Towards Preprocessing for Abstract Argumentation Frameworks

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Based on joint work with
Ringo Baumann, Wolfgang Dvořák and Stefan Woltran

Workshop on New Trends in Formal Argumentation
August 17th, 2017

Prologue

Seminal Paper by Phan Minh Dung:
On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. Artif. Intell., 77(2):321–358, 1995.

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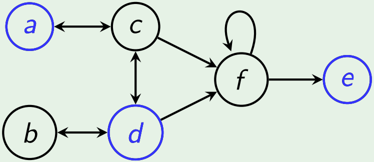

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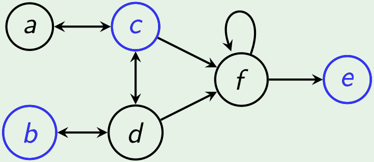

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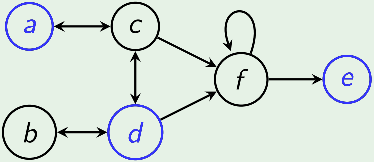

$$stb(F) = \{\{a, d, e\}, \{b, c, e\}\}$$
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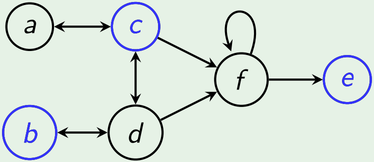

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\begin{aligned}
stb(F) &= \{\{a, d, e\}, \{b, c, e\}\} \\
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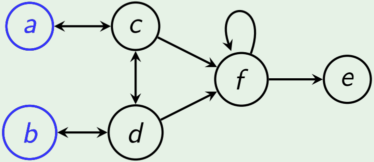

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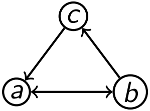

Nonmon. Reasoning

Logic Programming

n-Person Games

⋮

ABA

ASPIC

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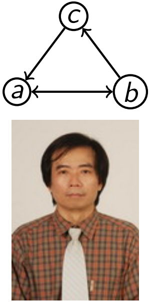

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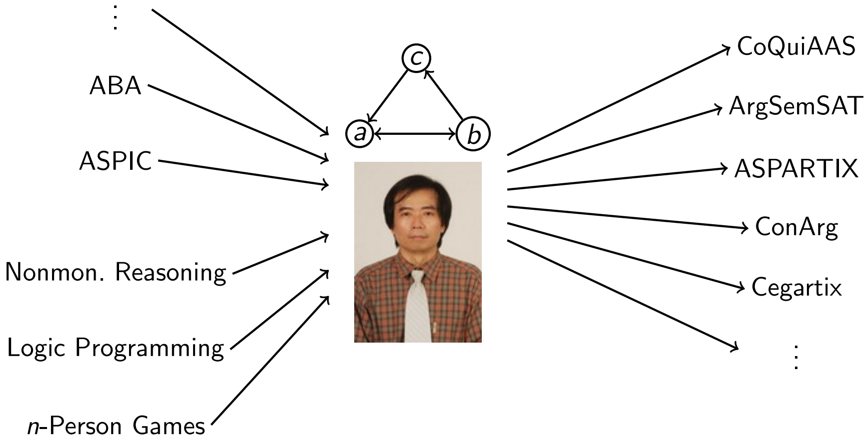

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ABA
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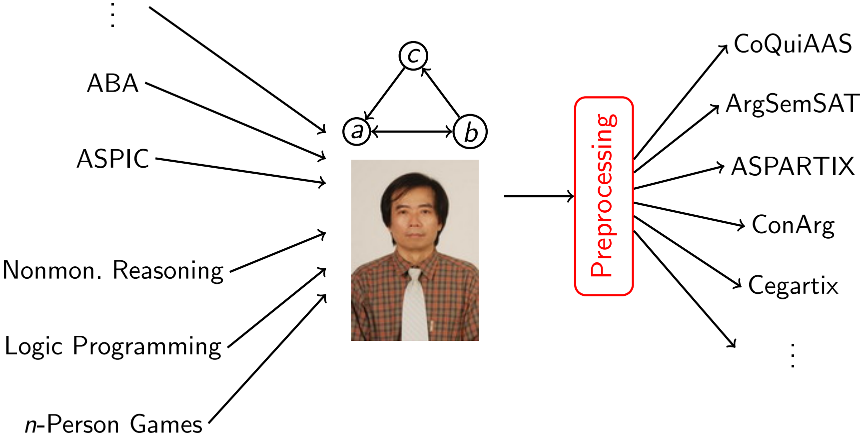
Prologue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⋮

Outline

- Quick Background on Argumentation Frameworks
- The Role of Preprocessing
- Theoretical Foundations
- Building a Preprocessing Machine
- Conclusions and Open Questions

Background

Definition

An argumentation framework (AF) is a pair (A, R) where A is a finite set of arguments and $R \subseteq A \times A$ is the attack relation representing conflicts.

Semantics

For AF $F = (A, R)$, $E \in \sigma(F)$ iff ...

- admissible: E is conflict-free and defends itself
- stable: E is conflict-free and has full range
- preferred: E is subset-maximal admissible
- complete: E is admissible and contains all defended arguments
- semi-stable: E is admissible with subset-maximal range
- stage: E is conflict-free with subset-maximal range
- grounded: E is subset-minimal complete set
- ideal: E is subset-maximal *adm* contained in each *pref* extension

Background

σ	$Cred_\sigma$	$Skept_\sigma$	Ver_σ	NE_σ
cf	in L	trivial	in L	in L
grd	P-c	P-c	P-c	in L
stb	NP-c	coNP-c	in L	NP-c
adm	NP-c	trivial	in L	NP-c
comp	NP-c	P-c	in L	NP-c
ideal	in Θ_2^P	in Θ_2^P	in Θ_2^P	in Θ_2^P
pref	NP-c	Π_2^P-c	coNP-c	NP-c
sem	Σ_2^P-c	Π_2^P-c	coNP-c	NP-c
stage	Σ_2^P-c	Π_2^P-c	coNP-c	in L

Background - ICCMA'17

(http://www.dbai.tuwien.ac.at/iccma17/)

Home | Calls | Rules | Participation | Submissions | Results | Organization

ICCMA 2017

The tasks supported by the solvers are summarized in the following table:

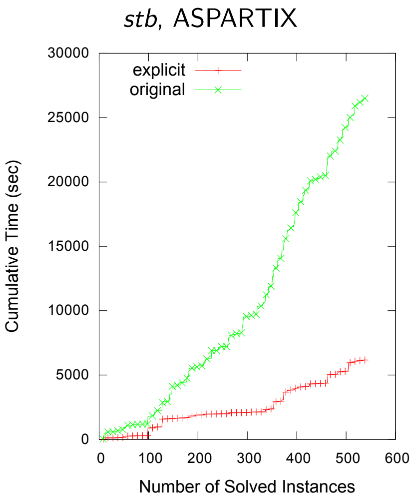
	D3	CO				PR				ST				SST				STG				GR		ID	
		DC	DS	SE	EE	DC	DS	SE	EE	DC	DS	SE	EE	DC	DS	SE	EE	DC	DS	SE	EE	DC	SE	DC	SE
argmat olpb		1	1	1	1					1	1	1	1									1	1		
argmat dvisat	1	1	1	1	1	1	1	1	1	1	1	1	1									1	1	1	1
argmat-mpg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
argmat-sat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ArgSemSAT		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1		
ArgTools		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ASPrMin									1																
cegartix	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chimaerarg									1				1												
ConArg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CoQuiAAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
EqArgSolver	1	1	1	1	1	1	1	1	1	1	1	1	1									1	1		
gg-sts	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
goDIAMOND	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
heureka		1	1	1	1	1	1	1	1	1	1	1	1									1	1		
pyglaf	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

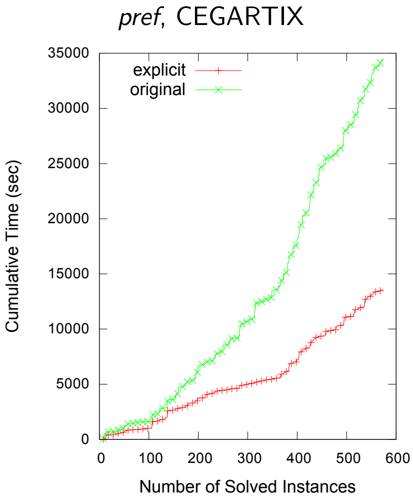
Preprocessing

- Preprocessing refers to a family of simplifications which are computationally easy to perform and are equivalence preserving
  - SAT: tautology elimination, clause subsumption, ...
- Proved very successful in SAT and QSAT solving
- Example from the QBF world:
  - Preprocessor Bloqqer solved 471 of 1130 instances from QBFEVAL'16.
  - DepQBF solves 556 instances without preprocessing, but 817 with preprocessing.

- Preprocessing in the context of argumentation poses some additional challenges

Preprocessing for Argumentation – Some Experiments





Effect of (non equivalence-preserving) modifications with instances from the ICCMA'15 stable generator.

Theoretical Foundations

In order to define possible preprocessing steps, we require

- a suitable notion of equivalence ...
- which allows to verify which subparts of AFs
  can be simplified ...
- under different semantics

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- a suitable notion of equivalence ...
- which allows to verify which subparts of AFs can be simplified ...
- under different semantics

More precisely, we want to find pairs (F, F') such that replacing F by F' in any AF G does not change the extensions of G

Theoretical Foundations – Notions of Equivalence

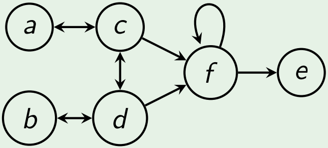
Definition

Given a semantics σ. Two AFs F and F' are (standard) equivalent w.r.t. σ (in symbols $F \equiv^{\sigma} F'$) iff $\sigma(F) = \sigma(F')$.

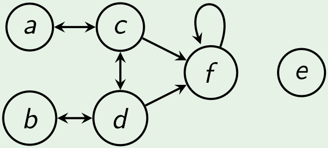
Definition

Given a semantics σ. Two AFs F and F' are strongly equivalent w.r.t. σ (in symbols $F \equiv^{\sigma}_{\mathcal{S}} F'$) iff $F \cup H \equiv^{\sigma} F' \cup H$ holds for each AF H.

Example



$\equiv^{stb}$



$stb(F) = \{\{a, d, e\}, \{b, c, e\}\}$

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Theoretical Foundations – Notions of Equivalence

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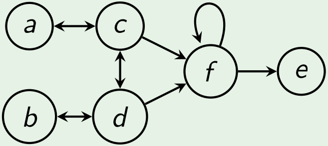
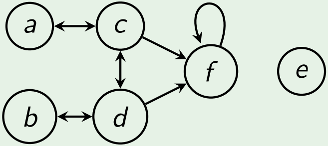


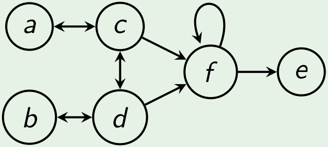
$$\equiv_{\mathcal{S}}^{stb}$$



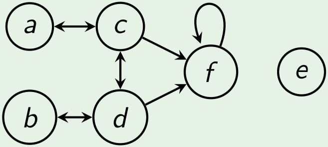
Follows from results in [Oikarinen & Woltran, 2011].

Theoretical Foundations – Notions of Equivalence

Example



$\not\equiv^{pref}$



$pref(F) =$
$\{\{a, d, e\}, \{b, c, e\}, \{a, b\}\}$

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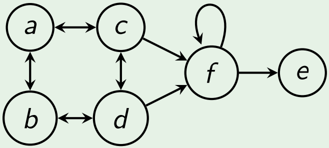
$\{\{a, d, e\}, \{b, c, e\}, \{a, b, e\}\}$

Example



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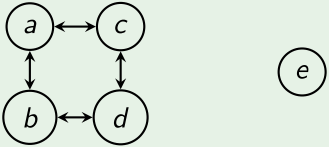

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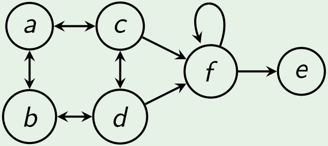
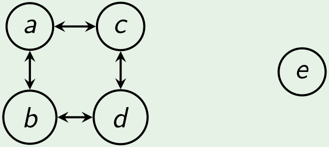


$$\not\equiv^{stb}_{\mathcal{S}}$$



Theoretical Foundations – Notions of Equivalence

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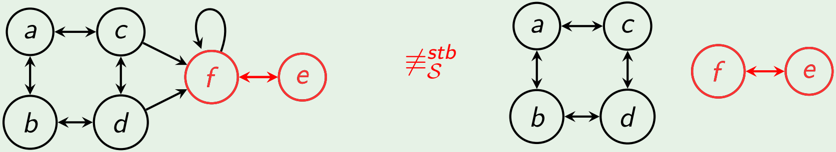

$stb(F \cup H) = \{\{a, d, e\}, \{b, c, e\}, \{a, b, e\}\}$, but $stb(F' \cup H) = \{\{a, d, e\}, \{b, c, e\}, \{a, b, e\}, \{a, d, f\}, \{b, c, f\}, \{a, b, f\}\}$

Theoretical Foundations – Main Results

Observations:

- Standard equivalence is too weak for our purpose
- Strong equivalence is too restricted
  - For self-loop free AFs F, F': $F \equiv^{\sigma}_{\mathcal{S}} F'$ iff $F = F'$!

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We thus require a notion of equivalence which takes into account the neighborhood in an adequate way.

Definition

Given a semantics σ and arguments $C \subseteq U$. Two AFs F and F' are C-relativized equivalent w.r.t. σ (in symbols $F \equiv^{\sigma}_{C} F'$) iff $F \cup H \equiv^{\sigma} F' \cup H$ holds for each AF H not containing arguments from C.

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- for $C = \emptyset$, C-relativized equivalence coincides with strong equivalence
- for $C = U$, C-relativized equivalence is just standard equivalence

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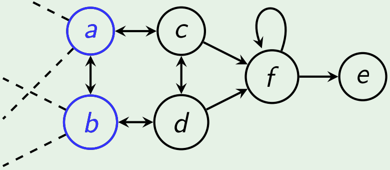
Example with $C = \{c, d, e, f\}$



Theoretical Foundations – Main Results

We first define a parameterized notion of the semantics.

Definition

Let $F = (A, R)$, $C \subseteq U$. The C-restricted stable extensions of F are

$$stb_C(F) = \{E \in cf(F) \mid A \cap C \subseteq E_F^{\oplus}\}$$

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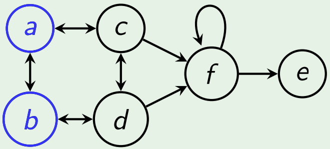

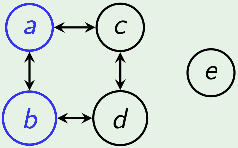

$stb_C(F) = \{\{a, d, e\}, \{b, c, e\}, \{d, e\}, \{c, e\}\}$

$stb_C(F') = \{\{a, d, e\}, \{b, c, e\}, \{d, e\}, \{c, e\}\}$

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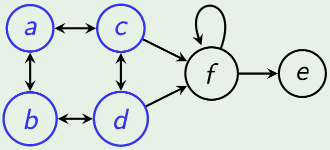
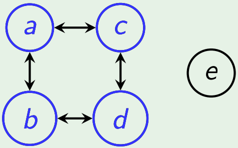
Example with $C = \{e, f\}$





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$stb_C(F') = \{\{a, d, e\}, \{b, c, e\}, \{d, e\}, \{c, e\}, \{a, e\}, \{b, e\}, \{e\}\}$

Theoretical Foundations – Main Results

For other semantics, such variants can be defined accordingly.

Definition

Let F be an AF, $C \subseteq U$. We define

$$
\begin{aligned}
adm_C(F) &= \{E \in cf(F) \mid E_F^- \cap C \subseteq E_F^+\} \\
pref_C(F) &= \{E \in adm_C(F) \mid \text{ for all } D \in adm_C(F) \text{ with} \\
&\quad E \setminus C = D \setminus C, E_F^+ \setminus C \subseteq D_F^+ \setminus, E_F^- \setminus E_F^+ \supseteq D_F^- \setminus D_F^+ : \\
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For complete and grounded semantics, similar definitions can be given by using a parameterized version of the characteristic function.

Theoretical Foundations – Main Results

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Let F be an AF, $C \subseteq U$. We define

$$\begin{aligned} adm_C(F) &= \{E \in cf(F) \mid E^-_F \cap C \subseteq E^+_F\} \\ pref_C(F) &= \{E \in adm_C(F) \mid \text{ for all } D \in adm_C(F) \text{ with} \\ &\quad E \setminus C = D \setminus C, E^+_F \setminus C \subseteq D^+_F \setminus, E^-_F \setminus E^+_F \supseteq D^-_F \setminus D^+_F : \\ &\quad E \cap C \not\subset D \cap C\} \end{aligned}$$

For complete and grounded semantics, similar definitions can be given by using a parameterized version of the characteristic function.

Theorem

Let F be an AF and $C \subseteq U$. Then, the following relations hold:
$stb_C(F) \subseteq pref_C(F) \subseteq comp_C(F) \subseteq adm_C(F)$; $grd_C(F) \subseteq comp_C(F)$.

Theoretical Foundations – Main Results

Theorem

Let F, F' be AFs and $C \subseteq U$. Then, $F \equiv_C^{stb} F'$ iff jointly

(1) $stb_C(F) = stb_C(F')$;

(2) *if* $stb_C(F) \neq \emptyset$, $A(F) \setminus C = A(F') \setminus C$;

(3) *for all* $E \in stb_C(F)$, $E_F^+ \setminus C = E_{F'}^+ \setminus C$.

Theoretical Foundations – Main Results

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Let F, F' be AFs and $C \subseteq U$. Then, $F \equiv^{stb}_{C} F'$ iff jointly

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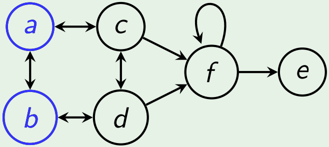
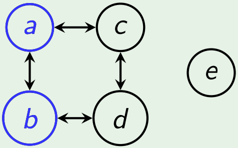
Example with $C = \{c, d, e, f\}$



$\equiv^{stb}_{C}$



Recall (1) $stb_C(F) = stb_C(F') = \{\{a, d, e\}, \{b, c, e\}, \{d, e\}, \{c, e\}\}$;
(2) and (3) also hold.

Theoretical Foundations – Main Results

Theorem

Let F, F' be AFs and $C \subseteq U$. Then, $F \equiv_C^{stb} F'$ iff jointly

(1) $stb_C(F) = stb_C(F')$;

(2) *if* $stb_C(F) \neq \emptyset$, $A(F) \setminus C = A(F') \setminus C$;

(3) *for all* $E \in stb_C(F)$, $E_F^+ \setminus C = E_{F'}^+ \setminus C$.

Similar characterization results can be shown for the other main semantics.

Theoretical Foundations – Main Results

Replacement Theorem

For AFs F, F', G and $C \subseteq U$ such that $A(F) \cup A(F') \subseteq C$, $(A(G) \setminus A(F)) \cap C = \emptyset$, and F is a sub-AF of G, let $B = (A(F))^{\oplus}_{G} \cup (A(F))^{-}_{G}$ and $F^G = (B, R(G) \cap (B \times B))$.

Then, $F^G \equiv^{\sigma}_{C} F^G[F/F']$ implies $G \equiv^{\sigma} G[F/F']$.

Theoretical Foundations – Main Results

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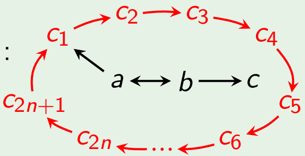
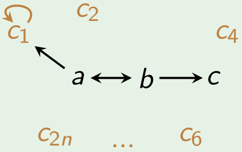
Example

G :



$G[F/F']$:

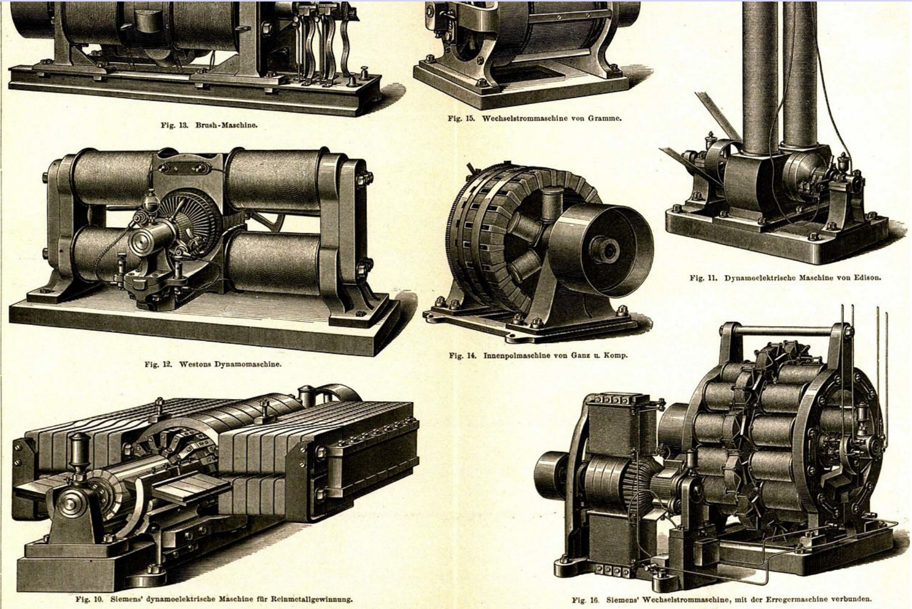


Theoretical Foundations – Main Results

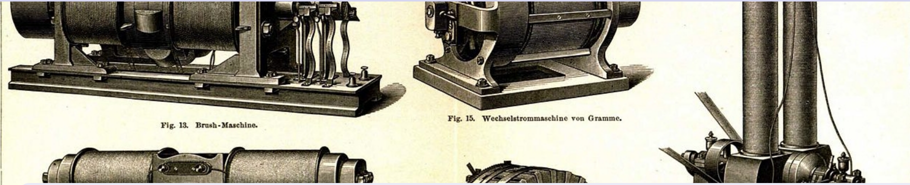
Some complexity results:

σ	*grd*	*stb*	*adm*	*comp*	*pref*
$F \equiv^{\sigma}_{\mathcal{S}} G$	in L	in L	in L	in L	in L
$F \equiv^{\sigma} G$	P-c	coNP-c.	coNP-c.	coNP-c.	Π^P_2-c.
$F \equiv^{\sigma}_{C} G$	coNP-c.	coNP-c.	coNP-c.	coNP-c.	Π^P_2-c.

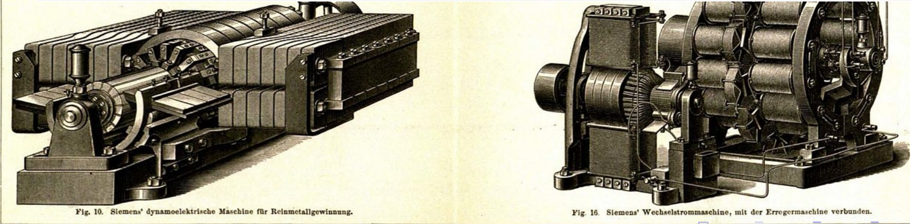
Building a Preprocessing Machine - Our Vision



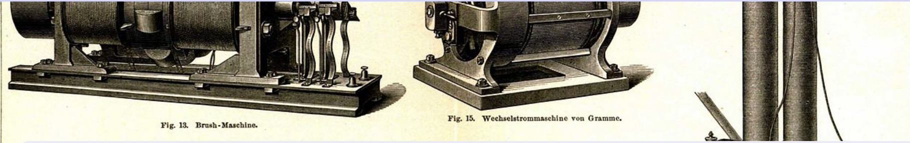
Building a Preprocessing Machine - Our Vision



1. Collect patterns (F^G, F, F') which apply for the replacement theorem
   - This can be done in an offline-phase
   - employ the equivalence characterizations
   - different patterns for different semantics

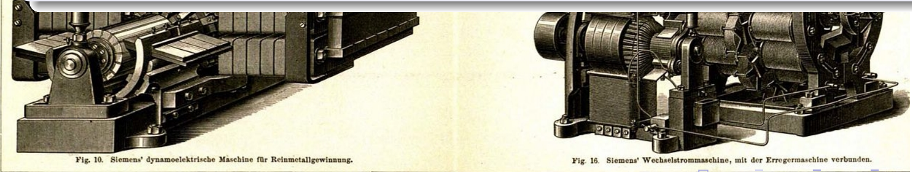


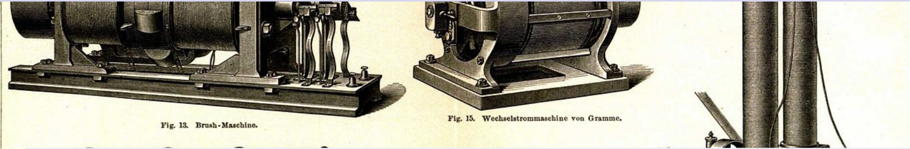
Building a Preprocessing Machine - Our Vision



2. Build a tool that scans a given AF for possible application of the replacement patterns (F^G, F, F')

- Requires efficient implementation of subgraph-isomorphism problem
- sort out which size of subgraphs allow for efficient scanning for patterns
- integrate other known simplifications (computation of grounded extension) and interleave this with the applied replacements





3. Experimental Evaluation and Fine-Tuning
   - which replacements actually help solvers?
     - Preprocessing on the argumentation level should go beyond preprocessing on encodings
   - identification of "promising regions" (e.g. potential separation into SCCs)
   - integration of ML techniques

Conclusion

- Increasing interest in development of AF solvers
- In other domains, preprocessing recognized as a crucial step to improve efficiency
- Nonmonotonic nature of argumentation semantics makes life complicated

In this talk:

- Introduced a suitable notion of equivalence to seek for simplification patterns
- Discussion of next steps towards practical realization of a preprocessing tool
  - Recall: this is beneficial for all solvers!

Future Work and Open Questions

- Understand C-relativized equivalence for further semantics
- What can be done for acceptance problems?
- Claim: preprocessing could be more powerful if we allow to shift from AFs to a more general formalism (for instance, SETAFs)
  - however, this requires solvers for this general formalism

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Thank you for your attention!

References

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