BIOROB
EPFL Biorobotics Laboratory

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Feedback for stabilization during swimming in lamprey and salamander robots

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Final Presentation

Minor Project (8 credits)

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Reminder

- Postural stabilization method against rolling and pitch tilt

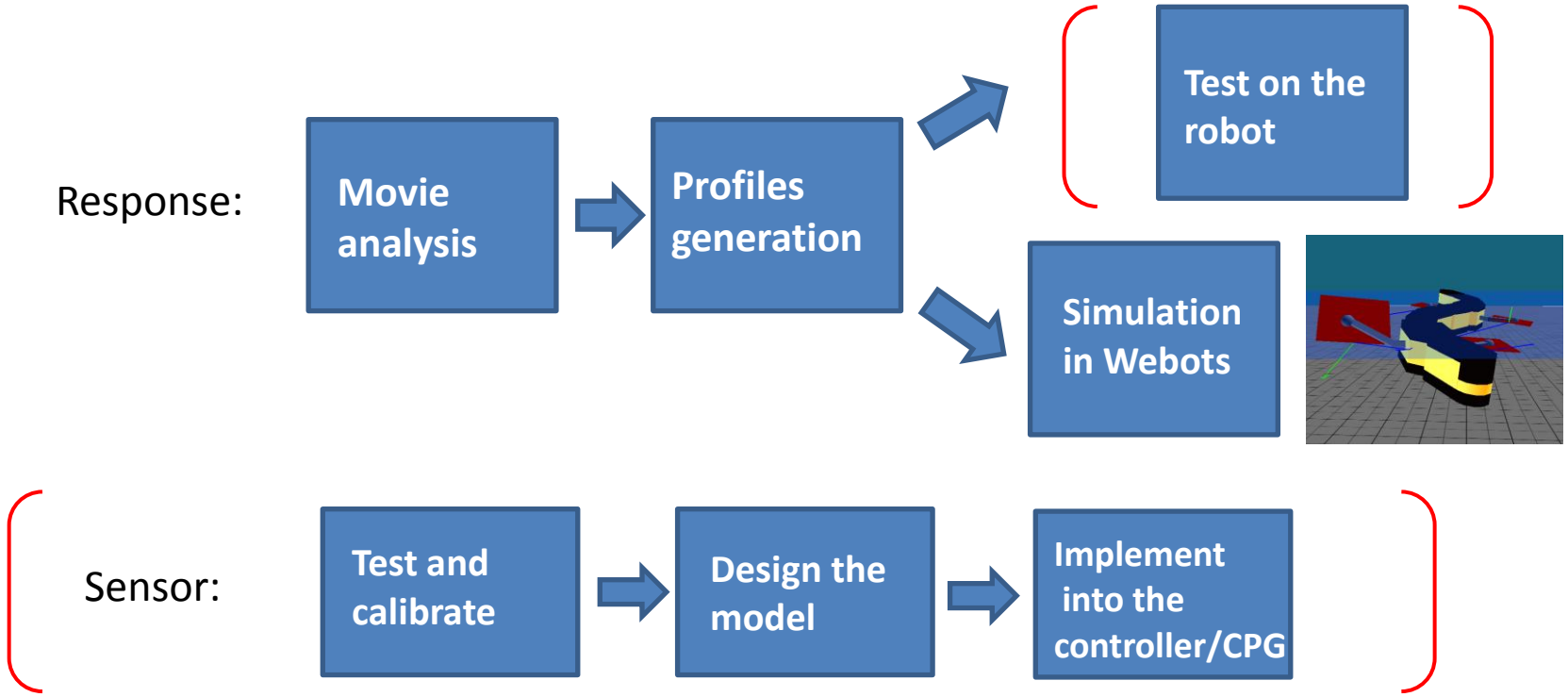
- Bio-inspired response based on the vestibular system

  from A.K. Kozlov et al., *Modelling postural control in the lamprey* (2001)

- Feedback sensor: 3-Axes Digital Accelerometer (MMA8453Q)

Goals

- Stabilization during swimming (2 parallel investigations)

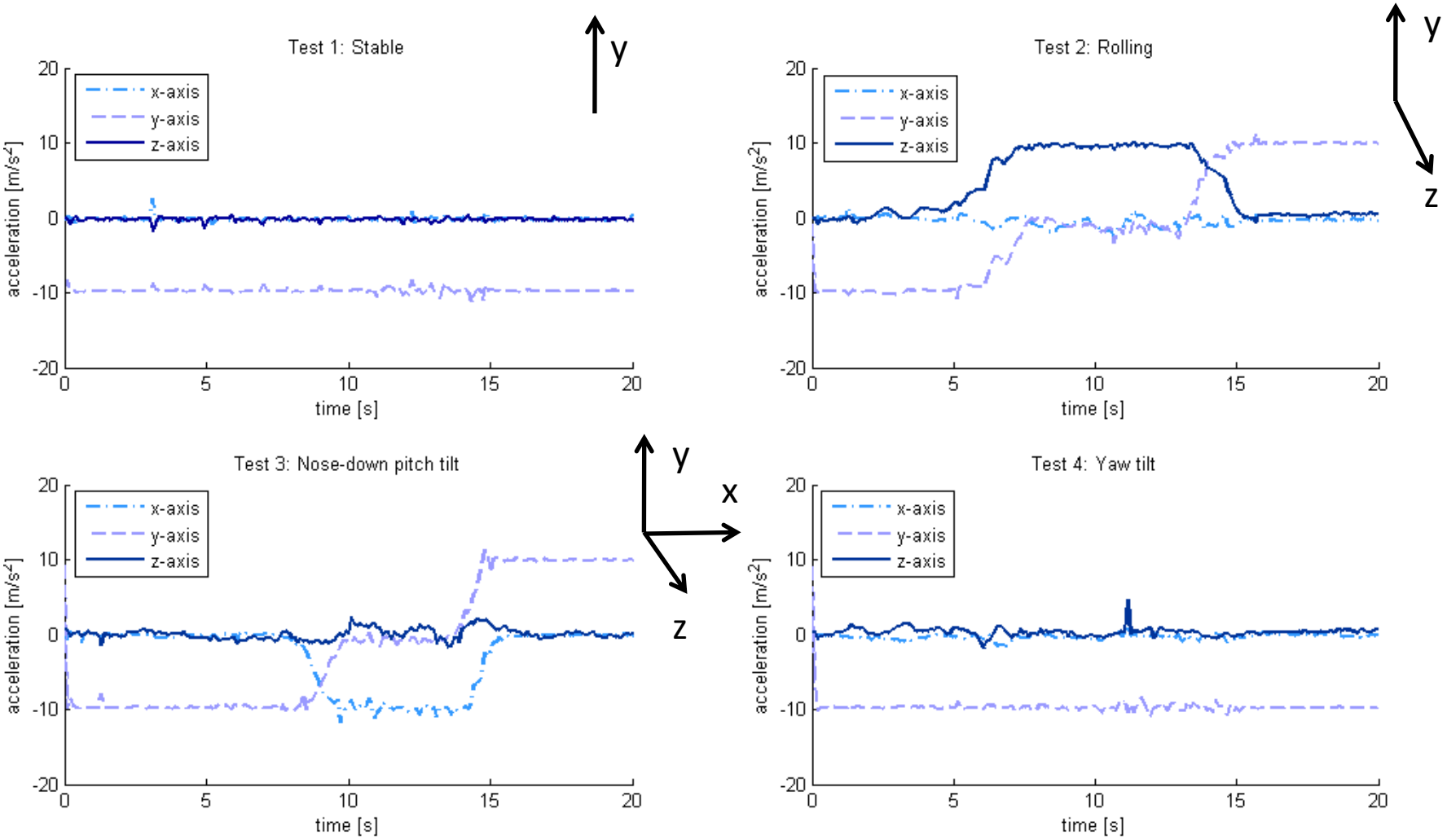


Framework orientation

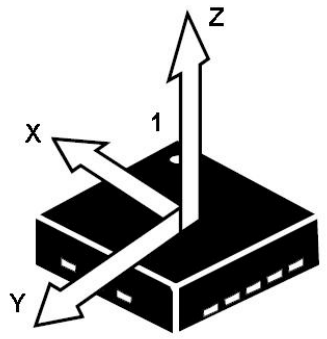
- Investigate postural control methods using the limbs directly on the salamander robot
    - Test different limb shapes and effects

- Perturbation case-sensitive method
    - Test different swimming gaits
    - Prepare control experiments
    - Tests postural control with perturbations

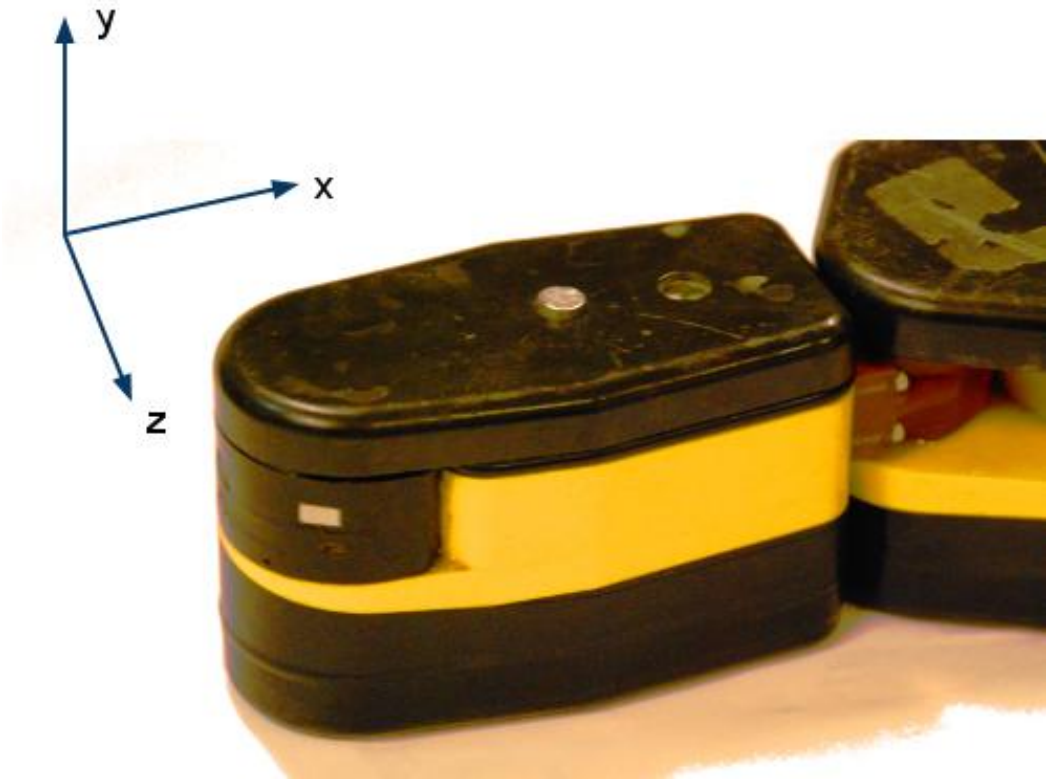
Sensor calibration



Referential



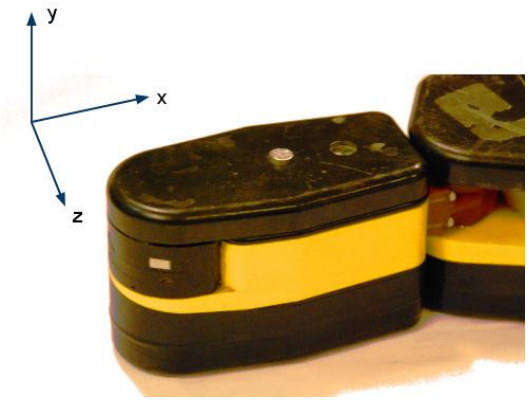
(TOP VIEW)
DIRECTION OF THE
DETECTABLE ACCELERATIONS



Perturbation cases

Stability is defined by gravity sensing on the three axes.

Perturbation	X-axis	Y-axis	Z-axis
Rolling CW	Constant	Increasing	<0
Rolling CCW	Constant	Increasing	>0
Pitch tilt up	>0	Increasing	Constant
Pitch tilt down	<0	Increasing	Constant
Yaw tilt right and left	Constant	Constant	Constant



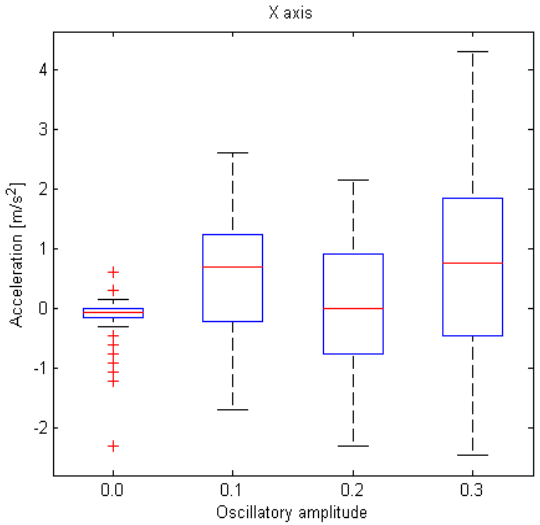
Variations on the three axes are necessary to identify the perturbation type

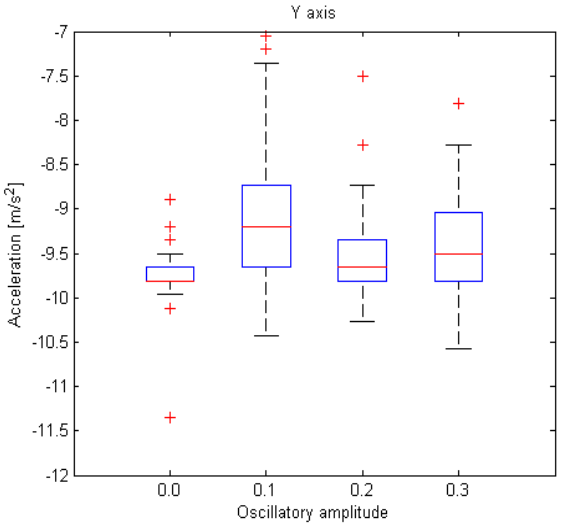
Stabilization model
Progressive implementation

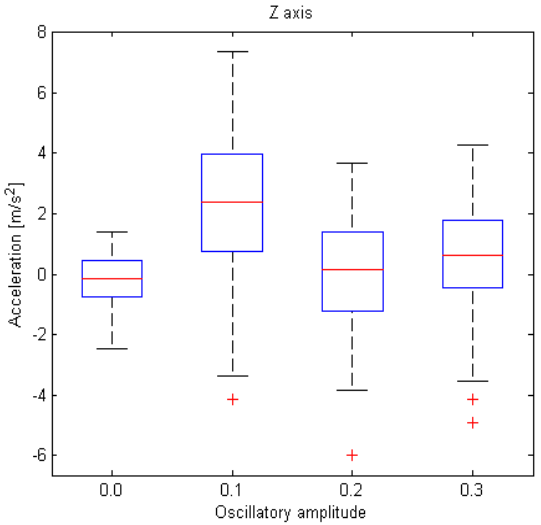
- 1st into the Controller
  - Perturbation case-sensitive model for rolling and pitch tilt
- 2nd into the CPG
  - Perturbation case-sensitive model for rolling and pitch tilt
  - Reduce oscillation amplitude while correcting
  - Use oscillation phase of limbs

Limbs selection

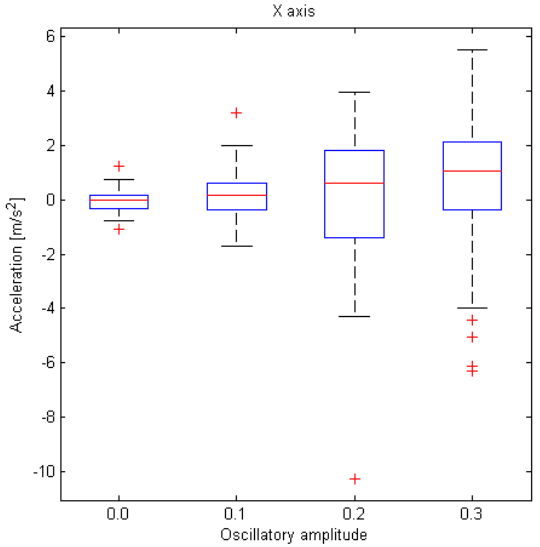
Small ailerons

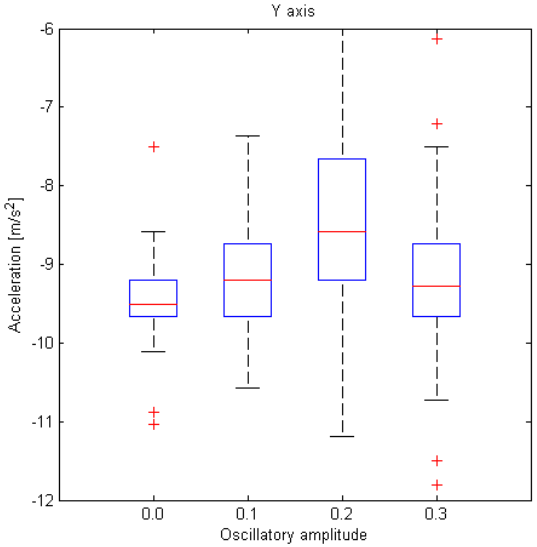


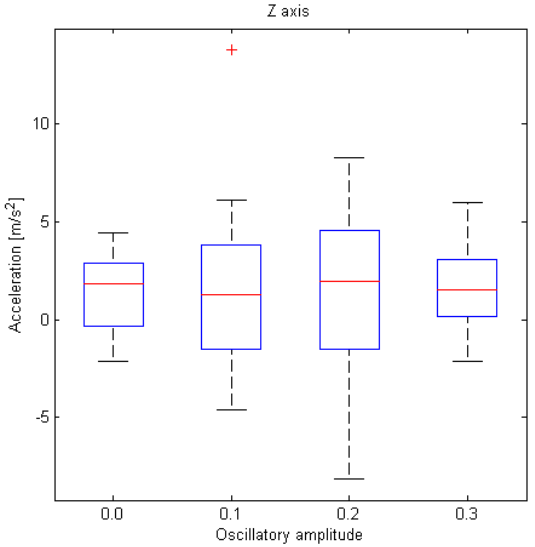




Control (without limbs)





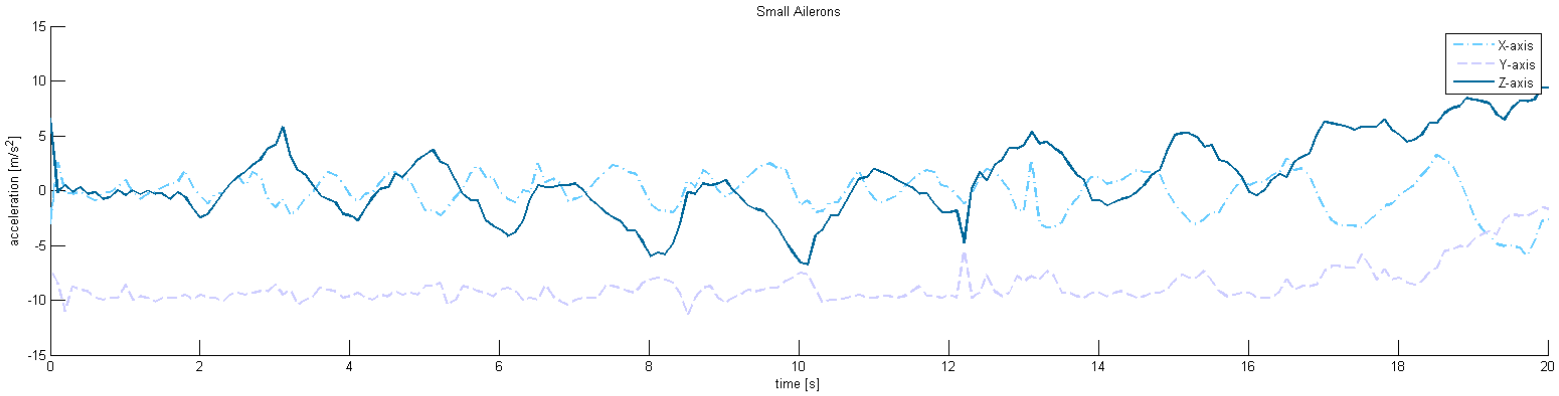


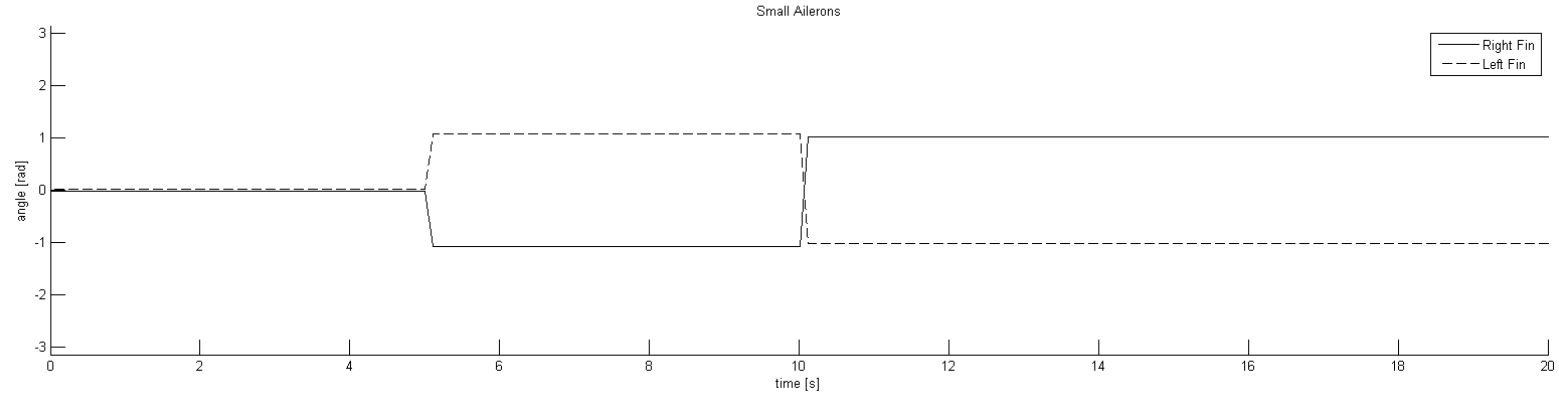
Swim guidance I

- Dive / surface

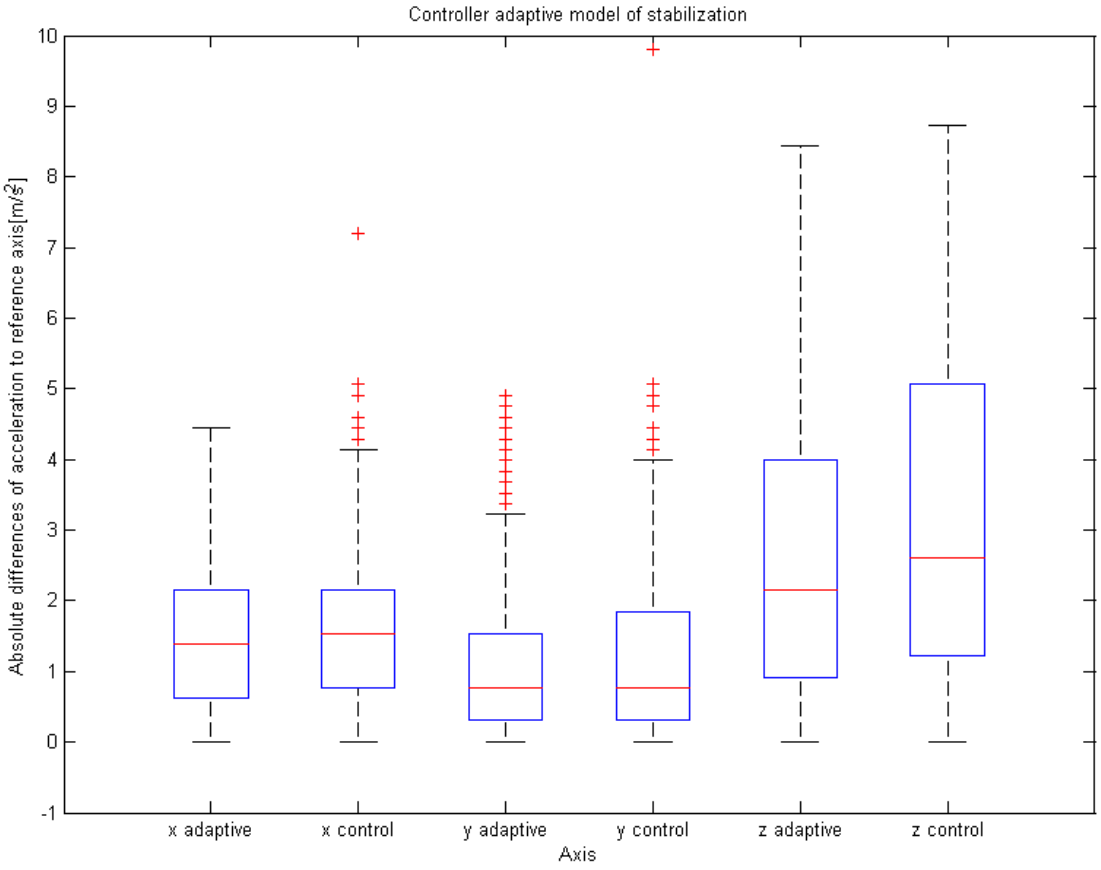
Swim guidance II

- Turn right / left



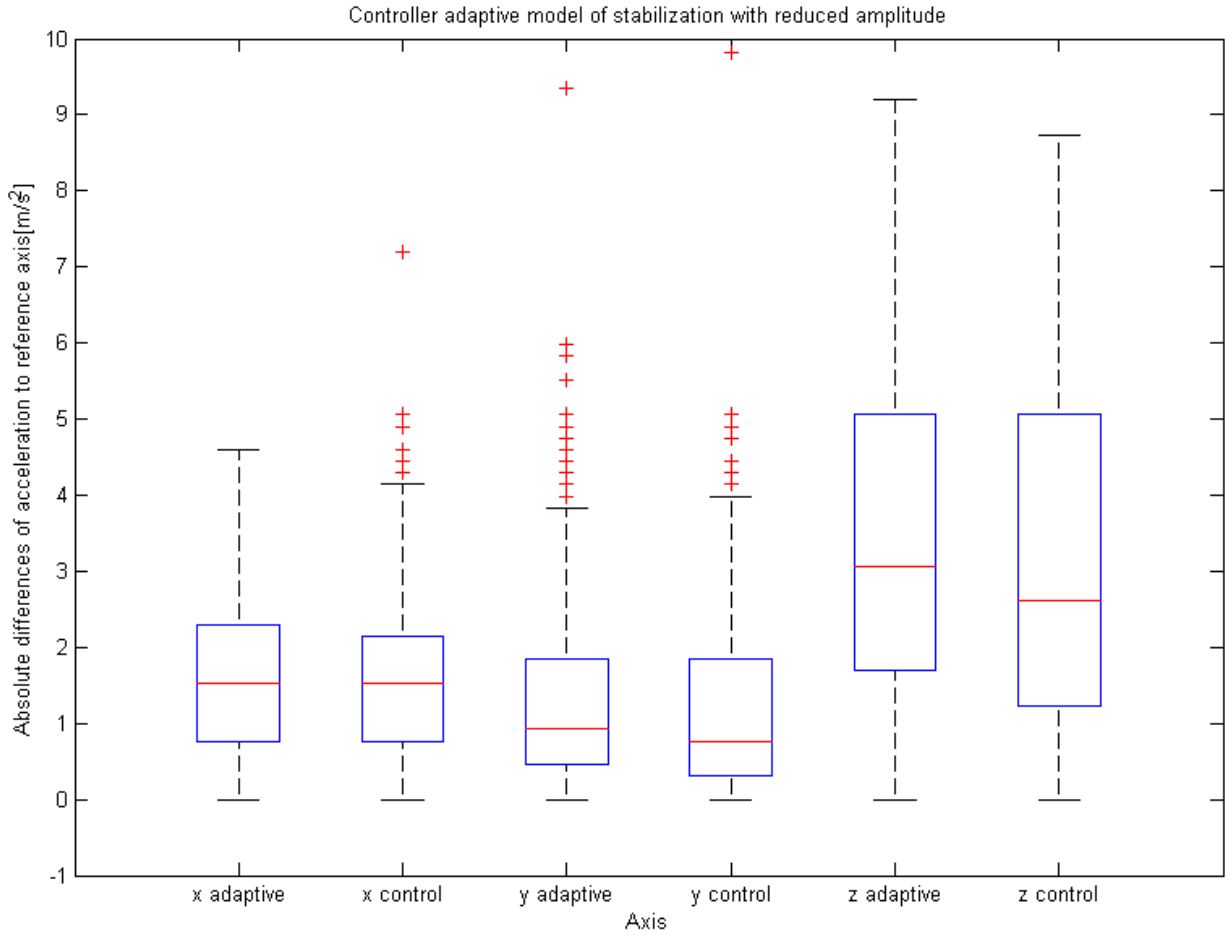


Non-perturbed swimming: controller



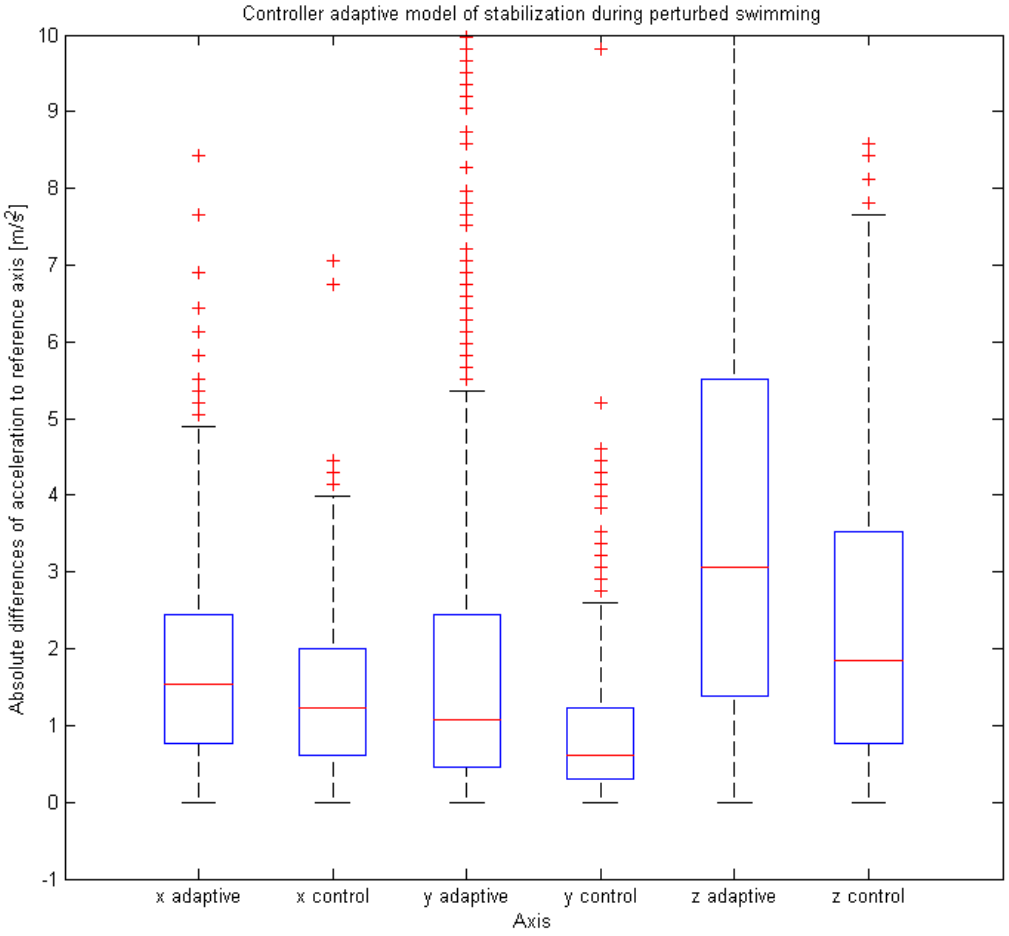
Ailerons stabilize the swimming (even without postural control method)
Globally the adaptive model gives lower differences but not significantly
Combined rolling and yaw tilt of the head remains important

Front oscillation reduced amplitude



Reducing the oscillation amplitude on the front is not a solution. Results are even worse because the guidance is perturbed by the push effect of the rear oscillation.

Perturbed swimming: controller

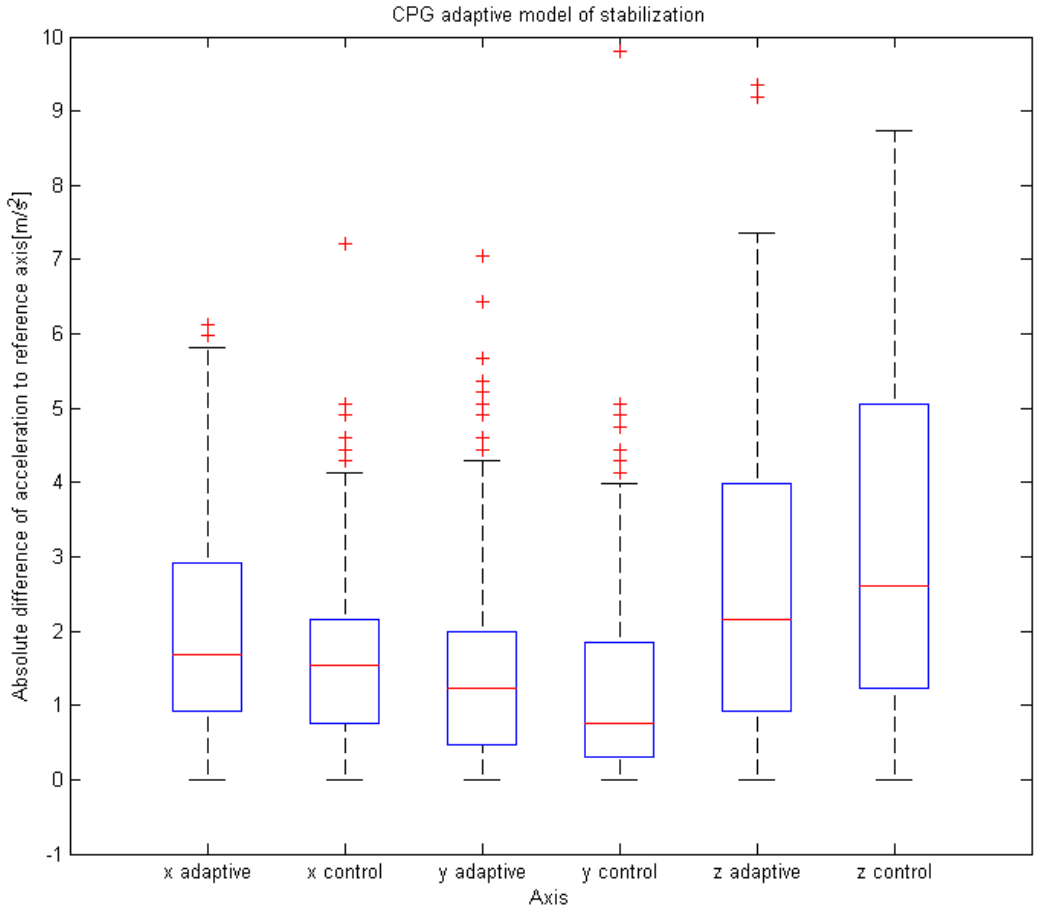


In reality, the stabilization model corrects mainly against the pitch tilt (efficiently) but fails to correct at the same time the rolling cases.

Test example

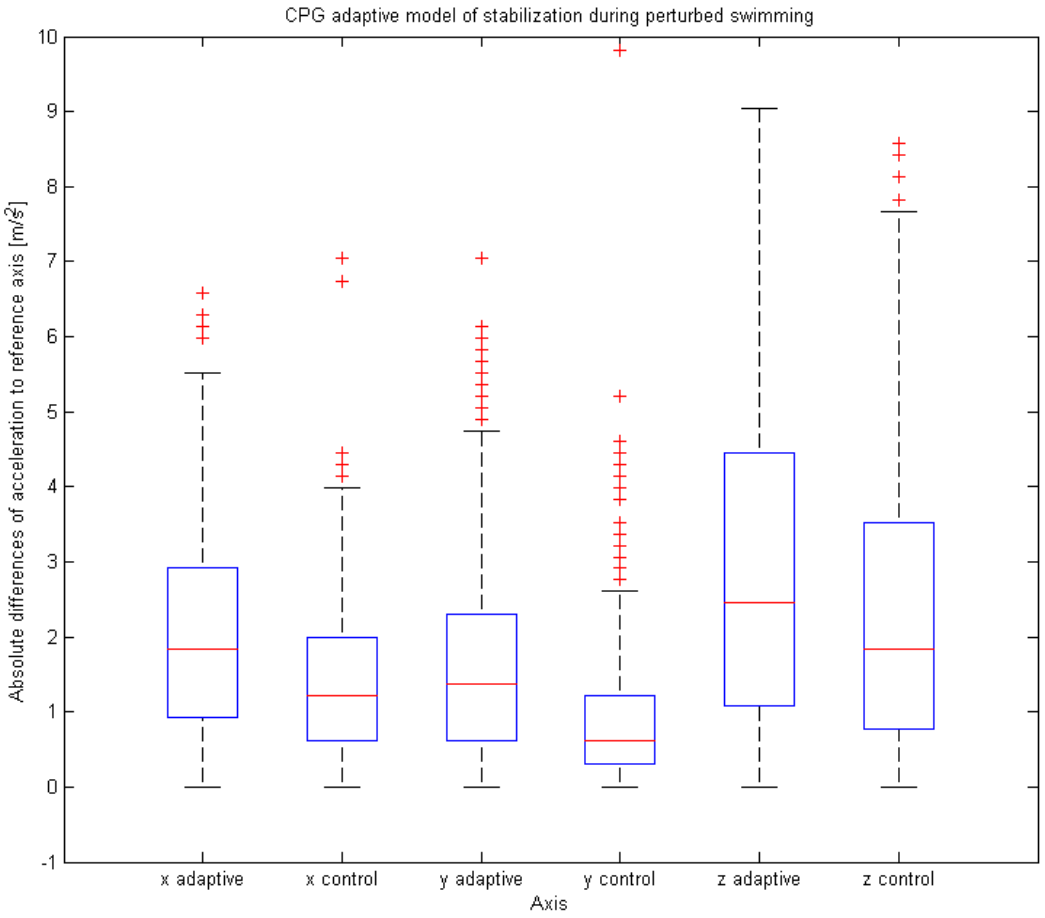
Model into the controller
Turning back and recovering the posture
with aileron movements
with the counter wave
with its inertia

Non-perturbed swimming: CPG



The stabilization model into the CPG was still in trial. Thus it is not efficient.

Perturbed swimming: CPG



Also not efficient during perturbed swimming

Encountered problems

- Large prospective study

- Accelerometer unavailability
- Pool leaking
- Hydrodynamic model error
- Robot waterproofing with perturbations
- Depth of the pool
- Back girdles broken

Future Work

- Improve the CPG with more tests
- Tests in a big pool
- Tests with various oscillation frequencies

- Integrate a gyroscope
- Add freedom degrees

Questions

Main references

- Auke Jan Ijspeert et al., *From Swimming to Walking with a Salamander Robot Driven by a Spinal Cord Model*, Science 315, 1416 (2007)
- Auke Jan Ijspeert et al., Supporting Online Material for *From Swimming to Walking with a Salamander Robot Driven by a Spinal Cord Model, (2007)*
- A.K. Kozlov et al, *Modeling postural control in the lamprey*, Biol. Cybern. 84, 323-330 (2001)
- Elena Pavlova, *Vestibular control of body orientation in lamprey*, Nobel Institute for Neurophysiology, Department of Neuroscience, Karolinska Institute, Stockholm, Sweden (2004)
- T. G. Deliagina, *Vestibular compensation in lampreys: impairment and recovery of equilibrium control during locomotion***,** The Journal of Experimental Biology 200, 1459–1471 (1997)
- A. Karayannidou, *Responses of Reticulospinal Neurons in the Lamprey to Lateral Turns*, J Neurophysiol 97: 512–521 (2007)