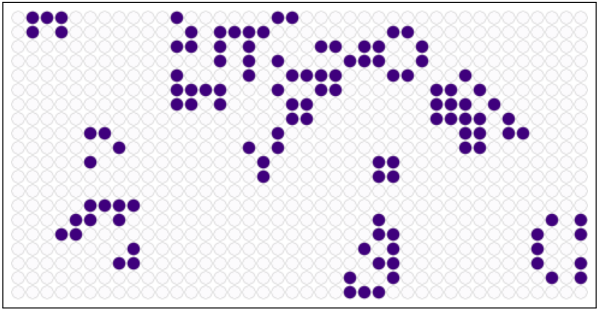
The Game of Life, Decision & Communication

Roland Mühlenbernd

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Overview

1. Introduction: The Game Of Life
2. Pre-Decision
3. Learning
4. Communication



Game of Life's Rules of Nature

1. *under-population:* any alive cell with fewer then two alive neighbor cells dies
2. *surviving:* any alive cell with two or three alive neighbor cells lives on to the next generation
3. *overcrowding:* any alive cell with more than three alive neighbor cells dies
4. *reproduction:* any dead cell with exactly three alive neighbors becomes an alive cell

	X_{du}	
	X_{do}	
X_s	X_s	X_s
	X_r	

GAME OF LIFE'S RULES OF NATURE

Play the Game of Life on
http://www.bitstorm.org/gameoflife/
or
http://www.denkoffen.de/Games/SpieldesLebens/

DECREASING OCCUPATION SHARE

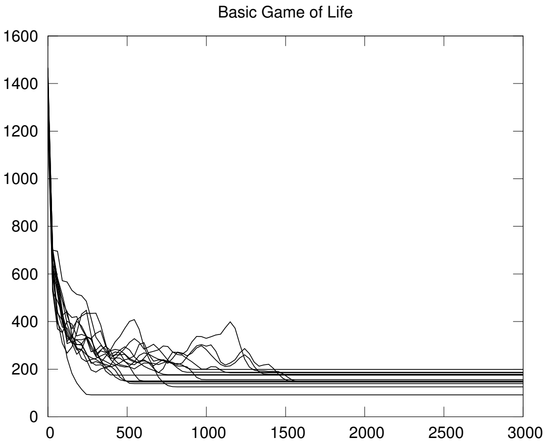


Figure : The number of alive cells decreases from initially around 1225 (25%) to finally 158 (3.2%) on average over 15 runs (70x70 grid).

The non-deterministic n-die game

P1: *Initialization*

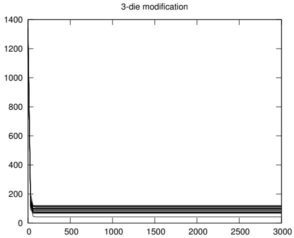
1. Create a list of all alive cells in a random order

P2: *Sacrifice Decision*

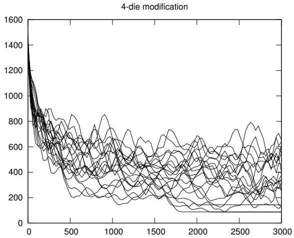
2. Delete successively all cells with n neighbors

P3: *Rules of Nature*

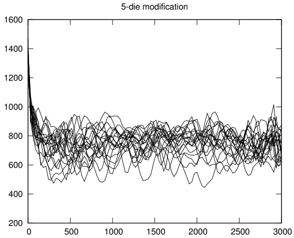
3. Apply the rules of nature of the game of life



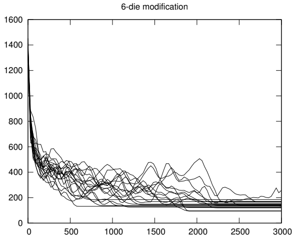
3-die game (1.8%)



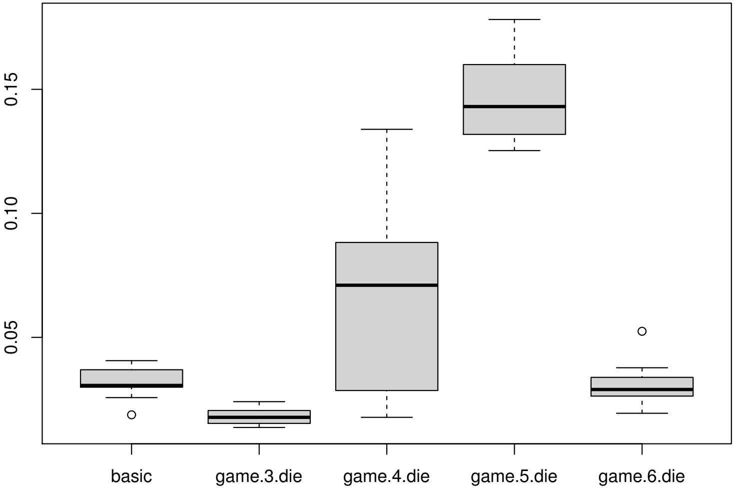
4-die game (6.9%)



5-die game (14.7%)



6-die game (3%)


0.05
0.10
0.15
basic
game.3.die
game.4.die
game.5.die
game.6.die

From Situations to Actions

- Set of states $T = \{t_1, t_2, t_3, t_4, t_5, t_6, t_7, t_8\}$
- Set of situations $\Gamma = \{\gamma = \langle t_i, t_j \rangle | t_i \in T$ is the state of an alive cell c, $t_j \in T$ the state of an alive neighbor cell of $c\}$
- Set of actions $A = \{a_{die}, a_{stay}\}$

	X $\langle t_2, t_2 \rangle$	X $\langle t_2, t_3 \rangle$
	X $\langle t_3, t_1 \rangle$	
X $\langle t_1, t_3 \rangle$		

REINFORCEMENT LEARNING

Reinforcement learning account $RL = \{\sigma, \Omega\}$

- *response rule* $\sigma \in (\Gamma \rightarrow \Delta(A))$
- *update rule* Ω: if action a is successful in situation γ, then increase the probability $\sigma(a|\gamma)$
- an action a is considered as successful, if and only if $OS_a > OS_{\neg a}$

THE $n \times m$-DIE LEARNING GAME

P1: *Initialization*

1. Initialize an RL account for Γ and A

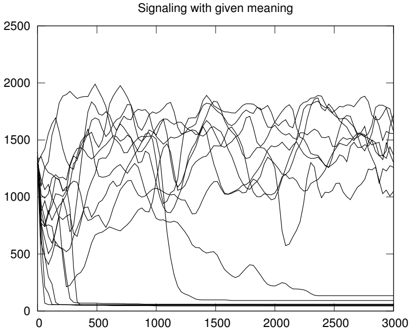
P2: *Sacrifice Decision*

2. For all $c_i \in C$:
   - 2.1 pick randomly a neighbor $c_j \in N_i$ and request its state t_m
   - 2.2 play action a via response rule $\sigma(a|\langle t_n, t_m \rangle)$, where t_n is the state of c_i
   - 2.3 if $a = a_{die}$ delete cell c_i, RL update Ω

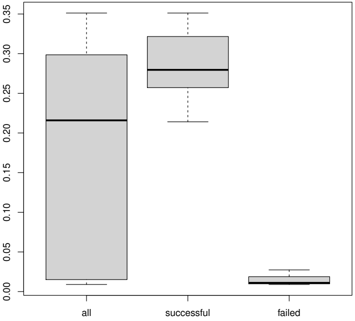
P3: *Rules of Nature*

3. Apply the rules of nature of the game of life

RESULTS



Course of 20 simulation runs



Box plots of all, successful and failed runs

- the average occupation share over all runs is 17.6% (862 cells)
- the average occupation share of successful runs is 28.4% (1392 cells), for failed runs 1.4% (69 cells)

RESULTS

Definition (Neighbor treatment rules)

For the $n \times m$-die learning game a successful strategy can be characterized by the following two rules:

1. *Sacrifice if your neighbor has exactly 4 neighbors.*
2. *Never sacrifice if your neighbor has less than 4 neighbors.*

But...

"In our opinion, the property of *access restriction to direct neighborhood information* is an important requirement for all following pre-games since this property reflects the spatial character of the rules of nature of the game of life. We denote this requirement as the *local information rule*."

	X $\langle t_2, t_2 \rangle$	X $\langle t_2, t_3 \rangle$
	X $\langle t_3, t_2 \rangle$	
X $\langle t_1, t_3 \rangle$		

SIGNALING GAMES

A signaling game $SG = \langle (S, R), T, M, A, U \rangle$ is

- played between a sender S and a receiver R
- S has private information state $t \in T$
- S sends a message $m \in M$
- R responds with a choice of action $a \in A$
- $U : T \times A \to \mathbb{R}$ defines the success of communication

THE n-MESSAGES SIGNALING GAME

P1: *Initialization*

1. Create a RL account for the signaling game $SG_n = \langle (S, R), T, M, A, U \rangle$ witn n messages

P2: *Sacrifice Decision*

2. For all $c_i \in C$:

   2.1 pick randomly a neighbor $c_j \in N_i$ and make a state request for its state t

   2.2 c_j sends a message $m \in M$ via response rule $\sigma(m|t)$

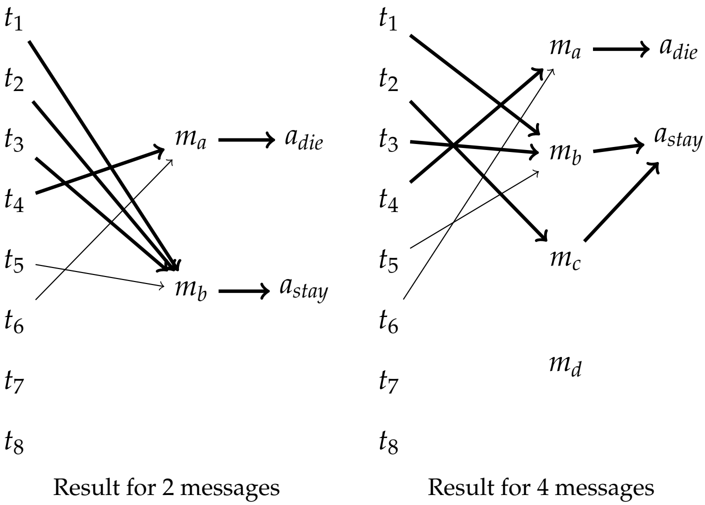
   2.3 c_i plays action $a \in A$ via response rule $\sigma(a|m)$

   2.4 if $a = a_{die}$ delete cell c_i, RL-update Ω

P3: *Rules on Nature*

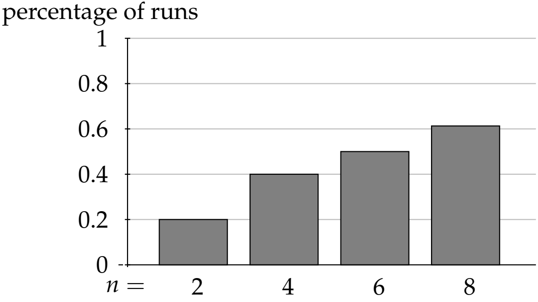
3. Apply the rules of nature of the game of life

RESULTING SUCCESSFUL STRATEGIES



RESULTS

- Always one ”death message”, but often multiple ”survive messages” and unused messages
- Successful strategies realize ”Neighbor treatment rules”
- Strong tendency for $\langle t_5, a_{stay} \rangle$ and $\langle t_6, a_{die} \rangle$
- The rate for learning a successful strategy increases with the number of messages



OUTLOOK

- How do rules of nature affect evolving signaling systems?
  $\rightarrow$ Experiments with changed rules of nature
- General question: how do signaling strategies evolve under selective pressure determined by environmental / nature rules?

Thanks for attention!