LEARNING & CONTESTING ASSUMPTION-BASED ARGUMENTATION FRAMEWORKS

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ROADMAP

- Assumption-based Argumentation
  ABA frameworks
- Learning
  ABA frameworks
- Contesting
  argumentative claims
- Redressing
  as a way of learning

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- **Assumption-based Argumentation**
  ABA frameworks
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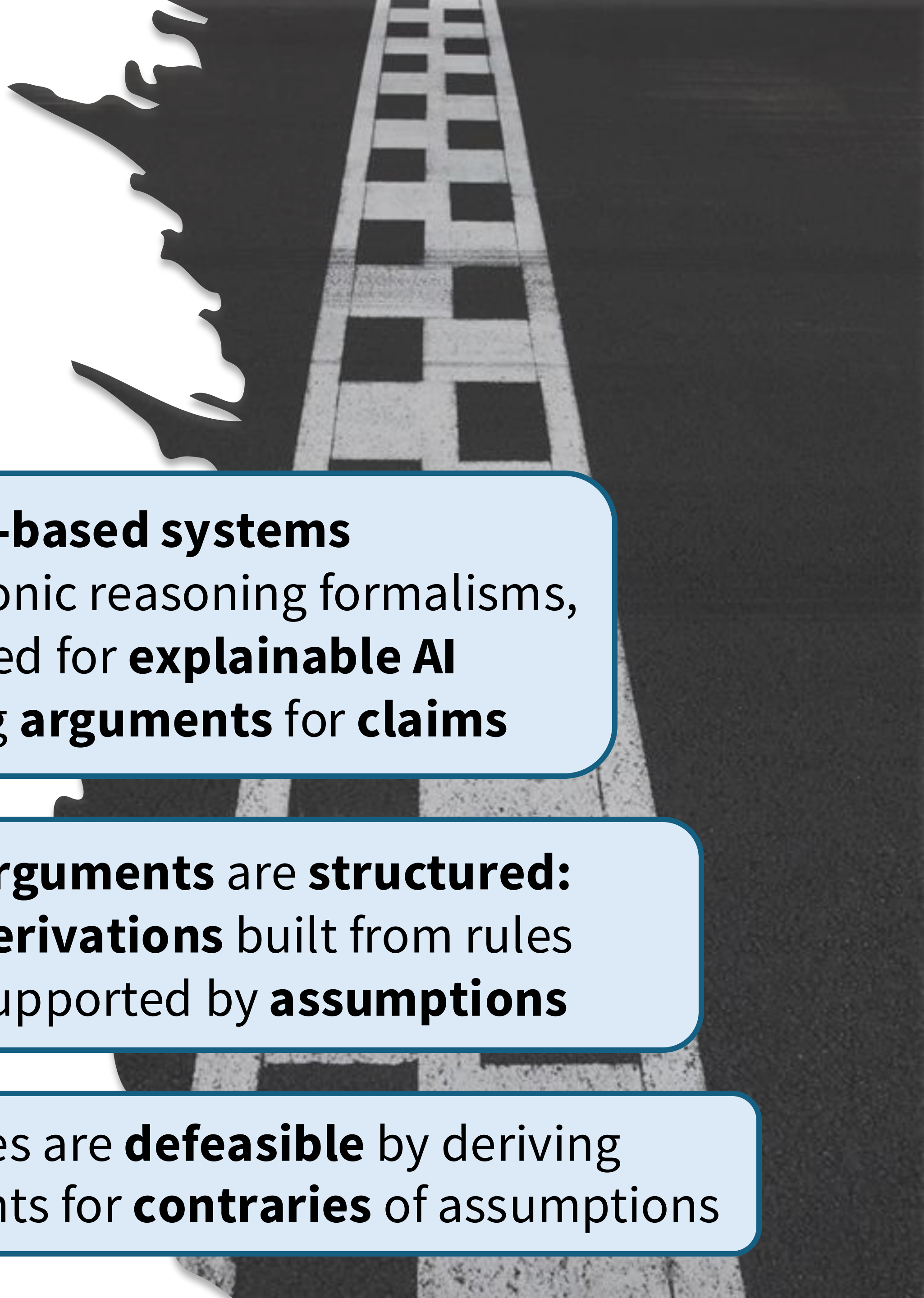
Rule-based systems
for non-monotonic reasoning formalisms,
can be used for **explainable AI**
by providing **arguments** for **claims**

Arguments are **structured:**
derivations built from rules
supported by **assumptions**

Rules are **defeasible** by deriving
arguments for **contraries** of assumptions



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- **Assumption-based Argumentation**
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- **Learning**
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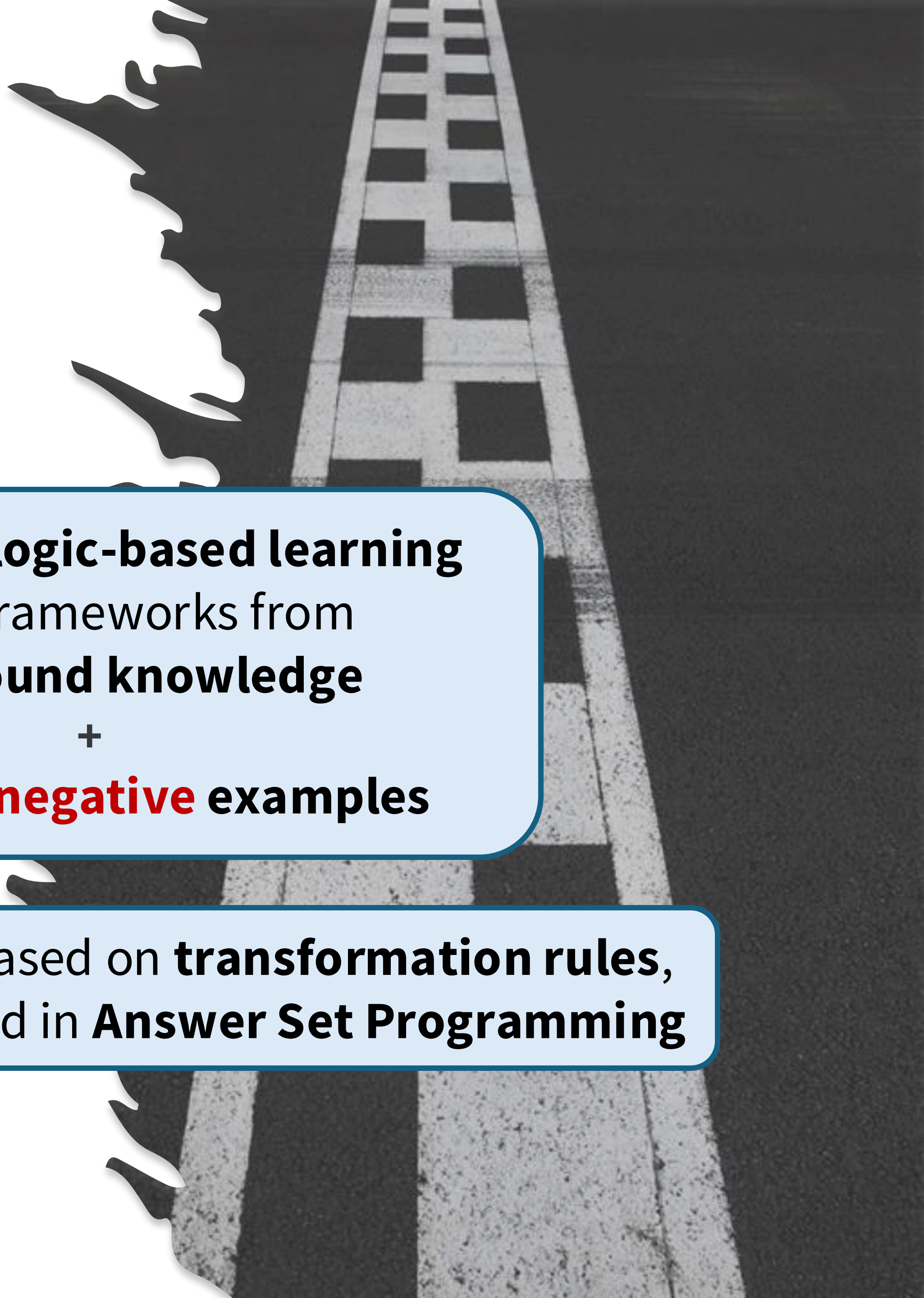
Automated logic-based learning
of ABA frameworks from
background knowledge
+
positive & **negative** **examples**

Algorithm based on **transformation rules**,
implemented in **Answer Set Programming**



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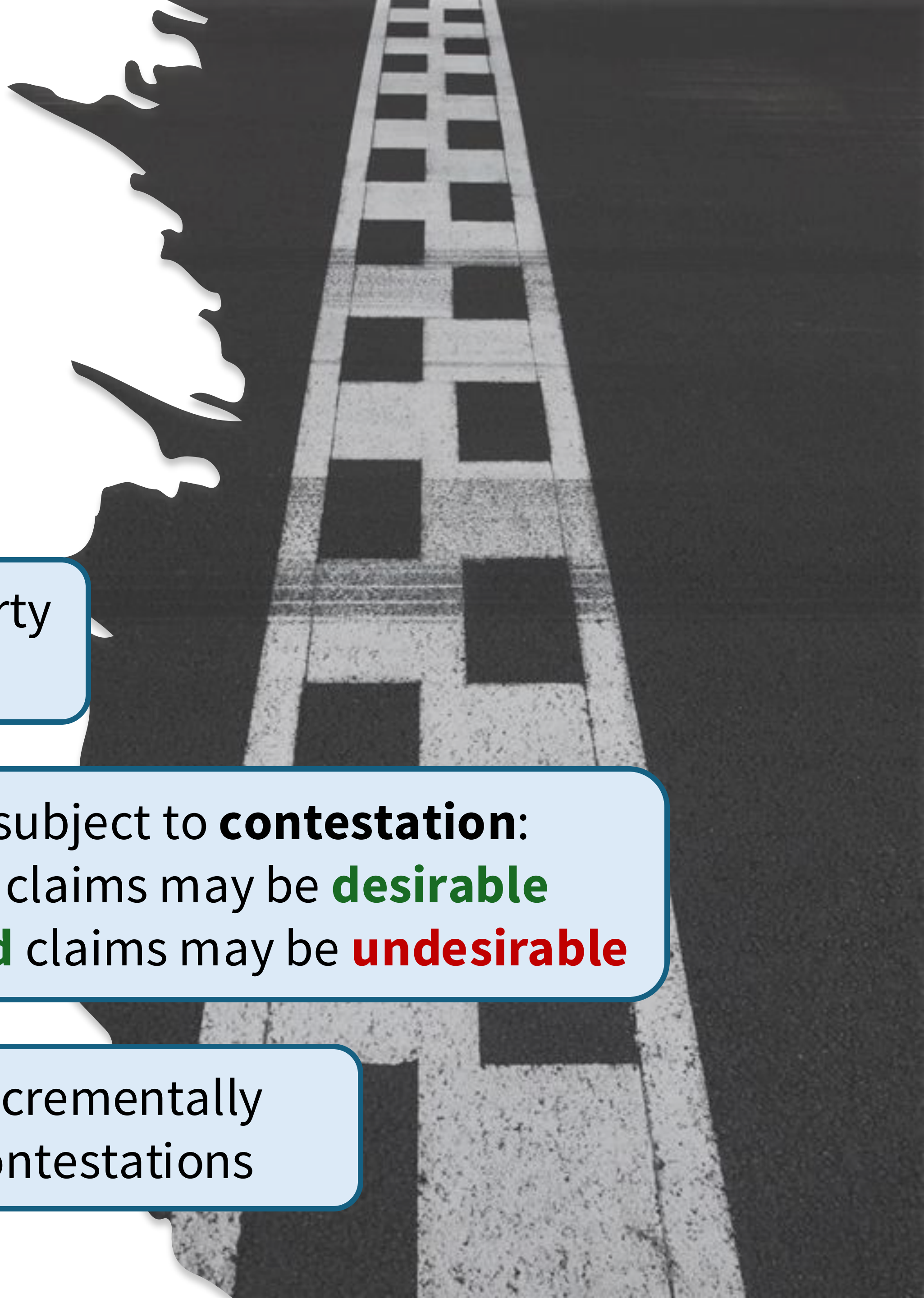
highly desirable property
for **human-centric AI**

claims are subject to **contestation**:
- **rejected** claims may be **desirable**
- **accepted** claims may be **undesirable**

modify rules incrementally
to **reconcile** contestations



ABA FRAMEWORKS

Assumptions

Language
(set of sentences)

$$< \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} >$$

flat ABAFs
assumptions are
not heads of rules

Rules

$$\underbrace{h}_{\textbf{head}} \leftarrow \underbrace{s_1, \ldots, s_n}_{\textbf{body}}$$

if n=0, h ← is called **fact**

total mapping from $\mathcal{A}$ into $\mathcal{L}$
$\bar{a}$ is the **Contrary** of a in $\mathcal{A}$

ABA FRAMEWORKS

an example ...

```
employed(jo) ←          onleave(jo) ←     maternity(jo) ←
employed(bob) ←         onleave(bob) ←    maternity(diana) ←
employed(claudia) ←
```

facts

```
loan(X) ← employed(X), nobreaks(X)
breaks(X) ← onleave(X)
```

rules

contrary of nobreaks

assumption

nobreaks(X) renders the rule defeasible:
it can be applied only if **breaks**(X) cannot be derived

ABA FRAMEWORKS - SEMANTICS

"**acceptable**" extensions:
sets of **arguments** able to
"defend" themselves from "attacks"
(as determined by the chosen semantics)

- **Arguments** are **deductions** of claims using **rules** and supported by **assumptions**
- **Attacks** are directed at the assumptions in the support of arguments

```
employed(jo) ←          onleave(jo) ←      maternity(jo) ←
employed(bob) ←         onleave(bob) ←     maternity(diana) ←
employed(claudia) ←
loan(X) ← employed(X), nobreaks(X)
breaks(X) ← onleave(X)
```

attacks

{
~~arg1: { nobreaks(jo) } ⊢ loan(jo)~~
~~arg2: { nobreaks(bob) } ⊢ loan(bob)~~
arg3: { nobreaks(claudia) } ⊢ loan(claudia)
arg4: { } ⊢ breaks(jo)
arg5: { } ⊢ breaks(bob)
}

We focus on **stable extensions**

any set of arguments S that
1. do not attack each other (conflict-free)
2. S attacks all arguments it does not contain

Accepted claims: loan(claudia)

Rejected claims: loan(jo)
loan(bob)

BRAVE ABA LEARNING PROBLEM

Given

1. ABA framework **F** = $< \mathcal{L}, \mathcal{R}, \mathcal{A}, \bar{\ } >$ (**background knowledge**) with at least one stable extension
2. **Ep** = { **positive examples** }
3. **En** = { **negative examples** }
4. **T** = { **learnable predicates** }

find **F'** = $< \mathcal{L}', \mathcal{R}', \mathcal{A}', \bar{\ }' >$ with **a stable extension** S such that

i. **F** $\subseteq$ **F'**
ii. **positive** are **covered**: every positive has an argument in S
iii. **negative** are **not covered**: no negative has an argument in S

F' is a **solution** to the brave ABA learning problem

CAUTIOUS ABA LEARNING PROBLEM

Given

1. ABA framework **F** = $< \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} >$ (**background knowledge**) with at least one stable extension
2. **Ep** = { **positive examples** }
3. **En** = { **negative examples** }
4. **T** = { **learnable predicates** }

find **F'** = $< \mathcal{L}', \mathcal{R}', \mathcal{A}', \overline{}' >$ with **at least one stable extension**

i. **F** ⊆ **F'**
ii. **positive** are **covered**: every positive has an argument in C
iii. **negative** are **not covered**: no negative has an argument in C

$C = \bigcap_k^n S_i$

$S_1,\ldots,S_n$: stable extensions of **F'**

F' is a **solution** to the cautious ABA learning problem

ABA LEARNING VIA TRANSFORMATION RULES

Learning ABA frameworks relies upon a set of **transformation rules**

$$\langle \mathcal{L}_1, \mathcal{R}_1, \mathcal{A}_1, \overline{}^{1} \rangle \longrightarrow \langle \mathcal{L}_2, \mathcal{R}_2, \mathcal{A}_2, \overline{}^{2} \rangle \longrightarrow \dots \longrightarrow \langle \mathcal{L}_n, \mathcal{R}_n, \mathcal{A}_n, \overline{}^{n} \rangle$$

background knowledge **intensional solution**

learnt rules **do not** make explicit **reference** to specific values in the universe

$\longrightarrow \in$ { **Rote Learning**, **Folding**, **Assumption Introduction**, **Subsumption** }

A **strategy** controls the order of application of the transformation rules

ABA LEARNING at work

Language

{ employed(X)←, onleave(X)←, maternity(X)←, loan(X)← }

Assumptions

{ nobreaks(X) }

1. Background Knowledge $< \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} >$

Contraries

{ $\overline{\texttt{nobreaks(X)}}$ = breaks(X) }

Rules

{ employed(jo)←, employed(bob)←, employed(claudia)←,
onleave(jo)←, onleave(bob)←,
maternity(jo)←, maternity(diana)← }

X ∈ {claudia,jo,bob,diana}

2. Positive examples **Ep** = { loan(claudia) }
3. Negative examples **En** = { loan(bob) }
4. Learnable Predicates **T** = { loan }

TRANSFORMATION RULES at work
ROTE LEARNING

Add **facts**

- from **positive** examples
- for **contraries** of **assumptions**

to get a (**non-intensional**) **solution**

It's enough to learn

`loan(X) ← X=claudia`

Ep = { `loan(claudia)` }

to get

$\mathcal{R}' = \mathcal{R} \cup \{$ `loan(X) ← X=claudia` $\}$

TRANSFORMATION RULES at work
FOLDING

Towards an **intensional** solution …

Generalise

```
loan(X) ← X=claudia
```

to

```
loan(X) ← employed(X)
```

by using

```
employed(X) ← X=claudia
```

WARNING
It also constructs an argument
for a negative example: `loan(bob)`

ABA LEARNING is **parametric** w.r.t. the folding strategy
It includes a portfolio of strategies, such as “nondeterministic” and “greedy” folding

TRANSFORMATION RULES at work
ASSUMPTION INTRODUCTION

Repairing the ABA framework to get a solution …

Add an **assumption** to avoid

- **rejecting** a positive example
- **accepting** a negative example

```
loan(X) ← employed(X), nobreaks(X)
```

with contrary
`breaks(X)`

AND REPEAT!

Rote Learning	`breaks(X) ← X=bob`
Folding	`breaks(X) ← onleave(X)`

No more rules to learn:

LEARNING COMPLETED!

```
employed(jo) ←          onleave(jo) ←        maternity(jo) ←
employed(bob) ←         onleave(bob) ←       maternity(diana) ←
employed(claudia) ←
```

Rules in the Background Knowledge

```
loan(X) ← employed(X), nobreaks(X)
breaks(X) ← onleave(X)
```

Learnt rules

TRANSFORMATION RULES at work
ASSUMPTION INTRODUCTION

Repairing the ABA framework to get a solution …

Add an **assumption** to avoid

- **rejecting** a positive example
- **accepting** a negative example

```
loan(X) ← employed(X), nobreaks(X)
```

with contrary
`breaks(X)`

To get termination …

p1(X) ← **Q(X)**, **asm_Q**(X)

reuse

…

p2(X) ← **Q(X)**, **asm_Q**(X)

asm_Q(X)
is "relative to"
Q(X)

Algorithm 1: *RASP-ABAlearn*

Input: $(\langle \mathcal{R}_0, \mathcal{A}_0, \overline{\ \ }^0 \rangle, \langle \mathcal{E}^+, \mathcal{E}^- \rangle, \langle \mathcal{E}_C^+, \mathcal{E}_C^- \rangle, \mathcal{T})$: redress problem
Output: $\langle \mathcal{R}, \mathcal{A}, \overline{\ \ } \rangle$: incremental redress relative to $\langle \mathcal{E}_C^+, \mathcal{E}_C^- \rangle$

$\mathcal{R} := \mathcal{R}_0$; $\mathcal{A} := \mathcal{A}_0$; $\overline{\ \ } := \overline{\ \ }^0$; $\mathcal{R}_l := \emptyset$;
$RoLe()$; $Gen()$; **return** $\langle \mathcal{R}, \mathcal{A}, \overline{\ \ } \rangle$;
Procedure $RoLe()$
  $P := ASP(\langle \mathcal{R}, \mathcal{A}, \overline{\ \ } \rangle, \langle \mathcal{E}^+, \mathcal{E}^- \rangle, \langle \mathcal{E}_C^+, \mathcal{E}_C^- \rangle, \mathcal{T})$;
  if $\neg sat(P)$ **then**
    fail;
  else
    $S := as(P)$;
    // R1. Rote Learning
    foreach $\texttt{newp(t)} \in S$ **do**
      $\mathcal{R}_l := \mathcal{R}_l \cup \{p(X) \leftarrow X = t\}$;
    end
  end
Procedure $Gen()$
  foreach $\rho : (p(X) \leftarrow X = t) \in \mathcal{R}_l$ **do**
    $\mathcal{R}_l := \mathcal{R}_l \setminus \{\rho\}$;
    // R4. Fact Subsumption
    if $\neg\, sat(ASP(\langle \mathcal{R} \cup \mathcal{R}_l, \mathcal{A}, \overline{\ \ } \rangle, \langle \mathcal{E}^+, \mathcal{E}^- \rangle, \langle \mathcal{E}_C^+, \mathcal{E}_C^- \rangle, \emptyset))$ **then**
      // R2 w/ R3. Folding with Assumption Introduction
      $\langle \rho_g, \alpha(X), C_\alpha \rangle := FoldingWAsmIntro(\rho)$;
      $\mathcal{R} := \mathcal{R} \cup \{\rho_g\}$;
      $\mathcal{A} := \mathcal{A} \cup \{\alpha(X)\}$;
      $\overline{\alpha(X)} := c\_\alpha(X)$;
      // R1. Rote Learning
      foreach $\texttt{c\_}\alpha\texttt{(t)} \in C_\alpha$ **do**
        $\mathcal{R}_l := \mathcal{R}_l \cup \{c\_\alpha(X) \leftarrow X = t\}$;
      end
    end
  end
Function $FoldingWAsmIntro(\rho)$
  // R2. Folding
  while $foldable(\rho, \mathcal{R})$ **do**
    $\rho := fold(\rho, \mathcal{R})$;
  end
  // R3. Assumption Introduction
  Let ρ be $H \leftarrow B$; $X := vars(B)$;
  if *there exists* $\alpha(X) \in \mathcal{A}$ *relative to* B **then**
    $\rho_g := H \leftarrow B, \alpha(X)$; $C_\alpha := \emptyset$;
    if $\neg sat(ASP(\langle \mathcal{R} \cup \{\rho\}, \mathcal{A}, \overline{\ \ } \rangle, \langle \mathcal{E}^+, \mathcal{E}^- \rangle, \langle \mathcal{E}_C^+, \mathcal{E}_C^- \rangle, \emptyset))$ **then**
      fail;
    end
  else // introduce an assumption $\alpha(X)$, with a new predicate α
    $\rho_g := H \leftarrow B, \alpha(X)$;
    $F := \langle \mathcal{R} \cup \{\rho\}, \mathcal{A} \cup \{\alpha(X)\}, \overline{\ \ } \cup \{\alpha(X) \mapsto c\_\alpha(X)\} \rangle$;
    $C_\alpha := \{c\_\alpha(X) \mid c\_\alpha(X) \in as(ASP(F, \langle \mathcal{E}^+, \mathcal{E}^- \rangle, \langle \mathcal{E}_C^+, \mathcal{E}_C^- \rangle, \{c\_\alpha\}))\}$;
  end
  return $\langle \rho_g, \alpha(X), C_\alpha \rangle$;

A GLIMPSE OF IMPLEMENTATION via ASP

- **ASP encoding**

```
loan(X) :- employed(X), nobreaks(X). ...
nobreaks(X) :- employed(X), not breaks(X).
breaks(X) :- onleave(X).
```

```
{ breaksP(X) } :- onleave(X).
breaks(X) :- breaksP(X).
#minimize{1,X: breaksP(X)}.
:- not loan(claudia).
:- loan(bob).
```

learning facts for contraries

- **Answer sets**

(1-to-1 correspondence with **Stable extensions**)

```
{ breaksP(bob), … }, …
```

- **Rote learning**

```
breaks(X) ←X=bob
```

SWI Prolog + **Clingo** (ASP) Potassco

https://github.com/ABALearn/aba_asp

EXPERIMENTS

ASP-ABAlearnB

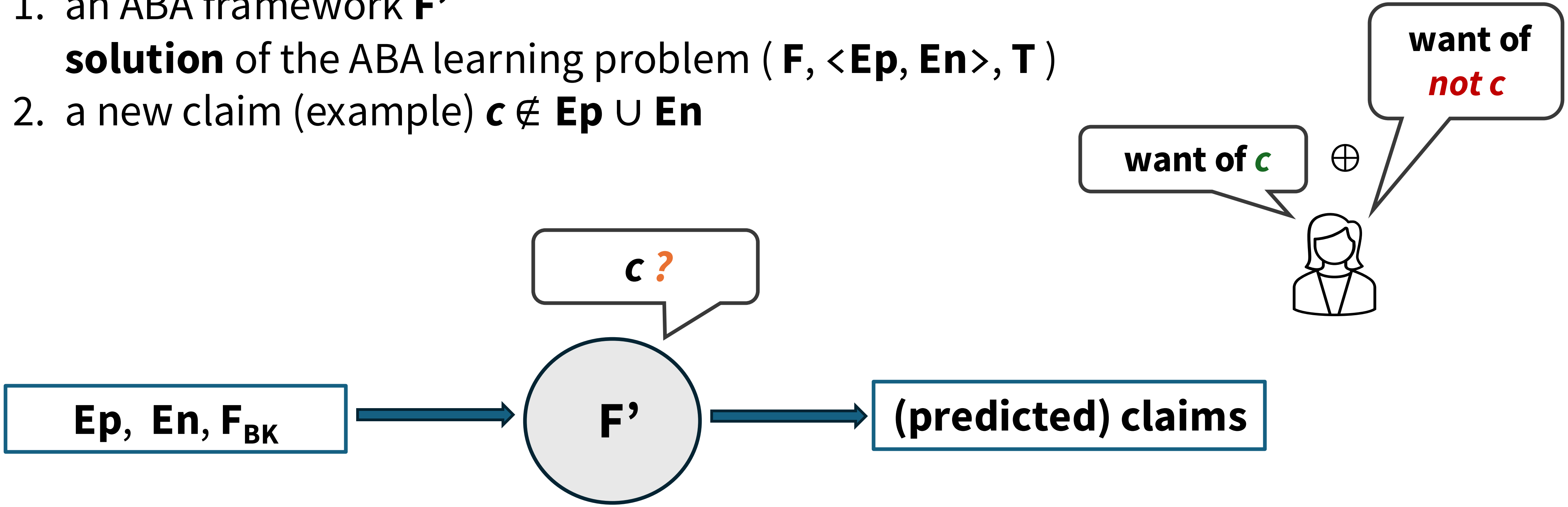
https://doi.org/10.5281/zenodo.13330013

Learning problem	BK	Ep	En	ASP-ABAlearnB	ILASP
Flies	8	4	2	0.01	0.09
Flies_bird&planes	10	5	2	0.02	0.25
Innocent	15	2	2	0.01	1.84
Nixon_diamond	6	1	1	0.01	unsat
Nixon_diamond_2	15	3	2	0.01	unsat
Tax_law	16	2	2	0.02	0.66
Tax_law_2	17	2	2	0.01	0.92
Acute	96	21	19	0.04	unsat
Autism	5716	189	515	23.43	timeout
Breast-w	6291	241	458	16.32	timeout

CONTESTATION

Given

1. an ABA framework **F'**
   solution of the ABA learning problem (**F**, **<Ep**, **En>**, **T**)
2. a new claim (example) $\boldsymbol{c} \notin \mathbf{Ep} \cup \mathbf{En}$



CONTESTATION

Given

1. an ABA framework **F'**
   solution of the ABA learning problem (F, <Ep, En>, T)
2. a new claim (example) ***c*** $\notin$ Ep ∪ En

F' is **contested** by

want of *c*	**want of *not c***

iff ∄ stable extension S of **F'** s.t.

Ep ∪ { *c* } are **covered** in S & En are not covered in S	Ep are covered in S & En ∪ { *c* } are **not covered** in S

REDRESS

When a solution **F'** is **contested** by either ***want of c*** or ***want of not c***,
redressing consists in deriving a **solution F''** of the ABA learning problem

- (**want of *c***) $(F, \langle \mathbf{Ep} \cup \{ c \}, En \rangle, T)$
- (**want of *not c***) $(F, \langle Ep, \mathbf{En} \cup \{ c \} \rangle, T)$

How to redress

from scratch

trivial form

1. forgetting F'
2. solving the <u>original</u> problem w/***c***
   either $(F, \langle \mathbf{Ep} \cup \{ c \}, En \rangle, T)$
   or $(F, \langle Ep, \mathbf{En} \cup \{ c \} \rangle, T)$

Incremental

modifies F' *as little as possible*

1. selecting some of the **learnt** rules & making them **defeasible** by assumption introduction, to get the <u>new</u> problem $(\mathbf{F'_{ai}}, \langle Ep, En \rangle, \mathbf{T'_{ai}})$
2. solving the new problem w/***c***
   either $(\mathbf{F'_{ai}}, \langle \mathbf{Ep} \cup \{ c \}, En \rangle, \mathbf{T'_{ai}})$
   or $(\mathbf{F'_{ai}}, \langle Ep, \mathbf{En} \cup \{ c \} \rangle, \mathbf{T'_{ai}})$

INCREMENTAL REDRESS w/ABA Learning

Suppose (the current solution) F'

```
employed(jo) ←          onleave(jo) ←     maternity(jo) ←
employed(bob) ←         onleave(bob) ←    maternity(diana) ←
employed(claudia) ←
loan(X) ← employed(X), nobreaks(X)
breaks(X) ← onleave(X)
```

is contested by the **want of** `loan(jo)`, which is not covered by any stable extension

We can **incrementally modify** F', by applying the transformation rules

(0) Select the learnt rule to redress

`breaks(X) ← onleave(X), alpha(X)` (1) by **assumption introduction** rule

`c_alpha(X) ← X=jo` (2) by **rote learning** rule

`c_alpha(X) ← maternity(X)` (3) by **folding** rule

to get a new solution **F''** with at least one stable extension covering `loan(jo)`

EXPERIMENTS

RASP-ABAlearn

https://github.com/ABALearn/aba_asp

Learning problems

six standard datasets of the UCI ML Repo as ABA learning problems

Experimental processes

Redress from scratch (***S***) **vs.** Incremental redress (***R***)

11 runs of **RASP-ABALearn**:

0: run (*S*) and (*R*) using 90% of positive and negative examples

1-10: run (*S*) and (*R*) each using a randomly selected **new example** either **positive** or **negative**

Problem		0	1	2	3	4	5	6	7	8	9	10
			+	−	−	−	−	+	−	+	+	+
acute	T_S	39	31	32	31	32	32	37	41	38	40	39
495	T_R	36	2	3	3	2	4	7	2	3	2	3
⟨54, 55⟩	S_S	501	501	501	501	501	501	503	503	503	503	503
	S_R	501	501	501	501	501	501	502	502	502	502	502
			+	+	+	−	+	−	−	−	−	+
autism	T_S	13524	14427	14552	15004	14985	15252	15048	15114	15246	15097	15329
6568	T_R	12741	970	905	999	44	1126	47	46	44	44	1144
⟨171, 464⟩	S_S	6953	6954	6955	6956	6956	6958	6958	6958	6958	6958	6961
	S_R	6953	6954	6955	6956	6956	6957	6957	6957	6957	6957	6958
			+	−	−	−	−	+	−	+	+	+
breastw	T_S	8371	8749	9061	9258	9208	9082	9039	9086	9061	9235	9318
6325	T_R	8482	36	430	35	36	36	36	35	35	37	418
⟨216, 400⟩	S_S	6519	6519	6520	6520	6520	6520	6520	6520	6520	6520	6521
	S_R	6519	6519	6520	6520	6520	6520	6520	6520	6520	6520	6521
			−	−	−	+	+	+	−	−	+	−
krkp	T_S	40595	42557	42250	42173	42357	41985	42417	42673	[illegible]	[illegible]	[illegible]
33210	T_R	40475	111	1711	106	106	108	106	1682	1189	[illegible]	[illegible]
⟨1503, 1374⟩	S_S	33409	33409	33410	33410	33410	33410	33410	33411	[illegible]	[illegible]	[illegible]
	S_R	33409	33409	33410	33410	33410	33410	33410	33411	[illegible]	[illegible]	[illegible]
			+	−	−	−	−	+	−	−	[illegible]	[illegible]
mushroom	T_S	555525	559972	471200	469676	474180	552260	552583	579530	[illegible]	[illegible]	[illegible]
33868	T_R	471191	300	11338	280	11680	11409	279	279	280	[illegible]	[illegible]
⟨214, 1587⟩	S_S	34762	34762	34763	34763	34764	34763	34763	34763	[illegible]	[illegible]	[illegible]
	S_R	34762	34762	34763	34763	34764	34765	34765	34765	[illegible]	[illegible]	[illegible]
			+	+	−	+	+	−	−	+	[illegible]	[illegible]
voting	T_S	663	663	675	670	669	705	707	664	664	[illegible]	[illegible]
2172	T_R	664	11	12	12	12	70	10	185	11	12	12
⟨98, 112⟩	S_S	2230	2230	2230	2230	2230	2233	2233	2229	2229	2229	2229
	S_R	2230	2230	2230	2230	2230	2231	2231	2234	2234	2234	2234

			+	+	+	−	+	−	−	−	−	+
autism	T_S	13524	14427	14552	15004	14985	15252	15048	15114	15246	15097	15329
6568	T_R	12741	970	905	999	44	1126	47	46	44	44	1144
⟨171, 464⟩	S_S	6953	6954	6955	6956	6956	6958	6958	6958	6958	6958	6961
	S_R	6953	6954	6955	6956	6956	6957	6957	6957	6957	6957	6958

size of the background knowledge (# rules)

⟨ |Ep| , |En| ⟩

T_S, T_R: time in ms

S_S, S_R: # learnt rules

CONCLUSIONS

- **Automatic learning** of **ABA frameworks** from a background knowledge, and positive and negative examples
- **Contestability** for ABA frameworks
- **Redressing** as **a way of learning** from additional positive or negative examples
- Experiments show
  - **folding** & **assumption introduction** improve **effectiveness** in learning
  - **incremental redress** is more **efficient** than **re-learning from scratch**