Using Automated Reasoning for Problems in Machine Learning

...or rather how to get rid of ML!

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There are two types of people...

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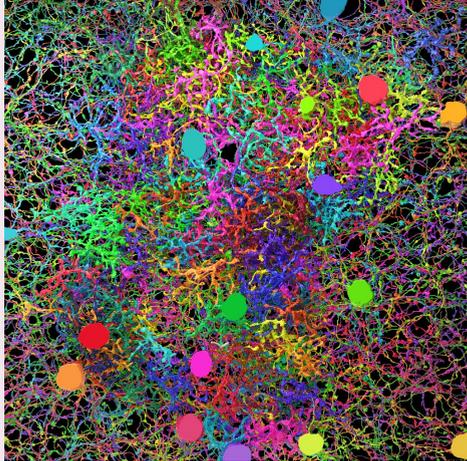   ...those who can interpolate from incomplete data

Recognize this one?

Given a relation R describing a partial function:

$$\exists f \forall (a, b) \in R.(f\ a) = b$$

A Safe Alternative to Machine Learning

(joint work with Jay Morgan)

### Traditional Method:

The new Method:

```
let func = new()
for (a,b) in observ
  if (func(a) != b)
    adjust(func, a, b)
forall b. func(a)=b
  if !(b.unique)
    adjust(func,b)
```

depth	examples	time	hits on ex.	hits total	safety	optimum
1	100	41s	**100%**	87.86%	YES	**YES**
1	200	49m28s	98.5%	91.67%	YES	NO
3	100	2h41m	**98%**	87.8%	YES	**YES**
3	200	9h3m	91%	88.5%	YES	NO

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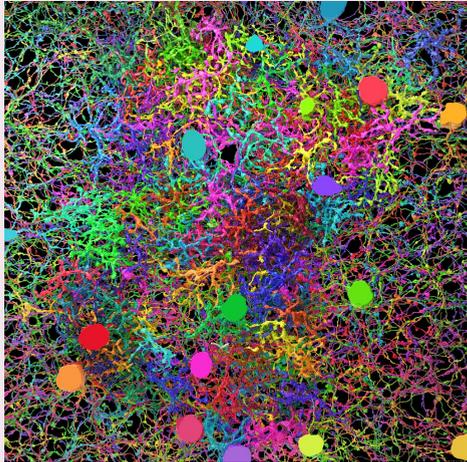
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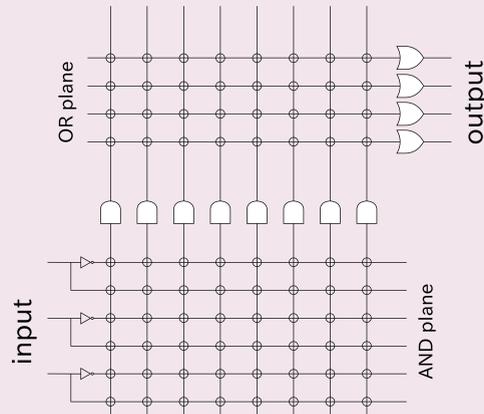| depth	examples	time	hits on ex.	hits total	safety	optimum
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```
term ( var (V)).
term ( lam (X,E)) :- var (X), term (E).
term ( appl (A,B)) :- term (A), term (B).
...
learn (F, R) :- term (F),
  forall (member ((A,B), R), eval (appl (F, A), B)).
```

Problem: PROLOG appraoch: F doesn't work?
Let's try F+1!

```
- learn ( lam (X,X), R) ? fail .
- learn ( lam (Y, lam (X,X)), R) ? fail .
- learn ( lam (Z, lam (Y, lam (X,X))), R) ? fail . ...
```

Clause learning (example):

$$X \ a \ b = \lambda x.x$$
$$(\lambda y.\lambda z.\lambda x.x \ x) \ a \ b = \lambda x.x$$
$$(\lambda x.x \ \textcolor{red}{x}) = \lambda x.x$$

not the entire formula is wrong!

Track which choice was the wrong one.

$$(\lambda y.\lambda z.\lambda x.x) \ a \ b = \lambda x.x$$
$$(\lambda x.x) = \lambda x.x$$

Other techniques:

- Breadth-first search (esp. conj. statements)
- Meta branch reduction
- (SAT)-Heuristics
- Concurrency
- ...

There are two types of people...

> ...those who can interpolate from incomplete data,
>
> ...and intuitionists complaining they can't.