

## Collective Emotions on the Internet

### How to quantify and model emotional influence

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*in collaboration with:*

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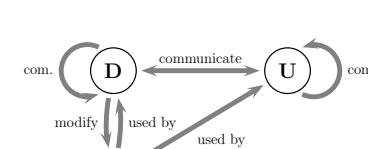


## Chair of Systems Design at ETH Zurich

### ■ Main Research Areas

#### ■ Economic Networks & Social Organizations

- e.g. ownership networks, R&D networks, financial networks, ...
- e.g. online communities, OSS projects, animal societies, ...



#### ■ Methodological Approach: Data Driven Modeling

- **economic databases:** ORBIS, Bloomberg, patent databases
- **online data:** user interaction, communication records, blogs

## Outline

- 1 Motivation: Why Collective Emotions
- 2 Quantifying Emotions
- 3 Modeling Cyber Emotions
- 4 Applications
- 5 Outlook

## Motivation: What drives our behavior?

#### ■ rational agent: calculates utility

- perfect knowledge?, how to quantify utility?

#### ■ social “ingredients”: for the good and the bad

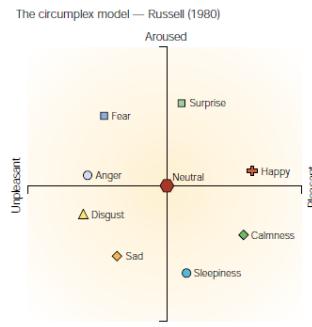
- *individual*: (dis)trust, empathy, aggression, emotions
- *collective*: herding, group feeling, collective emotions



## What are emotions?



- short-lived psychological states that consume individual's energy and strongly bias behavior (for example expression)



(Credit: Calder et al. 2001)

### Russell's dimensional model

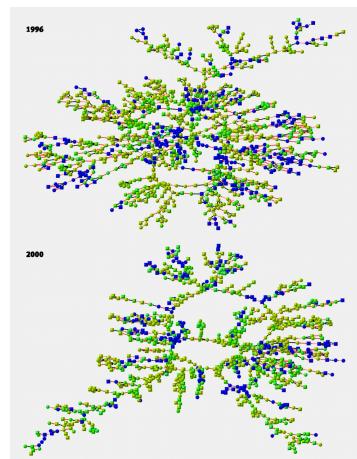
#### Valence

Pleasure associated with the emotion.

#### Arousal

Degree of activity induced by the emotion.

## A big difference: Happiness network



<sup>a</sup>Fowler, Christakis, 2008

- time aggregated clusters of happy individuals based on two snapshots within 20 years
- correlations don't show collective emotional states, but global lifetime happiness
- hypothesis of happiness contagion is not verified

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### 1 Motivation: Why Collective Emotions

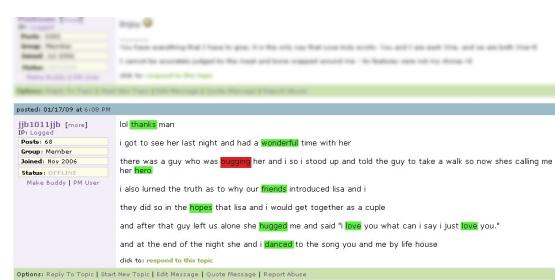
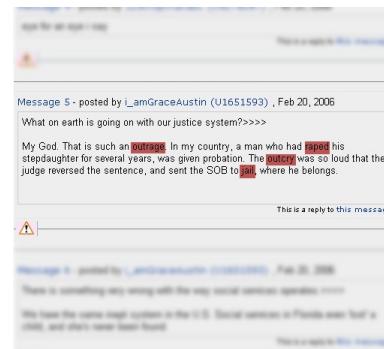
### 2 Quantifying Emotions

### 3 Modeling Cyber Emotions

### 4 Applications

### 5 Outlook

## Emotional Posts in Fora



Example of a negative (left) and a positive (right) post

- Threads analysed in two different ways

- text-based emotion classification ⇒ *sentiment analysis*
- measuring physiological responses of users

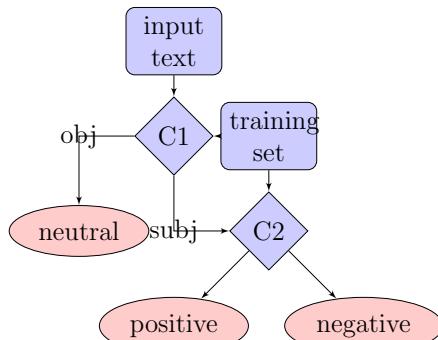
## Text-based emotion classification

### Annotated lexicon

- positive and negative score for predefined words

### Supervised learning

- training set: annotated text, output: subjectivity, polarity



### Survey based lexicon (ANEW)

- dataset of word emotionality  $\Rightarrow$  valence, arousal, dominance
- improvement: stemming of words  $\Rightarrow$  better accuracy, recall

Lyrics for  
Michael Jackson's Billie Jean

"She was more like a beauty queen  
from a movie scene.  
:  
And mother always told me,  
be careful who you love.  
And be careful of what you do  
'cause the lie becomes the truth.  
Billie Jean is not my lover,  
She's just a girl who claims  
that I am the one.  
:"

| ANEW words   | $v_k$ | $f_k$ | $v_{text} = \frac{\sum v_k f_k}{\sum f_k}$ |
|--------------|-------|-------|--|
| $k=1$ , love | 8.72  | 1     |  |
| 2, mother    | 8.39  | 1     |  |
| 3, baby      | 8.22  | 3     |  |
| 4, beauty    | 7.82  | 1     |  |
| 5, truth     | 7.80  | 1     |  |
| 6, people    | 7.33  | 2     |  |
| 7, strong    | 7.11  | 1     |  |
| 8, young     | 6.89  | 2     |  |
| 9, girl      | 6.87  | 4     |  |
| 10, movie    | 6.86  | 1     |  |
| 11, perfume  | 6.76  | 1     |  |
| 12, queen    | 6.44  | 1     |  |
| 13, name     | 5.55  | 1     |  |
| 14, lie      | 2.79  | 1     |  |

\*

## What is problematic here?

### 1 performance of algorithm

- context sensitivity*: emotions only in words?
- subtle meaning*: That's not bad ... – how good is it?

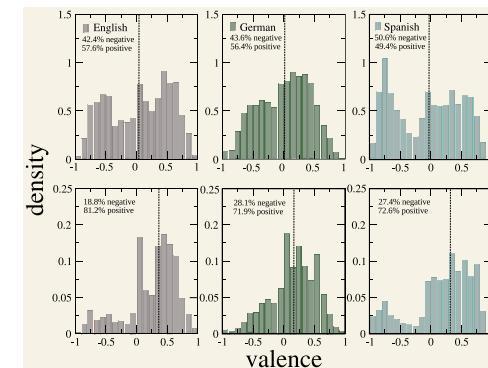
### 2 quality of lexicon

- human ratings*: English (1034 w), German (2902 w), Spanish (1034 w)
- validation against independent measurements (*physiology*)?

### 3 inherent properties of used language

- how emotional is "neutral" communication?
- what is the reference point for "normal" valence? (zero???)

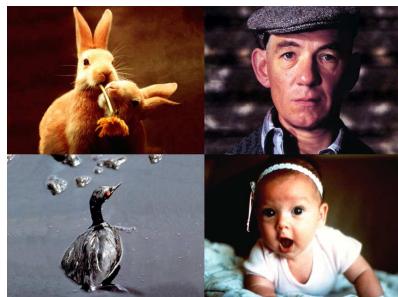
## How emotional is used language?



- positive words are more frequently used (Polyanna hypothesis)

- lexica: *no bias*, full range of valence  $\Rightarrow$  *neutral* (mean, median)
- frequency of word usage from Google N-gram dataset ( $10^{12}$  token)
- example*:  $v = 0.715$ : "party" ( $144.7 \cdot 10^{-6}$ ) "sunrise" ( $6.8 \cdot 10^{-6}$ )

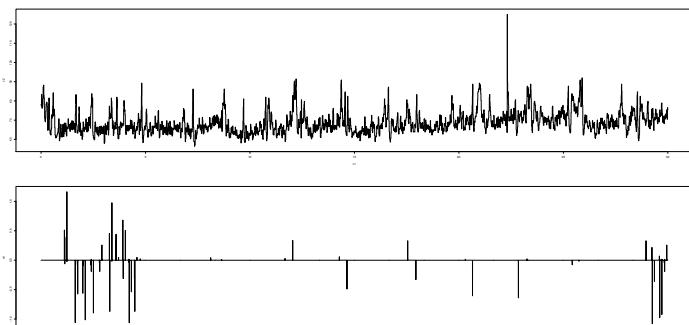
## Measuring physiological response



- physiological response to classified pictures<sup>†</sup> and flora
  - monitoring heart rate, skin conductance, frowning and smiling
  - already known to correlate with valence and arousal

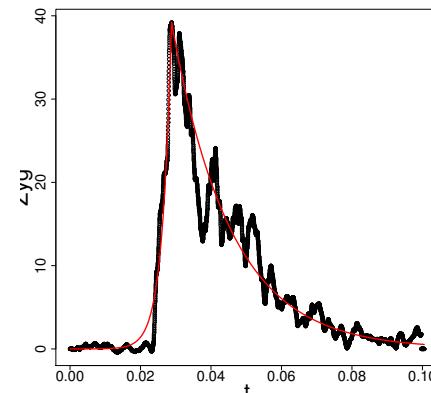
<sup>†</sup>IAPS - International affective picture system

## Heart rate and skin conductance



- 1270 variables in SSPS data
- Baseline extraction, rescaling ⇒ time series analysis

## The Zygomaticus peak



$$z(t) = \begin{cases} z_0 e^{(\beta_1(x-\Theta))} & x \leq \Theta, \\ z_0 e^{(\beta_2(x-\Theta))} & x > \Theta. \end{cases}$$

- uniform distribution of peak time  $\Theta$
- Yet to understand relation between valence and parameters of fit
- tools to estimate valence from physiological data
- training from valence values of IAPS emotional picture system.

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## Modeling framework: Brownian agents

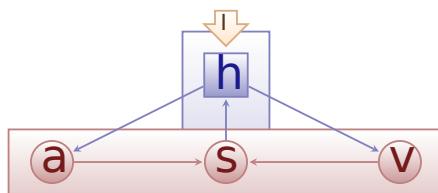
- emotional state of agent  $i$ :  $E_i(t) = \{v_i(t), a_i(t)\}$
- without external/internal excitation:  $v_i(t) \rightarrow 0, a_i(t) \rightarrow 0$ 
  - relaxation into a 'silent' mode
- dynamics of the Brownian agent:

$$\begin{aligned}\dot{v}_i &= -\gamma_{vi} v_i(t) + \mathcal{F}_v + A_{vi} \xi_v(t) \\ \dot{a}_i &= -\gamma_{ai} a_i(t) + \mathcal{F}_a + A_{ai} \xi_a(t)\end{aligned}$$

- $\gamma_{vi}, \gamma_{ai}$ : decay on valence and arousal
- $\mathcal{F}_v, \mathcal{F}_a$ : reflect specific influences

† Frank Schweitzer: *Brownian Agents and Active Particles. On the Emergence of Complex Behavior in the Natural and Social Sciences*, Berlin: Springer (2003)

## Modeling framework: Schema



- agents described by *arousal*  $a$ , *valence*  $v$ , *expression*  $s$
  - arousal causes expression wrt on valence
  - emotional information stored in field  $h$
- $$\dot{h}_{\pm} = -\gamma_{h\pm} h_{\pm}(t) + s n_{\pm}(t) + I_{\pm}(t)$$
- valence and arousal are affected by the field

† F.S., D. Garcia: D. *An agent-based model of collective emotions in online communities*, European Physical Journal B, vol. 77, no. 4 (2010) pp. 533-545, <http://arxiv.org/abs/1006.5305>

## Valence and Arousal

- **valence**: nonlinear influence of information

$$\mathcal{F}_v[h_{\pm}(t), v_i(t)] = h_{\pm}(t) \sum_{k=0}^n b_k v^k(t)$$

- **arousal**: subthreshold dynamics: nonlinear response

$$\mathcal{F}_a \propto (h_+(t) + h_-(t)) \sum_{k=0}^n d_k a^k(t)$$

- $a_i(t) > T_i$ : agent takes action

- expresses emotions in blogs, fora, reviews, ...

$$s_i(t + \Delta t) = f[v_i(t)] \Theta[a_i(t) - T_i]$$

- after expressing emotion, arousal is set back to zero

$$\dot{a}_i = \dot{a}_i(t) \Theta[T_i - a_i(t)] - a_i(t) \Theta[a_i(t) - T_i]$$

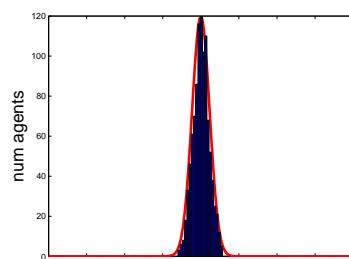
## Valence dynamics

- Cubic dependence on the valence

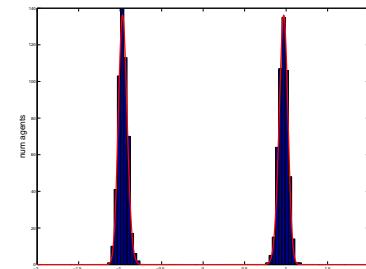
$$\dot{v} = -\gamma_v v(t) + h_{\pm}(t) \{b_0 + b_1 v(t) + b_2 v^2(t) + b_3 v^3(t)\}$$

- allow for 'silent' mode:  $v(t) \rightarrow 0$ :  $b_0 = 0$
- positive and negative valences 'equal':  $b_2 = 0$
- **collective emotions** emerge if  $b_1 \cdot h_{\pm} > \gamma_v$   
 $\Rightarrow$  regime with high emotional information (!)

## Valence distribution



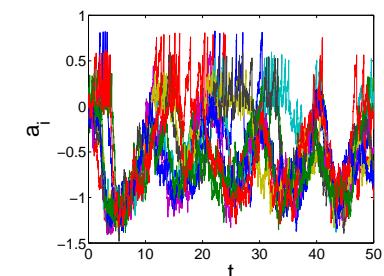
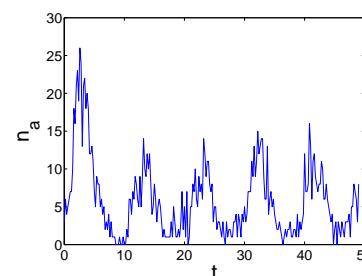
$p_s(v)$  under low  $h$



$p_s(v)$  under high  $h$

- polarization of emotions emerges under high information exchange
- agreement of analytical results with simulations

## Collective arousal $\mathcal{T}_i \sim U(\mathcal{T}_{min}, \mathcal{T}_{max})$

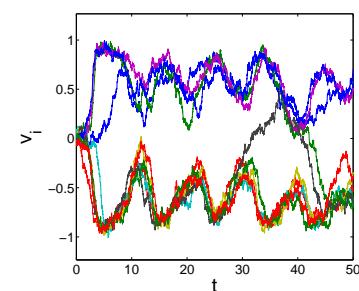
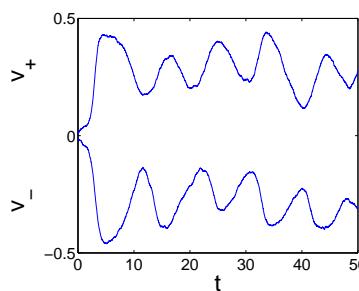


- amount of agents expressing emotions fluctuates
- appearance and fading of collective emotions can be observed

## Arousal dynamics

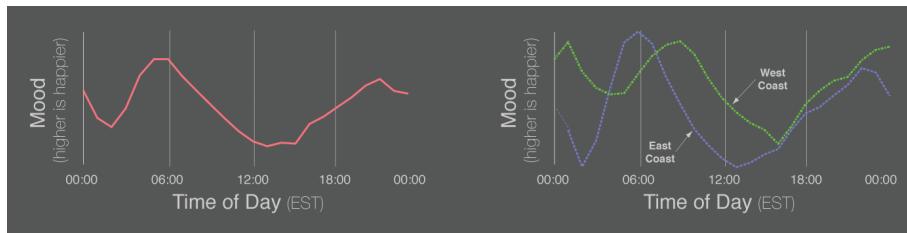
- quadratic dependence on the arousal  
 $\dot{a} = -\gamma_a a(t) + h(t) \{ d_0 + d_1 a(t) + d_2 a^2(t) \}$
- response to total information  $h(t) = h_+(t) + h_-(t)$
- initial bias to positive arousal  $d_0 > 0$
- if  $d_2 \neq 0$ , two possible solutions
- two cases:
  - 1  $d_2 < 0$  lower solution unstable, higher stable  $\Rightarrow$  one CE
  - 2  $d_2 > 0$  lower solution stable, higher unstable  $\Rightarrow$  fluctuating CEs

## Collective emotions oscillate



- valence polarizes with activity fluctuations
- agent trajectories show change in emotions

## A big difference: Expression patterns



- U.S. daily mood changes inferred from Twitter
- no self-organized collective emotion, but daily/weekly effects
- possible origin: tweeds '*good morning*', '*good night*' dominate pattern

<sup>†</sup><http://www.ccs.neu.edu/home/amislove/twittermood/>

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## Let's start an emotional discussion ...



### Zürich als Hauptstadt?

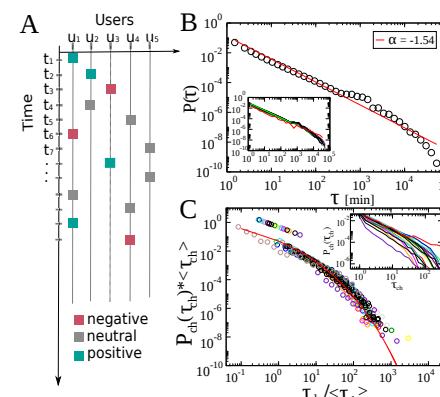
ZÜRICH. «Was zum Teufel ist Bern? Ich bin mir sicher, dass man das Bundeshaus auch in Zürich aufstellen könnte. Yes, we can!» Mit solchen Parolen fordern bereits über 5000 Facebook-Mitglieder die Verlegung der Schweizer Hauptstadt nach Zürich. Mehrere Gruppen haben

zum Ziel, über 100 000 Einträge für eine Petition zu sammeln. Schliesslich sei Zürich als Verkehrsknotenpunkt und internationaler Finanzplatz die einzige «Global City» der Schweiz. Zudem sei die Limmatstadt zum siebten Mal in Folge als Stadt mit der weltweit höchsten Lebensqualität

ausgezeichnet worden. Die Berner wehren sich mit Händen und Füßen gegen die Bewegung: 1500 Mitglieder zählt die Gruppe «Anti-Petition, Bern bleibt Bundeshauptstadt». Berns Stadtpolitiker Alexander Tschäppat bleibt gelassen: «Schön, dass uns die Zürcher derart beneiden.»

<sup>†</sup>January 2009: Emotional discussion of more than 5.000 facebook users to make Zurich the Swiss capital, instead of the much smaller Berne ('What the hell is Berne?'). This raised an anti-campaign of another 1.500 facebook users to keep Berne as the capital.

## User temporal activity in IRC channels



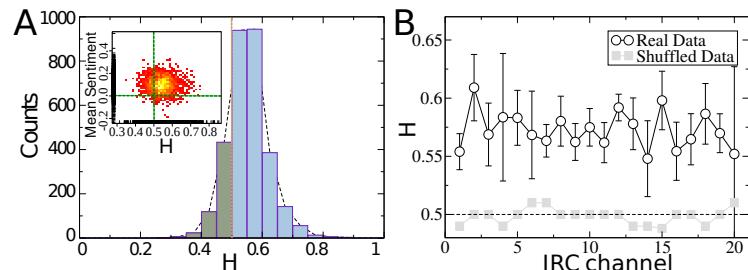
- B) Power-law distribution of user delay: **individual time dynamics are indepent of conversation**
- C) Distribution of inter-event time in each channel: **channels have a natural time delay**

Dialog systems can sample believable individual behavior from **B** and keep conversations natural if delays follow **C**

<sup>†</sup>A. Garas, D. Garcia, FS, M. Skowron, EPJ DataScience (2011 subm.)

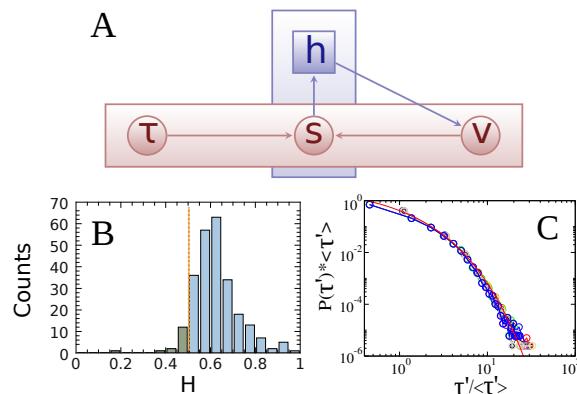
## Emotional persistence of user behavior

- A) Most individual users are persistent wrt emotions
  - Hurst exponent  $H$  measures deviation from random behavior ( $H = 0.5$ )
- B) Conversations are persistent (social norms)



†A. Garas, D. Garcia, FS, M. Skowron, EPJ DataScience (2011 subm.)

## An agent-based model for chatroom users



$$N = 10^4, V_- = -0.15, V_+ = 0.05, \gamma_v = 0.2, A_v = 0.2, b = 0.01, c = 0.05, \gamma_h = 0.9$$

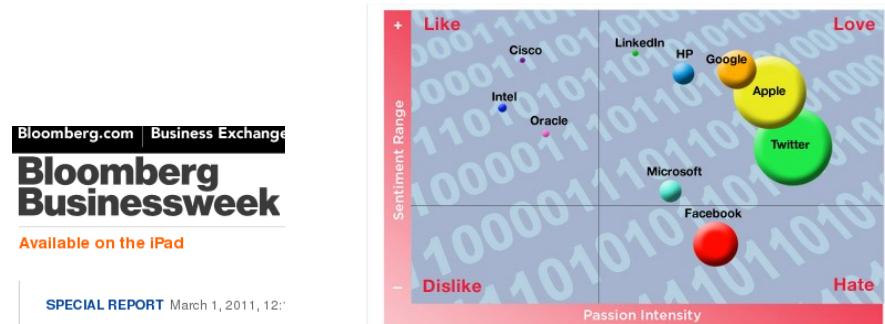
Distribution of  $H$  (B) and rescaled distribution of inter-message time (C) similar to real data.

†A. Garas, D. Garcia, FS, M. Skowron, EPJ DataScience (2011 subm.)

## How do customers really feel?

### Most Loved -- And Hated -- Tech Companies

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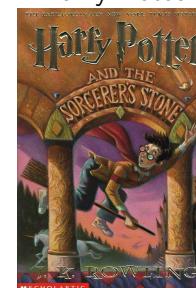
### Sentiment Analysis Gives Companies Insight Into Consumer Opinion

Kia, Best Buy, and Viacom are using new tools to mine comments on the Web to see what consumers really think of their brands

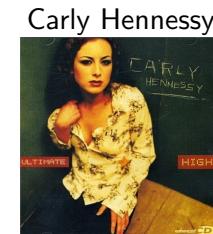
## How do consumers really decide?

- often wrong predictions in market research
- social effects (herding, emotions) commonly neglected

Harry Potter

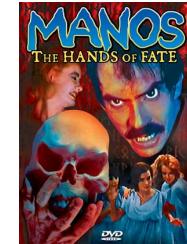


Rejected by 12 publishers.  
More than 400 million sales.



2.2 Million dollars invested.  
Sold 378 copies in the first three months.

Manos: the hands of fate (1966)



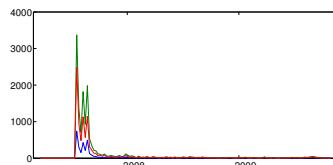
Worst movie ever (IMDB.com). DVD sales boost, sequel in production.

Distribution of  $H$  (B) and rescaled distribution of inter-message time (C) similar to real data.

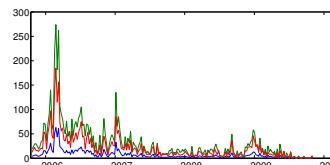
†A. Garas, D. Garcia, FS, M. Skowron, EPJ DataScience (2011 subm.)

## Hot selling vs slow moving products: Emotions

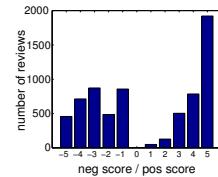
Weekly statistics (ratings: blue, positive: green, negative: red)



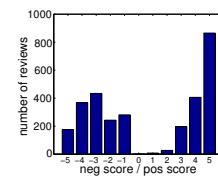
(left) "Harry Potter and the Deathly Hallows", (right) "Twilight: New Moon"



### Distribution of emotional scores

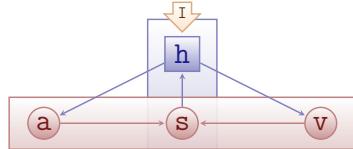


(left) "Harry Potter and the Deathly Hallows", (right) "Marley and Me"

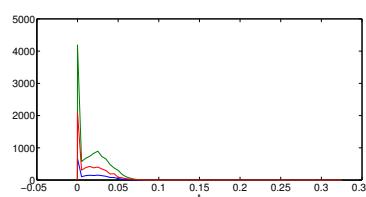
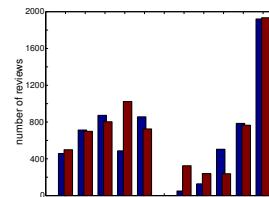


†D. Garcia, FS, IEEE SocialCom (2011), pp. pp. 483-488

## An agent-based model for emotions in reviews



(right) Distribution of emotional scores "Harry Potter" (blue), simulations (red)



Weekly statistics (left) hot selling, (right) slow moving product

†D. Garcia, FS, IEEE SocialCom (2011), pp. pp. 483-488

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## Project: Productivity in OSS

**SNF project:** *Impact of social interactions on software evolution*

### ■ impact on emergence of collaboration

- Why do people contribute to OSS at all?
- emotions solve cooperation paradox  $\Rightarrow$  explain responsibility

### ■ impact on project success/failure

- role of emotional feedback of users and empathy of developers
- emotions as building blocks of self-organized, non-profit community



## Example: OSS Forum fights

Open Source Software fora show bursts of negative conversations between users and developers:

The screenshot shows a Pidgin Trac ticket page for ticket #4986. The ticket details an enhancement request where automatic chat input field resizing is optional. The ticket was opened 3 years ago and last modified 15 months ago. A comment from G-sus discusses the difficulty of unsubscribing from the ticket list. Another comment from Apewall expresses frustration over a feature that has been in use for years. The ticket has received several replies, with the latest one from TacBoy.

## EU Project on Cyber Emotions (CE) <http://www.cyberemotions.eu/>

To understand the role of *collective emotions* in creating, forming and breaking-up *ICT mediated communities* as a spontaneous emergent behaviour occurring in complex techno-social networks

- Funded by 7th Framework Programme (start 02/2009)
- Collaboration of 8 European universities for 4 years



JSI Ljubljana



TU Berlin

## CE Project: Monitoring, Mitigating

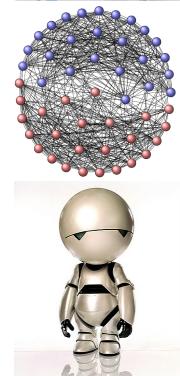
### ■ virtual humans

- emotional interaction beyond textual expression
- users realize “impact” of their text



### ■ visualization of collective emotions

- monitoring/ prediction of emotional status of communities
- when (and where) are issues heating up?



### ■ emotional chatbots

- mitigate emotional problems, online conflicts, encourage cooperation, interaction ⇒ *Artificial emotional intelligence*



### ■ The ultimate Touring Test

## Conclusions

### ■ emotions

- differ from opinions(!), quantified by *valence*, *arousal*
- collective emotions important in decision processes; overcome dilemma

### ■ empirics on emotions/cyber emotions

- sentiment mining in text, plus *physiological responses*
- vast datasets to analyse: Myspace, IRC, Amazon reviews, Twitter ...

### ■ agent based model of collective emotions

- considers psychological variables (*arousal*, *valence*)
- provides *testable hypotheses* on agent's response
- predicts distribution of valence ⇒ data comparison
- framework applicable to IRC chats, product reviews, ...

### ■ applications

- understand viral marketing based on emotions
- impact on productivity: OSS
- developing bots to enhance user interaction

## EPJ Data Science starts Jan 2012 ... stay tuned

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**Aims & scope**  
The 21st century is currently witnessing the establishment of data-driven science as a complementary approach to the traditional hypothesis-driven method. This (r)evolution accompanying the paradigm shift from reductionism to complex systems sciences has already largely transformed the natural sciences and is about to bring the same changes to the techno-socio-economic sciences, viewed broadly.

**EPJ Data Science** offers a publication platform to address this scientific horizon.

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