Inductive general game playing

Andrew Cropper, Richard Evans, and Mark Law

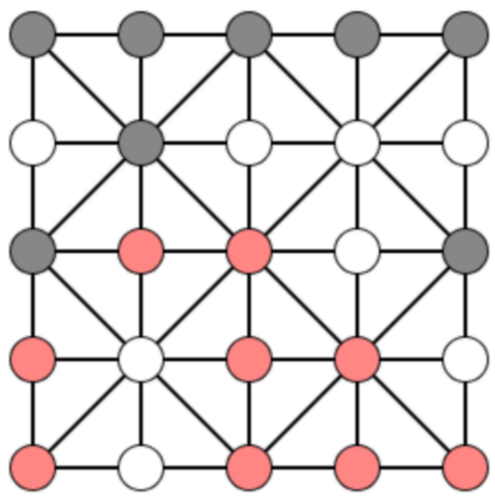
Inverse general game playing

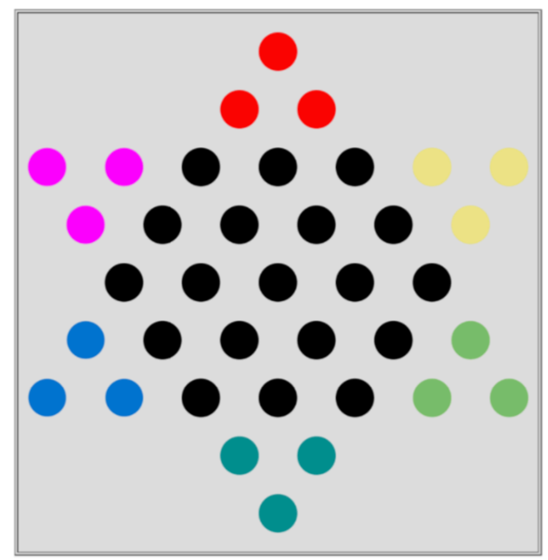
Andrew Cropper, Richard Evans, and Mark Law

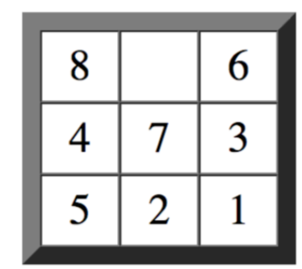
Inducing game rules

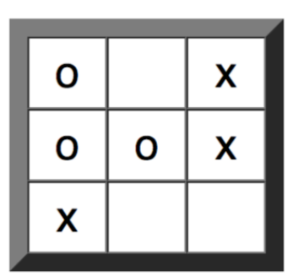
Andrew Cropper, Richard Evans, and Mark Law

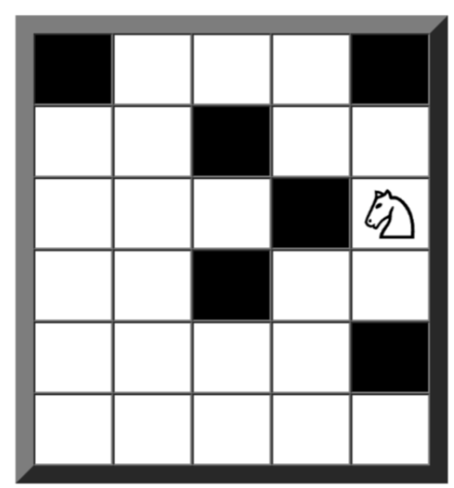
General game playing competition

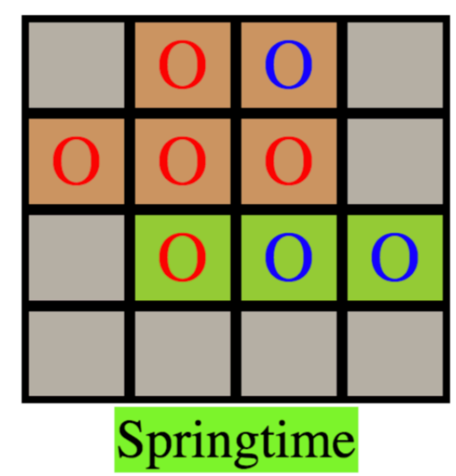












Game description language

- initial game state
- legal moves
- how moves update the game state
- how the game terminates

Game description language

```
(succ 0 1)
(succ 1 2)
(succ 2 3)
(beats scissors paper)
(beats paper stone)
(beats stone scissors)
(<= (next (step ?n)) (true (step ?m)) (succ ?m ?n))
(<= (next (score ?p ?n)) (true (score ?p ?n)) (draws ?p))
(<= (next (score ?p ?n)) (true (score ?p ?n)) (loses ?p))
(<= (next (score ?p ?n)) (true (score ?p ?n2)) (succ ?n2 ?n) (wins ?p))
(<= (draws ?p) (does ?p ?a) (does ?q ?a) (distinct ?p ?q))
(<= (wins ?p) (does ?p ?a1) (does ?q ?a2) (distinct ?p ?q) (beats ?a1 ?a2))
(<= (loses ?p) (does ?p ?a1) (does ?q ?a2) (distinct ?p ?q) (beats ?a2 ?a1))
```

Our problem

Learn rules from observations

- goal
- legal
- next
- terminal

Why?

Many diverse games

New games each year

Why?

Independent language

Not hand-crafted by the system designer

Cannot predefine the perfect language bias

Focus on the problem, not the representation

Why?

Hard problems?

Game	R	L	D	P
Minimal Decay	2	6	0	1
Minimal Even	8	19	0	1
Rainbow	10	48	0	1
Rock Paper Scissors	12	36	0	1
GT Chicken	16	78	0	2
GT Attrition	16	60	0	2
Coins	16	45	0	1
Buttons and Lights	16	44	1	1
Leafy	17	80	2	2
GT Prisoner	17	75	0	2
Eight Puzzle	17	60	2	1
Lightboard	18	69	2	2
Knights Tour	18	46	2	1
Sukoshi	19	49	1	2
Walkabout	22	66	2	2
Horseshoe	22	59	2	2
GT Ultimatum	22	67	0	2
Tron	23	76	2	2
9x Buttons and Lights	24	77	2	1
Hunter	24	69	2	1
GT Centipede	24	69	0	2
Fizz Buzz	25	74	0	1
Untwisty Corridor	27	68	0	1
Don't Touch	29	84	2	2
Tiger vs Dogs	30	88	2	2

Game	R	L	D	P
Sheep and Wolf	30	89	2	2
Duikoshi	31	76	2	2
TicTacToe	32	92	2	2
HexForThree	35	130	2	3
Connect 4	36	124	2	4
Breakthrough	36	126	2	2
Centipede	37	134	2	1
Forager	40	106	2	1
Sudoku	41	101	2	1
Sokoban	41	172	2	1
9x TicTacToe	42	149	2	2
Switches	44	183	2	1
Battle of Numbers	44	134	2	2
Free For All	46	130	2	2
Alquerque	49	134	2	2
Kono	50	134	2	2
Checkers	52	167	2	2
Pentago	53	188	2	2
Platform Jumpers	62	168	2	2
Pilgrimage	80	240	2	2
Firesheep	85	290	2	2
Farming Quandries	88	451	2	2
TTCC4	94	301	2	2
Frogs and Toads	97	431	2	2
Asylum	101	273	2	2

Rock, paper, scissors

```
% BK
beats(paper,stone).
beats(scissors,paper).
beats(stone,scissors).
player(p1).
player(p2).
succ(0,1).
succ(1,2).
succ(2,3).
does(p1,stone).
does(p2,paper).
true_score(p1,0).
true_score(p2,0).
true_step(0).
```

```
% E+
next_step(1).

% E-
next_step(0).
next_step(2).
next_step(3).
```

Rock, paper, scissors

```
next_step(N):-
    true_step(M),
    succ(M,N).
```

Rock, paper, scissors

```
% BK
beats(paper,stone).
beats(scissors,paper).
beats(stone,scissors).
player(p1).
player(p2).
succ(0,1).
succ(1,2).
succ(2,3).
does(p1,stone).
does(p2,paper).
true_score(p1,0).
true_score(p2,0).
true_step(0).
```

```
% E+
next_score(p1,0).
next_score(p2,1).

% E-
next_score(p2,0).
next_score(p1,1).
next_score(p1,2).
next_score(p2,2).
next_score(p1,3).
next_score(p2,3).
```

Rock, paper, scissors

```
next_score(P,N):-
    true_score(P,N),
    draws(P).
next_score(P,N):-
    true_score(P,N),
    loses(P).
next_score(P,N2):-
    true_score(P,N1),
    succ(N2,N1),
    wins(P).
```

```
draws(P):-
    does(P,A),
    does(Q,A),
    distinct(P,Q).
loses(P):-
    does(P,A1),
    does(Q,A2),
    distinct(P,Q),
    beats(A2,A1).
wins(P):-
    does(P,A1),
    does(Q,A2),
    distinct(P,Q),
    beats(A1,A2).
```

*draws/1, loses/1, wins/1 not provided as BK!

Fizzbuzz BK

```
divisible(12,1).
divisible(12,2).
...
divisible(12,12).
input_say(player,1).
input_say(player,2).
...
input_say(player,30).
input_say(player,fizz).
input_say(player,buzz).
input_say(player,fizzbuzz).
role(player).
int(0).
int(1).
...
int(31).
```

```
less_than(0,1).
less_than(0,2).
...
less_than(30, 31).
minus(1,1,0).
minus(2,1,1).
...
minus(31,31,0).
positive_int(1).
positive_int(2).
...
positive_int(31).
succ(0,1).
succ(0,2).
...
succ(30,31).
```

Fizzbuzz next count

```
% BK
does_say(player,buzz).
true_count(12).

% E+
next_count(13).

% E-
next_count(0).
next_count(1).
...
next_count(12).
next_count(14).
...
next_count(31).
```

Fizzbuzz next count

```
% BK
does_say(player,buzz).
true_count(12).

% E+
next_count(13).

% E-
next_count(0).
next_count(1).
...
next_count(12).
next_count(14).
...
next_count(31).
```

```
% hypothesis
next_count(After):-
    true_count(Before),
    succ(Before,after).
```

Fizzbuzz next success

```
% BK
does_say(player,buzz).
true_count(4).
true_success(3).

% E+
next_success(3).

% E-
next_success(0).
next_success(1).
next_success(2).
next_success(4).
...
next_success(31).
```

Fizzbuzz next success

```
next_success(After):-
    correct,
    true_success(Before),
    succ(Before,After).

next_success(A):-
    \+ correct,
    true_success(A).

correct:-
    true_count(N),
    \+ divisible(N,5),
    \+ divisible(N,3),
    does_player_say(N).
```

```
correct:-
    true_count(N),
    divisible(N,15),
    does_player_say(fizzbuzz).
correct:-
    true_count(N),
    divisible(N,3),
    \+ divisible(N,5),
    does_player_say(fizz).
correct:-
    true_count(N),
    divisible(N,5),
    \+ divisible(N,3),
    does_player_say(buzz).
```

Hard problems?

Balanced accuracy

$$ba = (tp/p + tn/n)/2$$

Perfectly solved

the percentage of tasks that an approach solves with 100% accuracy

Results

Metric	Baseline	Inertia	Mean	KNN_1	KNN_5	Aleph	ASPAL	Metagol	ILASP^*
BA (%)	48	56	64	80	80	66	55	69	**86**
PS (%)	4	4	15	16	19	18	10	34	**40**

Results

Metric	**Aleph**	**ASPAL**	**Metagol**	**ILASP***
BA (%)	66	55	69	**86**
PS (%)	18	10	34	**40**

Results balanced accuracy

Approach	**`goal`**	**`legal`**	**`next`**	**`terminal`**
True	47	56	47	42
Inertia	47	56	80	42
Mean	82	61	62	53
Knn1	**92**	78	86	63
Knn5	**92**	79	86	64
Aleph	83	60	59	60
ASPAL	52	59	50	59
Metagol	74	66	60	77
Ilasp	**92**	**86**	**88**	**80**
Mean	73	67	69	60

Results perfectly solved

Approach	`goal`	`legal`	`next`	`terminal`
True	0	16	0	0
Inertia	0	16	0	0
Mean	32	16	0	12
Knn_1	34	16	0	12
Knn_5	34	22	0	18
Aleph	32	18	4	16
ASPAL	4	18	0	18
Metagol	**48**	28	6	**52**
ILASP	46	**44**	**18**	**52**
Mean	26	22	3	20

Summary

IGGP poses many challenges

Systems struggle without perfect language bias

Limitations and future work

More metrics

More games

More systems

Better ILP systems

https://github.com/andrewcropper/iggp

https://github.com/andrewcropper/mlj19-iggp