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MATH. - NATURWISS. FAKULTÄT
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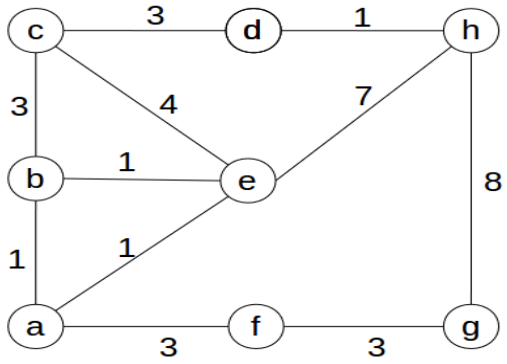
# Artificial Intelligence

## Assignment 6

Assignment due by: 7.12.2016, Discussion: 13.12.2016

### Question 1 Learning Real-Time A* (2+3+2=7 points)

Solve this question using the graph shown below. The initial node is $a$, the target node is $h$.




| $n$ | $h(n)$ |
|---|---|
| $a$ | 5 |
| $b$ | 5 |
| $c$ | 3 |
| $d$ | 1 |
| $e$ | 4 |
| $f$ | 6 |
| $g$ | 7 |
| $h$ | 0 |

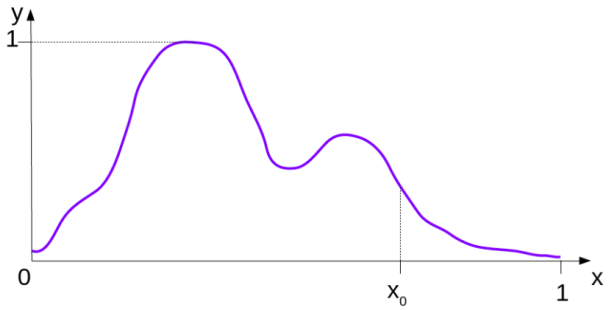
(a) Find a path using the graph-search version of A*.

(b) Following the LRTA* algorithm shown in slide 77 (chapter 4) , fill in the table below:

| $a$ | $s$ | $s'$ | $H[a]$ | $H[b]$ | $H[c]$ | $H[d]$ | $H[e]$ | $H[f]$ | $H[g]$ | $H[h]$ |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | a | 5 | | | | | | | |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

(c) Applying the heuristic $H$ found in task b, find a path using the graph-search version of A*. Compare the number of iterations with task a. What can you conclude?

### Question 2 Simulated annealing (3+3=6 points)




| $n$ | $x_n$ |
|---|---|
| 0 | 0.7 |
| 1 | 0.05 |
| 2 | 0.2 |
| 3 | 0.85 |
| 4 | 0.4 |
| 5 | 0.55 |
| 6 | 0.1 |

| $n$ | $P(x_n \to x_{n+1})$ |
|---|---|
| 0 | 0.3 |
| 1 | 0.7 |
| 2 | $10^{-6}$ |
| 3 | 0.27 |
| 4 | 0.2 |
| 5 | 0.9 |

(a) Using the function displayed in the figure above, apply the first five steps of simulated annealing in order to find the global maximum. For this question, use the following simulated annealing parameters: $T_0 = 0.2$ with $T_{n+1} = T_n \cdot 0.8$ and acceptance probability $P(x_{n+1}, x_n) = \exp(-\frac{|E(x_{n+1}) - E(x_n)|}{T_n})$. The starting point is $x_0 = 0.7$ with $y = E(x_0) = 0.33$ as displayed

on the figure. You are required to use the random sequences $x_n$ and $P(x_{n+1} \to x_n)$ displayed in the tables to carry out the algorithm (i.e. no need to generate your own random samples). Please detail each step.

(b) We now decide to let the acceptance probability be $P(x_{n+1}, x_n) = \frac{E(x_{n+1})}{E(x_n)}$. Using starting point $x_0 = 0.7$ with $y = E(x_0) = 0.33$ and using the random sequences displayed in the tables, carry out simulated annealing process for the first five steps. Please detail each step. Can simulated annealing eventually (i.e. $n$ goes to infinity) converge towards the global maximum with such an acceptance probability? Describe with your own word how we can use samples generated with this modified version of simulated annealing when $n$ is sufficiently large.

## Question 3 Learning Real-Time A* in LISP (5+2 = 7 points)

When doing these exercises you are **not** allowed to use general looping constructs. You can use the specific `(loop for x in list collect (expression with x))` construct, since this is basically just list comprehension.

Similar to A* and RBFS, download the file *graphsearch-lras.lisp*, which contains a graph of German cities and the distances between them, as well as the coordinates of each city and some functions to access that information: `(expand city)` returns a list of all the cities connected to `city`, `(get-distance city1 city2)` returns the distance between two adjacent cities in km (or `nil` if they are not adjacent) and `(get-coordinates city)` returns the $xy$ position (in km) of `city` relative to a flat coordinate system. The file also contains a function stub for the exercise.

(a) Implement Learning Real-Time A* in LISP, using the straight line heuristic.

(b) Run the function to find paths for the following trips: Karlsruhe $\to$ Aachen, Trier $\to$ Dresden, Passau $\to$ Wilhelmshaven. Look at the paths travelled by the algorithm, are they optimal? If not, explain why.