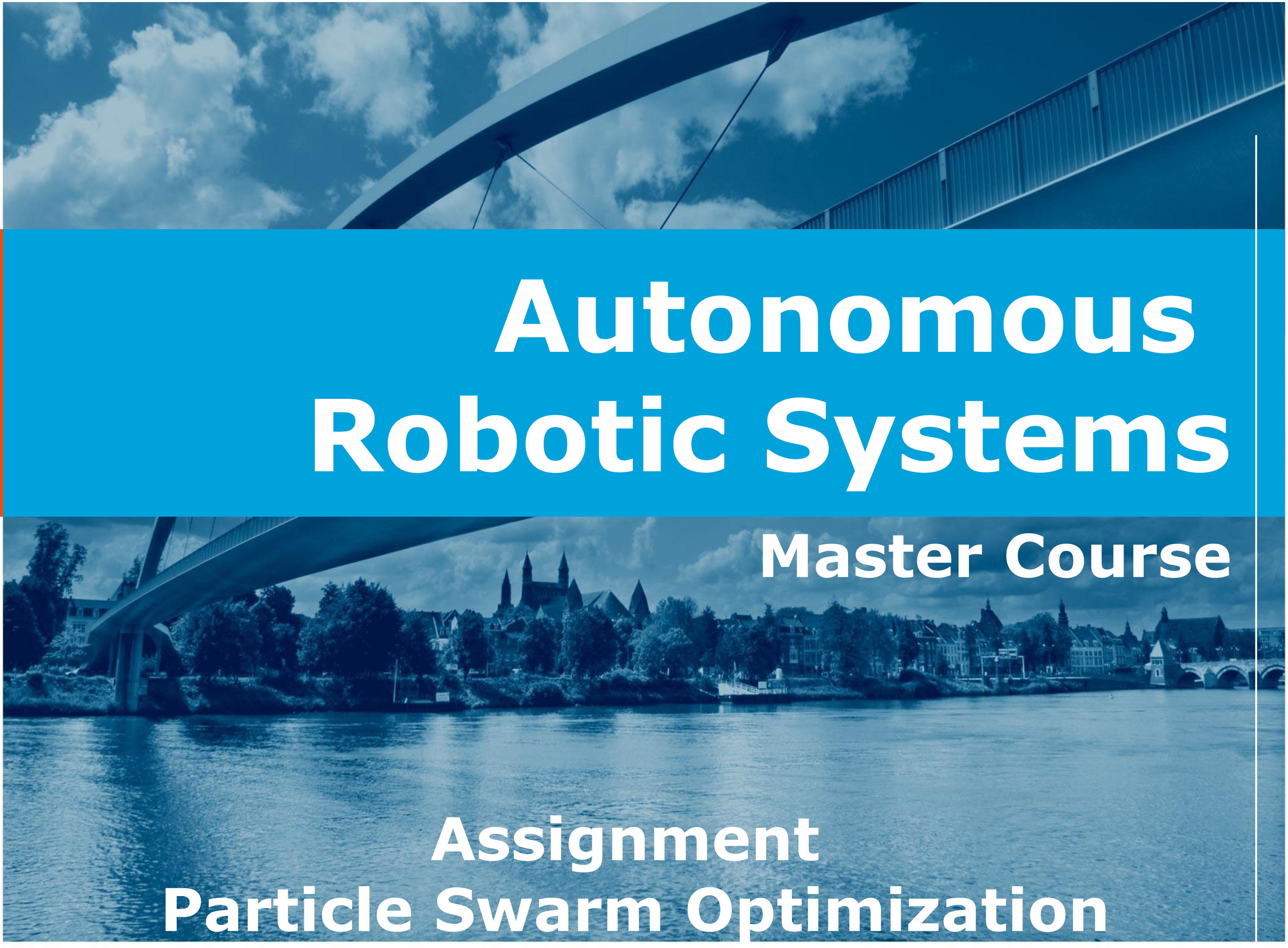


Autonomous Robotic Systems

Master Course

Assignment
Particle Swarm Optimization

Strategy and advice for assignments

- Do first programming in class (so you can ask questions if you get stuck early)
- Prepare for assignments at home (read lecture slides again, read material)
- Finish programming at home
- **Write simple code**
- To get graded:

  Upload code and video demonstration to CANVAS

Task

- Evaluate properties of PSO and compare PSO against gradient descent
- Use simulations to convince a customer/project leader/colleague of the pros and cons of PSO
- Find out if it makes sense to combine PSO and gradient descent

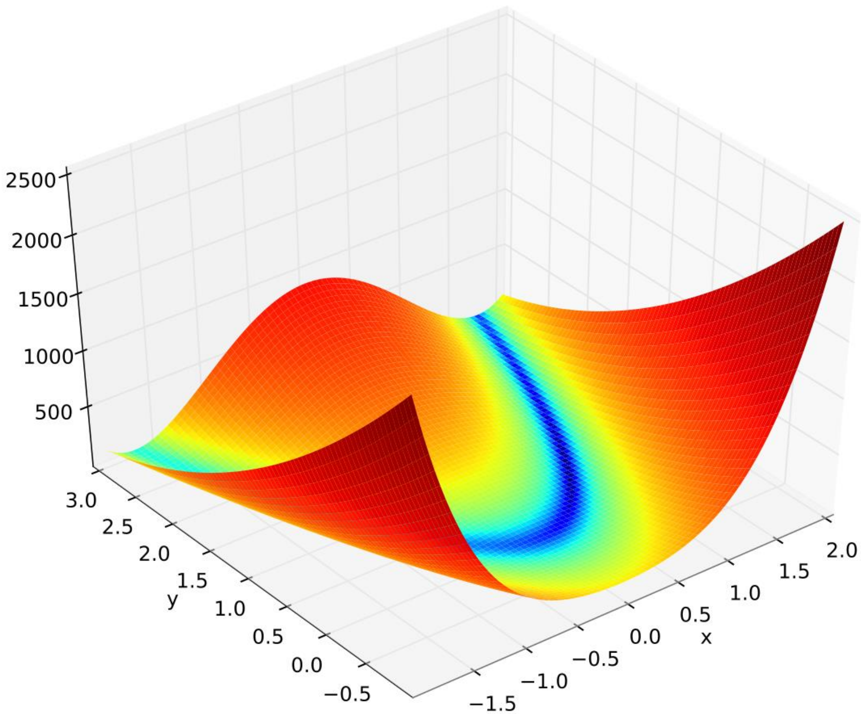
How would you do such experiments?

(You only have to implement PSO!)

Motivation to use benchmark functions

- Need test function also for future algorithms
- Final tasks of robot navigation is too time consuming to debug the algorithm
- Benchmark functions help us to understand if our algorithm works

Benchmark function: Rosenbrock

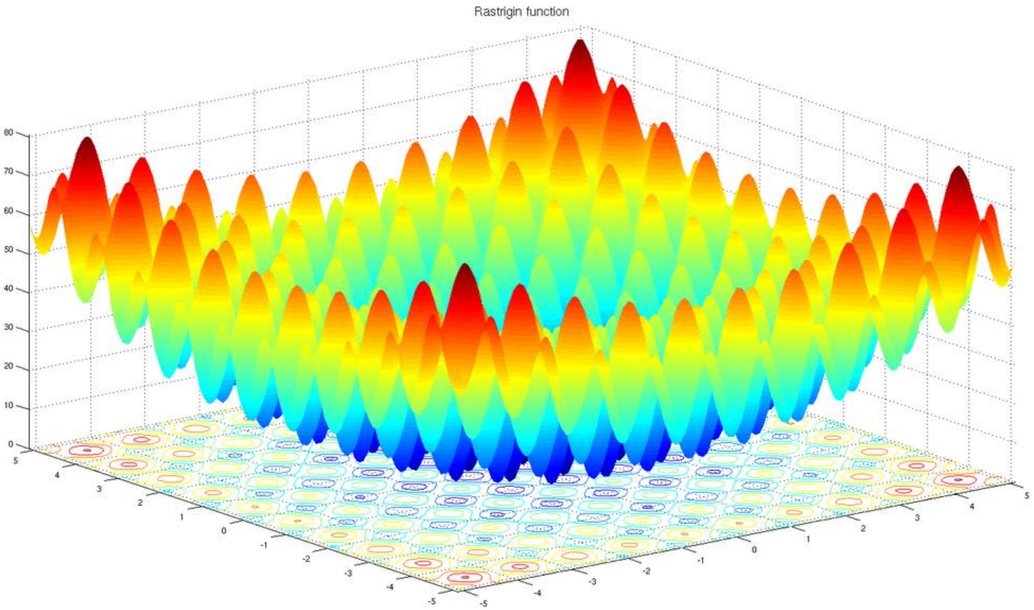


Rosenbrock function with two variables

$$f(x, y) = (a - x)^2 + b(y - x^2)^2$$

- Deep valley with known minimum minimum at (a,a^2)
- We use a=0, b=100
- Easy to find valley
- Difficult to find global minimum
- Also defined for multiple dimensions (see Wikipedia)

Benchmark function: Rastrigin



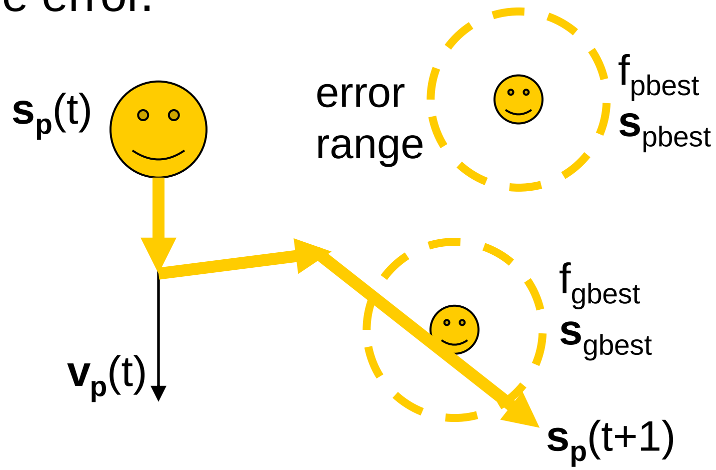
Rastrigin function with two variables

$$f_2(\boldsymbol{x}) = 10n + \sum_{i=1}^{n}\left(x_i^2 - 10cos(2\pi x_i)\right)$$

- Many local minima
- Known global minimum at **x=0**

Particle’s actions

A particle computes the next position by taking into account a fraction of its current velocity **v**, the direction to its previous best location pbest, and the direction to the location of the best neighbor gbest. The movement towards other particles has some error.



$$\boldsymbol{v}_p(t+1) = \boldsymbol{a} \cdot \boldsymbol{v}_p(t) + b \cdot R \cdot \left(\boldsymbol{s}_{pbest} - \boldsymbol{s}_p(t)\right) + c \cdot R \cdot \left(\boldsymbol{s}_{gbest} - \boldsymbol{s}_p(t)\right)$$

$\boldsymbol{s}_p(t) = \boldsymbol{s}_p(t-1) + \boldsymbol{v}_p(t) \cdot \Delta t$ (Euler Integration, here $\Delta t = 1$)

where a, b, c are learning constants often between 0 and 1 (but see next slide)
R is a random number between 0 and 1

Parameter tuning → read papers

Parameters have been found empirically. E.g. Russell C. Eberhart suggested for best tradeoff between global and local exploration.

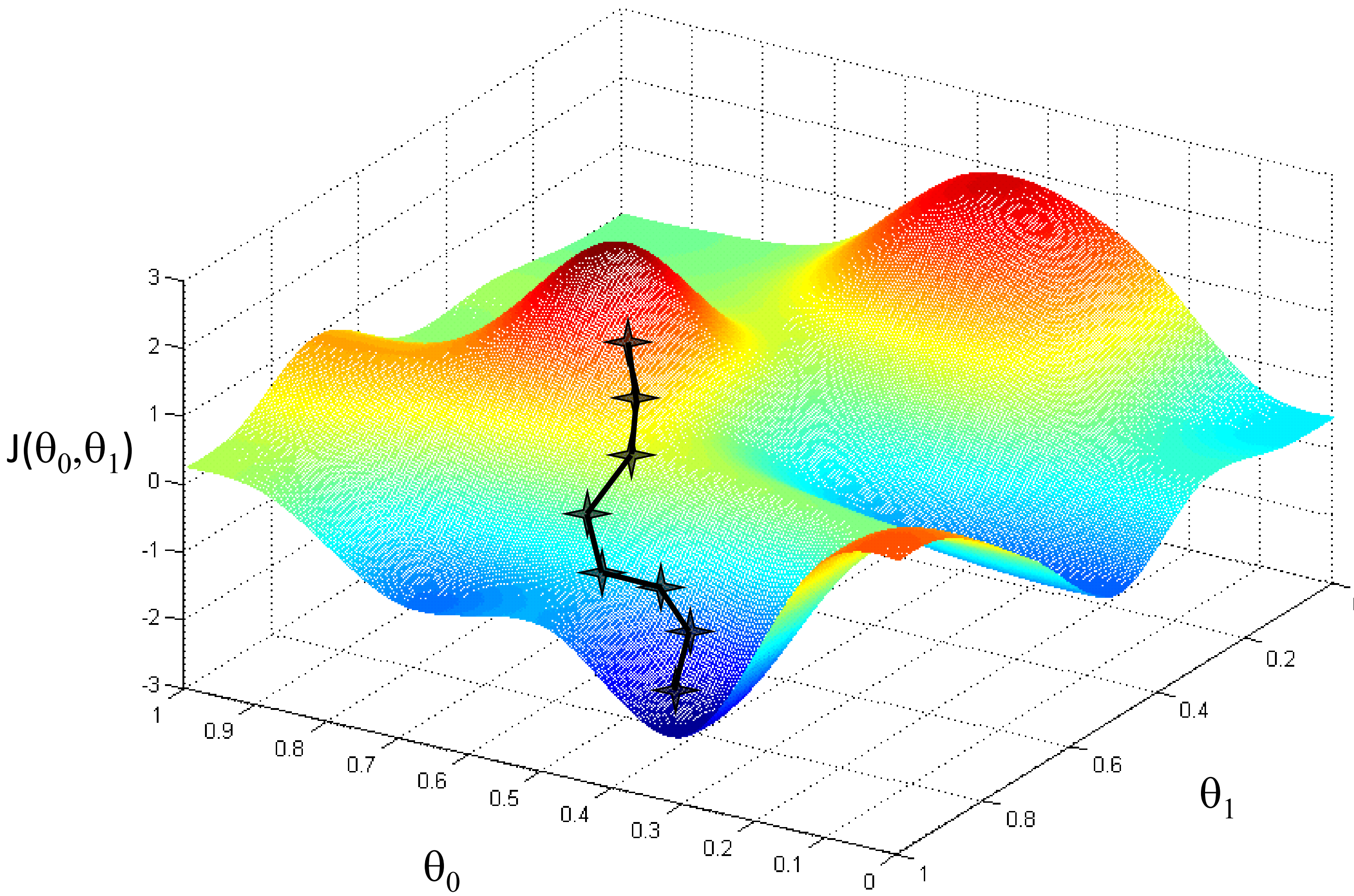
- Good approach is to reduce inertia weight *a* during run (i.e., from 0.9 to 0.4 over 1000 generations)
- Then usually set *b* and *c* to 2

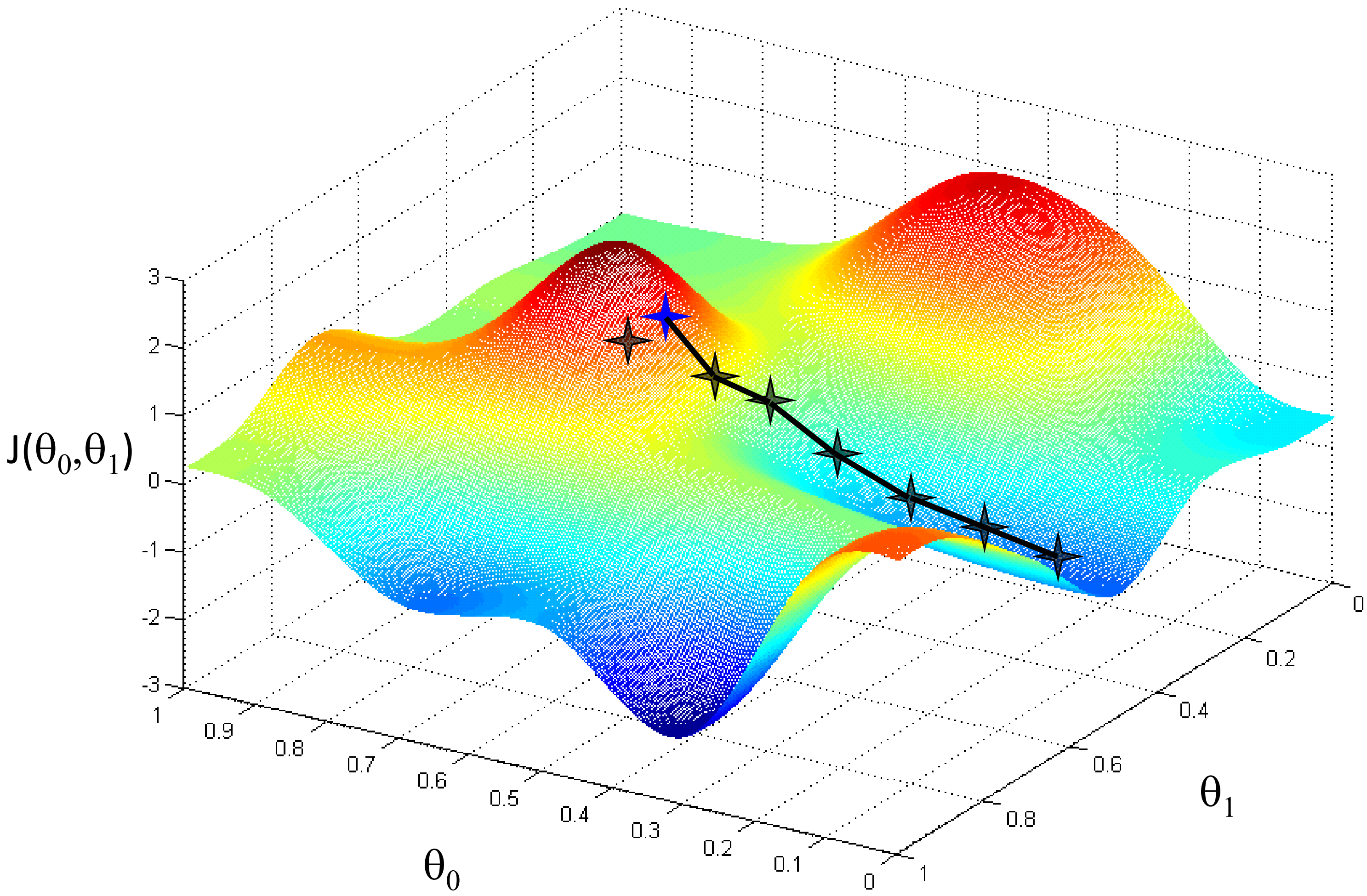
Gradient Descent

- Very well-known algorithm for finding (local) minima and maxima.
- Used for many optimization problems – not just regression.
- There are other and way more sophisticated methods

Iterative algorithm for finding min/max of function

1. Start with some θ_0, θ_1
2. Keep changing θ_0, θ_1 to reduce $J(\theta_0, \theta_1)$ until you reach a minimum (hopefully)


3
2
1
0
-1
-2
-3
J(θ_0,θ_1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
θ_0
0
0.2
0.4
0.6
0.8
1
θ_1



3
2
1
0
-1
-2
-3
J(θ0,θ1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
θ0
0
0.2
0.4
0.6
0.8
1
θ1

Group discussions & assignment: Get some deep understanding

- What do you think will happen if you run PSO on the benchmark functions?
- Which algorithm will have better performance (PSO or gradient descent)? – why?
- Under which circumstances does is make sense to combine PSO and gradient descent? How would it be best to combine these?

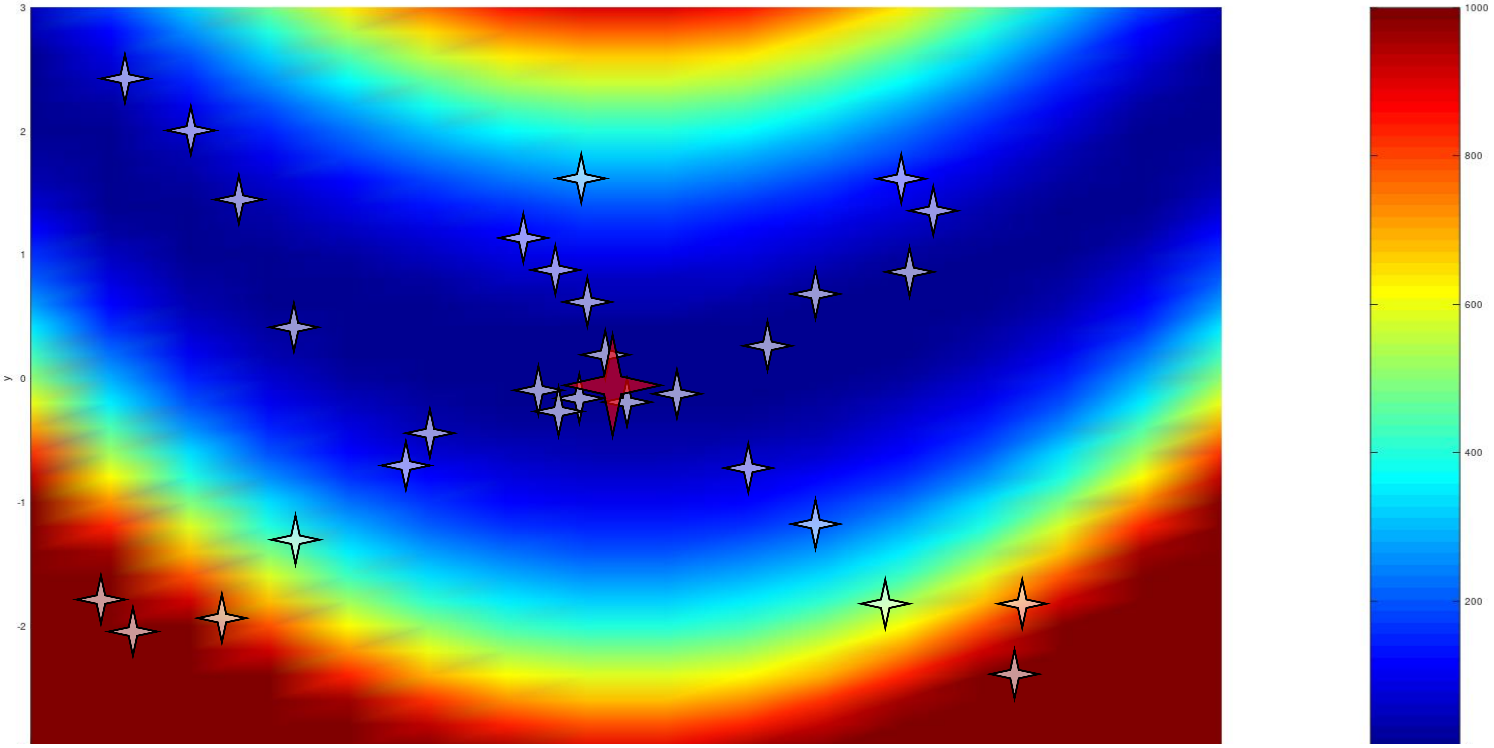
Summary: Your task

- Implement Rosenbrock and Rastrigin functions with two parameters
- Test PSO on both
- Reason about how Gradient Descent would perform on these functions (Gradient Descent does not have to be implemented – but you can if you want)
- Upload documented code
- Demonstrate simulations **(video demonstration)**
  - Show how particles move on benchmark function
  - Show plot of benchmark function at the same time
  - **Provide real simulation recordings (as in video game), not just pictures, no slides!**
  - Analyse your data by varying parameters. Provide plots!

Hand in

- Documented code (Python, C++, C, Java, Matlab)
  - Make sure that each group member codes something, add names to code (who did what?)
  - **Upload zip archive** containing all code (no other types of archives)
- Recommendation: use language for simple prototyping and plotting (e.g. Python-Anaconda, Matlab/Octave)
- Video demonstration: (mp4 only!, 5-6 minutes max, 150MB max)
  - Explain with your own voice - all team members must present something
  - Perform meaningful experiments, document experimental setup (parameters), explain results

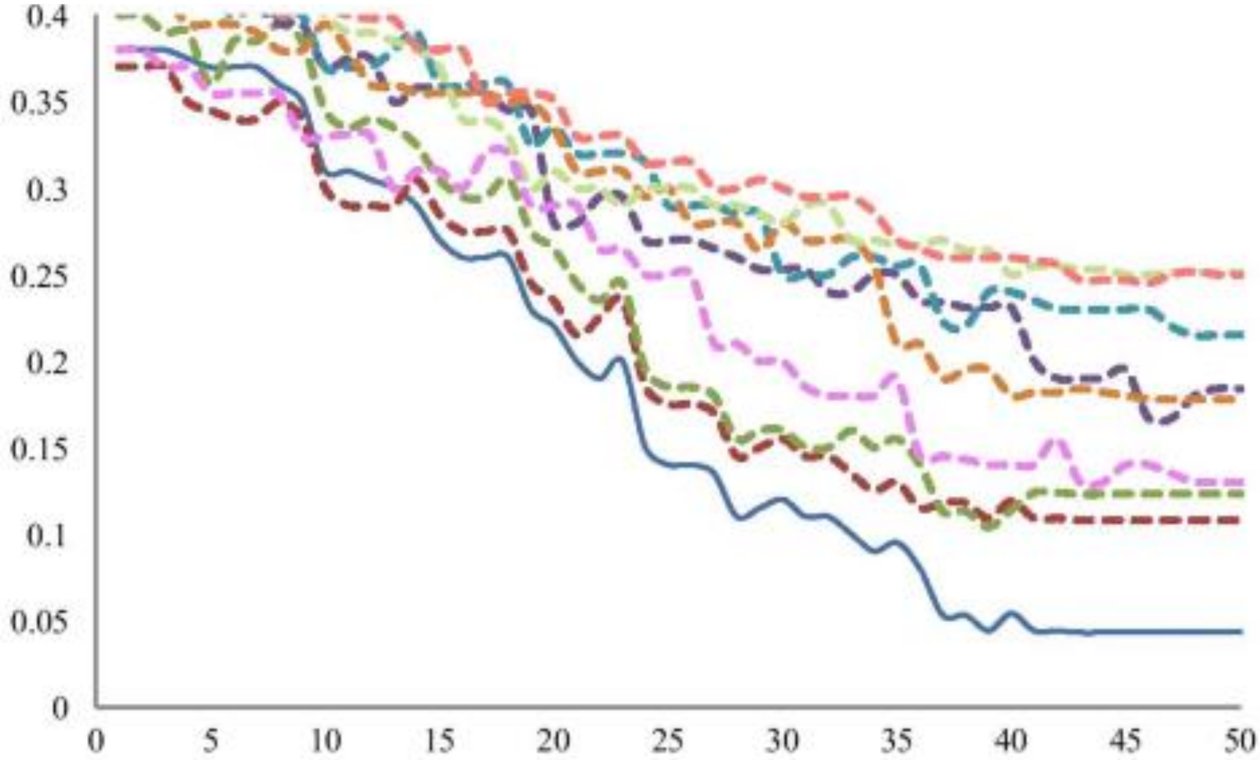
Expected demo (but for actual PSO and both benchmark function)



Show how particles move together at every iteration

Expected plots

???



???

Come up with some actually meaningful experiments!

Plagiarism

- Do not copy and hand in code from colleagues
- You can talk to colleagues and help each other, but you cannot exchange code between groups.
- Write your own software

- **You must implement PSO yourself (no use of libraries here!)**

Homework until Tuesday

- Hand in **before** lecture start

Find favourite colleagues

- Group assignments (2-3 people per group)
  - Add your names here, so we can form groups on CANVAS
  - You can change your group again for coming assignment

- Always make sure that you understand all aspects of an assignment
- Several exam questions will be based on assignments!

https://docs.google.com/spreadsheets/d/1Zwho72baI0YQf8oAYn5Hs-PRx6U53OQz57NhqbSrLcc/edit?usp=sharing