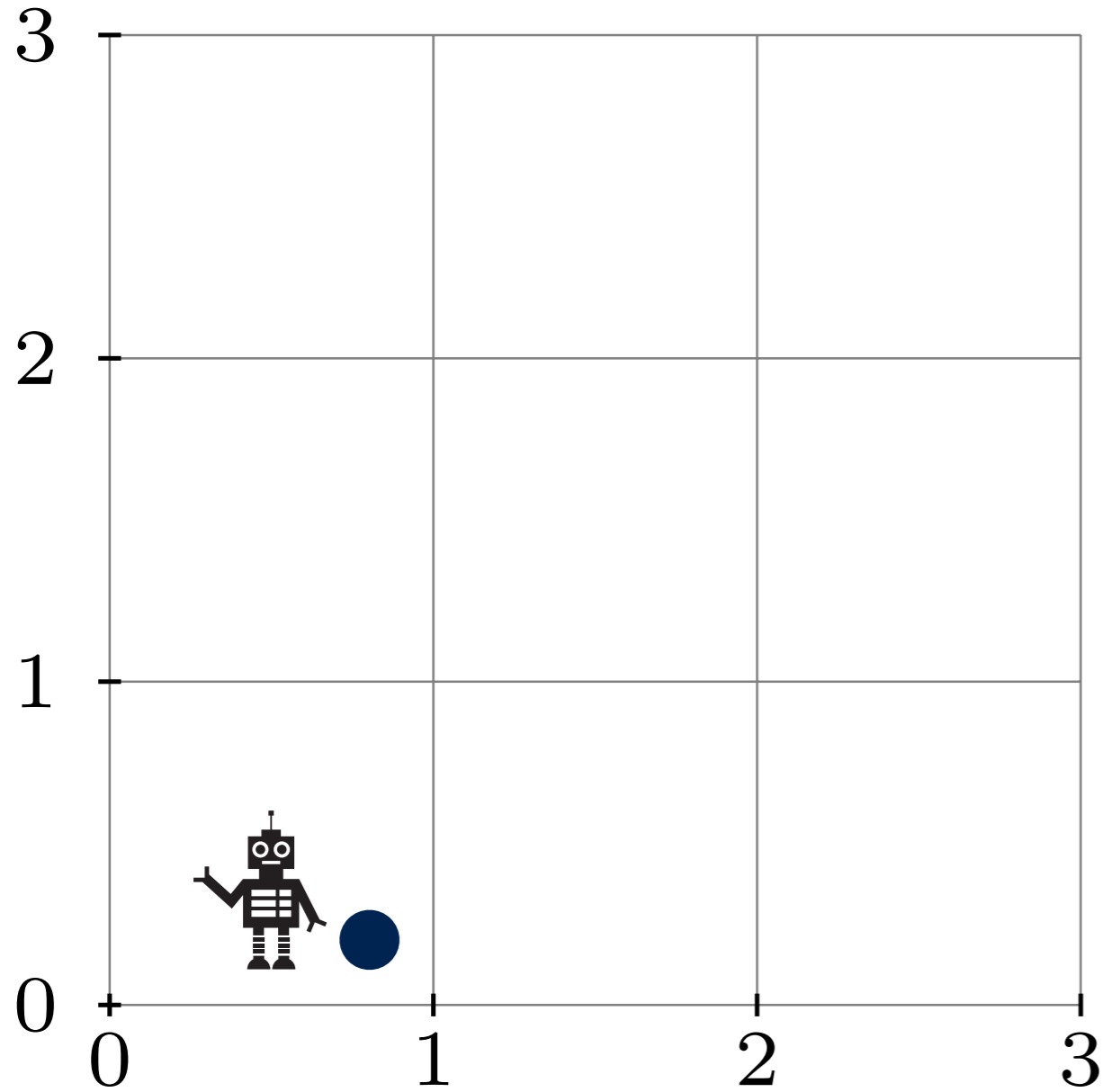


# Learning efficient logical robot strategies involving composable objects

Andrew Cropper and Stephen H. Muggleton

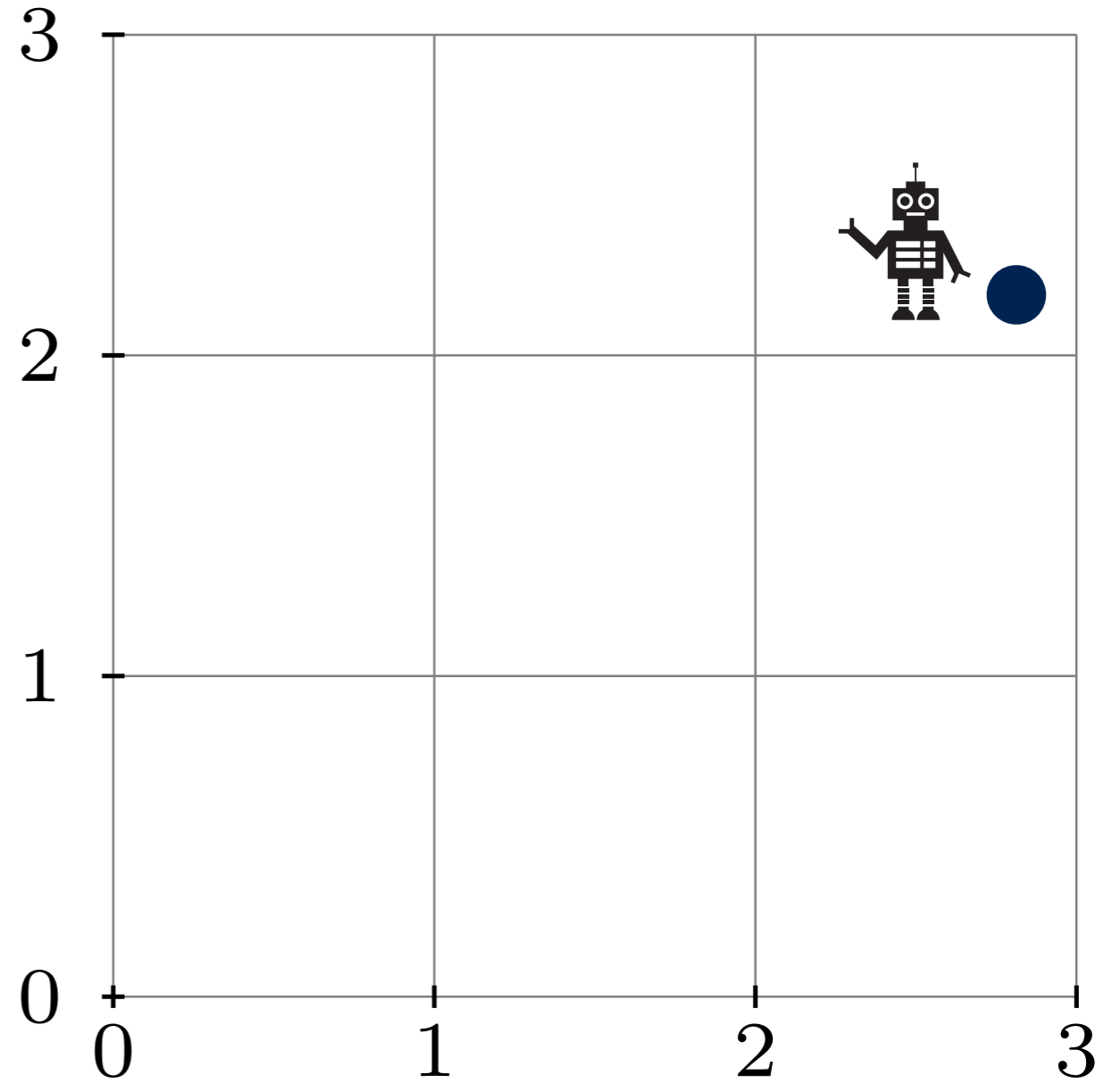
Imperial College London

## Initial state



$[\text{pos}(\text{robot}, 1/1), \text{pos}(\text{ball}, 1/1)]$

## Final state



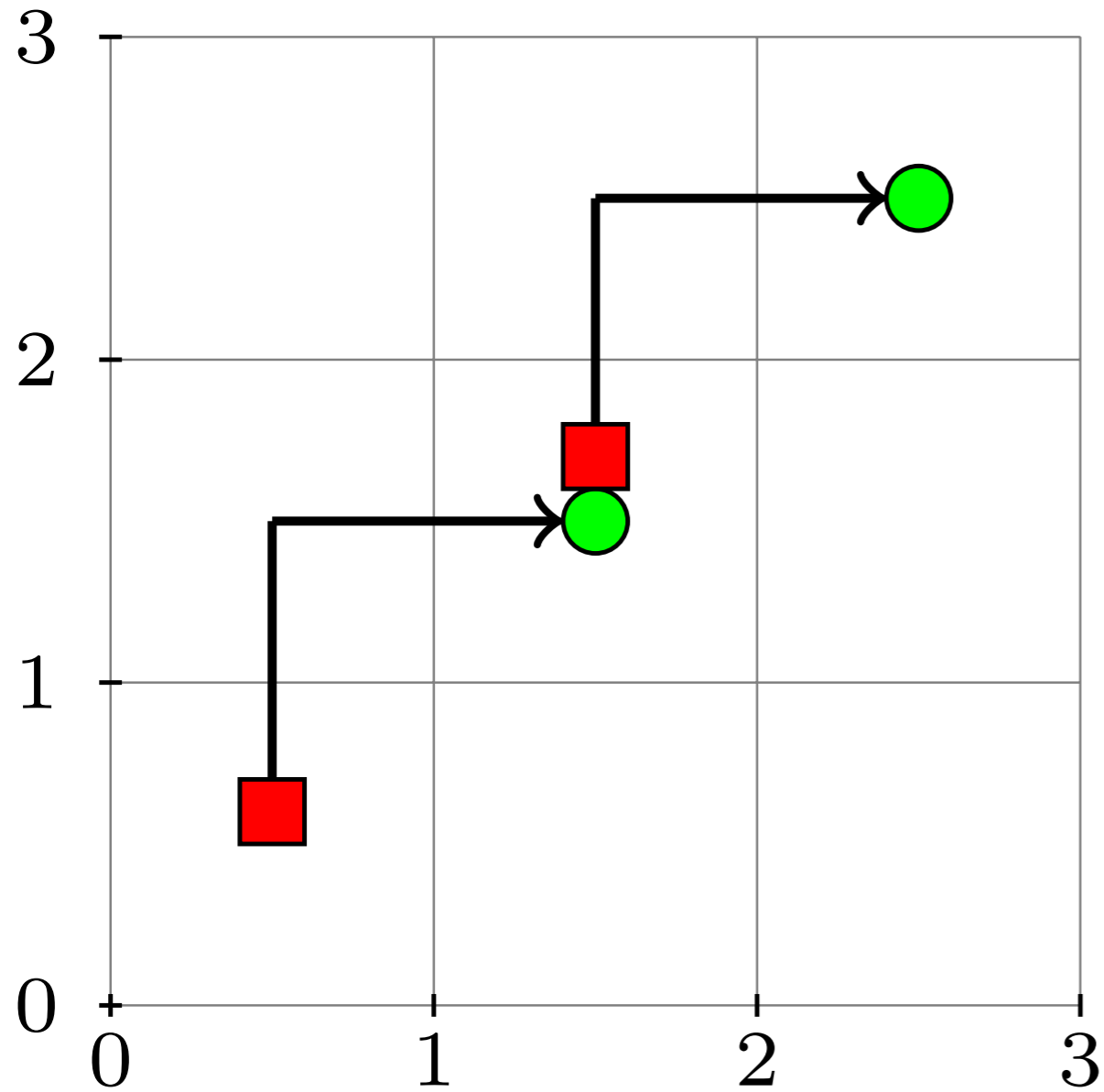
$[\text{pos}(\text{robot}, 3/3), \text{pos}(\text{ball}, 3/3)]$

move(X,Y):- p3(X,Z),p3(Z,Y).  
p3(X,Y):- p2(X,Z), drop(Z,Y).  
p2(X,Y):- grab(X,Z), p1(Z,Y).  
p1(X,Y):- north(X,Z), east(Z,Y).

move(X,Y):- p3(X,Z),drop(Z,Y).  
p3(X,Y):- grab(X,Z), p2(Z,Y).  
p2(X,Y):- p1(X,Z), p1(Z,Y).  
p1(X,Y):- north(X,Z), east(Z,Y).

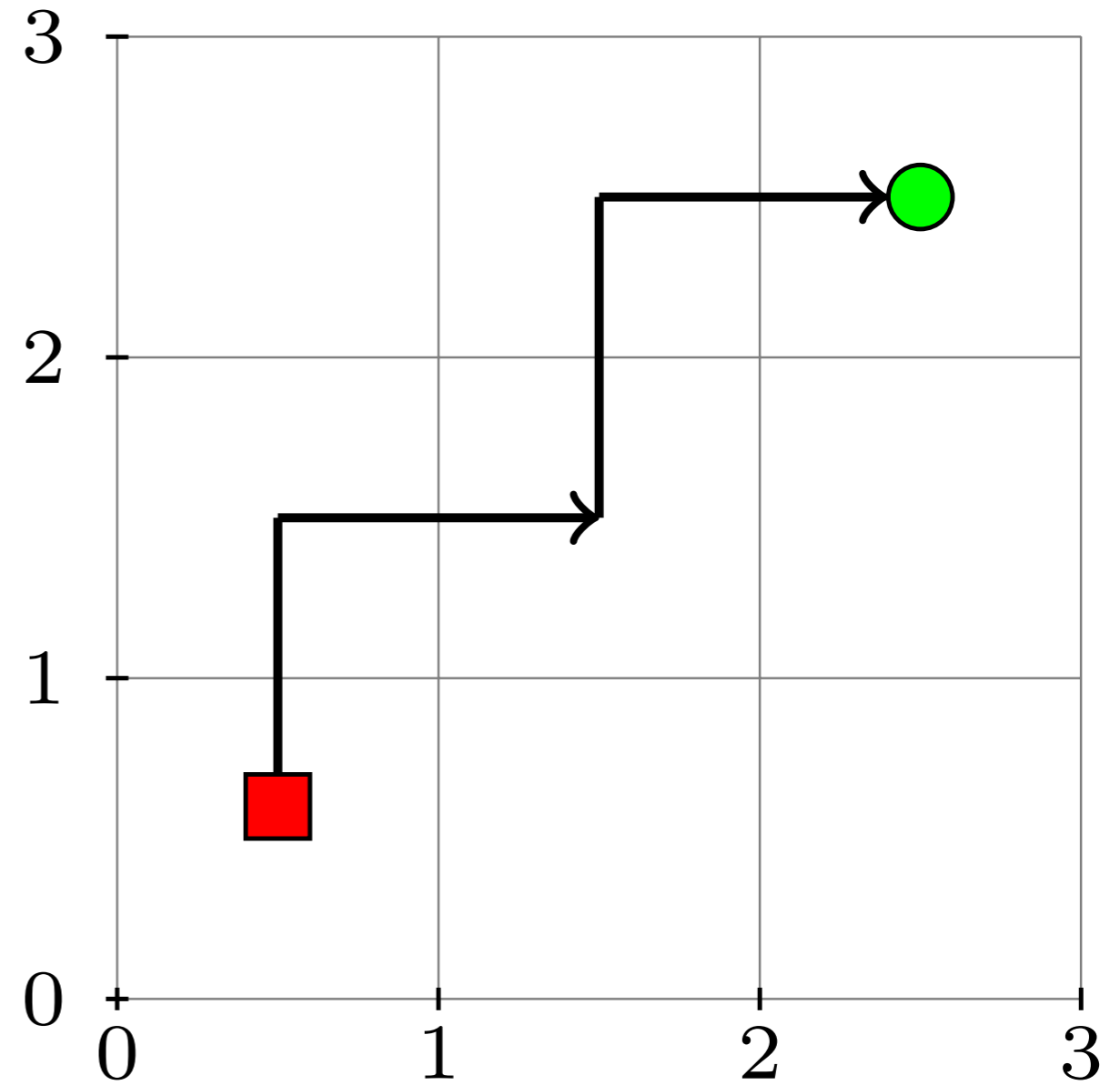
■ grab ● drop

## Inefficient solution



```
move(X,Y):- p3(X,Z),p3(Z,Y).  
p3(X,Y):- p2(X,Z), drop(Z,Y).  
p2(X,Y):- grab(X,Z), p1(Z,Y).  
p1(X,Y):- north(X,Z), east(Z,Y).
```

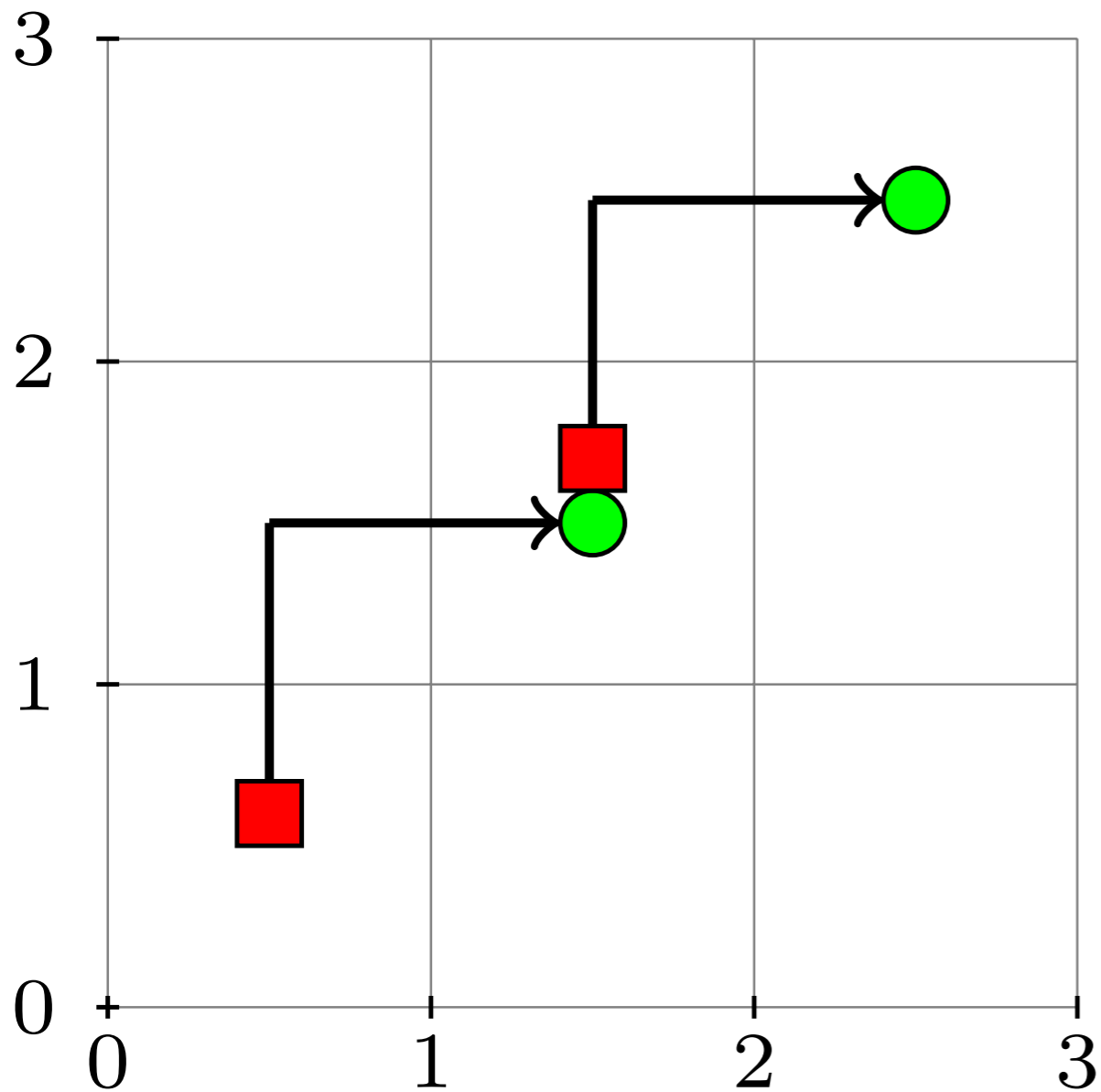
## Efficient solution



```
move(X,Y):- p3(X,Z),drop(Z,Y).  
p3(X,Y):- grab(X,Z), p2(Z,Y).  
p2(X,Y):- p1(X,Z), p1(Z,Y).  
p1(X,Y):- north(X,Z), east(Z,Y).
```

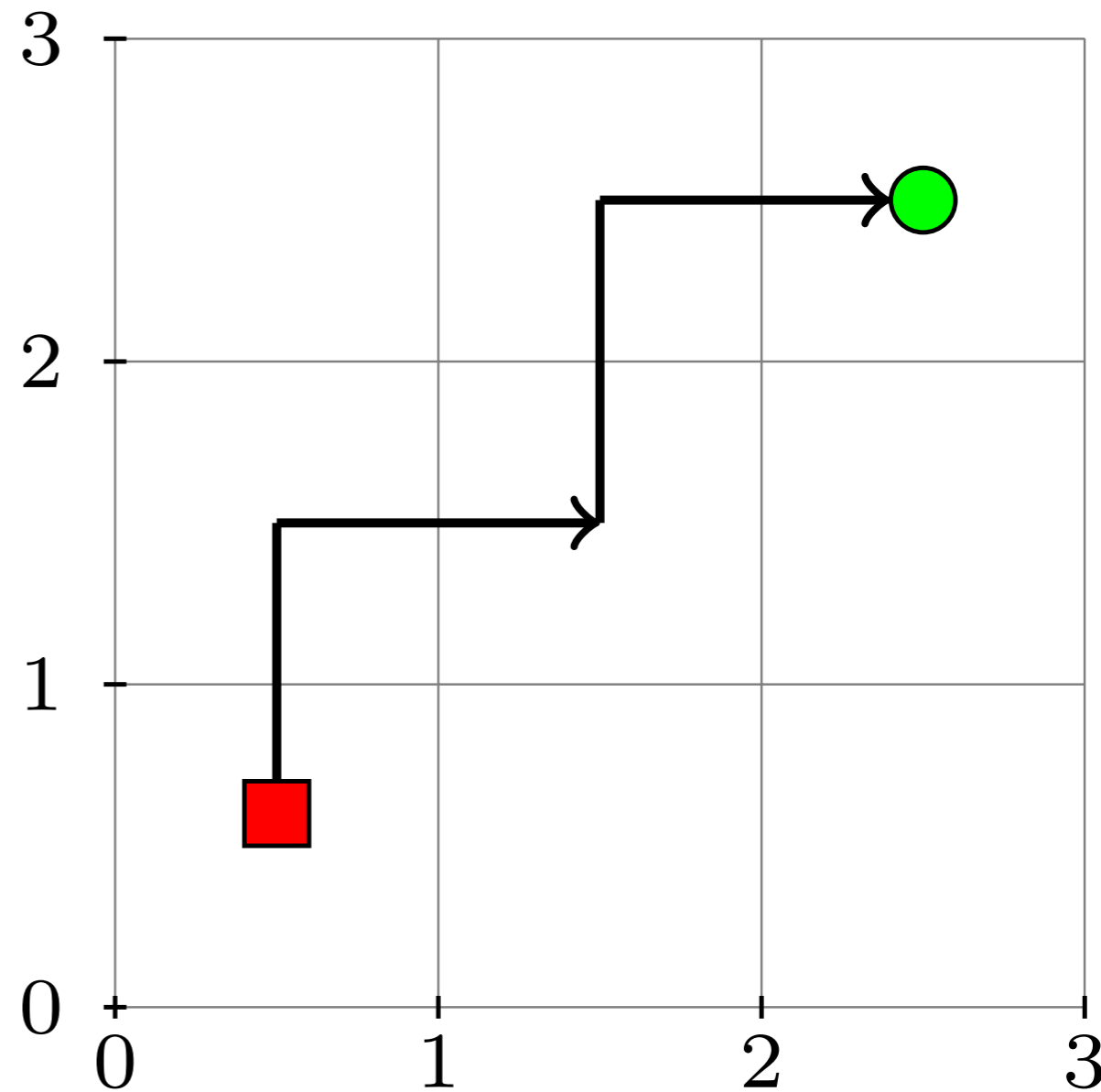
■ grab ● drop

### Inefficient solution



resource complexity: 12

### Efficient solution



resource complexity: 8

<b>Action</b>	drop	grab	north	east
<b>Cost</b>	2	2	1	1

# Iterative descent

1. find first consistent solution with minimal textual complexity
2. repeat until convergence:
  - A. calculate resource complexity of learned solution
  - B. learn new solution with a maximum resource bound that is smaller than the resource complexity of the previous solution

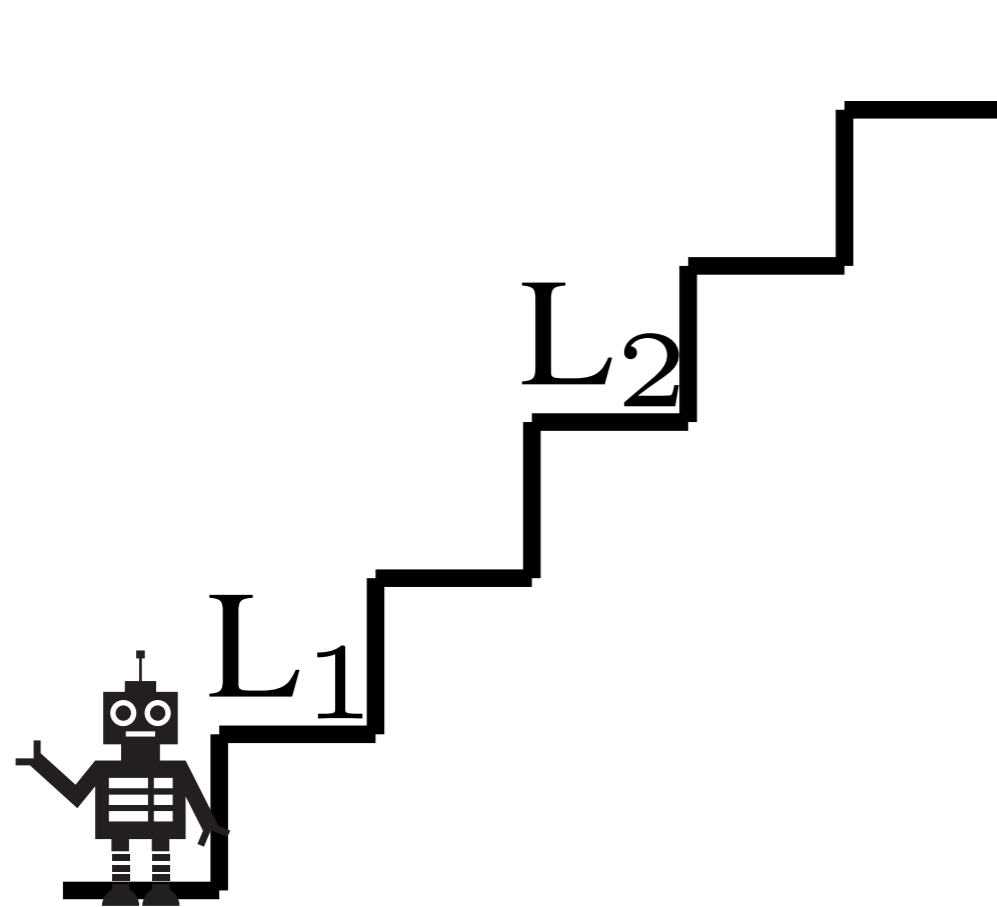
**Theorem: guaranteed to converge to minimal resource complexity hypothesis**

# MetagolO

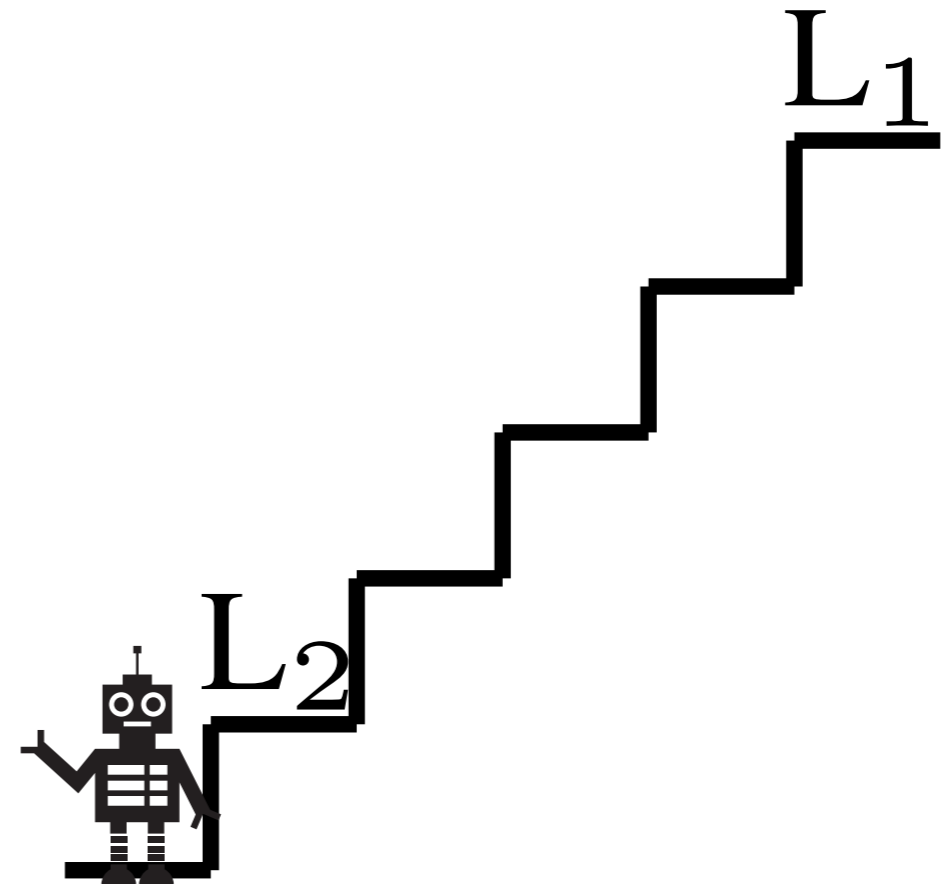
Implementation of meta-interpretive learning\*, a form of inductive logic programming based on a Prolog meta-interpreter, which supports predicate invention and the learning of recursive theories

\* S.H. Muggleton, D. Lin, and A. Tamaddoni-Nezhad. Meta-interpretive learning of higher-order dyadic datalog: Predicate invention revisited. *Machine Learning*, 100(1):49-73, 2015.

**Initial state**

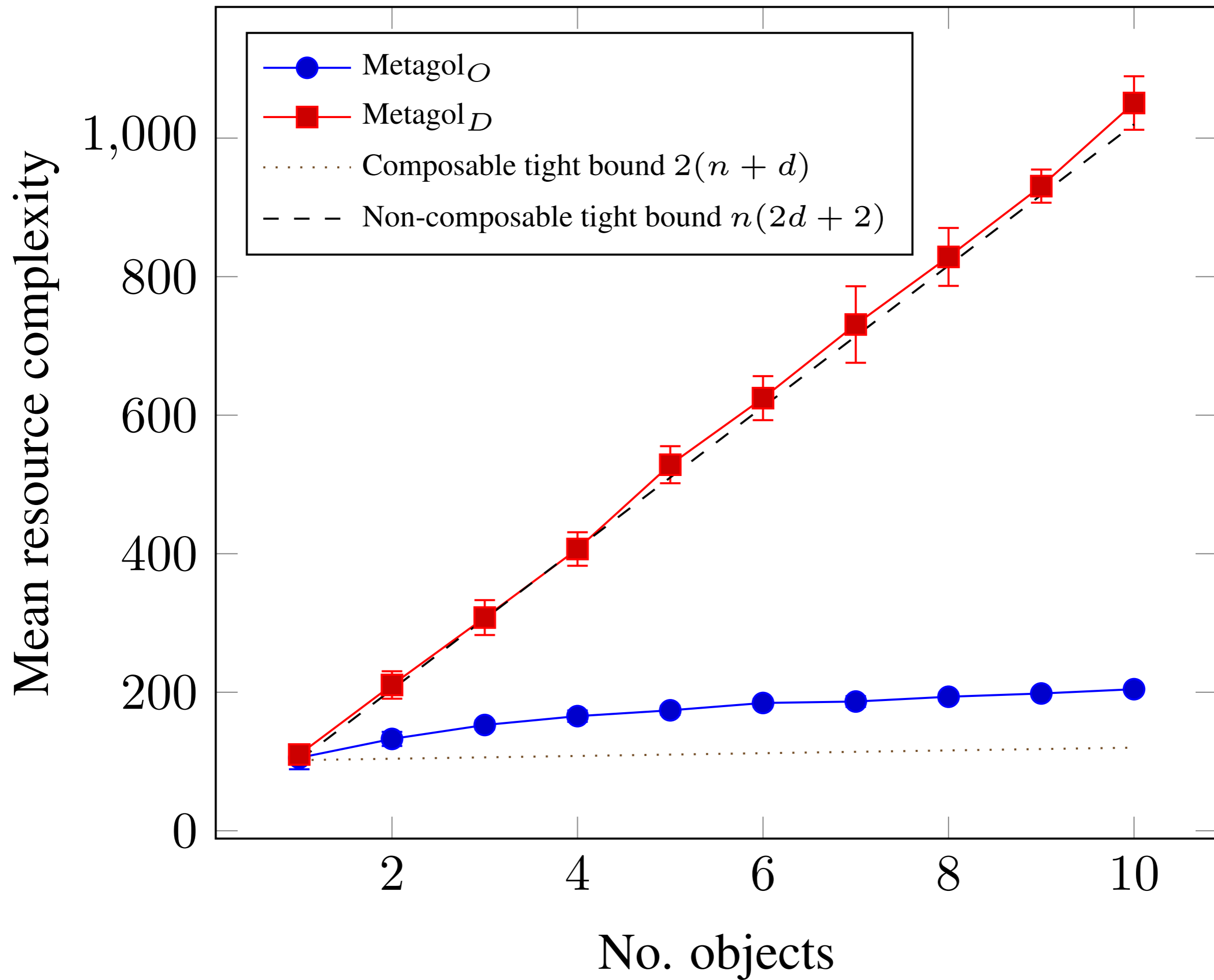


**Final state**



**Actions:** go\_to\_bottom/2, go\_to\_top/2, find\_next\_sender/2, find\_next\_recipient/2, take\_letter/2, give\_letter/2, bag\_letter/2





**Initial state**

[2,5,6,1,9,7,3,4,8]

**Final state**

[1,2,3,4,5,6,7,8,9]

**Actions:**

comp\_adjacent/2

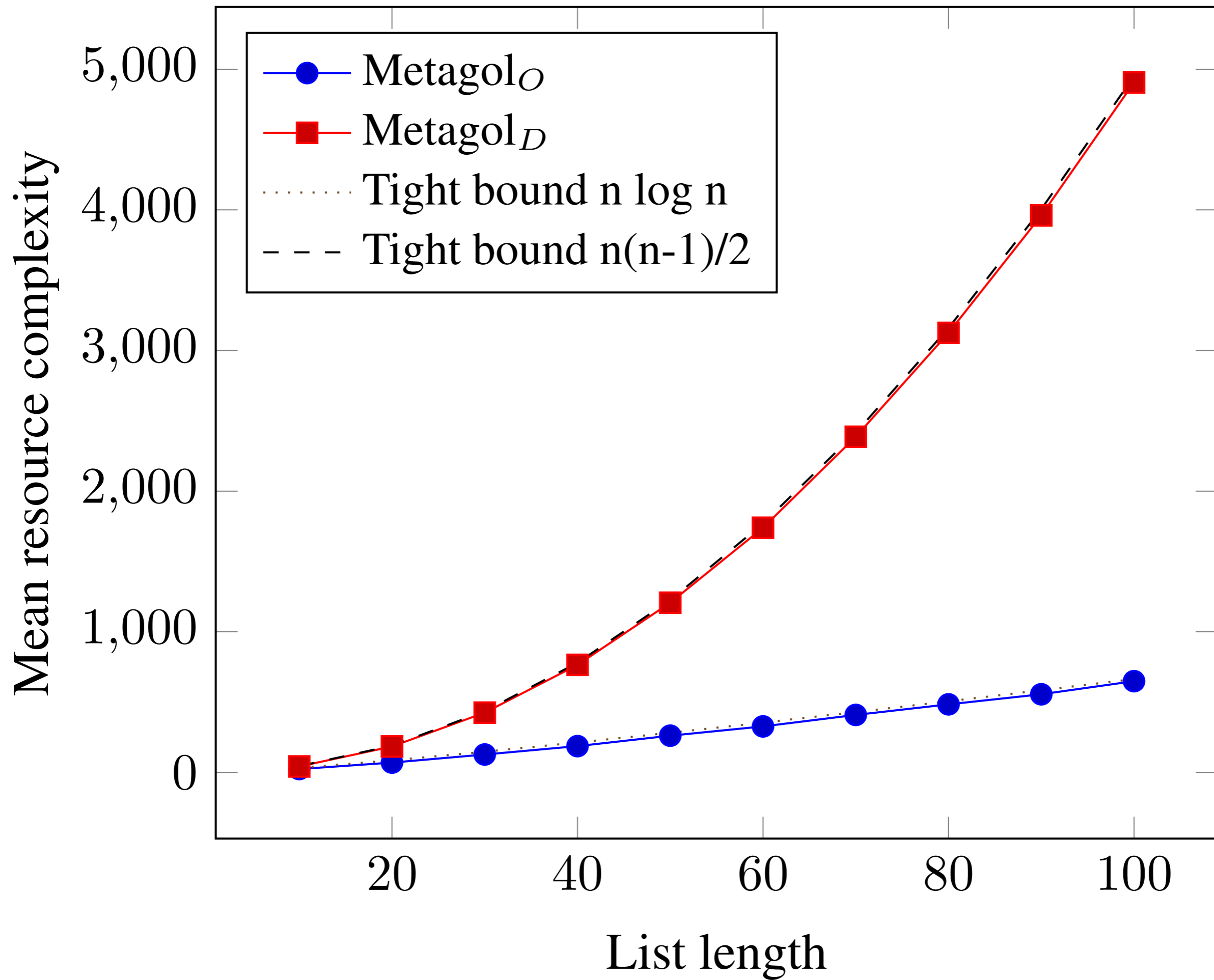
decrement\_end/2

go\_to\_start/2

pick\_up\_left/2

split/2

combine/2



## **Conclusions**

- Suggests that we can build delivery and sorting robots which learn resource efficient strategies from examples

## **Future work**

- Optimise the iterative descent search procedure
- Generalise to a broader class of logic programs

Thank you