Social Networks and Belief Merge Communication Protocols

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Beijing, October 18 2013

Outline

1) Seligman, Girard & Liu (2011, 2013)

- social network
- peer pressure effects, influence inbetween "friends"

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- plausibility
- effects of group members sharing information with the rest of the group

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2) Baltag & Smets (2009)

- plausibility
- effects of group members sharing information with the rest of the group

3) Aim: a unified social network plausibility framework

- model social influence on beliefs through communication among agents in a social network
- define some particular communication protocols (in the new framework) inspired by 2) to represent some level of influence as defined in 1)

1) Social influence à la Girard, Liu & Seligman

The framework

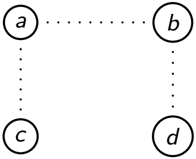
Static hybrid logic to represent who is friend with whom and who believes what
+ an (external) influence operator

The main ideas

- Agents are influenced by their friends and only by their friends.
- Simple "peer pressure principle": I tend to align with my friends.
- "Being influenced" is defined as "aligning my beliefs to the ones of my friends".
- No communication is (at least explicitly) involved. (transparency?)

Friends network

Social network frame:



- a is friend with agents b and c
- b is d's only friend
- a is c's only friend.

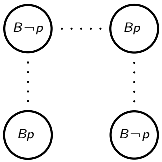
Belief revision induced by (direct) social influence

3 possible states

- Bp
- $B\neg p$
- $Up := \neg Bp$ and $\neg B\neg p$

Strong influence

When all of my friends believe that p, I (successfully) *revise* with p. When all of my friends believe that $\neg p$, I (successfully) *revise* with $\neg p$.



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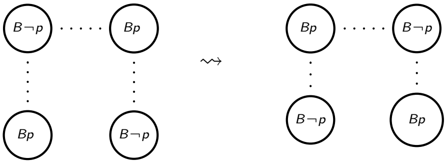

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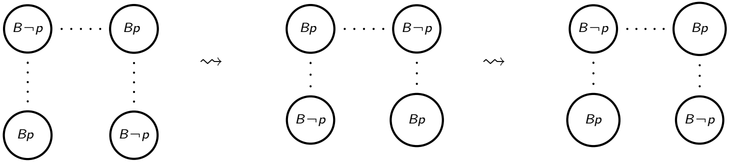
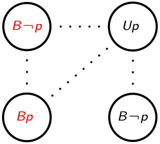


Belief contraction induced by social influence

Weak influence

None of my friends supports my belief in p and some believe that $\neg p$.
I (successfully) *contract* it.
(And similarly for $\neg p$)



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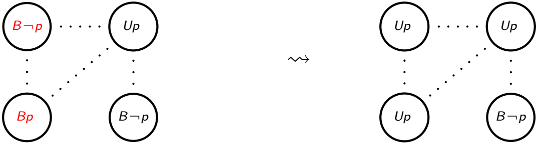
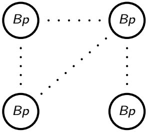


Stabilization

- Stable state: applying the social influence operator doesn't change the state of any agent.
- Stabilization: some configurations will reach a stable state after a finite number of applications of the influence operator (see example of weak influence above) and some won't (see example of strong influence).
- Sufficient condition for stability: all friends are in the same state.



2) Communication protocols à la Baltag & Smets

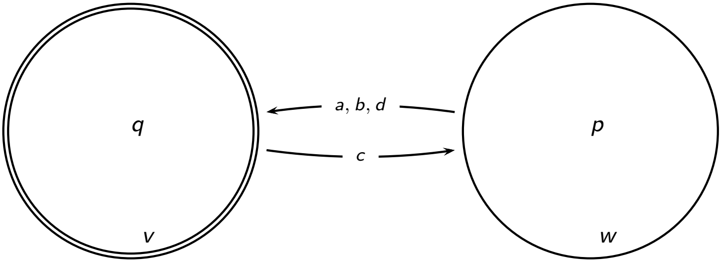
The framework

DEL type: plausibility modeling of (several) doxastic attitudes + communication events

The main ideas

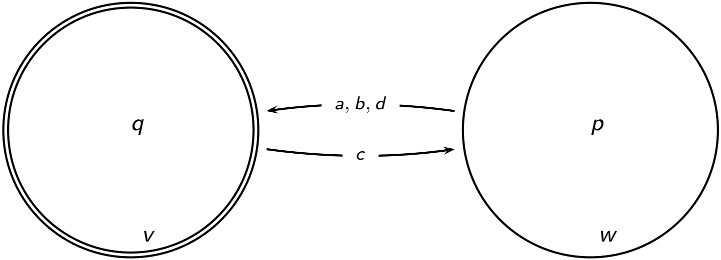
- Agents communicate via public announcements.
- Assuming that they trust each other enough, agents all revise their beliefs with each of the announced formula, sequentially.
- In this sense, each announcement influences everybody (else) into belief revision.

Plausibility model



Plausibility model

q 



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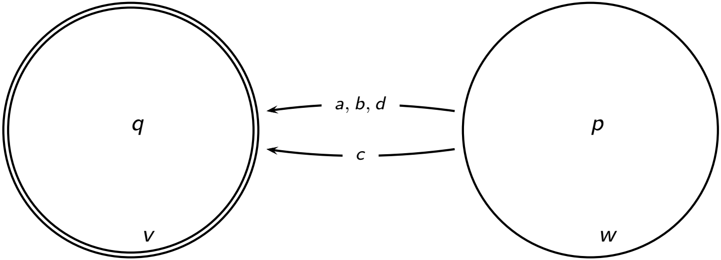

Reaching a stable state of agreement

How to communicate?

- Agents speak in turn (given expertise rank).
- An agent announces all and only (non-equivalent) sentences that she believes (honesty + exhaustivity).
- After a finite number of announcements (and corresponding revisions), everybody holds the same beliefs.
- This is a stable state: nothing which could be announced by any agent would change anything anymore.

Reaching a stable state of agreement

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Lexicographic belief merge protocol

$$\rho_a := \prod\{\Uparrow \phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}, w \models B_a\phi\}$$

$$\rho_b := \prod\{\Uparrow \phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}_{[\rho_a]}, w \models B_b\phi\}$$

$$\text{etc for all } c \in \mathcal{A}$$

where $\prod$ is a sequential composition operator and $\mathcal{M}_{[\rho_a]}$ is the new model after joint revision with each formula announced by a.

Big picture

Common features

- Agents are influenced into revising their beliefs to make them closer to the ones of (some) others.
- A global agreement state is stable (both under honest communication and under social conformity pressure).

From 1)

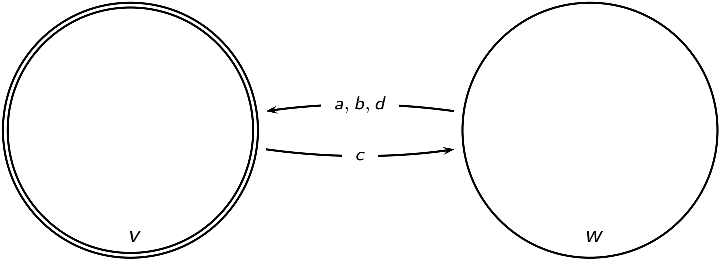
- **Social network**
- Synchronic
- **Over friends only**
- Equal power (among friends)
- Direct
- **Tools**: nominals, @, F

From 2)

- **Plausibility**
- Sequential
- Over everybody
- Ranking
- **Via communication**
- **Tools:** $B, \uparrow, \Uparrow$

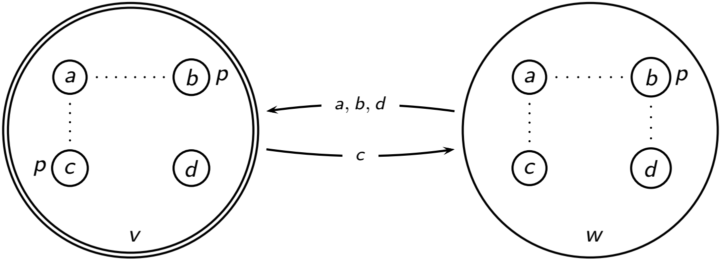
3) A social network plausibility framework

plausibility model:



3) A social network plausibility framework + 

Social network plausibility model:



Social network plausibility model

$$\mathcal{M} = (S, \mathcal{A}, \leq_{a \in \mathcal{A}}, \|\cdot\|, s_0, \asymp_{s \in S})$$

- S is a (finite) set of possible states.
- $\mathcal{A}$ is a (finite) set of agents.
- $\leq_a \subseteq S \times S$ is a locally connected preorder, interpreted as the subjective plausibility relation of agent a, for each $a \in \mathcal{A}$
- $s_0 \in S$ is a designated state, interpreted as the actual state
- $\asymp_s \subseteq A \times A$ is an irreflexive and symmetric relation, interpreted as friendship, for each state $s \in S$
- $\|\cdot\| : \Phi \cup N \to \mathcal{P}(S \times \mathcal{A})$ is a valuation, assigning:
  - a set $\|p\| \subseteq S \times \mathcal{A}$ to every element p of some given set Φ of "atomic propositions"
  - a set $\|n\| = S \times \{a\}$ for some $a \in \mathcal{A}$ to every element n of some given set N of "nominals".

Syntax

$$\phi := p \mid n \mid \neg\phi \mid \phi \wedge \phi \mid F\phi \mid @n\,\phi \mid B\phi$$

where p belongs to a set of atomic propositions Φ and n to a set of nominals N.

Inheritated indexicality

Formulas evaluated both at a state $w \in S$ and at an agent $a \in A$.

- p : "I have a moustache."
- BFp: "I believe that all my friends have a moustache."
- FBp: "All of my friends believe that they have a moustache".

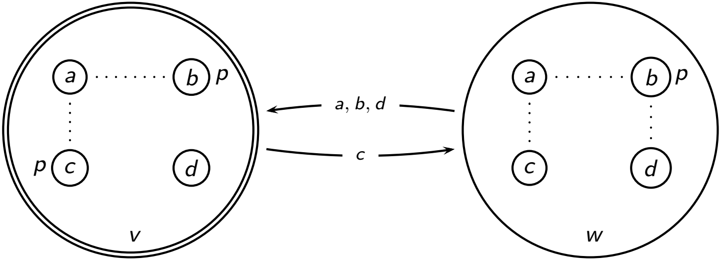
Semantic clauses

- $\mathcal{M}, w, a \vDash p$ iff $\langle w, a \rangle \in \|p\|$
- $\mathcal{M}, w, a \vDash n$ iff $\langle w, a \rangle \in \|n\|$ iff $a = \underline{n}$
- $\mathcal{M}, w, a \vDash \neg\phi$ iff $\mathcal{M}, w, a \nvDash \phi$
- $\mathcal{M}, w, a \vDash \phi \wedge \psi$ iff $\mathcal{M}, w, a \vDash \phi$ and $M, w, a \vDash \psi$
- $\mathcal{M}, w, a \vDash F\phi$ iff $\mathcal{M}, w, b \vDash \phi$ for all b such that $a \asymp b$
- $\mathcal{M}, w, a \vDash @b\,\phi$ iff $\mathcal{M}, w, \underline{b} \vDash \phi$
- $\mathcal{M}, w, a \vDash B\phi$ iff $\mathcal{M}, v, a \vDash \phi$ for all $v \in S$ such that $v \in best_a w(a)$

notation:

- $\underline{n}$ the unique agent at which the nominal n holds
- $s(a)$ the comparability class of state s relative to agent a: $t \in s(a)$ iff $s \leq_a t$ or $t \leq_a s$
- $best_a s(a)$ the most plausible states in $s(a)$ according to a: $best_a s(a) := \{s \in s(a) : t \leq_a s$ for all $t \in s(a)\}$

Example



- $M, v, \underline{c} \vDash p$
- $M, v, \underline{a} \vDash Fp$
- $M, v, \underline{a} \vDash \langle F \rangle b$
- $M, w, \underline{d} \vDash FBp$
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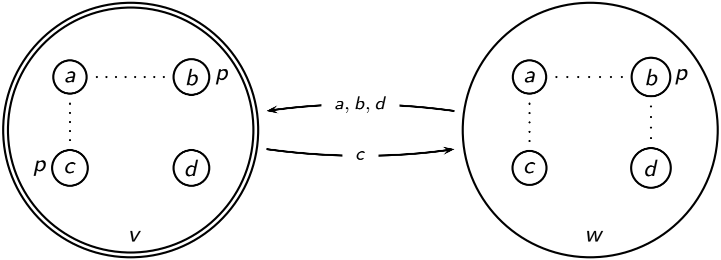

- $M, v, \underline{c} \models p$
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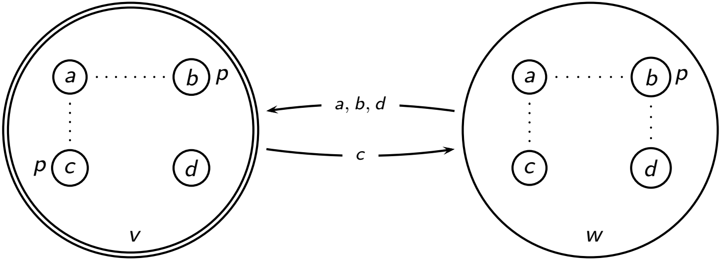
- $M, w, \underline{c} \models B@b\langle F \rangle d$

Example

$\neg @b\langle F\rangle d$



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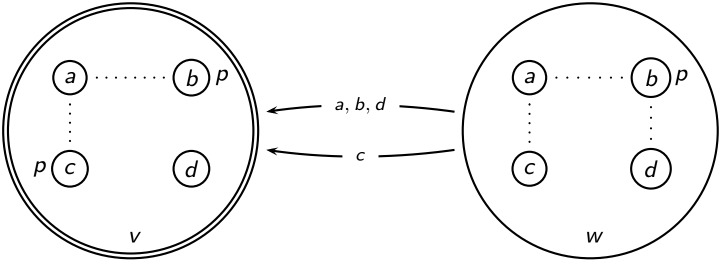

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- $M, v, \underline{a} \models \langle F\rangle b$

- $M, w, \underline{d} \models FBp$
- $M, w, \underline{a} \models BFp$

- $M, w, \underline{c} \models B\neg @b\langle F\rangle d$

Influence dynamics

Simplifying assumptions

- agents speak in turn (rank)
- only friends communicate
- agents revise with (all) sentences announced (trust)

Revision operator

Joint radical upgrade $\Uparrow \phi$

- "Promote" all the $||\phi||$-worlds so that they become more plausible than all $\neg||\phi||$-worlds (in the same information cell), keeping everything else the same:

Revision operator

Joint radical upgrade $\Uparrow \phi$

- "Promote" all the $\|\phi\|$-worlds so that they become more plausible than all $\neg\|\phi\|$-worlds (in the same information cell), keeping everything else the same:
- $\Uparrow \phi$ is a model transformer which takes as input any model $\mathcal{M}= (S, \mathcal{A}, \leq_{a\in\mathcal{A}}, \|\cdot\|, s_0, \asymp_{s\in S})$ and outputs a new model $\mathcal{M}'=(S, \mathcal{A}, \leq'_{a\in\mathcal{A}}, \|\cdot\|, s_0, \asymp_{s\in S})$ such that:

  $s \leq'_a t$ iff either $(s, t \notin \|\phi\|$ and $s \leq_a t)$ or $(s, t \in \|\phi\|$ and $s \leq_a t)$ or $(t \in s(a)$ and $s \notin \|\phi\|$ and $t \in \|\phi\|)$.

Belief merge

Baltag & Smets' lexicographic belief merge protocol

$$\rho_a := \prod \{\Uparrow \phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}, w \models B\phi\}$$

$$\rho_b := \prod \{\Uparrow \phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}_{[\rho_a]}, w \models B\phi\}$$

$$\text{etc for all } c \in \mathcal{A}$$

where $\prod$ is a sequential composition operator and $\mathcal{M}_{[\rho_a]}$ is the new model after joint revision with each formula announced by a.

Belief merge

Indexical lexicographic belief merge protocol

$$\rho_a := \prod \{\Uparrow @_a \phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}, w, a \models B\phi\}$$

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$$\text{etc for all } c \in \mathcal{A}$$

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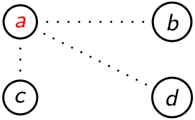
A central friend

Assumptions

- a is other agents' only friend.
- a speaks first.



One-to-others unilateral strong influence protocol

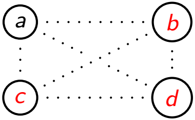
One step version of the indexical lexicographic belief merge protocol:

$$\rho_a := \prod\{\Uparrow @_a\phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}, w, \underline{a} \models B\phi\}$$

Everybody is friends with everybody else

Assumption

- Connectedness



Others-to-one unilateral strong influence protocol

$$\rho_b := \prod\{\Uparrow @_b B\phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}, w, \underline{b} \models B\phi\}$$

$$\rho_c := \prod\{\Uparrow @_c B\phi : \|\phi\| \subseteq S \times \mathcal{A} \text{ such that } \mathcal{M}, w, \underline{c} \models B\phi\}$$

$$\text{etc, for all } d \in \mathcal{A} \text{ such that } \mathcal{M}, w, d \models \langle F \rangle a$$

$$\rho_a := \prod\{\Uparrow @_a \phi \text{ iff } \mathcal{M}_{[\rho_b;\rho_c,\ldots]}, w, \underline{a} \models BFB\phi\}$$

where $\mathcal{M}_{[\rho_b;\rho_c,\ldots]}$ is the model resulting from the successive revisions (by all friends) with each of the formulas announced by each of them.

Summary

- Social network plausibility framework with communication events
- Indexical protocol to merge beliefs
- Unilateral strong influence *one-to-all-the-others* protocol
- Unilateral strong influence *all-the-others-to-one* protocol

To do next

- Private (and synchronic?) communication: *friends to friends* influence (level of privacy to determine)
- Different doxastic attitudes (conditional belief, strong belief, safe belief) + different levels of trust (dynamic attitudes) corresponding to different types of revision (minimal revision, update).
- Avoid counterintuitive consequences of strong influence + indexicality?
- Consider how to merge (as quickly as possible) knowledge and/or belief within a social network.

More further research

Related work

- Use a less complex one-dimensional logic (without the plausibility dimension) to model properties distribution change within a network structure: current work with Jens U. Hansen (LORI-IV paper).
- Use a less complex one-dimensional logic (without the social network dimension): current work with Alexandru Baltag and Rasmus Rendsvig.
- Try to get an overview of logics for social science: future work with Sonja Smets.
- Consider how the network structure constrains the dynamics (example: odd circle forcing stabilization): future work with Johan van Benthem.
- Show how agents can come to know the structure of the network they are part of: future work with Nina Gierasimczuk.

Thank you 

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