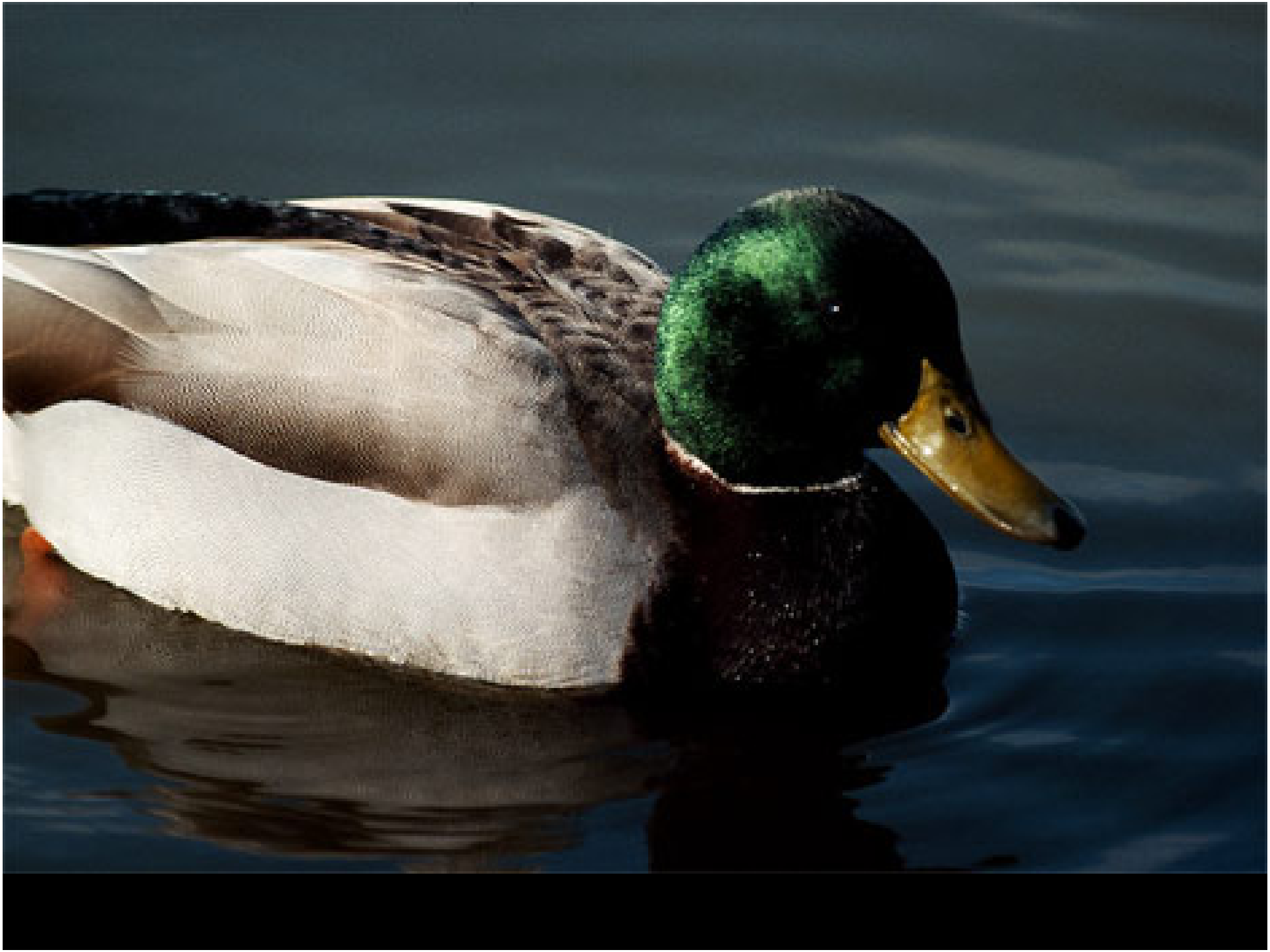
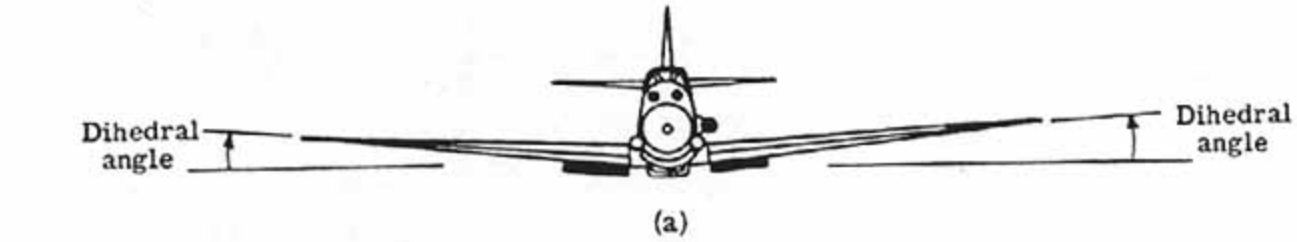
Natural stability

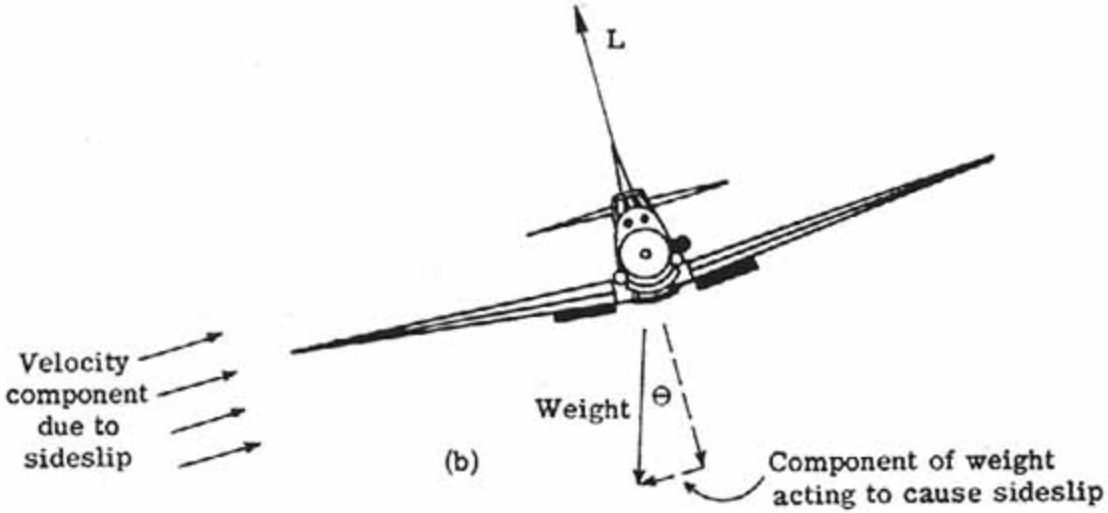
Keywords: creating stable motion



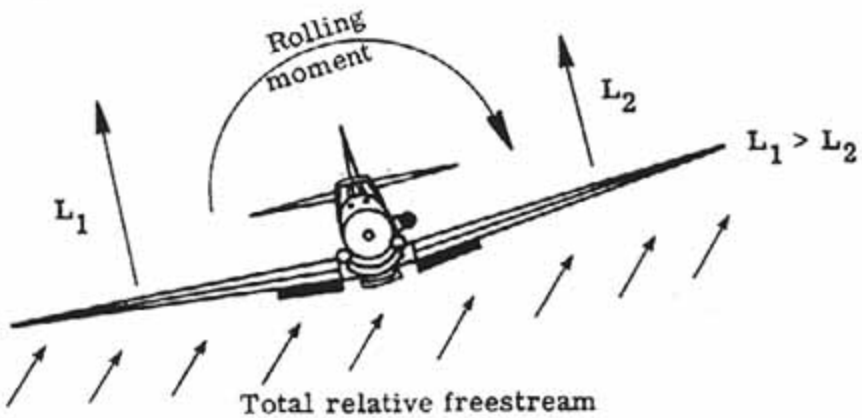
Stable flight


Dihedral angle
Dihedral angle

(a)

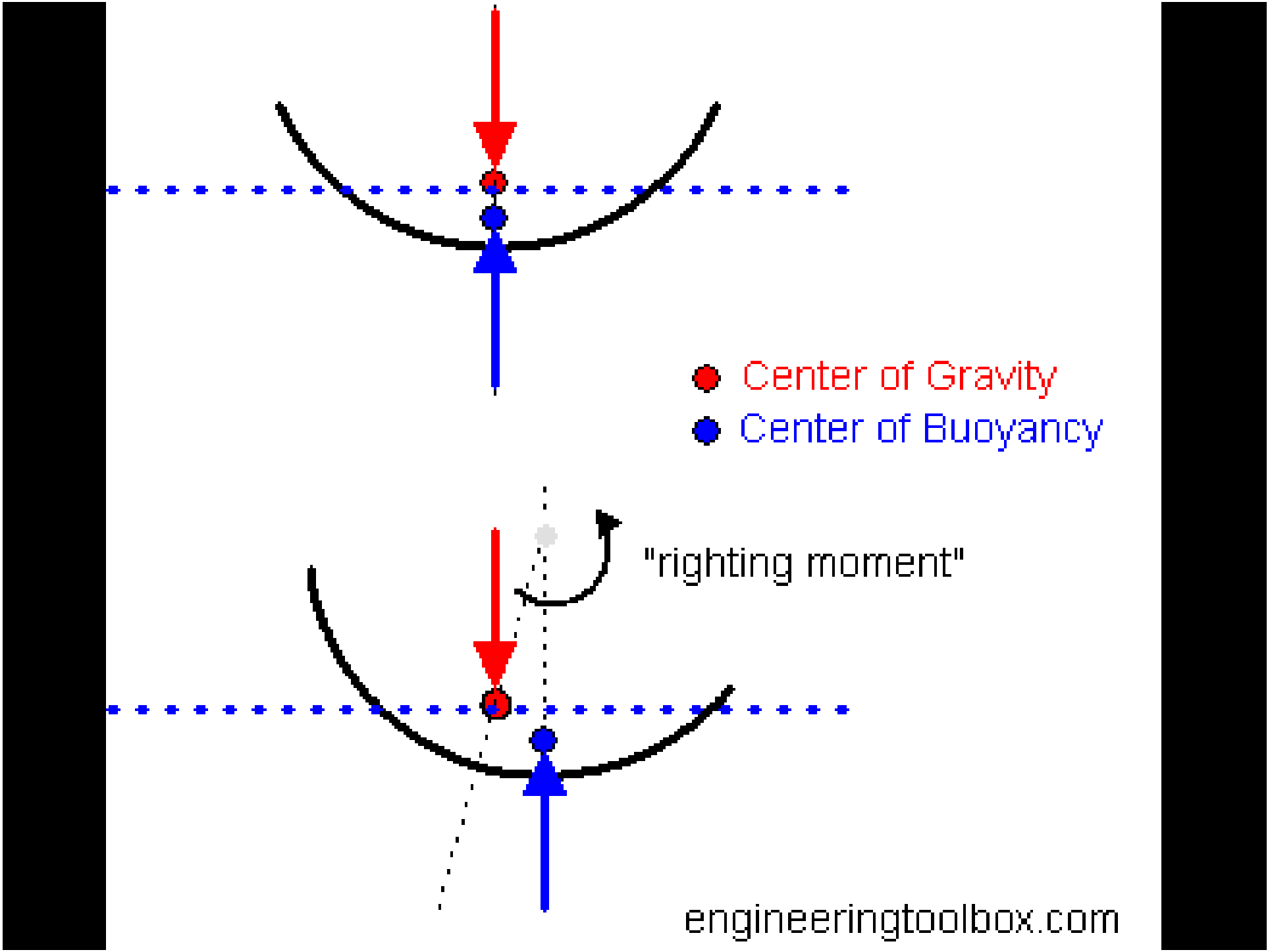

L
Velocity component due to sideslip
Weight
Θ
Component of weight acting to cause sideslip

(b)


Rolling moment
L2
L1 > L2
L1
Total relative freestream (main component along longitudinal axis)

(c)

Stable swim


Center of Gravity
Center of Buoyancy
"righting moment"
engineeringtoolbox.com

Flying and swimming:

use passive stability as much as possible

Nothing new...

Biology: always search for natural (passive) stability

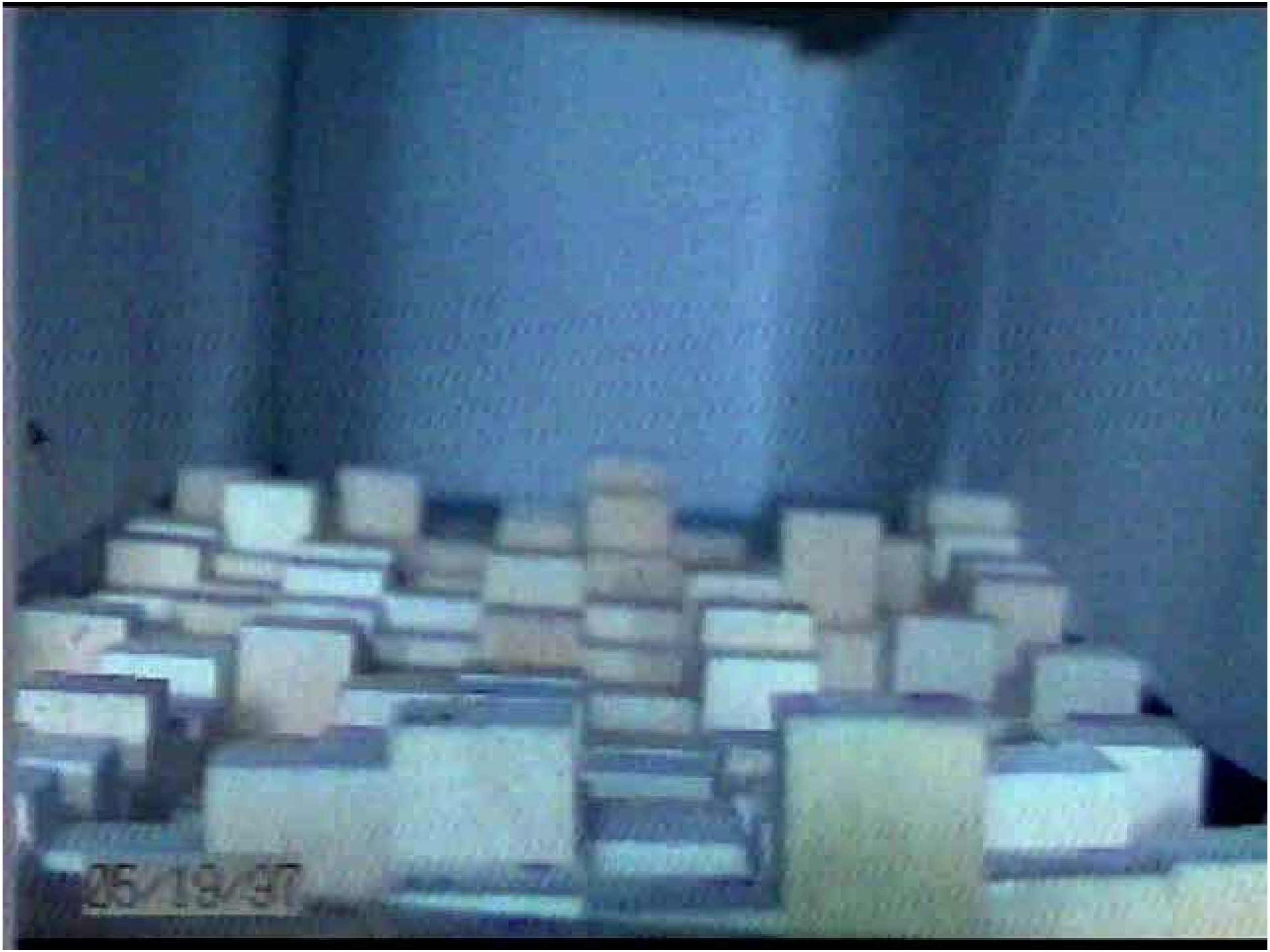
Insects that run

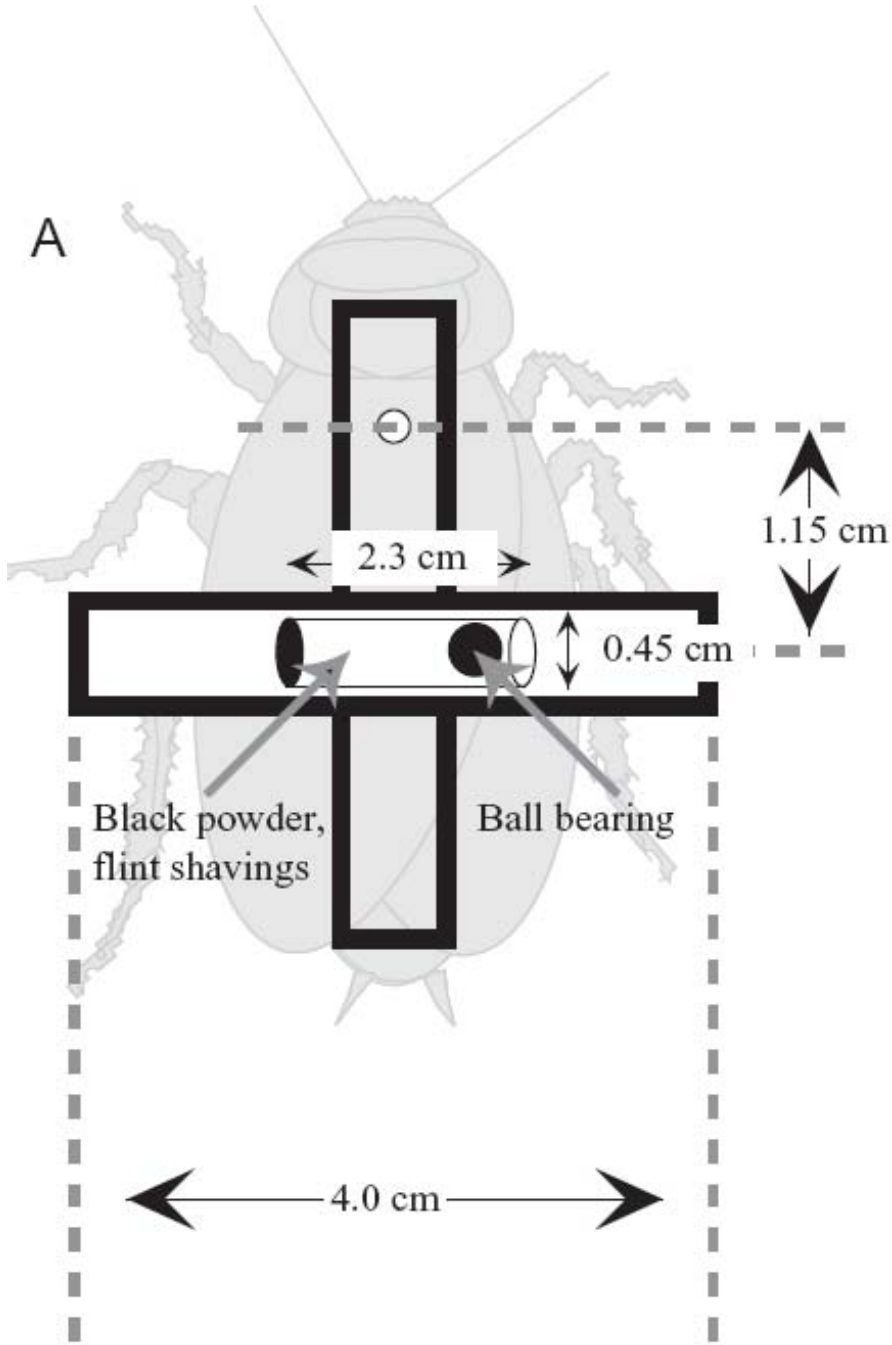
Riding a bike

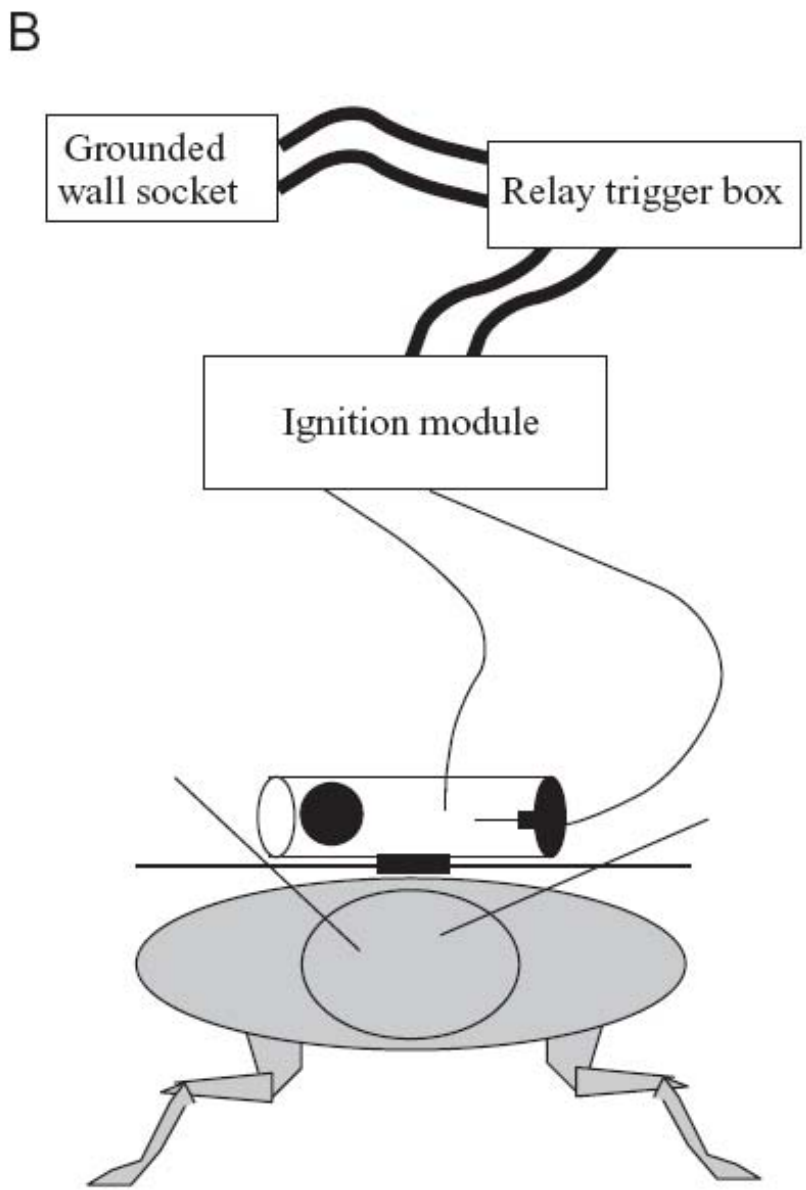
Juggling

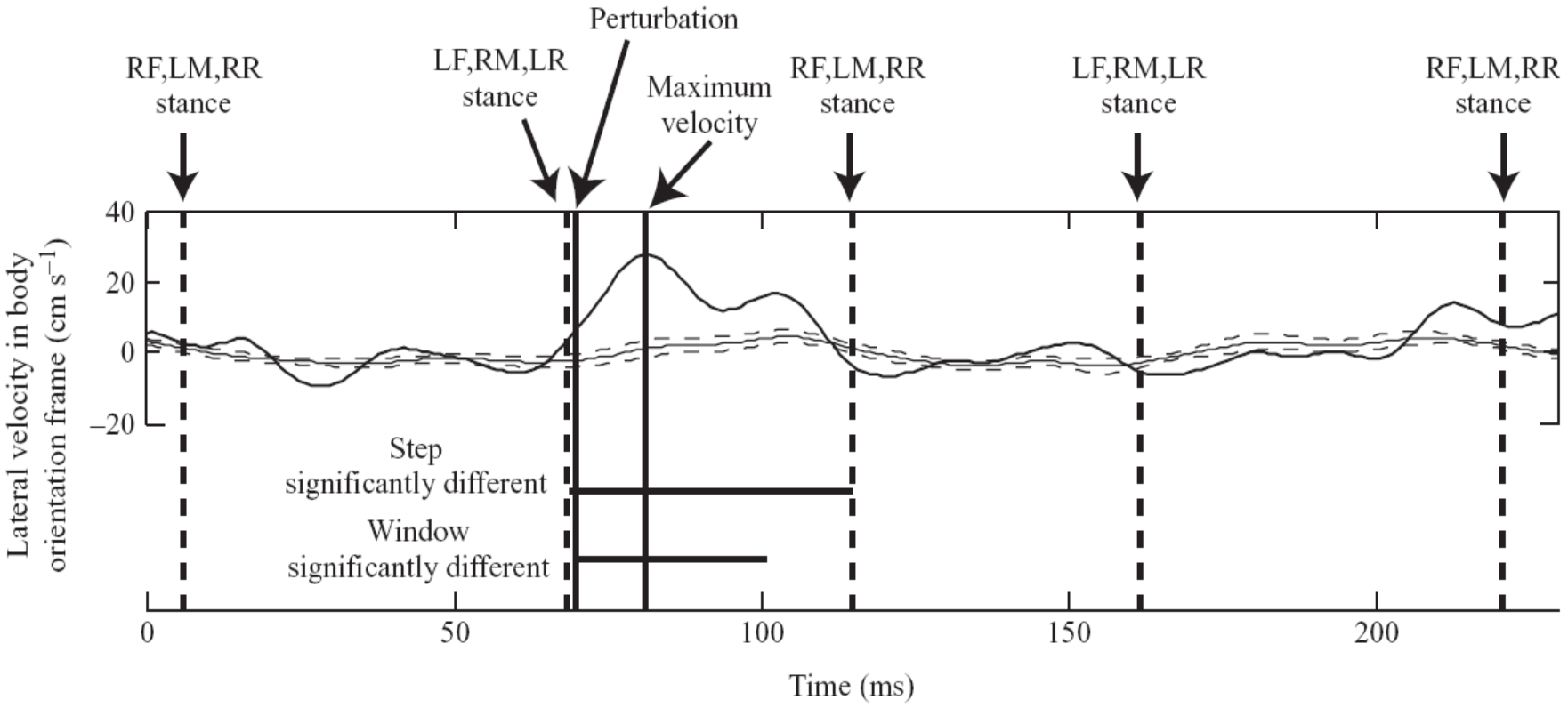
Walking

Insects that run


05/19/97


A
2.3 cm
1.15 cm
0.45 cm
Black powder,
flint shavings
Ball bearing
4.0 cm


B
Grounded
wall socket
Relay trigger box
Ignition module


Perturbation
RF,LM,RR stance
LF,RM,LR stance
Maximum velocity
RF,LM,RR stance
LF,RM,LR stance
RF,LM,RR stance
40
20
0
–20
Lateral velocity in body orientation frame (cm s^{-1})
Step significantly different
Window significantly different
0
50
100
150
200
Time (ms)

Riding a bike

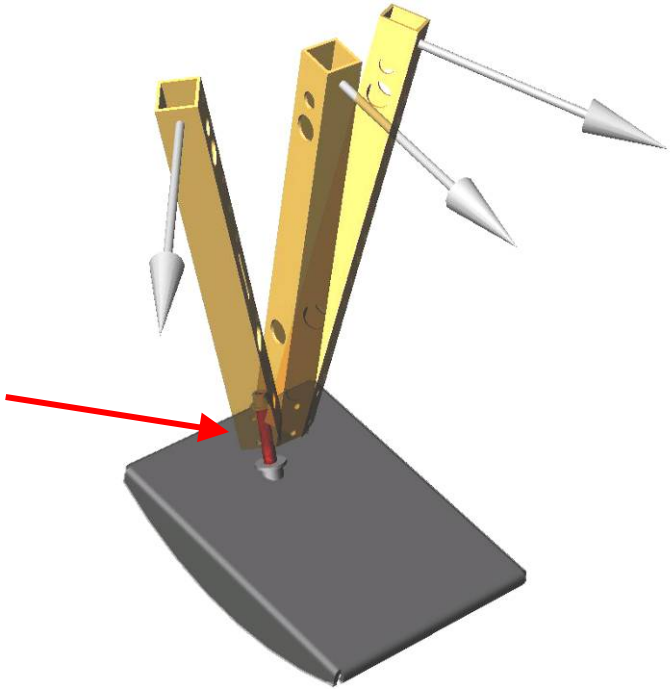
平均台走行

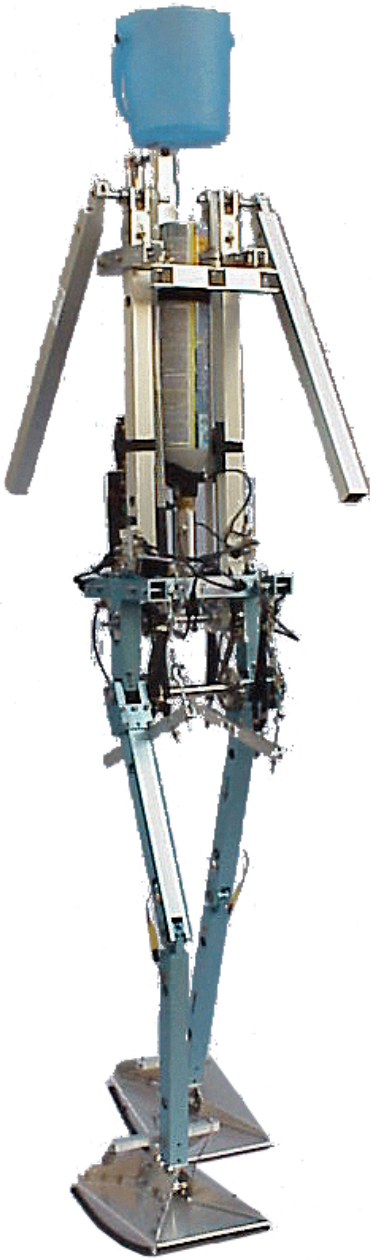
Running on a Balance Beam


Cornell Human Power, Biomechanics and Robotics Laboratory:
Wheel and Bicycle Stability Demonstration Video

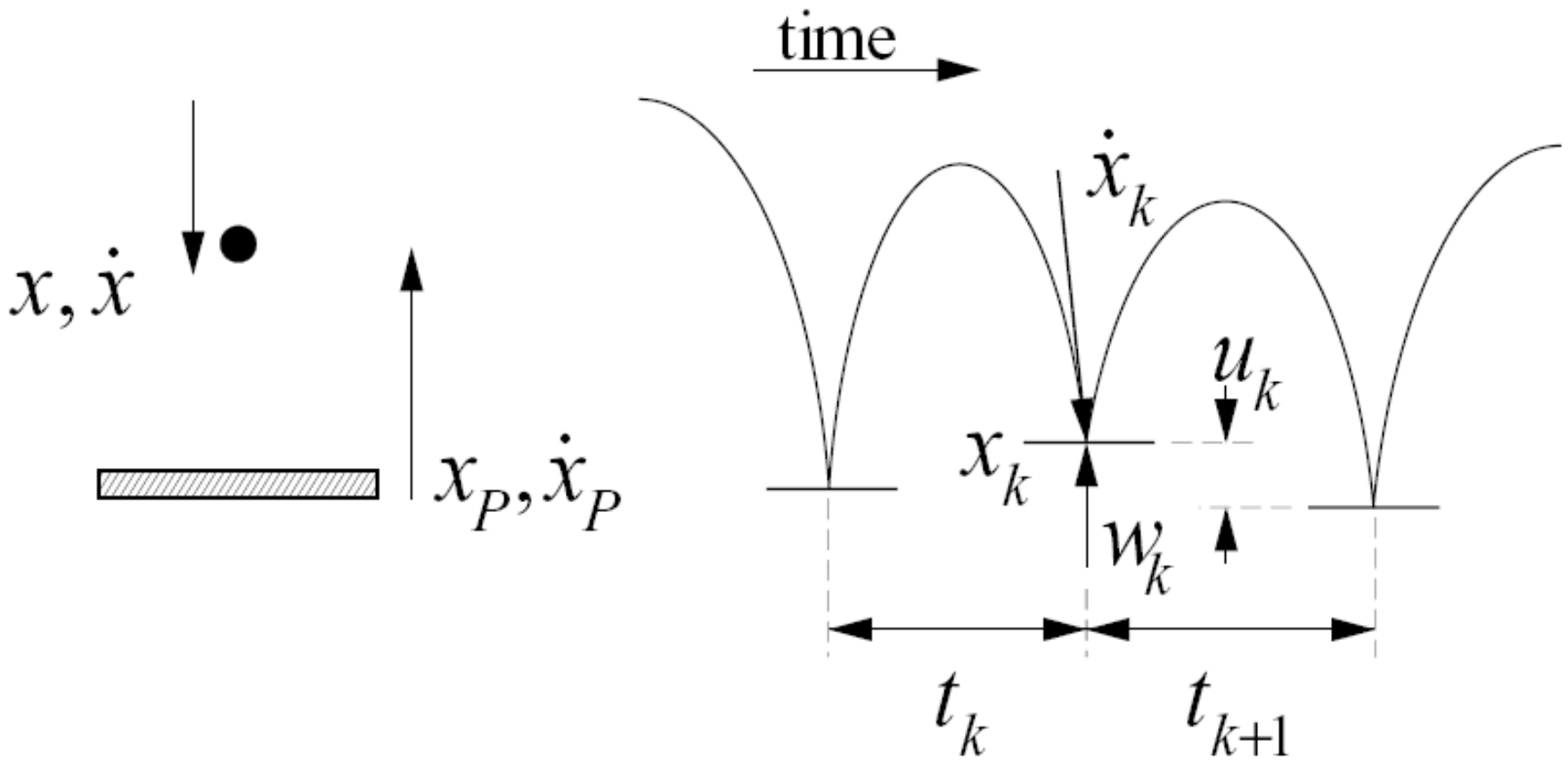
No, not the gyroscopic effect

Lean-to-steer coupling





1D juggling



(a) (b)

In: *IEEE International Conference on Robotics and Automation*, **3**, pp.913-918, Georgia, Atlanta.

Open Loop Stable Control Strategies for Robot Juggling

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Abstract: *In a series of case studies out of the field of dynamic manipulation (Mason, 1992), different principles for open loop stable control are introduced and analyzed. This investigation may provide some insight into how open loop control can serve as a useful foundation for closed loop control and, particularly, what to focus on in learning control.*

1 Introduction

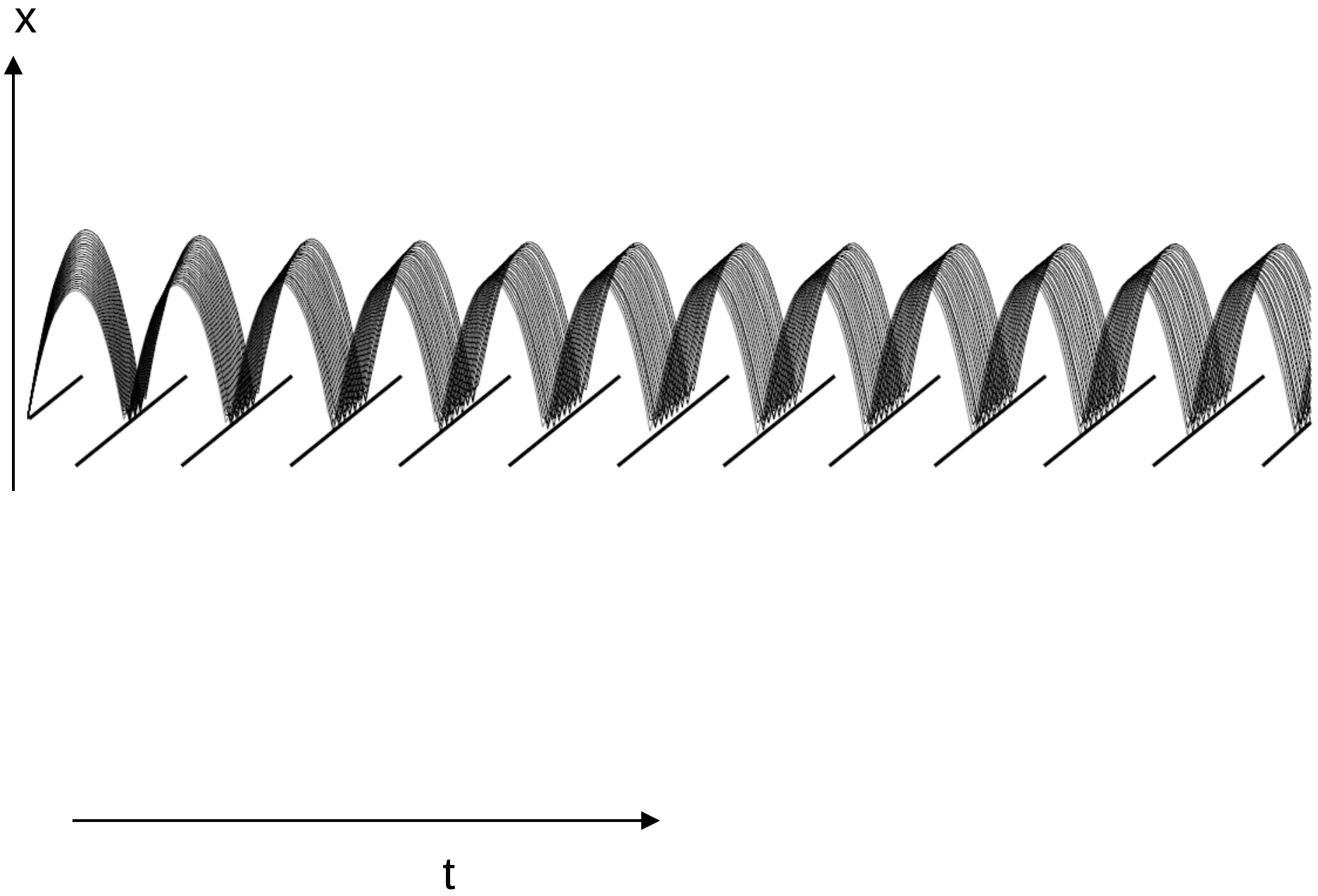
This paper explores open loop stable control strategies for a variety of juggling tasks. By control strategy we mean the way a movement system structures itself to approach a task. An *open loop stable* control strategy does not use active reaction to respond to perturbations. It uses the geometry of the mechanical device, the kinematics and dynamics of motion, and the properties of materials to stabilize the task execution. It is distinguished from closed loop control strategies by the absence of sensory input to the computing of actuator commands for error compensation. Some open loop controlled devices use no actuators at all (McGeer, 1990).

As has been shown by McGeer's (1990) passive dynamic walking machines, dynamic systems are likely to offer regions in state and control space which are inherently more advantageous to the execution of a task then others. Analogously, such favorable, although not open loop, con-

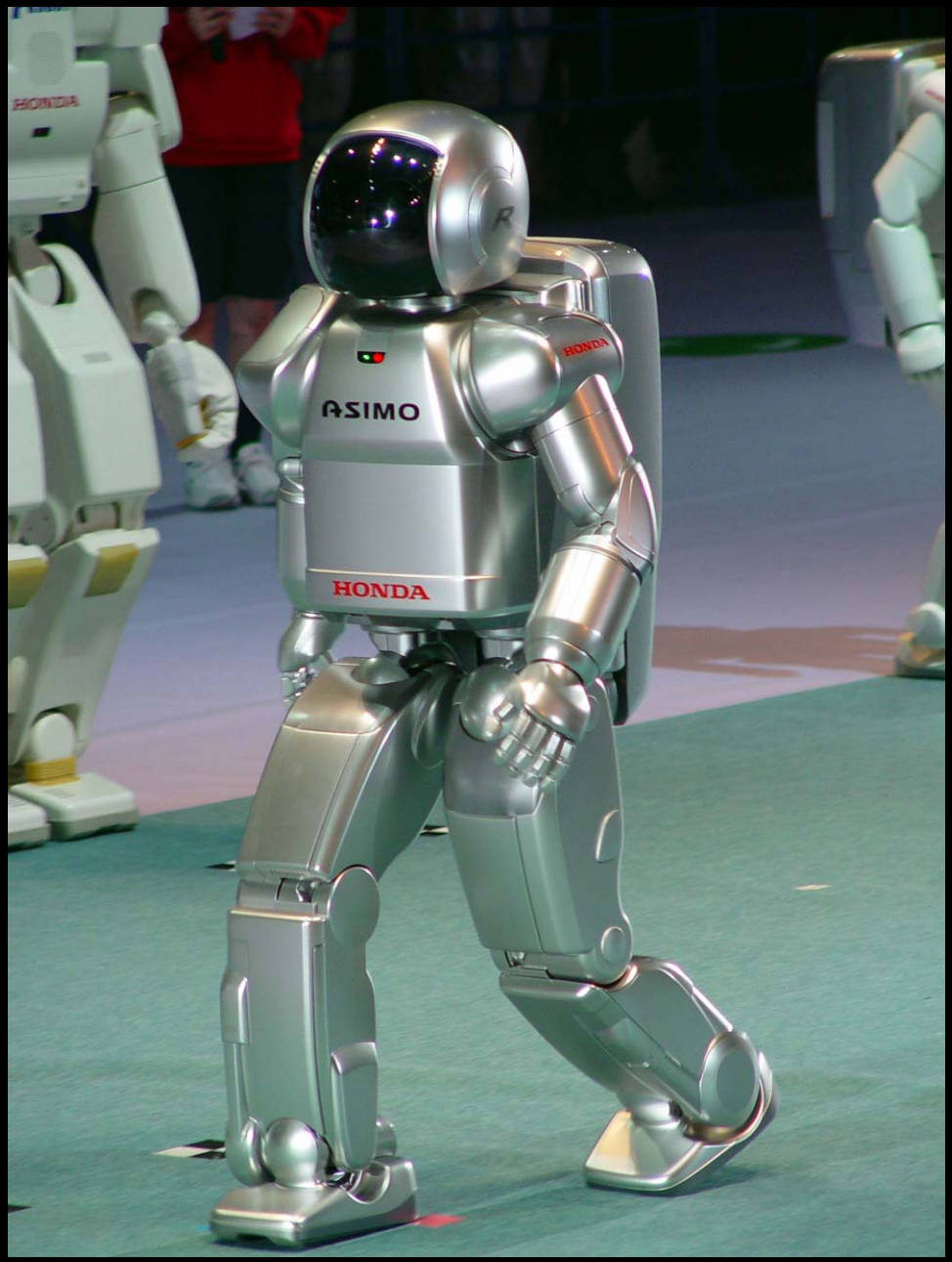
2 Case Studies of Stable Open Loop Control

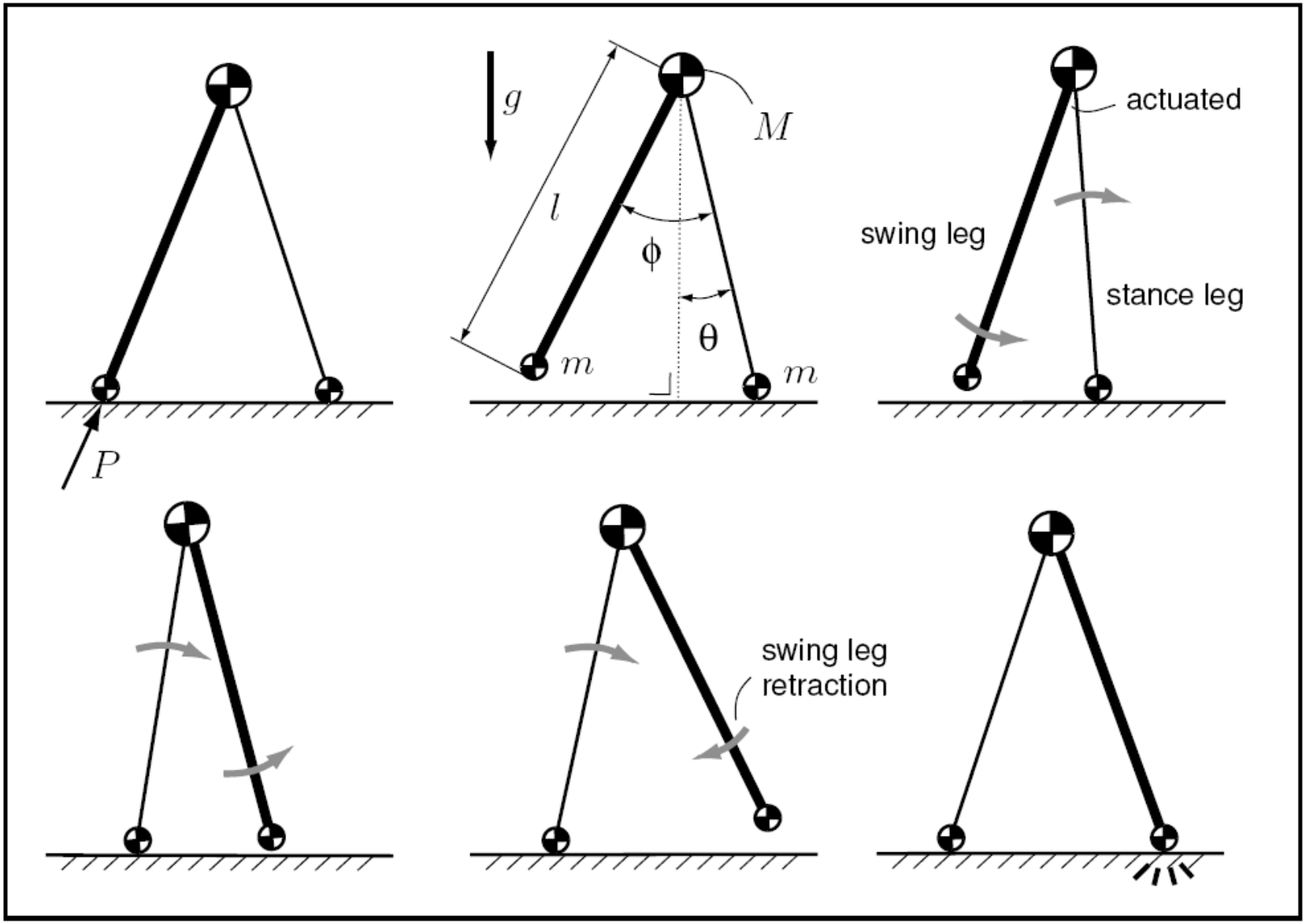
2.1 Paddle Juggling

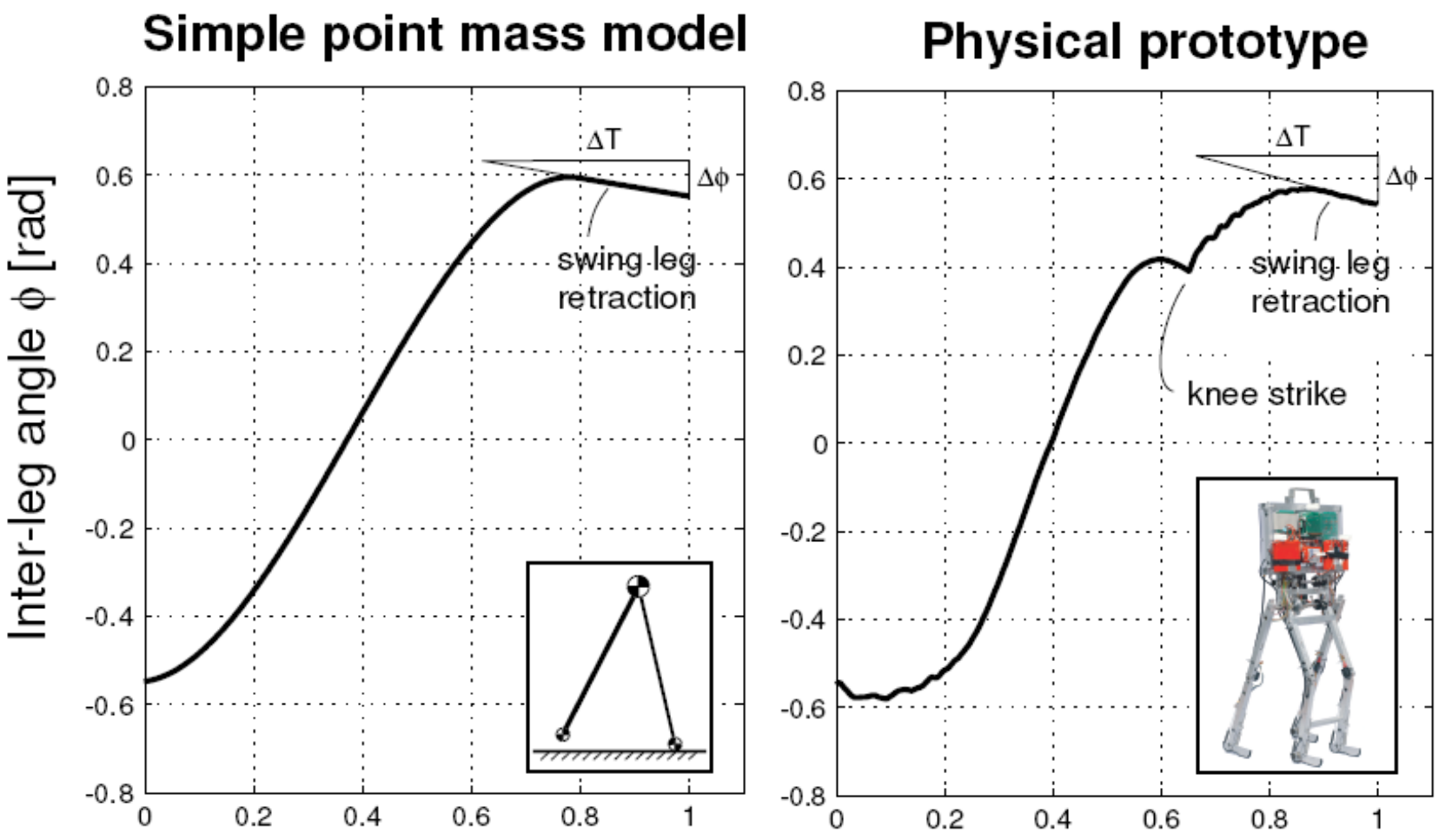
In paddle juggling, a ball (or multiple balls) is kept in the air by hitting the ball vertically with a horizontal paddle (a behavior often exhibited by tennis players waiting for a court). Under visual guidance, this is a closed loop task which has been examined by (Aboaf 1988, Bühler 1990, Rizzi 1992a&b, Ballard 1989, and Toshiba 1989). Without information about the ball state, only open loop control is possible. This task received considerable attention in recent years, for the vibrating paddle version (high paddle oscillation frequency with small amplitude) can be shown to exhibit period bifurcations, strange attractors, and chaos-like motion (Lichtenberg & Lieberman, 1982; Guckenheimer & Holmes, 1983; Moon, 1987; Tufillaro et al., 1992). In the following, open loop stable control strategies for paddle juggling will be explored. The emphasis lies on achieving a constant bouncing height and period; control of the horizontal dimensions will be neglected for the moment. The paddle mass is assumed to be much larger than the ball mass.

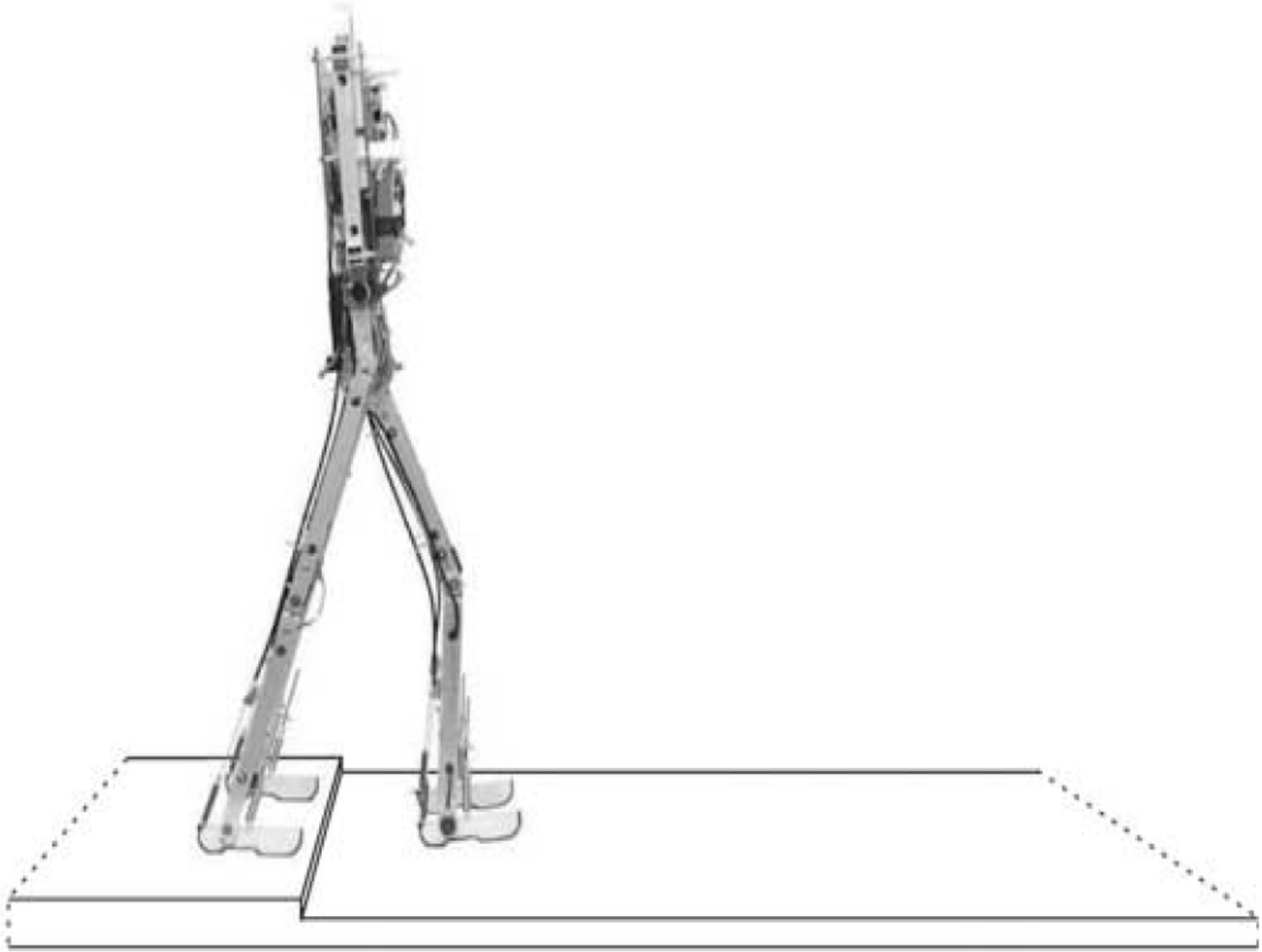

x
t

walking

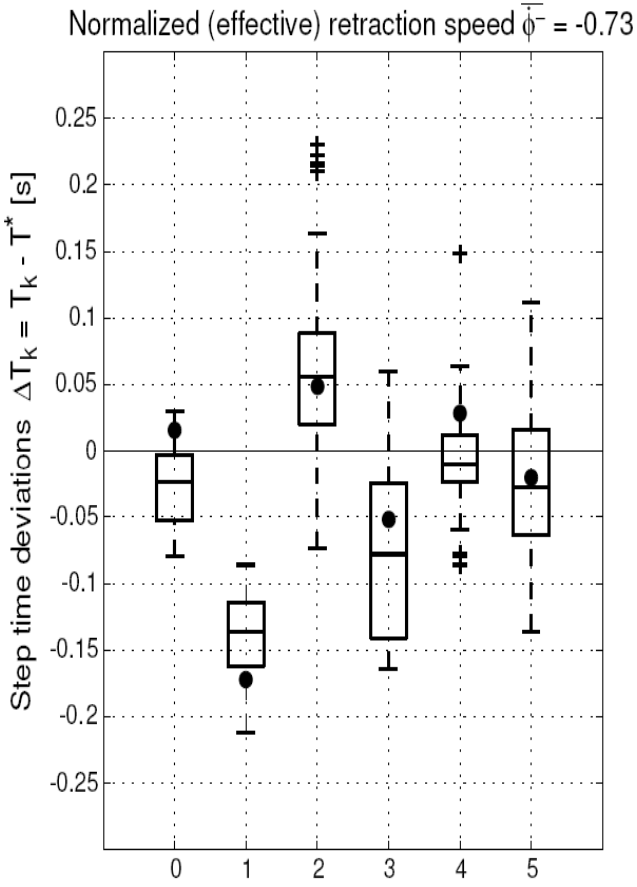

HONDA
ASIMO
HONDA
HONDA


g
M
l
ϕ
θ
m
m
P
actuated
swing leg
stance leg
swing leg
retraction

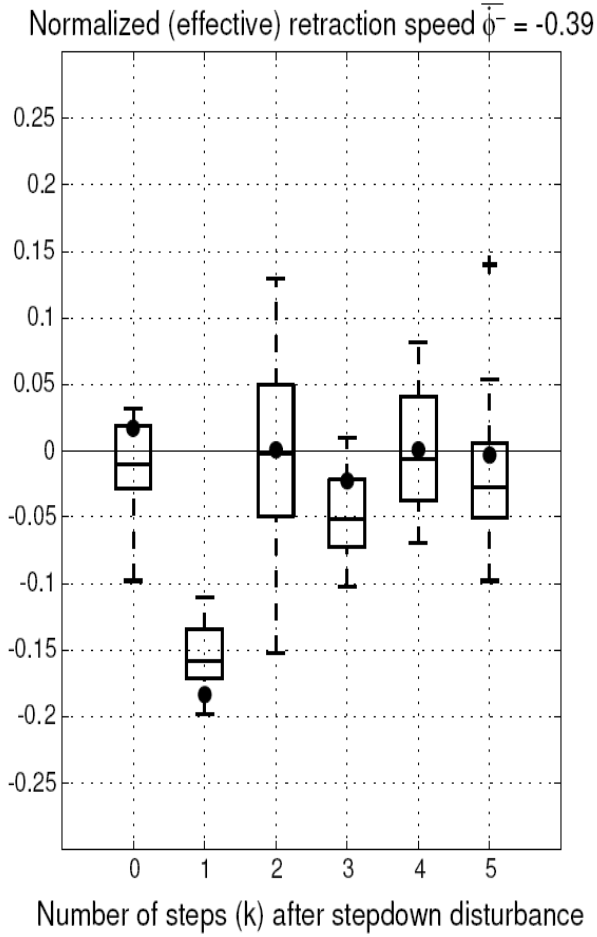

Simple point mass model
Physical prototype
Inter-leg angle ϕ [rad]
ΔT
Δϕ
swing leg retraction
knee strike
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.2
0.4
0.6
0.8
1



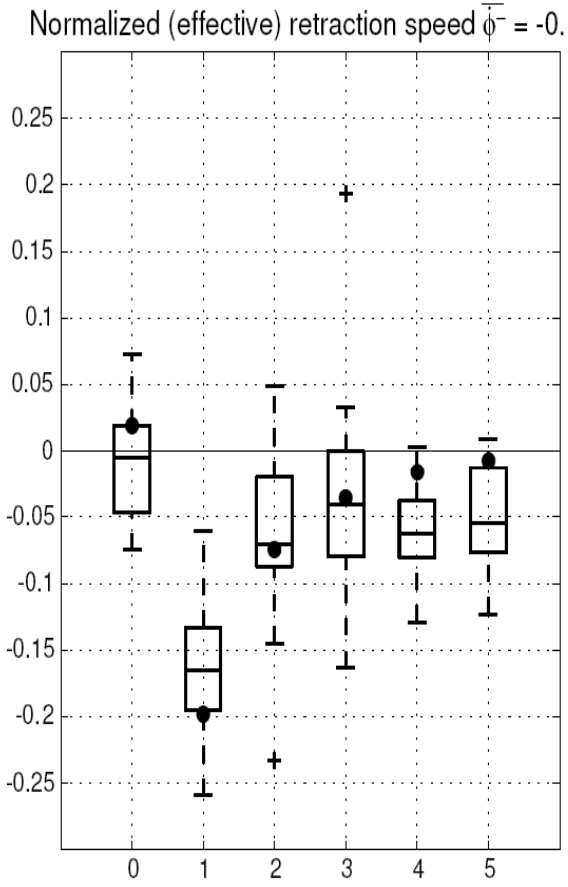
Too much retraction



Perfect retraction



No retraction



2D biped Meta taking a 3cm stepdown

Daan Hobbelen
Jan van Frankenhuyzen
2007

Delft Biorobotics Laboratory
TU Delft

3D biped Flame walking in the hallway

Daan Hobbelen
Jan van Frankenhuyzen
Thijs Mandersloot
Martijn Wisse
Garth Zeglin

2007

Delft Biorobotics Laboratory

TU Delft

Keywords: creating stable motion

- **Biology: find the easy way**

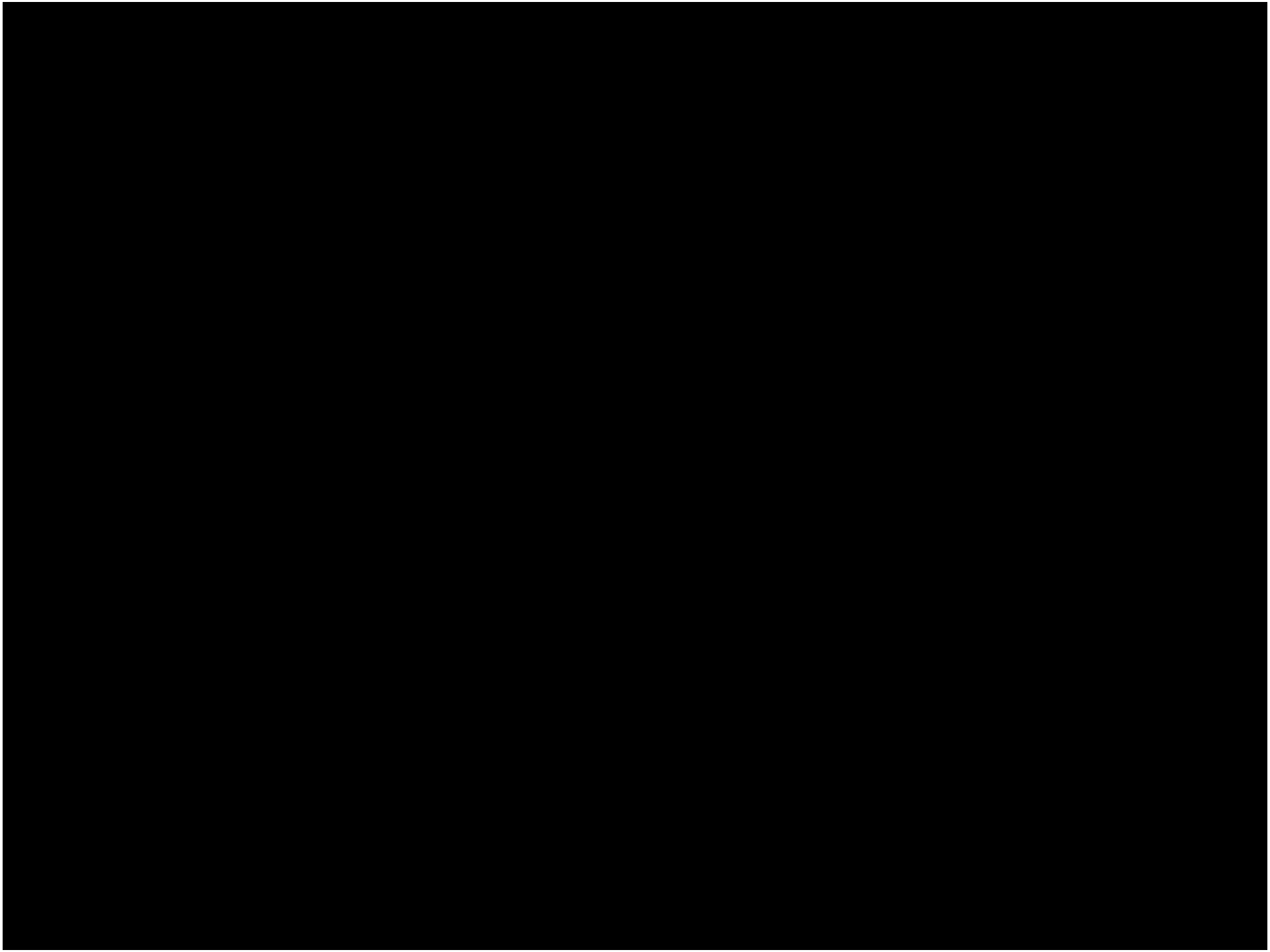
Find natural (passive) stability

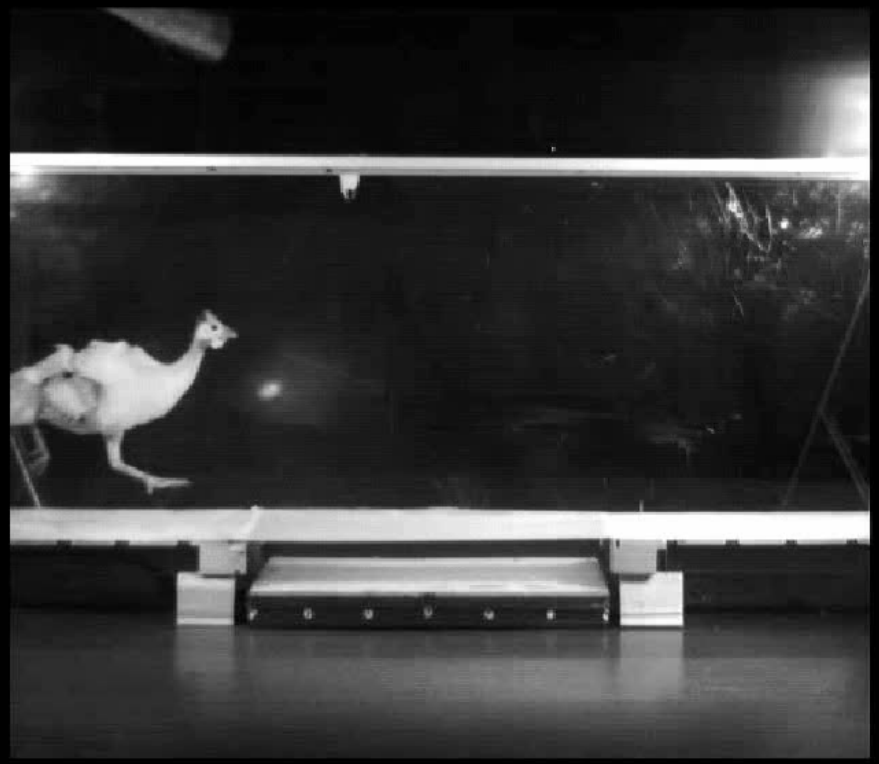
Steady state

- flying
- swimming

Cyclic motion

- running
- biking
- juggling
- walking





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