Logic-based inductive synthesis of efficient programs

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String transformations

Input	**Output**
Computer Aided Verification	CAV
Principles Of Programming Languages	POPL
International Conference on Functional Programming	???
International Joint Conference Artificial Intelligence	???
Neural Information Processing Systems	???

```python
% python
def f(input):
 output=[]
  for x in string:
    if x.isupper():
      output.append(x)
return output
```

```prolog
% prolog
f([],[]).
f([X|Input],[X|Output]):-
  is_uppercase(X),
  f(Input,Output).
f([X|Input],Output):-
  not_uppercase(X),
  f(Input,Output).
```

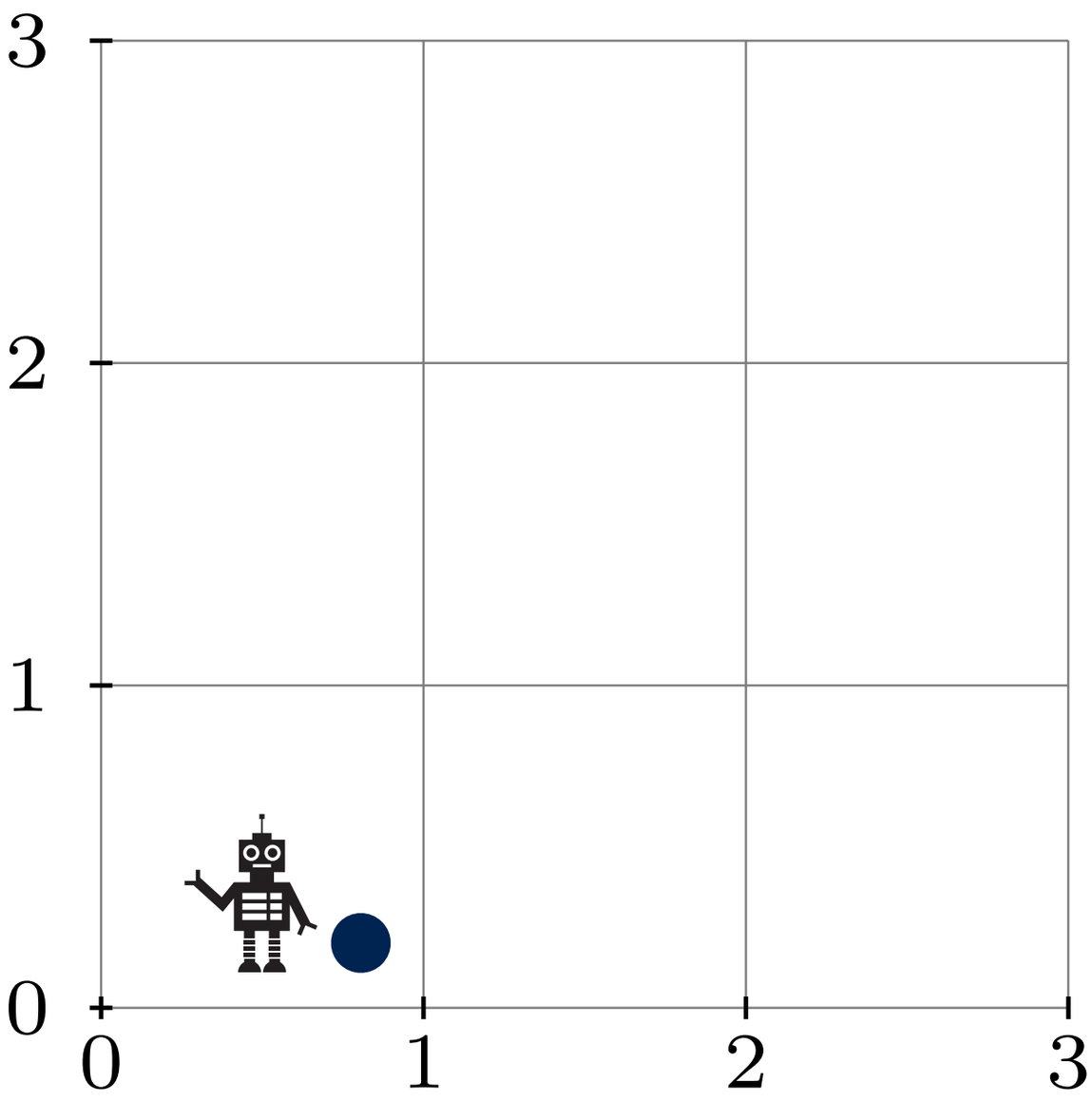
Sorting

Input	**Output**
[9,13,1,8,4]	[1,4,8,9,13]
[1,18,20,6,15,5]	[1,5,6,15,18,20]
[12,16,18,6,15,3,5]	???
[16,1,4,12,3,18,2,14]	???
[12,17,5,13,6,4,14,2,15]	???

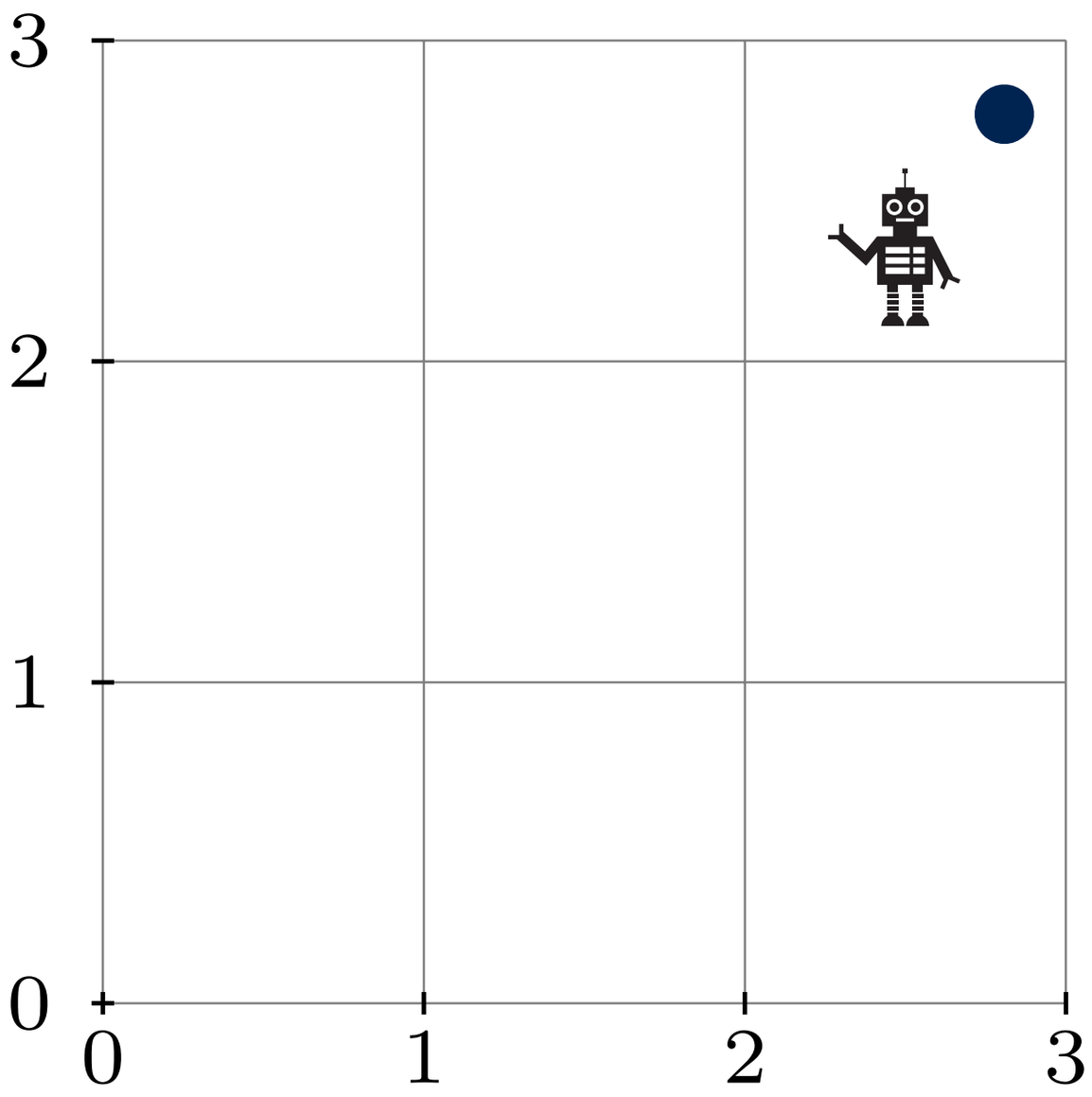
Learning efficient robot strategies

[IJCAI15]

Initial state



Final state

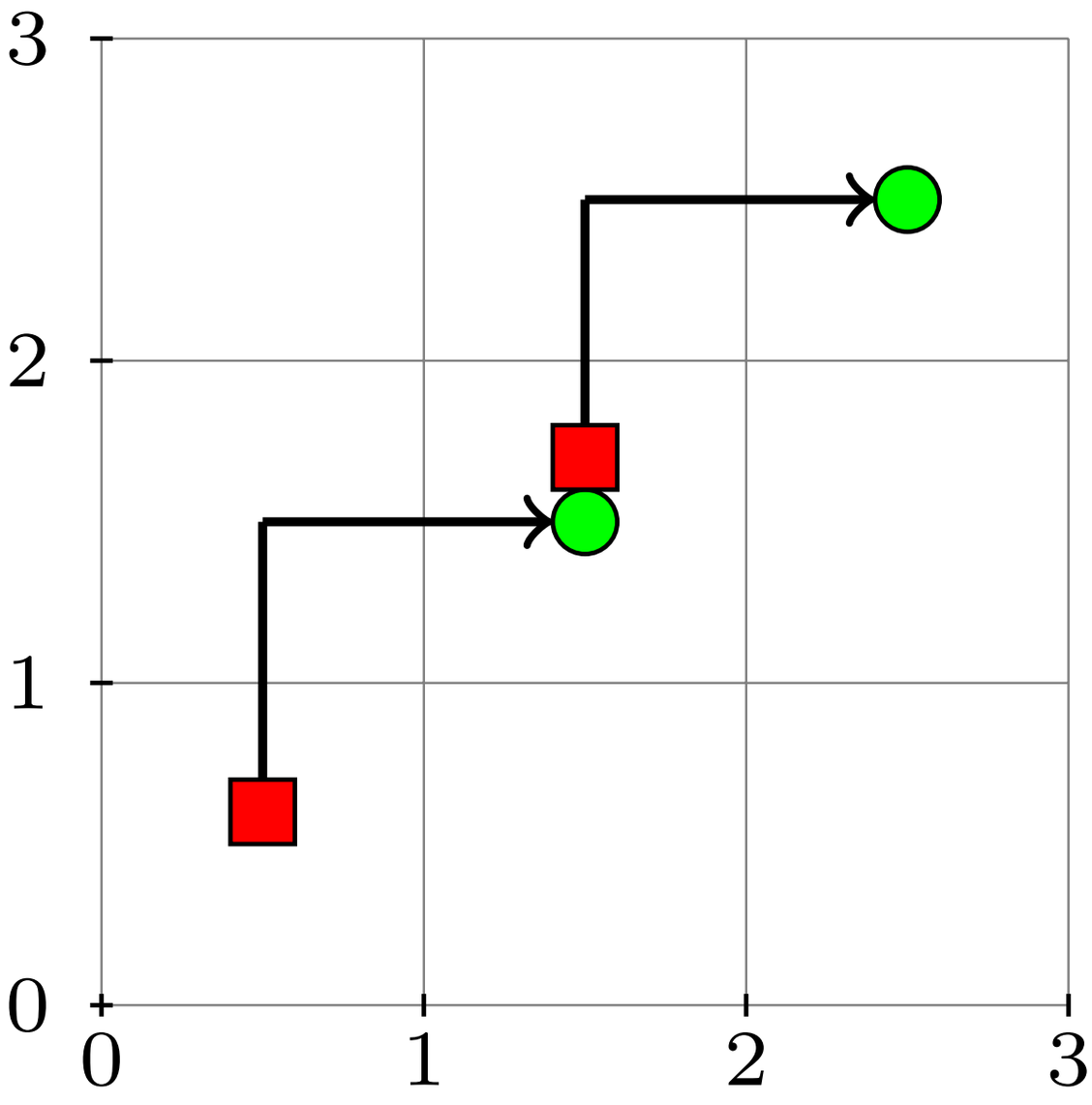


```
move(X,Y):-p3(X,Z),p3(Z,Y).
p3(X,Y):-p2(X,Z),drop(Z,Y).
p2(X,Y):-grab(X,Z),p1(Z,Y).
p1(X,Y):-north(X,Z),east(Z,Y).
```

```
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).
```

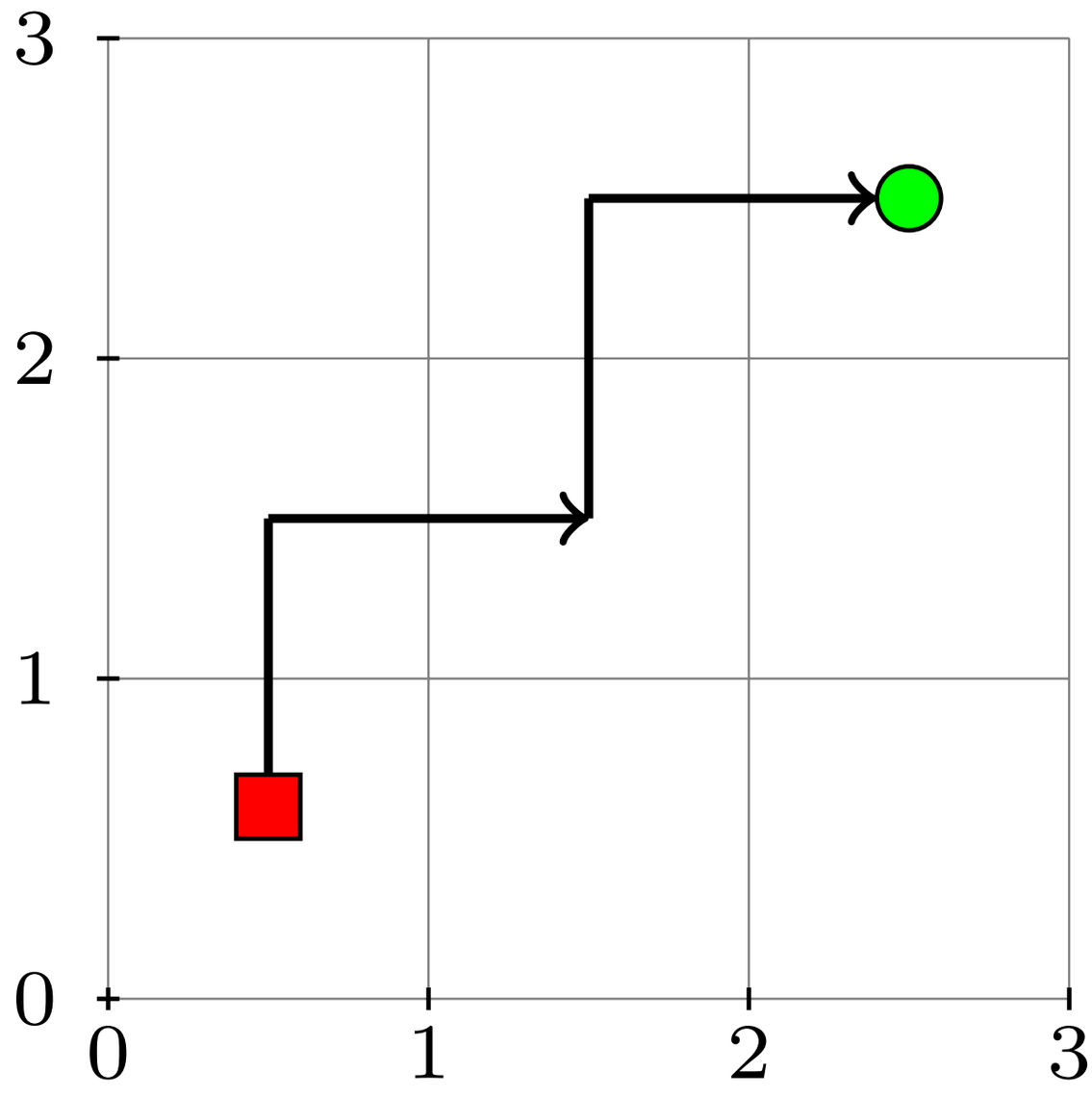
grab drop

Inefficient solution



resource complexity: 8

Efficient solution



resource complexity: 6

Action	drop	grab	north	east
Cost	1	1	1	1

Meta-interpretive learning (MIL)

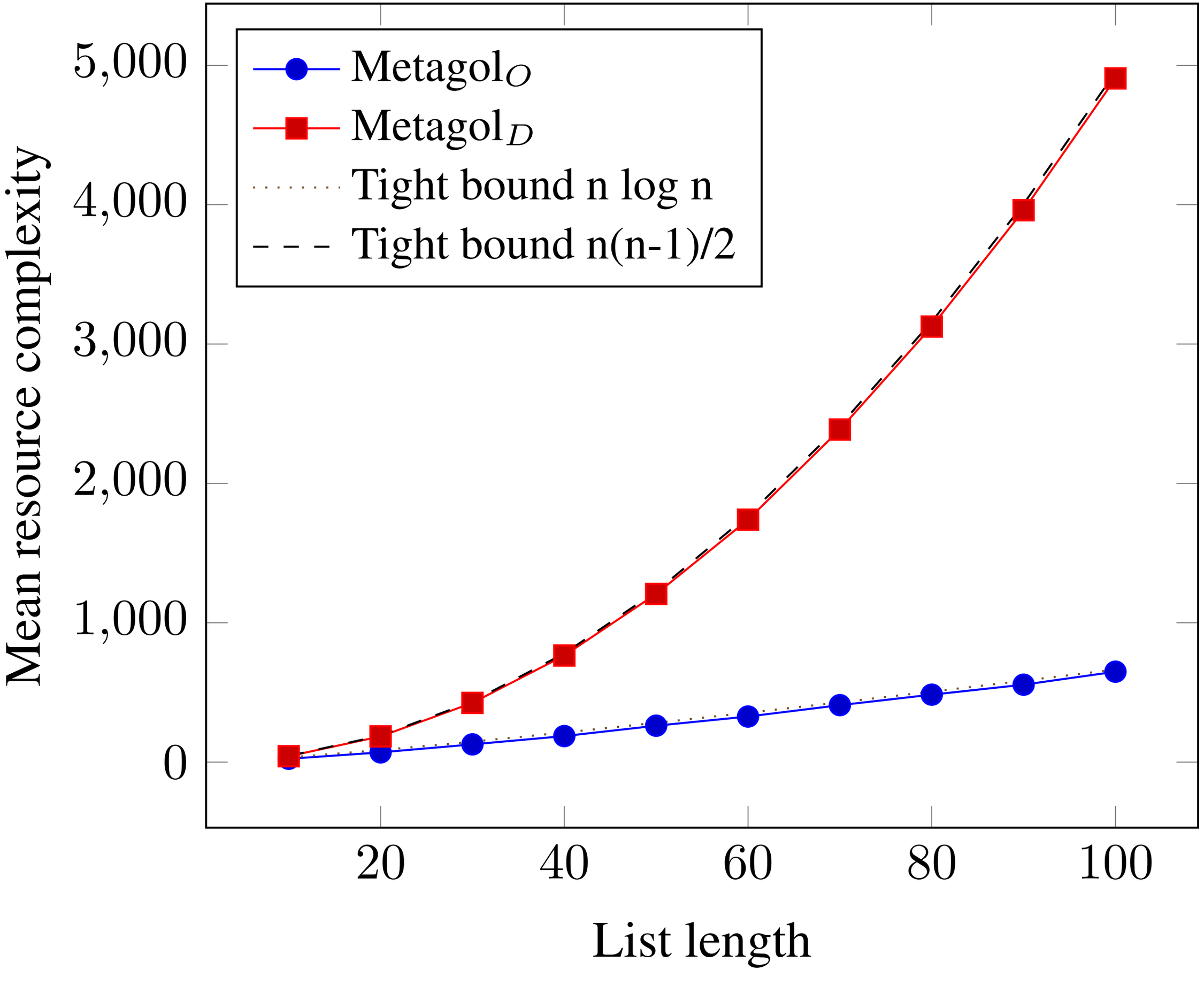
A form of inductive logic programming based on Prolog meta-interpreter which supports:

- predicate invention
- learning recursive programs
- learning efficient programs
- learning higher-order programs

https://github.com/metagol

Sorting experiment

Input	**Output**
[9,13,1,8,4]	[1,4,8,9,13]
[1,18,20,6,15,5]	[1,5,6,15,18,20]
[12,16,18,6,15,3,5]	???
[16,1,4,12,3,18,2,14]	???
[12,17,5,13,6,4,14,2,15]	???


Metagol$_O$
Metagol$_D$
Tight bound n log n
Tight bound n(n-1)/2
Mean resource complexity
5,000
4,000
3,000
2,000
1,000
0
20
40
60
80
100
List length

Conclusions

- pruning the search space [IJCAI15]
- higher-order programs [IJCAI16]

Future work

- Demonstrate generality
- Use to discover novel algorithms

Thank you