General Game Playing

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Motivation

"A human being should be able to change a diaper, plan an invasion, butcher a hog, conn a ship, design a building, write a sonnet, balance accounts, build a wall, set a bone, comfort the dying, take orders, give orders, cooperate, act alone, solve equations, analyze a new problem, pitch manure, program a computer, cook a tasty meal, fight efficiently, die gallantly. ***Specialization is for insects.****"*

—Robert A. Heinlein, Time Enough for Love, 1973

"In general, we are building tools that amplify the human ability."

—Steve Jobs, 1980

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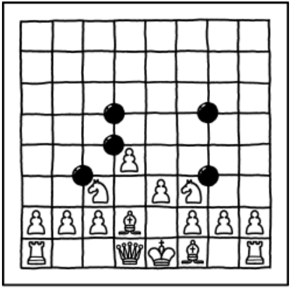


WHITE TO CONTINUE INSISTING THIS IS A CHESSBOARD

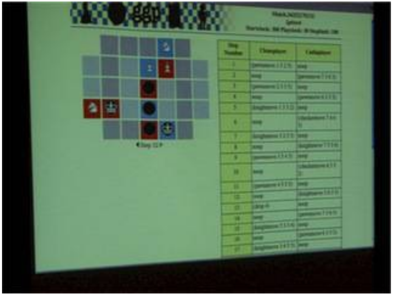
Introduction

General Game Playing

- aims at developing game playing agents that are able to play a variety of games
- raises questions about the nature of inteligence
- testbed for artificial inteligence
- develops new techiques for
  - descriptive programming
  - planning and scheduling
  - reasoning and formal verification
  - expert systems
  - machine learning
  - knowledge representation
- Jacques Pitrat: Realization of a general game playing program (1968)

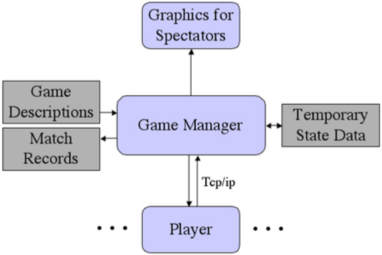
The International General Game Playing Competition

- since 2005
- organised by Stanford Logic Group of Stanford University
- held annualy at AAAI Conference



Game play

- Game Manager
- GGP Protocol
  - (info)
  - (start *id role description startclock playclock*)
  - (play *id move*)
  - (stop *id move*)
  - (abort *id*)
- Game Description Language

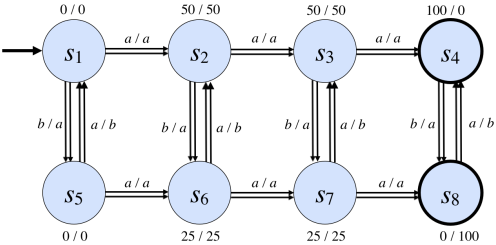


Game representation

- games must be
  - finite
  - synchronous (all players move on every step)
  - with complete information
  - playable
  - weakly winnable

Game Description Language

- logic programming language, variant of Datalog
- similar to Prolog (or Lisp - prefix GDL), except:
  - purely declarative
  - restrictions:
    - safety
    - stratified recursion and negation
    - no nested functional terms
  - every term can be computed in finite time
- structured state machine



Game Description Language: rules

role(a) means that *a* is a role in the game.

base(p) means that *p* is a base proposition in the game.

input(r,a) means that *a* is an action for role *r*.

init(p) means that the proposition *p* is true in the initial state.

true(p) means that the proposition *p* is true in the current state.

does(r,a) means that player *r* performs action *a* in the current state.

next(p) means that the proposition *p* is true in the next state.

legal(r,a) means it is legal for role *r* to play action *a* in the current state.

goal(r,n) means that player the current state has utility *n* for player *r*.

terminal means that the current state is a terminal state.

Game representation example: Tic Tac Toe

```
role(white)
role(black)

base(cell(M,N,x)) :- index(M) & index(N)
base(cell(M,N,o)) :- index(M) & index(N)
base(cell(M,N,b)) :- index(M) & index(N)

base(control(white))
base(control(black))

input(R,mark(M,N)) :- role(R) & index(M) & index(N)
input(R, noop) :- role(R)

index(1)
index(2)
index(3)
```

Game representation example: Tic Tac Toe

```
init(cell(1,1,b))
init(cell(1,2,b))
init(cell(1,3,b))
init(cell(2,1,b))
init(cell(2,2,b))
init(cell(2,3,b))
init(cell(3,1,b))
init(cell(3,2,b))
init(cell(3,3,b))
init(control(white))
```

```
legal(W,mark(X,Y)) :-
    true(cell(X,Y,b)) &
    true(control(W))

legal(white,noop) :-
    true(control(black))

legal(black,noop) :-
    true(control(white))
```

Game representation example: Tic Tac Toe

```
next(cell(M,N,x)) :-
    does(white,mark(M,N)) & true(cell(M,N,b))

next(cell(M,N,o)) :-
    does(black,mark(M,N)) & true(cell(M,N,b))

next(cell(M,N,W)) :-
    true(cell(M,N,W)) & distinct(W,b)

next(cell(M,N,b)) :-
    does(W,mark(J,K)) & true(cell(M,N,W)) &
    distinct(M,J)

next(cell(M,N,b)) :-
    does(W,mark(J,K)) & true(cell(M,N,W)) &
    distinct(N,K)

next(control(white)) :- true(control(black))
next(control(black)) :- true(control(white))
```

Game representation example: Tic Tac Toe

```
goal(white,100) :- line(x) & ~line(o)
goal(white,50) :- ~line(x) & ~line(o)
goal(white,0) :- ~line(x) & line(o)

goal(black,100) :- ~line(x) & line(o)
goal(black,50) :- ~line(x) & ~line(o)
goal(black,0) :- line(x) & ~line(o)

line(X) :- row(M,X)
line(X) :- column(M,X)
line(X) :- diagonal(X)
```

Game representation example: Tic Tac Toe

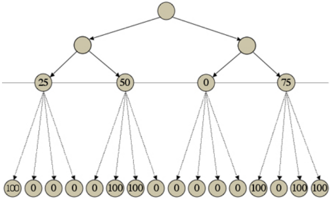
```
row(M,X) :-
    true(cell(M,1,X)) & true(cell(M,2,X)) &
    true(cell(M,3,X))

column(M,X) :-
    true(cell(1,N,X)) & true(cell(2,N,X)) &
    true(cell(3,N,X))

diagonal(X) :-
    true(cell(1,1,X)) & true(cell(2,2,X)) &
    true(cell(3,3,X))

diagonal(X) :-
    true(cell(1,3,X)) & true(cell(2,2,X)) &
    true(cell(3,1,X))
```

Game representation example: Tic Tac Toe

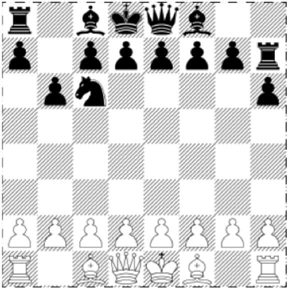
```
terminal :- line(W)
terminal :- ~open

open :- true(cell(M,N,b))
```

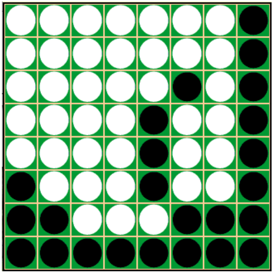
Game play

- expanding the game tree
- min-max
- Monte Carlo
  - winning the AAAI competition since 2007
- general heuristics
  - mobility
  - focus
  - goal proximity
  - combination
- metagaming

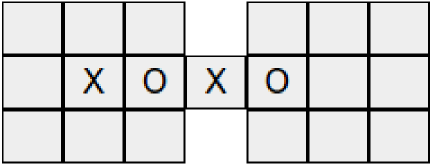


Hodgepodge





Joint Tic Tac Toe



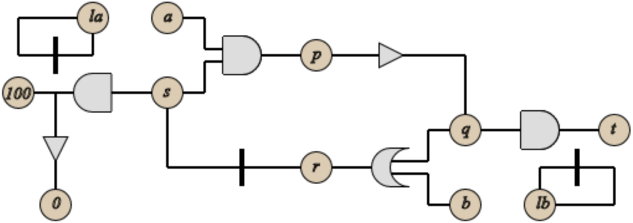
Metagaming

- analysis of propositional nets and rule graphs
  - compact representation
- proofs using logic
- finding structure in games:
  - factoring
  - bottlenecks (Triathalon)
  - symmetry detection (Tic-Tac-Toe)
- trade-off of finding structure vs savings
  - *sometimes* proportional to size of description, not the game tree

Propositional nets

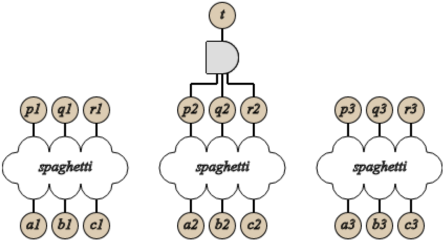
- definition
  - directed bipartite hypergraph
- propositions
- connectives
  - inverter
  - and-gate
  - or-gate
  - transition
- latches, inhibitors, dead state removal

Example propnet

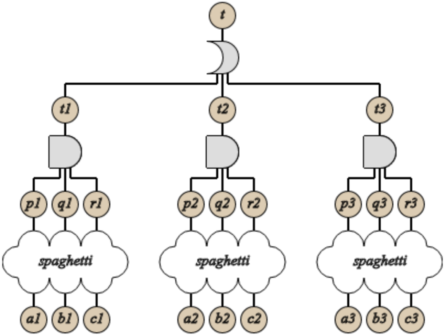


```
role(white)                q :- ~p
base(s)                    r :- true(q)
input(white,a)             r :- does(white,b)
input(white,b)             next(s) :- r
legal(white,a)             goal(white,100) :- true(s)
legal(white,b)             goal(white,0) :- ~true(s)
p :- does(white,a) & true(s)

                           terminal :- true(q)
```

Multiple Buttons and Lights



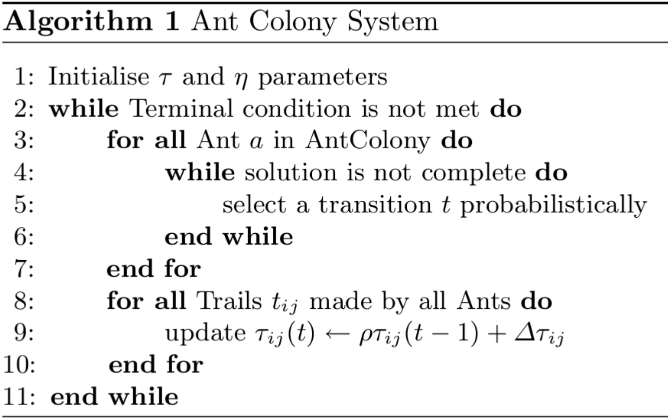
Best Buttons and Lights



General Game Playing with Ants

Ant Colony Optimization

- Marco Dorigo, 1992



Algorithm 1 Ant Colony System

```
Initialise $\tau$ and $\eta$ parameters
while Terminal condition is not met do
    for all Ant $a$ in AntColony do
        while solution is not complete do
            select a transition $t$ probabilistically
        end while
    end for
    for all Trails $t_{ij}$ made by all Ants do
        update $\tau_{ij}(t) \leftarrow \rho\tau_{ij}(t-1) + \Delta\tau_{ij}$
    end for
end while
```

Ant decision propability

$$p_{xy}^{k} = \frac{(\tau_{xy}^{\alpha})(\eta_{xy}^{\beta})}{\sum_{z \in \mathrm{allowed}_x} (\tau_{xz}^{\alpha})(\eta_{xz}^{\beta})}$$

where

- τ_{xy} is the amount of pheromone deposited for transition from state x to y
- $0 \leq \alpha$ is a parameter to control the influence of τ_{xy}
- η_{xy} is the desirability of state transition xy ("a priori" knowledge)
- $\beta \geq 1$ is a parameter to control the influence of η_{xy}

Pheromon update

$$\tau_{xy} \leftarrow (1-\rho)\tau_{xy} + \sum_k \Delta\tau_{xy}^k$$

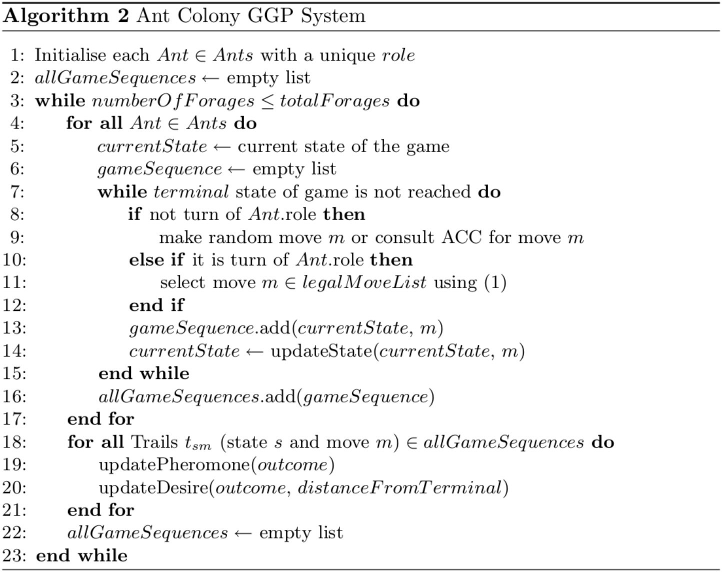
where

τ_{xy} is the amount of pheromone deposited for a state transition *xy*

ρ is the *pheromone evaporation coefficient*

$\Delta\tau_{xy}^k$ is the amount of pheromone deposited by *k*th ant

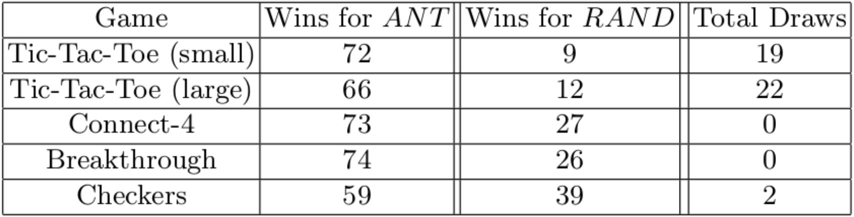
Ants for GGP



Algorithm 2 Ant Colony GGP System

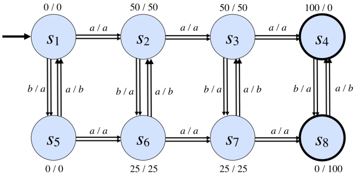
```
Initialise each $Ant \in Ants$ with a unique $role$
$allGameSequences \leftarrow$ empty list
while $numberOfForages \leq totalForages$ do
    for all $Ant \in Ants$ do
        $currentState \leftarrow$ current state of the game
        $gameSequence \leftarrow$ empty list
        while $terminal$ state of game is not reached do
            if not turn of $Ant$.role then
                make random move $m$ or consult ACC for move $m$
            else if it is turn of $Ant$.role then
                select move $m \in legalMoveList$ using (1)
            end if
            $gameSequence$.add($currentState$, $m$)
            $currentState \leftarrow$ updateState($currentState$, $m$)
        end while
        $allGameSequences$.add($gameSequence$)
    end for
    for all Trails $t_{sm}$ (state $s$ and move $m$) $\in allGameSequences$ do
        updatePheromone($outcome$)
        updateDesire($outcome$, $distanceFromTerminal$)
    end for
    $allGameSequences \leftarrow$ empty list
end while
```

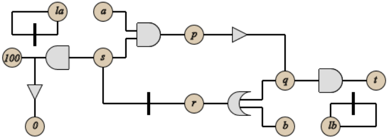
Results



Game	Wins for ANT	Wins for $RAND$	Total Draws
Tic-Tac-Toe (small)	72	9	19
Tic-Tac-Toe (large)	66	12	22
Connect-4	73	27	0
Breakthrough	74	26	0
Checkers	59	39	2

Questions?


0 / 0
50 / 50
50 / 50
100 / 0
s_1
s_2
s_3
s_4
a / a
b / a
a / b
s_5
s_6
s_7
s_8
0 / 0
25 / 25
25 / 25
0 / 100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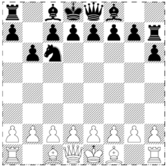

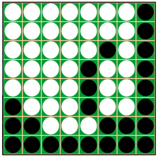

References

- Stanford **General Game Playing** course by Michael Genesereth (`http://www.coursera.org/course/ggp`)
- Michael Genesereth, Michael Thielscher: **General Game Playing** (`http://arrogant.stanford.edu/ggp/chapters/cover.html`)
- Sharma, Shiven, Ziad Kobti, and Scott Goodwin. **"General game playing with ants."** Simulated Evolution and Learning. Springer Berlin Heidelberg, 2008. 381-390.

Image atributions (in order of aperance)

puzzle

> ***Randall Munroe***, `http://xkcd.com/1287/`

GGP competition 1, 2

> `http://cadia.ru.is/wiki/public:cadiaplayer:main#photos`

game manager, state graph, monte carlo, hodgepodge, joint tic tac toe, propnet 1, 2, 3

> ***Michael Genesereth***, `http://arrogant.stanford.edu/ggp/chapters/cover.html`

ants

> ***Mehmet Karatay***, `http://en.wikipedia.org/wiki/File:Safari_ants.jpg`