Schemata Bandits

A novel approach in Genetic algorithms

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Overview

- Motivation
- Background
- A baseline schemata bandits
- Experimental results
- Conclusions
- Future work

Motivation

- The synergy of two machine learning areas
  - Evolutionary Computation
    - Schema theorem
  - Multi-armed bandits
    - Hierarchical bandits

- Efficient evolutionary algorithms that replace the usage of recombination with hierarchical bandits

Schemata theorem

- Binary coded combinatorial optimization problems, e.g. knapsack problem
- Population of bit strings that are successively selected and recombined to generate new fit individuals
- Schema theorem (Holland,1975)
  - Mechanism to explaining / study the success of genetic algorithms
  - Implicit and parallel processing of information about parts of the search space (schemata)
  - Building blocks – the interesting schemata those combination lead to fit individuals

Multi-armed bandits (MAB)

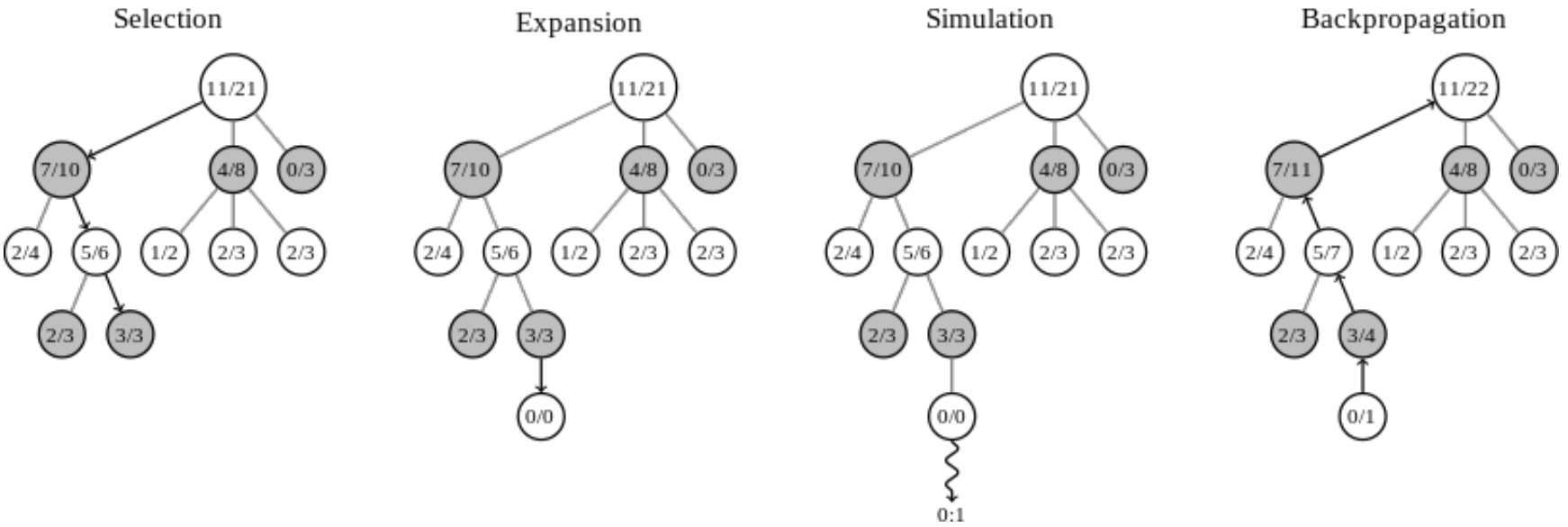
- A machine learning paradigm used to study and analyze resource allocation in stochastic and noisy environments.

- It is the problem a gambler facing a row of slot machines and deciding
  - which machines to play,
  - how many times to play each machine
  - in which order to play them
- When played, each machine provides a reward generated from an unknown distribution specific to that machine.
- The goal of the gambler is to *maximize the sum of rewards* earned through a sequence of lever pulls.

Monte Carlo tree search (MCTS)

- Builds a search tree using a search policy selecting the most probable node to expand
- A top down approach, i.e. root to leaves
- Used to play complicated games like Go with huge search spaces
- Selection of the most promising children
- Expansion → creates new nodes using a tree policy
- Simulation → plays at random from the current node to the end of the game
- Backpropagation → update the information on the explored path

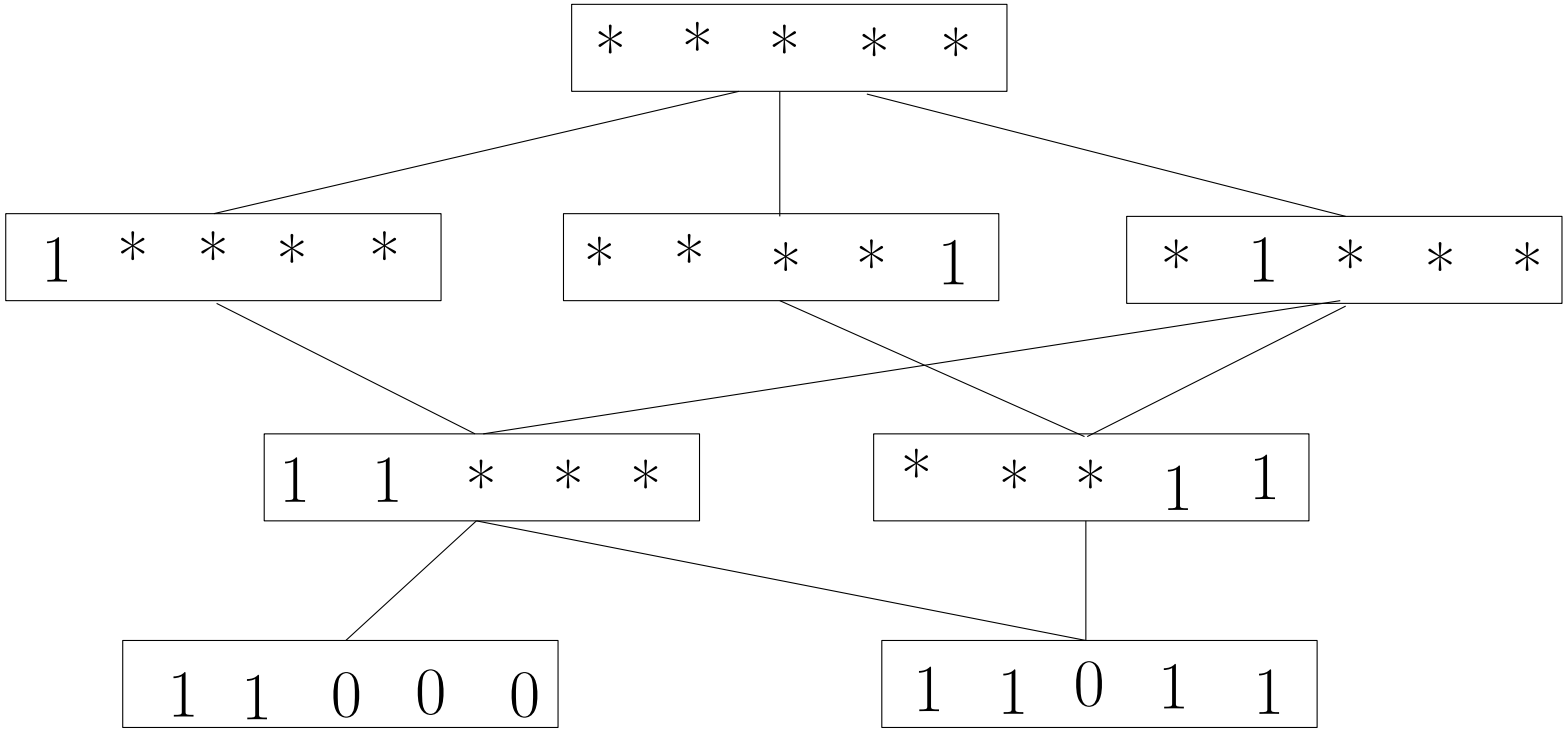
Monte Carlo Tree Search (MCTS)



A schemata net structure

- L – dimensional hypercube, 2^L bitstrings
- Schema H is represented as $H \in \{0, 1, *\}$
  - 3^L schemata
  - o(H) – the order of schemata is the nr of 0s or 1s
  - d(H) – the dimension of the schema H (nr of * symbol)
- Schemata net
  - *root* - the most general schema **…*,
  - *the leaves* – each * is replaced with 0 or 1
  - Each *node has*:
    - Value – the mean over the individual belonging to the schema and sampled
    - 2 * d(H) children → replace a * symbol with 0 or 1
    - o(h) parents → replace of 0 or 1 with * symbol

An example of schemata net



A baseline schemata algorithm

- Initialize the algorithm with n random individuals
- FOR a fixed number of schemata net iterations DO
  - Select the root schemata
  - WHILE a leaf node is NOT reached DO
    - Select the most promising child of the current schemata using UCB1

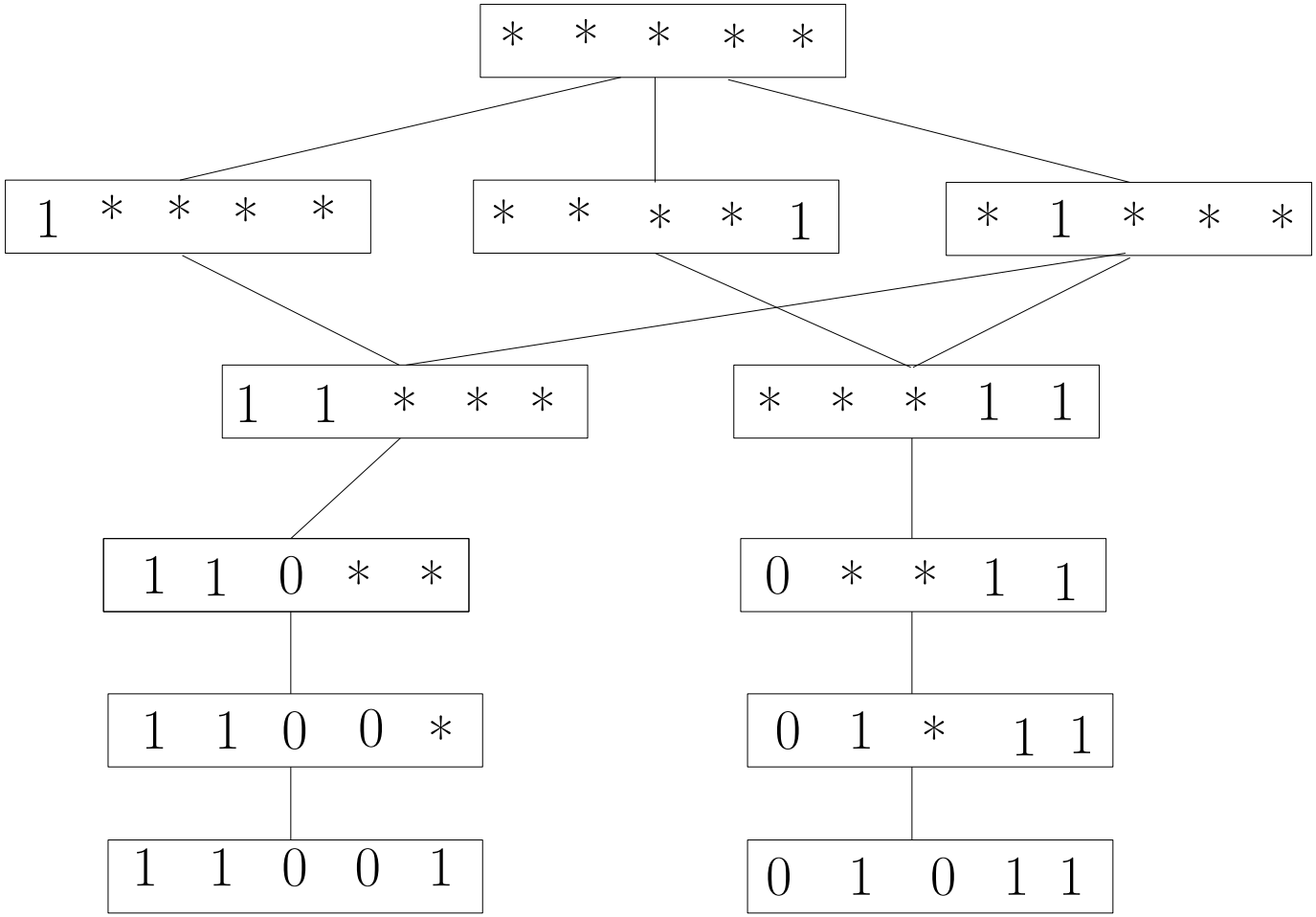
$$argmax_i \overline{f}(H_i) + C \cdot \sqrt{\frac{2\log(t)}{t_i}}$$

    - Update counters $t \leftarrow t+1, \;\; t_i \leftarrow t_i + 1$
    - Update the current schema $H \leftarrow H_i$
  - IF the leaf node was not expanded before THEN
    - Expand all the individual solutions in the leaf node
    - Update nodes on the expanded path

A baseline schemata net algorithm

- Parameter free optimization algorithm
- Schemata net is densely connected → computationally infeasible for large L
  - use schemata net
  - expand only a part of the schemata net
  - hybrid between the two approaches
- The multi-armed bandits algorithm
  - Select a different MAB algorithm
  - Tune the exploration term of UCB1

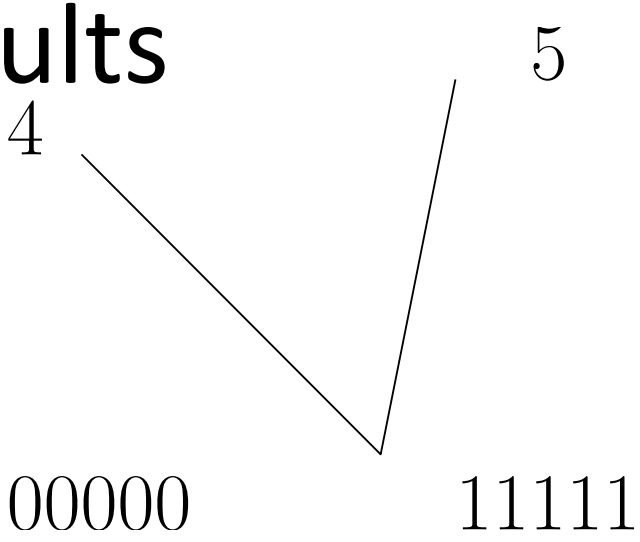
Schemata bandits



Schemata nets vs other GAs

- Schemata net vs Monte Carlo tree search
  - MCTS is a graph not a net
  - Schemata has strong overlap
    - the rewards are strongly correlated
    - in few iterations, we have a completely connected graph
- Schemata net vs Estimation Distribution Algorithms (EDAs)
  - No genetic operator is needed to generate new individuals
  - Schemata bandits could offer theoretical guaranties on the convergence to the optimal value and convergence performance

Experimental results



- Deceptive trap functions
- Several deceptive blocks
- Difficult test problems for GAs

Nr bl.	L	Found solution / best solution	Mean solutions / best solution	Nr schema	Funct evaluat	Regret
1	5	100%	34%	210	32	58
2	10	100%	34%	35870	1024	3598
3	15	100%	34%	171104	31818	169063
4	20	95%	34%	127019	276017	1926978
5	25	92%	34%	179329	318433	2786122
6	30	88%	34%	230715	319954	3312440
7	35	86%	34%	281795	319998	3865973

Contributions

- Schemata net structure
- Schemata bandits
  - A synergy between
    - Schemata Theory and
    - Monte Carlo tree search
  - Genetic algorithms that do not use the genetic operators to generate new individuals
  - Current version → computational challenging

An alternative schemata algorithm with 2^L search space