Modeling and Solving Weighted Bipolar Argumentation Problems

Tutorial at the 42nd German Conference on Artificial Intelligence (KI 2019)

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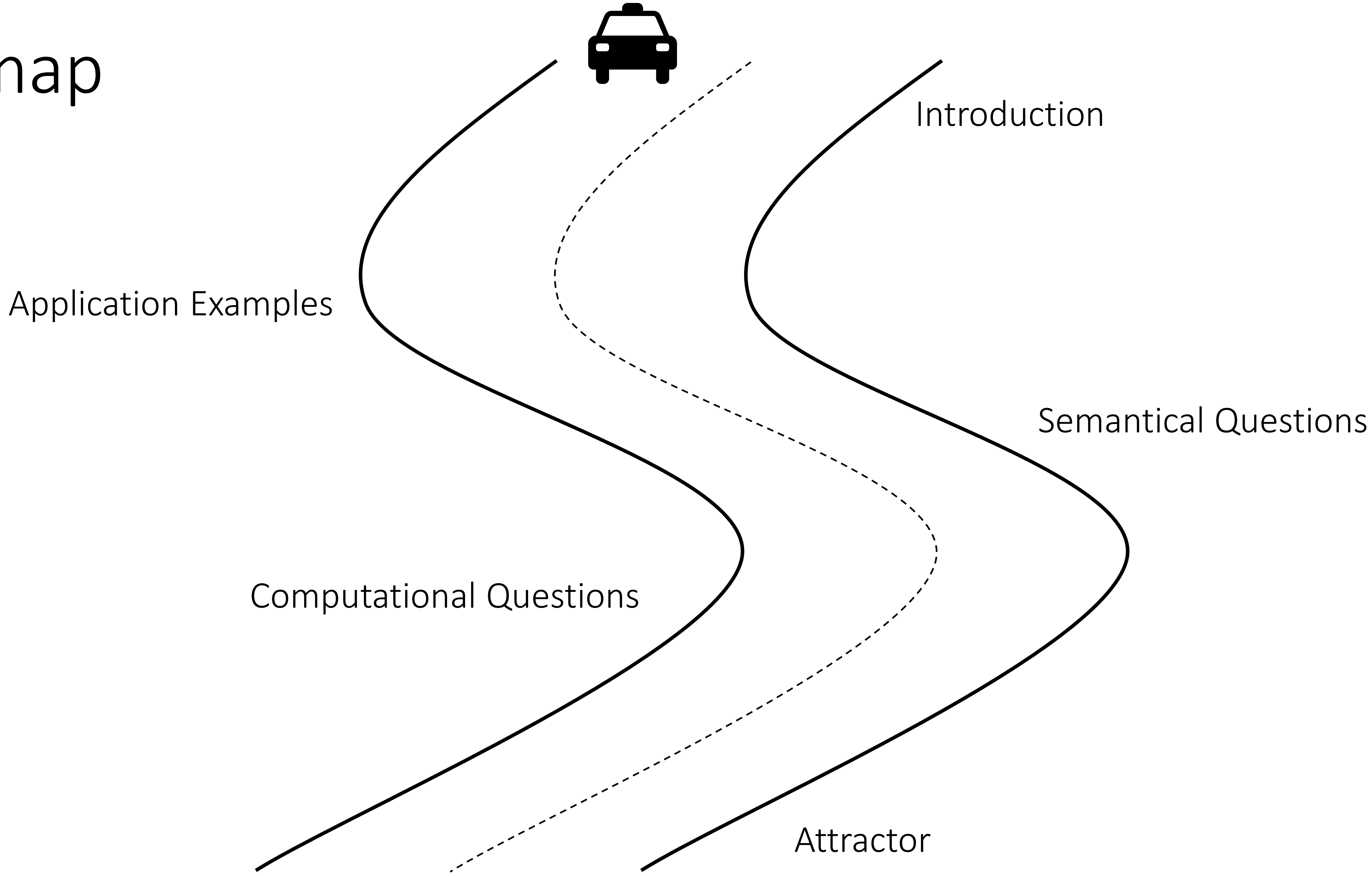
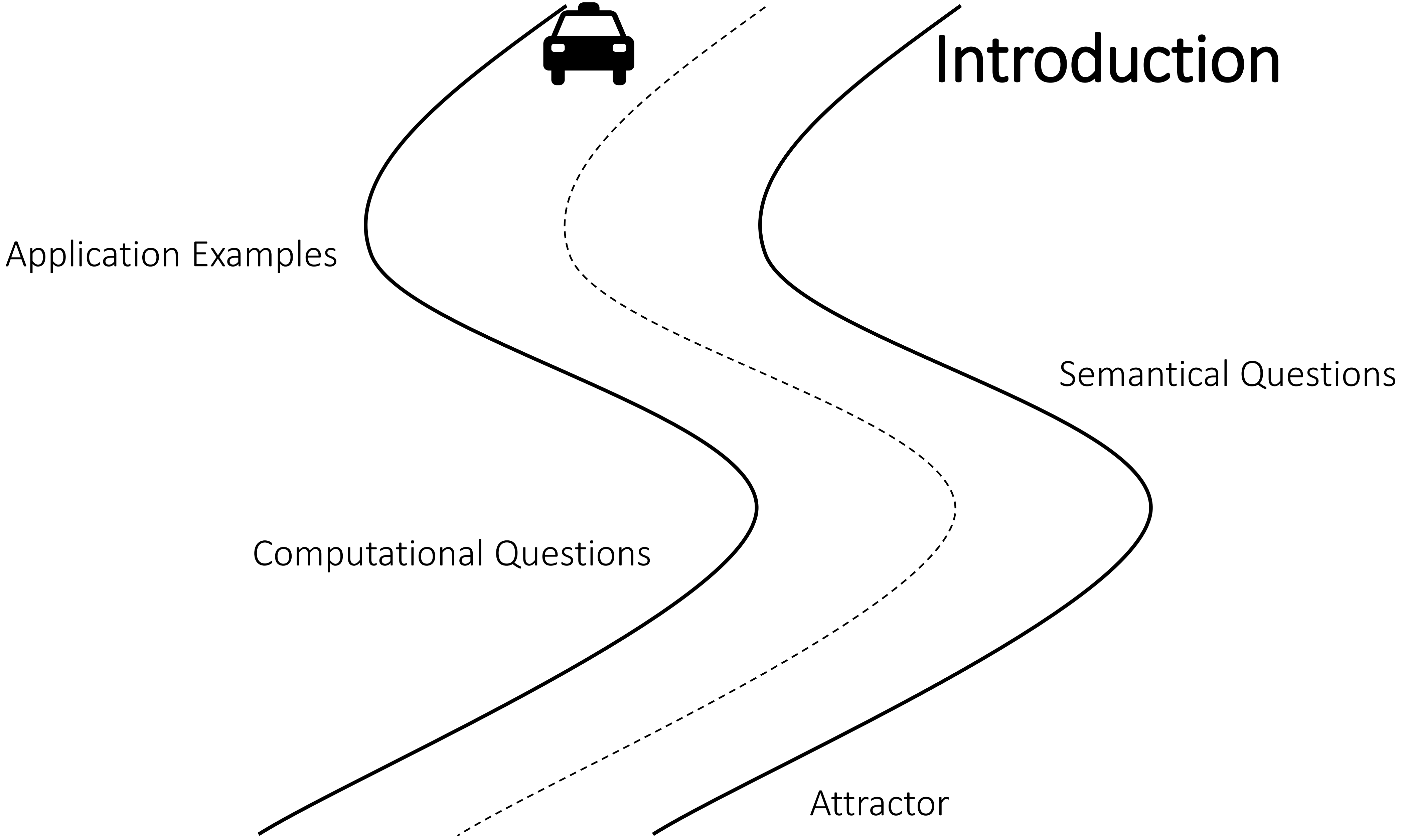
INSTITUT FÜR KOGNITIONSWISSENSCHAFT
Institute of Cognitive Science

Roadmap


Introduction
Application Examples
Semantical Questions
Computational Questions
Attractor

Introduction

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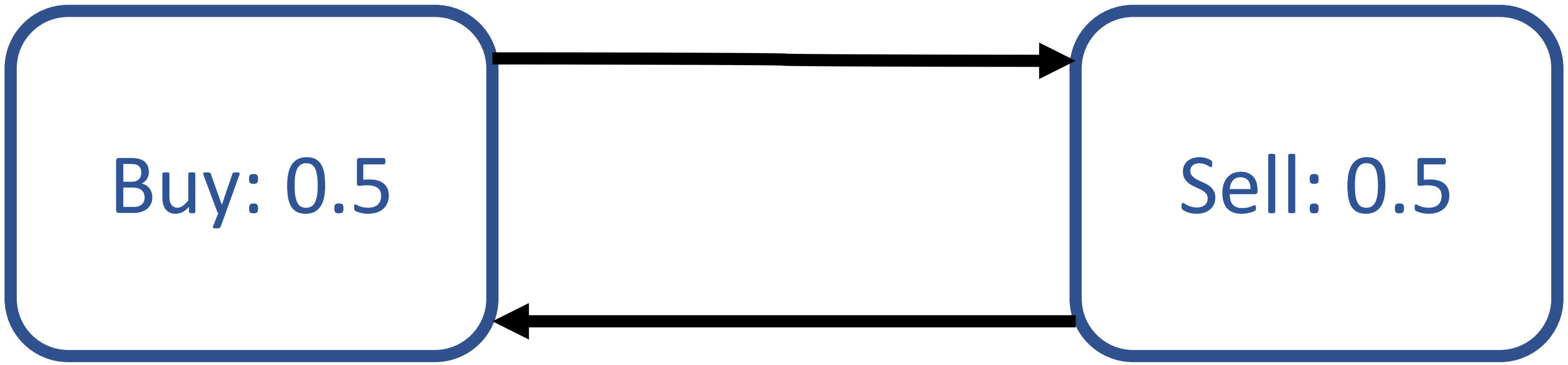
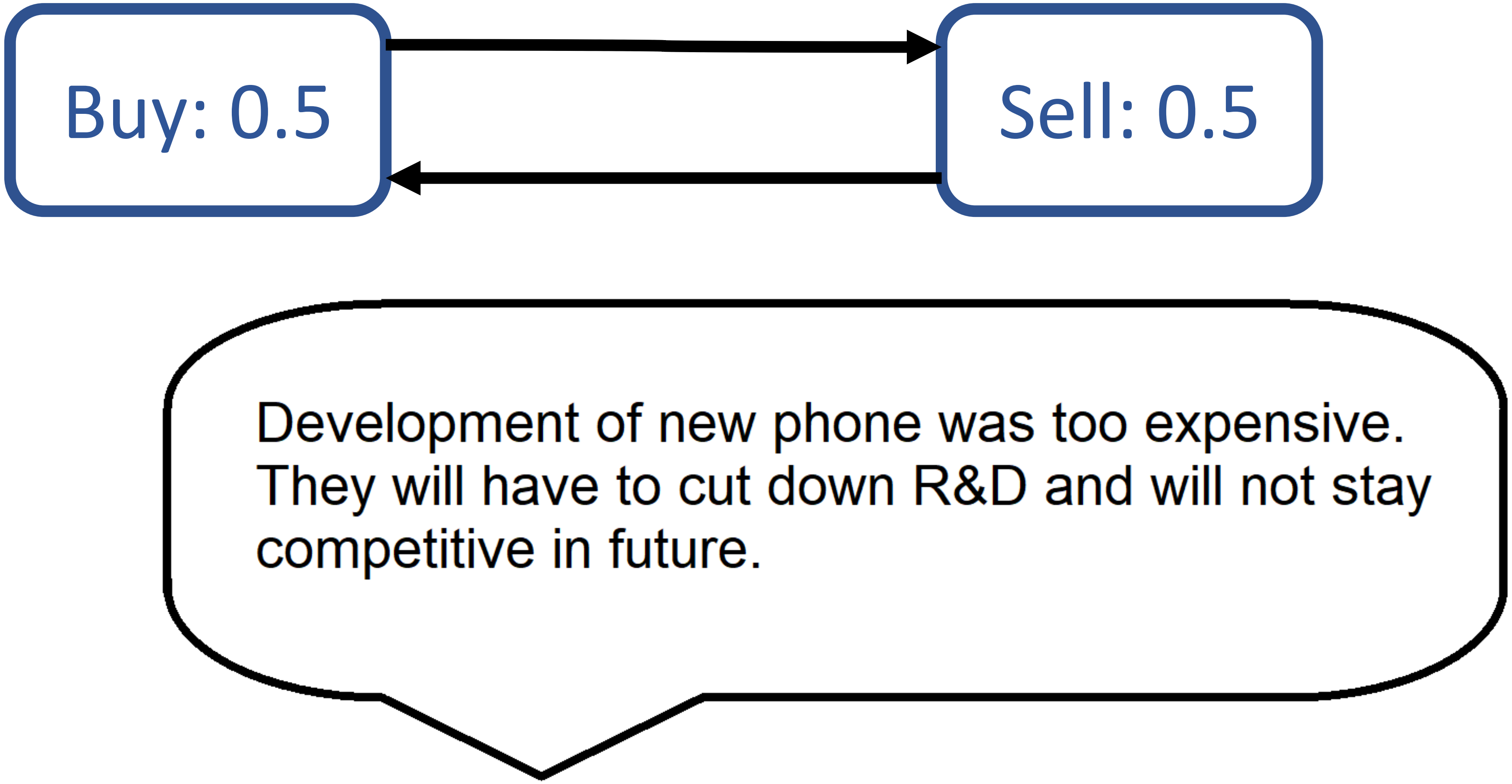
Buy?
Sell?

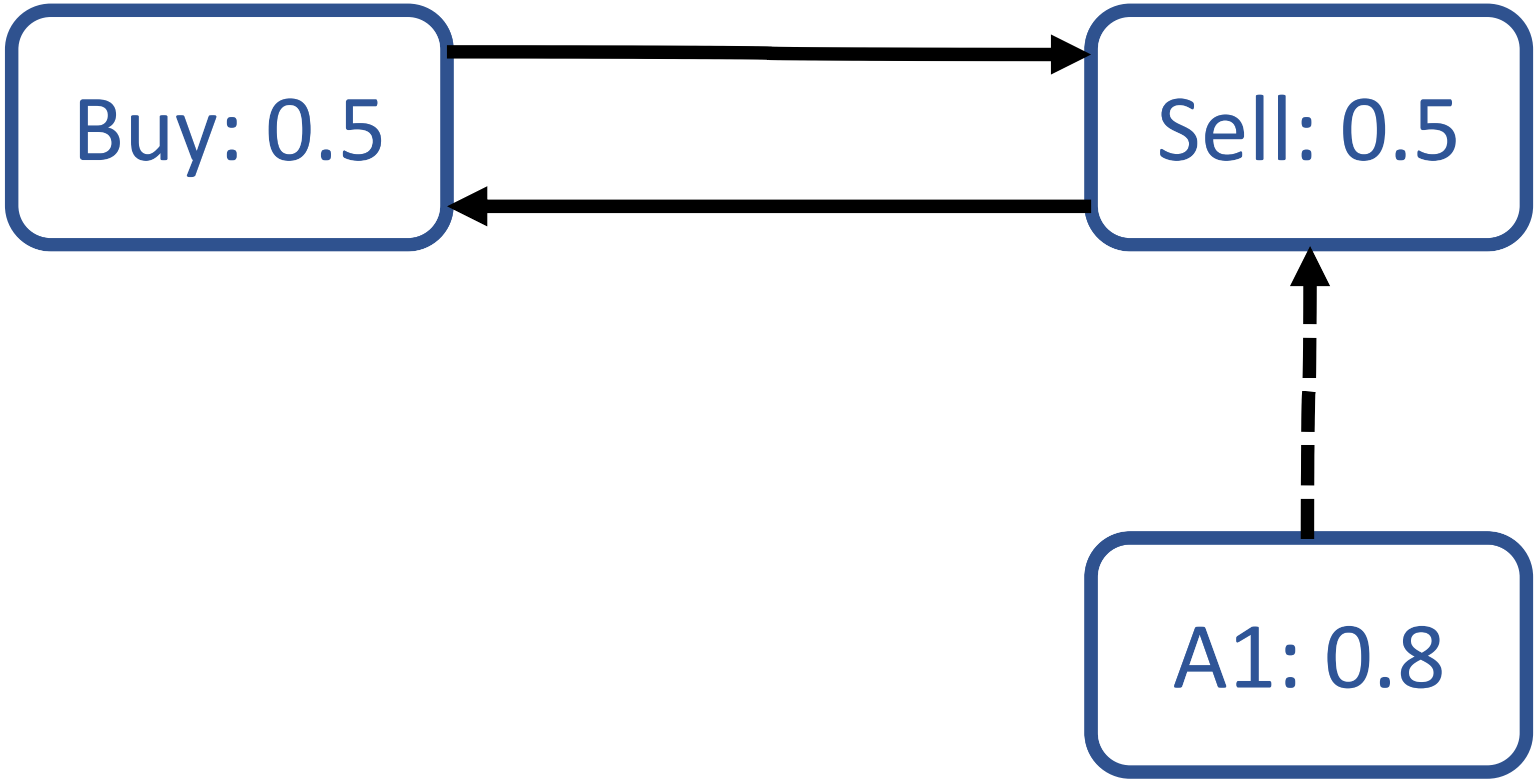
Buy: 0.5

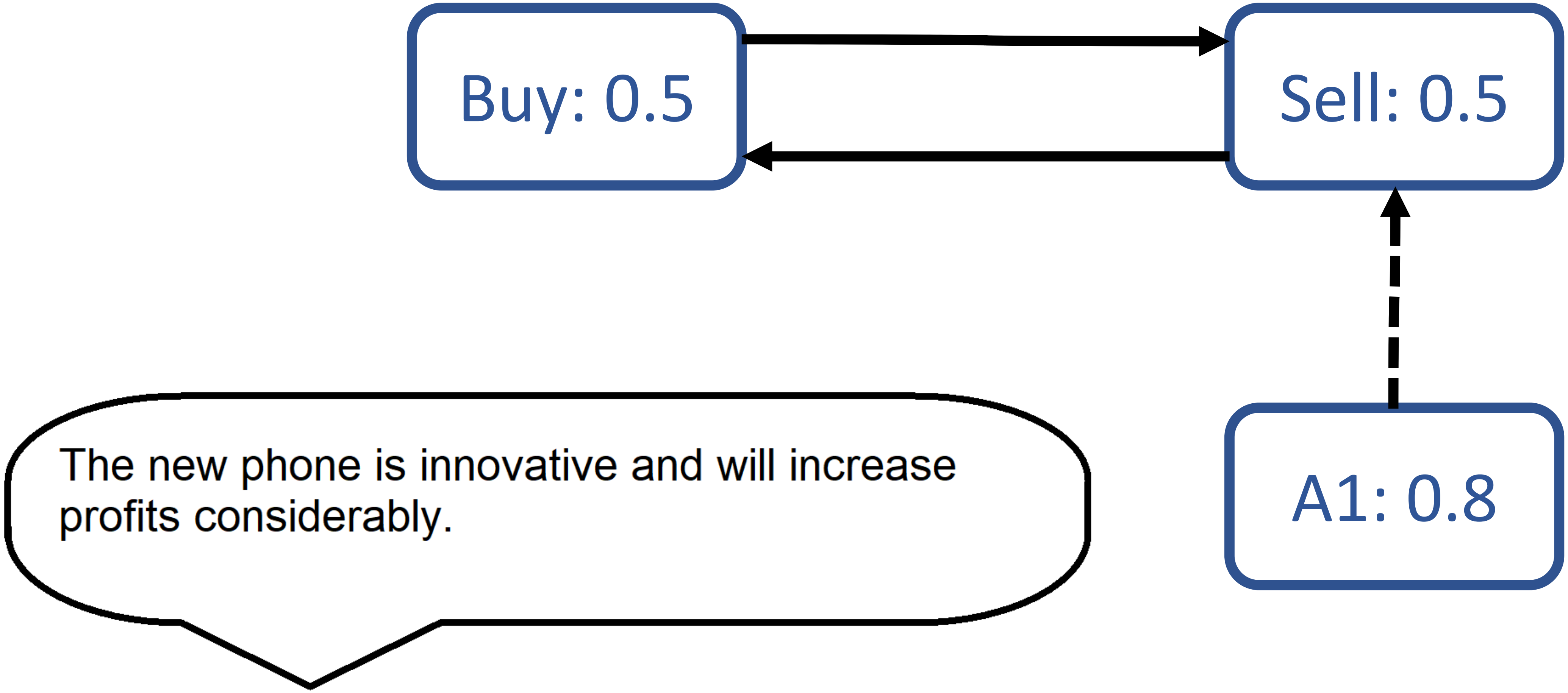
Sell: 0.5

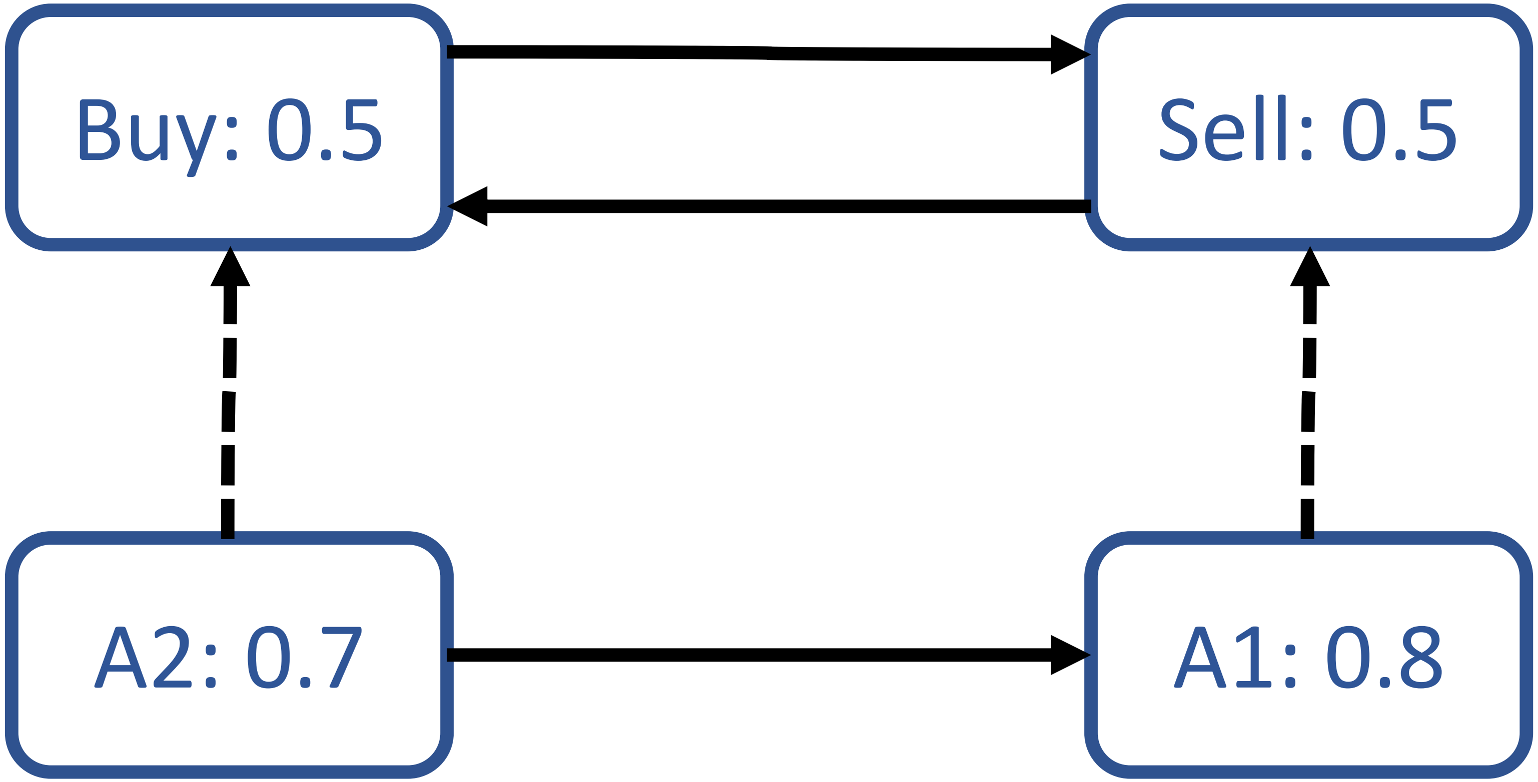


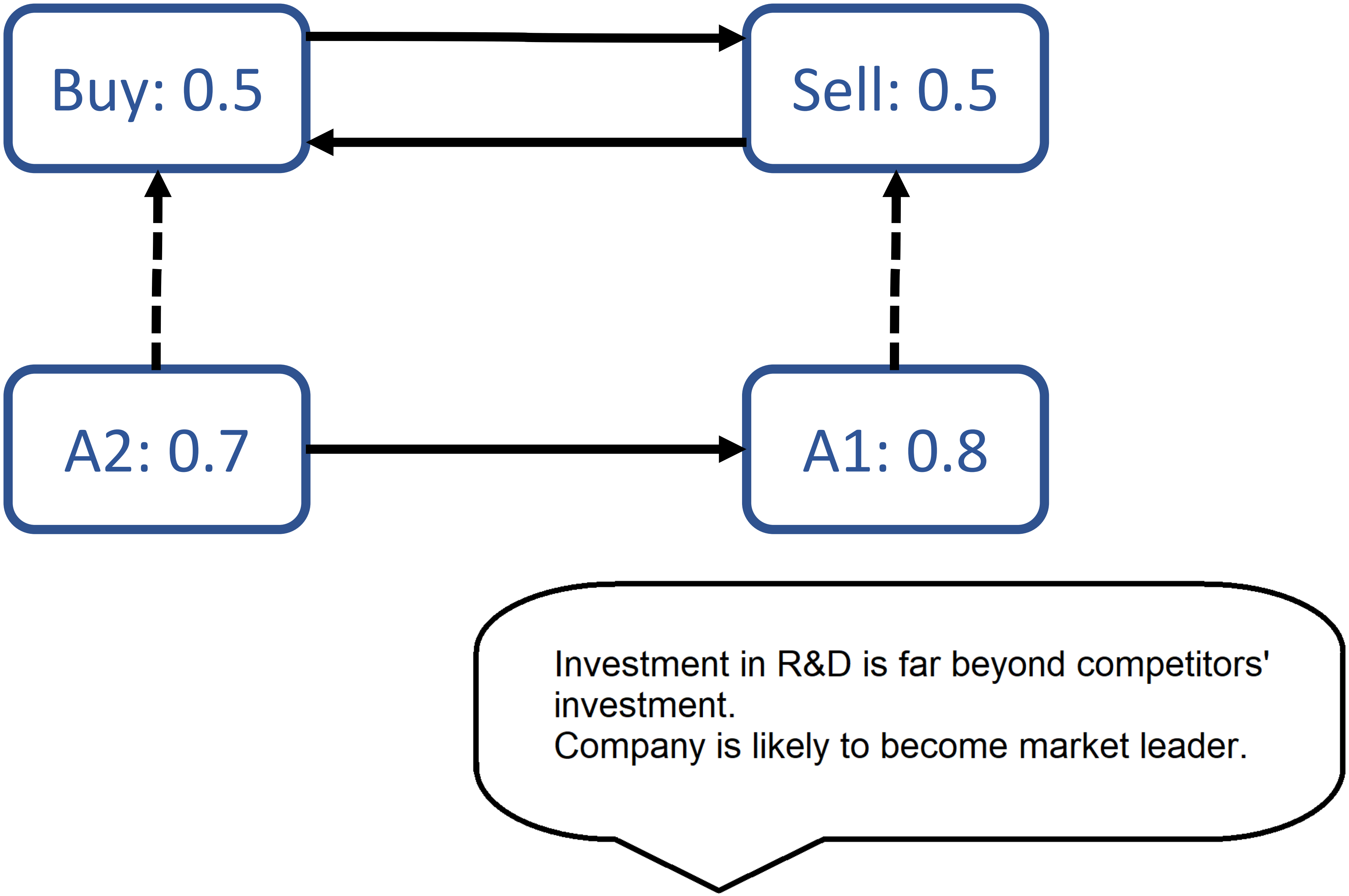
Buy: 0.5
Sell: 0.5

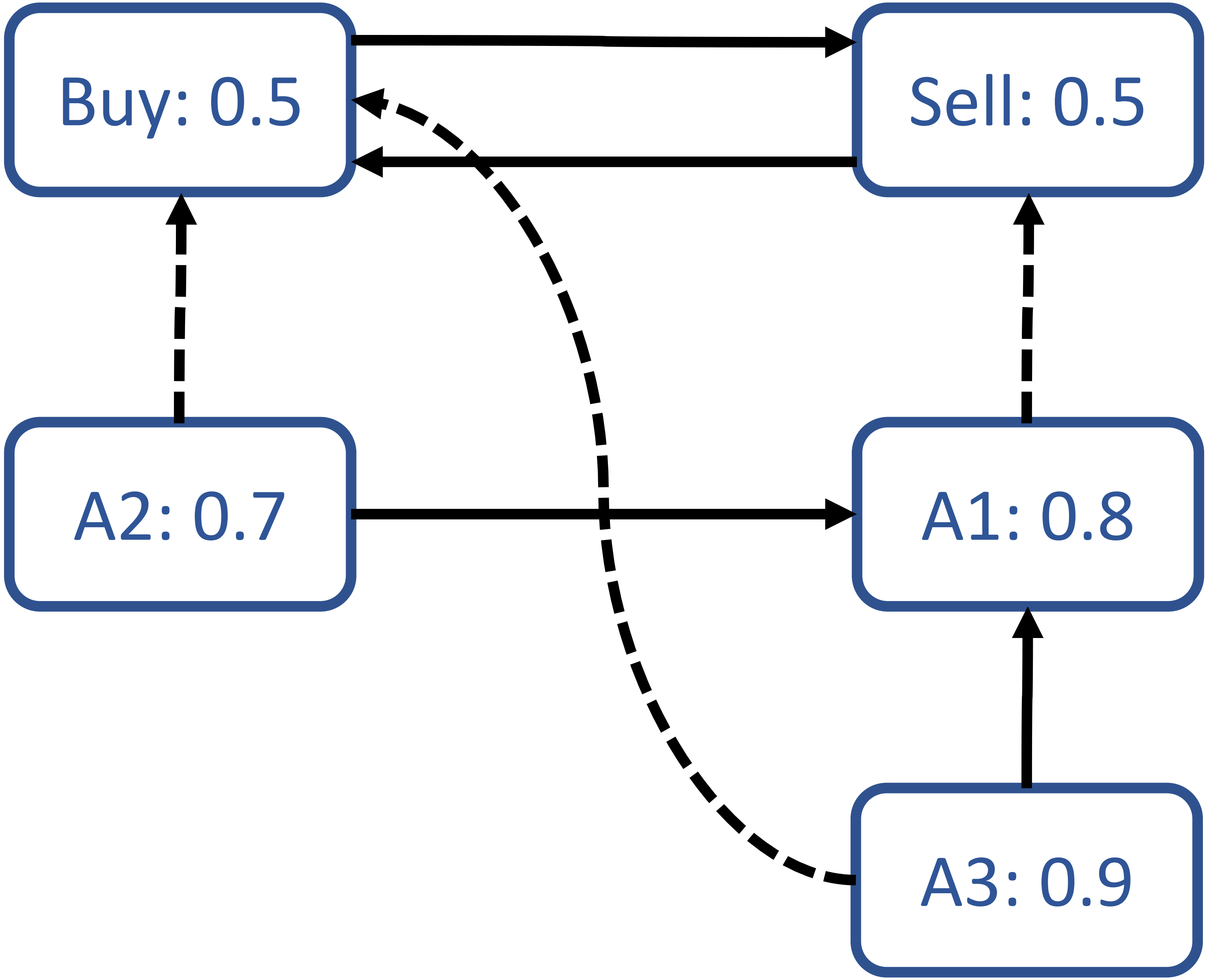

Buy: 0.5
Sell: 0.5
Development of new phone was too expensive. They will have to cut down R&D and will not stay competitive in future.


Buy: 0.5
Sell: 0.5
A1: 0.8


Buy: 0.5
Sell: 0.5
A1: 0.8
The new phone is innovative and will increase profits considerably.

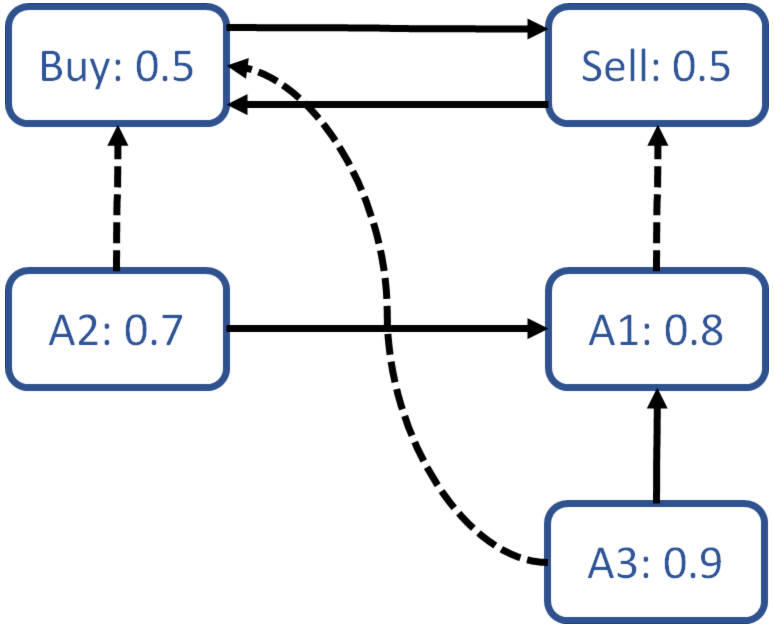

Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.8


Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.8
Investment in R&D is far beyond competitors' investment.
Company is likely to become market leader.


Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.8
A3: 0.9

Weighted Bipolar Argumentation Graph (BAG)

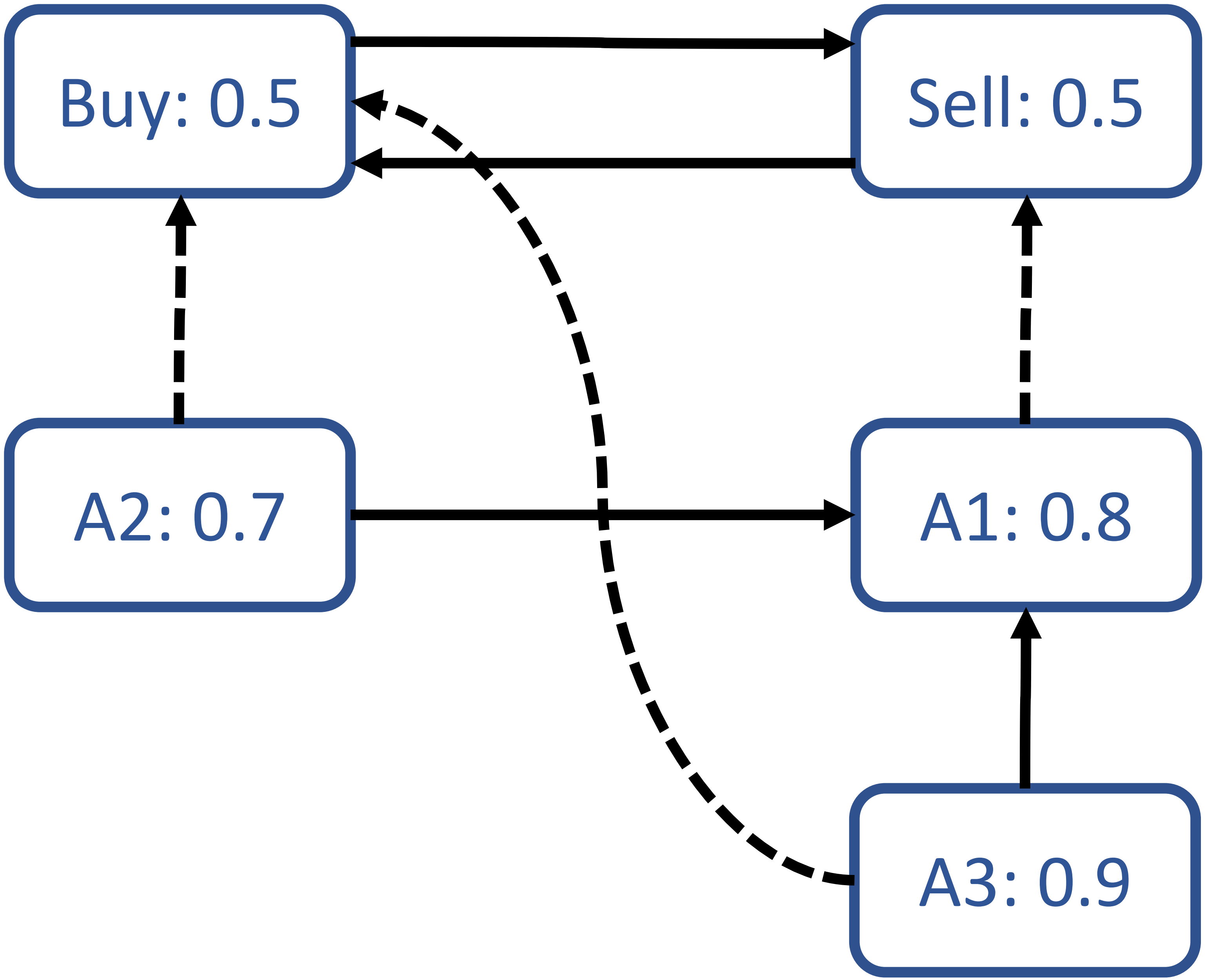
- Set of arguments
- Initial weights
- Attack and support relation

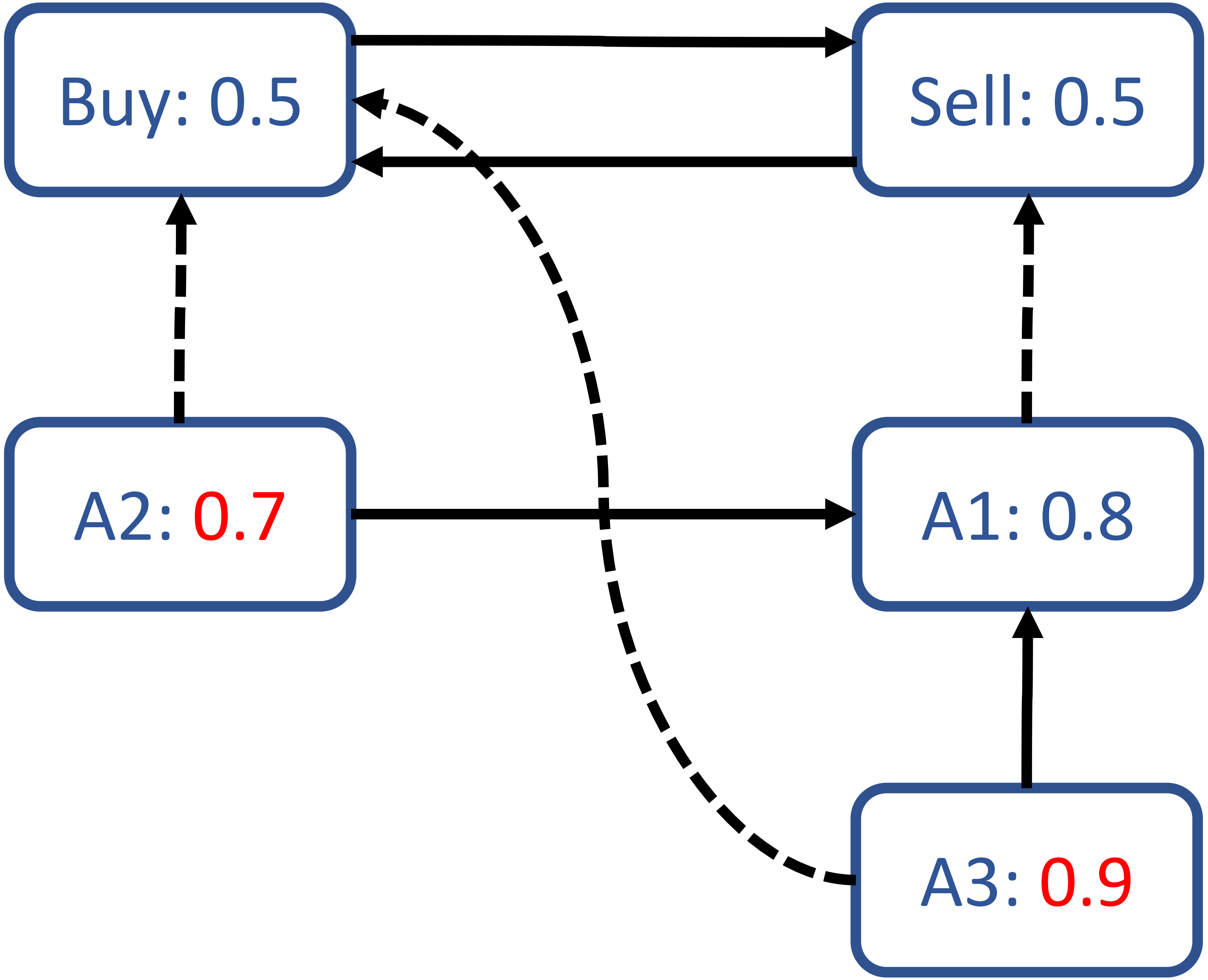


Semantics: define final strength of arguments based on

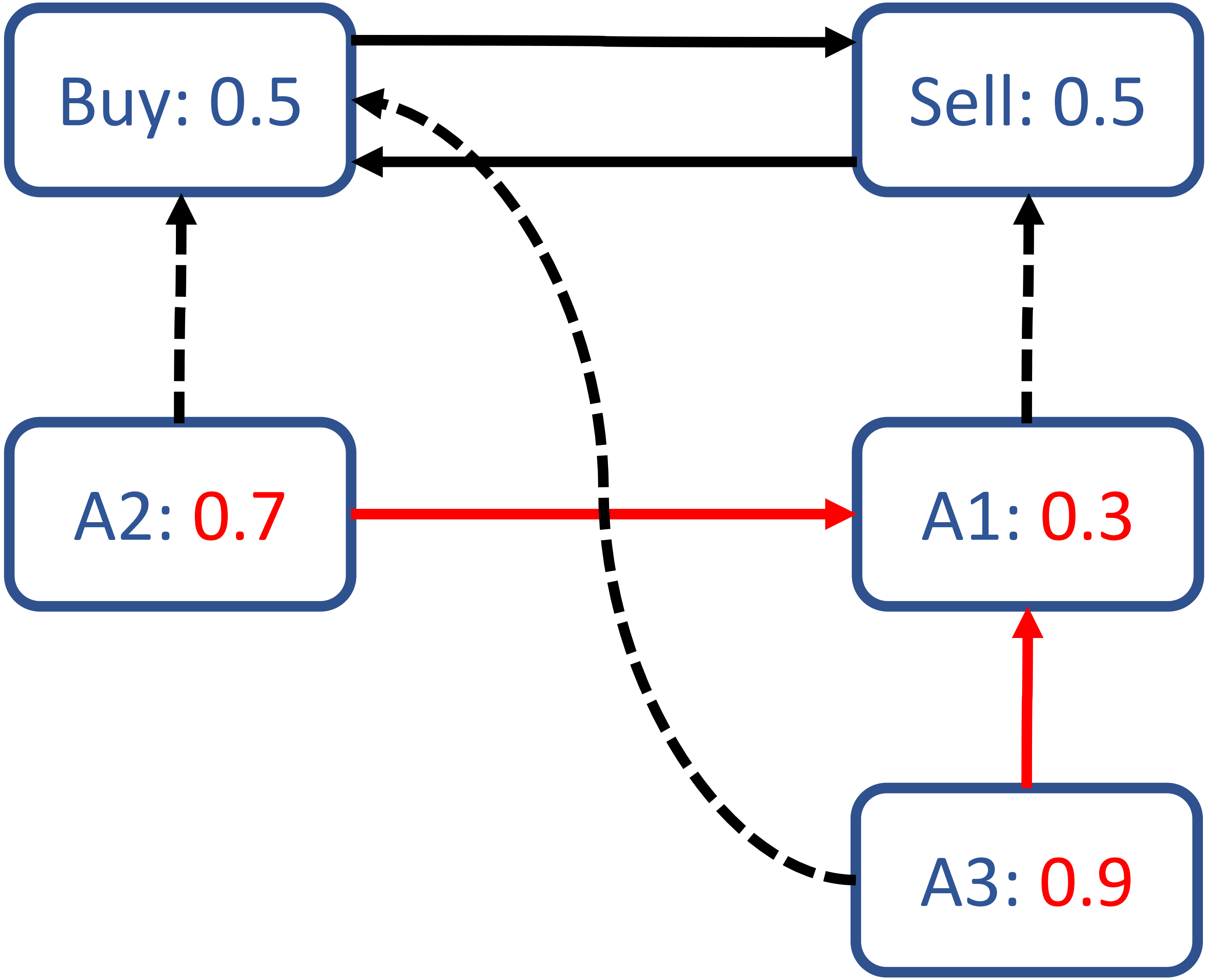
- Initial weights and
- Strength of parents

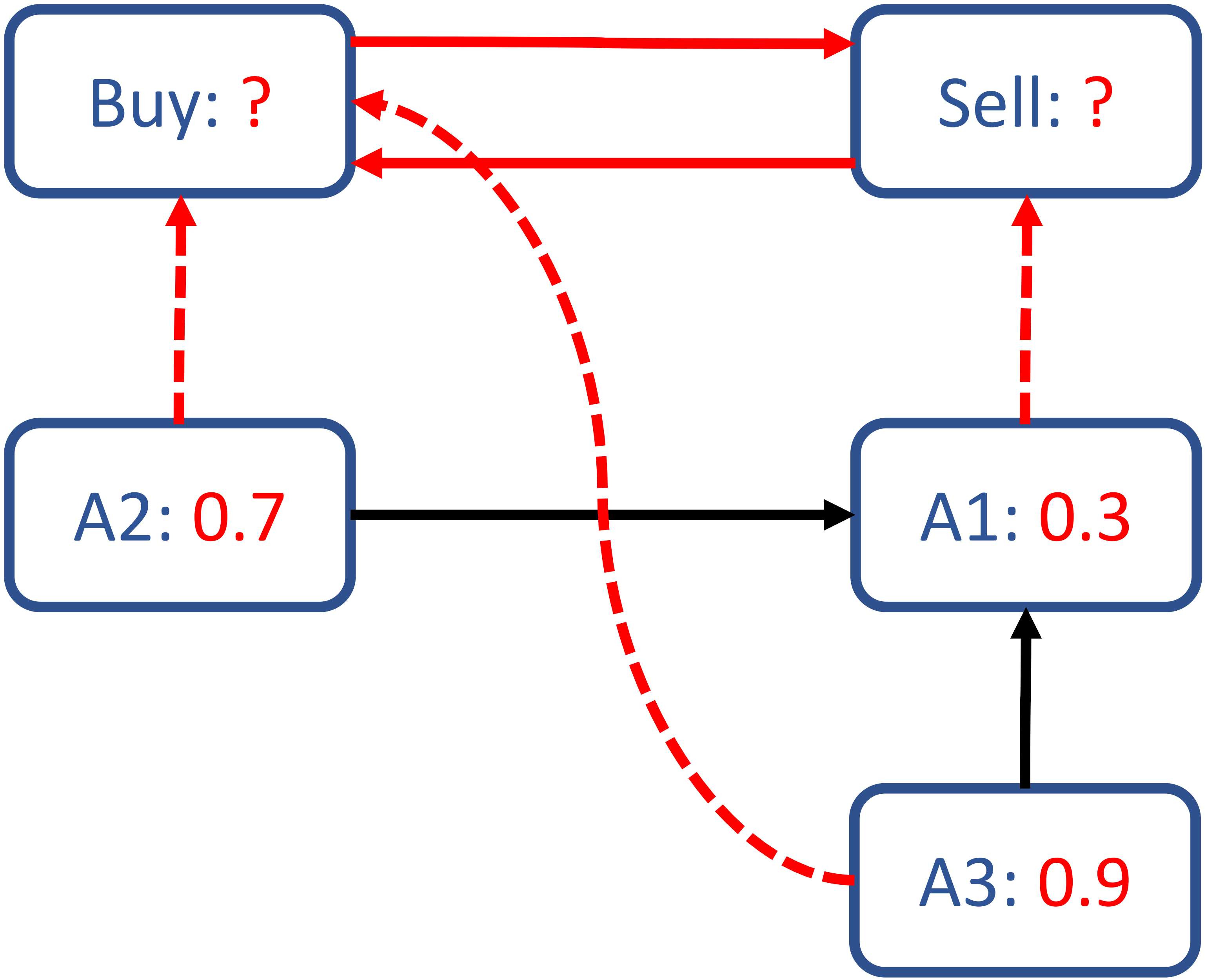
s(i) = f(w(i), Parents(i))


Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.8
A3: 0.9



Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.8
A3: 0.9


Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.3
A3: 0.9

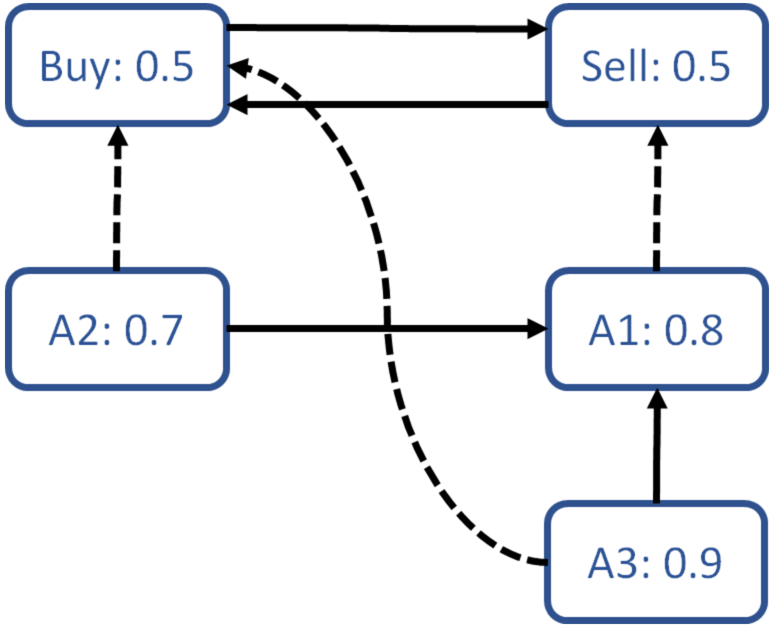


Buy: ?
Sell: ?
A2: 0.7
A1: 0.3
A3: 0.9

Computing Strength Values in Acyclic BAGs

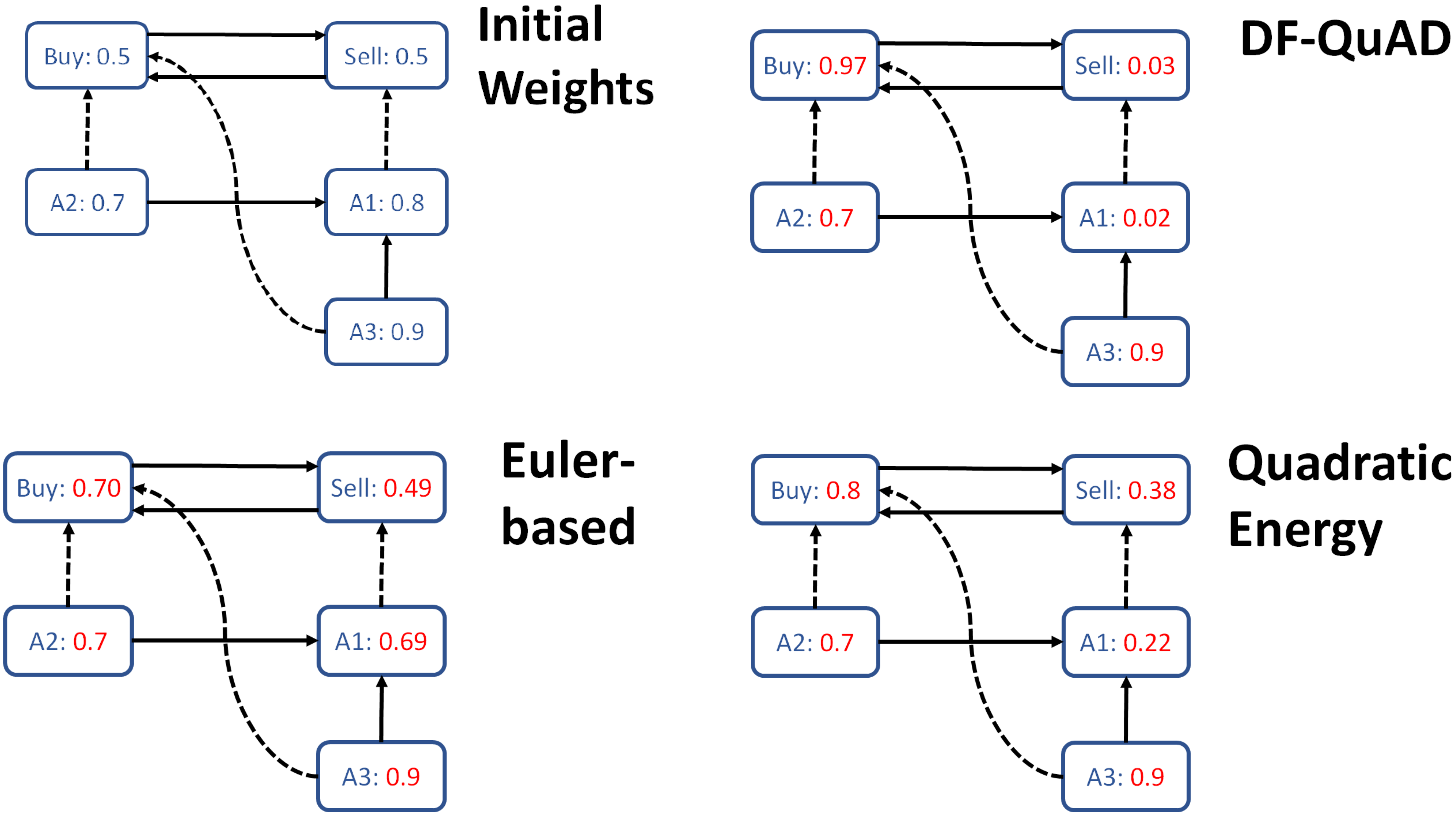
- Compute topological ordering
- Evaluate arguments in order

s(i) = f(w(i), Parents(i))



Computing Strength Values in Cyclic BAGs

- Set initial strength values to initial weights
- Update by applying update formula to all arguments simultaneously
- Repeat until process converges



Initial Weights
Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.8
A3: 0.9
DF-QuAD
Buy: 0.97
Sell: 0.03
A2: 0.7
A1: 0.02
A3: 0.9
Euler-based
Buy: 0.70
Sell: 0.49
A2: 0.7
A1: 0.69
A3: 0.9
Quadratic Energy
Buy: 0.8
Sell: 0.38
A2: 0.7
A1: 0.22
A3: 0.9

Semantical Questions

- What properties should final strength values satisfy?
- How can we satisfy these properties?

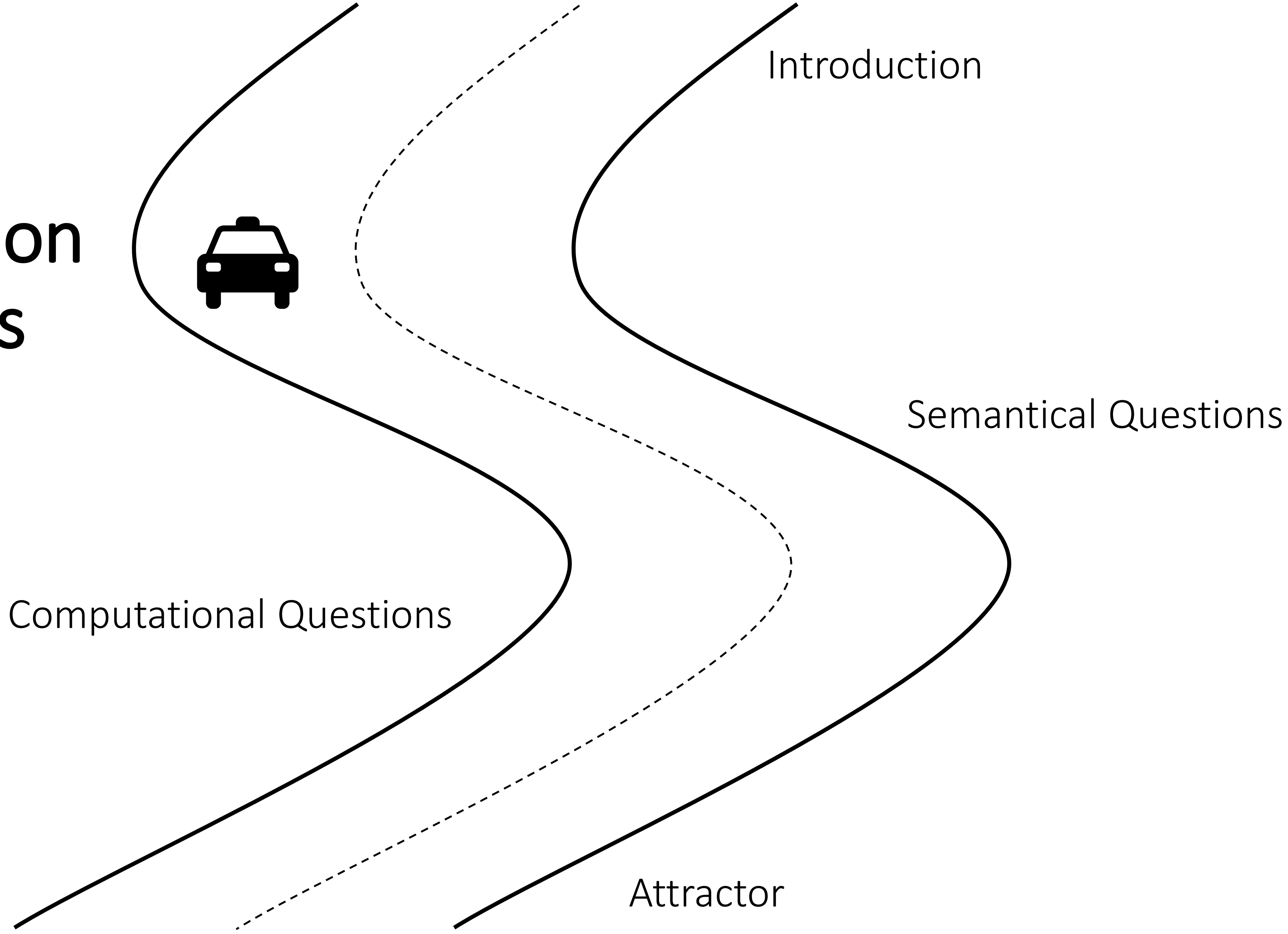
Computational Questions

- Does update process converge in cyclic BAGs?
- What is the computational performance/ complexity?

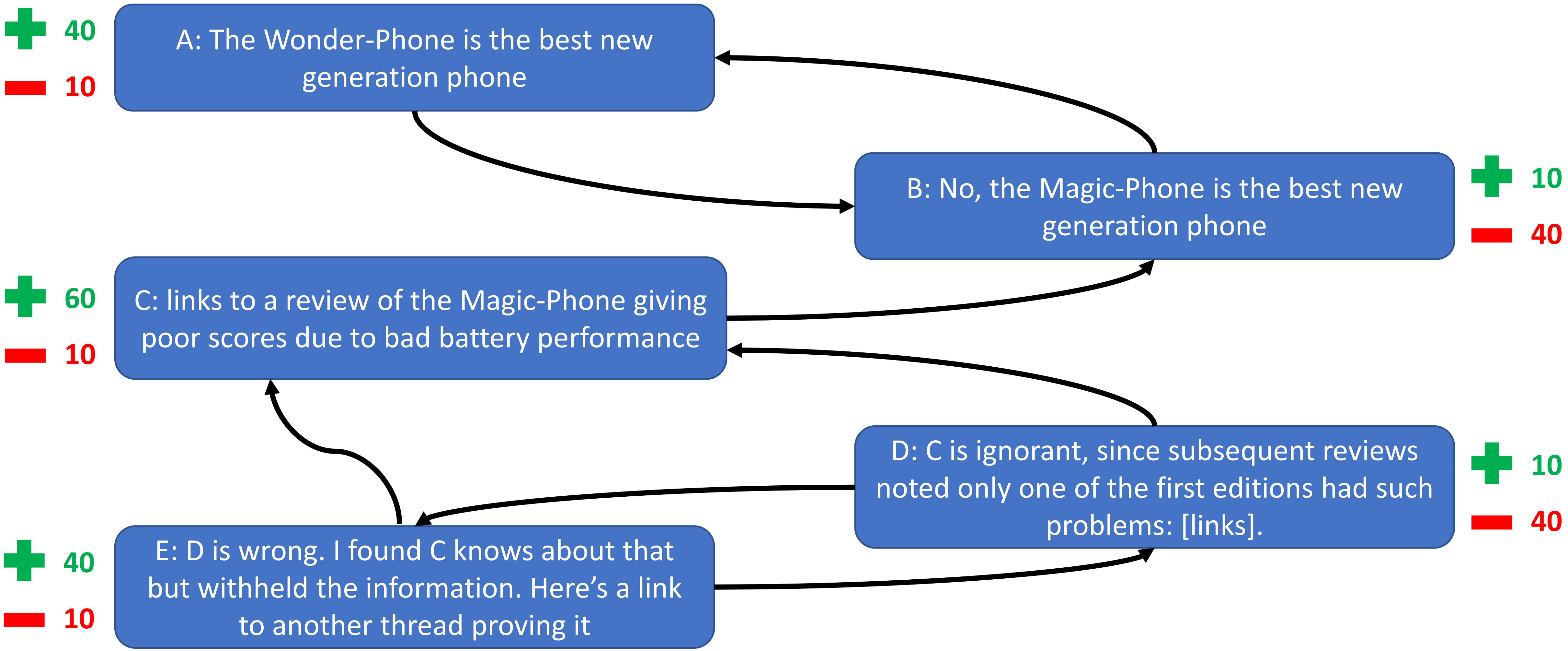
Applications

- Social Media Analysis
- Decision Support
- Explainable AI

Application Examples



Social Media Analysis (Leite & Martins 2011)



Leite, J., & Martins, J. Social abstract argumentation. In Twenty-Second International Joint Conference on Artificial Intelligence (IJCAI 2011). 2011.

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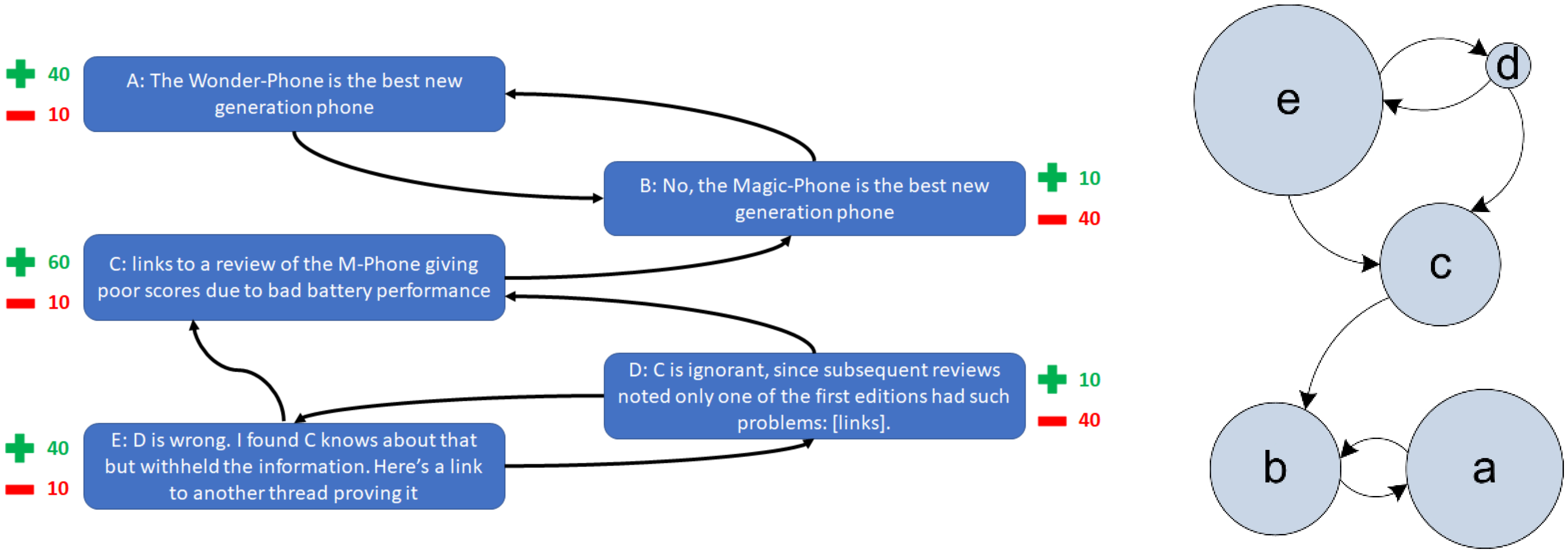


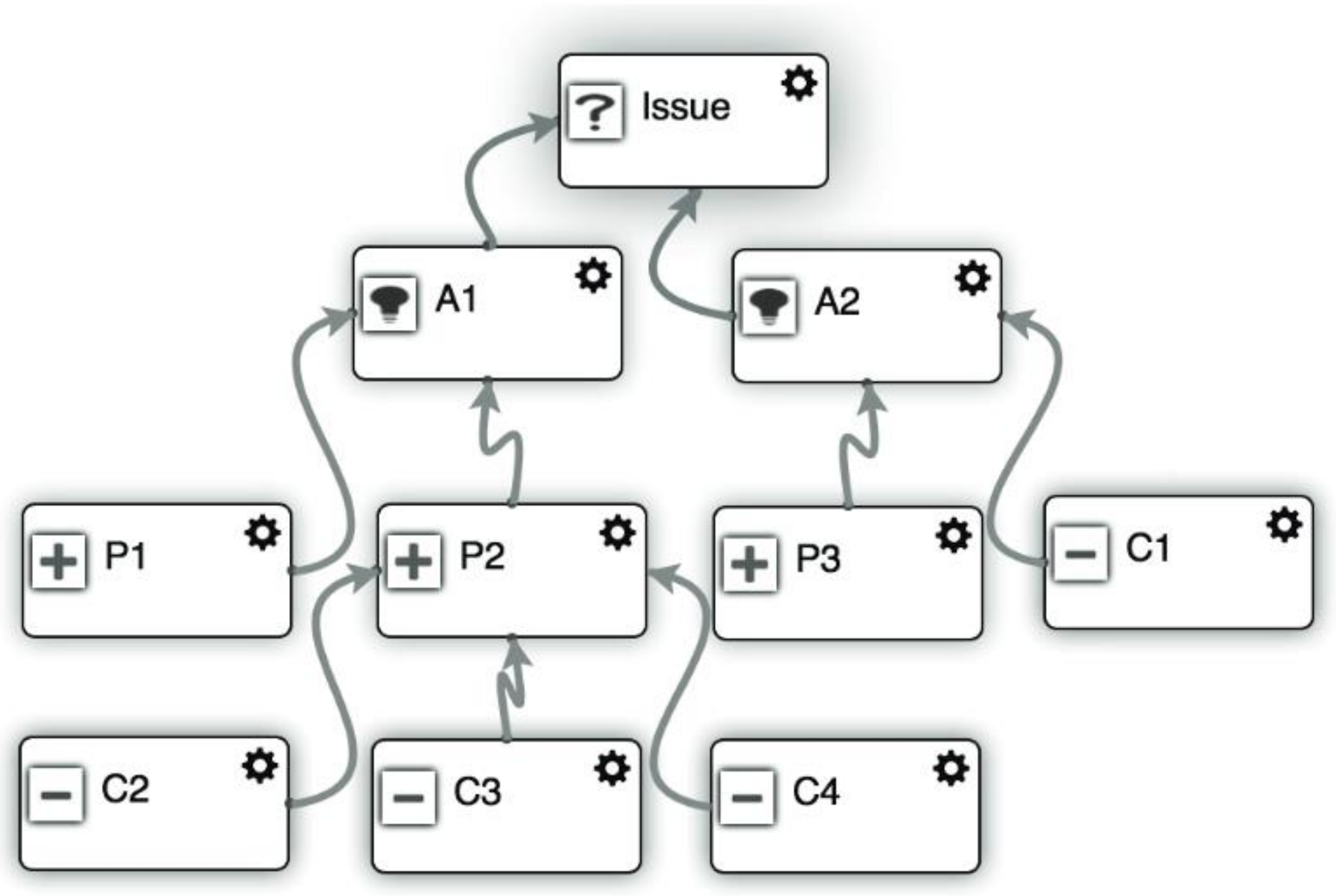
Leite, J., & Martins, J. Social abstract argumentation. In Twenty-Second International Joint Conference on Artificial Intelligence (IJCAI 2011). 2011.

Decision Support (Rago et al. 2016)

Issue

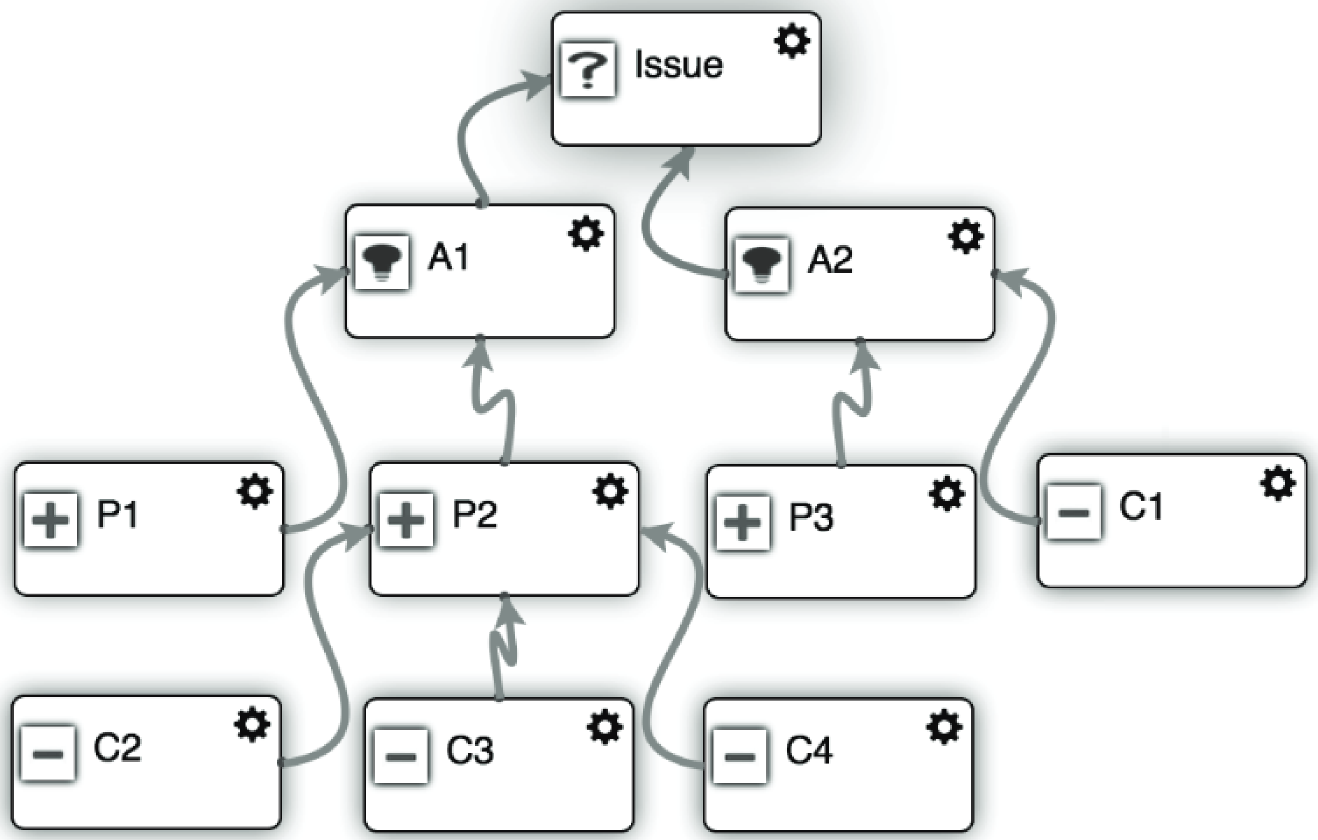
Alternatives

Pro and Con Arguments



Rago, A., Toni, F., Aurisicchio, M., & Baroni, P. Discontinuity-free decision support with quantitative argumentation debates. In Fifteenth International Conference on the Principles of Knowledge Representation and Reasoning (KR 2016). 2016.

Decision Support (Rago et al. 2016)



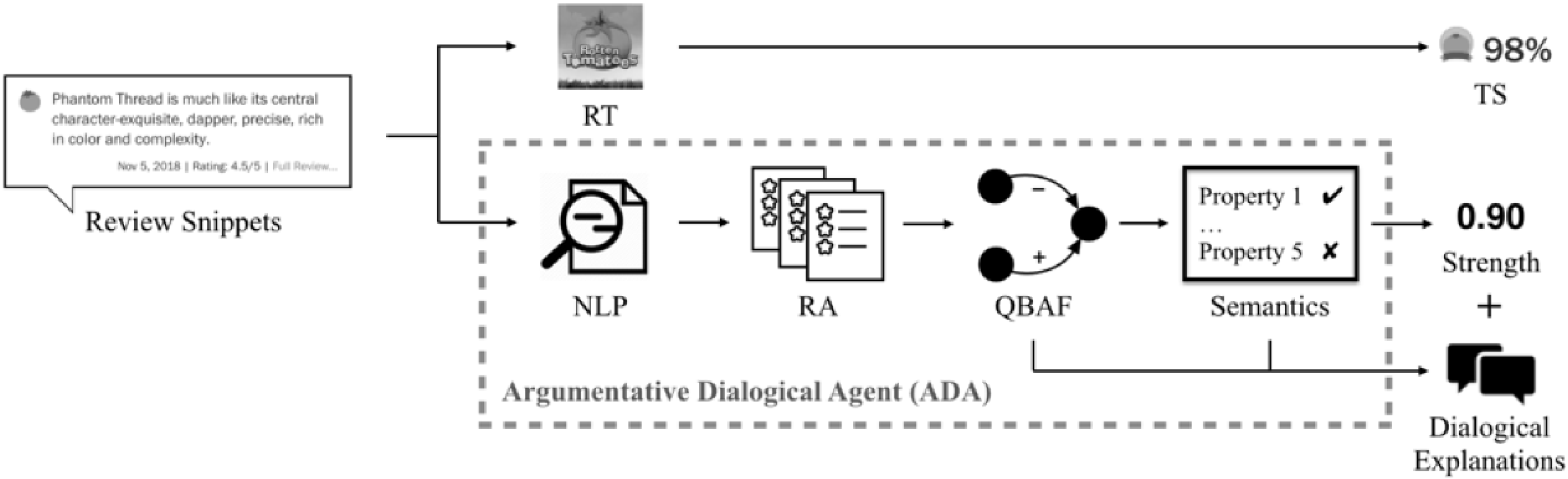
Issue: How to spend council's budget?

A1: Build a new cycle path.
A2: Repair current infrastructure.

P1: Cyclists complain of dangerous roads.
P2: A path would enhance the council's green image.
P3: Potholes have caused several accidents recently.
C1: Significant disruptions to traffic would occur.
C2: Environmentalists are a fraction of the population.
C3: Recent policies already enhance this green image.
C4: Donors do not see the environment as a priority.

Rago, A., Toni, F., Aurisicchio, M., & Baroni, P. Discontinuity-free decision support with quantitative argumentation debates. In Fifteenth International Conference on the Principles of Knowledge Representation and Reasoning (KR 2016). 2016.

Explainable Review Aggregation (Cocarascu et al. 2019)



Cocarascu, O., Rago, A., & Toni, F. Extracting Dialogical Explanations for Review Aggregations with Argumentative Dialogical Agents. In 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2019). 2019.

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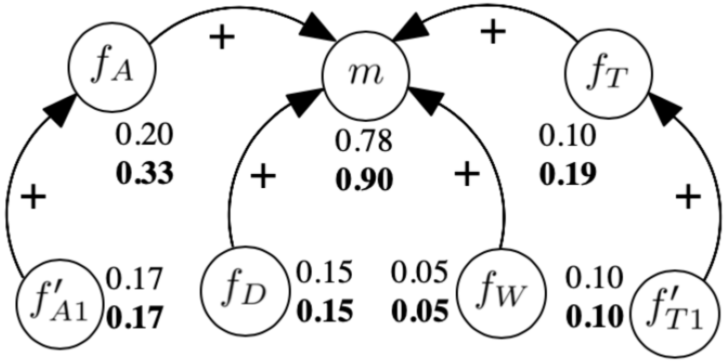

user: *Why was Phantom Thread highly rated?*
ADA: *This movie was highly rated because the acting was great.*
user: *Why was the acting considered to be great?*
ADA: *The acting was considered to be great because Daniel Day-Lewis was great.*
user: *What did critics say about Daniel Day-Lewis being great?*
ADA: *"...Daniel Day-Lewis remains our greatest actor..."*

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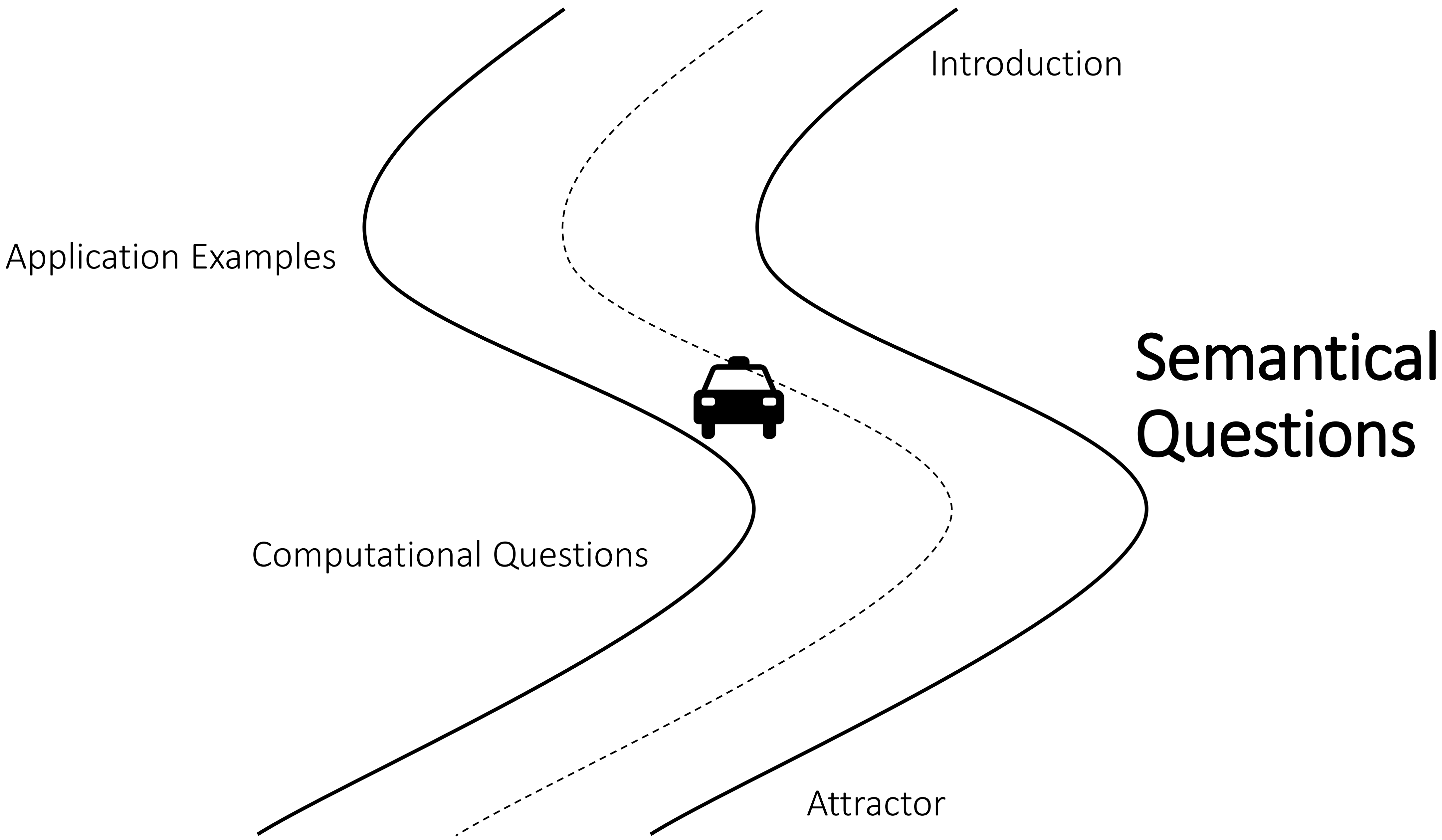
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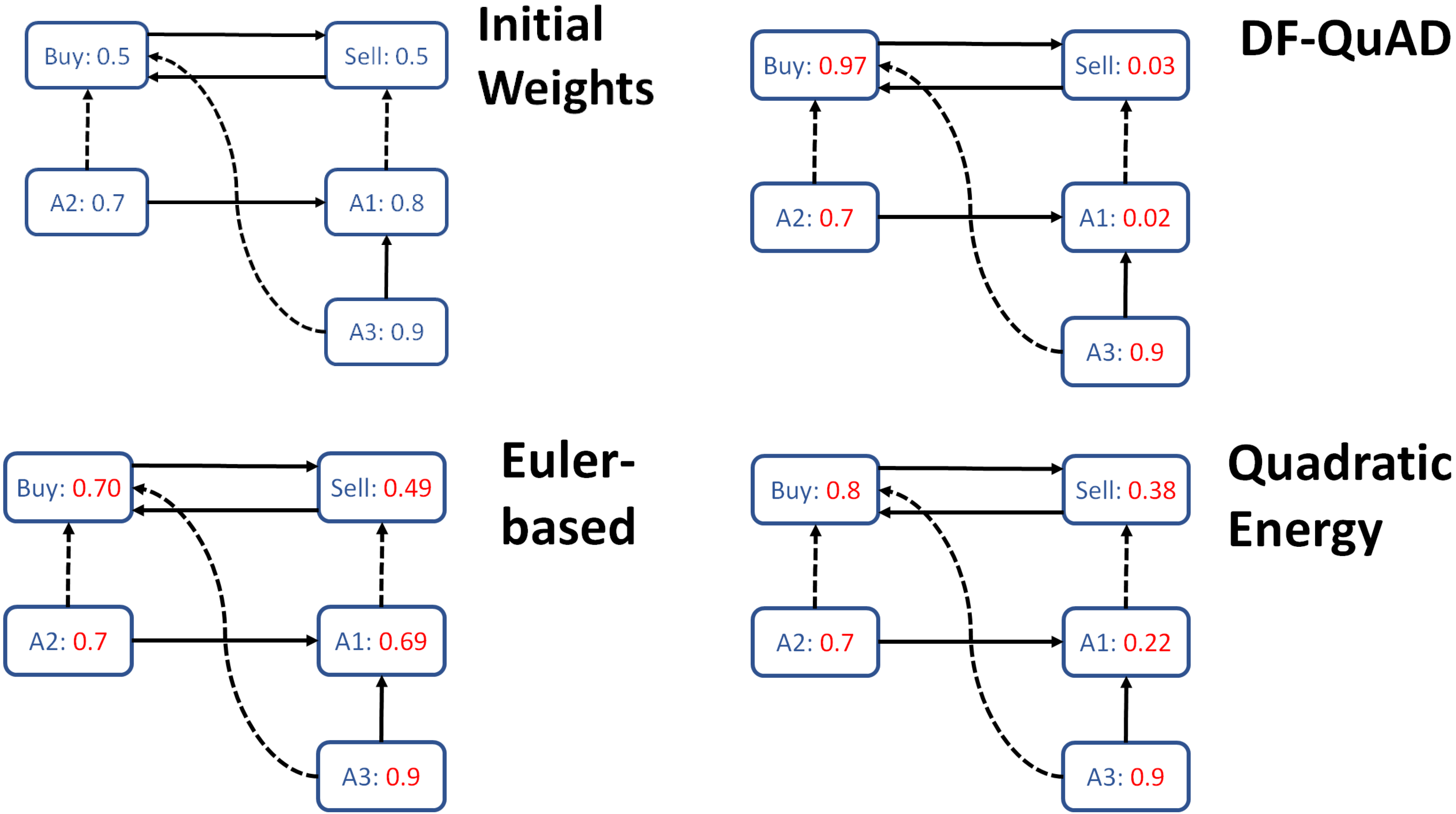

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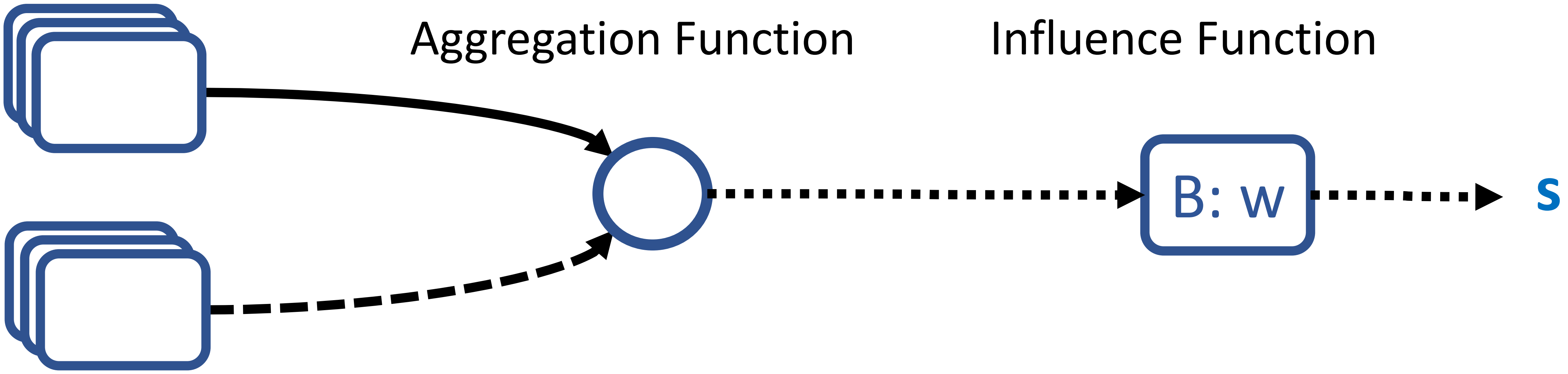
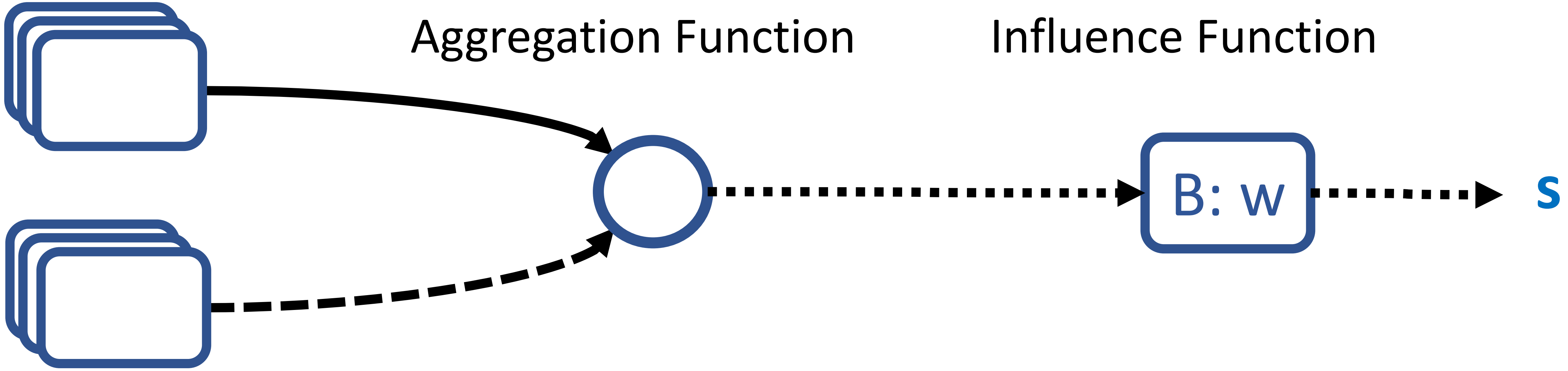
Modular Semantics *(Mossakowski, Neuhaus 2018)*



- Similar ideas have been considered before
  - Local Gradual Valuations (Amgoud et al. 2008)
  - Semantic Frameworks (Leite, Martins 2011)

Mossakowski, T., & Neuhaus, F.. Modular semantics and characteristics for bipolar weighted argumentation graphs. *arXiv preprint arXiv:1807.06685*. 2018.
Amgoud, L., Cayrol, C., Lagasquie-Schiex, M. C., & Livet, P. On bipolarity in argumentation frameworks. *International Journal of Intelligent Systems*, *23*(10), 1062-1093. 2008.
Leite, J., & Martins, J. Social abstract argumentation. In Twenty-Second International Joint Conference on Artificial Intelligence (IJCAI 2011). 2011.

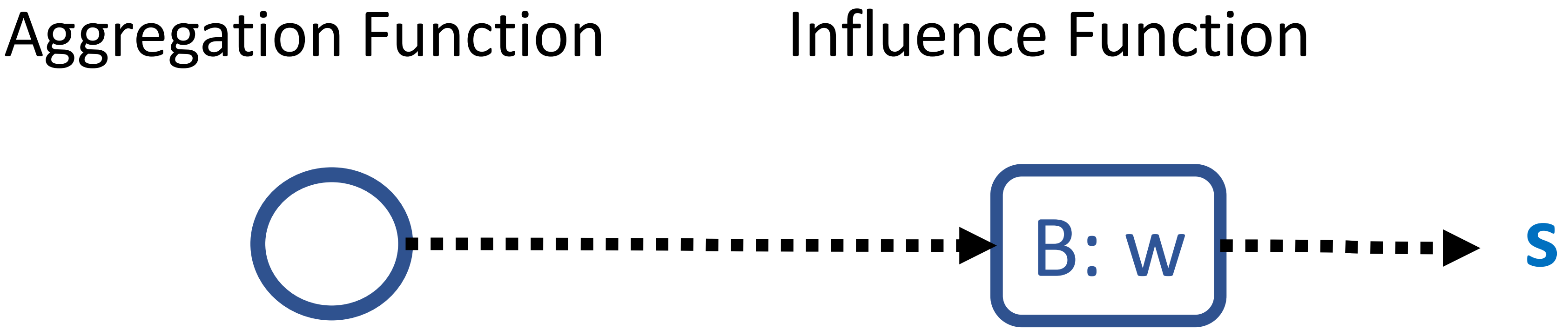
DF-QuAD *(Rago et al. 2016)*



- *Aggregation:* a = $\prod_{i \in Att(B)}(1 - s_i) - \prod_{i \in Sup(B)}(1 - s_i)$
- *Influence:* s = $\begin{cases} w + w \times a & if\ a < 0 \\ w + (1 - w) \times a & else \end{cases}$

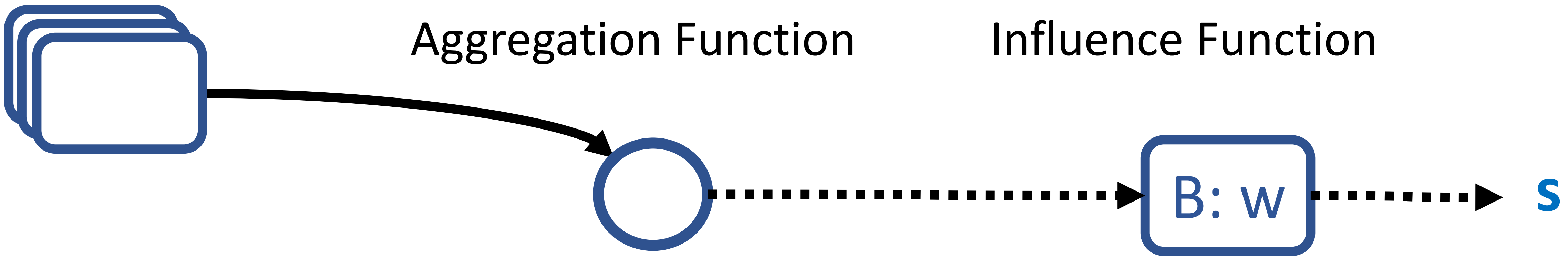
Rago, A., Toni, F., Aurisicchio, M., & Baroni, P. Discontinuity-free decision support with quantitative argumentation debates. In Fifteenth International Conference on the Principles of Knowledge Representation and Reasoning (KR 2016). 2016.

Some Special Cases: No Parents



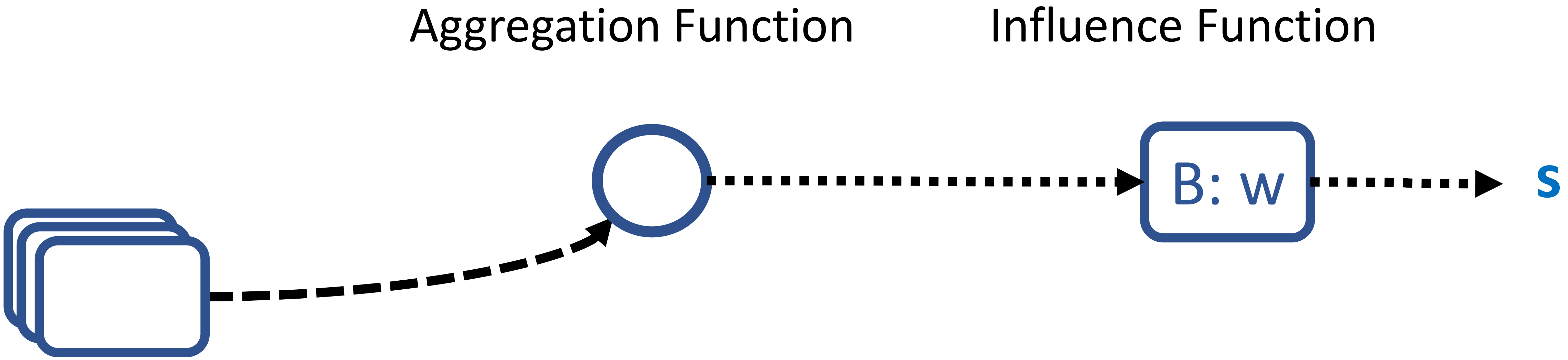
- *Aggregation:* a = 1 – 1 = 0
- *Influence:* s = w

Some Special Cases: No Supporters

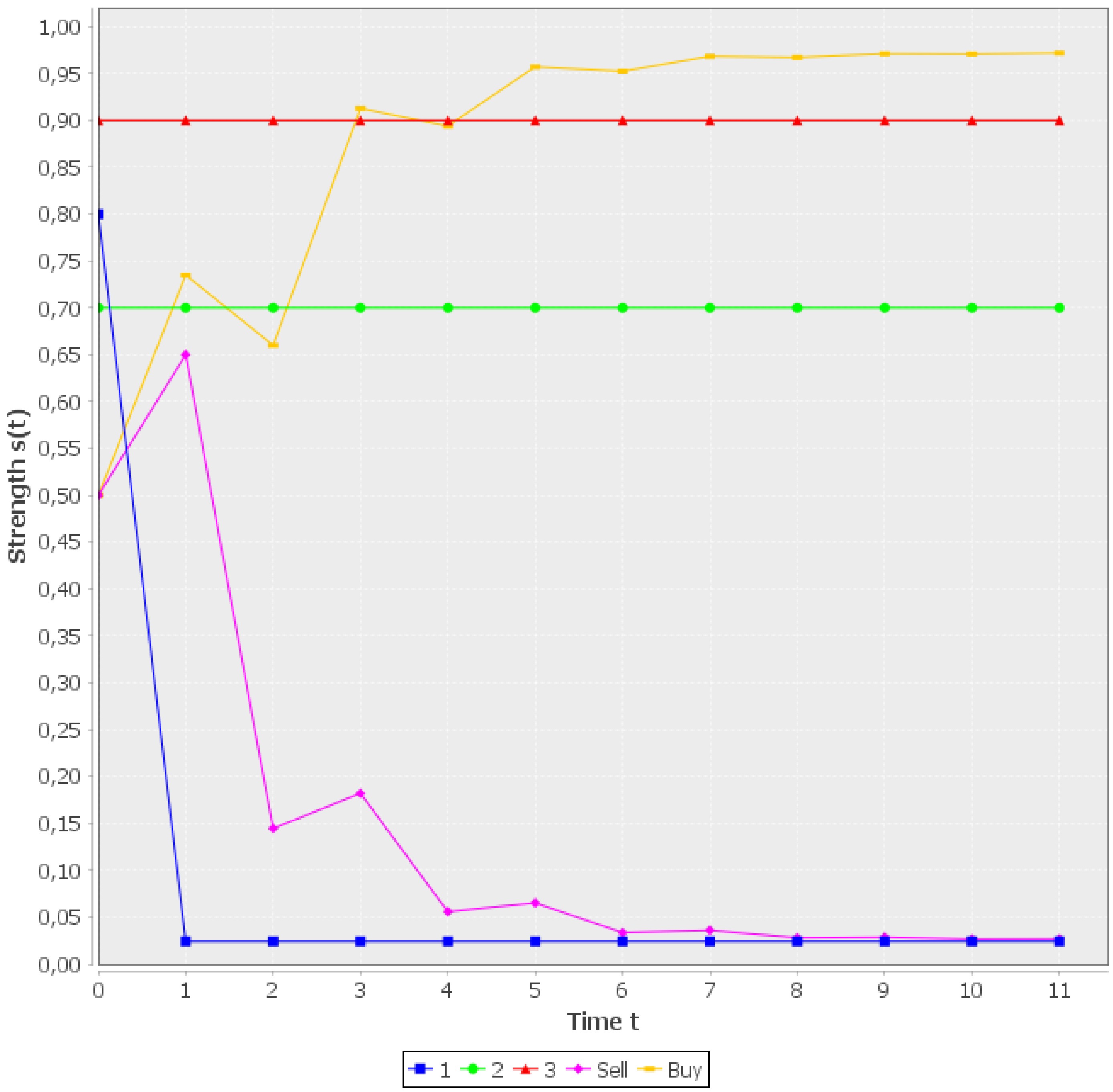


- *Aggregation:* a = $\prod_{i\in Att(B)}(1 - s_i) - 1 \leq 0$
- *Influence:* s = $w + w \times a \leq w$

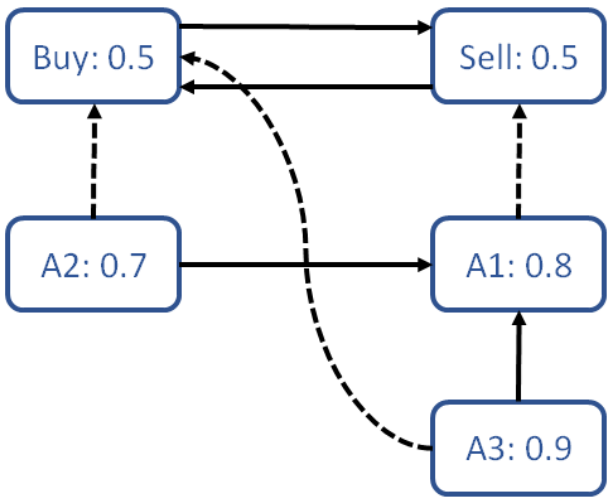
Some Special Cases: No Attackers



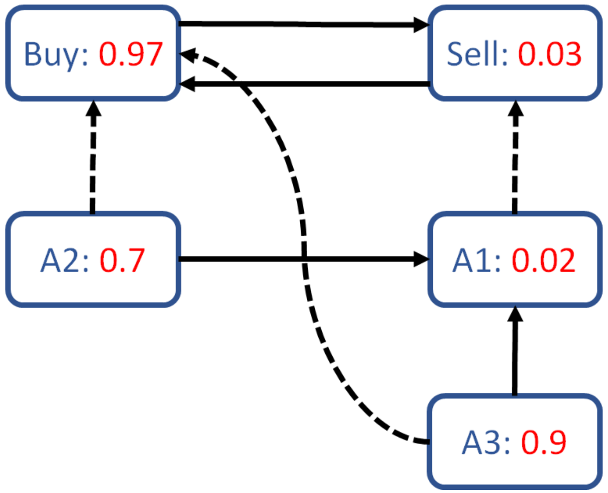
- *Aggregation:* a = $1 - \prod_{i \in \sup(B)}(1 - s_i) \geq 0$
- *Influence:* s = $w + (1 - w) \times a \geq w$



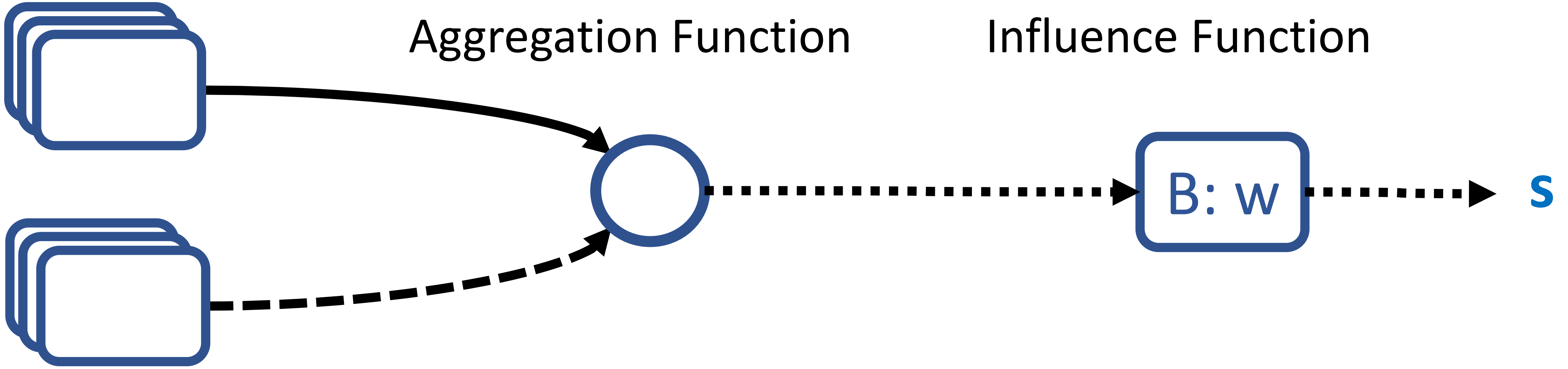
Initial Weights



DF-QuAD

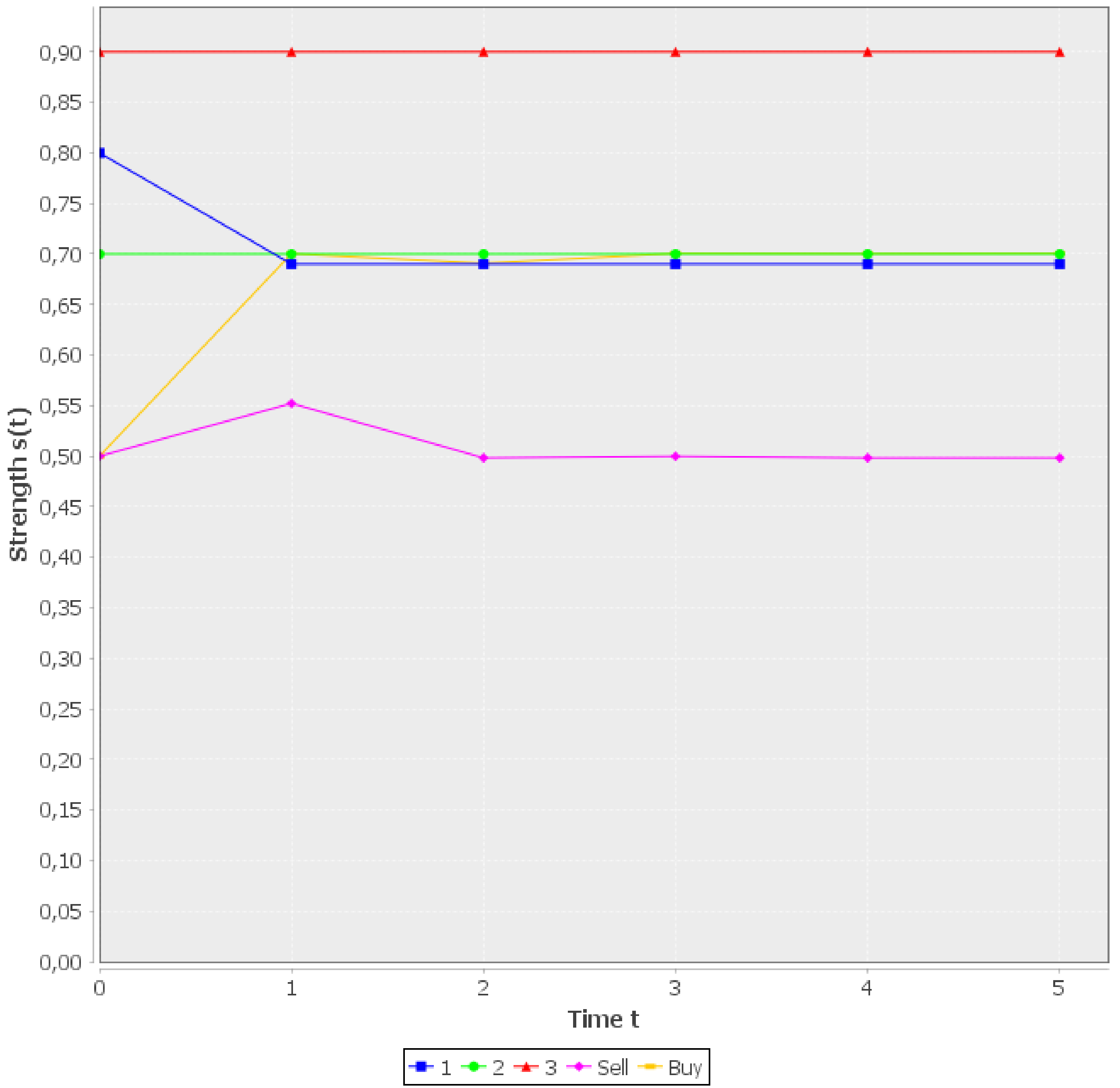


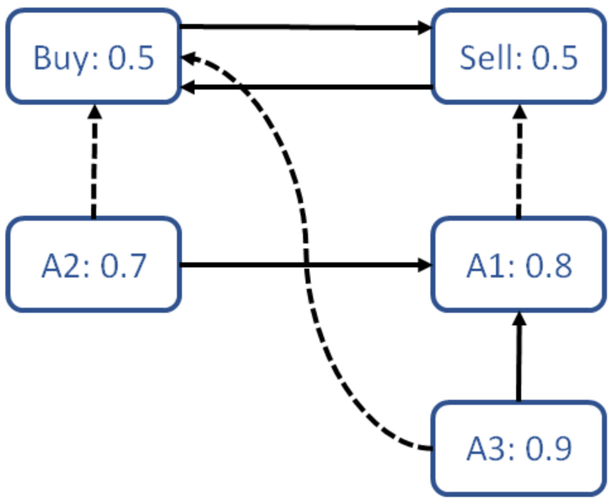
Euler-based Semantics *(Amgoud, Ben-Naim 2017)*



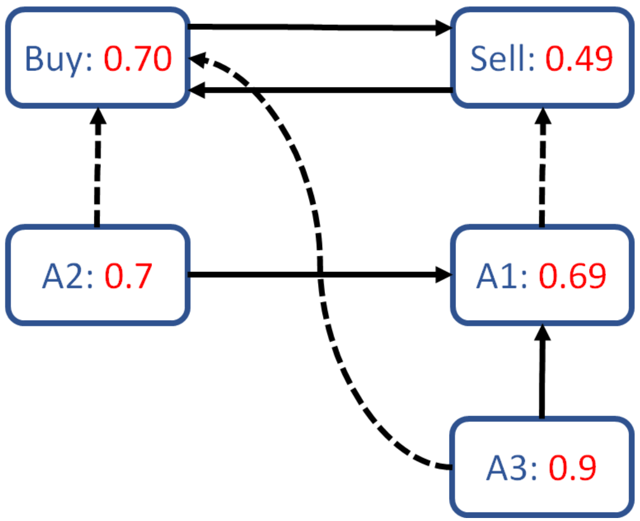
- *Aggregation:* a = $\sum_{i \in Sup(B)} s_i - \sum_{i \in Att(B)} s_i$
- *Influence:* s = $1 - \frac{1 - w^2}{1 + w \times e^a}$

Amgoud, L., Ben-Naim, J. Evaluation of arguments in weighted bipolar graphs. In Fourtheenth European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty (ECSQARU 2017). 2017.



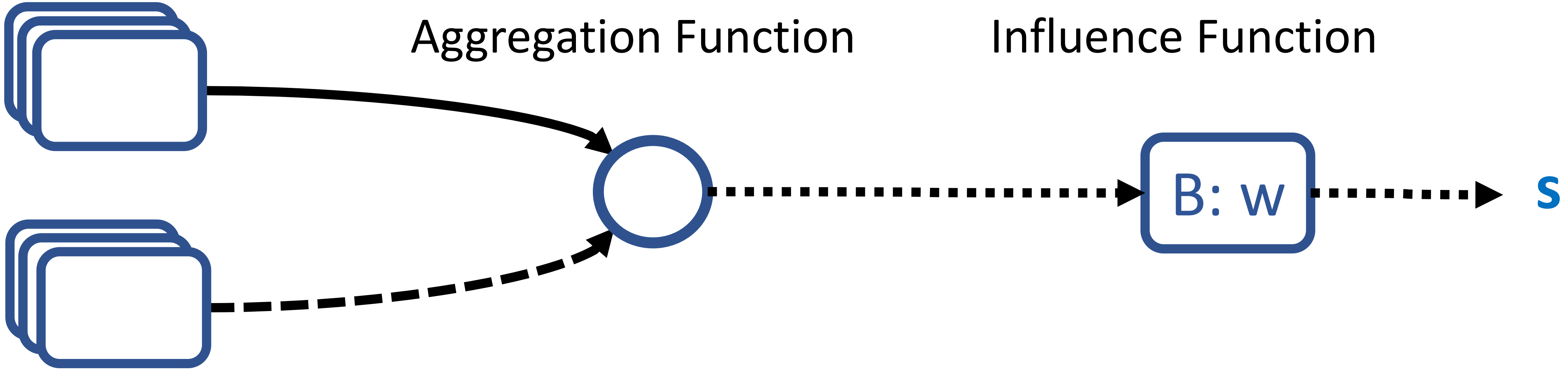


Initial Weights



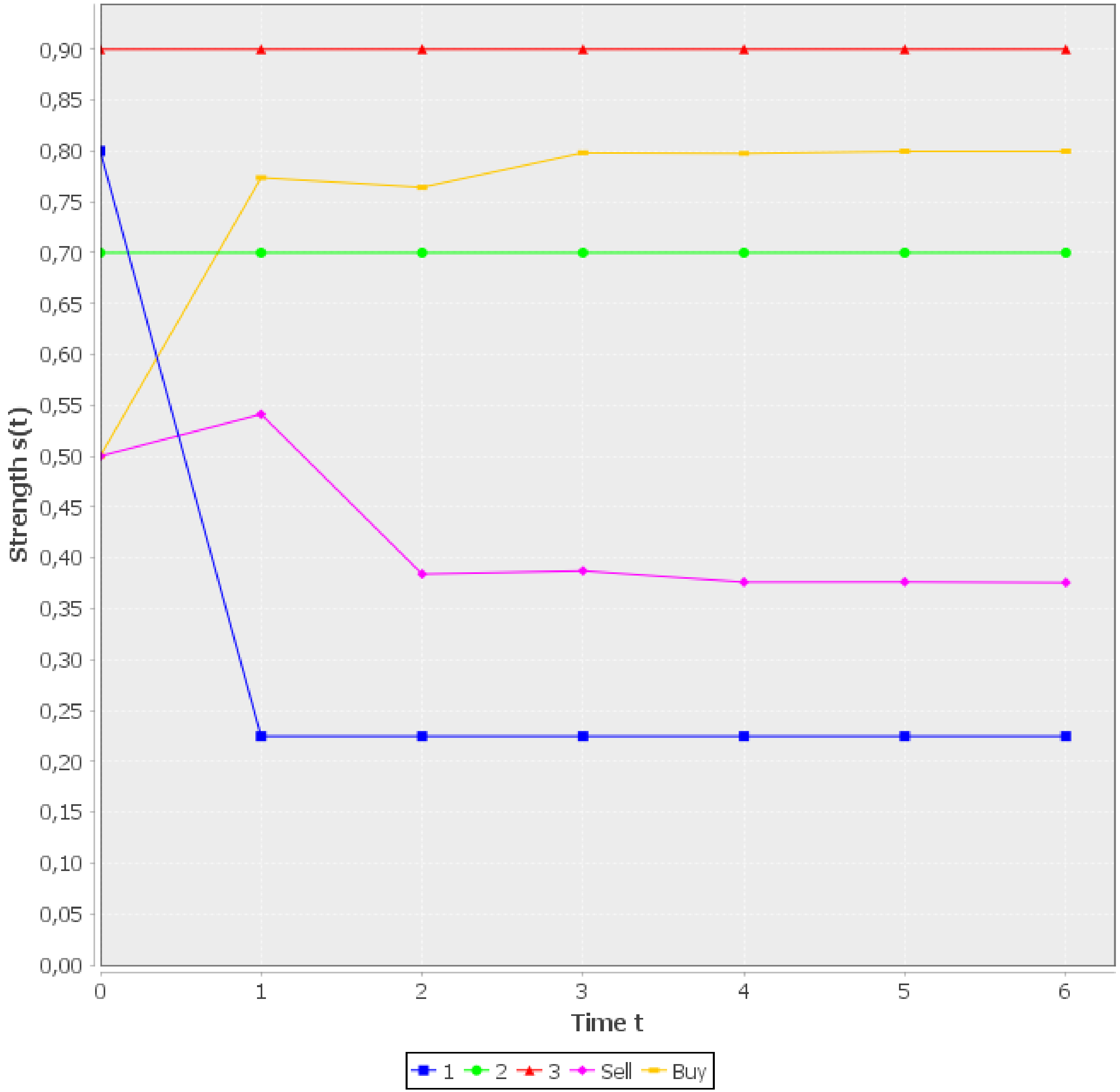
Euler-based

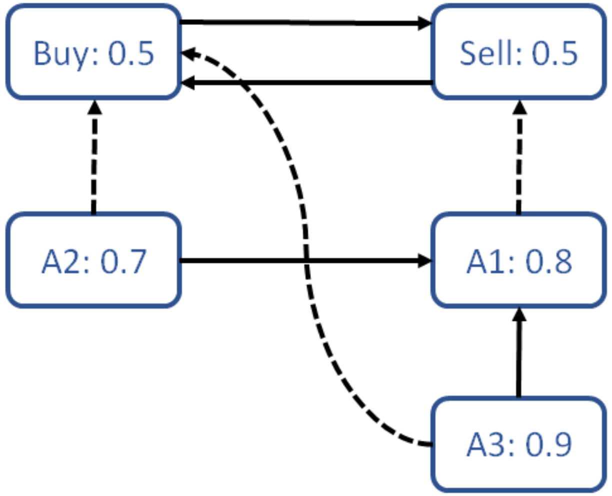
Quadratic-energy Model *(KR 2018)*



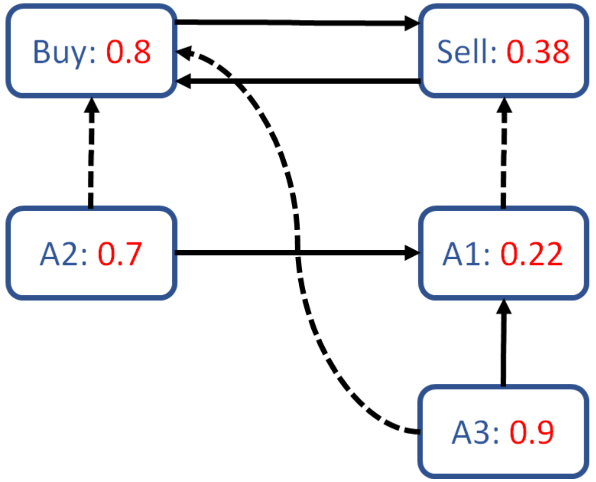
- *Aggregation:* a = $\sum_{i \in Sup(B)} s_i - \sum_{i \in Att(B)} s_i$
- *Influence:* s = $\begin{cases} w + (1 - w) \times \frac{a^2}{1+a^2} & if\ a > 0 \\ w - w \times \frac{a^2}{1+a^2} & else \end{cases}$

Potyka, N. Continuous dynamical systems for weighted bipolar argumentation. In *Sixteenth International Conference on Principles of Knowledge Representation and Reasoning (KR 2018)*. 2018.





Initial Weights



Quadratic Energy

Aggregation Functions

- *Product:* $\prod_{i \in Att(B)}(1 - s_i) - \prod_{i \in Sup(B)}(1 - s_i)$

- *Sum:* $\sum_{i \in Sup(B)} s_i - \sum_{i \in Att(B)} s_i$

- *Top:* $\max \{s_i : i \in Sup(B)\} - \max \{s_i : i \in Att(B)\}$

Influence Functions

- *Linear(k):* $\begin{cases} w + \frac{w}{k} \times a & if\ a < 0 \\ w + \frac{1-w}{k} \times a & else \end{cases}$

- *Euler-based:* $1 - \frac{1-w^2}{1 + w \times e^a}$

- *qmax(k):* $\begin{cases} w + \frac{1-w}{k} \times \frac{a^2}{1+a^2} & if\ a > 0 \\ w - \frac{w}{k} \times \frac{a^2}{1+a^2} & else \end{cases}$

Semantical Desiderata

- *Equivalence*
- *Neutrality*
- *Dummy*
- *Maximality/ Minimality*
- *Strengthening/ Weakening*
- *Void Precedence*
- *Triggering*
- *Counting*
- *Proportionality*
- …

- *(Baroni et al. 2018) showed that most properties can be broken down to two fundamental principles called **Balance** and **Monotonicity***

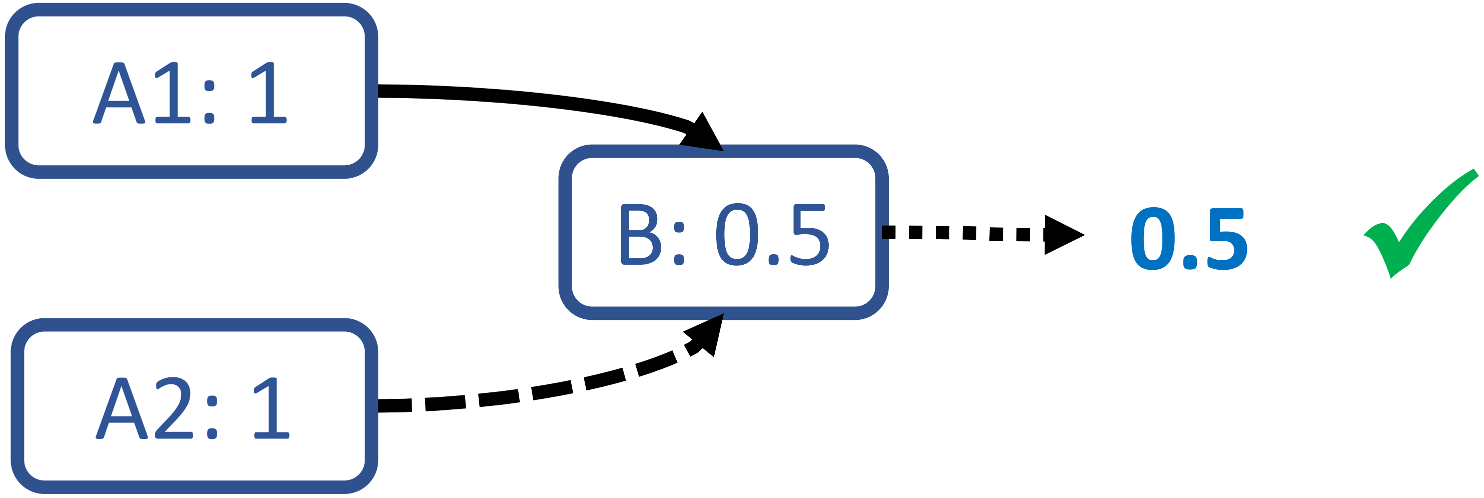
Baroni, P., Rago, A., & Toni, F. How many properties do we need for gradual argumentation? In *Thirty-Second AAAI Conference on Artificial Intelligence (AAAI 2018)*. 2018.

Balance (Intuition)

1. If attackers and supporters are „equally strong“, strength should be equal to initial weight

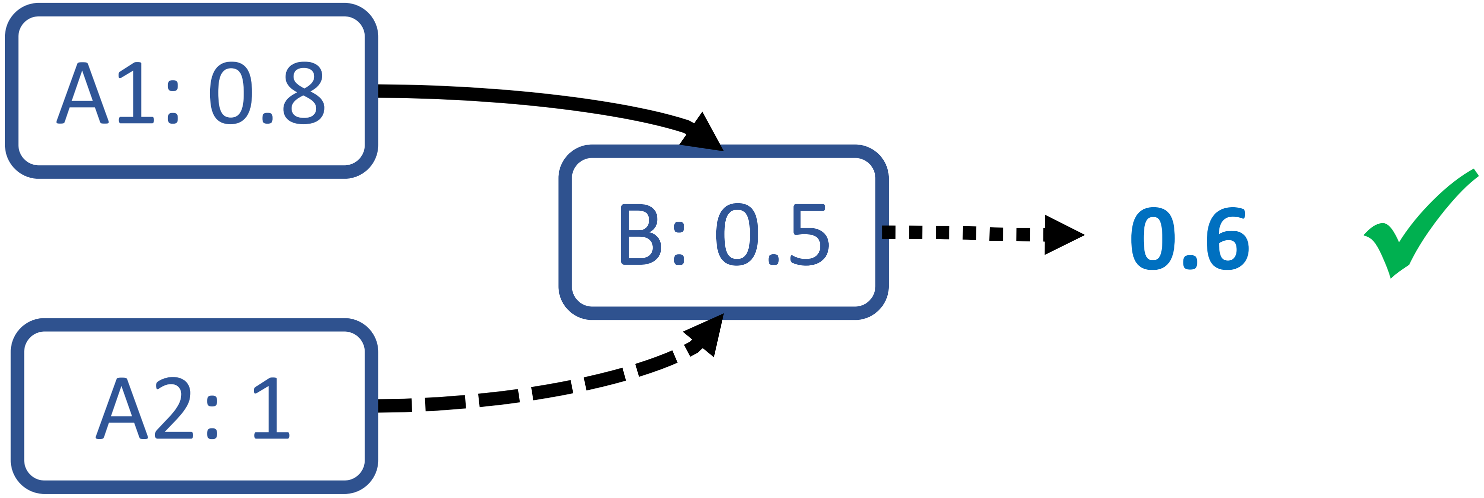
2. If attackers are „stronger (weaker) than“ supporters, strength should be smaller (larger)

Balance: DF-QuAD



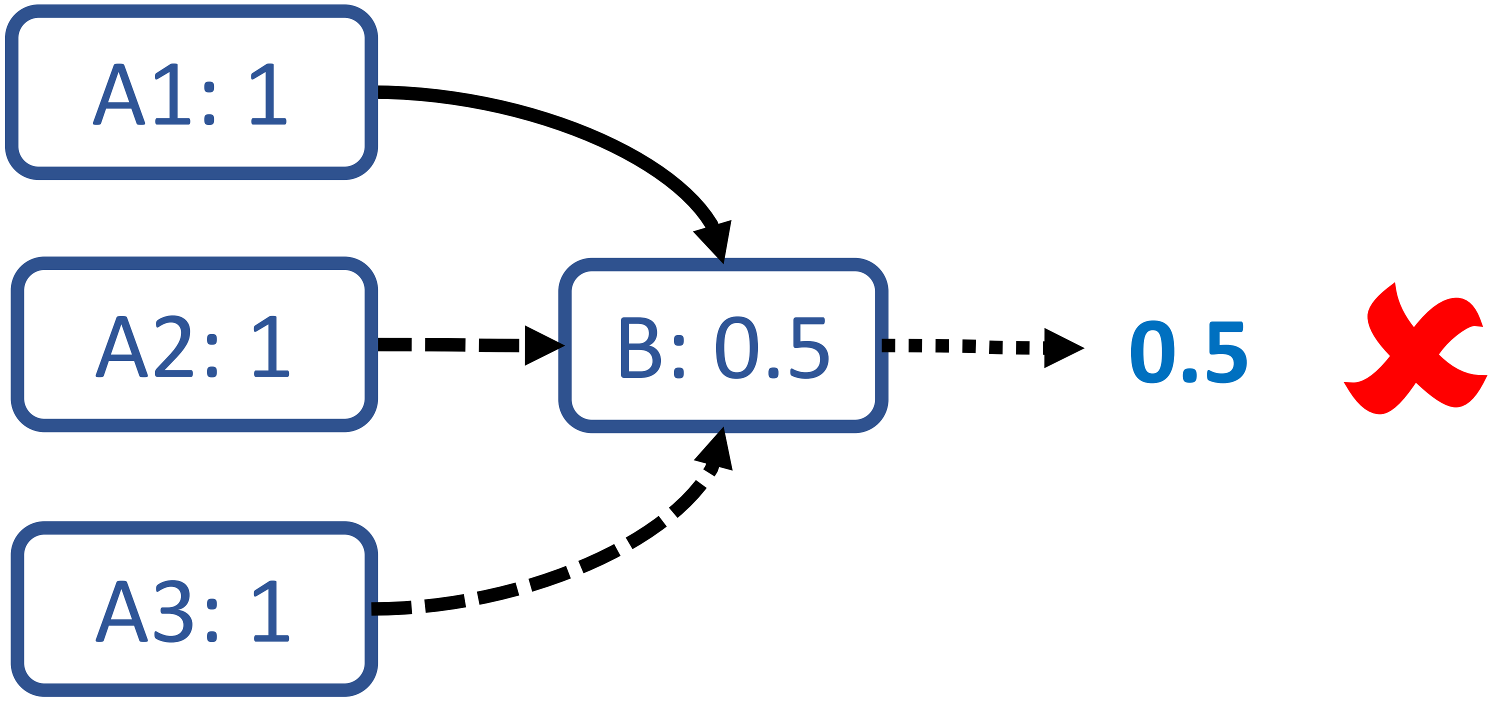
- *Aggregation:* a = (1 – 1) – (1 - 1) = 0
- *Influence:* s = 0.5 + (1 – 0.5) × 0 = 0.5

Balance: DF-QuAD



- *Aggregation:* a = (1 – 0.8) – (1 - 1) = 0.2
- *Influence:* s = 0.5 + (1 – 0.5) × 0.2 = 0.6

Balance: DF-QuAD



Product Aggregation and *Top Aggregation* can violate balance

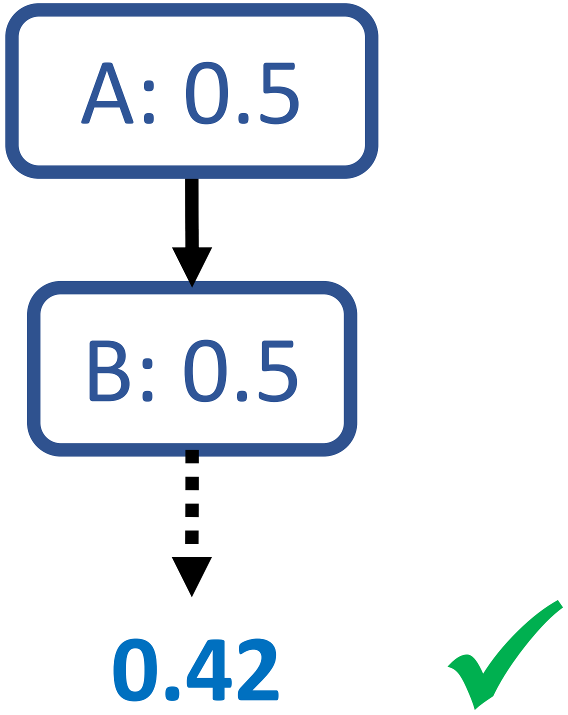
- *Aggregation:* a = (1 – 1) – (1 - 1) × (1 - 1) = 0
- *Influence:* s = 0.5 + (1 – 0.5) × 0 = 0.5

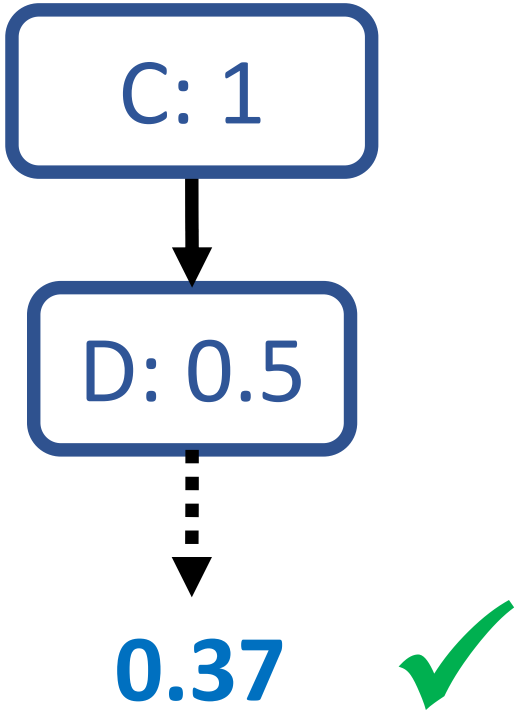
Monotonicity (Intuition)

1. *If the „same impact“ (in terms of initial weight, attack and support) acts on A1 and A2, then they should have the same strength.*

2. *If the impact on A1 is „more positive“, then it should have a larger strength than A2.*

Monotonicity: Euler-based Semantics

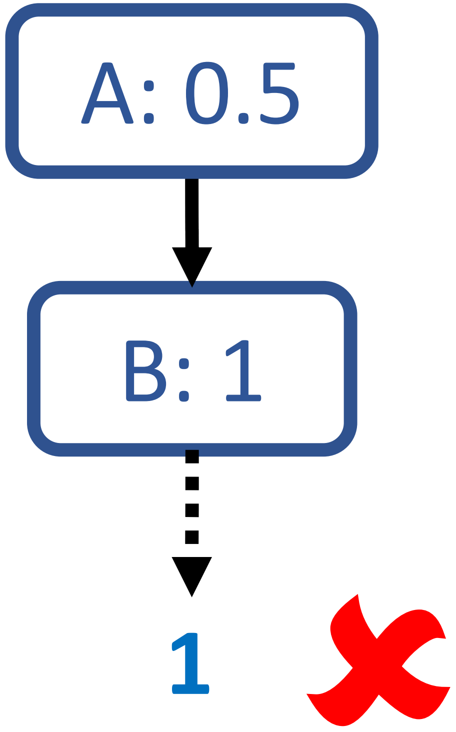


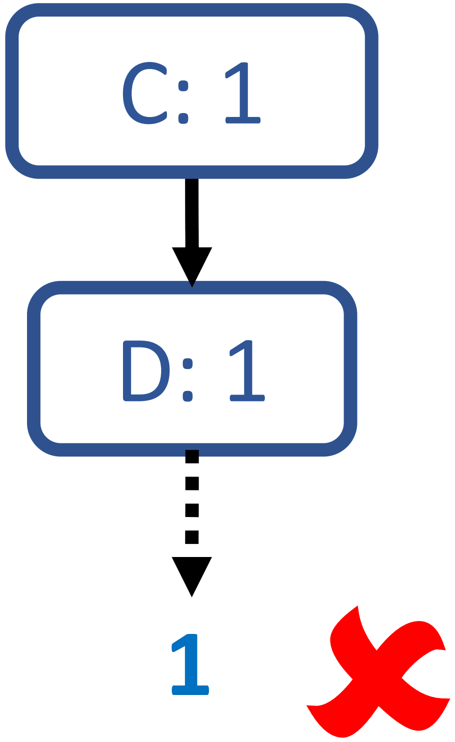


- a = -0.5
- s = $1 - \frac{1 - 0.5^2}{1 + 0.5 \times \exp(-0.5)} \approx 0.42$

- a = -1
- s = $1 - \frac{1 - 0.5^2}{1 + 0.5 \times \exp(-1)} \approx 0.37$

Monotonicity: Euler-based Semantics





Euler-based Influence
violates monotonicity
in boundary cases

- a = -0.5
- s = $1 - \frac{1 - 1^2}{1 + 1 \times \exp(-0.5)} = 1$

- a = -1
- s = $1 - \frac{1 - 1^2}{1 + 1 \times \exp(-1)} = 1$

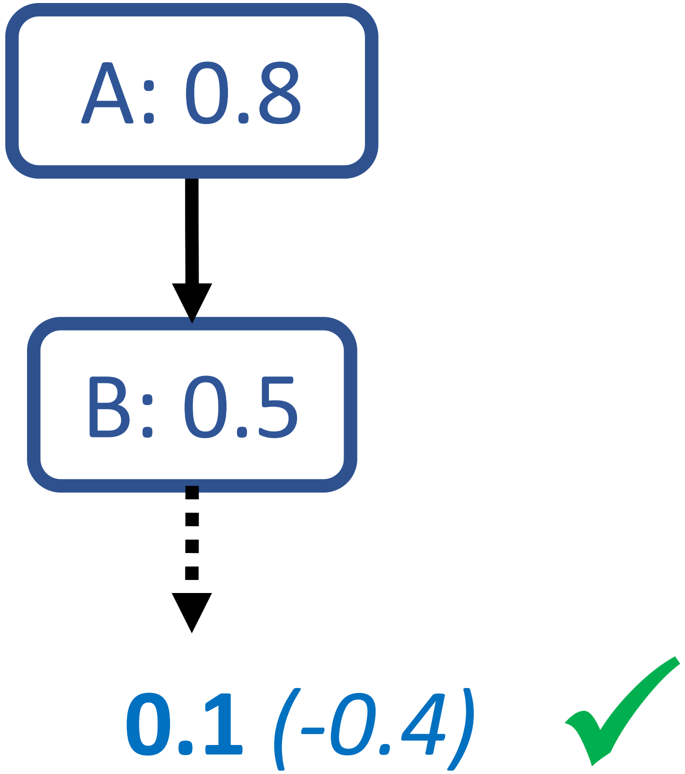
Beyond Balance and Monotonicity (AAMAS 2019)

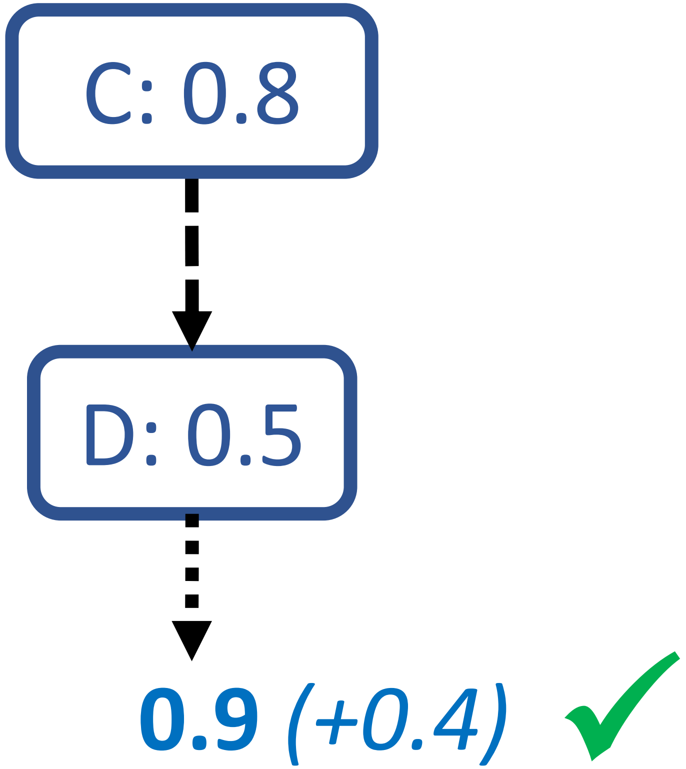
- **Duality:** Attack and support should behave „in a dual manner“

- **Open-Mindedness:** strength should become arbitrarily close to 0 (1) if we keep adding „strong“ attackers (supporters)

Potyka, N. Extending Modular Semantics for Bipolar Weighted Argumentation. In Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2019*)*. 2019.

Duality: DF-QuAD

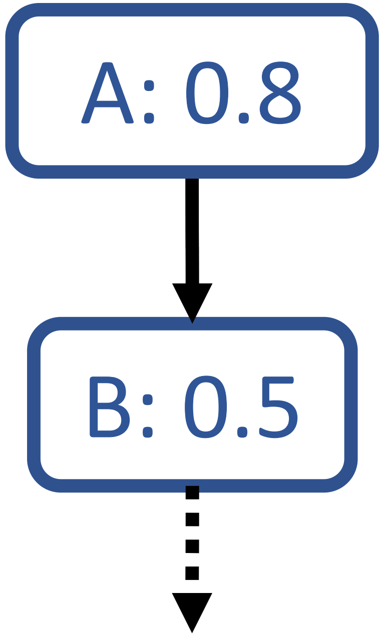




- a = $(1 - 0.8) - 1$ = -0.8
- s = $0.5 - 0.5 \times 0.8 = 0.1$

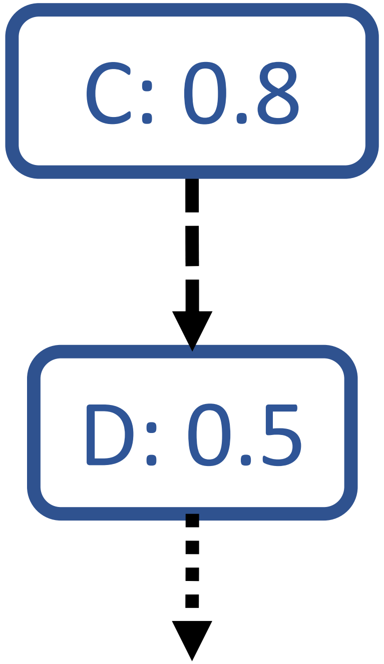
- a = $1 - (1 - 0.8) = 0.8$
- s = 0.5 + (1 - 0.5) × 0.8 = 0.9

Duality: Euler-based



0.39 *(-0.11)* ✗

Euler-based Influence can violate Duality

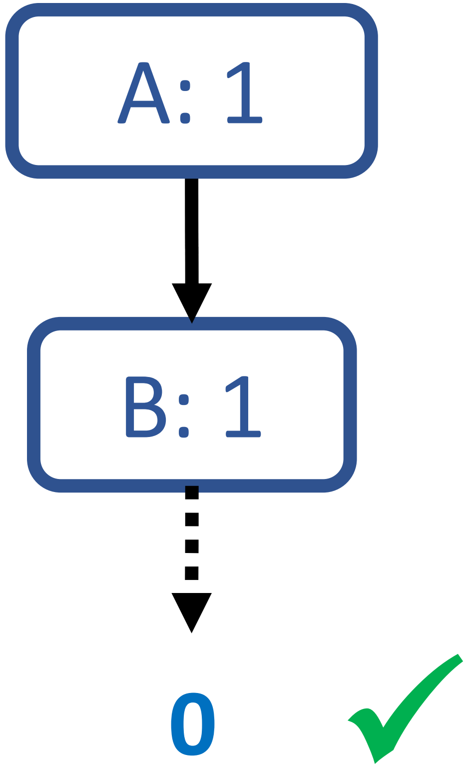


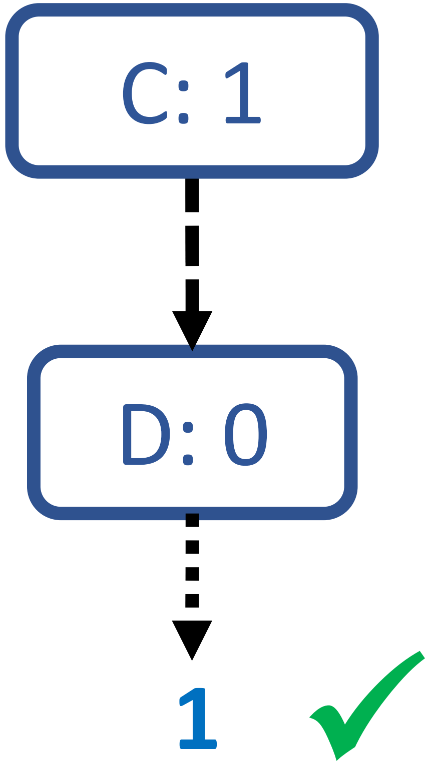
0.65 *(+0.15)* ✗

- a = -0.8
- s = $1 - \frac{1 - 0.5^2}{1 + 0.5 \times \exp(-0.8)} = 0.39$

- a = 0.8
- s = $1 - \frac{1 - 0.5^2}{1 + 0.5 \times \exp(-0.8)} = 0.65$

Open-Mindedness: DF-QuAD

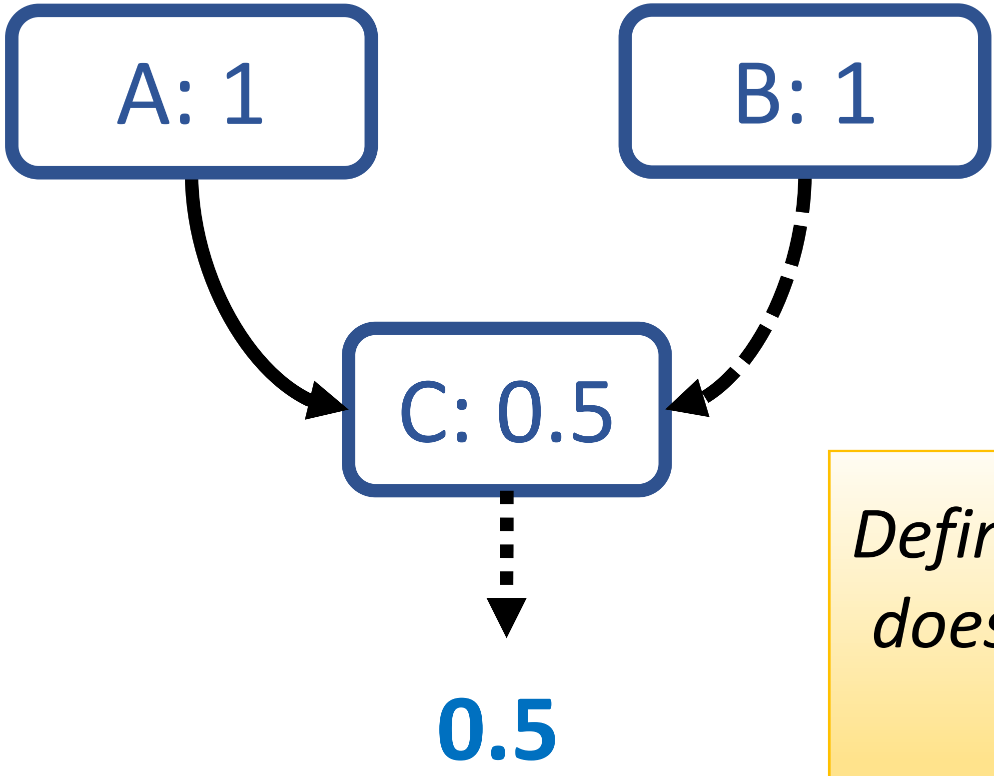




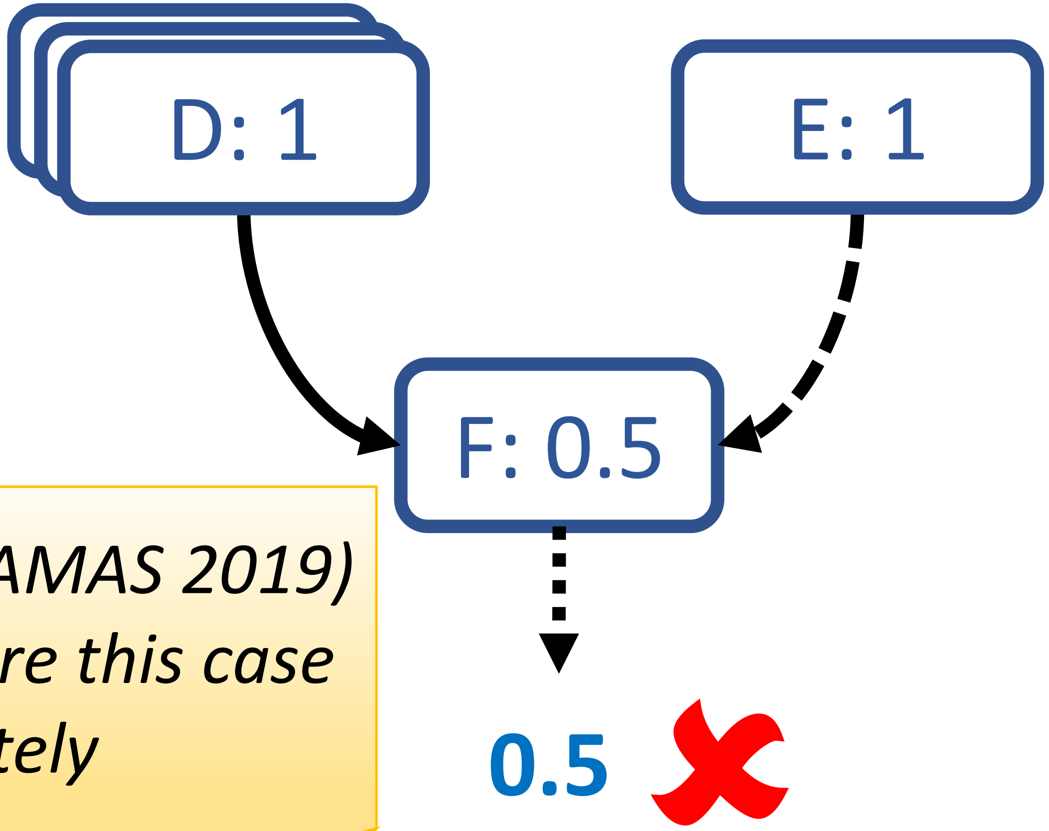
- $a = (1 - 1) - 1 = -1$
- $s = 1 - 1 \times 1 = 0$

- $a = 1 - (1 - 1) = 1$
- $s = 0 + (1 - 0) \times 1 = 1$

Open-Mindedness: DF-QuAD



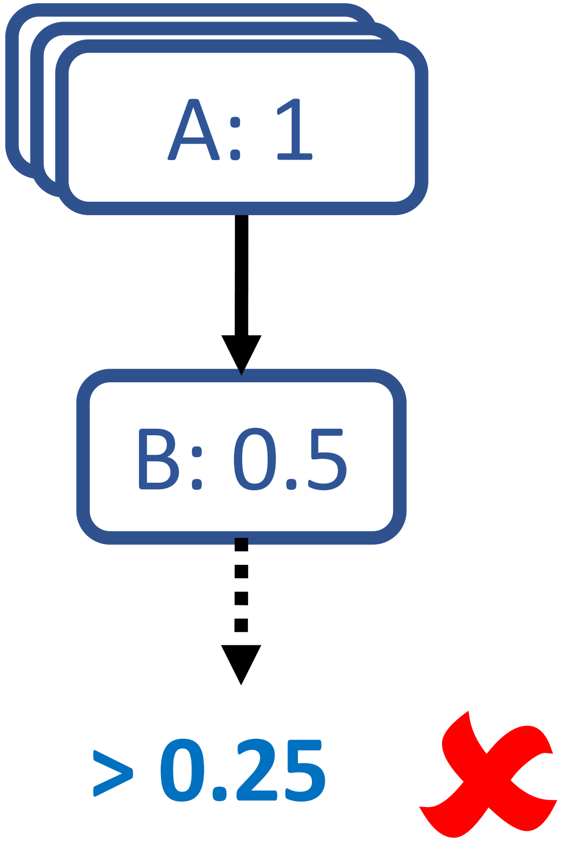
Definition in (AAMAS 2019) does not capture this case accurately



- a = 0 – 0 = 0
- s = 0.5 – 0.5 × 0 = 0

- a = 0 – 0 = 0
- s = 0.5 + (1 – 0.5) × 0 = 0.5

Open-Mindedness: Euler-based



Euler-based Influence can violate Open-Mindedness

- a = $-n \rightarrow -\infty$
- s = $1 - \frac{1 - 0.5^2}{1 + 0.5 \times \exp(-n)} > 0.25$

Summary: Potential Semantical Problems

Aggregation Function	Balance	Monotonicity	Duality	Open-Mindedness
Product	(✘)	(✘)		(✘)
Sum				
Top	(✘)	(✘)		(✘)

Influence Function	Balance	Monotonicity	Duality	Open-Mindedness
Linear				
Euler-based		(✘)	✘	✘
qmax				

Aggregation/ Influence Function	Balance	Monotonicity	Duality	Open-Mindedness
Sum/ qmax	✓	✓	✓	✓

Some Further Readings about Weighted Semantics

- *Attack-only Graphs*

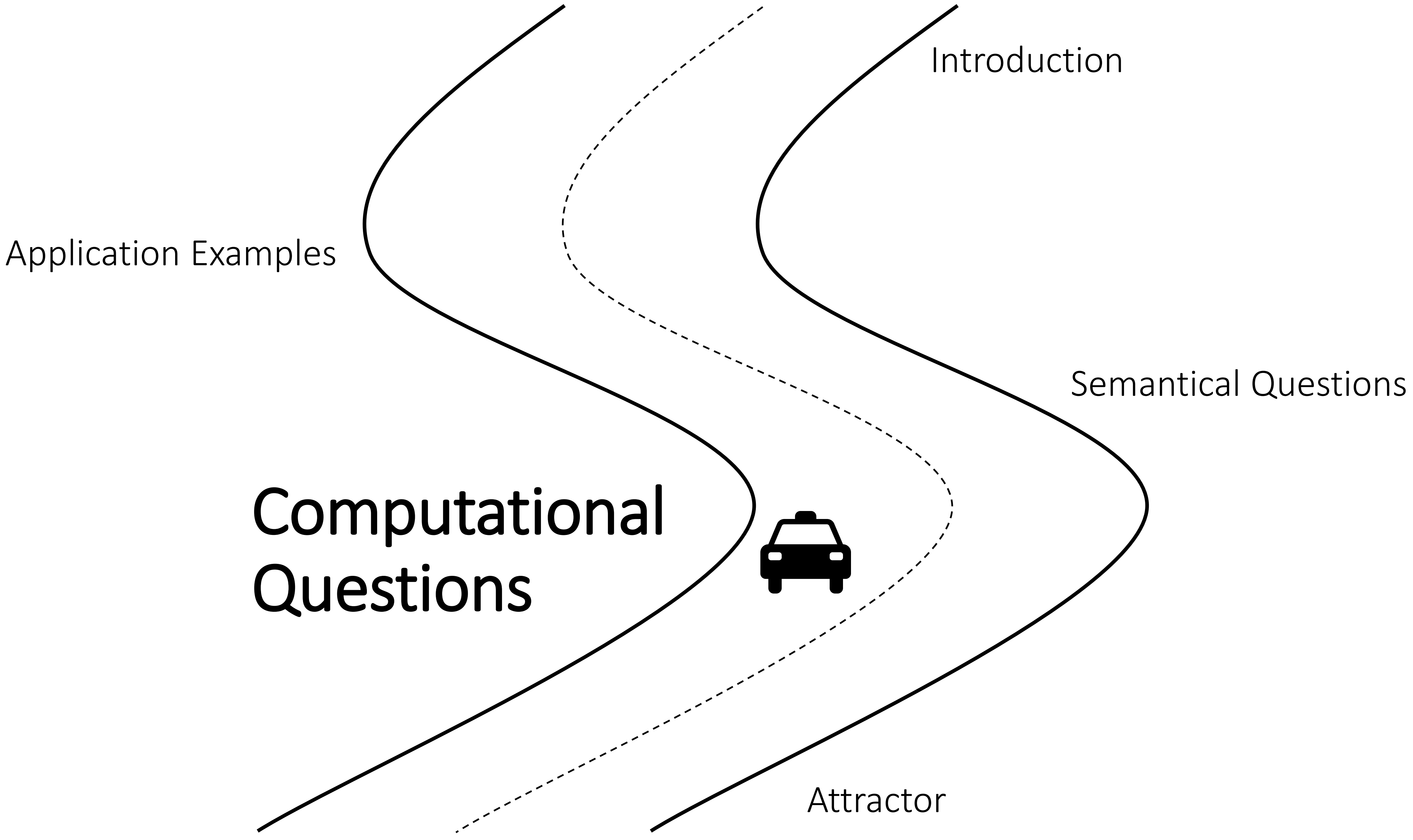
Amgoud, L., Ben-Naim, J., Doder, D., & Vesic, S. Acceptability Semantics for Weighted Argumentation Frameworks. In Twenty-Sixth International Joint Conference on Artificial Intelligence (IJCAI 2017). 2017.

- *Support-only Graphs*

Amgoud, L., & Ben-Naim, J. Evaluation of arguments from support relations: Axioms and semantics. In Twenty-Fifth International Joint Conference on Artificial Intelligence (IJCAI 2016). 2016.

- *Bipolar Graphs*

Baroni, P., Romano, M., Toni, F., Aurisicchio, M., & Bertanza, G. Automatic evaluation of design alternatives with quantitative argumentation. Argument & Computation, 6(1), 24-49. 2015.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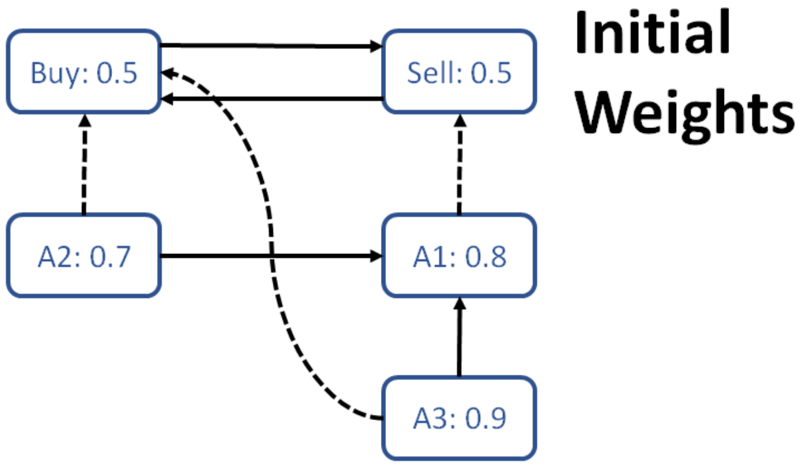
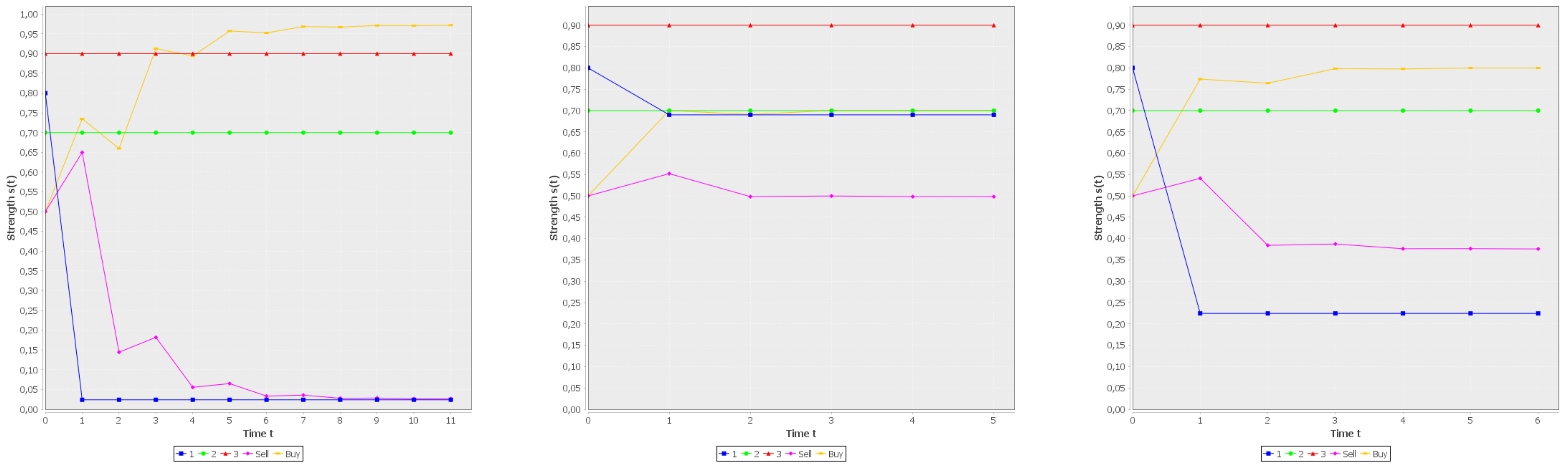
Computational Questions
Attractor


Buy: 0.5
Sell: 0.5
A2: 0.7
A1: 0.8
A3: 0.9
Initial Weights


Strength s(t)
Time t
1
2
3
Sell
Buy

Computing Strength Values

$i \leftarrow 0$

FOR $a = 1,\ldots,n$

$\quad s^{(i)}(a) = w(a)$

DO

$\quad i \leftarrow i + 1$

$\quad$ **FOR** $a = 1,\ldots,n$

$\quad\quad s^{(i)}(a) = f(w(a), Parents(a), s^{(i-1)}(a))$

UNTIL $|s^{(i)} - s^{(i-1)}| < \varepsilon$

$s \leftarrow s^{(i)}$

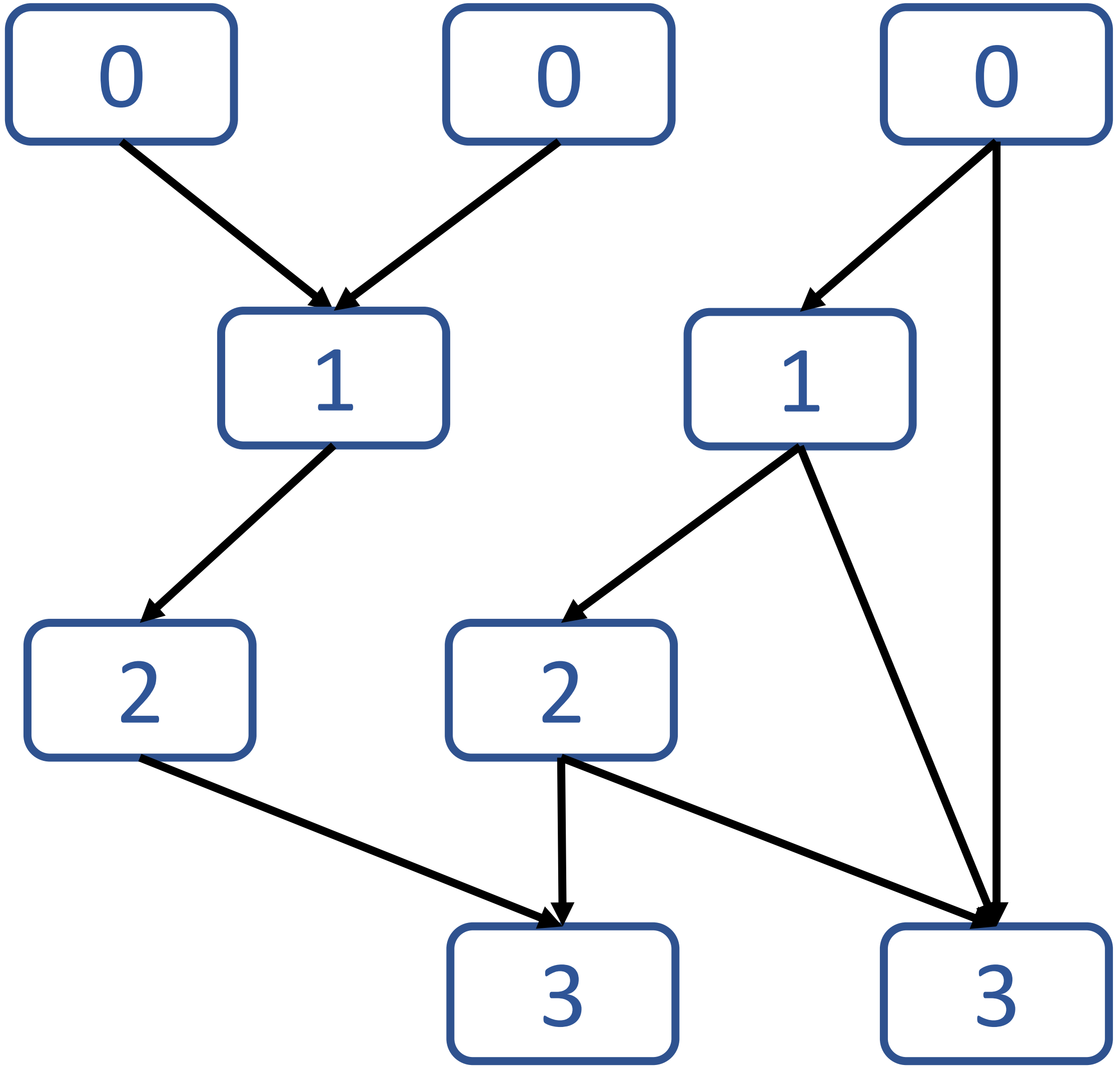
Initialization with initial weights

Update strength values simultaneously until convergence

Depth in Acyclic BAGs

Depth(i) *is defined as*

0	*if Parents(i) = Ø*
1 + max {depth(j) : j ∈ Parents(i)}	*else*



Convergence in Acyclic BAGs

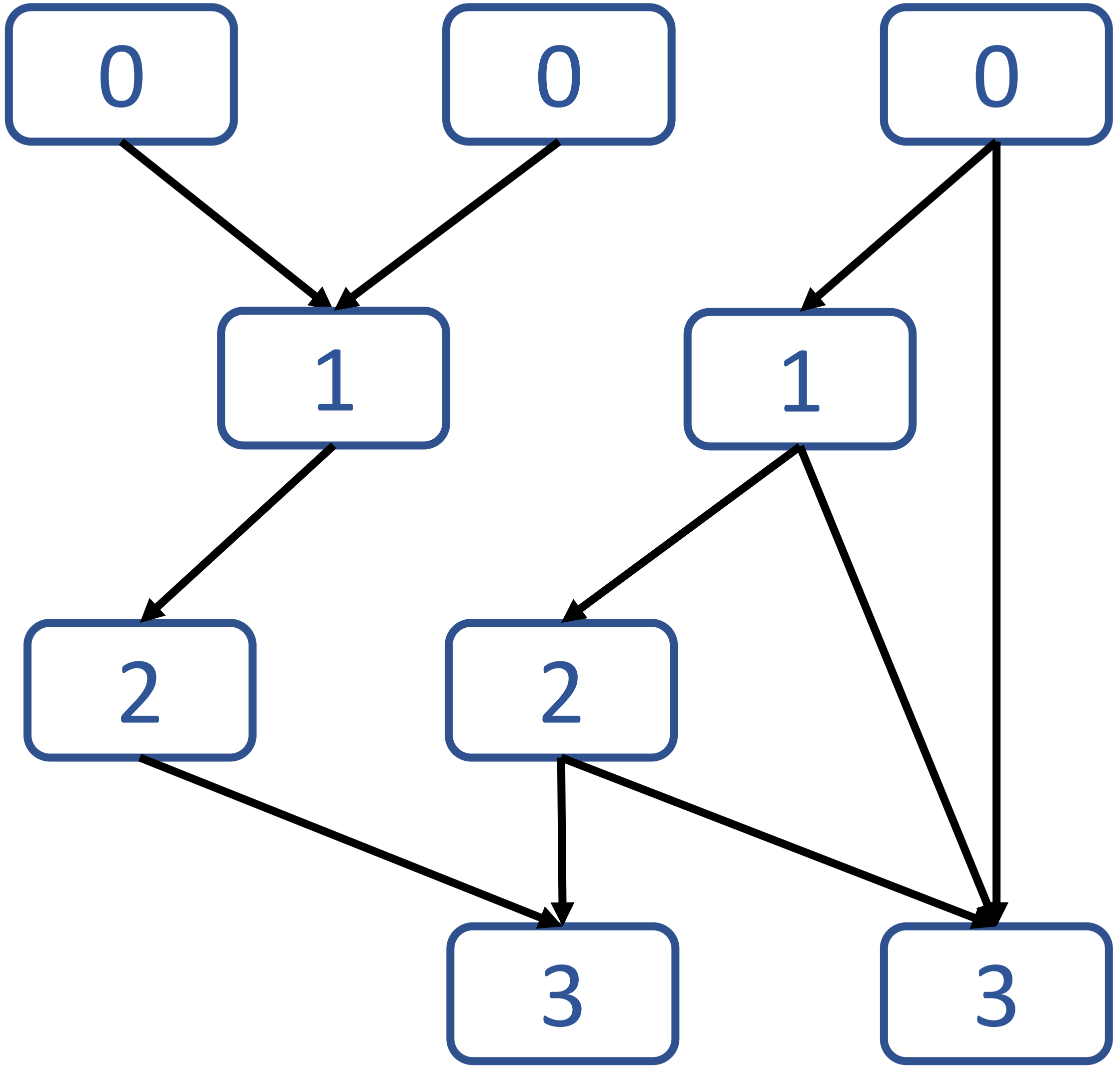
Lemma
If depth(A)=d, then strength of A remains unchanged after iteration i.

Theorem
In acyclic BAGs, strength values converge in n-1 iterations.

$O(n^2)$ updates

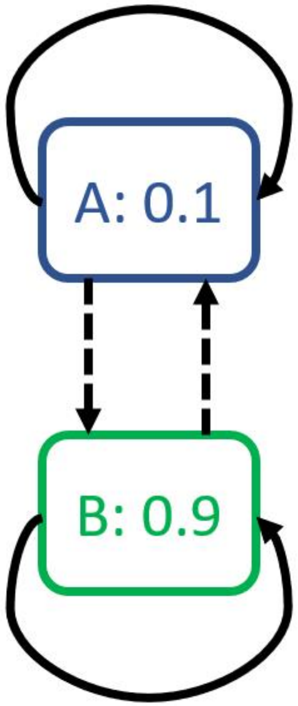
Theorem
Computing strength values once according to topological ordering yields the same result.

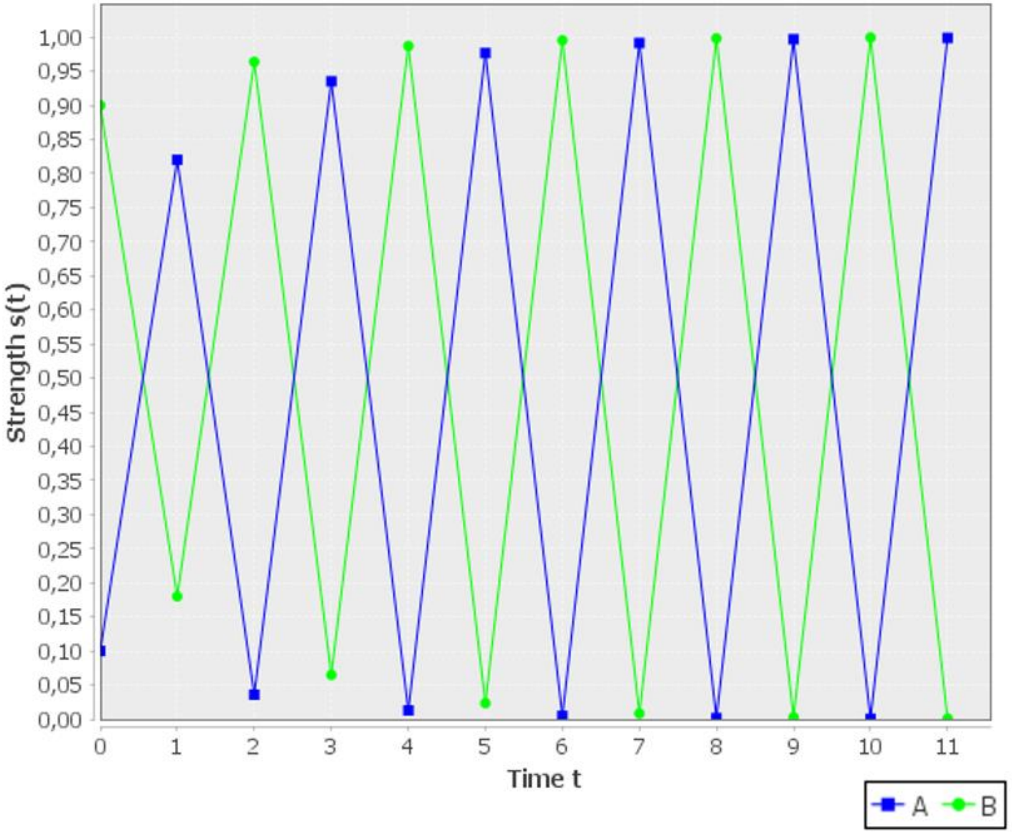
O(n+m) for ordering + O(n) updates



Convergence in Cyclic BAGs

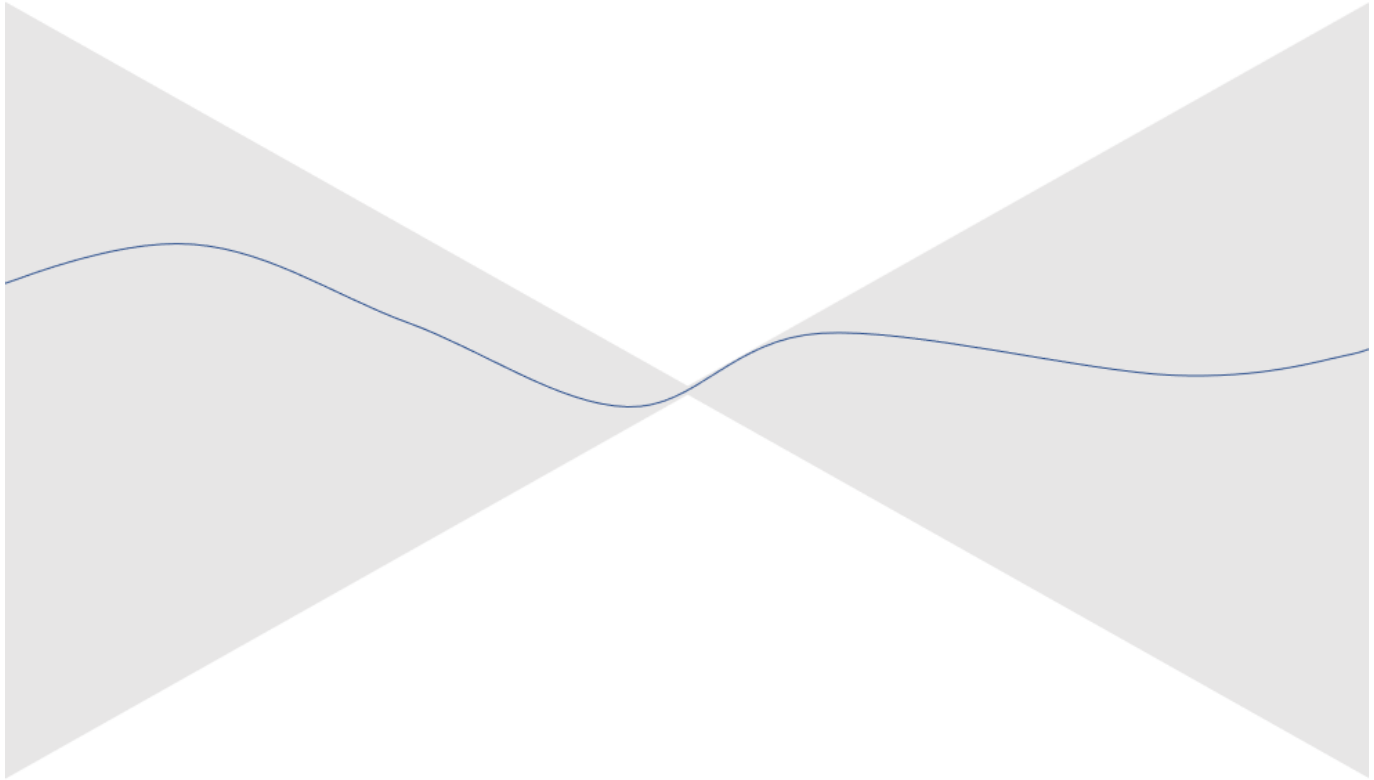
- *In cyclic BAGs, algorithm may not converge (Mossakowski, Neuhaus 2018)*





Mossakowski, T., & Neuhaus, F.. Modular semantics and characteristics for bipolar weighted argumentation graphs. *arXiv preprint arXiv:1807.06685*. 2018.

Digression: Lipschitz Continuity



- Lipschitz-continuous: *„function does not grow faster than some linear function"*

there is some λ such that $| f(x_1) - f(x_2) | \leq \lambda \times |x_1 - x_2|$ *for all* x_1, x_2

- *λ is called* Lipschitz-constant

Convergence in Cyclic BAGs

- *Sufficient conditions for converge can be derived assuming*
  - *bounded derivatives (Mossakowski, Neuhaus 2018) or, more general,*
  - *Lipschitz-continuity (AAMAS 2019)*

Theorem (AAMAS 2019)
If semantics is contractive, that is,
1. aggregation function has Lipschitz-constant λ_1,
2. influence function has Lipschitz-constant λ_2,
3. $\lambda_1 \times \lambda_2 < 1$,

then the algorithm is guaranteed to converge.

Convergence up to D digits after $O(C(\lambda_1, \lambda_2) \times D)$ iterations

Mossakowski, T., & Neuhaus, F.. Modular semantics and characteristics for bipolar weighted argumentation graphs. *arXiv preprint arXiv:1807.06685*. 2018.
Potyka, N. Extending Modular Semantics for Bipolar Weighted Argumentation. In Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2019). 2019.

Some Lipschitz Constants

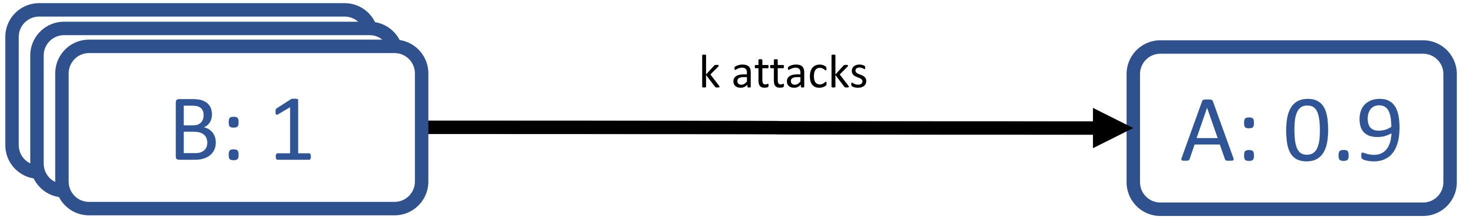
Aggregation Function	λ
Product	max. indegree of any argument in BAG
Sum	max. indegree of any argument in BAG
Top	≤2

Influence Function	λ
Linear(k)	$\frac{1}{k} \max \{w(i), 1 - w(i) : i = 1, \dots, n\}$
Euler-based	0.25
qmax(k)	$\frac{1}{k} \max \{w(i), 1 - w(i) : i = 1, \dots, n\}$

Some Convergence Guarantees

Semantics	Aggregation	Influence	Sufficient Conditions
(Mossakowski, Neuhaus 2018)	Top	Euler-based	Always
DF-QuAD (k=1)	Product	Linear(k)	Max. indegree < k
Euler-based	Sum	Euler-based	Max. indegree < 4
Quadratic Energy (k=1)	Sum	qmax(k)	Max. indegree $< \frac{k}{p}$

Convergence Guarantees vs. Open-Mindedness



Aggregation	Influence	k=0	k=1	k=10	k=100
Top	Euler	0.9	0.862	0.862	0.862
Addition	Euler	0.9	0.862	0.811	0.811
Top	qmax(1)	0.9	0.498	0.498	0.498
Addition	qmax(1)	0.9	0.498	0.012	0.001
Top	qmax(5)	0.9	0.873	0.873	0.873
Addition	qmax(5)	0.9	0.873	0.213	0.004

Convergence Guarantees vs. Open-Mindedness

Lemma (AAMAS 2019)
If semantics is defined by
1. aggregation function that maps to [-B, B],
2. combination function with Lipschitz-constant λ,

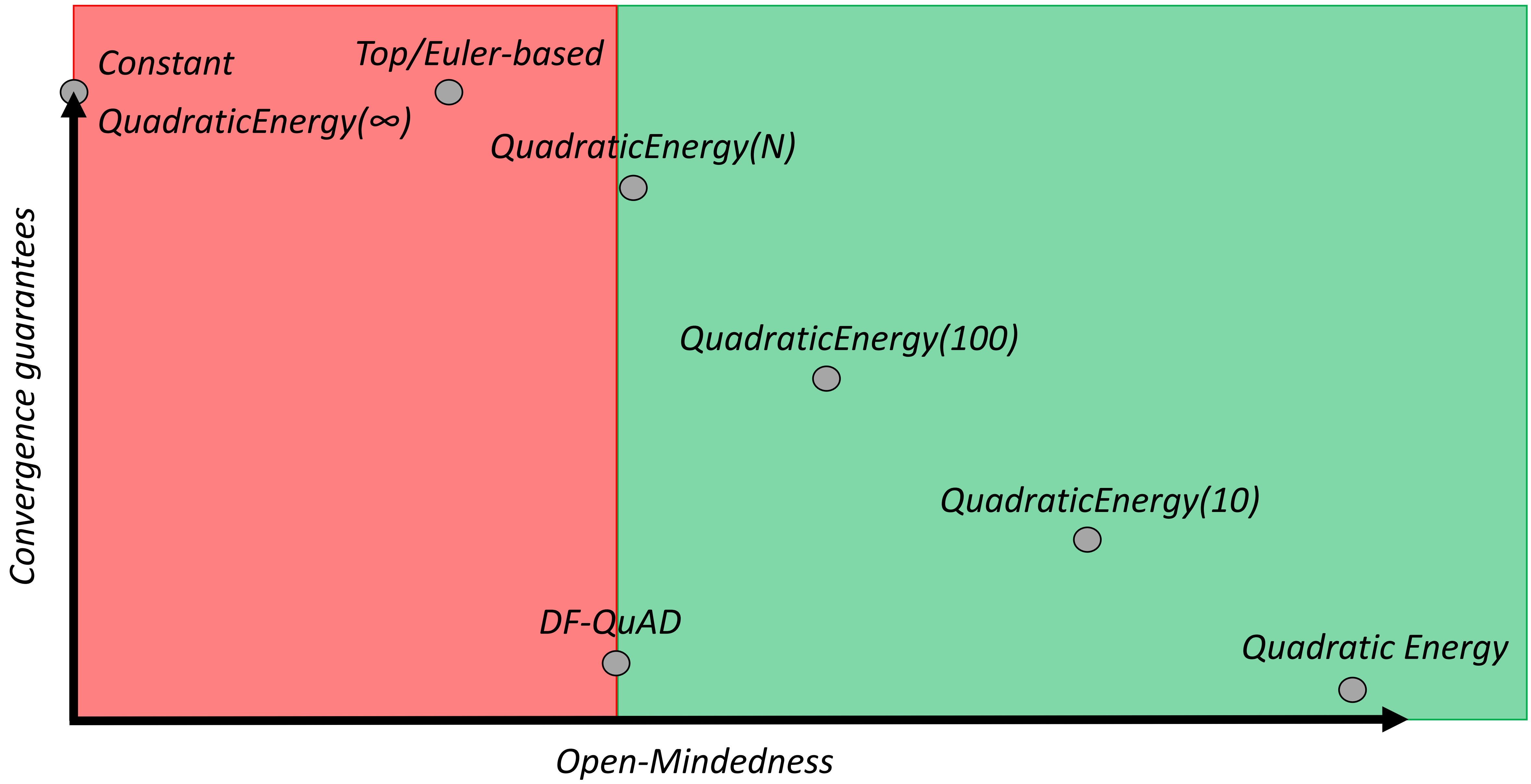
then $|s(i) - w(i)| \leq \lambda \times B$.

Aggregation Function	Range
Product	[-1, 1]
Sum	(-∞, ∞)
Top	[-1, 1]

Influence Function	λ
Linear(k)	$\geq \frac{1}{2k}$
Euler-based	$\frac{1}{4}$
qmax(k)	$\geq \frac{1}{2k}$

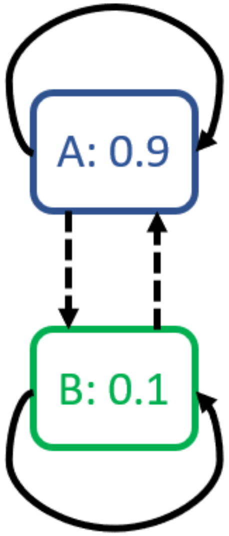
Potyka, N. Extending Modular Semantics for Bipolar Weighted Argumentation. In Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2019). 2019.

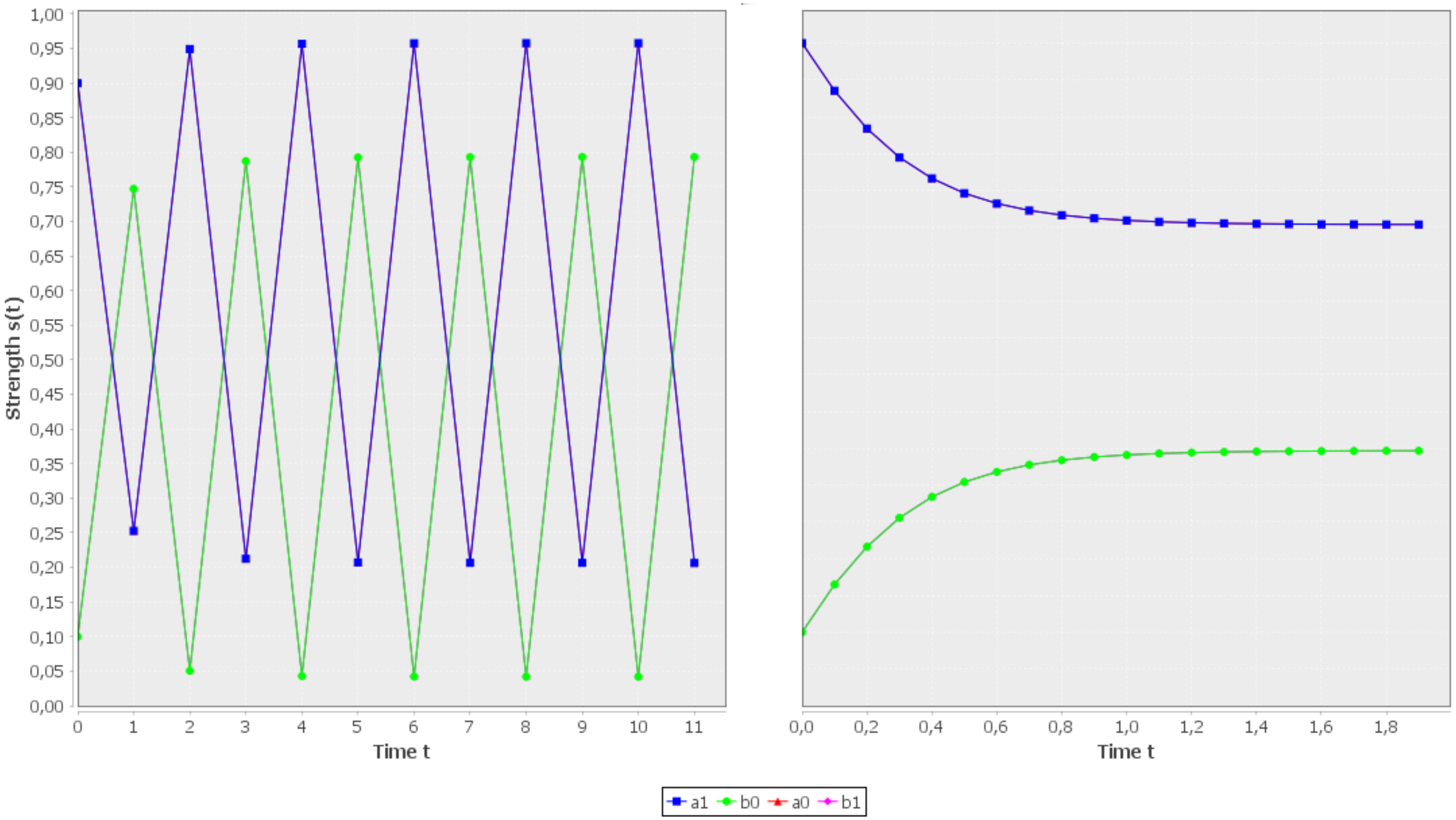
Convergence Guarantees vs. Open-Mindedness



Improving Guarantees by Continuization

- *(Discrete) semantics can be seen as coarse approximations of continuous semantics (KR2014)*
- *Continuizing semantics can solve divergence problems without loosing open-mindedness*



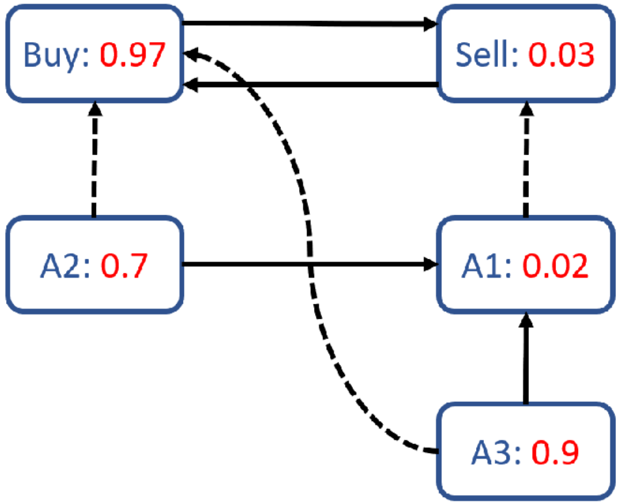


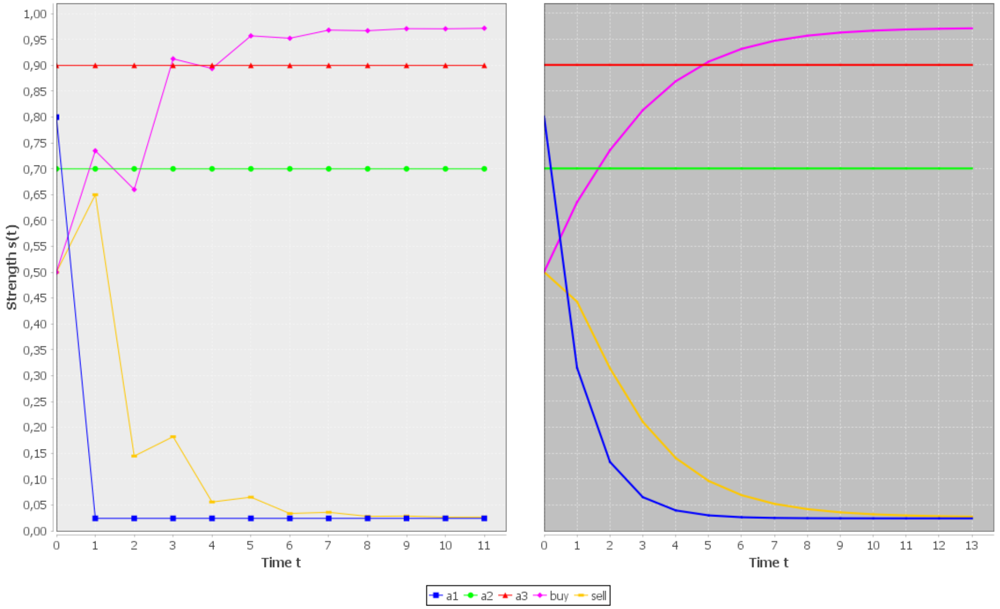
Potyka, N. Continuous dynamical systems for weighted bipolar argumentation. In *Sixteenth International Conference on Principles of Knowledge Representation and Reasoning (KR 2018)*. 2018.

Improving Guarantees by Continuization

Theorem (AAMAS 2019)
If semantics is contractive (satisfies convergence conditions), continuized semantics converges to the same strength values.

Empirically, convergence in subquadratic time.





Potyka, N. Extending Modular Semantics for Bipolar Weighted Argumentation. In Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2019). 2019.

Convergence Guarantees for Continuized Semantics

- *Support-only: yes (mon. increasing and bounded from above)*
- *Attack-only: probably (hand-waving argument)*
- *Bipolar: maybe (neither proof idea nor counterexamples are known)*

Potyka, N. Extending Modular Semantics for Bipolar Weighted Argumentation. In Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2019*)*. 2019.

Some Further Readings about Computational Issues

- *Fixed points in Social Abstract Argumentation*

Leite, J., & Martins, J. Social abstract argumentation. In Twenty-Second International Joint Conference on Artificial Intelligence (IJCAI 2011). 2011.

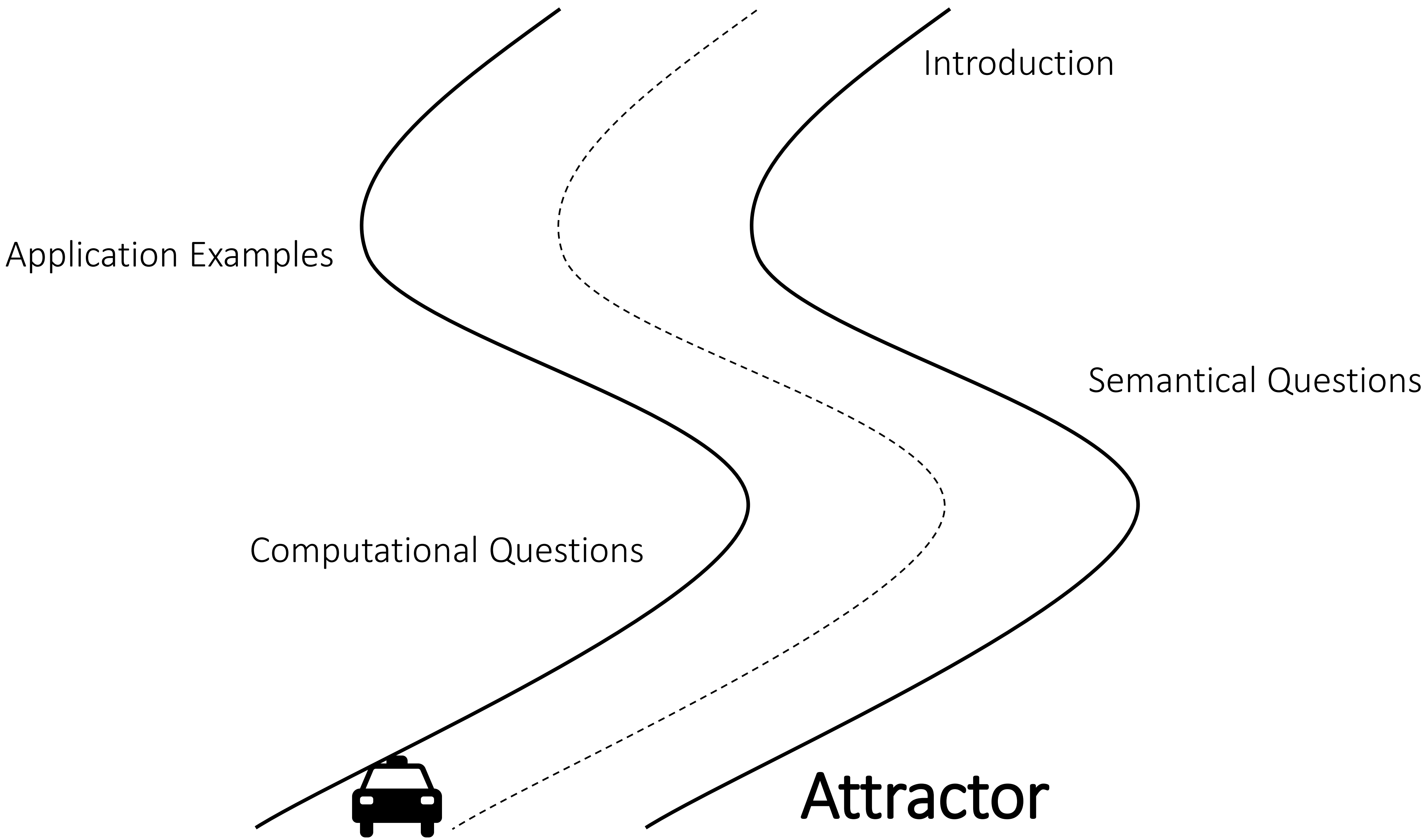
Amgoud, L. et al. A note on the uniqueness of models in social abstract argumentation. arXiv preprint arXiv:1705.03381.

- *Convergence of Discrete Semantics in Attack-only Graphs*

Amgoud, L., & Doder, D. Gradual Semantics Accounting for Varied-Strength Attacks. In Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2019). 2019.

- *High-Level Introduction to Continuous Semantics*

Potyka, N. (2018). A Tutorial for Weighted Bipolar Argumentation with Continuous Dynamical Systems and the Java Library Attractor. 17th International Workshop on Non-Monotonic Reasoning (NMR 2018). 2018.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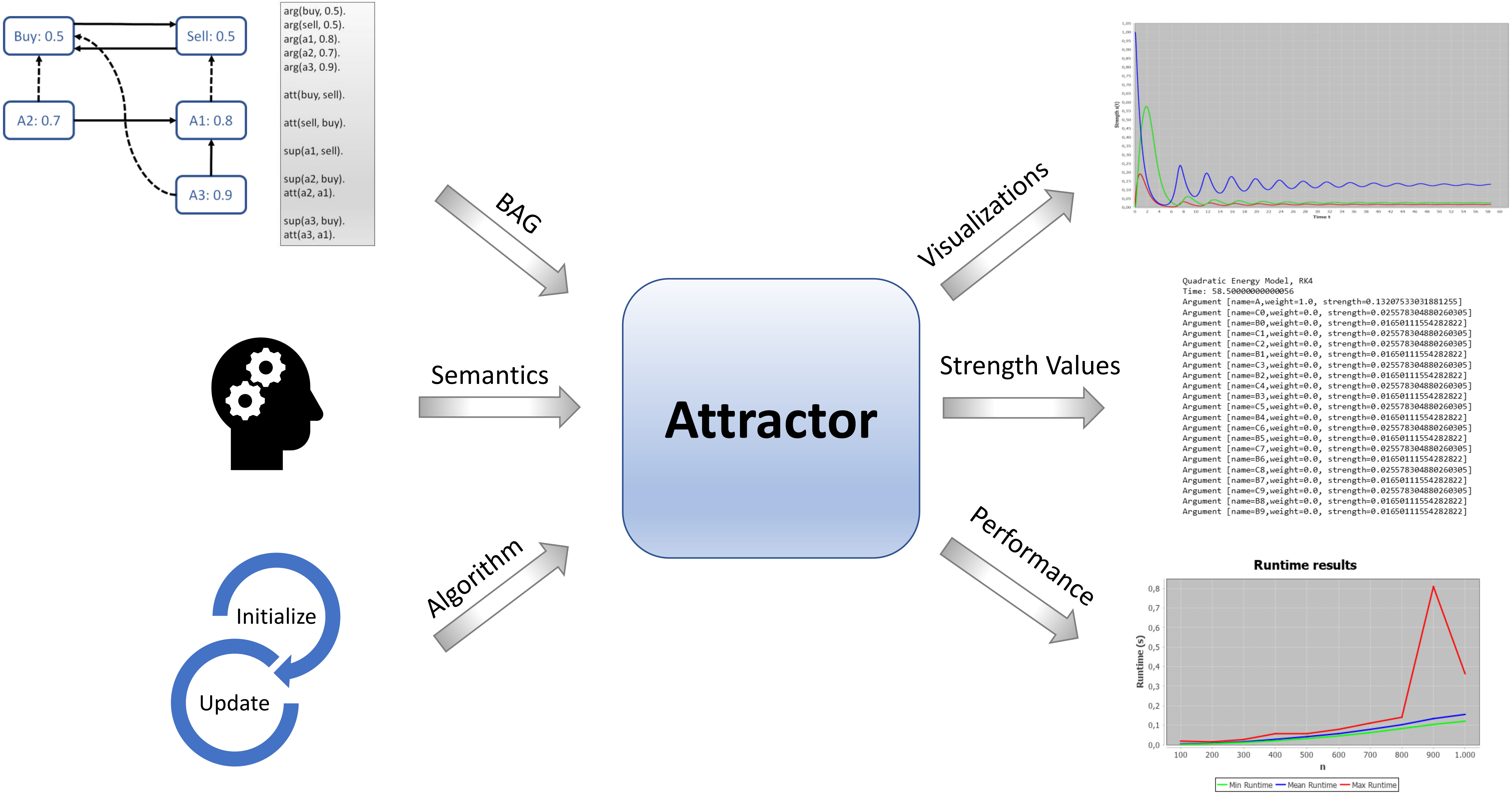
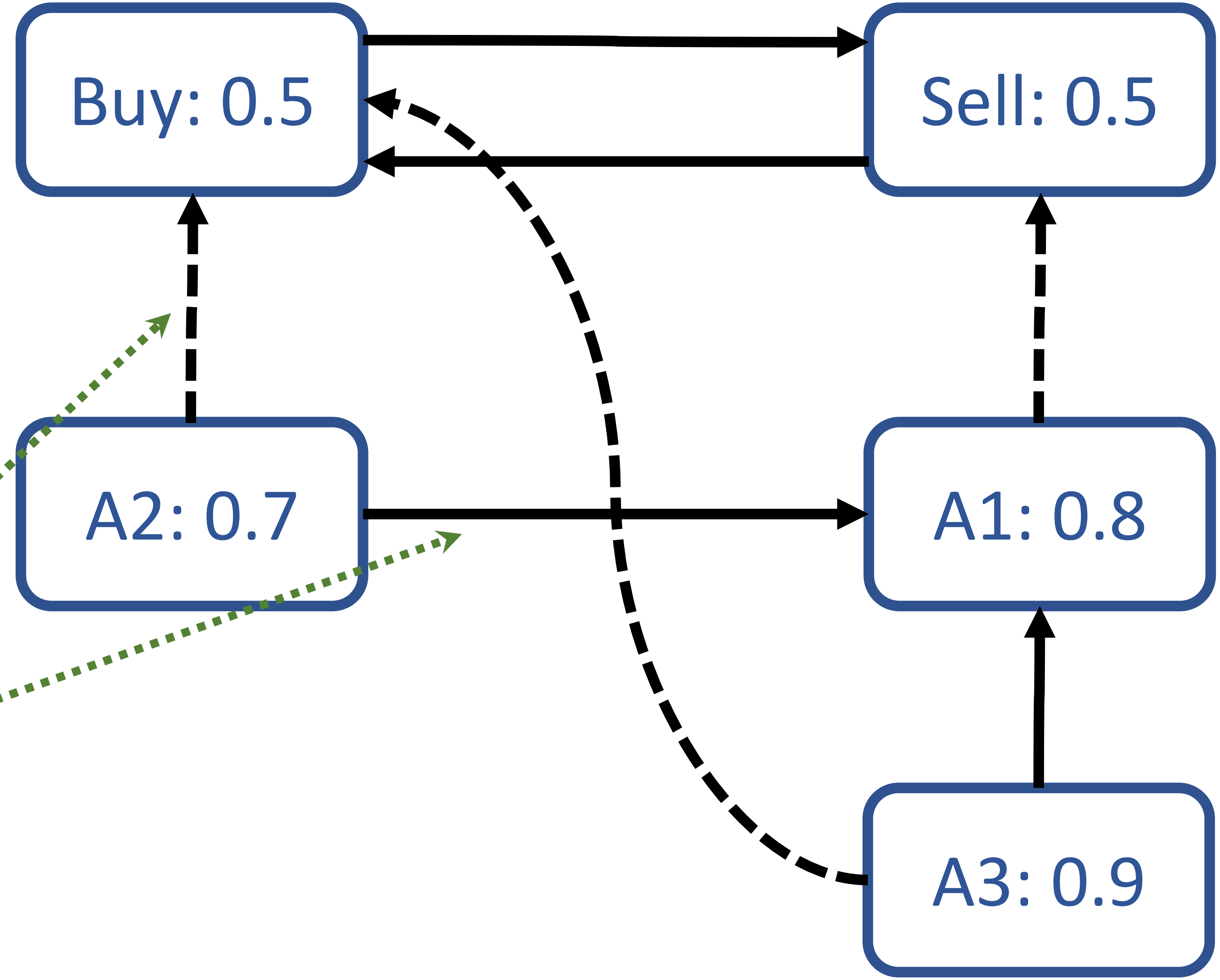


https://sourceforge.net/projects/attractorproject/

```
arg(buy, 0.5).
arg(sell, 0.5).
arg(a1, 0.8).
arg(a2, 0.7).
arg(a3, 0.9).

att(buy, sell).

att(sell, buy).

sup(a1, sell).

sup(a2, buy).
att(a2, a1).

sup(a3, buy).
att(a3, a1).
```



Solving Weighted Argumentation Problems

```
AbstractDynamicArgumentationSystem ads = new ContinuousDFQuADModel();

AbstractIterativeApproximator approximator = new RK4(ads);
ads.setApproximator(approximator);

BAGFileUtils fileUtils = new BAGFileUtils();
BAG bag;

try {

        bag = fileUtils.readBAGFromFile(new File("files/PresentationBAG.bag"));
        ads.setBag(bag);
        ads.approximateSolution(10e-3, 10e-4, true);

}
catch (Exception e) {
      e.printStackTrace();
}
```

Select Semantics

Select Algorithm

Use utility tools to read BAG

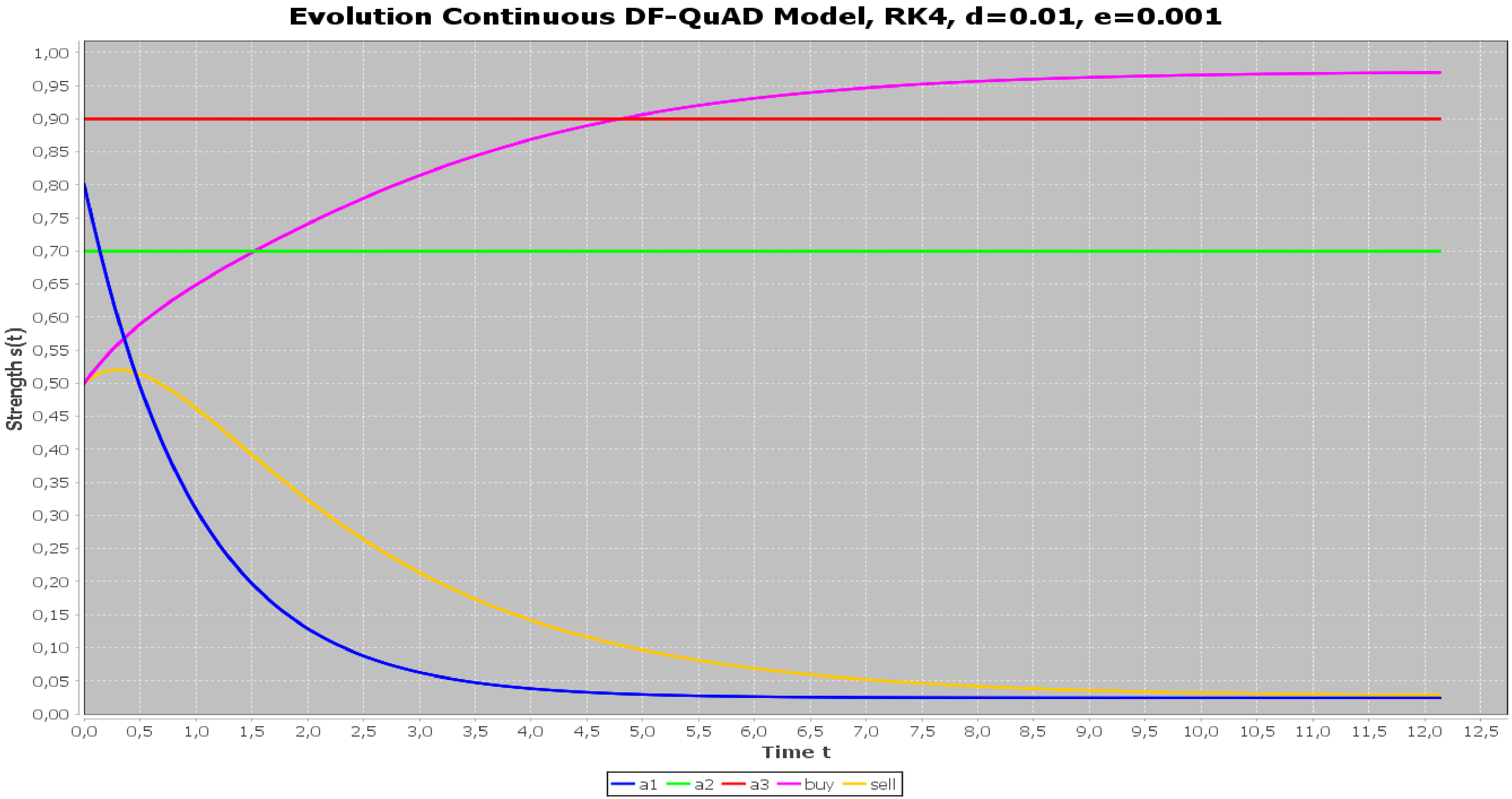
Step size

ε

Info

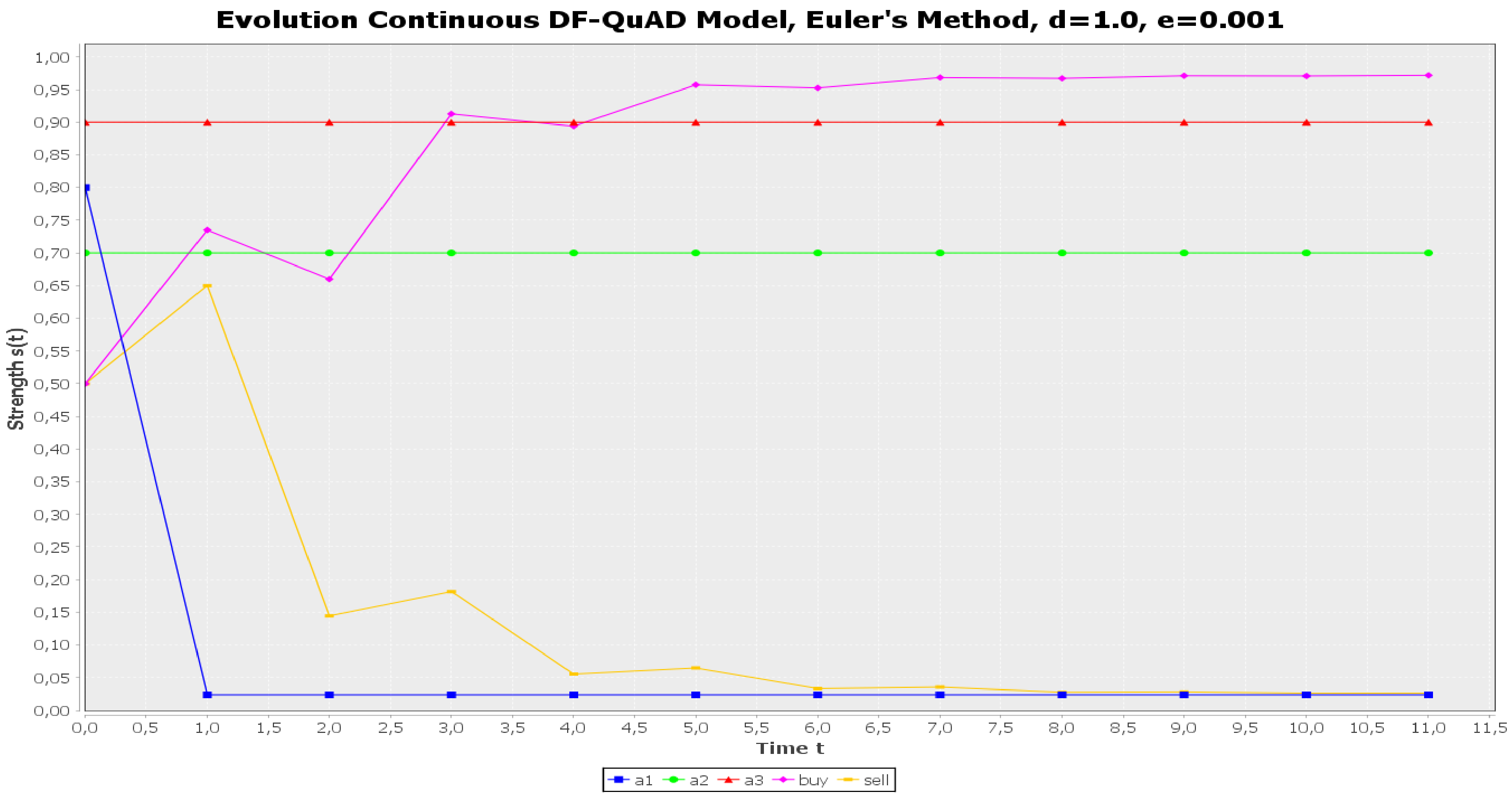
```
ads.setApproximator(new PlottingRK4(ads));
ads.approximateSolution(10e-3, 10e-4, true);
```

Generate visualizations with JFreeChart



```
ads.setApproximator(new PlottingEulersMethod(ads));
ads.approximateSolution(1, 10e-4, true);
```

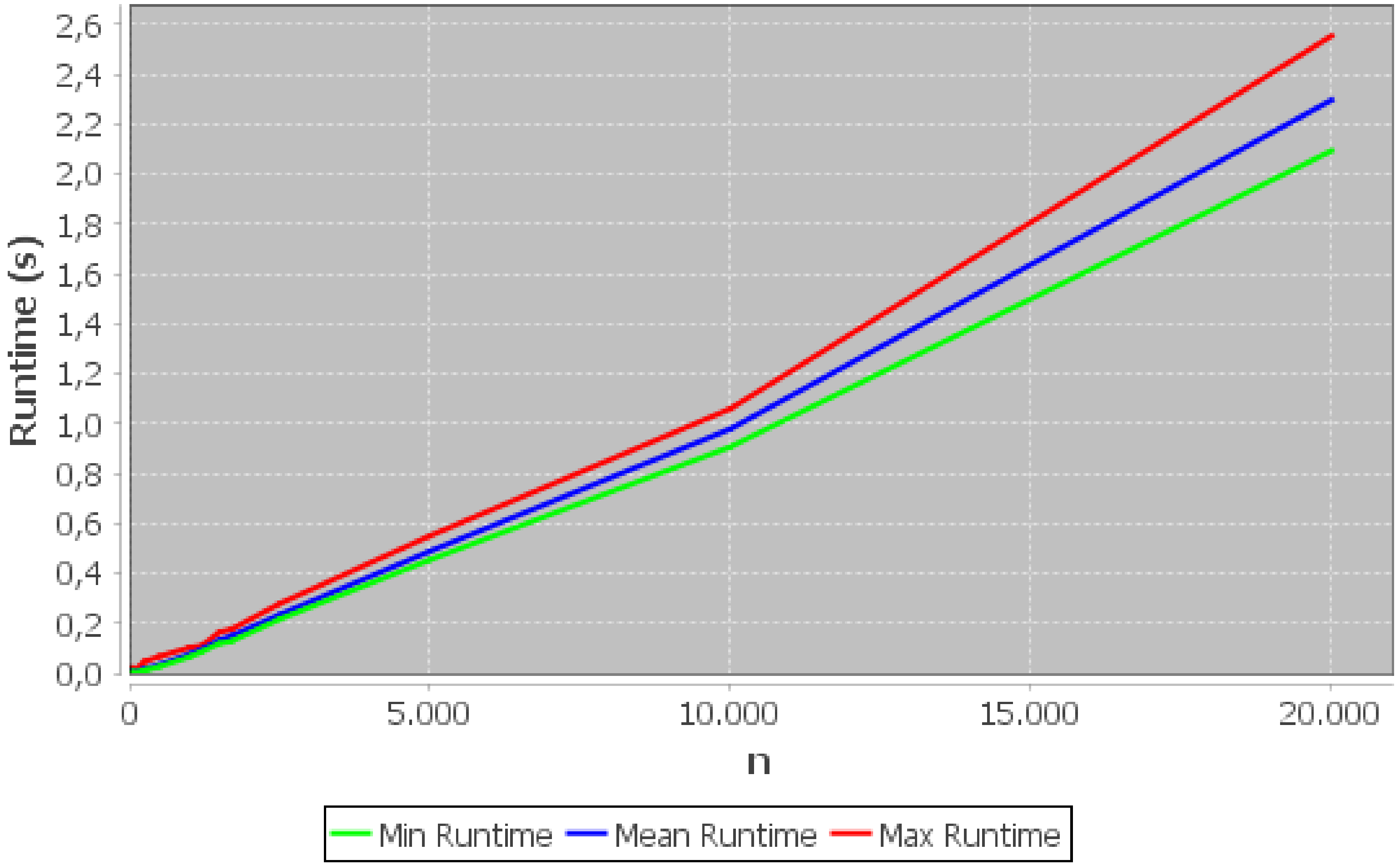
Simulate Discrete Semantics using Euler‘s Method (KR 2018)



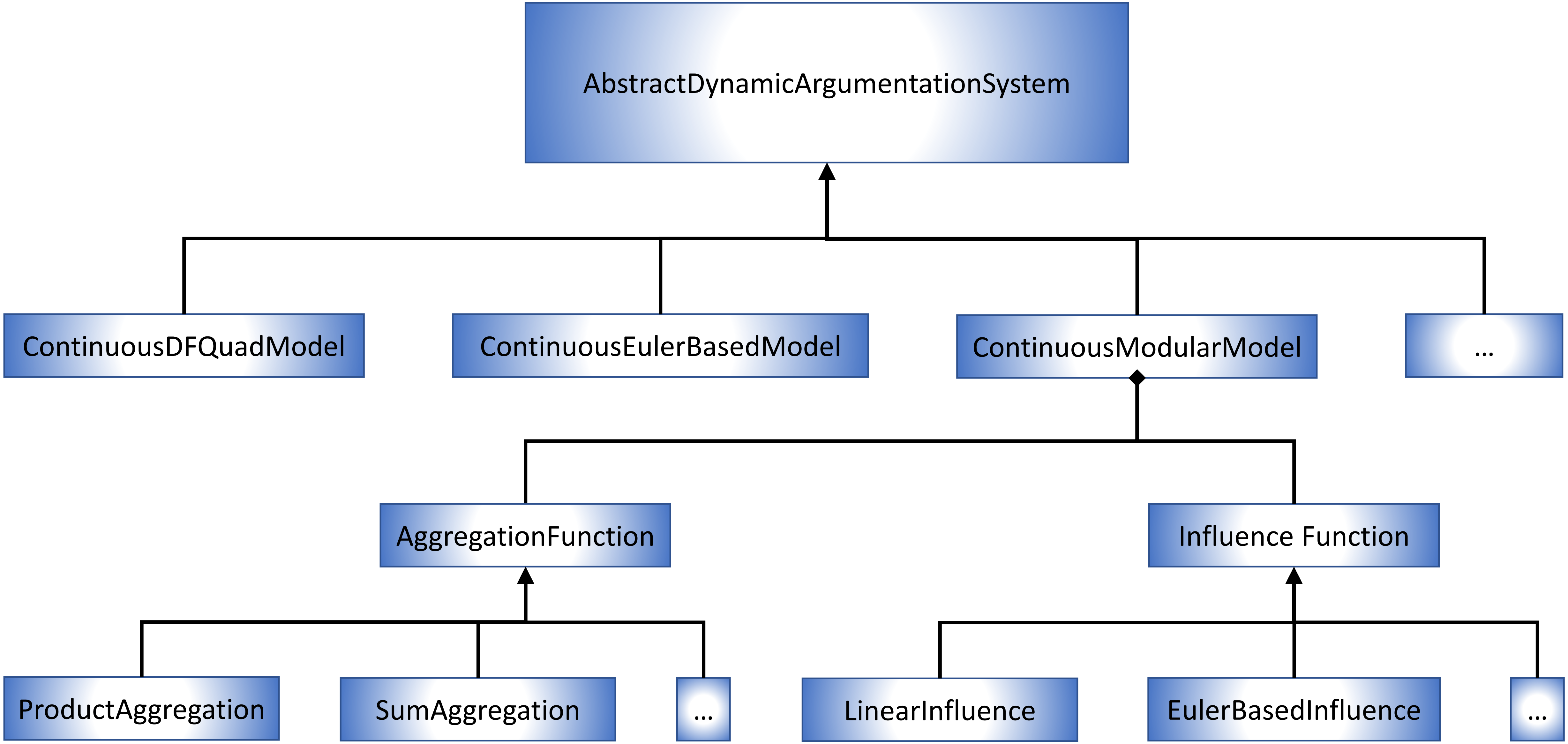
Potyka, N. Continuous dynamical systems for weighted bipolar argumentation. In *Sixteenth International Conference on Principles of Knowledge Representation and Reasoning (KR 2018)*. 2018.

Perform Benchmarks

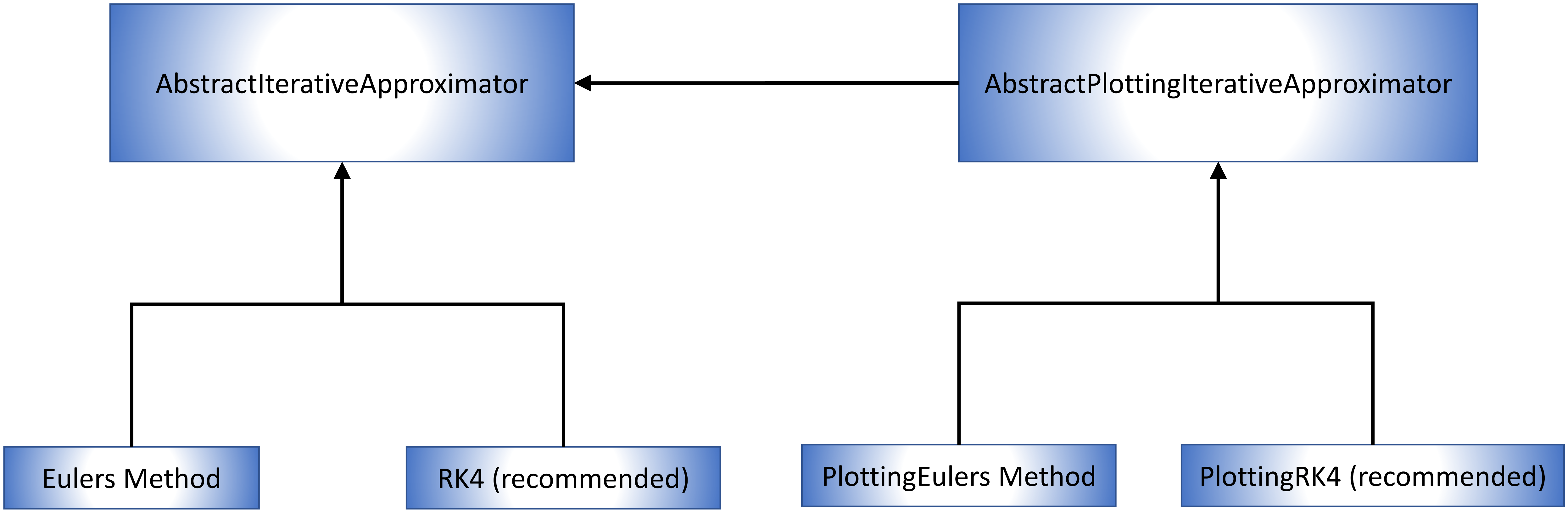
```
BenchmarkUtils benchmark = new BenchmarkUtils();
File benchmarkDirectory = new File("files/networks/barabasi");
QuadraticEnergyModel qas = new QuadraticEnergyModel();

benchmark.runBenchmark(benchmarkDirectory, qas);
```



Using and Adding Semantics



Using and Adding Algorithms



Documentation

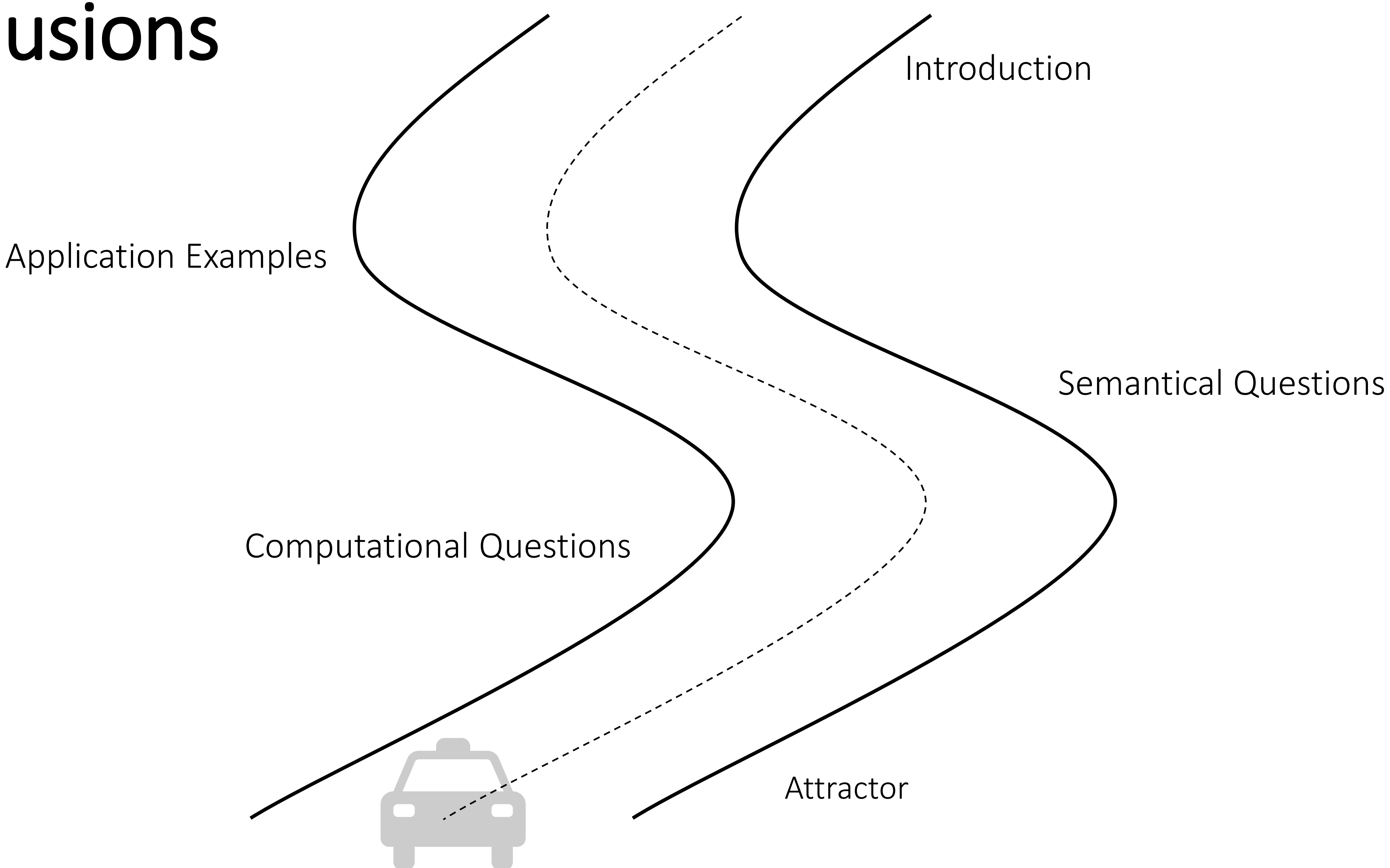
- *Tutorial Article*

Potyka, N. (2018). A Tutorial for Weighted Bipolar Argumentation with Continuous Dynamical Systems and the Java Library Attractor. 17th International Workshop on Non-Monotonic Reasoning (NMR 2018). 2018.

- *Javadoc*

https://sourceforge.net/projects/attractorproject/

Conclusions



Weighted Bipolar Argumentation

- Computationally efficient tool for
  - *Social Media Analysis*
  - *Decision Problems*
  - *Explainable AI*

- *Some interesting research questions*
  - *convergence guarantees*
  - *learning BAGs from data*
  - *empirical investigation of semantical properties*
  - *new applications*
  - …

https://sourceforge.net/projects/attractorproject/