Path Planning with the humanoid robot iCub

Semester Project 2008

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Overview of the presentation

- **What is Path Planning?**
- Ant Colony Optimization
- Performance Tests – Parameters selection
- iCub robot – Steering
- Integration of the ACO algorithm in the iCub simulation
- Results
- Future Improvements

What is Path Planning?

- Examine of the existence of a collision-free path in an environment with obstacles
- Computation of such a path
- Efficiency : to find the shortest path to the destination in short time.
- Reliability : the robot must not collide with obstacles.

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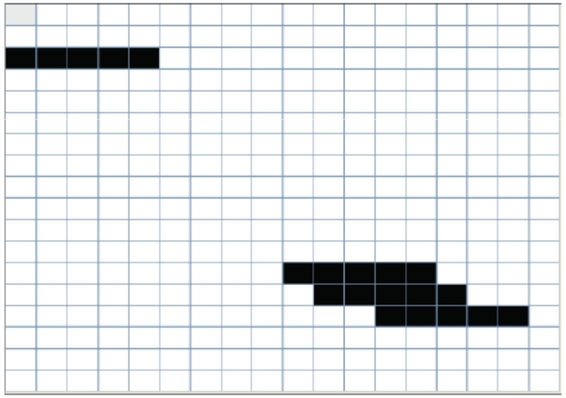
Ant Colony Optimization (1)

- **Biological inspiration:** many ant species deposit on the ground a substance, called **pheromone**, on their way to the food. Other ants follow the path with the highest concentration in pheromone…
- They will find a solution in any case, if it exists. **Theoretical proof of the convergence to the optimal solution** (Gutjahr 2000).

Ant Colony Optimization (2)

- **Heuristic function:** ACO algorithm is able to take advantage of the specific characteristics of a problem by using a well defined **heuristic** function.
- **In our implementation:** the world considered as a grid of squares.
- A set of artificial ants search for a short path from the start to the end.



Ant Colony Optimization (3)

- Each agent has a current position in the grid, can move by one square, 7 possible new positions.
- At each step, random decision according to a probability distribution.

$$P(S_i) = \begin{cases} \frac{\tau_i^\alpha \eta_i^\beta}{\Sigma_i \tau_i^\alpha \eta_i^\beta} & if q \geq q_0 \\ 1 & if q < q_0 \quad and \quad i = argmax(\tau_i^\alpha \eta_i^\beta) \\ 0 & if q < q_0 \quad and \quad i \neq argmax(\tau_i^\alpha \eta_i^\beta) \end{cases}$$

- After all ants have found a solution, the shortest path is selected and is updated with pheromone.
- Continue until no more improvement is happening or until a fixed number of iterations (generations).

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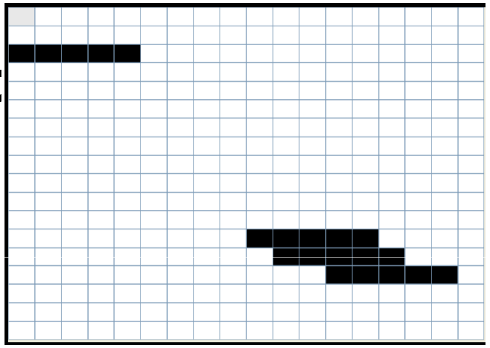
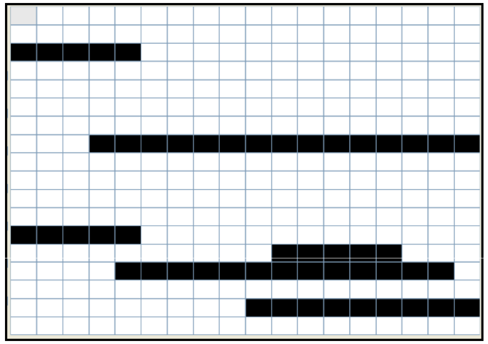
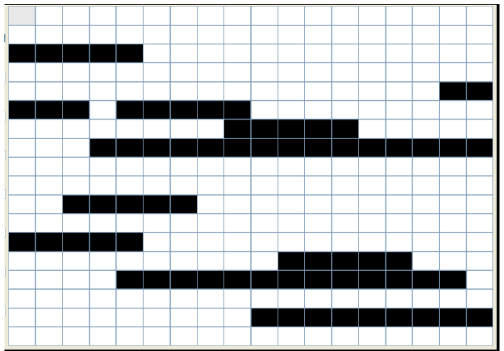
Performance Tests – Parameters selection (1)

- **Heuristic function used:** $$h_i = \sqrt{(x_{end} - x_{curr})^2 + (y_{end} - y_{curr})^2}$$

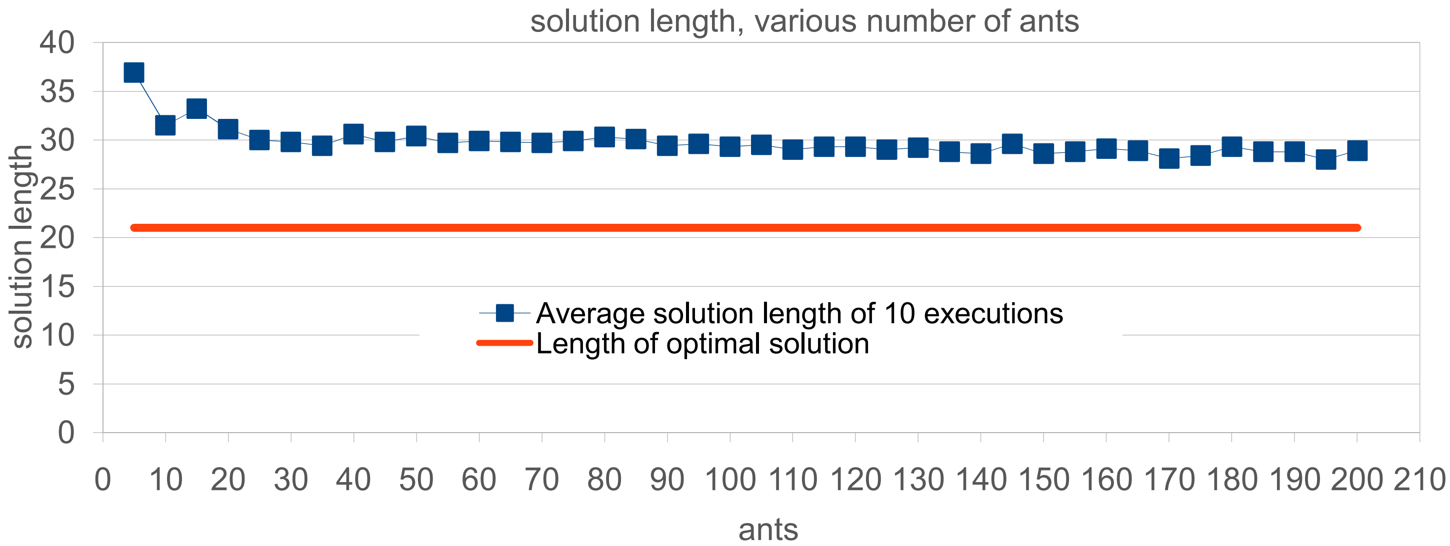




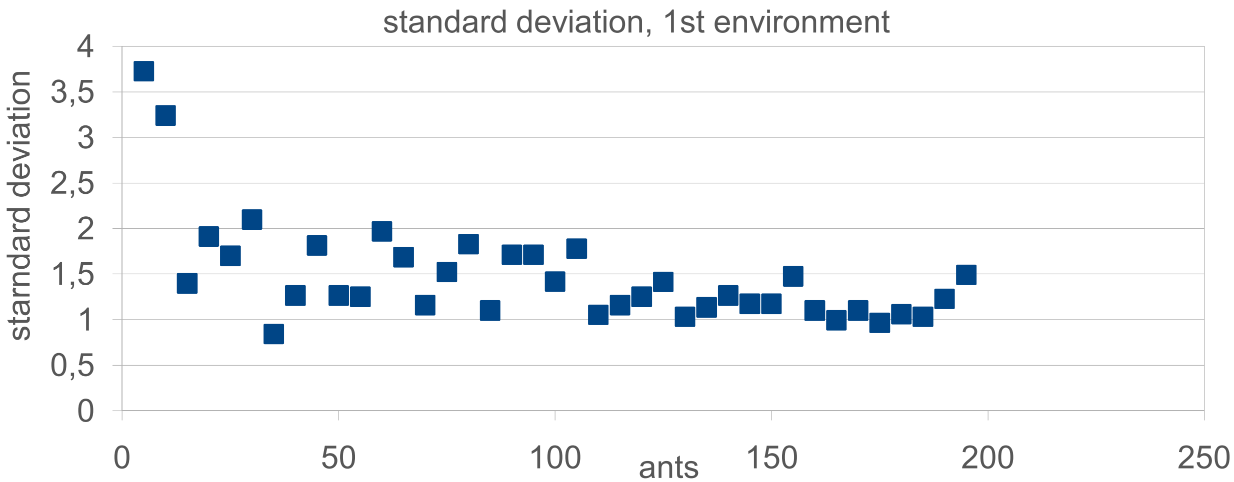
- **Parameters to select**
- Number of ants
- Number of generations
- α , the pheromone factor
- β , the heuristic factor
- 3 different environments (18x18)



Performance Tests – Parameters selection (2)

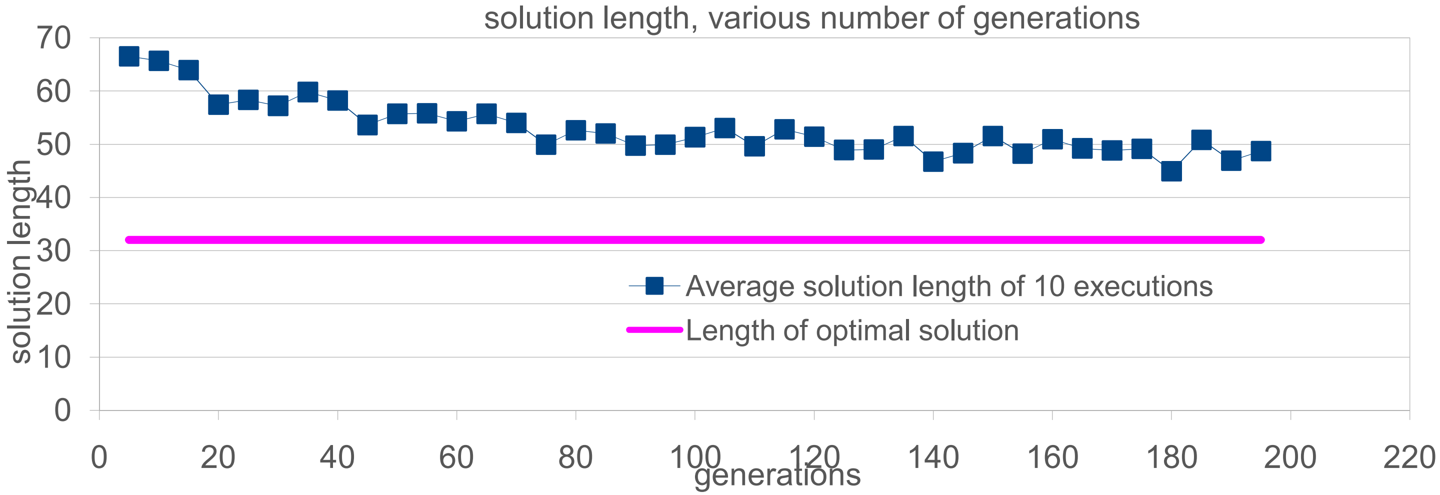


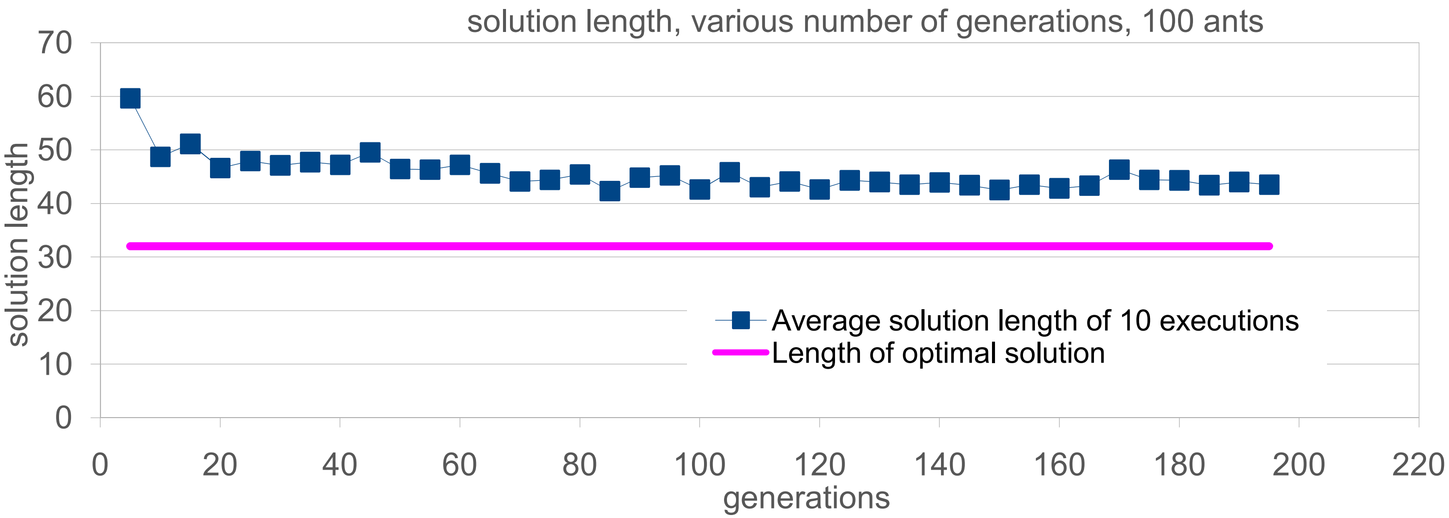
- 1st environment. **Increasing number of ants.**
- 10 executions for each set of parameters. Average solution length



- The **variance** of the found solutions decreases as the number of ants increases.
- Stabilization after 100 ants.

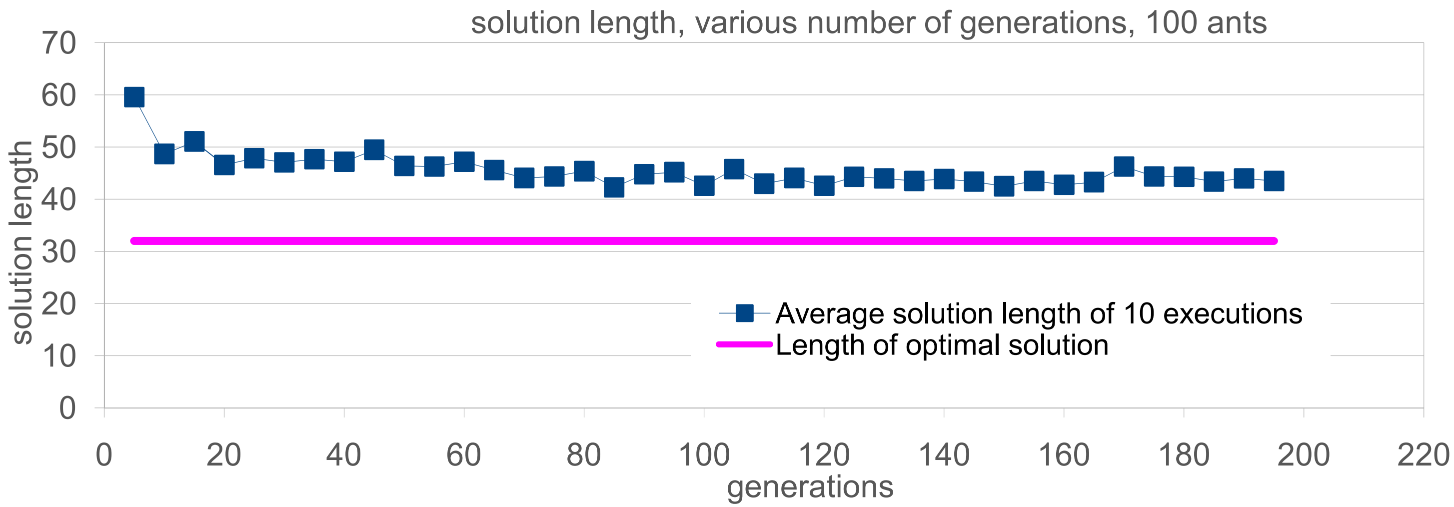
Performance Tests – Parameters selection (3)

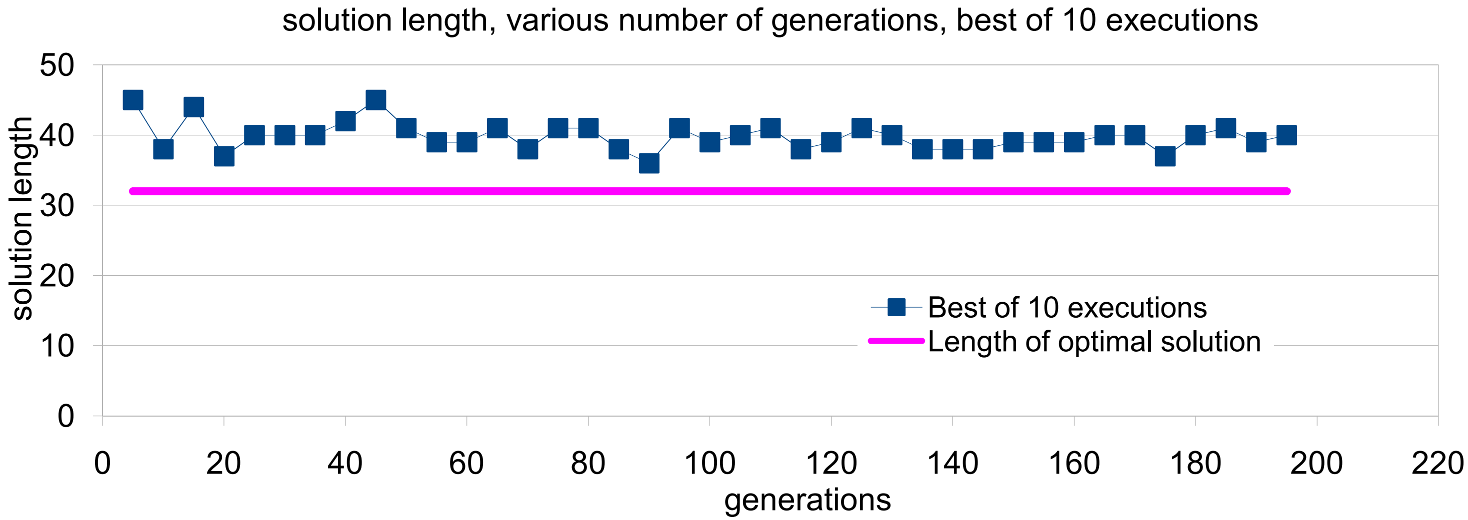




- **2nd environment. 20 and 100 ants. Increasing number of generations.**
- **For 100 ants, stabilization after about 100 generations.**

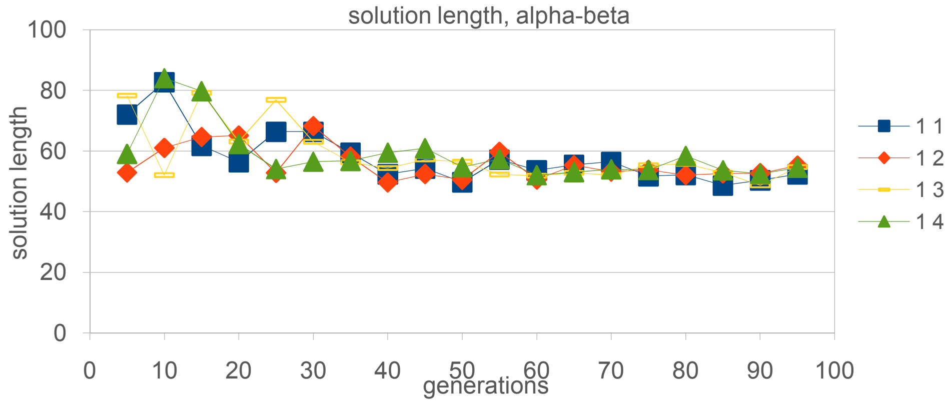
Performance Tests – Parameters selection (4)

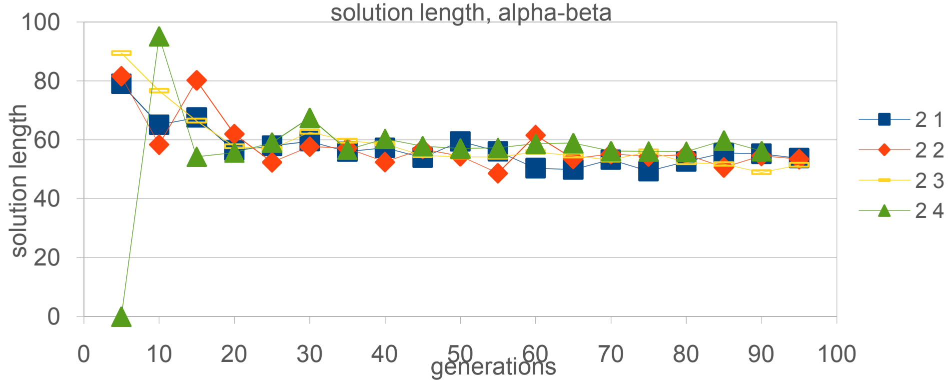


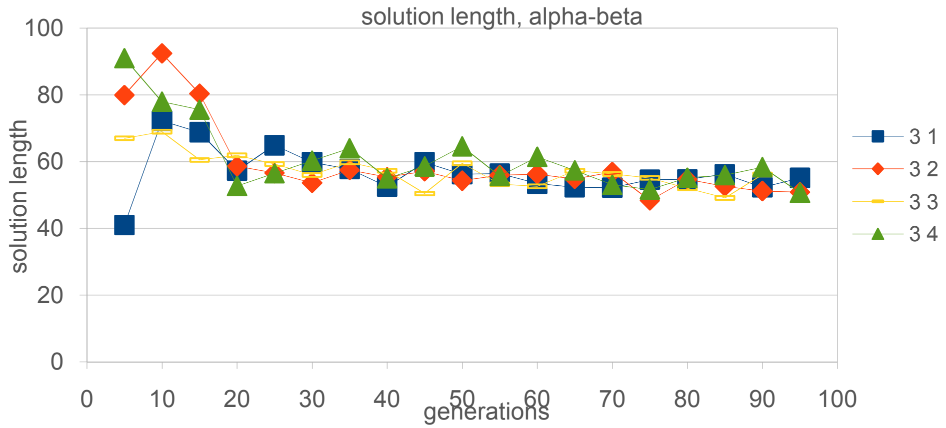


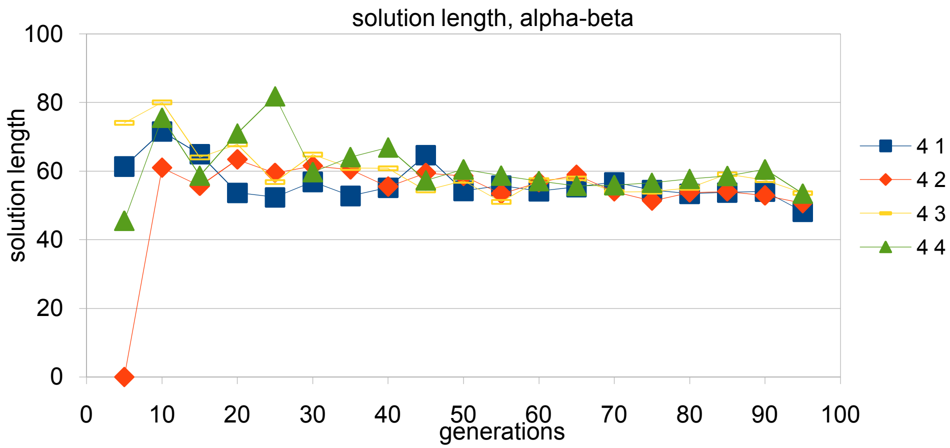
- 2^{nd} environment .100 ants. **Increasing number of generations**.
- **Comparison of average solution and best of 10 executions.**

Performance Tests – Parameters selection (5)









- **3rd environment. Different combinations of α and β. All combinations converge at about same quality solutions but in different number of generations. The pair α=2, β=1 was chosen.**

Performance Tests – Parameters selection (6)

- For large values of α (bigger than 1), the algorithm is expected to stagnate to the first good solution found.
- If a very good heuristic is available we should use bigger values for β in order to take advantage of it.
- Environments with random distribution of obstacles : difficult to find a very good heuristic for every kind of problem.
- Parameters selected for the integration of the ACO algorithm to the iCub:
- Number of ants = 100. $\alpha = 2$, $\beta=1$.
- Number of generations : time limit or fixed number.

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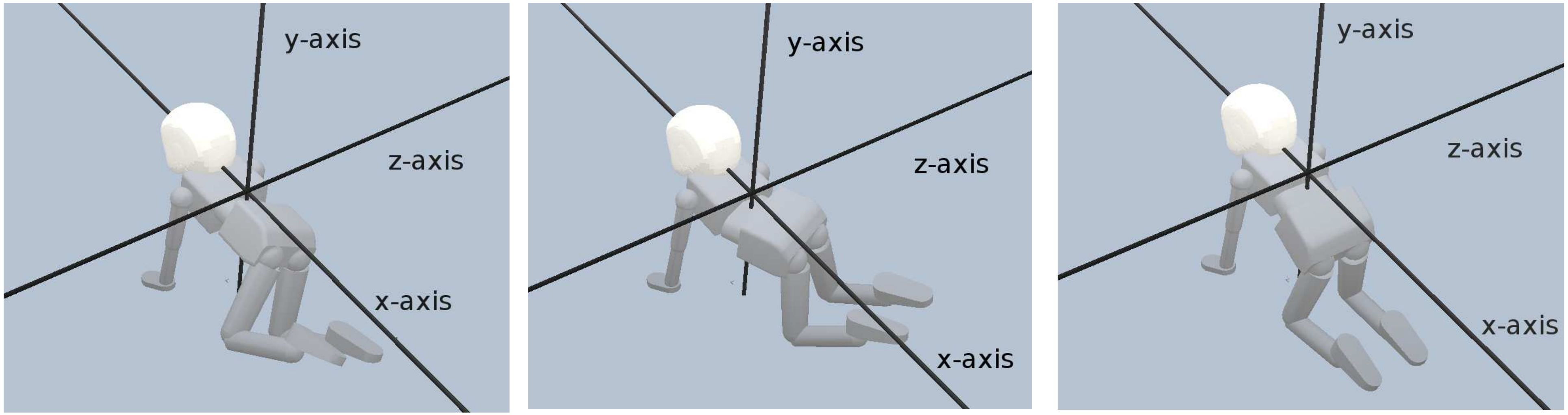
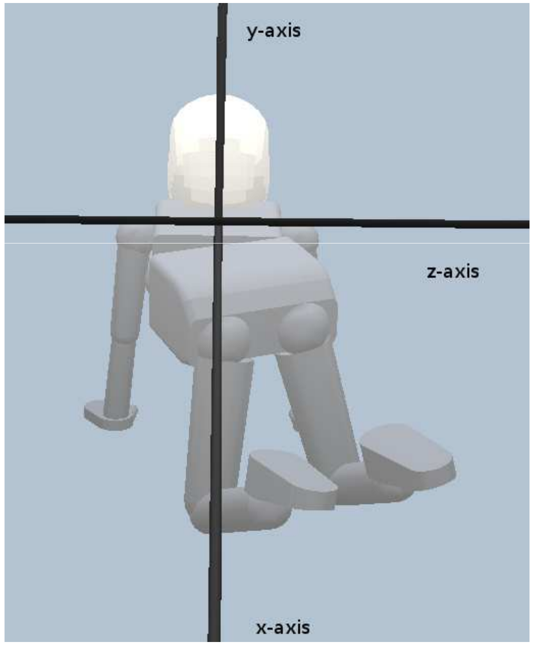
iCub robot – Steering (1)

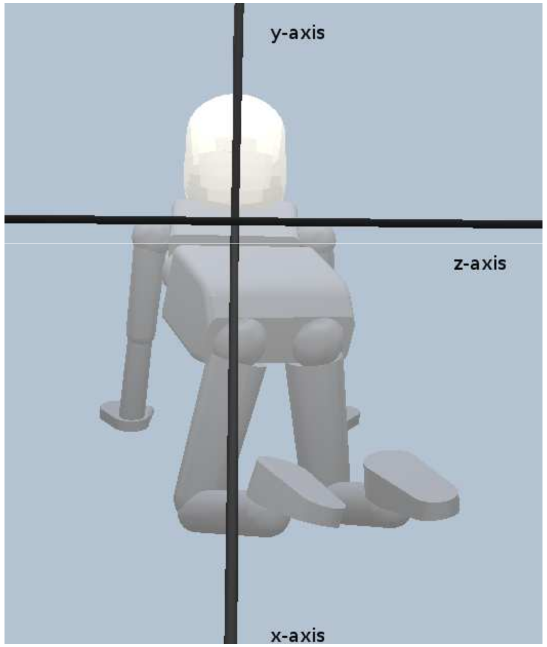
- iCub is an infant-like robot with the cognitive abilities of a 2 years-old child.
- Its crawling is controlled by a CPG developed by Righetti (2006).
- Add steering ability to iCub. Take advantage of the ability to turn its torso around 3 axises.



iCub robot – Steering (2)

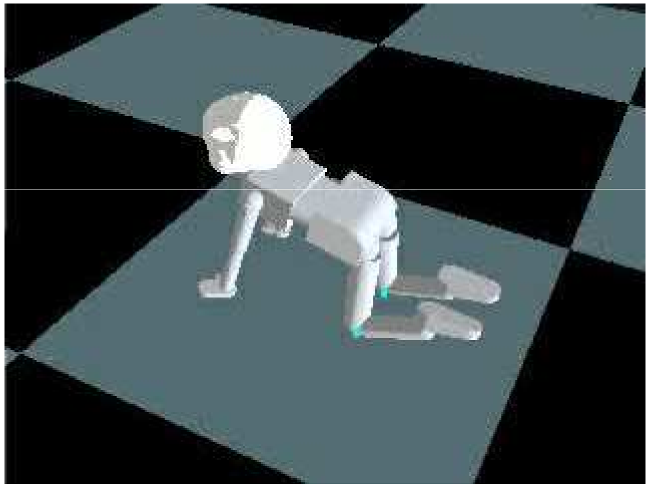
- Rotate around y-axis and x-axis.





- The outer limbs have to make a bigger step than the inner ones during steering.
- Very small changes at each step, such that the motion to be as smooth as possible.

iCub robot – Steering (2)



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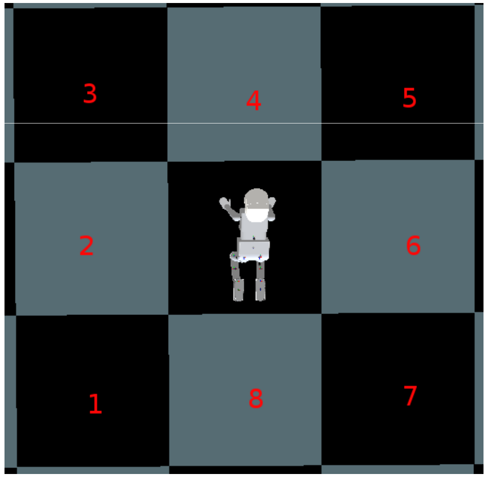
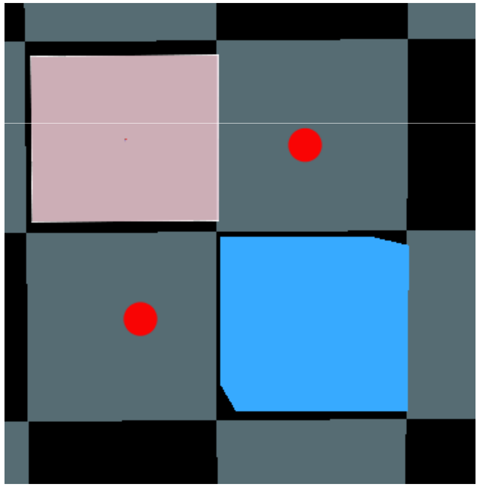
Integration of the ACO algorithm in the iCub simulation (1)

- Board of 8x8 squares surrounded by a wall and with 5 square obstacles inside





- 4 modifications.

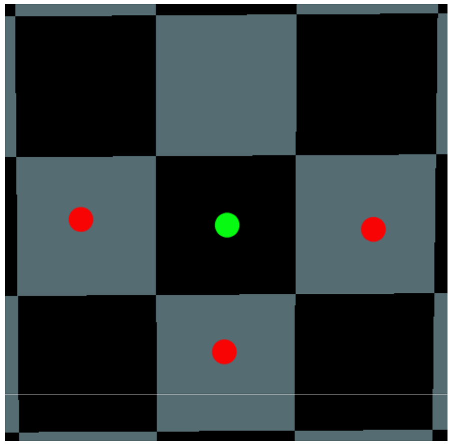
1. The robot is not able to steer in a very big angle.
2. a diagonal movement must not be valid if there are two obstacles adjacent to the robot's movement.

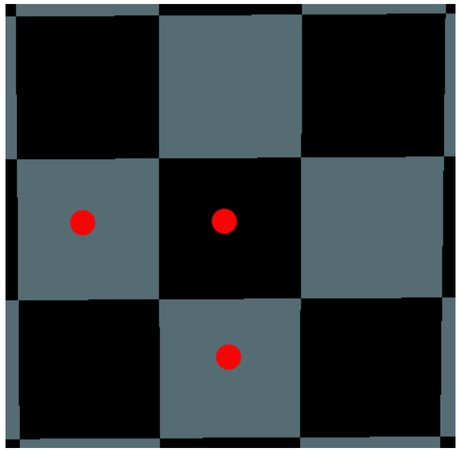
Integration of the ACO algorithm in the iCub simulation (2)

- 4 modifications.

3. The robot prefers to move straight instead of steering.
4. The robot prefers to move diagonally instead of making a 90° turn.

- The obstacles can change their position dynamically.





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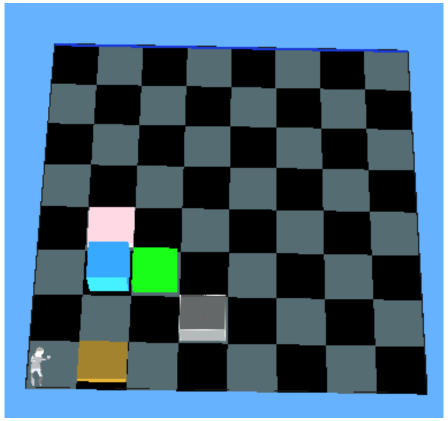
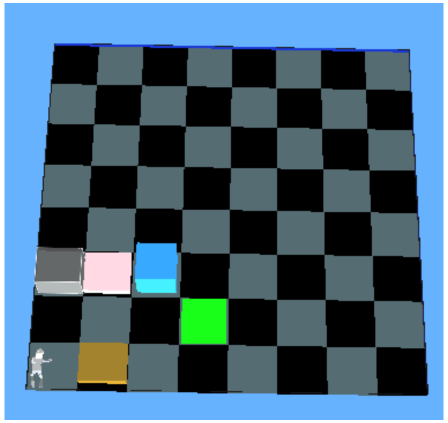
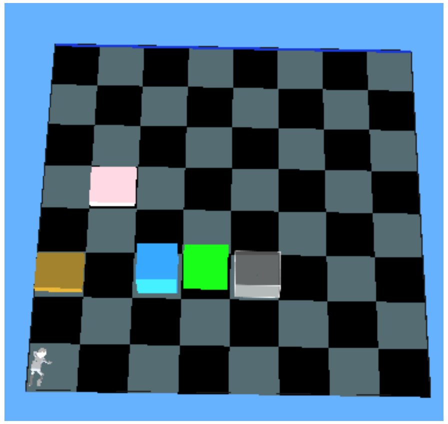
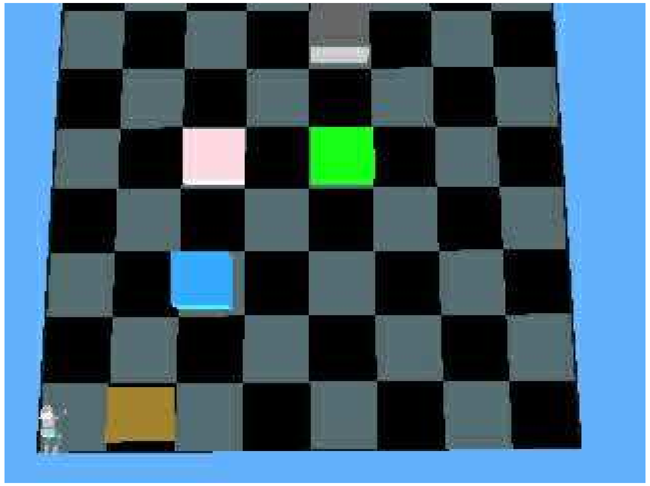
Results

- Grids, in which the iCub successfully reached the goal position.



- Example of dynamically changed environment. The robot recomputes its plan to the goal position, when it detects a change in the positions of the obstacles.

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Future Improvements

- Recomputation of the robot's path to the goal position during the simulation, for instance after every 5 steps.
- Multiple executions of the algorithm and selection of the shortest path.
- Ability to detect if iCub is following a wrong route.
- Integration of the ACO algorithm in the real iCub robot and test of its performance in real environment conditions.

Questions