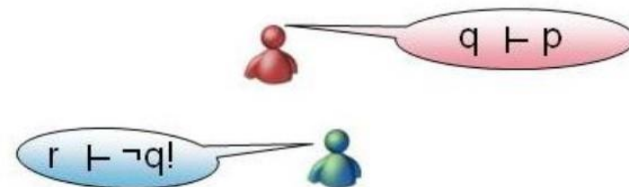


Can a machine ever argue?

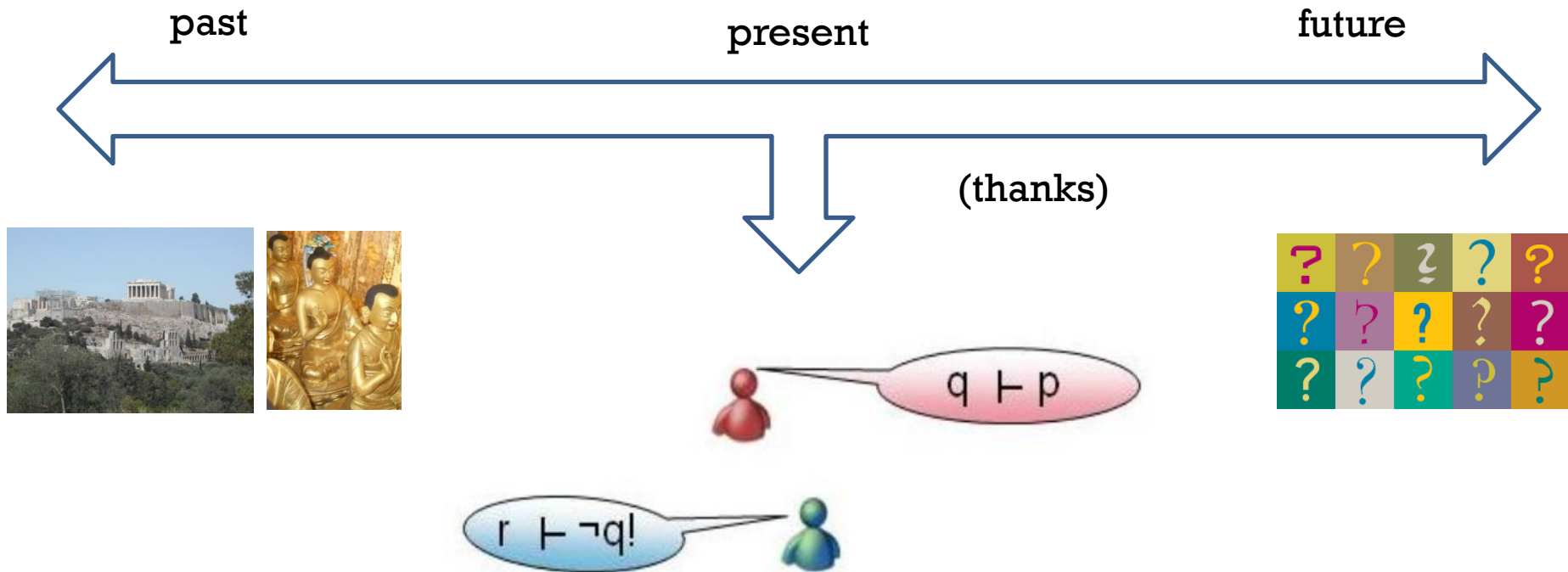


Francesca Toni
Department of Computing
Imperial College London



Computational Logic and Argumentation

Roadmap



**Computational Argumentation
(Argumentation in AI)**

Artificial Intelligence (AI)

Designing and building
machines

that behave intelligently=human-like



Arguing

Pervasive human ability



Reasoning as Arguing

“The function of reasoning is argumentative. It is to devise and evaluate arguments intended to persuade.”

Hugo Mercier, Dan Sperber: BEHAVIORAL AND BRAIN SCIENCES (2011)

Arguments vs Logic



Logic is the study of *valid* arguments

1st meaning: valid chains of reasoning

- ✓ Every human is mortal, Socrates is human, therefore **Socrates is mortal**
- × Every human is mortal, Socrates is human, therefore **Socrates is blond**
- ✓ No Martian is human, every human is mortal, therefore **some mortal is not Martian**
- ✓ Axioms of number theory hold, therefore **$\sqrt{2}$ is irrational**

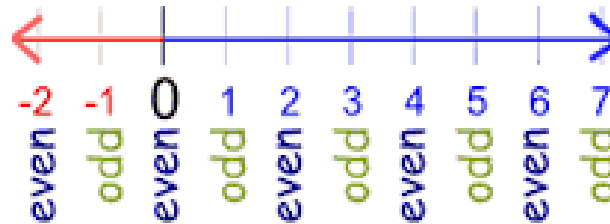
$$\frac{A \text{ implies } B, A}{B} \quad \text{modus ponens}$$

Law of Contradiction (LoC)

Opposite assertions are not true at the same time.

(Aristotle 384-322 BC)

for example, a number cannot be both odd and even



- Anyone who denies LoC... must be plunged into fire, since fire and non-fire are identical ...

(Avicenna (ibn Sīnā) 980–1037)

- Even “barbarians” must tacitly assume LoC...

(Leibniz 1646-1716)

- LoC is a consequence of the fundamental law of thought, whose expression is $\dots x(1-x)=0$

(Boole 1815-1864)

LoC vs Tetralemma

“Everything is real and not real.
Both real and not real.
Neither real nor not real.”

(Nāgārjuna, 150-250)

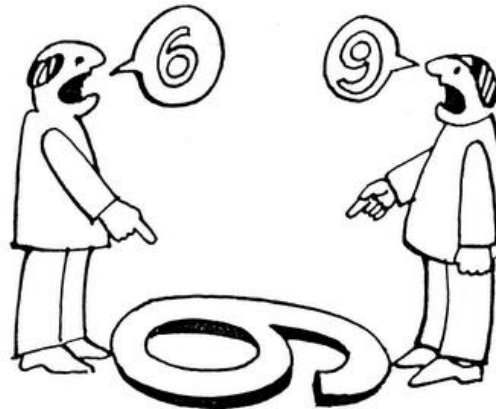


Arguments vs Logic

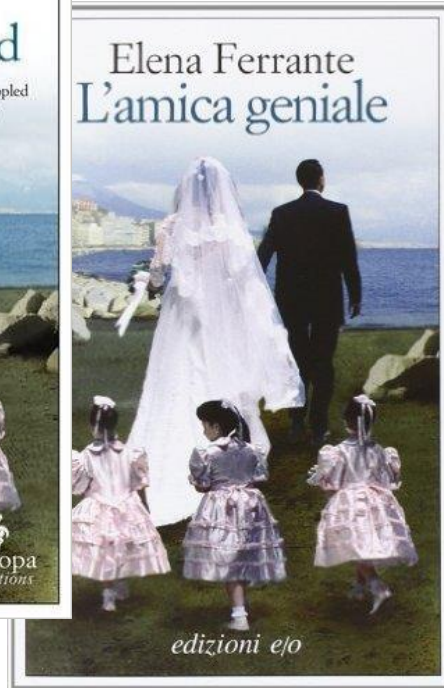
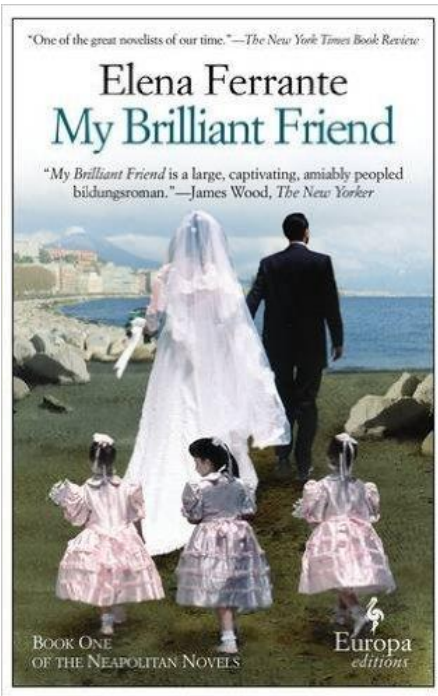


Logic is the study of *valid* arguments
2nd meaning: valid disputes

There are two sides to every issue
(*Protagoras 490 – 420 BC & Sophists 5th century BC*)



Conflicting (online) reviews



★★★★★ best book I've read this year

By [chickpea](#) on 28 Dec. 2013

Format: Paperback | **Verified Purchase**

My Brilliant Friend is about the close friendship, rivalry and

★★★☆☆ Really struggled with this

By [mac500](#) on 20 Sept. 2015

Format: Kindle Edition | **Verified Purchase**

Really struggled with this, found characters names confusing and the style very rambling.

Conflicting opinions

BREXIT



Leaving the EU would lead to lower trade between the UK and the EU



Leaving the EU would lead to a lower net contribution to the EU budget

Conflicting evidence

*Hormone Replacement Therapy (HRT)
for postmenopausal women:
does it help or harm your heart?*



- Questionnaire-based studies suggested a **benefit**.
- Trials randomising some women to HRT and some to placebo suggested **no benefit** and possible harm.
- Researchers found that **benefit may vary**: beneficial before 60, harmful after 60. However the evidence was not clear cut

Evidently Cochrane

Sharing health evidence you can trust

Conflicting rules

Am I eligible to claim for UK & European Breakdown & Recovery Assistance?

You need to think about whether the insurance meets your needs and whether you can claim when you need to.

You are covered for:

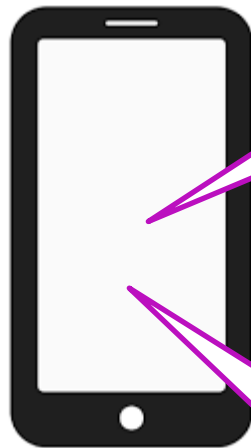
- ✓ UK and European Breakdown Assistance for account holder(s) in any private car that they are travelling in
- ✓ Anyone driving a private car registered to the account holder and which is being used with his/her permission. Where the account is in joint names then up to 2 private cars can be covered
- ✓ Assistance provided at home and on the roadside with national recovery and onward travel
- ✓ No call out limit
- ✓ No excess payable

You are not covered for:

- The cost of replacement parts and associated labour to repair the vehicle
- Private cars not registered to the account holder(s) unless the account holder(s) are in the vehicle at the time of the breakdown
- Motorcycles, motorhomes, caravanettes, commercial vehicles (all types), vans, pick up trucks and vehicles being used for hire and reward purposes (such as taxis)
- Vehicles that do not have a valid MOT or are not serviced or maintained in line with manufacturer guidelines
- Vehicles that are more than 7 metres in length, 2.3 metres wide, 3 metres high and weigh more than 3.5 tonnes when fully loaded

Computational Argumentation (Argumentation in AI)

Designing and building machines that argue



Get this book!
You will like it
because...

What about this?
It is about your
home town and
...



but I read
it already !



Arguing from conflicting rules

Am I eligible to claim for UK & European Breakdown & Recovery Assistance?

You need to think about whether the insurance meets your needs and whether you can claim when you need to.

You are covered for:

- ✓ UK and European Breakdown Assistance for account holder(s) in any private car that they are travelling in
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Reasoning with Rules

YOU ARE COVERED FOR: UK and EU Breakdown Assistance for account holder(s) in any private car they are travelling in

YOU ARE NOT COVERED FOR: private cars not registered to the account holder(s) **unless** the account holder(s) are in the vehicle at the time of the breakdown

Zoe, Stef, Gio are all account holders

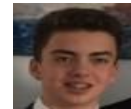


Zoe travels in her own car and the car breaks down

covered

Stef travels with a friend in her car and the car breaks down when he is out of the car

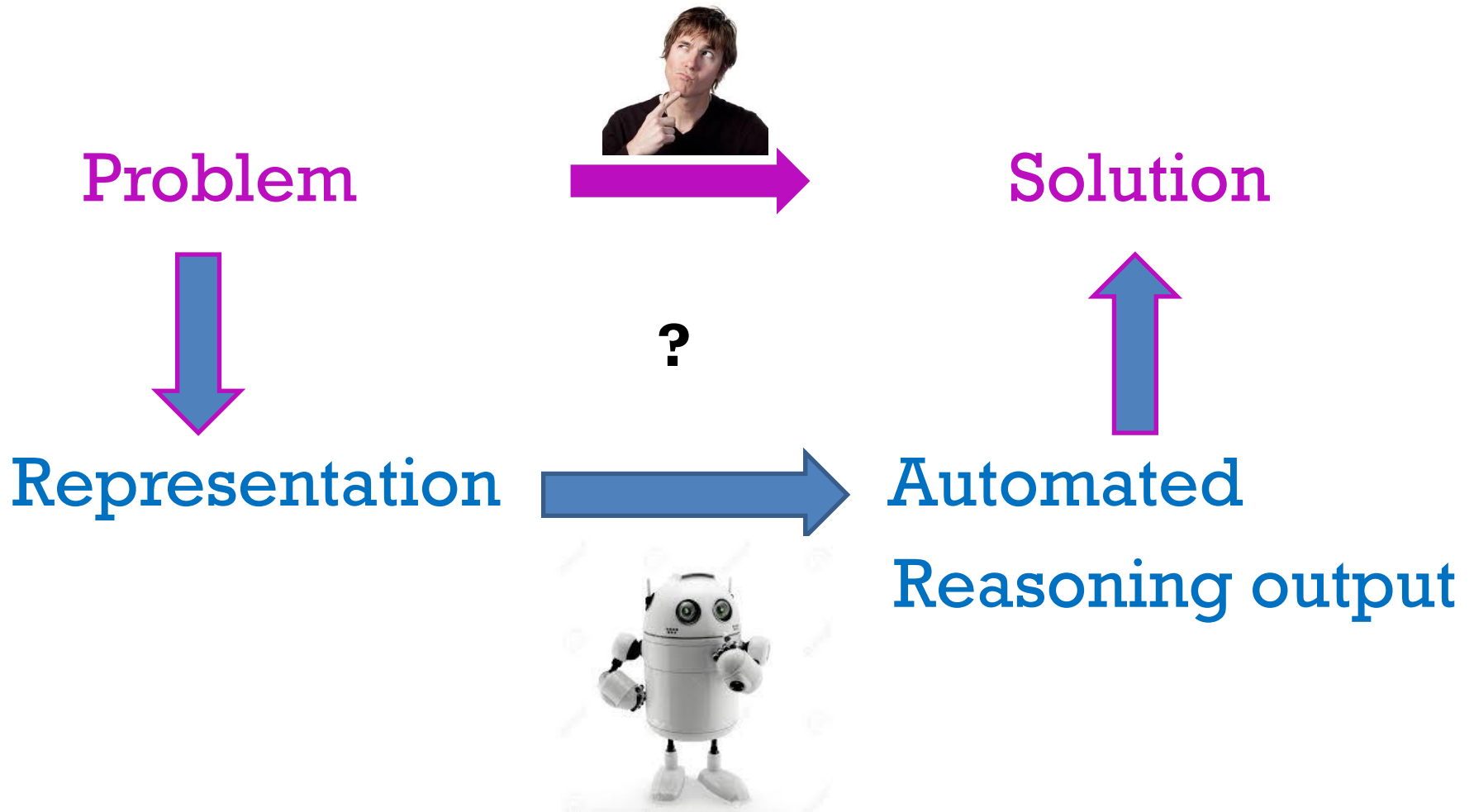
not covered



Gio travels in a friend's car and the car breaks down when he is in it

covered

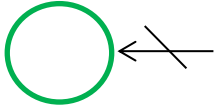
Knowledge Representation and Reasoning (KR) in AI



KR via Argumentation



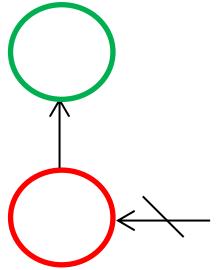
(own car) **covered** as travelling in private car



cannot be attacked



(friend's car, out of car) covered as travelling in private car



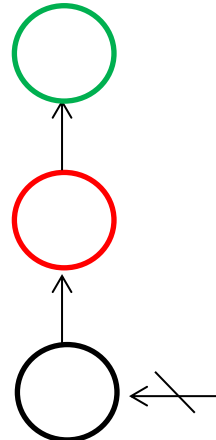
attacked by

not covered as car not registered to Stef

cannot be (counter-)attacked



(friend's car, in car) **covered** as travelling in private car



attacked by

not covered as car not registered to Gio

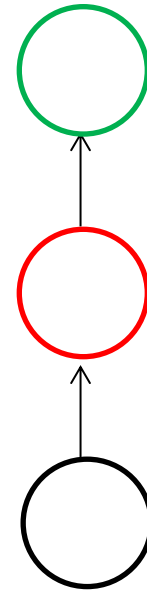
(counter-)attacked by

Gio in car at time of breakdown

cannot be attacked

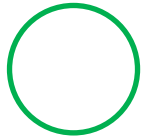
Abstract Argumentation (AA)

- A dispute can be abstracted away as a (directed) graph:
 - Nodes are *arguments*
 - Edges are *attacks*



Assumption-Based Argumentation (ABA)

- Arguments have a “structure”: premises and conclusions (connected by **rules**); some of the premises can be *assumed*



covered because

account holder,

travelling in private car (since her own car),

assuming that

there are no objections against her being covered

- Arguments can only be attacked by attacking their assumptions (i.e. building arguments for *contraries* of assumptions)

Which KR? ABA instances

YOU ARE COVERED FOR: UK and EU Breakdown Assistance for account holder(s) in any private car they are travelling in

YOU ARE NOT COVERED FOR: private cars not registered to the account holder(s) **unless** the account holder(s) are in the vehicle at the time of the breakdown

- **Logic Programming**

contrary: $\neg cov(Y, V)$

$\forall Y, V [cov(Y, V) \leftarrow ah(Y), tr(Y, V), pr(V), \underline{not} \underline{\neg} \underline{cov}(Y, \underline{V})]$

$\forall Y, V [\neg cov(Y, V) \leftarrow \neg reg(V, Y), \underline{not} \underline{cov}'(Y, \underline{V})]$

$\forall Y, V [cov'(Y, V) \leftarrow in(Y, V)]$

$ah(Stef) \leftarrow$

contrary: $cov'(Y, V)$

...

Which KR? ABA instances

YOU ARE COVERED FOR: UK and EU Breakdown Assistance for account holder(s) in any private car they are travelling in

YOU ARE NOT COVERED FOR: private cars not registered to the account holder(s) **unless** the account holder(s) are in the vehicle at the time of the breakdown

- **Default logic** (Reiter 1980) contrary: $\neg cov(Y, V)$

$$D : \frac{ah(Y), tr(Y, V), pr(V) : \underline{M} \underline{cov}(Y, V)}{cov(Y, V)}$$

$$\frac{\neg reg(V, Y) : \underline{M} \underline{\neg cov}'(Y, V)}{\neg cov(Y, V)}$$

contrary: $cov'(Y, V)$

$$W : \forall Y, V [in(Y, V) \rightarrow cov'(Y, V)]$$

$$ah(Stef)$$

...

Which KR? ABA instances

YOU ARE COVERED FOR: UK and EU Breakdown Assistance for account holder(s) in any private car they are travelling in

YOU ARE NOT COVERED FOR: private cars not registered to the account holder(s) **unless** the account holder(s) are in the vehicle at the time of the breakdown

- **Non-monotonic modal logic** (McDermott 1982)

$\forall Y, V [ah(Y) \wedge tr(Y, V) \wedge pr(V) \wedge \neg L \neg cov(Y, V) \rightarrow cov(Y, V)]$

$\forall Y, V [\neg reg(V, Y) \wedge \neg L cov'(Y, V) \rightarrow \neg cov(Y, V)]$

$\forall Y, V [in(Y, V) \rightarrow cov'(Y, V)]$

contrary: $\neg cov(Y, V)$

$ah(Stef)$

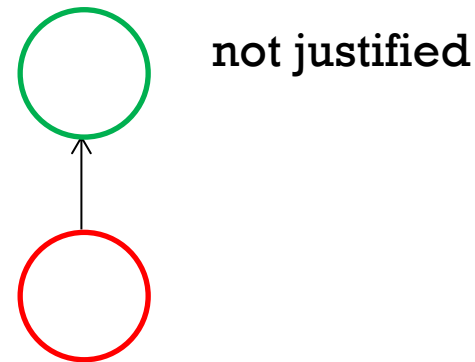
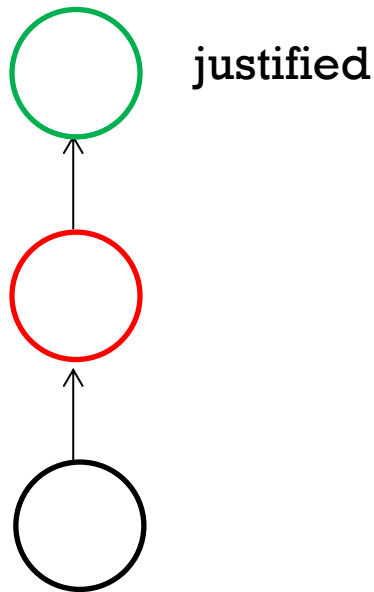
contrary: $cov'(Y, V)$

...

- Autoepistemic Logic (Moore 1985) Circumscription (McCarthy 1980), Theorist (Poole, 1988)

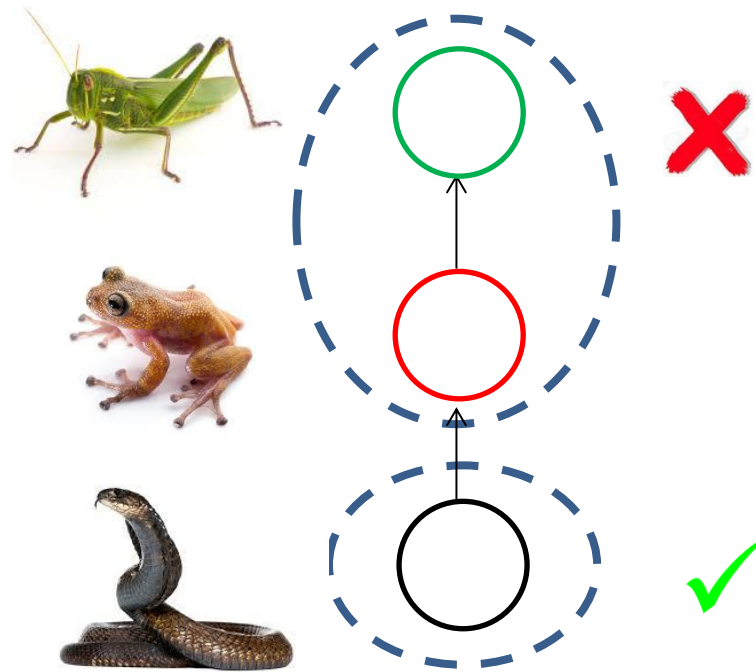
Conflict Resolution in AA and ABA

The outcome of a dispute can be determined by (dialectical) *semantics* evaluating arguments as justified if they belong to “good” sets of arguments



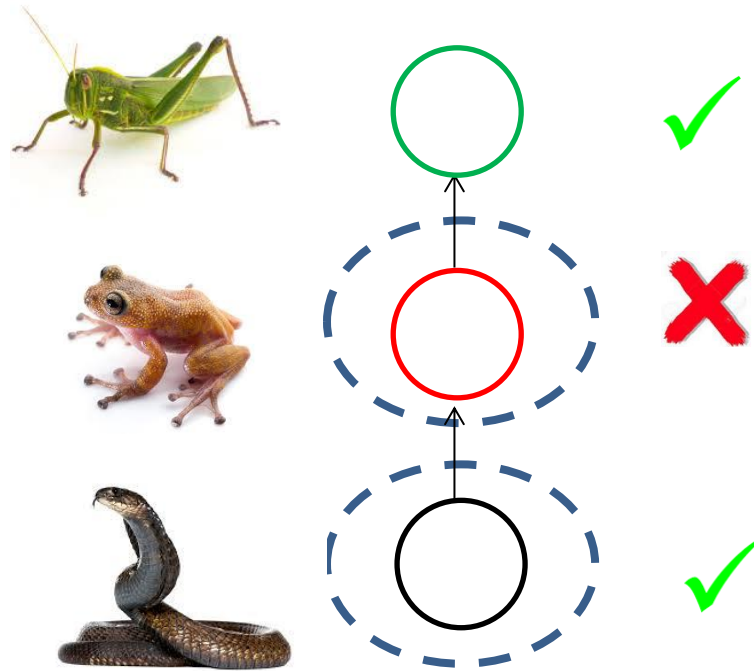
Conflict-free sets of arguments

A set of arguments is conflict-free if *it does not attack itself*



Admissible semantics

A set of arguments is **admissible** if it is conflict-free and *it attacks every argument that attacks it*

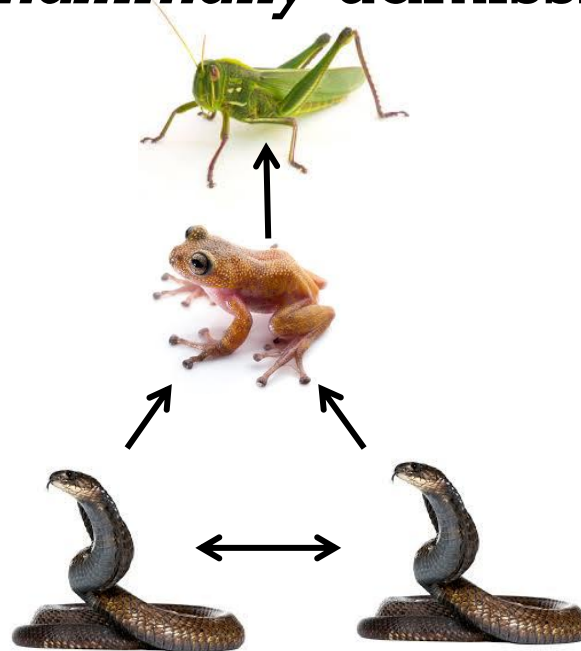


Ideal semantics

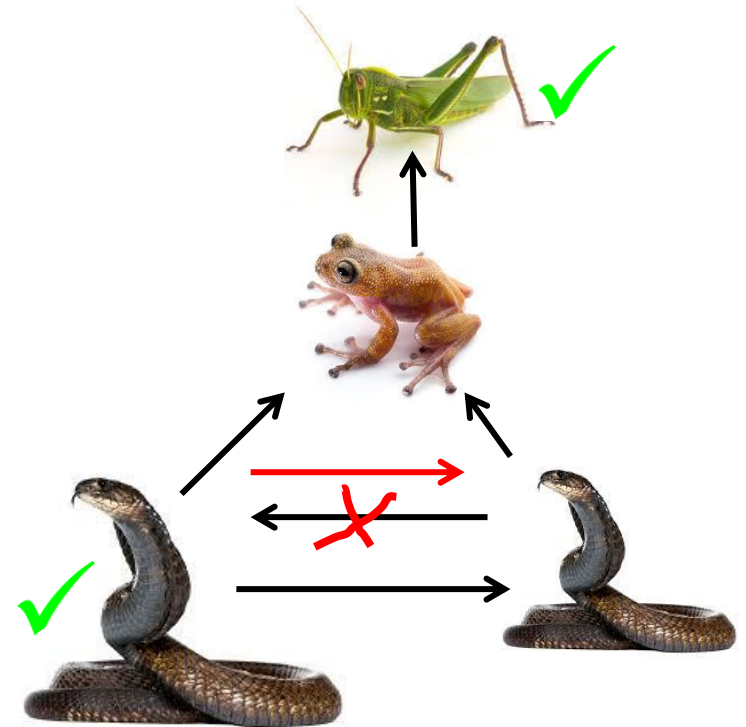
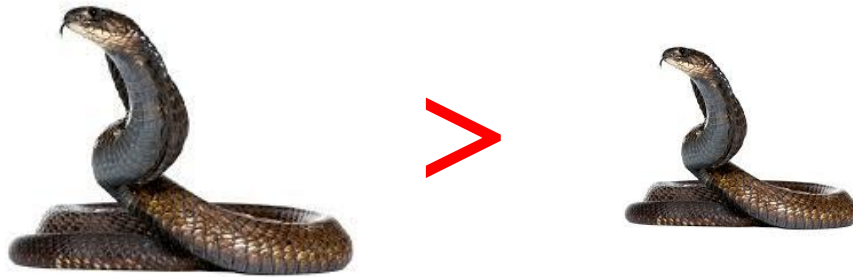
A set of arguments is **ideal** if it is maximal such that

(i) it is admissible and

(ii) it is *contained in all maximally admissible sets*



Argumentation with preferences



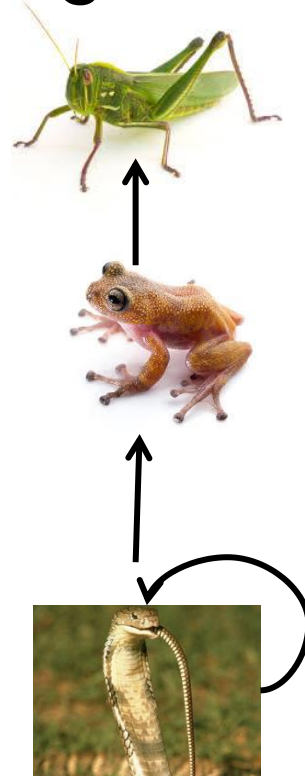
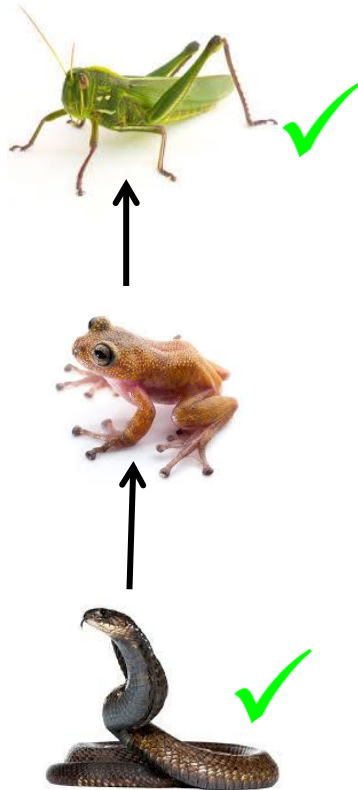
(maximally) admissible
ideal

Amgoud, Vesic 2014;
Cyras, Toni 2016

Stable semantics

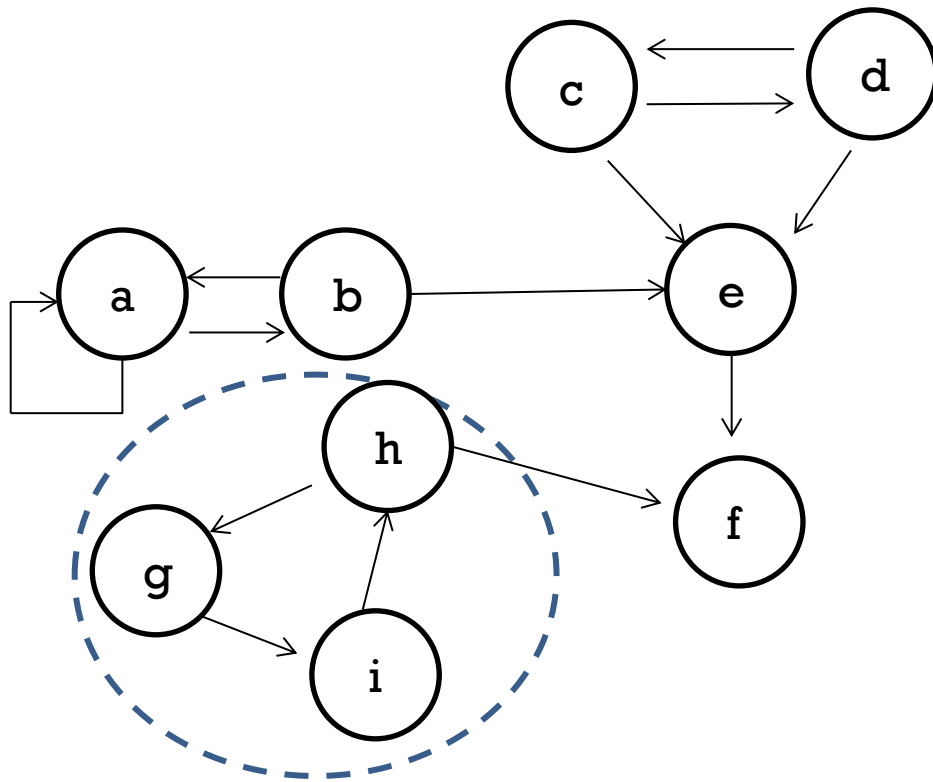


A set of arguments is **stable** iff it is conflict-free and *it attacks every argument it does not contain*



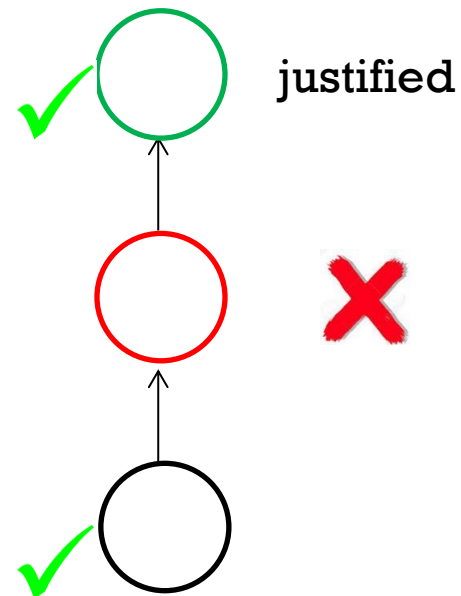
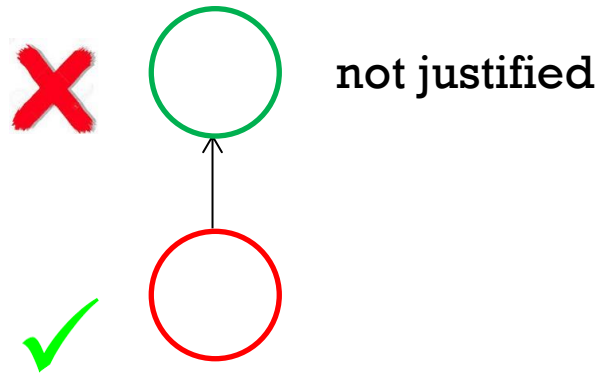
no stable set !

Why no stable set of arguments?



Conflict Resolution in in AA and ABA

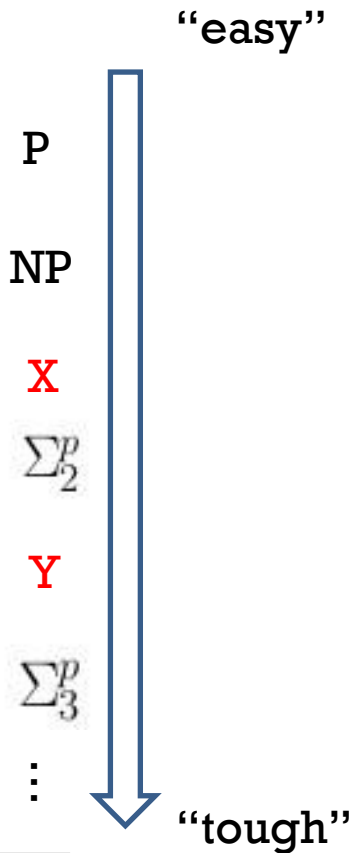
An argument is justified if it belongs to a “good” (e.g. admissible, ideal, stable) set of arguments



Computational Complexity

Problem: is an argument justified
(given a semantics)?

	admissible	stable	ideal
AA	NP	NP	X
ABA-LP	NP	NP	X
ABA-DL	Σ_2^P	Σ_2^P	Y
ABA-AEL	Σ_3^P	Σ_2^P	



Dispute derivations

Kakas, Toni 1999
Dung, Kowalski, Toni 2006
Dung, Mancarella, Toni 2007
Toni 2012, Craven, Toni 2016

TRaDAr 

proponent



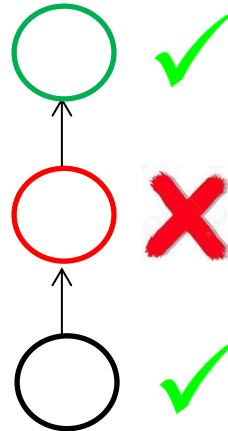
covered ✓

if Gio is account holder,
travelling in private car,
assuming covered ok

and indeed Gio is account holder
travelling in private car,

exception applies if
Gio was in the car when
it broke down

and indeed Gio was in the car



opponent

not covered
if car not registered to Gio,
assuming no exception applies

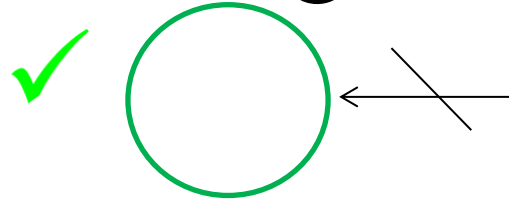
ABA Dialogues



covered ✓

if Zoe is account holder,
travelling in a private car,
assuming covered ok

not me



indeed Zoe is account holder

I cannot either

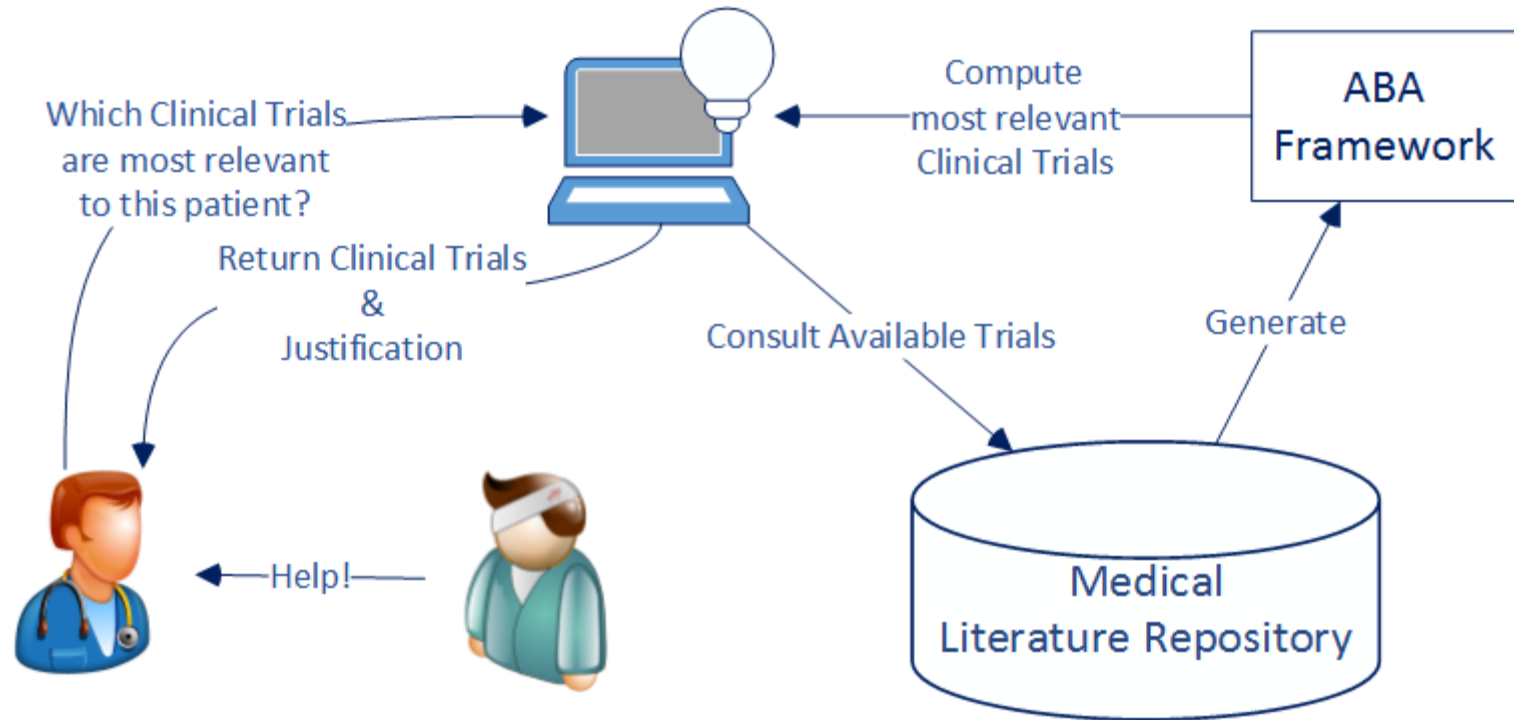


and she was travelling in a private car
since it was her own car

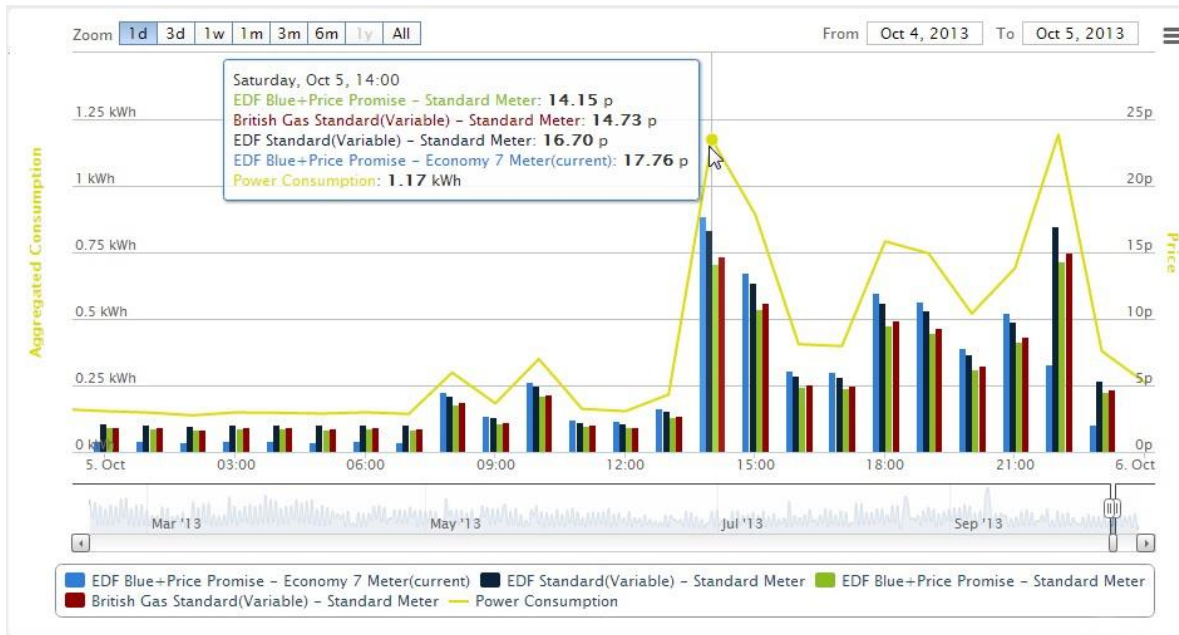
*can anybody argue that she is **not covered**?*

we are done then!

ABA for decision making in medicine



AA for Smart Electricity



Shifted Usage Recommendation

If you shift **10%** of your electricity consumption from the interval **08:00-22:00** to the interval **22:00-08:00**, you will save **£11.30**

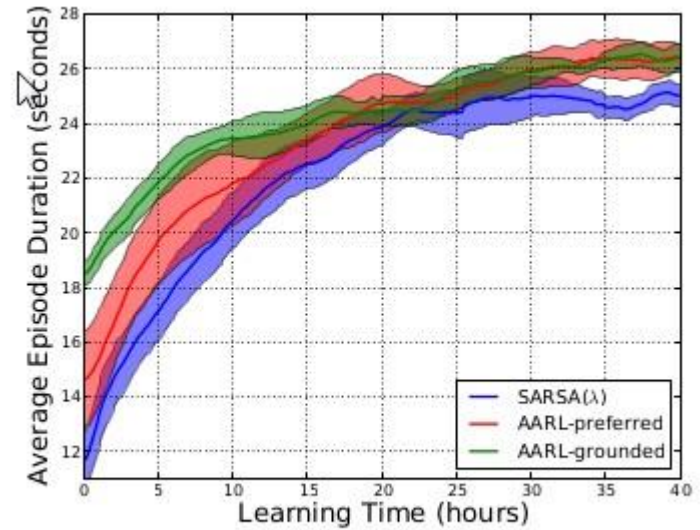
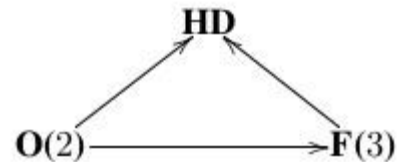
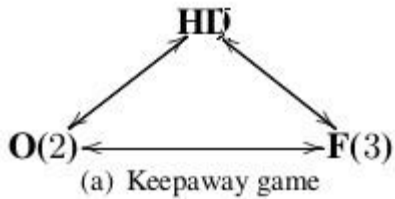
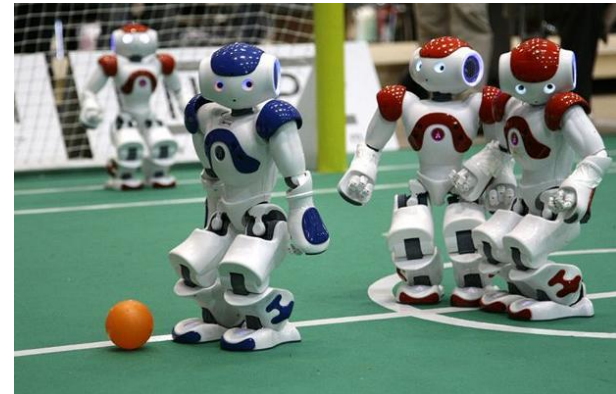
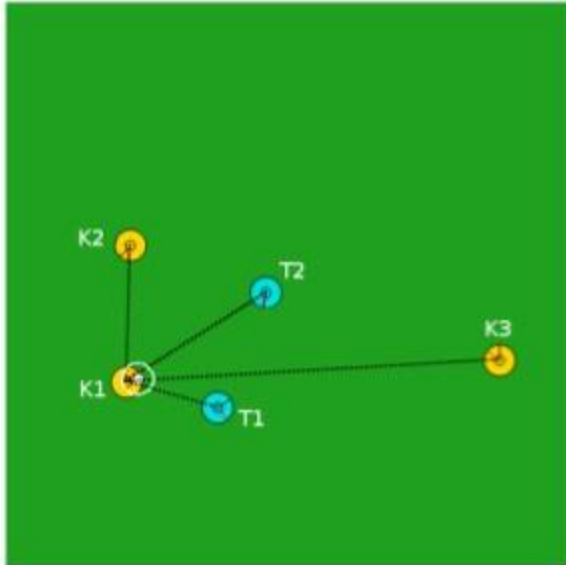
Furthermore, if you follow this recommendation and also switch to contract **EDF Blue+Price Freeeze - Economy 7 Meter**, you will save **£13.94**

Arguments:

- Your contract charges a lower tariff in the interval **22:00-08:00** than in the interval **08:00-22:00**. Contract **EDF Blue+Price Freeeze - Economy 7 Meter** is less costly overall than your current contract.

AA for Reinforcement Learning

robocup

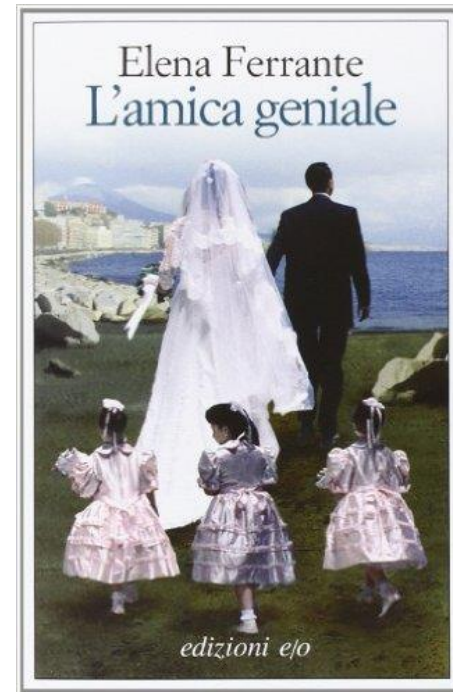


Gao, Toni 2012-15

(a) 2-Keepaway

Arguing from opinions

BREXIT



Brexit - what would happen if Britain left the EU?

exit



stay



We have a shared heritage as part of Europe.

Why for instance would China stop trading with us if we left the EU. We still trade significantly with lots of non EU countries.

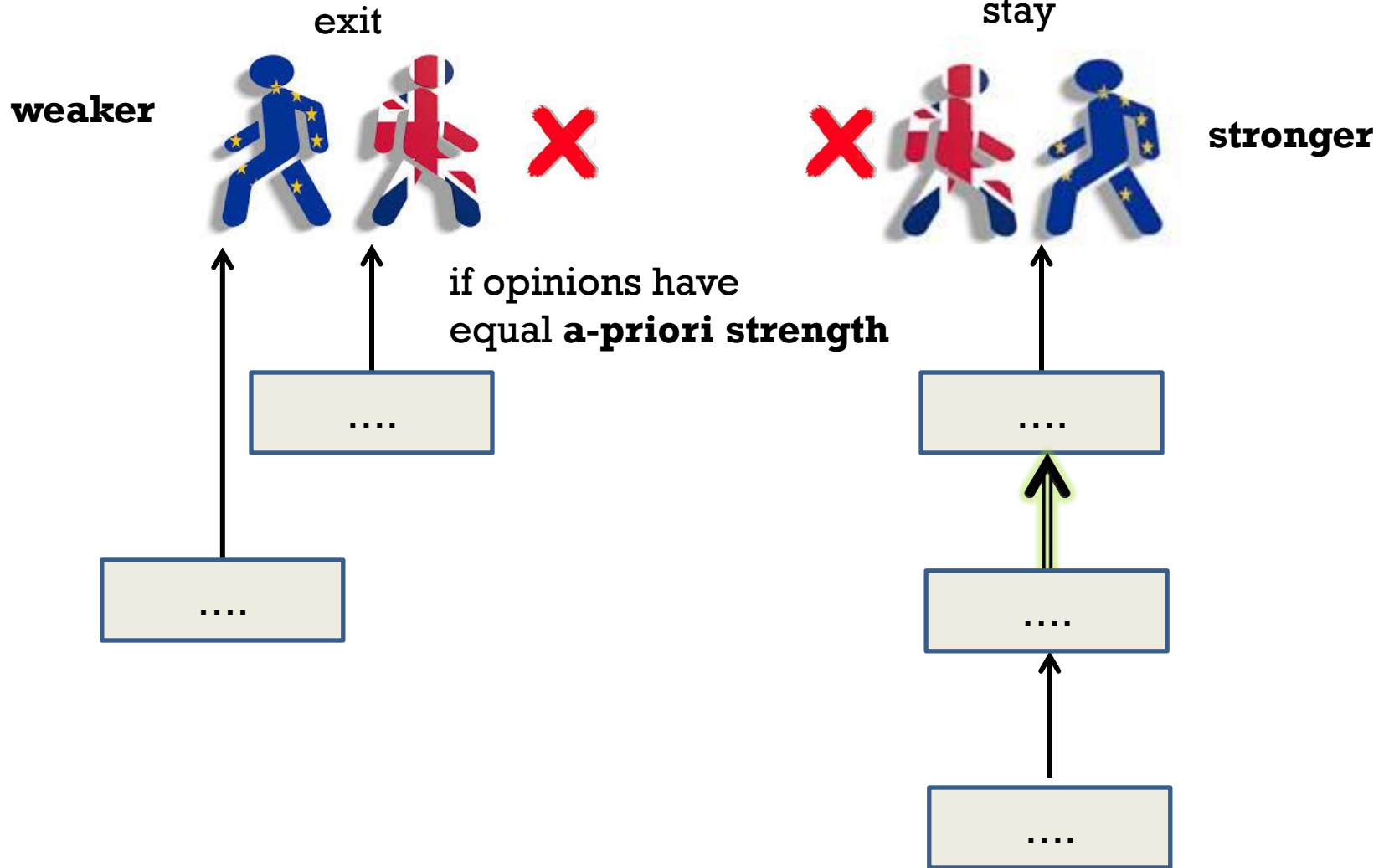
youngsters too, would no longer have the benefit of our EHIC insurance cards when holidaying abroad. From experience I can say this is a fantastic benefit, albeit on an

support

Good question.
We don't have to be in the EU to trade with it.

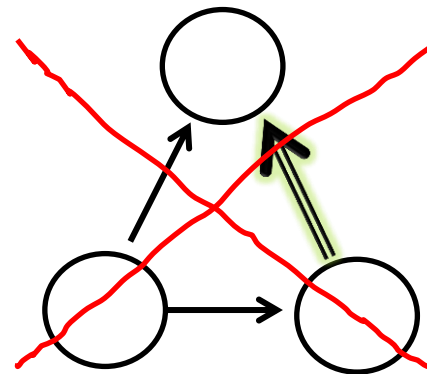
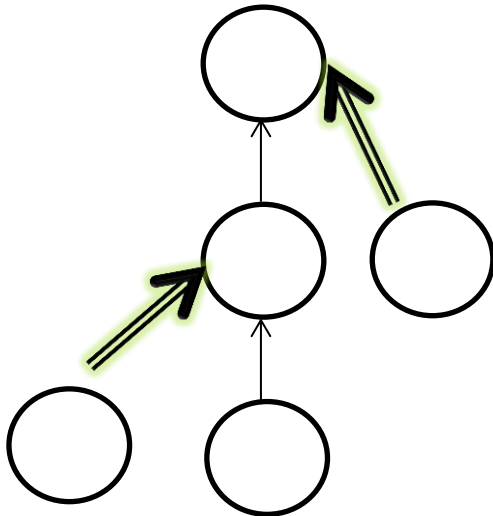
The problem is that there are no "facts" here, because nobody knows what will happen

Justified vs Weak/Strong Arguments



Computing strength

- All opinions have a **base score** (a-priori strength) in $[0,1]$
- Opinions (arguments) **attack** \uparrow or **support** $\uparrow\uparrow$ other opinions (arguments)
- Debates are (sets of) **trees**



Computing strength

To compute the **strength** $S\mathcal{F}$ of argument x the function \mathcal{C} combines three elements:

$$S\mathcal{F}(x) = \mathcal{C}(\mathcal{BS}(x), \mathcal{F}_a(S\mathcal{F}Seq(Atts(x))), \mathcal{F}_s(S\mathcal{F}Seq(Supps(x))))$$

the base
score of x

a factor summarizing
the attackers of x

a factor summarizing
the supporters of x

using the **sequence of the strengths** of the attackers of x

Defining attacker/supporter contribution

- For two attackers/supporters ($*=a/s$):

$$f_*(v_1, v_2) = v_1 + (1 - v_1) \cdot v_2 = v_1 + v_2 - v_1 \cdot v_2$$

- For any number of attackers/supporters (recursively, $*=a/s$):

$$\text{if } S = () : \mathcal{F}_*(S) = 0$$

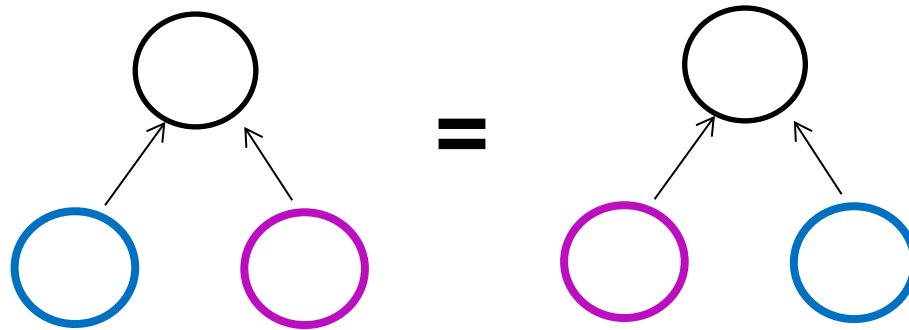
$$\text{if } S = (v) : \mathcal{F}_*(S) = v$$

$$\text{if } S = (v_1, v_2) : \mathcal{F}_*(S) = f_*(v_1, v_2)$$

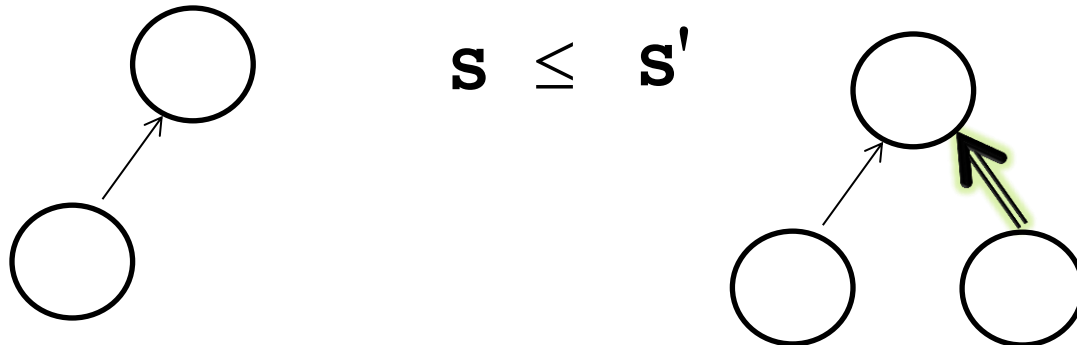
$$\text{if } S = (v_1, \dots, v_n), n > 2 : \mathcal{F}_*(S) = f_*(\mathcal{F}_*((v_1, \dots, v_{n-1})), v_n)$$

Combining all factors: properties

- The order of attackers/supporters does not matter

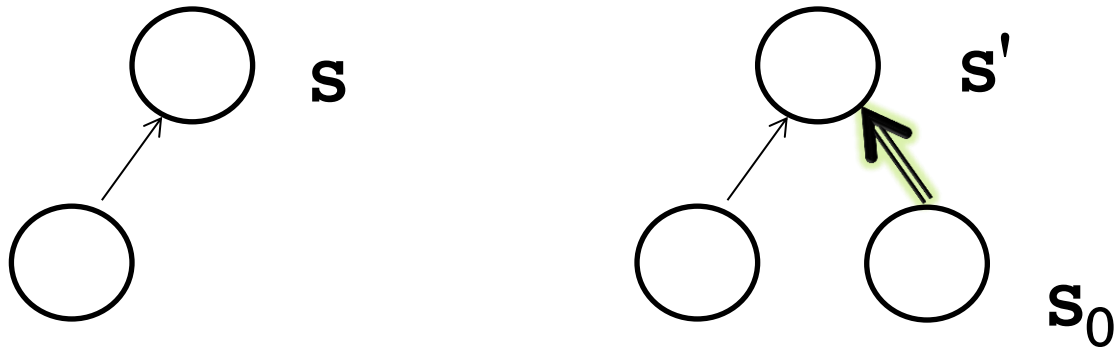


- Adding a supporter will not lower strength



Combining all factors: more properties

- The smaller the strength of an attacker/supporter the smaller its impact



if s_0 is very small
then s' is almost the same as s

Arg & Dec

Argue and Decide

www.arganddec.com



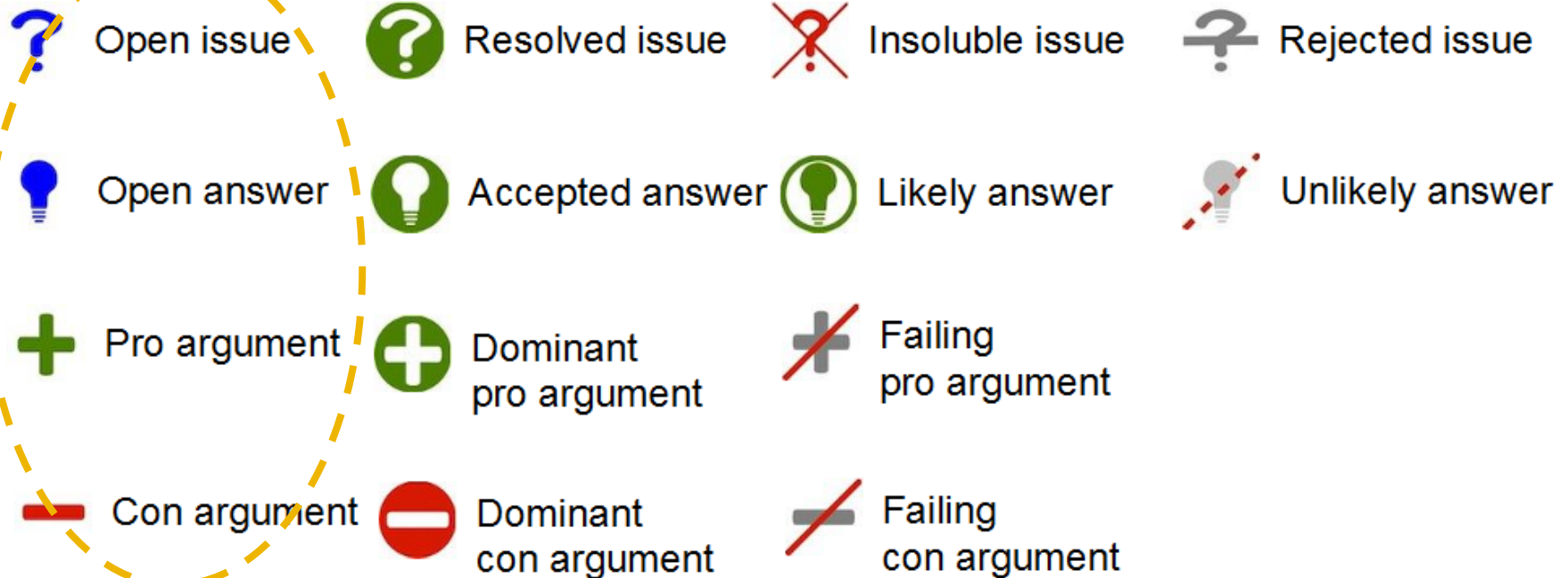
Username:

Password:

Login



IBIS (Issue Based Information System, Kunz and Rittel 1970)



Auriscchio, Baroni, Pellegrini, Toni (2015)

Arg & Dec

Argue and Decide

www.arganddec.com



Username:

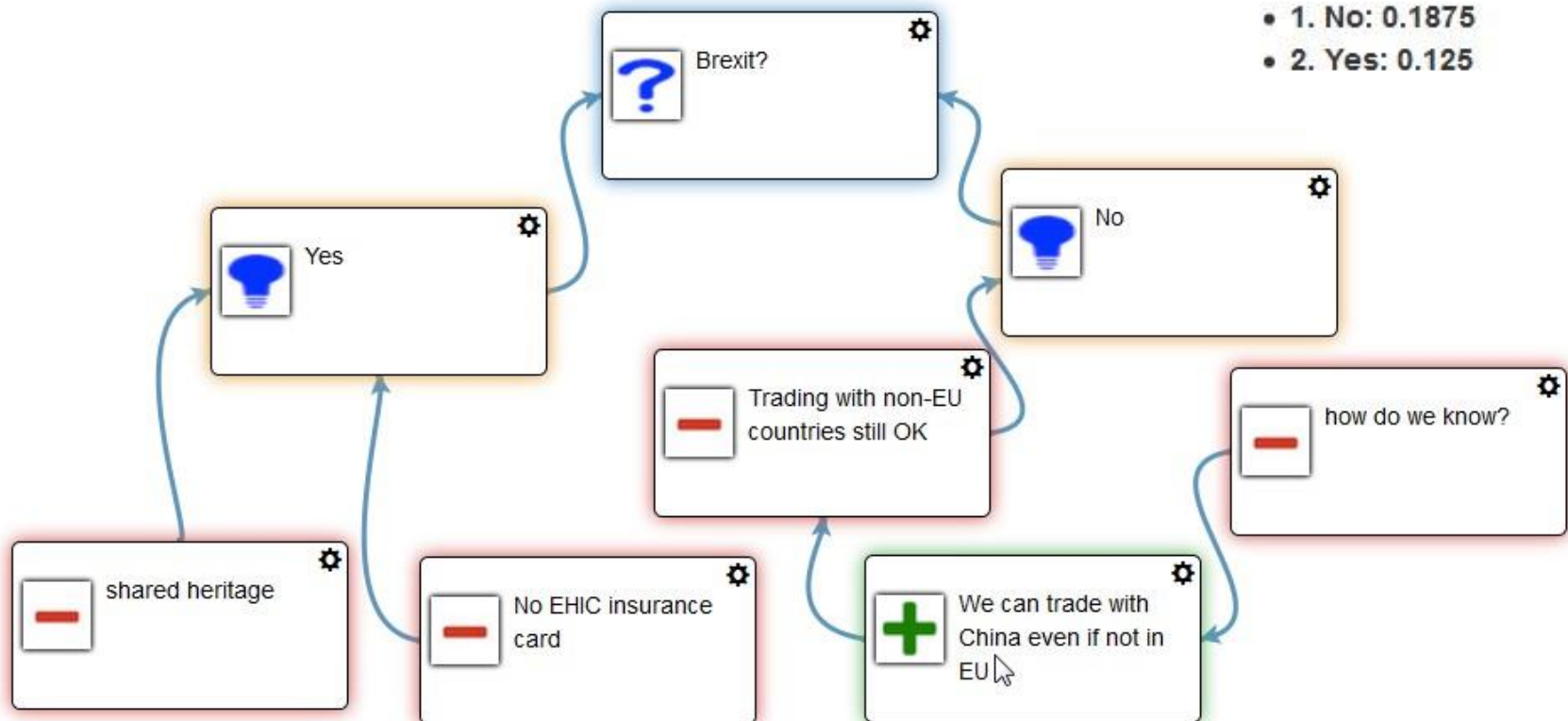
Password:

Login



Answer ranking

- 1. No: 0.1875
- 2. Yes: 0.125

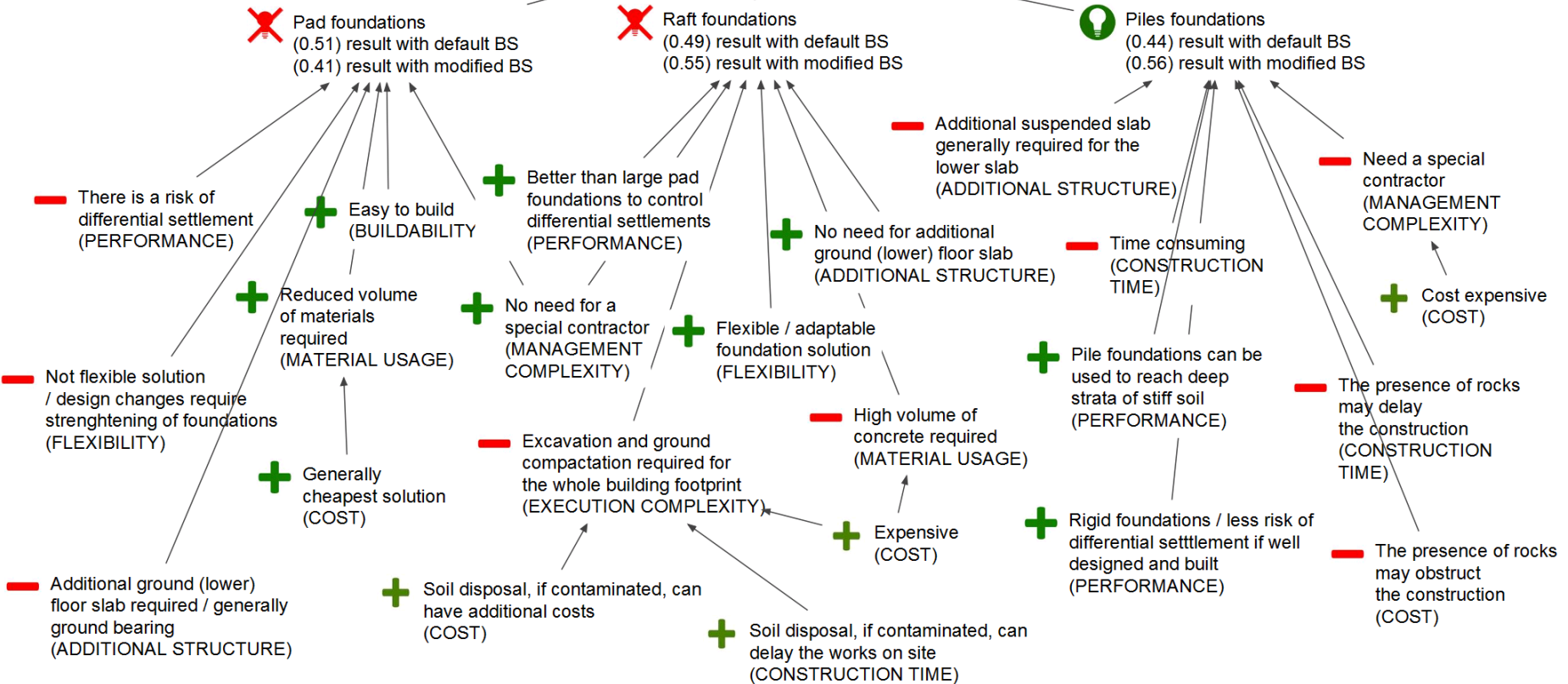


Brownfield sites are abandoned or underused industrial and commercial facilities available for re-use. The ground condition are generally variable with made ground and a mix of sandy/clay soil.

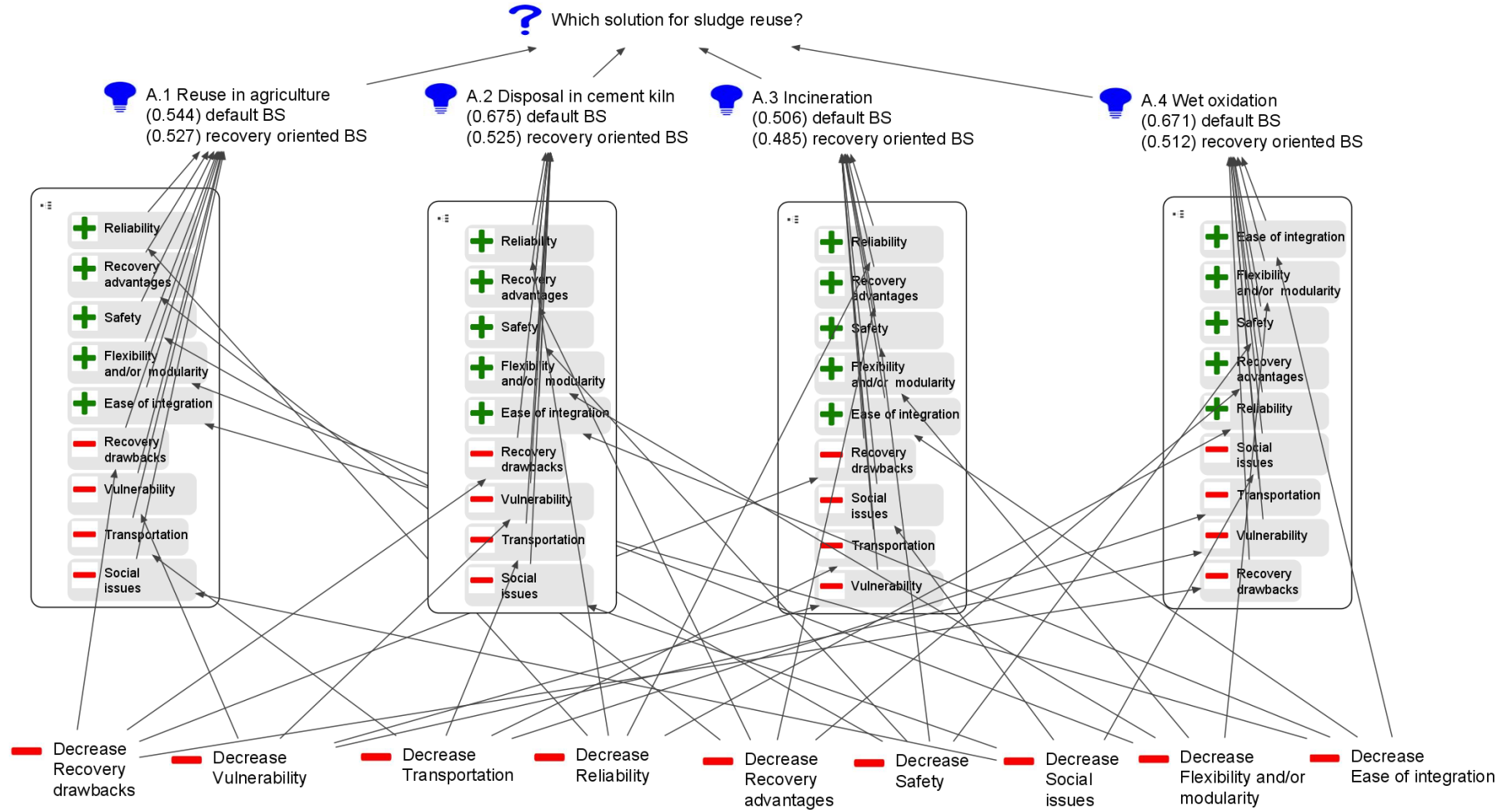
The load take down (to the foundations) for multistoreys buildings is generally concentrated at columns positions and requires good ground condition.

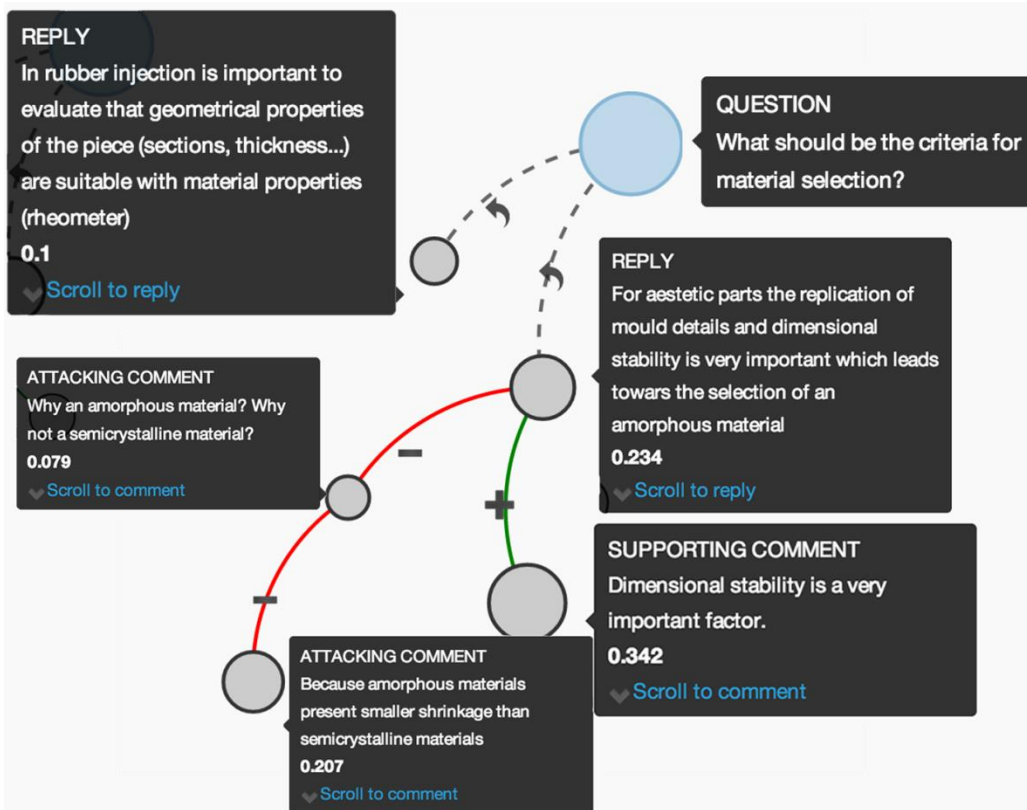
On this site we have between 3 and 6 m of made ground with low bearing capacity and possibly contaminated ground. We have good ground bearing capacity at 8-10 m below ground level and stiff solid clay at around 20 m

Which foundation to choose for a multistoreys building in a brownfield?

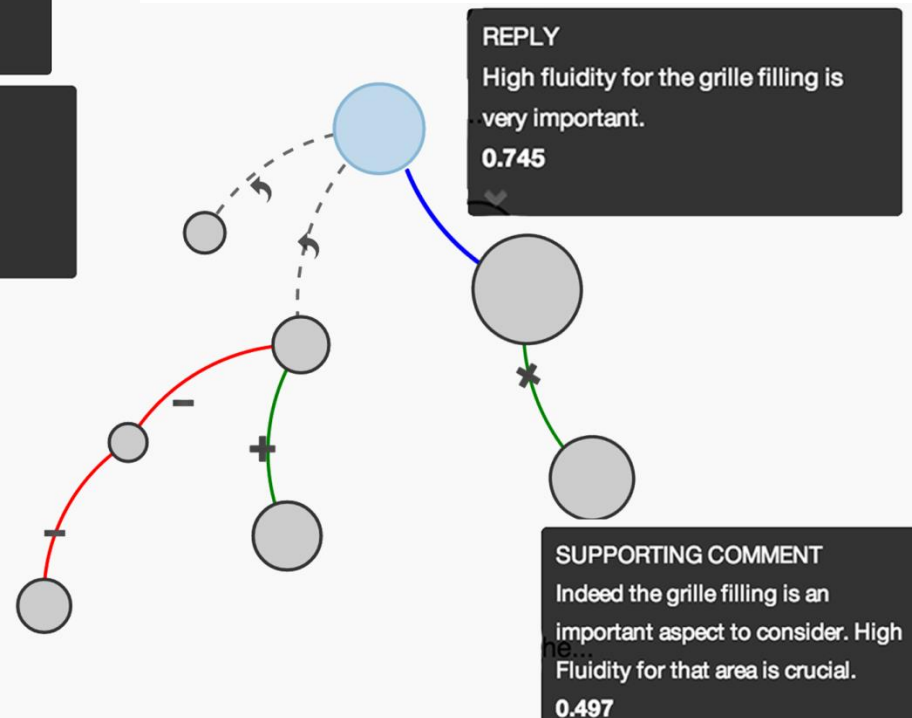


REUSE OF SLUDGE PRODUCED BY WASTEWATER TREATMENT PLANTS





Integration of past cases into debates



V. Evripidou, L. Carstens, F. Toni 2013-14

Acknowledgements and Thanks

Collaborators



Association for Logic Programming

COMMA - Computational Models of Argument

In particular...

Paolo Mancarella, Francesca Toni, and Franco Turini. Abduction and intensional negation in logic programming. In P. Asirelli, editor, *Proceedings of the 6th Italian Conference on Logic Programming (GULP 1991)*, pages 3–14, Pisa, Italy, 12–14 June 1991.

Antonis C. Kakas, Robert A. Kowalski, and Francesca Toni. Abductive logic programming. *Journal of Logic and Computation*, 2(6):719–770, 1992.

Andrei Bondarenko, Phan Minh Dung, Robert A. Kowalski, and Francesca Toni. An abstract, argumentation-theoretic approach to default reasoning. *Artificial Intelligence*, 93(1–2):63–101, 1997.

Foto Afrati, Manolis Gergatsoulis, and Francesca Toni. Linearisability on datalog programs. *Theoretical Computer Science*, 308(1-3):199–226, 2003.

Fariba Sadri and Francesca Toni. Abduction with negation as failure for active and reactive rules. In E. Lamma and P. Mello, editors, *AI*IA 99: Advances in Artificial Intelligence*, number 1792 in Lecture Notes in Computer Science, pages 49–60. Springer Verlag, 2000. Revised Papers, 6th Congress of the Italian Association for Artificial Intelligence (AI*IA 1999), 14–17 September 1999,

PhD students

**Semantic Integration of
Information by Abduction**

Ioannis Xanthakos

**Argumentation Accelerated
Reinforcement Learning**

Yang Gao

**Negotiating Socially Optimal Allocations of
Resources with Argumentation**

Adil Hussain

Argumentation and Normative Reasoning

Dorian Gaertner

**The CIFF Proof Procedure for Abductive Logic
Programming with Constraints: Definition,
Implementation and a Web Application**

Giacomo Terreni

**Argumentation as a practical foundation
for decision theory**

**Assumption-based Argumentation
Dialogues**

Xiuyi Fan

USING ARGUMENTATION TO IMPROVE
CLASSIFICATION IN NATURAL LANGUAGE
PROBLEMS

Lucas Carstens

**Quaestio-it - Supporting Online Debates
with Argumentation**

by

VALENTINOS EVRIPIDOU

PAUL-AMAURY MATT

**ABA & ASPIC+ VERSUS
ASP & DEFAULT THEORY**

COMPARING AND COMBINING ARGUMENTATION
FRAMEWORKS AND OTHER NON-MONOTONIC
REASONING SYSTEMS

BY

CLAUDIA SCHULZ

DETECTION OF MALICIOUS USER BEHAVIOUR
IN SOCIAL NETWORKS

**Default Reasoning with Preferences and
Its Connection to Argumentation**

Kristijonas Čyras

Author:
OANA COCARASCU

Supervisor:
FRANCESCA TOMI

**Evaluation Algorithms in Quantitative
Argumentation Frameworks and Their
Applications**

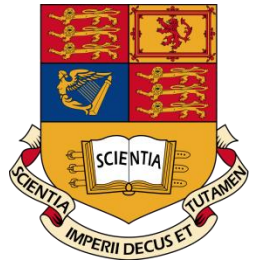
Author:
Antonio RAGO

Supervisors:
Prof. Francesca TOMI
Dr. Marco AURISICCHIO



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Early Years Education Centre

Funding



Ministero dell'Istruzione, dell'Università e della Ricerca

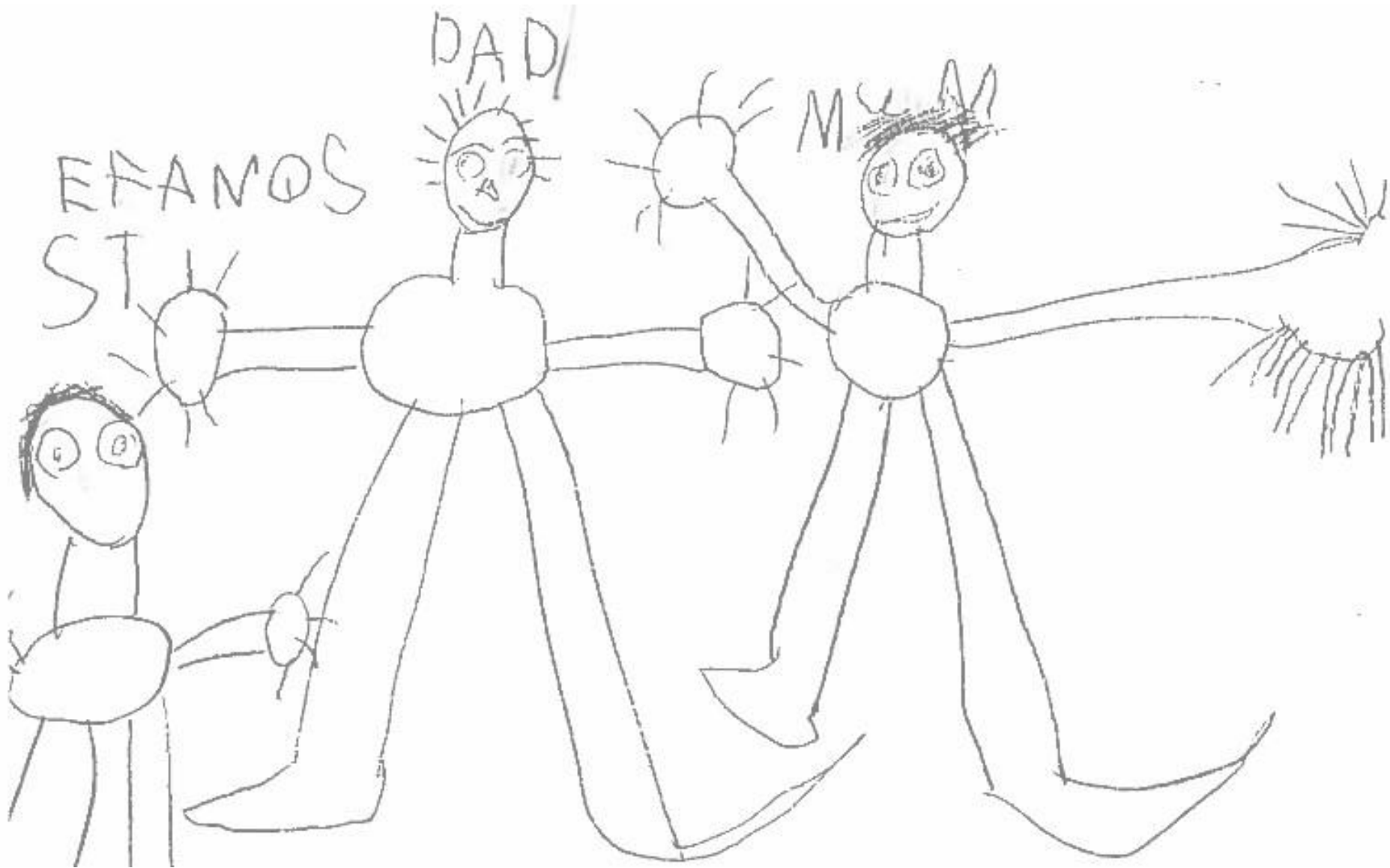


Transparent Rational Decisions by Argumentation (TRaDAr)



**Imperial College
London**

Family and Friends





AAMAS 2002



2003



GC 2004

Francesca Toni, Kostas Stathis:

Access-as-you-need: A Computational Logic Framework for Accessing Resources in Artificial Societies. ESAW 2002: 126-140

Kostas Stathis, Francesca Toni:

Ambient Intelligence Using KGP Agents. EUSAI 2004: 351-362





Don't you have homework?

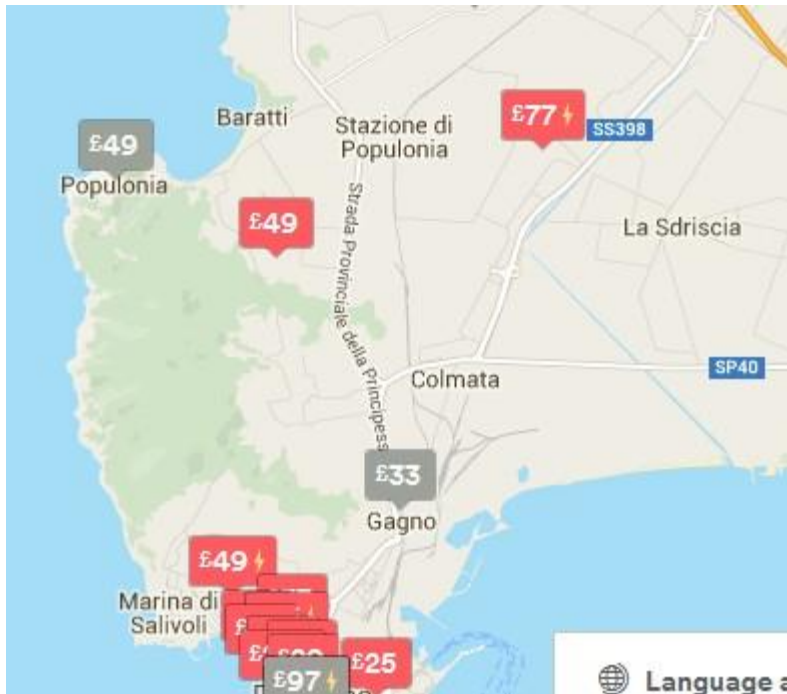
Yes, but I need to relax first...

?%#@!!!

better and more

Can a machine ~~ever~~ argue?

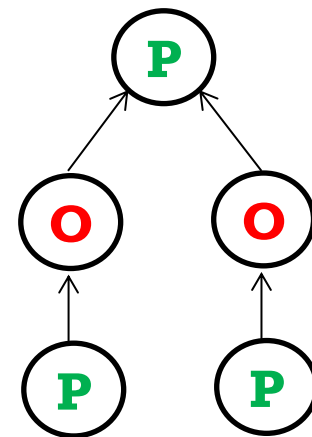
Informative Machine-Human Interaction



40-50 €
small, 20 €
small, wireless, 45 €

Argumentation-based Explanations

- Dispute trees as a basis for explanations
- in natural language
- for Medicine, Law



Proponent



Opponent

Mocanu, Fan, Toni, Williams, Chen 2014-16

Zhong, Fan, Toni, Luo 2014

TRaDAR **EPSRC**

Schulz, Toni 2015; Fan, Toni 2015

Probabilistic argumentation

Am I eligible to claim for UK & European Breakdown & Recovery Assistance?

You need to think about whether the insurance meets your needs and whether you can claim when you need to.

<p>You are covered for:</p> <ul style="list-style-type: none">✓ UK and European Breakdown Assistance for account holder(s) in any private car that they are travelling in✓ Anyone driving a private car registered to the account holder and which is being used with his/her permission. Where the account is in joint names then up to 2 private cars can be covered✓ Assistance provided at home and on the roadside with national recovery and onward travel✓ No call out limit✓ No excess payable	<p>You are not covered for:</p> <ul style="list-style-type: none">• The cost of replacement parts and associated labour to repair the vehicle• Private cars not registered to the account holder(s) unless the account holder(s) are in the vehicle at the time of the breakdown• Motorcycles, motorhomes, caravanners, commercial vehicles (all types), vans, pick up trucks and vehicles being used for hire and reward purposes (such as taxis)• Vehicles that do not have a valid MOT or are not serviced or maintained in line with manufacturer guidelines• Vehicles that are more than 7 metres in length, 2.3 metres wide, 3 metres high and weigh more than 3.5 tonnes when fully loaded
---	--



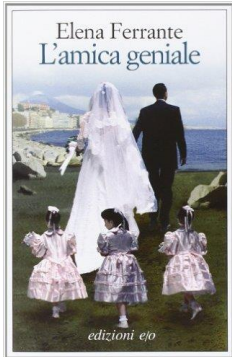
rules (breakdown cover policy)

data (account holders' claims)

Probability of an account holder breaking down when not travelling in own car?

Probabilistic arguments (how likely that an account holder will be covered?) supported by **assumptions** and **random variables**

Argument mining



This was a wonderful book and probably the best that I have read this year. Both the portrayal of the girls' friendship, and of the community they come from, are complex, detailed, realistic and

I really wanted to like this but I just can't. To my mind it just goes on and on into endless detail.

This book was an unexpected treat purchased as something light to read on the train I was immediately drawn in and impatient to get back to it. It is a tale of childhood, friendship, poverty overshadowed by post war paranoia. The friends are cleverly depicted. Lila the shoemaker's daughter is bright precocious a natural leader - even at 5 years of age, Lena the porter's daughter quiet studious well behaved is enthralled and frightened by her friend. There is an excellent cast of characters the brothers with a car who may have Mafia connections, the grocers children whose father may have collaborated with the nazis, the delusional neighbour obsessed with the local poet. It is a subtle book a lot is inferred but little is confirmed so I constantly felt I was missing something and flicking back. My only caveat is the names, there are a lot of similar

Really struggled with this, found characters names confusing and the style very rambling.

Deceptive behaviour



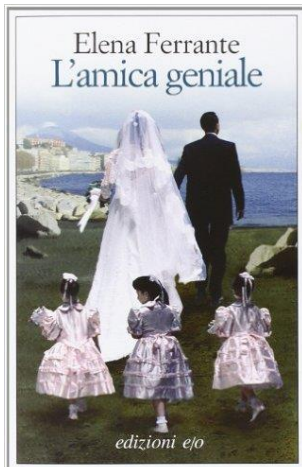
LIE

← Lovely book, I liked the bit when they travel to Andros:
what a lovely island, and not too busy at all in August!



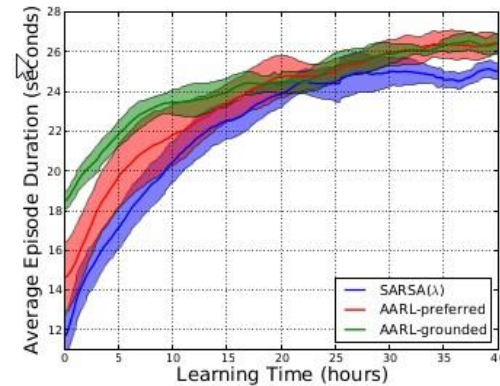
But nobody travels to Andros in the book!

OMISSION



Integrating qualitative + quantitative reasoning

Reinforcement learning



(a) 2-Keepaway

Gao, Toni (2012-15)

Cross-domain sentiment analysis

(A): standard classifier

(B): standard classifier+
argumentation

Classifier	Method	Precision	Recall	F1	Accuracy
Naive Bayes*	(A)	.51	.50	.51	.50
	(B)	.65	.64	.65	.64
Random Forest	(A)	.56	.51	.53	.51
	(B)	.65	.64	.65	.64
Support Vector Machines	(A)	.51	.50	.51	.50
	(B)	.65	.64	.65	.64

Carstens, Toni 2015

The future?



photo by Giulia

Are you joking?
Clean it yourself!



Thank you

