General Game Playing and the Game Description Language

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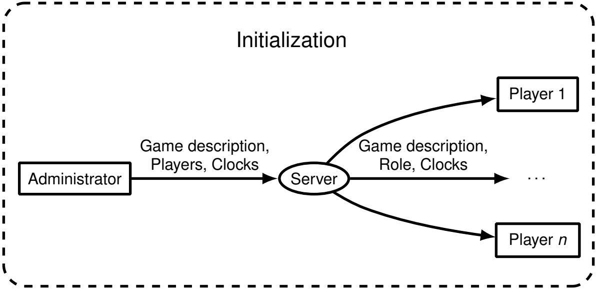
GENERAL
GAME
PLAYING



Initialization

Administrator

Game description, Players, Clocks

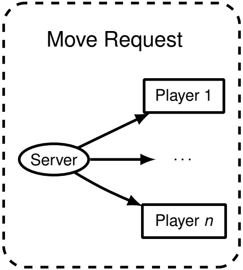
Server

Game description, Role, Clocks

Player 1

. . .

Player *n*



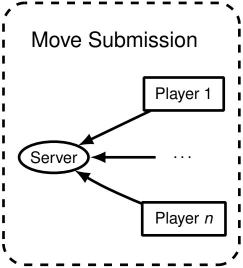
Move Request

Server

Player 1

. . .

Player *n*



Move Submission

Server

Player 1

. . .

Player *n*

Another Kind of Logic Language

GDL is not Prolog

- No cuts
- Hypotheses are not ordered
- Forward and backward chaining are possible
- Grounding

GDL is not Datalog

- Nested function symbols
- Recursion restriction

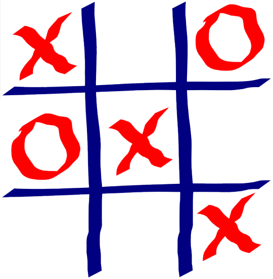
- Dynamic keywords: `init`, `true`, `next`
- Semantics = Transition system

Initial State

```
(init (cell 1 1 b))
 ...
(init (cell 3 3 b))
(init (ctrl xplayer))
```

Legal Actions

```
(← (legal P (mark M N))
   (true (ctrl P))
   (true (cell M N b)))
```



Next State

```
(← (next (cell M N P))
   (does P (mark M N)))
(← (next (ctrl oplayer))
   (true (ctrl xplayer)))
(← (next (ctrl xplayer))
   (true (ctrl oplayer)))
```

```
(← (next (cell M N C))
   (true (cell M N C))
   (does P (mark M′ N′))
   (or (distinct M M′)
       (distinct N N′)))
```

Auxiliary predicates

```
(← (line P) (true (cell M 1 P)) (true (cell M 2 P)) (true (cell M 3 P)))
(← (line P) (true (cell 1 N P)) (true (cell 2 N P)) (true (cell 3 N P)))
(← emptycell (true (cell M N b)))
```

Objective

```
(← (goal xplayer 100) (line xplayer))
(← (goal oplayer   0) (line xplayer))
```

Termination

```
(← terminal (line P))
(← terminal (not emptycell))
```

Typical competition time limits

- Startclock: 600 sec per match
- Playclock: 30 sec per move

Making the most out of the competition settings

- GDL is not Prolog → Hypotheses are not ordered
- Startclock → Optimize the compiler's parameters

Into perspective

- Classical compilers: globally-tune default flags.
- Automatic empirical optimization (ATLAS/FFTW3): tune to the hardware/installed software.
- Here: tune to the instance (also [Keller *et al.*, 2008]).

Hypotheses Ordering

Rule	Input	Restriction
(← (legal white (move X_1 Y_1 X_2 Y_2))		
(succ Y_1 Y_2)	Y_1, Y_2	
(succ X_1 X_2)	X_1, X_2	
(cell X_1 Y_1 w)		X_1, Y_1
(not (cell X_2 Y_2 w)))		X_2, Y_2

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(succ Y_1 Y_2)	Y_1, Y_2	
(cell X_1 Y_1 w)	X_1	Y_1
(succ X_1 X_2)	X_2	X_1
(not (cell X_2 Y_2 w)))		X_2, Y_2

Knowledge Base

{(succ 1 2), (succ 2 3), (succ 3 4), (cell 1 1 w), (cell 1 2 w), (cell 2 2 w), . . .}

Steps	Satisfying assignments: {[X_1 X_2 Y_1 Y_2]}
(succ Y_1 Y_2)	{[_ _ 1 2], [_ _ 2 3], [_ _ 3 4]}
(succ X_1 X_2)	{[1 2 1 2], [2 3 1 2], [3 4 1 2], [1 2 2 3], [2 3 2 3], [3 4 2 3], [1 2 3 4], [2 3 3 4], [3 4 3 4]}
(cell X_1 Y_1 w)	{[1 2 1 2], [1 2 2 3], [2 3 2 3]}
(not (cell X_2 Y_2 w)))	{[1 2 2 3], [2 3 2 3]}
(succ Y_1 Y_2)	{[_ _ 1 2], [_ _ 2 3], [_ _ 3 4]}
(cell X_1 Y_1 w)	{[1 _ 1 2], [1 _ 2 3], [2 _ 2 3]}
(succ X_1 X_2)	{[1 2 1 2], [1 2 2 3], [2 3 2 3]}
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Knowledge Base

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Steps	Satisfying assignments: {[X_1 X_2 Y_1 Y_2]}
(succ Y_1 Y_2)	{[_ _ 1 2], [_ _ 1 3]}
(succ X_1 X_2)	{[1 2 1 2], [1 3 1 2], [1 2 1 3], [1 3 1 3]}
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(not (cell X_2 Y_2 w)))	{[1 2 1 2], [1 3 1 2], [1 2 1 3], [1 3 1 3]}
(succ Y_1 Y_2)	{[_ _ 1 2], [_ _ 1 3]}
(cell X_1 Y_1 w)	{[1 _ 1 2], [2 _ 1 2], [3 _ 1 2], [4 _ 1 2], [1 _ 1 3], [2 _ 1 3], [3 _ 1 3], [4 _ 1 3]}
(succ X_1 X_2)	{[1 2 1 2], [1 3 1 2], [1 2 1 3], [1 3 1 3]}
(not (cell X_2 Y_2 w)))	{[1 2 1 2], [1 3 1 2], [1 2 1 3], [1 3 1 3]}

Empirical hypotheses ordering

- Get the rules
- Naive compilation
- Collect data via random games
- Infer a good hypotheses ordering
- → Smart compilation

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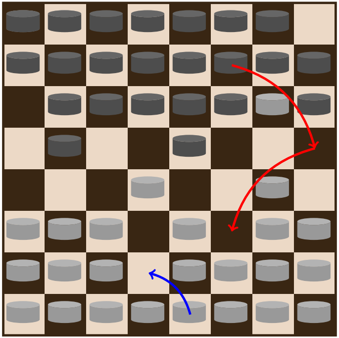
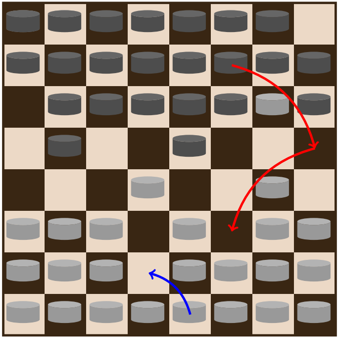
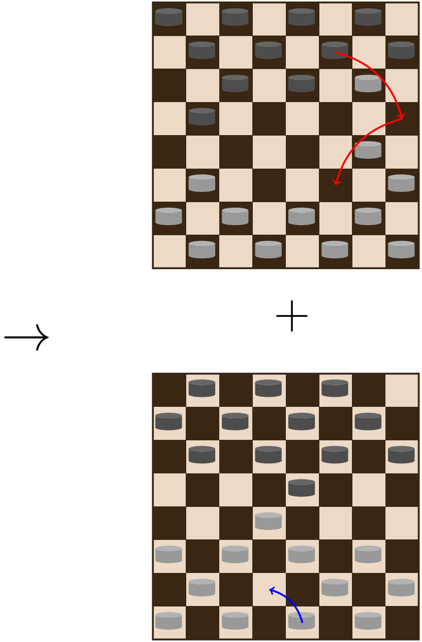
Experiments: engine speed (higher is better)

Game	Original	Inferred	Improvement
Peg solitaire	3.6	139	3800%
Connect 4	78.7	111	141%
Mini-chess	62.7	74.8	119%
Ro-sham-bo	1,480	1,610	109%
Sheep and Wolf	101	94.3	93%



Language-level: Decomposition into sub-games





AI level: Complexity reduction

$(b_1 b_2)^n \to b_1^n + b_2^n$

Reachability Analysis

What for?

- Deadlock analysis
- Termination analysis
- Precise static typing
- Dead-code detection

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- Prop: no variables
- Mono: facts are never removed from the KB
- Bounded: stronger recursion restriction

Fragment	Reachability
Prop, Mono	NP-c
Prop	PSPACE-c
Mono	NEXPTIME-c
Bounded	EXPSPACE-c
Full	UNDEC

Conclusion

In the AI community: a Hot Topic

- Yearly international competition
- Journal special issues, workshops
- Masters students, PhDs
- Massive OO Course ($\geq$ 50,000 students)

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In the PL community: We need You!

- Low hanging fruits
- Some interesting problems?