Problem Solving and Search in Artificial Intelligence

Algorithm Configuration

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Motivation

- Metaheuristic techniques usually include several parameters
  - Tabu search: length of tabu list, type of memory, …
  - Simulated annealing: start and end temperature, decrease of temperature…
  - Iterated local search: size of perturbation, acceptance criteria, running time of local search procedure …
  - Evolutionary algorithms: population size, crossover rate, mutation rate,…
  - …

- Different components can be used
  - Neighborhood structure
  - Mutation type/crossover type
  - …

Finding appropriate parameters/components to be used is crucial for the performance of heuristics
Algorithm configuration (setting of parameters)

- Parameters are determined manually
- Automated algorithm configuration
  - Off-line parameter setting
  - On-line parameter setting
Manual Algorithm Configuration (I)

- Select different configuration for parameters
- Select representative instances for the problem to be solved
- Run experiments on instances with each parameter configuration (typically many runs per instance should be executed)
- Select the best configuration based on quality of solutions, running time of algorithm, ...
- Statistical Analysis
Manual Algorithm Configuration (II)

- Disadvantages of manual configuration
  - Time consuming for the designer of algorithms
  - Limited number of configuration can be tested
  - Hard to find the best configuration

- Alternatives:
  - Automated algorithm configuration
Automated Algorithm Configuration

- Input for off-line configuration problem:
  - Algorithm A
  - A set of parameter configurations
  - A set of input instances

- Problem:
  - Find parameter configuration that gives the best results on the input instances (e.g. solutions with best quality, time performance, …)

- This problem is a search problem - > Number of solutions is equal to number of possible parameter configuration
Off-line algorithm configuration examples (I)

ParamILS [3]:

- Applies iterated local search to find the best configuration
  - Search space: all possible parameter configurations
  - Objective function: the performance of the algorithm with a specific configuration
  - Neighborhood: modification of one parameter value at a time
  - Additional mechanism to speed-up the algorithm (by avoiding unnecessary runs)

- Applied for configuration of CPLEX, SAT algorithms, …

Off-line algorithm configuration examples (II)


Three steps:

- Sampling new configurations according to a particular distribution
- Selecting the best configurations from the newly sampled ones by means of racing
- Updating the sampling distribution in order to bias the sampling towards the best configurations
Off-line algorithm configuration examples (III)

GGA - A Gender-Based Genetic Algorithm [4]
- Introduces a gender separation
- Speedup with parallelization

ISAC - Instance-Specific Algorithm Configuration [5]
- Integrates GGA and stochastic offline programming
- Training instances are clustered based on some features
- Best parameters are found for each cluster with GGA
- Offers selection of best parameters based on features of an input instance
- Applied for Set Cover, SAT and Mixed Integer Programming

Off-line algorithm configuration examples (IV)

SMAC [HHL2011]


http://www.cs.ubc.ca/labs/beta/Projects/SMAC/
http://www.ml4aad.org/algorithm-configuration/smac/
On-line parameter setting

- Parameters change based on feedback during the search
- A parameter can change based on simple rules:
  - Increase tabu length or mutation size if diversification is needed
  - Apply neighborhood relations that improved most of the times solutions
- ... 
- More sophisticated techniques use machine learning techniques (for example reinforcement learning)
Adaptive techniques: Example I

Reactive tabu search [6]

- The prohibition $T$ is determined based on feedback during the search
- $T=1$ in the start of the search
- $T$ increases for 1 if diversification is needed
- The evidence that diversification is needed appears if for example
  - Previous solutions are repeated
  - The solutions have a short distance to the previous solutions
- $T$ decreases if diversification is not needed

Adaptive techniques: Example II

Application of Reinforcement Learning (RL)

Online Control of Evolutionary Algorithms [7]

- A reinforcement method runs simultaneously with the evolutionary algorithm
- EA parameters: population size, tournament proportion, mutation probability, crossover probability
- RL learning changes above during the search based on the progress (best fitness, mean fitness, standard deviation, …) of EA between two time points