Swarm Intelligence

An official inofficial questionnaire from definitely nice people

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Part 1: General Questions

1. What is *organic computing*? Which directions can be identified?
2. What are the three main reasons which lead to complexity in a system?
3. a) What is the *liveness-property*?
   b) What does it mean for a system to be *self-configuring*?
   c) Name four other *self-*-properties*.
   d) What are two advantages of systems with *self-*-properties*? What is a disadvantage?
4. Name three *patterns of organization*.
5. a) What is *emergence*?
   b) Name two examples of emergent behavior.
   c) What are two properties for emergent phenomena?
6. a) Which research question for emergence was discussed in greater detail? Which algorithm was examined?
   b) Name three other research questions.

Part 2: Particle Swarm Optimization

1. Which of these functions can be optimized on the interval $[-1,1]^n$ using PSO as discussed in the lecture?
   a) $f : \mathbb{R}^3 \to \mathbb{R}^2, f(v) = \begin{pmatrix} v_0 \\ v_1 \end{pmatrix}$
   b) $f : \mathbb{R}^4 \to \mathbb{R}, f(v) = v_0 + v_1 + v_2 + v_3$
   c) $f : \mathbb{R} \to \mathbb{R}, f(v) = 2 \cdot |v_0|$
   d) $f : \mathbb{R}^2 \to \mathbb{R}, f(v) = \begin{cases} -1, & \text{for } |v| = 0 \\ |v| & \text{else} \end{cases}$
2. a) What are the three components of a particle?
   b) What are the two components of the swarm?
3. a) What is the movement equation used in PSO? Give the dimensionality and the meaning of all the different swarm parameters.
   b) Explain the relation between all the components graphically.
4. Name and explain three different ways of dealing with out-of-bounds particles.
5. a) What are the two contrasting heuristics of PSO?
   b) What are the three different neighborhoods which were discussed in the exercise? How do they relate to the two heuristics?

Part 3: Convergence

1. What does convergence look like for PSO? What happens to the position and speed of the particles?
2. a) What is a fixed point?
   b) Given a system $Y^{(k+1)} = A \cdot Y^{(k)} + B \cdot p$, what must be the case for the eigenvalues of A so that the system converges?
   c) Assuming the system converges, what happens if the eigenvalues are negative?
3. Calculate the eigenvalues of the matrix

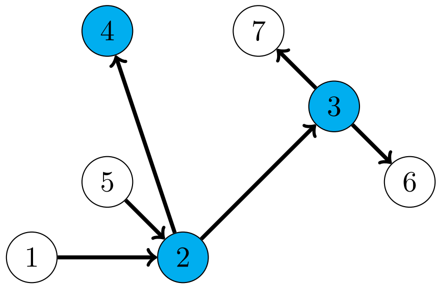
$$A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$$

   with $a, b, c, d \in \mathbb{R}$

Part 4: HITS and PageRank

1. What does HITS stand for?
2. Name the three types of queries that were discussed in the lecture? Which of these is used in HITS?
3. What are *authorities* and *hubs*? How do they relate to emergence?
4. a) What three properties must the base graph S possess, so that HITS works best?

   b) Given is the following graph representing a set of web pages. The nodes in blue were selected by using a text-based search for the query σ and form the root-graph R_σ.

   Which of the above named properties does R_σ not possess? Construct a suitable base graph S_σ for HITS using the method from the lecture. Use $d = 1$. If you have to choose between two or more nodes, always take the one with the smallest index.

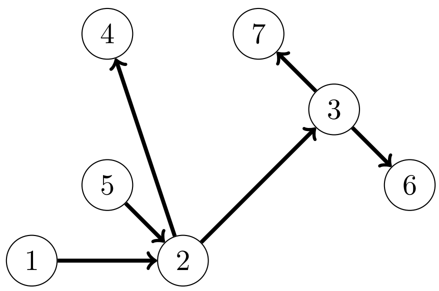
   c) What two additional heuristics can we apply to the base graph S_σ in order to improve the quality of the search result?

5. a) What do the vectors x and y in HITS describe?

   b) What formulas are used for calculating the next iteration of the x and y vectors? What is the idea behind these formulas?

   c) How can the adjacency matrix of the graph be used for the calculation of x and y? How can it be used to prove convergence of the HITS algorithm?

   d) Given is the following base graph S_σ:

   Calculate the values of the x and y arrays after the first two iterations of HITS.

Part 5: Ant Colony Optimization

1. a) Explain briefly each component of the three-tuple representation (S, Ω, f) of a combinatorical opimization problem P.

   b) Jonas and his friends are playing *The Legends of Andor*. The players have to protect a kingdom and defeat evil monsters. Especially the last part is challenging as it has a complex game mechanic:

   In this problem we consider one monster with health h. Every of the n players can participate in this fight, the i-th player dealing this monster d_i damage. Furthermore, Timo (the first player) has a special card which he can use to increase the damage of every player by one (including his own), but he can only use this card when he is participating in the fight himself. When the players can bring up more damage than the monster's health, the monster will be defeated. As every man- and girlpower is needed in other battles, Jonas wants to minimize the number of persons needed to defeat this enemy.

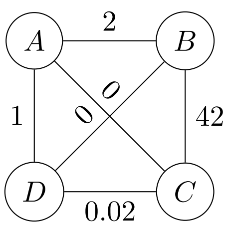
   Help Jonas by setting up a combinatorical optimization problem in the three-tuple representation (which can be used as a basis for an ant colony optimization solver).

2. a) Give the most widely used rule for determining the probability of a solution component $p(c_i^j | s_p; t)$.

   b) What effects does have setting $\alpha = 0$ or $\beta = 0$ on the result of the solution component $p(c_i^j | s_p; t)$?

3. a) Define briefly the combinatorical optimization problem P for the *traveling salesperson problem* in the three-tuple representation.

   b) Consider the following graph with the corresponding pheromone values written over the edges. Assume that there will be used no heuristic information at all. On that graph an 1-ANT algorithm will be started to find the shortest roundtrip ($\rightsquigarrow$ *Traveling salesperson problem*).



   i. An ant starts at node A. What roundtrips does this ant make with which probability? You may assume that the ant cannot return to already visited nodes.

   Assume that none of these tours is optimal. Without further changes, what problem occurs when executing the algorithm procedure some additional times? What could be a possible solution for that (without changing the heuristic or pheromone functions)?

   ii. Which condition must hold for the pheromone values such that the tour produced by the ant is uniformly random of all tours?

   c) Give one example for choosing a heuristic information $\eta(c_i^j)$ and two examples (and their name) of emission functions $g_{ij}^{<k>}(t, t+1)$ at the traveling salesperson problem.

Part 6: Evolutionary Algorithms

1. a) What is an *evolutionary algorithm*?

   b) What does reproduction involve?

   c) What is the difference between *genotype* and *phenotype*?

   d) Draw the *evolutionary cycle*. What do the parameters μ, λ and F mean?

2. a) Name and explain one possible selection operator.

   b) What is *elitism*?

3. a) Execute an *one point crossover* using the parents and crossover-point:

1	3	2	4	6	10	9	5	8	7

1	2	3	4	5	6	7	8	9	10

   b) Execute a *partially matched crossover* using the parents and crossover-points:

1	3	2	4	6	10	9	5	8	7

1	2	3	4	5	6	7	8	9	10

   c) What is the goal of the *edge recombination crossover*? How does it work?

4. a) Draw the tour which is encoded by the following array:

1	2	3	4	5	6	7	8	9	10

   b) Use the *swap mutation operator* on the entries 4 and 10. How does the tour change?

   c) Use the *inversion mutation operator* on the entries 1 and 10. How does the tour change?

5. a) Name two possible objective functions for measuring the "sortedness" of an array.

   b) Which two mutation operators for the $(1, 1)$-EA sorting algorithm where presented in the lecture?