Modeling collective emotions

A stochastic approach based on Brownian agents

Frank Schweitzer

fschweitzer@ethz.ch

in collaboration with:

David Garcia, Antonios Garas

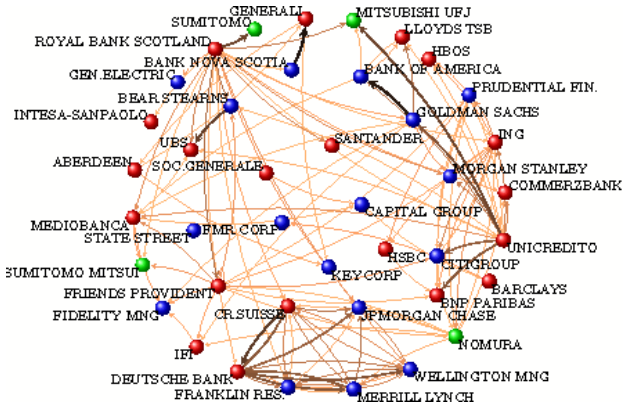
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

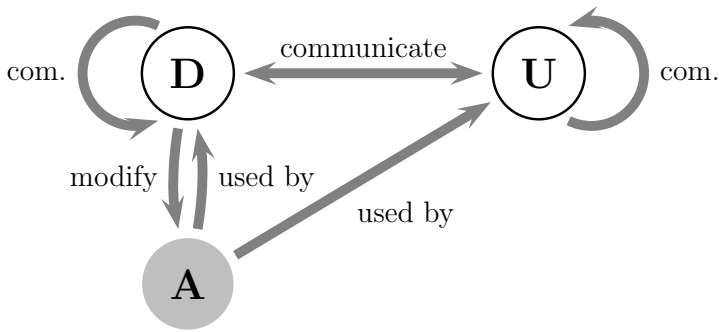
Chair of Systems Design
http://www.sg.ethz.ch/

Outline

Chair of Systems Design at ETH Zurich

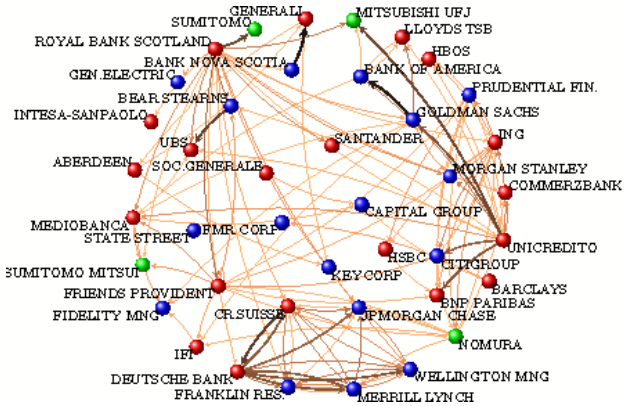
- **Main Research Areas**
  - **Economic Networks & Social Organizations**
    - ★ e.g. ownership networks, R&D networks, financial networks, ...
    - ★ e.g. online communities, OSS projects, animal societies, ...

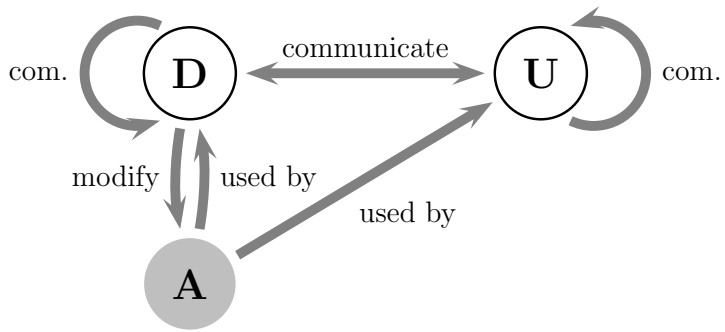




Chair of Systems Design at ETH Zurich

- **Main Research Areas**
  - **Economic Networks & Social Organizations**
    - ★ e.g. ownership networks, R&D networks, financial networks, ...
    - ★ e.g. online communities, OSS projects, animal societies, ...

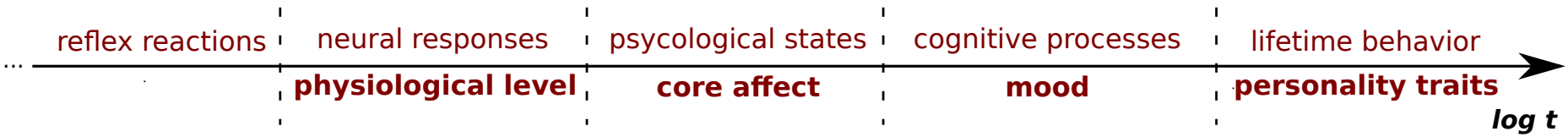




- **Methodological Approach: Data Driven Modeling**
  - **economic databases**: ORBIS, Bloomberg, patent databases
  - **online data**: user interaction, communication records, blogs

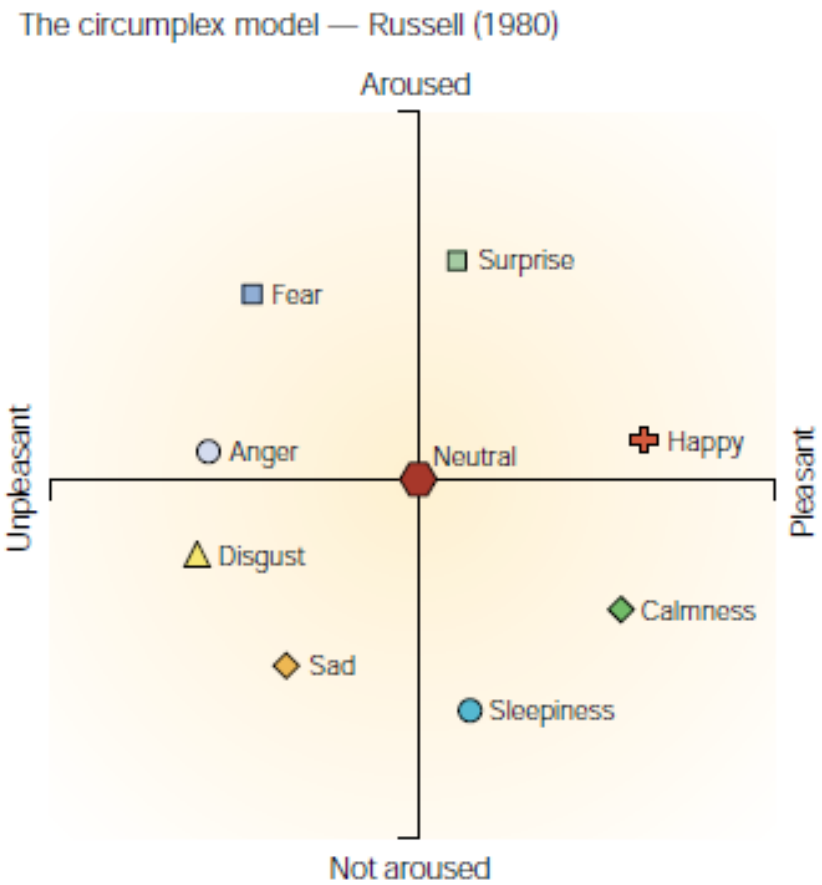
Outline

What are emotions?



- **Definition**: *Psychological states of high relevance for the individual that imply cognitive and physiological effects*
  - short-lived psychological states that consume individual's energy and strongly bias behavior (for example expression)
- **Different levels of description:**
  - *Physiological level:* brain parts active during emotion (e.g amigdala)
  - *Core affect:* basic psychological components of emotions
  - *Mood:* long-term psychological states related to cognitive antecedents
  - *Personality traits:* lifelong factors of personality sustained by emotions

Representation of emotions



(Credit: Calder et al. 2001)

Russell's dimensional model

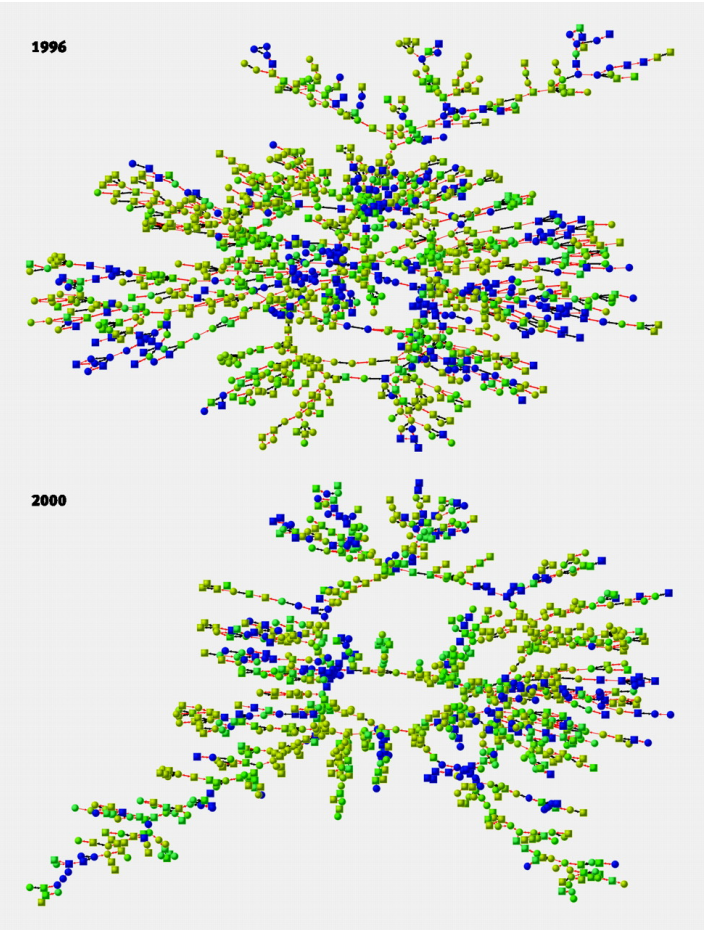
Valence

Pleasure associated with the emotion.

Arousal

Degree of activity induced by the emotion.

A big difference: Happiness network



[a]

- 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

[a] Fowler, Christakis, 2008

Outline

EU Project on Cyber Emotions (**CE**)

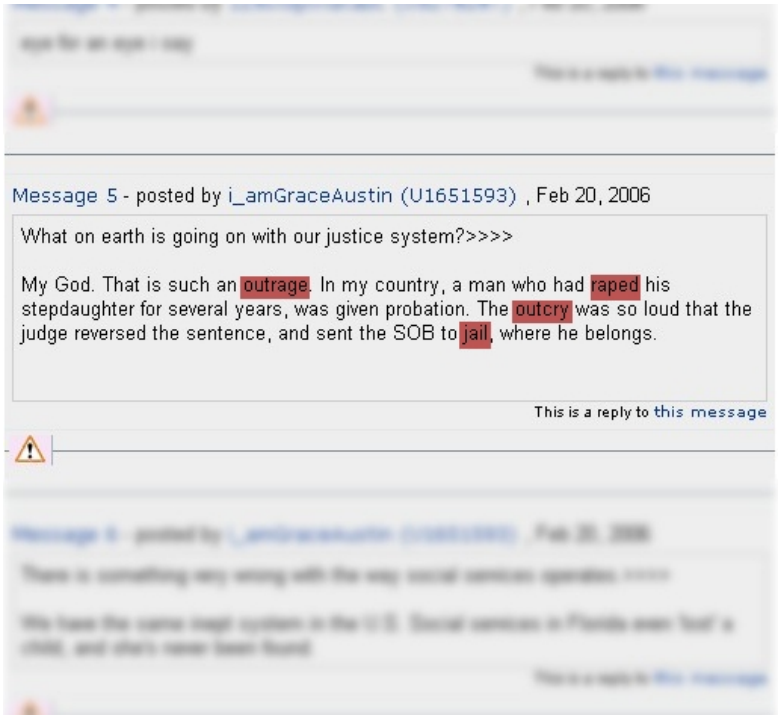
http://www.cyberemotions.eu/

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

Jacobs Bremen
UW UK
WUT Warsaw
ETH Zurich
JSI Ljubljana
EPFL Lausanne
OFAI Vienna
TUB Berlin

Emotional Posts in Fora

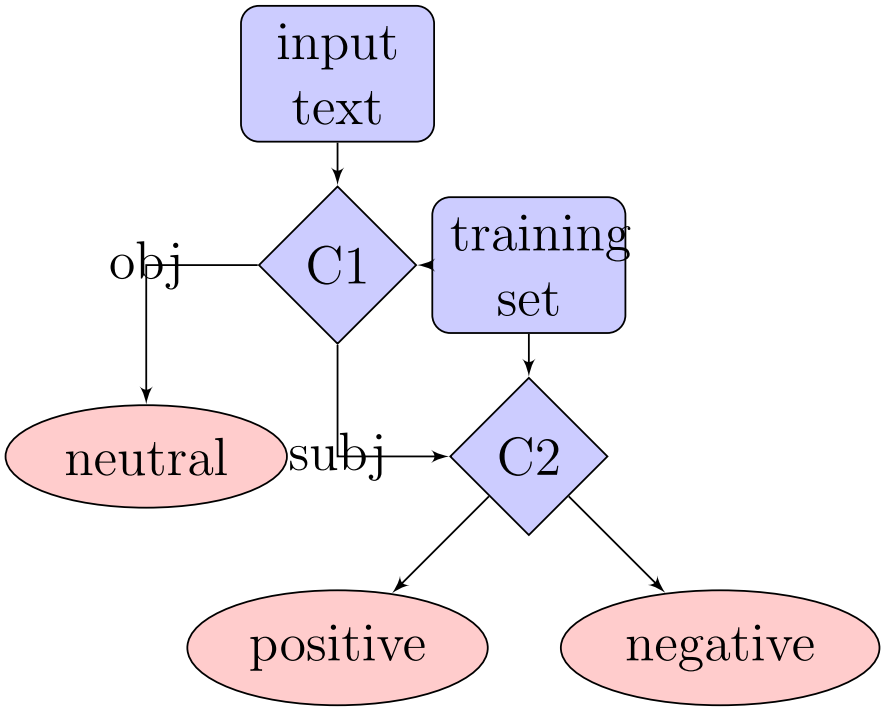


Example of a negative (left) and a positive (right) post

- 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 ⇒ valence, arousal, dominance
  - improvement: stemming of words ⇒ 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
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

$$v_{\text{text}} = \frac{\sum_k v_k f_k}{\sum_k f_k}$$

$v_{\text{Billie Jean}} = 7.1$

$v_{\text{Thriller}} = 6.3$

$v_{\text{Michael Jackson}} = 6.4$

*

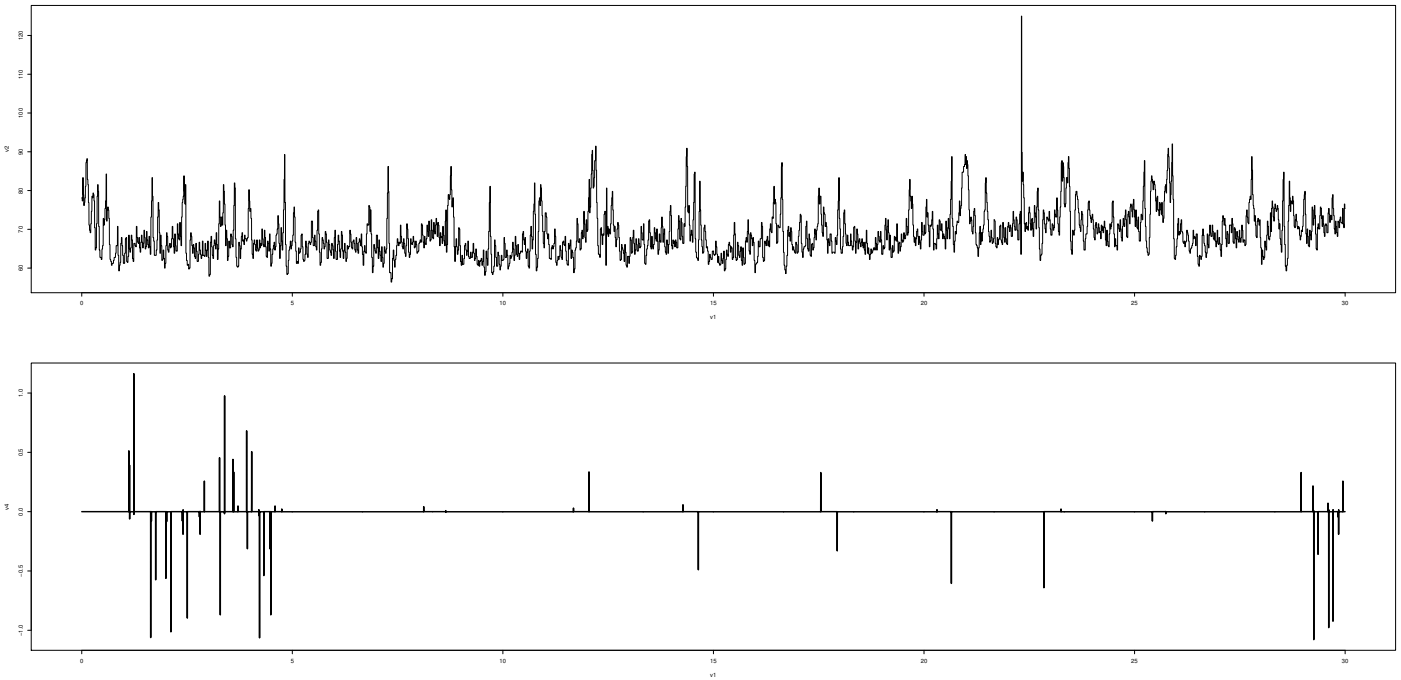
*P. S. Dodds, C. M. Danforth, 2010

Measuring physiological response

- physiological response to classified pictures† and fora
  - monitoring heart rate, skin conductance, frowning and smiling
  - already known to correlate with valence and arousal

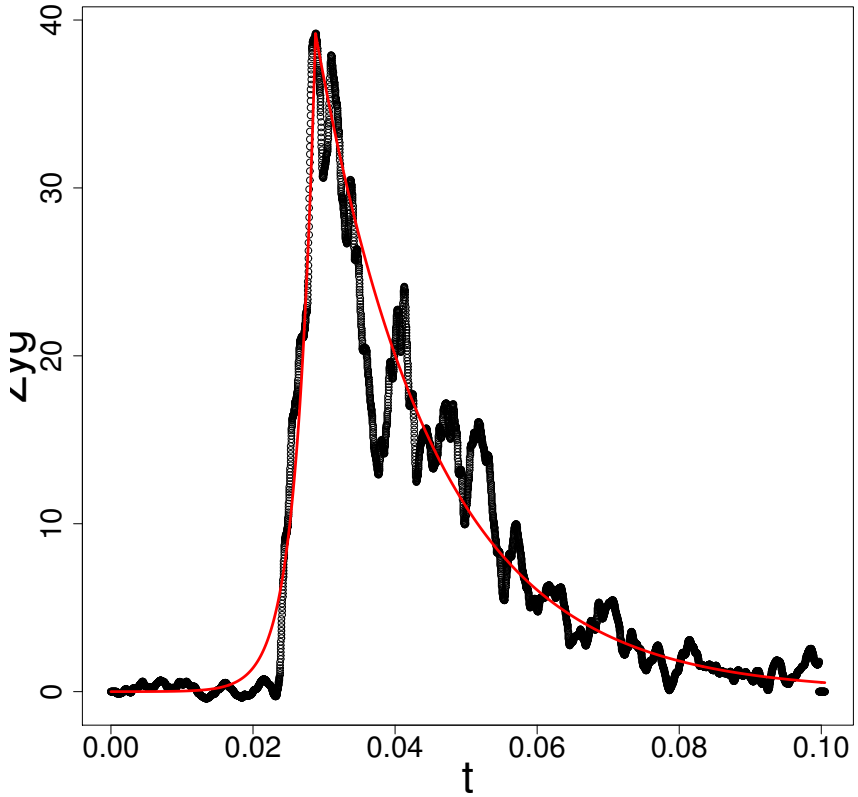
†IAPS - International affective picture system

Heart rate and skin conductance



- 1270 variables in SSPS data
- Baseline extraction, rescaling $\Rightarrow$ 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 Θ
- 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.

Outline

Exogeneously triggered CE

- *example:* Michael Jackson's death
  - shared sadness about the event
    $\Rightarrow$ synchronization of mio of independent emotional expressions
  - vast increase of user activity $\Rightarrow$ breakdown of news sites, twitter

Endogeneously triggered CE

- *example:* The Boxxy phenomenon‡
  - video created strong emotional polarization among mio. of netizens
  - community formation built on collective emotion
  - spread into other online-communities ⇒ Boxxy became a meme

‡Most subscribed channel in YouTube, Jan 2009

Outline

Modeling framework: Brownian agents

- Agent i state variables $u_i^k(t)$
- Dynamics based on *principle of causality:*

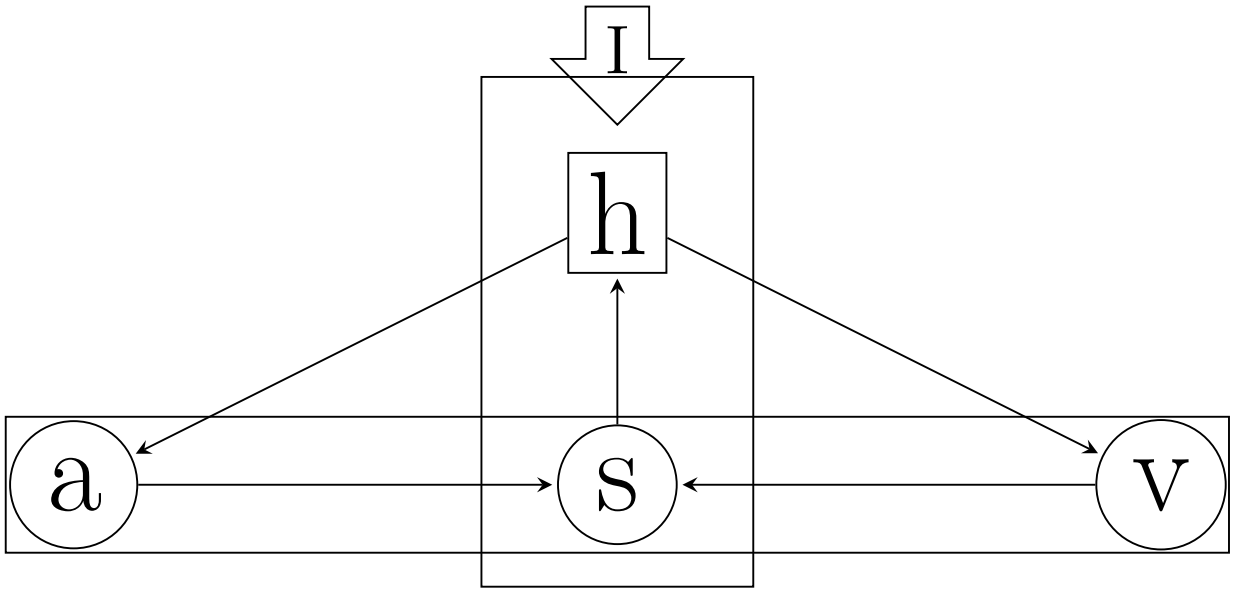
Effect	$\Longleftarrow$	**Causes**
changes of u_i		deterministic + stochastic influences
$\frac{du_i}{dt}$	$=$	$f_i(\underline{u}, \underline{\sigma}, t) + A_i\, \xi_i(t)$

- $f_i(\underline{u}, \underline{\sigma}, t)$: considers
  - nonlinear interaction with other agents $j \in N$
  - external conditions (information, resources)
  - eigendynamics (relaxation, internal dynamics)
- A_i: "other" (fast, heterogeneous) 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*
- 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 (October 2010), `http://arxiv.org/abs/1006.5305`

Emotional information

- emotional information is stored in a *communication field*

$$\dot{h}_{\pm} = -\gamma_{h\pm} h_{\pm}(t) + sn_{\pm}(t) + I_{\pm}(t)$$

  - field components for positive and negative emotional information
  - information does not last forever $\rightarrow$ decay of importance $\gamma_{h\pm}$
  - user impact on the field and external information
- other agents have access to these media
  - different forms of access possible (e.g. broadcast)
  - mean-field approximation of bidirectional communication

Emotional states

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

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

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

Valence

- emotional information affects valence of others through $\mathcal{F}_v$
  - agents respond to positive and negative information at the same time

  or
  - agents with positive emotions ($v_i(t) > 0$) respond to positive information, and vice versa.
- nonlinear influence of information, dependent on valence

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

Arousal

- nonlinear feedback between emotional information and arousal
  - all emotional information affects arousal of others
- subthreshold dynamics: nonlinear response

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

- after expressing emotion, arousal is set back to zero

$$\dot{a}_i = \dot{\bar{a}}_i(t)\,\Theta[\mathfrak{T}_i - a_i(t)] - a_i(t)\,\Theta[a_i(t) - \mathfrak{T}_i]$$

Emotional expression

- $a_i(t) > \mathcal{T}_i$: agent takes action
  - expresses emotions in blogs, fora, reviews, ...

$$s_i(t + \Delta t) = f[v_i(t)]\,\Theta[a_i(t) - \mathfrak{T}_i]$$

- different assumptions: $f[v_i] = v_i$, or $f[v_i] = s \cdot \mathrm{sign}(v_i) \Rightarrow$ *importance*, distribution: $P(\Delta t) \propto \Delta t^{-\alpha}$
  the more important the emotion, the shorter the waiting time

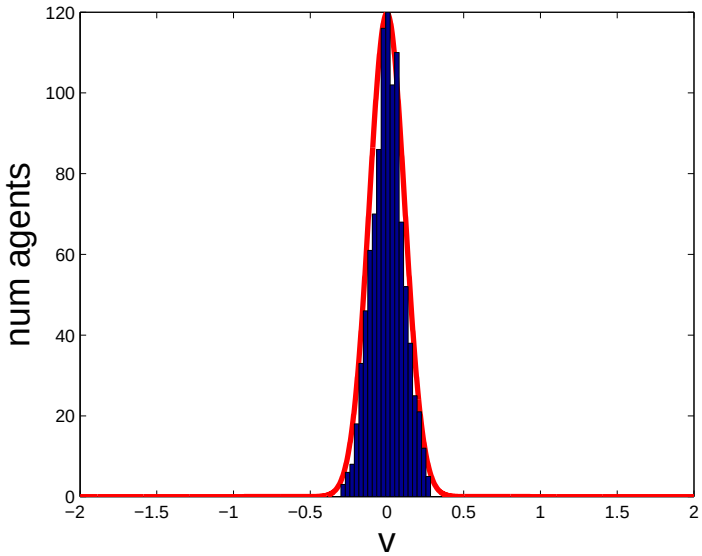
Valence dynamics

- Cubic dependence on the valence

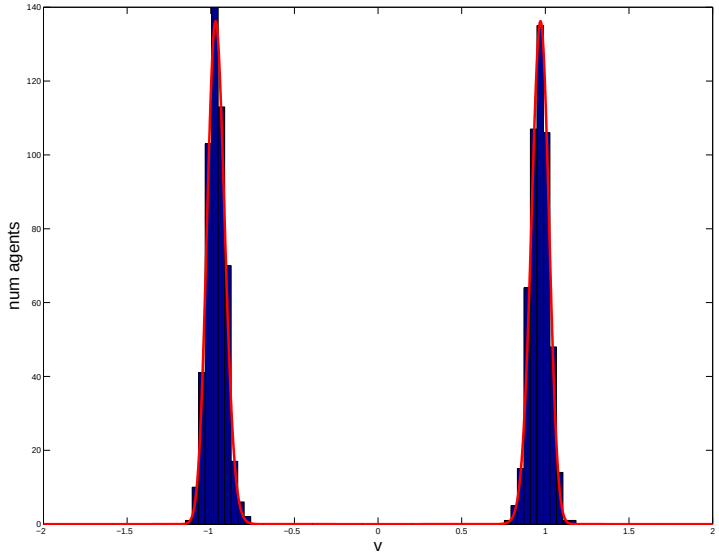
$$\dot{v} = -\gamma_v v(t) + h_{\pm}(t)\left\{b_0 + b_1 v(t) + b_2 v^2(t) + b_3 v^3(t)\right\}$$

  - allow for 'silent' mode: $v(t) \to 0$: $b_0 = 0$
  - 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

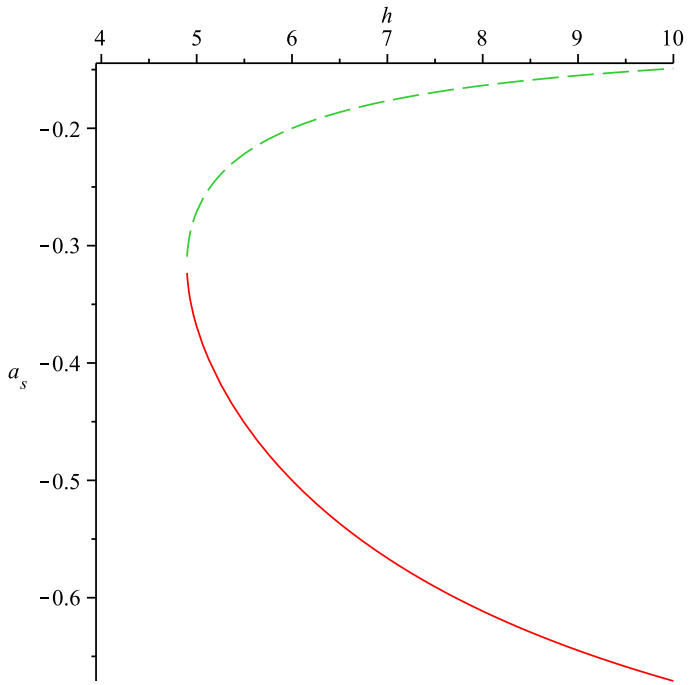
Arousal dynamics

- quadratic dependence on the arousal

$$\dot{a} = -\gamma_a a(t) + h(t)\left\{d_0 + d_1 a(t) + d_2 a^2(t)\right\}$$

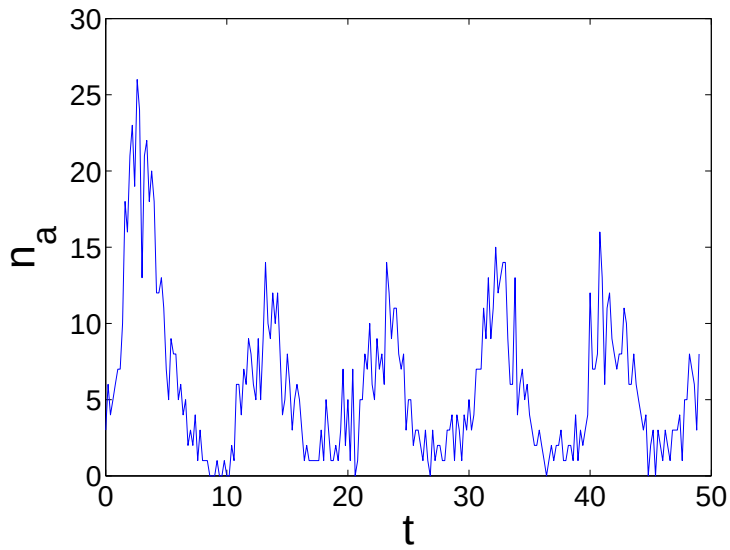
- response to total information $h(t) = h_+(t) + h_-(t)$
- initial bias to positive arousal $d_0 > 0$
- if $d_2 \neq 0$, two possible solutions
- two cases:
  1. $d_2 < 0$ lower solution unstable, higher stable $\Rightarrow$ one CE
  2. $d_2 > 0$ lower solution stable, higher unstable $\Rightarrow$ fluctuating CEs

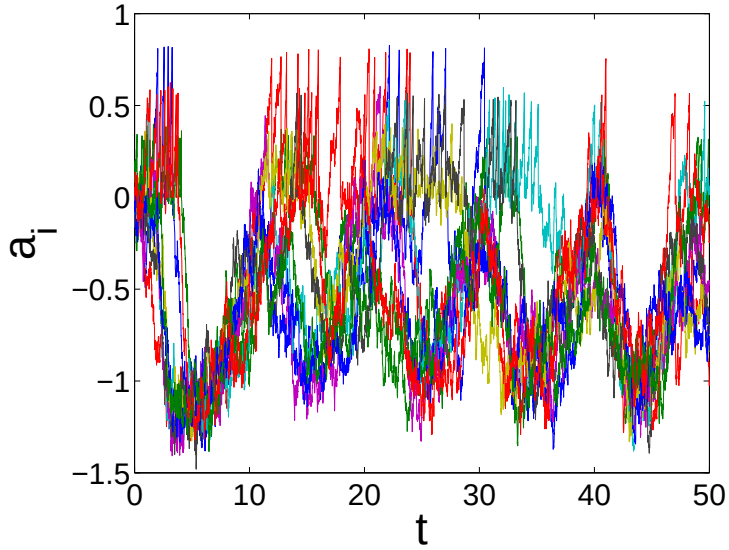
Arousal bifurcation



- below certain value of the field, the system is highly nonstationary
  - positive arousals increase the field
- when the field is high, agents can stabilize in negative arousals
  - field starts to decay

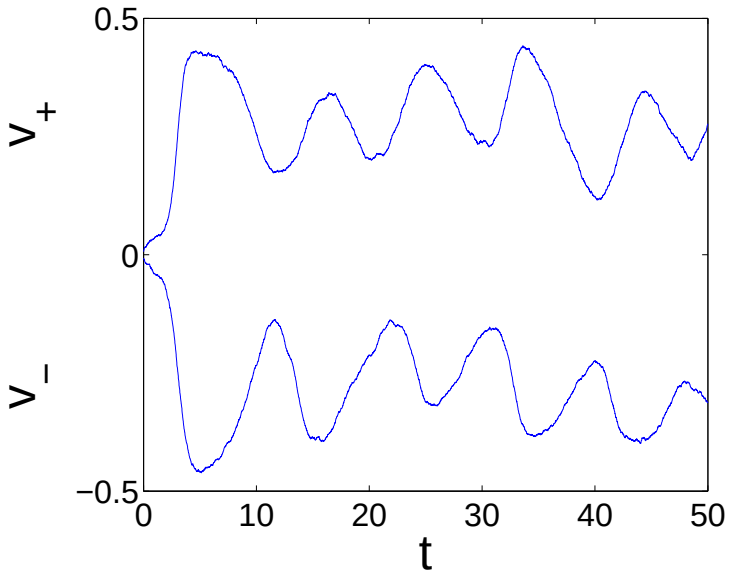
Collective emotion oscillations, $\mathcal{T}_i \sim U(\mathcal{T}_{min}, \mathcal{T}_{max})$

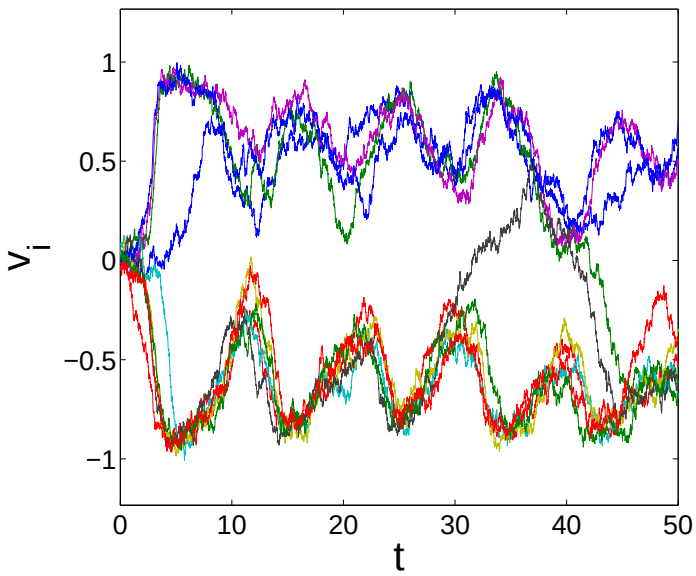




- amount of agents expressing emotions fuctuates
- appearance and fading of collective emotions can be observed

Collective emotion oscillations





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

Outline

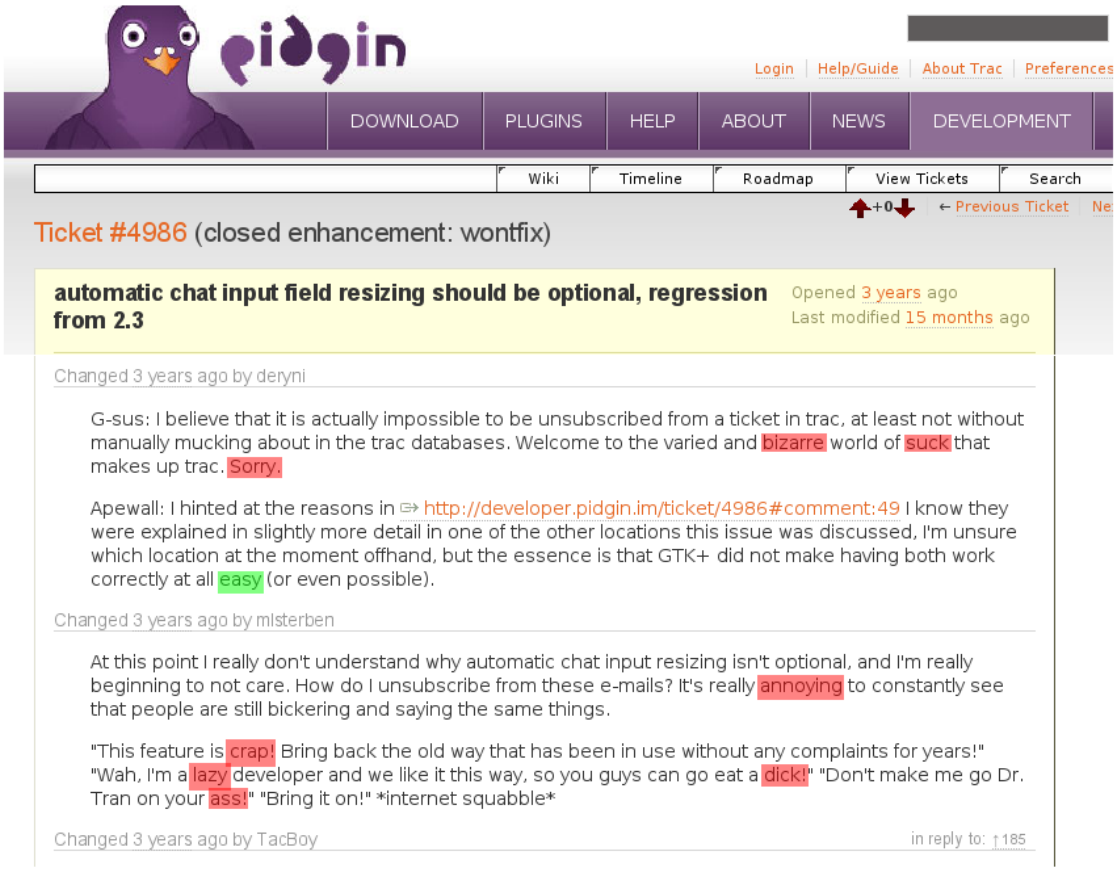
Example: Productivity in OSS

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 ⇒ 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

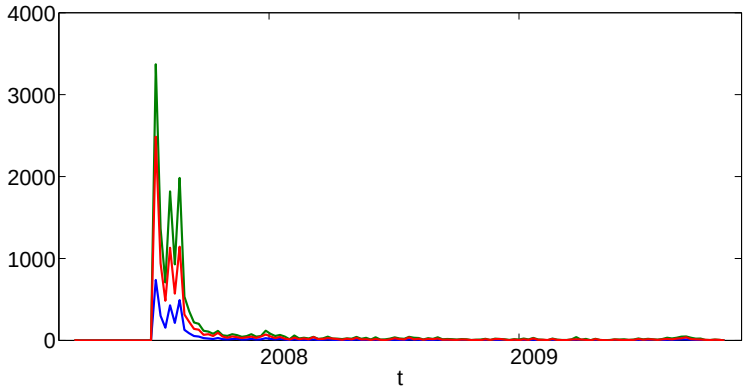
Open Source Software fora show bursts of negative conversations between users and developers:

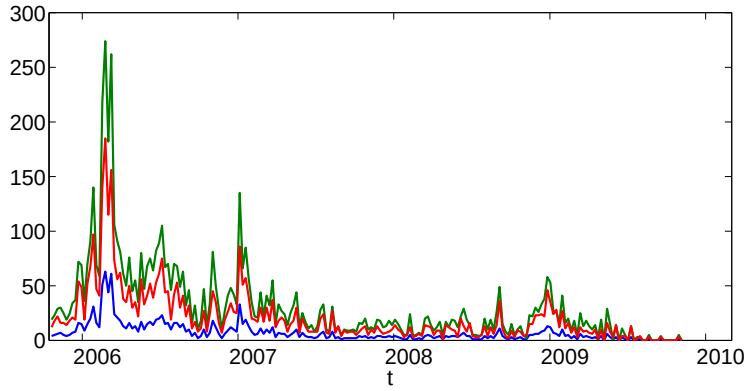


- OSS project hampered by CE
- Effect: fork of `Pidgin` into `FunPidgin`

Example: Impact on product reviews

Amazon, Dooyoo - Burst patterns





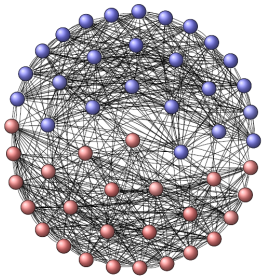
Reviews per week for "Harry Potter and the Deathly Hallows" (left) and "Marley and Me" (right). Amount of ratings (blue), total positive score (green) and total negative score (red) of emotions.

- different scenarios: *marketing campaign vs word of mouth*
- combined effect of *product experience* and *herding effects*
- feedback between mechanism design (recommender systems, incentive schemes) and collective emotions

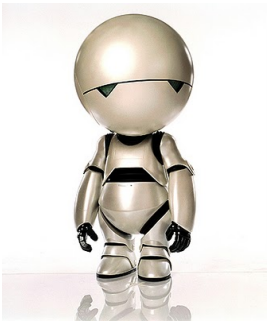
CE Project: Benefits for online communities

- **virtual humans**
  - emotional interaction beyond textual expression

- **visualization of collective emotions**
  - monitoring and prediction of emotional state of community



- **emotional chatbots**
  - mitigate emotional problems, online conflicts, encourage cooperation, interaction $\Rightarrow$ *Artificial emotional intelligence*



Further benefits for online communities

- **Fora / discussion groups**
  - mediation ⇒ mitigate risks, improve user experience
- **Social networks**
  - monitoring interface to real societal emotions
  - key point for success in social networks (twitter vs myspace)
- **Chatrooms**
  - real-time chat assistance with emotional support and/or activity encouragement

Conclusions

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

Conclusions

- **emotions**
  - differ from opinions(!), quantified by *valence*, *arousal*
  - collective emotions important in decision processes
- **empirics on emotions/cyber emotions**
  - sentiment mining in text, physiological responses
  - CE: exogeneously/endogeneously triggered, long-tail of human i.

Conclusions

- **emotions**
  - differ from opinions(!), quantified by *valence*, *arousal*
  - collective emotions important in decision processes
- **empirics on emotions/cyber emotions**
  - sentiment mining in text, physiological responses
  - CE: exogeneously/endogeneously triggered, long-tail of human i.
- **agent based model of collective emotions**
  - considers psychological variables (arousal, valence)
  - provides *testable hypotheses* on agent's response
  - predicts distribution of valence $\Rightarrow$ data comparison

Conclusions

- **emotions**
  - differ from opinions(!), quantified by *valence*, *arousal*
  - collective emotions important in decision processes
- **empirics on emotions/cyber emotions**
  - sentiment mining in text, physiological responses
  - CE: exogeneously/endogeneously triggered, long-tail of human i.
- **agent based model of collective emotions**
  - considers psychological variables (arousal, valence)
  - provides *testable hypotheses* on agent's response
  - predicts distribution of valence $\Rightarrow$ data comparison
- **applications**
  - mitigating risks of CE, fostering benefits of CE
  - developing bots to enhance user interaction