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（パドヴァ大学）
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（パドヴァ大学）
• Space exploration or forested paths require robot robustness

• Need to cope with damages
  – design of recovery behaviors and fault detection are difficult

http://www.nasa.gov/
Escherichia Coli Random Walk

E. Coli rotates CW/CCW direction

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

- 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 $\rightarrow$ target not reached
  - Example: encoder breaks
    $\rightarrow$ wheel rotates in the opposite direction
    $\rightarrow$ “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
- $\eta$: random variable
- $\alpha$: bias term scaling constant
- $\beta$: 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

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

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

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 $\alpha$ and $\beta$
  – The ratio is different for different hardware conditions
Future works

• Automatically determine the optimal $\alpha/\beta$ ratio
• Compare the performance of Levy walk to Brownian motion
• Extend the approach to target reaching with obstacle avoidance