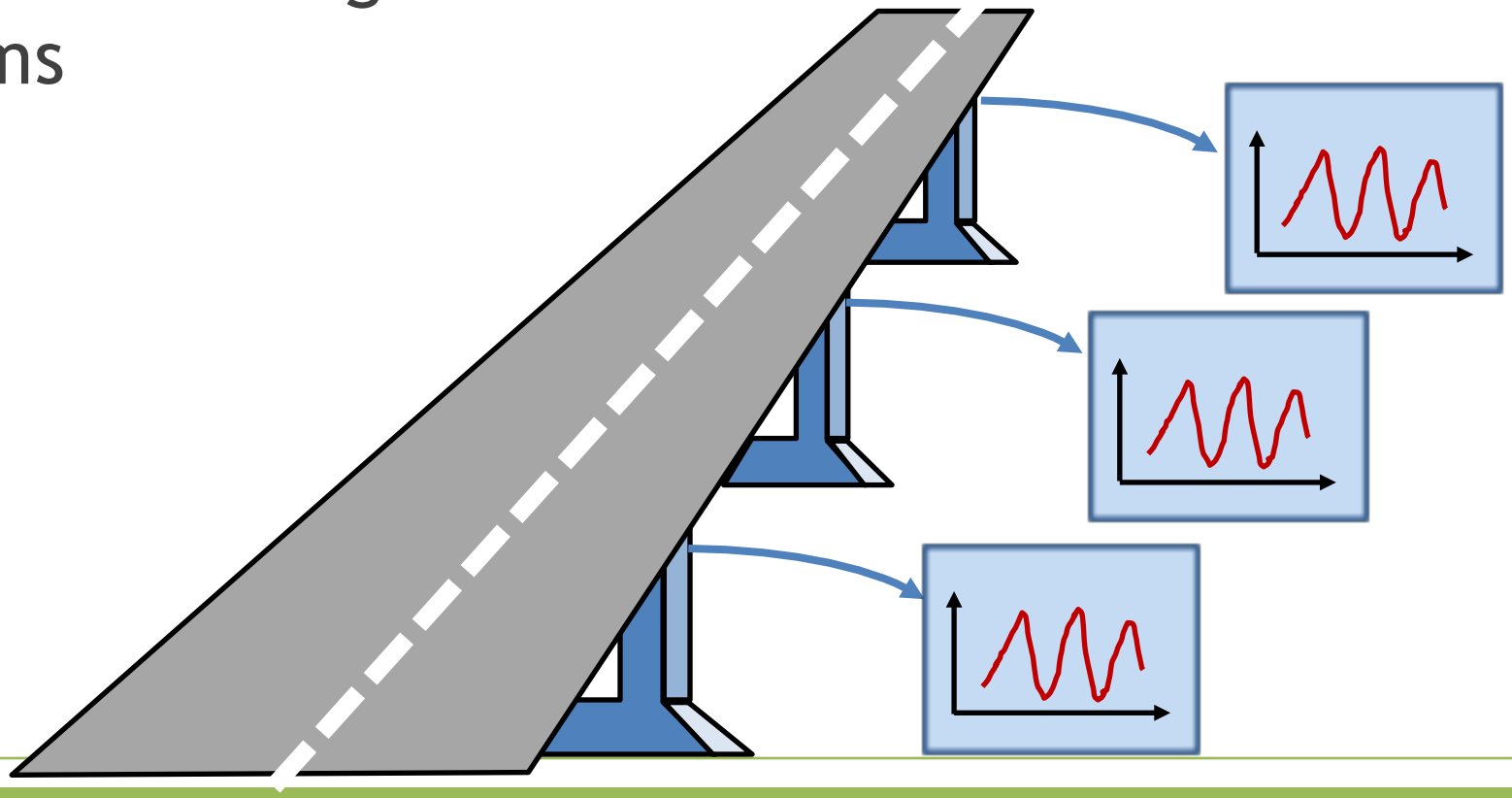
New challenge: MANT analysis

Multi-Aspect Non-linear Time-series

Industrial contribution

BRAID@ SIGMOD'05

- Bridge structural health monitoring
  - Structural monitoring using vibration/shock sensors
  - Keep track of lag correlations for sensor data streams



Industrial contribution

BRAID@ SIGMOD'05

- Bridge structural health monitoring
  - Goal: real-time anomaly detection for disaster prevention
  - Several thousands readings (per sec) from several hundreds sensor nodes

Structural health monitoring

Vibration/shock sensor

- Uses BRAID
- Metropolitan Expressway (Tokyo, Japan)

Industrial contribution

BRAID@ SIGMOD'05

- Bridge structural health monitoring with BRAID

Metropolitan Expressway (Tokyo, Japan)

Tokyo Gate Bridge (Tokyo, Japan)

Can Tho Bridge (Vietnam)

Industrial contribution

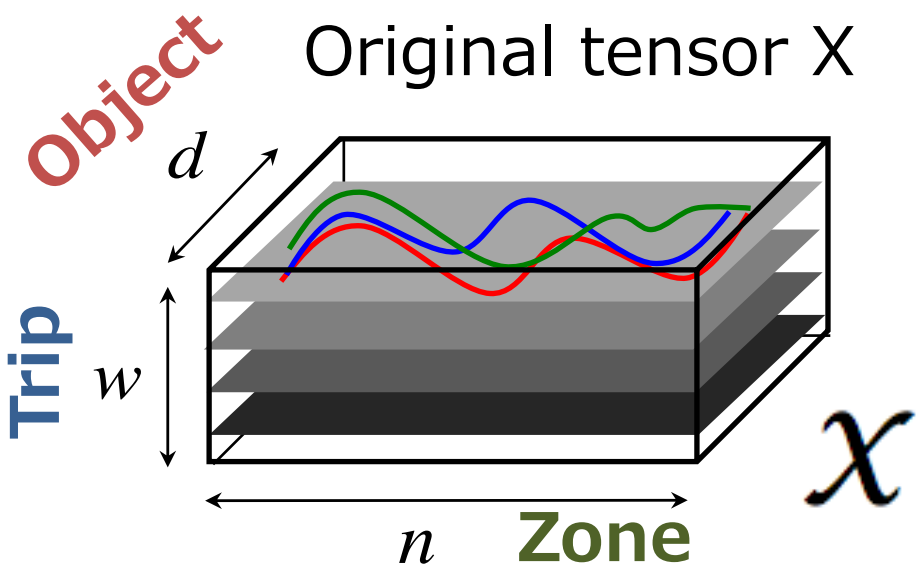
WebDBF'15 Best paper

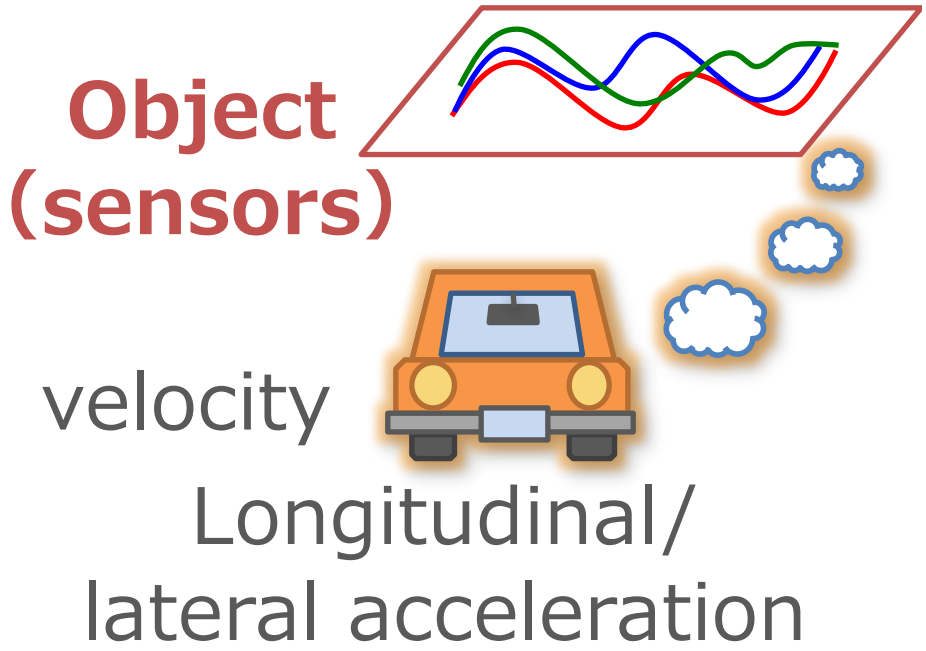
– **Automobile sensor data**

{ **trip ID**, **zone ID**, o

TOYOTA InfoTechnology Center Co., Ltd.

TrailMarker





Industrial contribution

WebDBF'15 Best paper

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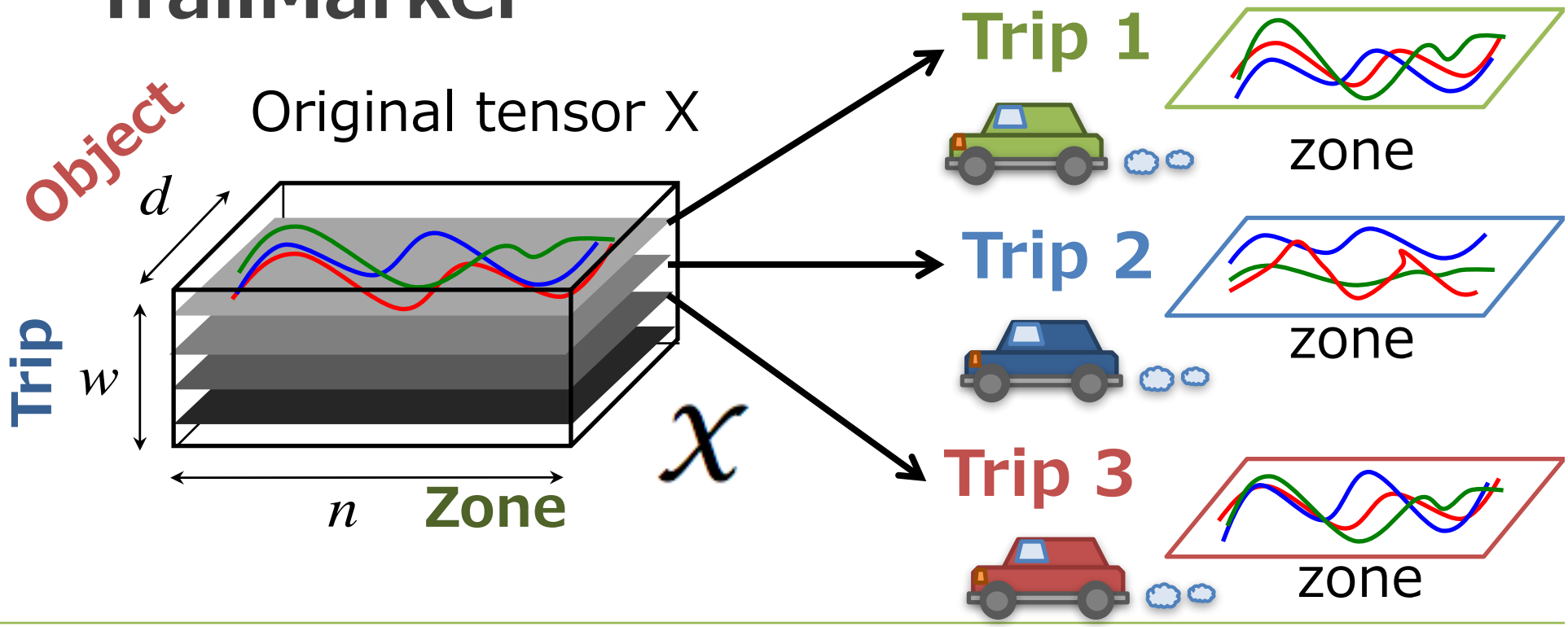

Industrial contribution

WebDBF'15 Best paper

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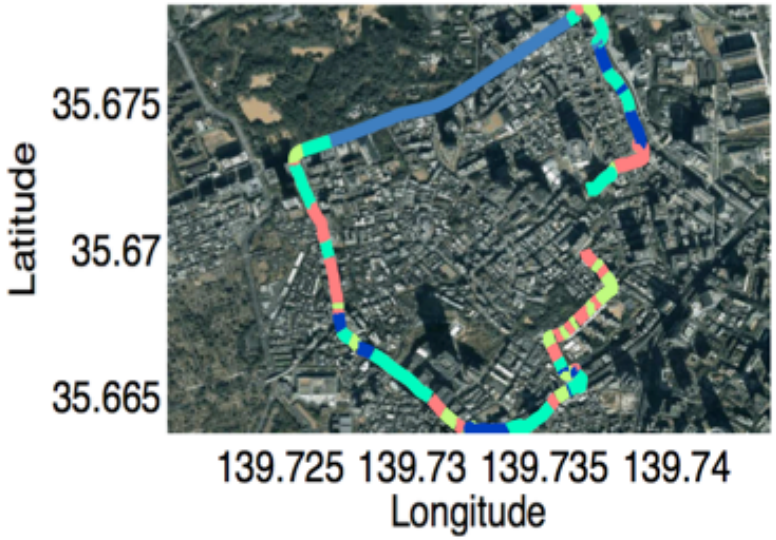

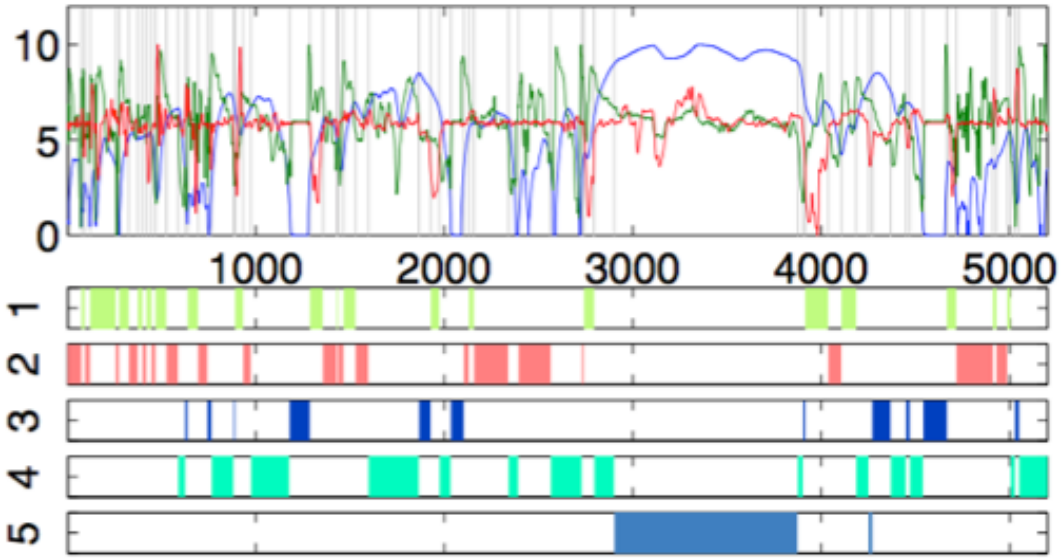

Thank you

Code/Data/Tutorial:

Sakurai Lab.

http://www.cs.kumamoto-u.ac.jp/~yasushi/

M A N T