Biased Random Walk を用いた車輪移動型ロボットのロバストな制御手法の提案

ダーラリベラ・ファビオ（パドバ大学）
池本 周平（大阪大学）
港 隆史（JST ERATO）
中村 泰（大阪大学）
石黒 浩（大阪大学、JST ERATO）
メネガッティ・エマヌエレ（パドバ大学）

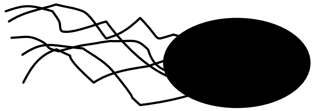
Background

http://www.nasa.gov/

- Space exploration or forested paths require robot robustness
- Need to cope with damages
  - design of recovery behaviors and fault detection are difficult

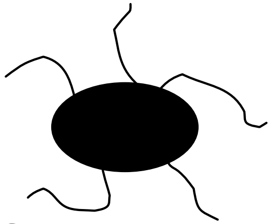
Escherichia Coli Random Walk

E. Coli rotates CW/CCW direction



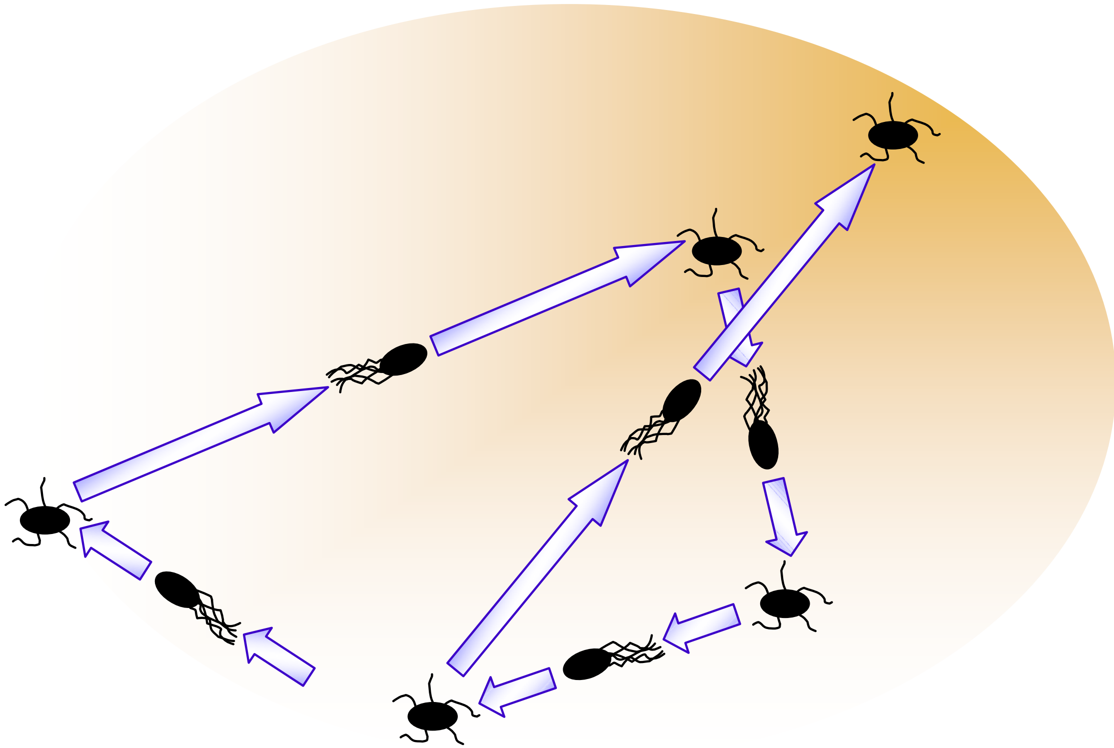
CCW rotation

- Flagella are aligned in a single bundle, swim in a straight line



CW rotation

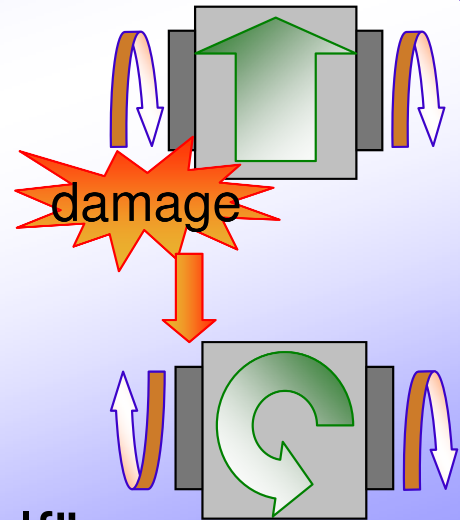
- Flagella bundle is broke apart, tumble in place, random direction change



- Two rotations alternated
- Positive attractants (food) gradient
  → longer straight swims (CCW rotation)
- Biased random walk toward attractants

E. Coli inspired robot navigation

- A. Dhariwal, G. Sukhatme and A. Requicha, *Bacterium-inspired Robots for Environmental Monitoring*, ICRA 2004
  - gradient descent is faster for tracking a single source, but random walk performs better in the presence of
    - Noisy sensors/actuators
    - Multiple/ Dissipative sources
  - Prevents ending up in local minima
- Two behaviors implemented
  - Go straight
  - Random rotation
- Hardware fault → target not reached
  - Example: encoder breaks
    →wheel rotates in the opposite direction
    → "go forward" becomes "spinning on itself"



Control space biased RW

- Biased random walk in the ***motor command space*** → appropriate behaviors that exploit the working hardware are found

Terms

u Control input (motor velocities)

$f(u)$ bias

η random variable

α bias term scaling constant

β random term scaling constant

x sensory information (state)

$A(x)$ Activity: state dependent bias term weight

Control equations

Biased random walk

$$\dot{u} = \alpha A(x) f(u) + \beta \eta$$

Bias term

$$A(x) = sgn(\frac{dx}{dt})$$

$$f(u) = \frac{u}{\|u\|}$$

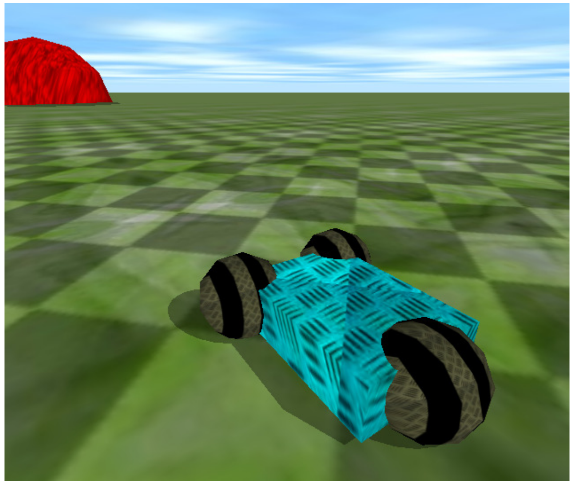
Intuitive meaning:

•Conditions improved

→keep the same motor command

Hardware damage robustness

Experimental setup

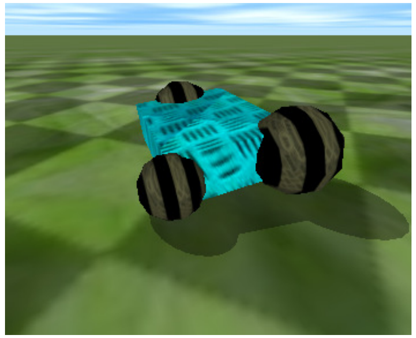


Robot: simulated mobile robot with two independent wheels and an omnidirectional camera

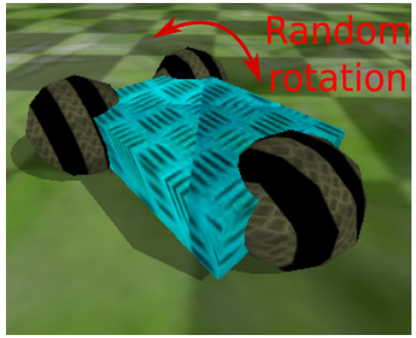
Task: reach a red hemisphere

Sensory information: number of red pixels in the camera image

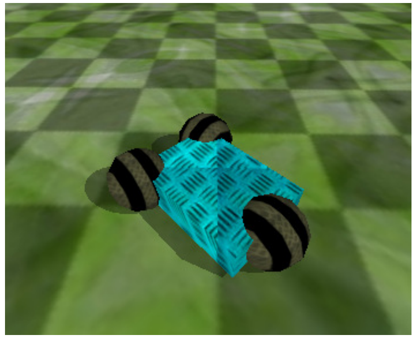
4 simulated hardware faults



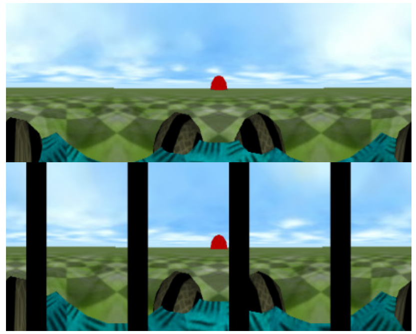
Change in the size of a wheel



Uncontrollability of a wheel



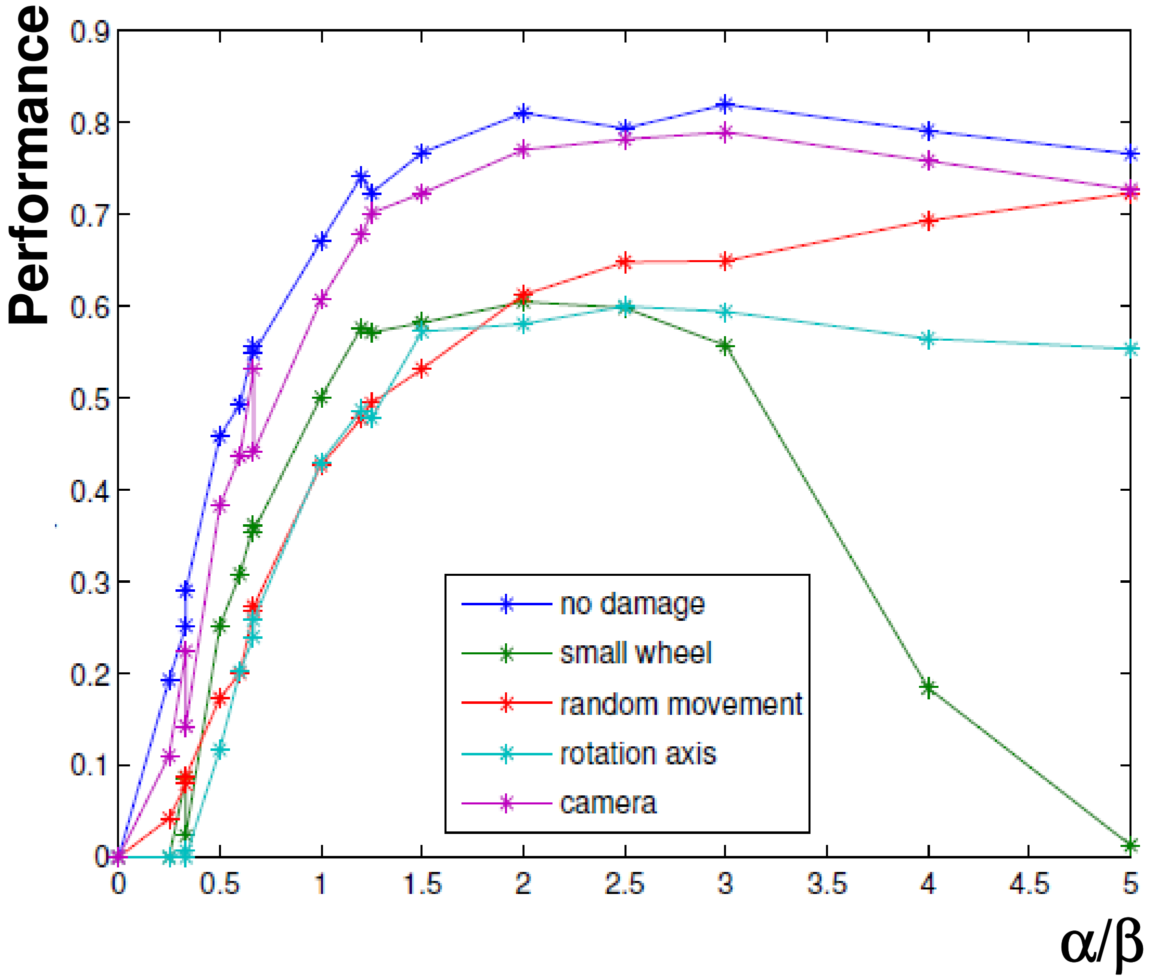
Change of the rotation axis of a wheel



Obscuration of 20% of the camera

Results

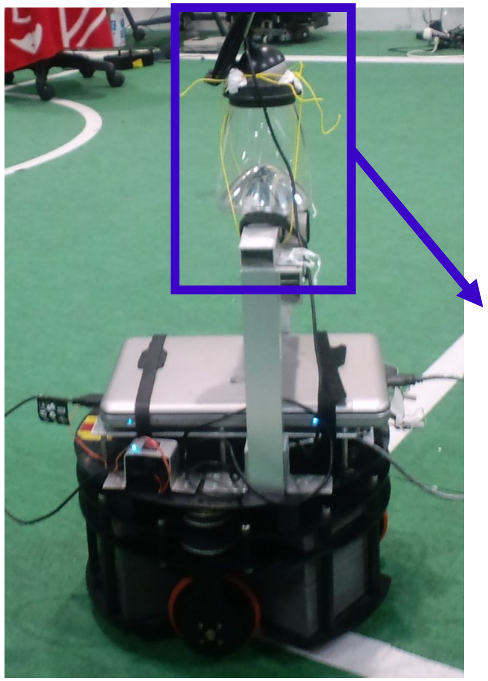
- The robot is able to reach the target in all the cases
- An optimal ratio between the noise and the signal exists
- This ratio depends on the hardware and environment conditions



Sensor noise robustness

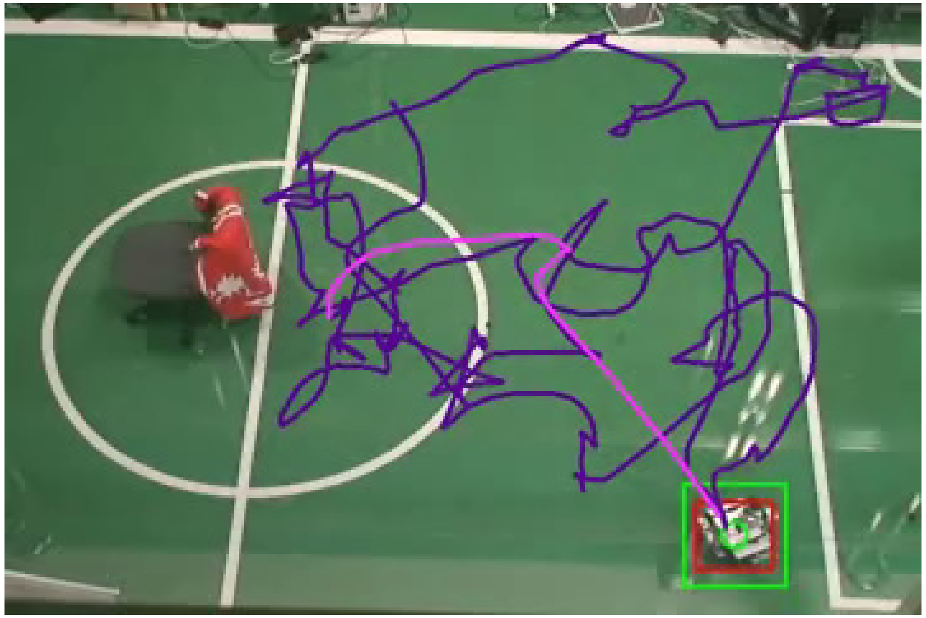
Experimental setup

Robot: real mobile robot equipped with an omnidirectional camera
Task: Reach a red blanket
Sensory information: Number of red pixels in the camera image



B12 mobile robot

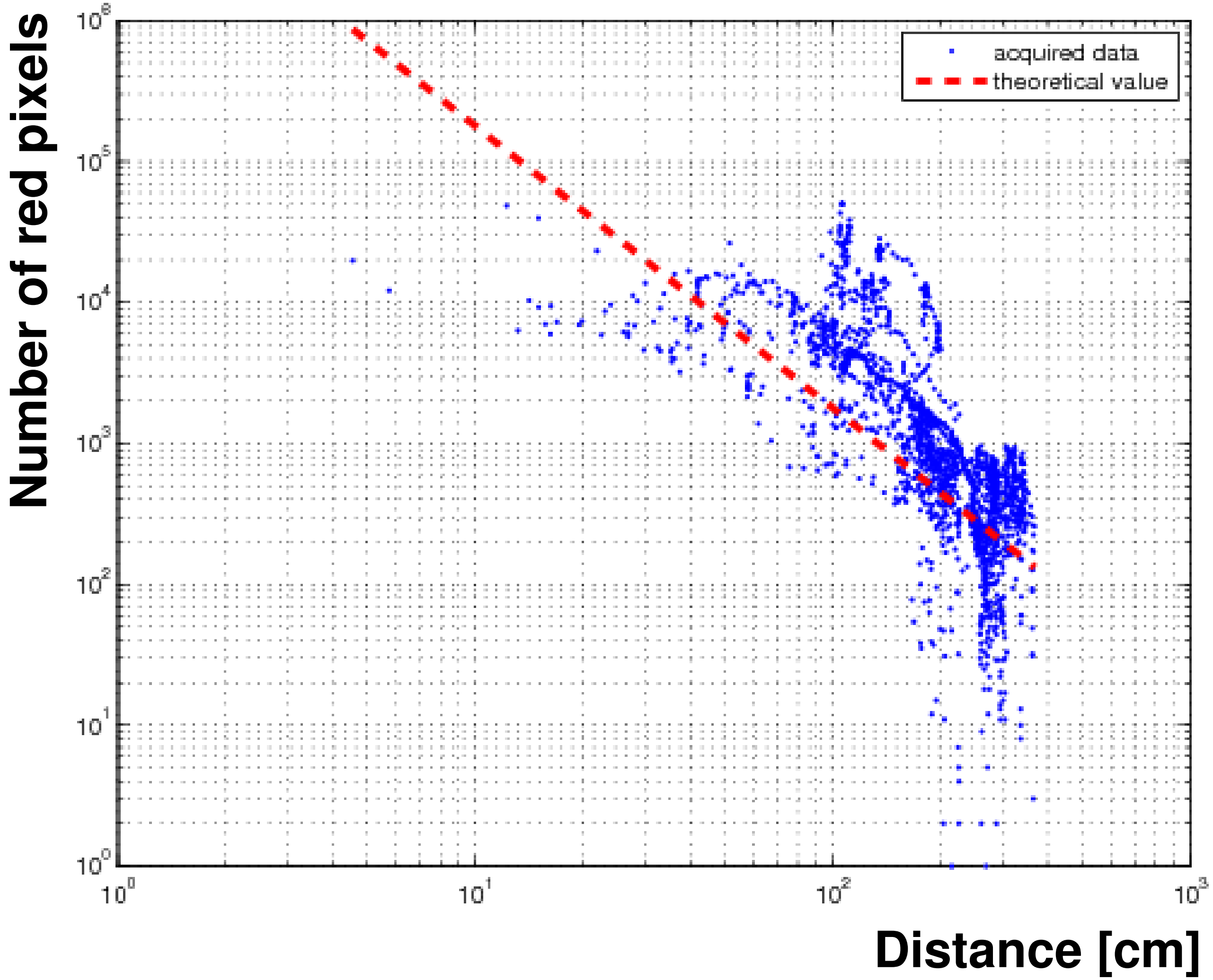
Omnidirectional camera



Reaching in a real environment

Results

- The robot is able to reach the target even given the really noisy input information
  - Can be used for real world problems



Conclusions

- Biased random walk is a very robust control method when applied in the control space
- Verified in a target reaching task
  - Robust to hardware damages
  - Robust to sensor noise
- The performance depends just on the ratio of the two scaling factors α and β
  - The ratio is different for different hardware conditions

Future works

- Automatically determine the optimal α/β ratio
- Compare the performance of Levy walk to Brownian motion
- Extend the approach to target reaching with obstacle avoidance