Social Algorithms

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Short presentation

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  Keywords: computational social choice, judgment aggregation

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  Keywords: voting, preference analysis, game theory

- Maitre de Conferences, since September 2014
  IRIT and Université Toulouse 1 Capitole
  Equipe LILaC

An algorithm describes a procedure
to be followed when solving a given problem

Society (interaction)
is full of interesting problems!

An outline

- First story: divide a cake
- Second story: to the beach with your friends
- Third story: a car accident
- More serious things: fair division, matching theory, judgment aggregation and voting
- Computational considerations: complexity, approximation, (simulations)

Story one - Cutting a cake

Story one - Cutting a cake

“uff…I am sacrificing half a cherry for love…”

“Half of the cream and half cherry is not enough for the loss of half of the chocolate!”

Story one - Happy ending

- When a cake is not uniformly distributed
- When the two people splitting the cake give different values to different ingredients
- When you don’t want to fight with your partner in the early morning

You cut, I choose.

For gentlemen: the chooser should always be the woman

Fair Division

Ingredients:

- A cake = [0,1] interval
- Individual utilities associating finite unions of [0,1] to $\mathbb{R}$
- Utility is non-negative, additive and continuous

Proportionality: Can we guarantee that each of n agents will get a piece she values more 1/n of the total?

H. Steinhaus. The Problem of Fair Division. *Econometrica*, 16:101–104, 1948.

S.J. Brams and A.D. Taylor. *Fair Division: From Cake-Cutting to Dispute Resolution*. Cambridge University Press, 1996.

What did computer scientists have to say?

Case of **indivisible goods**: resource allocation.

Y. Chevaleyre, Et Al. Issues in multiagent resource allocation. *Informatica*, 30(1):3–31, 2006.

A spin-off at Carnegie Mellon University implements fair division algorithms to divide goods, distribute tasks, share a rent, assign credit…

http://www.spliddit.org/

Story two - Let’s go to the beach

The passengers






The drivers



Story two - Let’s go to the beach

The passengers






“She is not from my region”

“I want to go with Ségolène”

“He can’t drive!”

“Ok, if there is no room with Macron”

“Najat goes too fast”

“Macron drives safely”

“Does he even has a driving licence?”

“Macron listens to weird music”

Story two -Let’s go to the beach

“He is not from my region”

The drivers

“I want to get Jean-Marc”

“Me, with her?!”

“Matthias never stop talking”

“I get Manuel!”

“I see Annick every day!”

Story two - Happy ending

Passenger first propose to drivers

Drivers pick the four they like the most

Rejected passengers propose to second choice

Drivers pick the four they like the most

Attention: they can reject people from 1st round too!

Rejected passengers propose to third choice

...

And they travelled happily ever after…

Stable Matching

Ingredients:

- N passengers and M drivers
- Passengers rank drivers
- Drivers rank passengers

Stability: can we find a matching passengers/drivers such that there is no pairs (p,d) and (P,D) such that p prefers D to d, D prefers p to P (same for drivers)?

A success story: Nobel prize in Economics to Shapley and Roth in 2012

And computer science?

Similar procedures are **actually implemented**:

- Matching kidney donors to receivers (US, UK)
- Doctor residents to hospitals (US, NL)
- Matching MDC and PR to universities (FR)[not sure]

Algorithmic analysis (among many others…):

- Gale-Shapley algorithm is polynomial (finding **a** solution)
- Deciding whether a stable matching with cardinality exceeding K exists is NP- complete for incomplete preferences with ties

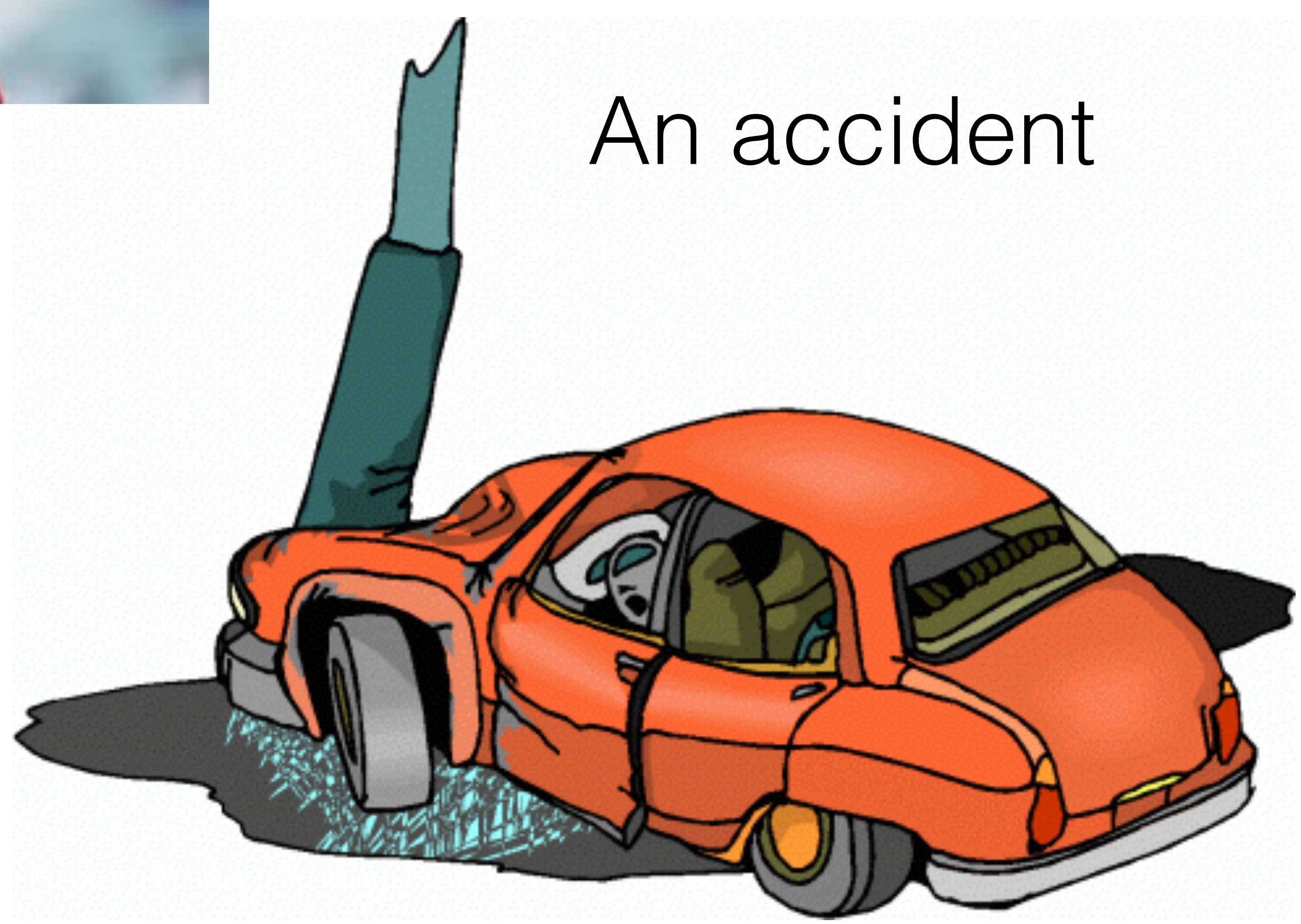
D.F. Manlove Et Al. Hard Variants of Stable Marriage. *Theoretical Computer Science*, 276(1–2):261–279, 2002.

Story three - A car accident

A careless driver

Three witnesses

An accident



Story three - A car accident

??

			
	YES	NO	YES
	NO	YES	YES
	NO	NO	NO

Story three - Happy ending

“Most witnesses did not see you on the phone”

“Most witnesses did not see a red light”

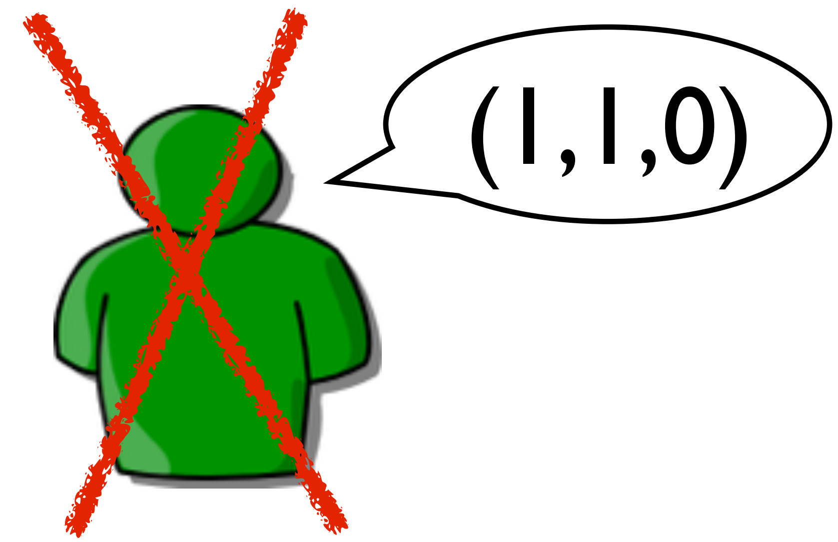
“I need to justify my judgment”

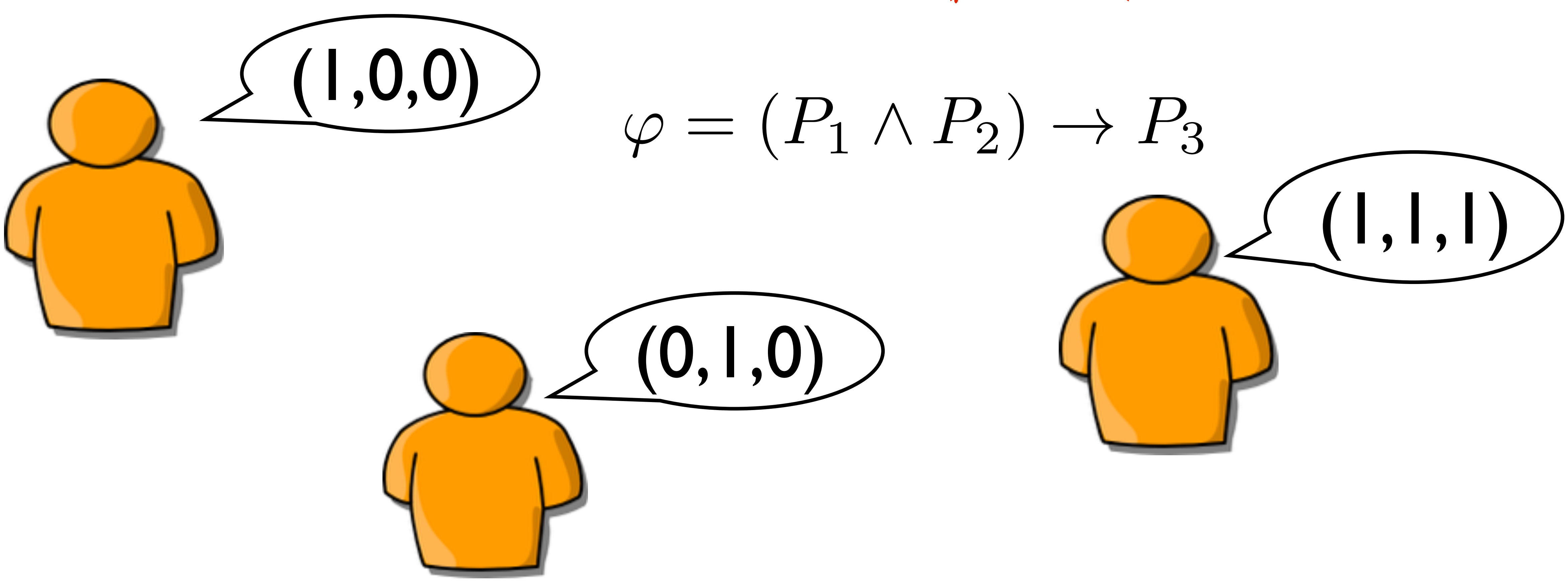
“Vous êtes libre”!

Judgment Aggregation

Ingredients:

- 1,…,n agents
- 1,…,m binary issues
- An integrity constraint IC





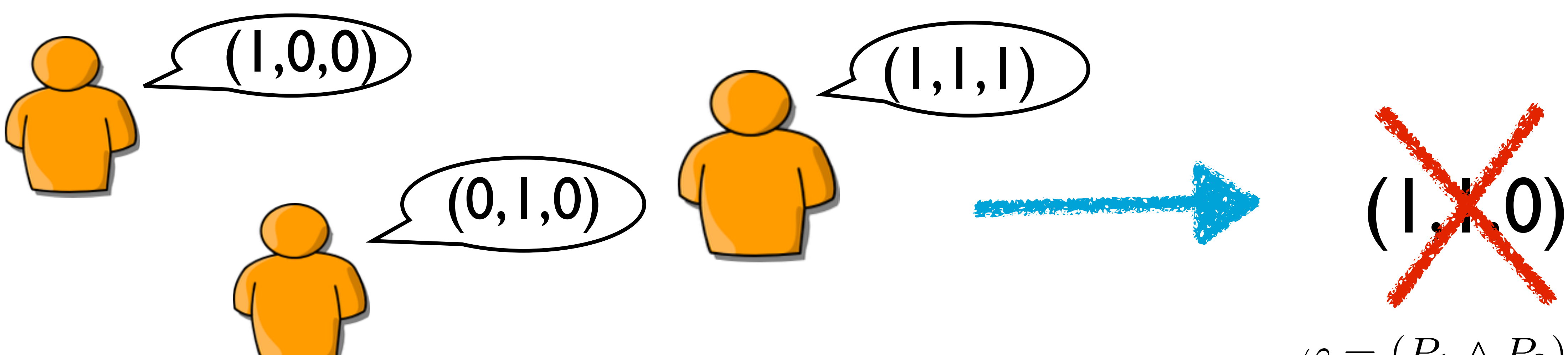
$$\varphi = (P_1 \wedge P_2) \rightarrow P_3$$

Aggregation procedures

Rules defining the collective outcome:

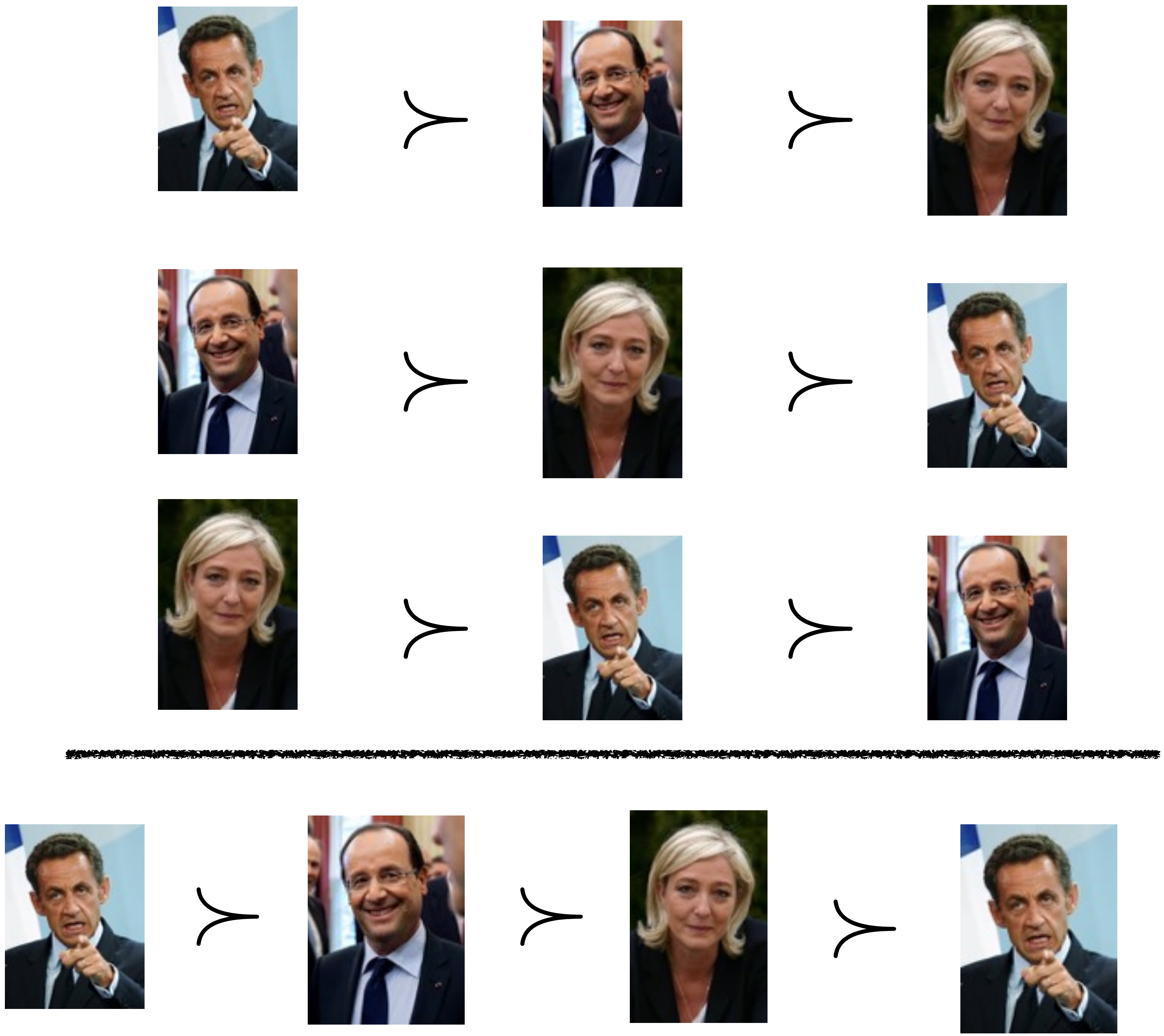
- **Majority rule**: accept issue j iff a majority of agents accept it
- **Quota rules**: same, but with a higher/lower quota
- **Distance-based rules**: accept the model of IC that is closest to the individual models
- …

Generate problems of **collective rationality**:



$\varphi = (P_1 \wedge P_2) \rightarrow P_3$

The Condorcet paradox, known since the XVIII century:



PA and JA

Preferences are binary ballots over a set of issues "AB" standing for "A is better than B", for all candidates A and B satisfying all constraints of transitivity $AB \wedge BC \rightarrow AC$

SH HL SL

(1 , 1 , 1)

(0 , 1 , 0)

(1 , 0 , 0)

(1 , 1 , 0)

$SH \wedge HL \rightarrow SL$ ✗

Can we characterise all paradoxes?

Theorem. The majority rule does not generate paradoxes with IC if and only if IC can be written in 2-CNF.

$$\varphi = (P_1 \wedge P_2) \rightarrow P_3$$ ✗

$$\phi = (\neg P_1 \vee \neg P_2) \wedge (P_1 \vee P_2)$$ ✓

Umberto Grandi and Ulle Endriss. Lifting Integrity Constraints in Binary Aggregation. *Artificial Intelligence*. 199-200: 45-66, 2013.

Algorithmic analysis

Are all judgment aggregation rules **easy to use**?

- Majority rule: polynomial
- Quota rules: polynomial
- Distance-based rule: Θ_2^p hard

Proof idea: finding a model at distance K is NP-hard, use binary search to call this problem a logarithmic number of times to find the minimal distance M, check whether the candidate model is at distance M

U. Endriss, U. Grandi and D. Porello. Complexity of Judgment Aggregation. *Journal of Artificial Intelligence Research*, 45:481-514, 2012.

J. Lang and M. Slavkovik, How Hard is it to Compute Majority-Preserving Judgment Aggregation Rules? Proceedings of ECAI-2014.

Strategic aspects

44%  $\succ$  $\succ$ 

46%  $\succ$  $\succ$ 

10%  $\succ$  $\succ$ 

Winner in US - style elections

But Sarkozy > Hollande by 54% !

Strategic aspects

44%  $\succ$  $\succ$ 

46%  $\succ$  $\succ$ 

10%  $\succ$  $\succ$ 

Winner of the manipulated election

Condorcet winner

Iterative voting

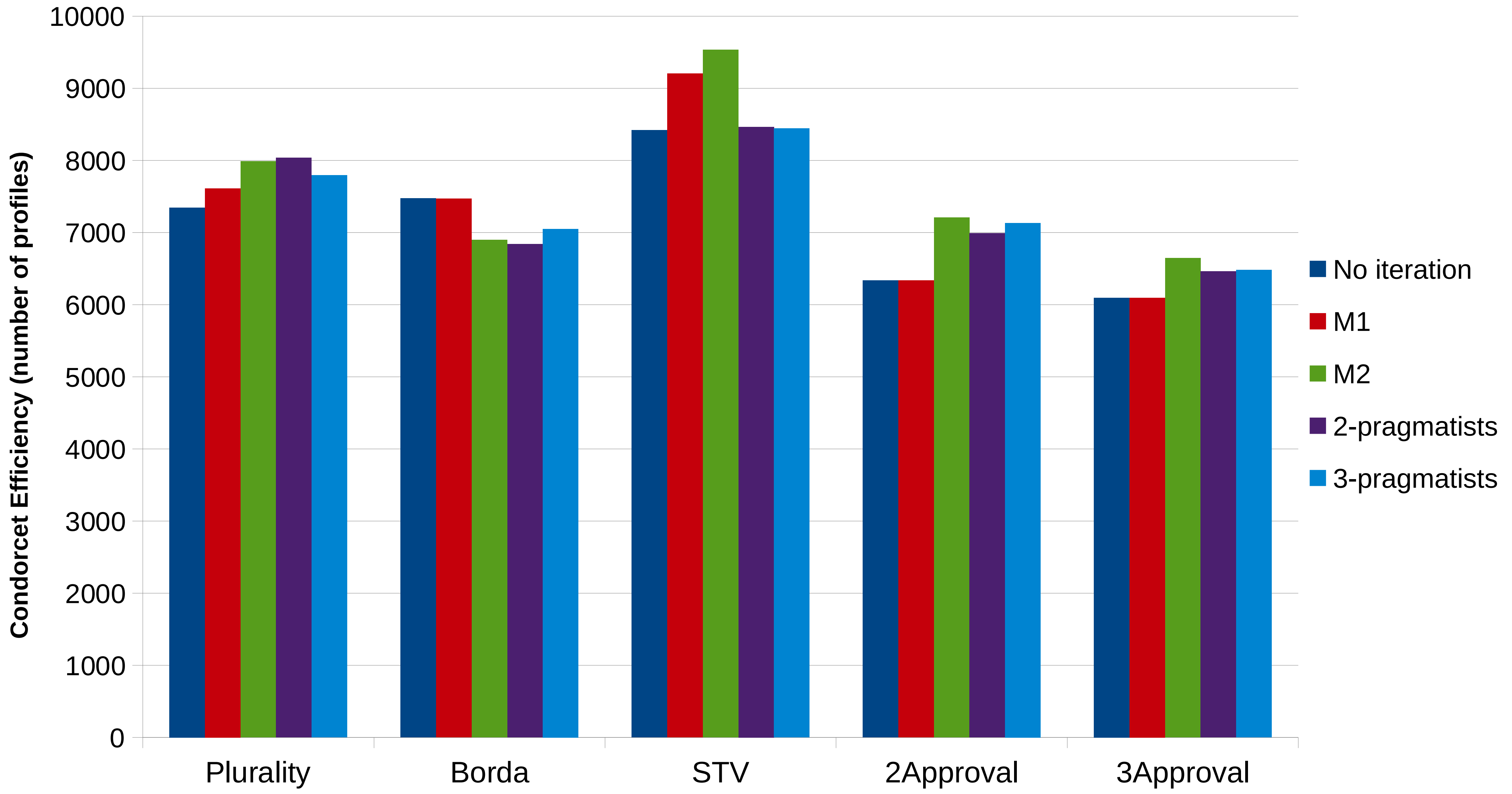
Idea: let voters manipulate sequentially until eventually they reach convergence (i.e., a Nash equilibrium)

Questions: Convergence? In how many steps?

O. Lev and J. S. Rosenschein. Convergence of iterative voting. AAMAS-2012.

R. Meir, M. Polukarov, J. S. Rosenschein, and N. R. Jennings. Convergence to equilibria in plurality voting. AAAI-2010.

Positive aspects of manipulation



Allowing restricted forms of manipulation, a Condorcet winner can be elected more often

Future directions

Social networks:
Diffusion models for
preferences and judgments
Do they influence voting?
Faster computation?

Game-theoretic
analysis of voting and
judgment aggregation:
Equilibrium selection

Sentiment analysis:
an application of aggregation
theory, preference representation,
more complex logical models?

Thank you for your attention!

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