Bridging the gap between bio-inspired steering and locomotion: a Braitenberg *3a* Snake robot

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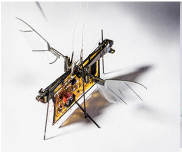
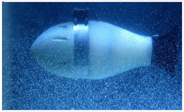
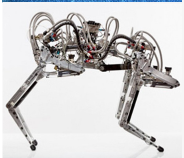
Summary

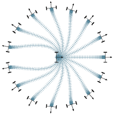
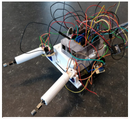
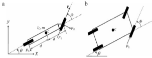
Biological Movement and Navigation

- Locomotion (Control)

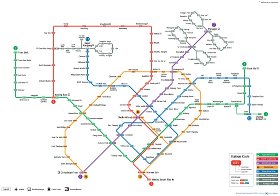



- Steering (local navigation or Guidance) ⇒ Braitenberg


- Navigation (sequence of steering movements)



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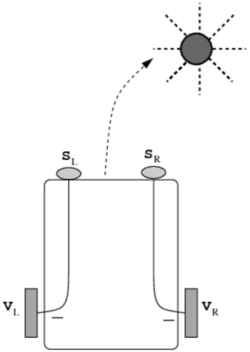
Biological Model of Steering (vehicle 3a)



Braitenberg vehicle 3a implements movement towards a stimulus

- Stimulus $S(\mathbf{x})$ on the plane
- Wheel speed control function $v = F(S)$
- Wheel speed depends on the corresponding sensor
- Decreasing sensor-speed connection $F'(S) < 0$

Has been successfully used for:

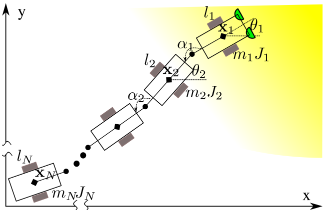
- Sound based steering
- Light based steering
- Chemical based steering

BUT always in wheeled robots.

Contribution:

- first implementation of a biologically inspired steering controller in a snake-like robot with passive wheels and active joints.

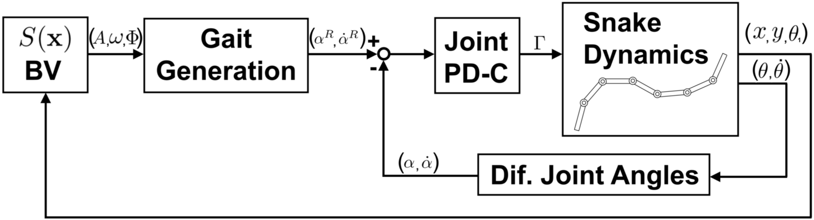
Snake-Robot with passive wheels



Simulated snake

- Dynamic model with ten links
- Nine actuated joints (torques F)
- Free rolling wheels (non-slip) $\Rightarrow$ non-holonomic constraints
- PD controllers on the joints
- Sinusoidal reference on the joints (undulatory locomotion)
- Gait parameters and controller gains not optimized
- Two simulated sensors (fist link) S_r and S_l

Control architecture for the Braitenberg snake robot



Steering and Forward control

Gait signal to the head:

$$\alpha_1^R(t) = \Phi(s_l, s_r) + (A_0 + \eta(s_l, s_r)A)\sin[\eta(s_l, s_r)\omega t]$$

Gait signal to the rest of the body:

$$\alpha_i^R(t) = (A_0 + \eta(s_l, s_r)A_1)\sin[\eta(s_l, s_r)\omega t + \phi_i]$$

where:

$$\Phi(s_l, s_r) = \Phi_0 \tanh(\beta(s_r - s_l))$$

is used to control the direction of movement and

$$\eta(s_l, s_r) = \frac{1}{2}\left[1 - \tanh\left(\gamma\left(\frac{s_r + s_l}{2} - s_0\right)\right)\right]$$

is a scaling function of the sensor readings.

Stimulus functions

We tested the steering controller in:

- Linearly increasing stimulus

$$S(x, y) = g_0 + ax$$

- Linear-parabolic stimulus

$$S(x, y) = g_0 + ax - by^2$$

- Parabolic stimulus

$$S(x, y) = g_0 - ax^2 - by^2$$

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Snake in a Constant Gradient Stimulus

Snake in a Linear-Parabolic Stimulus

Snake in a Parabolic Stimulus

Soft robotics and highly compliant elastic actuators

[1–4]

[1] Filippo Sanfilippo et al. "Virtual functional segmentation of snake robots for perception-driven obstacle-aided locomotion". In: *Proc. of the IEEE International Conference on Robotics and Biomimetics (ROBIO)*. 2016, pp. 1845–1851.

[2] Filippo Sanfilippo et al. "Perception-driven obstacle-aided locomotion for snake robots: the state of the art, challenges and possibilities". In: *Applied Sciences* 7.4 (2017), p. 336.

[3] Filippo Sanfilippo, Øyvind Stavdahl, and Pål Liljebäck. "SnakeSIM: a ROS-based control and simulation framework for perception-driven obstacle-aided locomotion of snake robots". In: *Artificial Life and Robotics* (2018), pp. 1–10.

[4] Filippo Sanfilippo et al. "Serpens, a low-cost ROS-based snake robot with series elastic actuators, torque-controlled actuators and a screw-less assembly mechanism". In: *Submitted to the Proc. of the 5th IEEE International Conference on Soft Robotics (RoboSoft 2019), Seoul, Korea*. IEEE. 2019.

Thank you for your attention

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References I

[1] Filippo Sanfilippo et al. "Virtual functional segmentation of snake robots for perception-driven obstacle-aided locomotion". In: *Proc. of the IEEE International Conference on Robotics and Biomimetics (ROBIO)*. 2016, pp. 1845–1851.

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