Locomotion Skills for Insects with Sample-based Controller

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Short Introduction

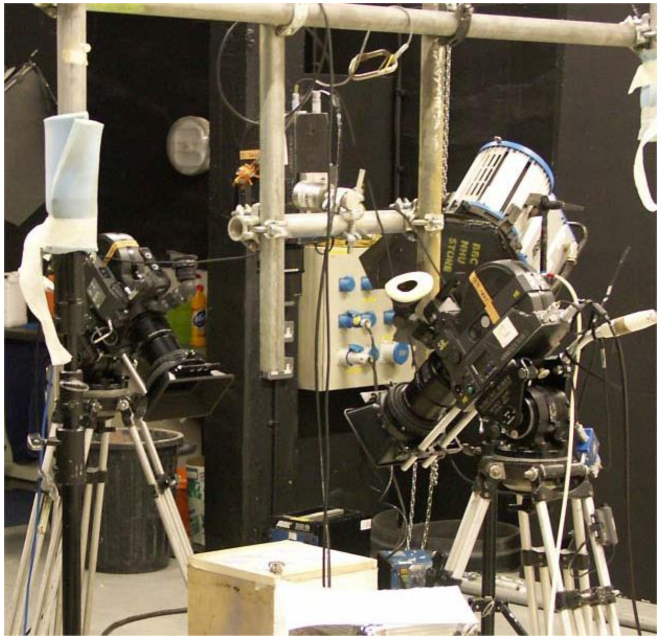
- Research Areas:
  - Character Animation
  - Geometry Processing
- Ph. D. at National Centre for Computer Animation, Bournemouth University, UK (2015. 9)
- B. S. at Peking University (2010. 7)
- China

Outline

- State-of-the-art
- Biological Backgrounds
- Breakdown of my framework
- Future Work

State-of-the-art

- Example-based
  - ✓Natural-looking
  - x Difficult to edit
  - x Specialized system



Gibson, D. P., Oziem, D. J., Dalton, C. J., & Campbell, N. W. (2005, July). Capture and synthesis of insect motion. In *Proceedings of the 2005 ACM SIGGRAPH/Eurographics symposium on Computer animation* (pp. 39-48). ACM

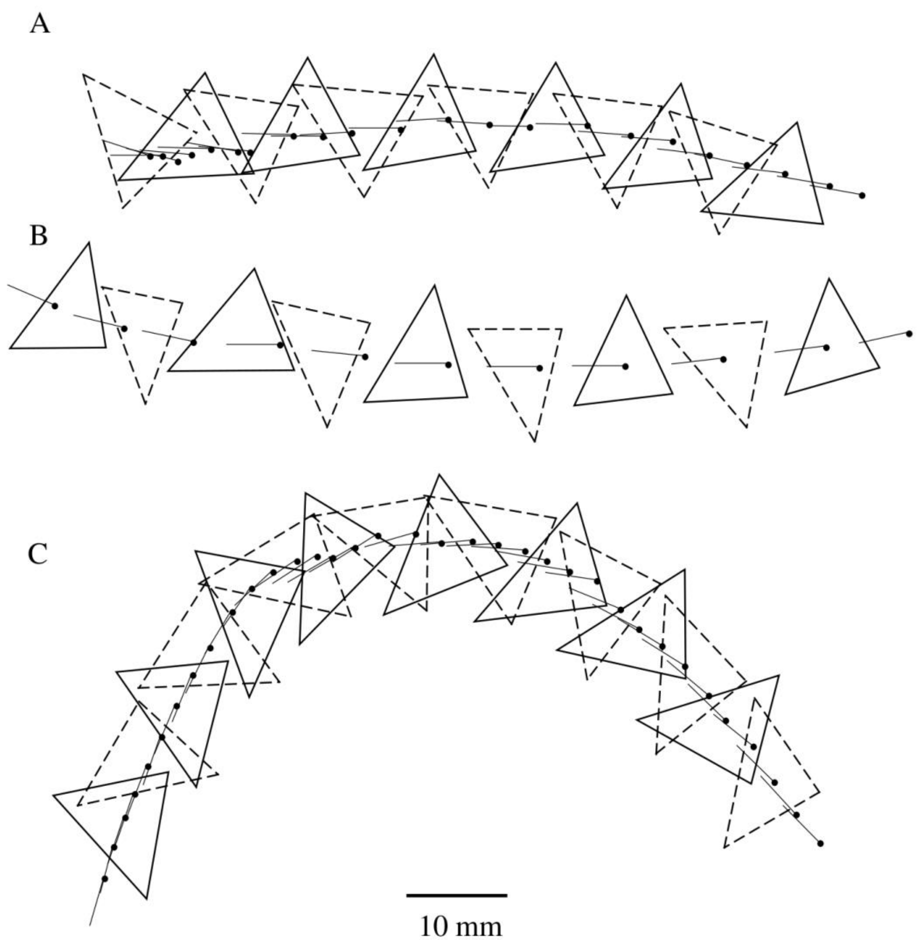
State-of-the-art

- Simulation-based
  - ✓ Accurate control
  - X Most methods are more <u>kinematic</u> than physics. Cheat?

Cenydd, L. A., & Teahan, B. (2013). An embodied approach to arthropod animation. *Computer Animation and Virtual Worlds*, *24*(1), 65-83

Biological Inspirations

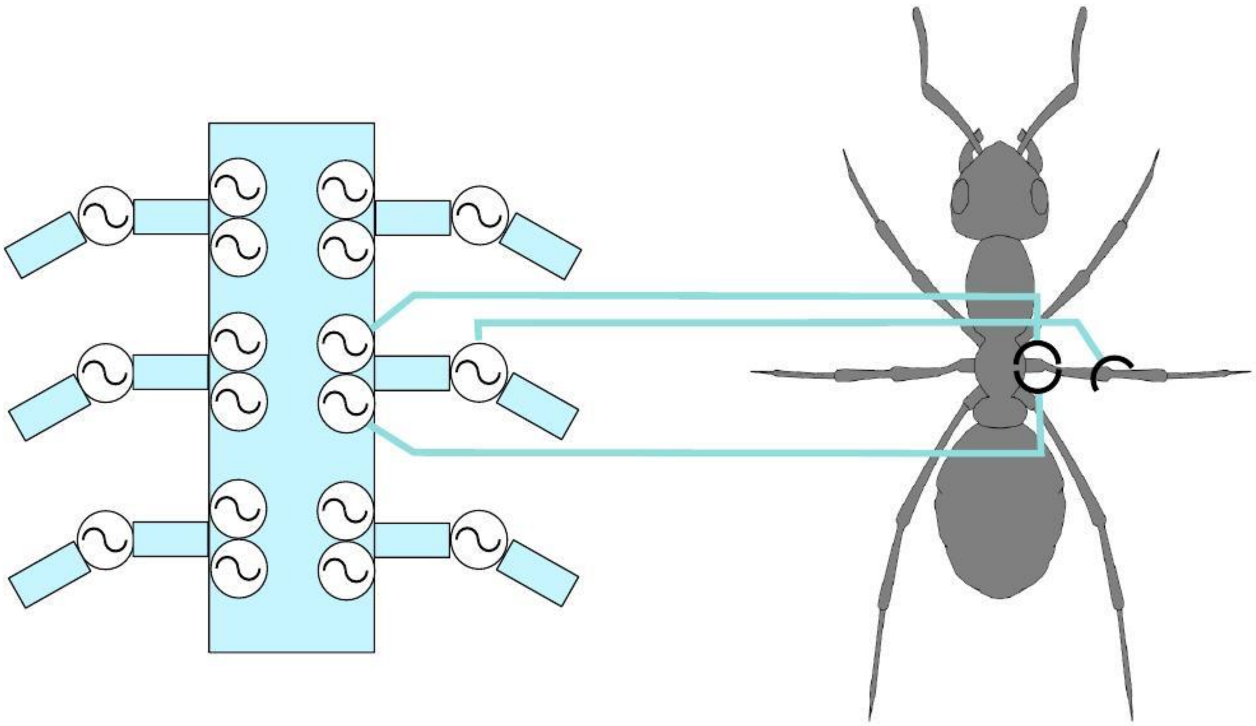
Biological Inspirations



Experimental results from zoologist Dr. Zollikofer, who conducted a series experiments to reveal the effects of morphology, load, speed and curvature on ants' gait.

- **Shape** of supporting triangles does **NOT** change at different speeds and curve paths.
- Shape of supporting triangle **changes** in the cases of carrying objects or travelling on uneven terrain.

Biological Inspirations



- Distributed System: brain and body ganglia
- Motion on each joint is controlled by independent ganglion

Research Question

Can we develop an equivalent framework, based on the biological inspirations, with following features:

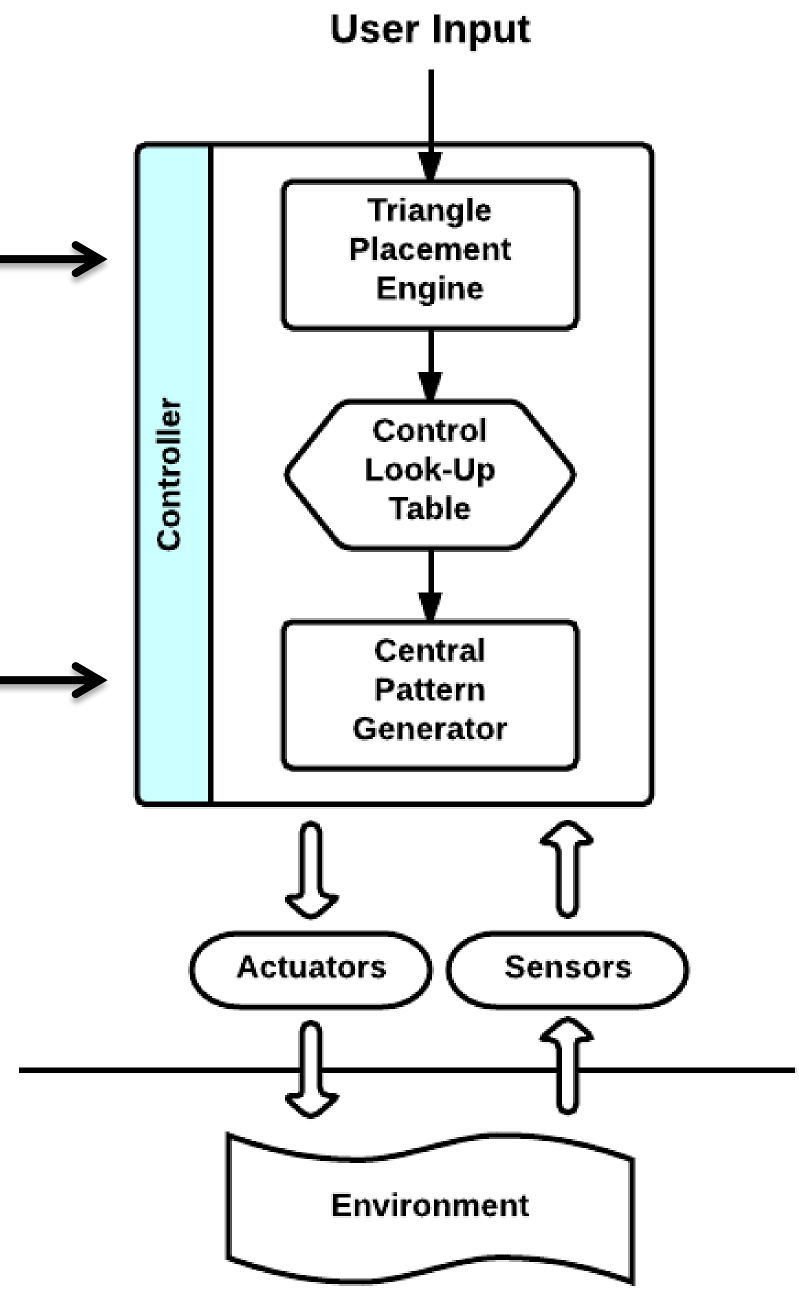
– Produce natural & physically-plausible movement

– Be artist-friendly

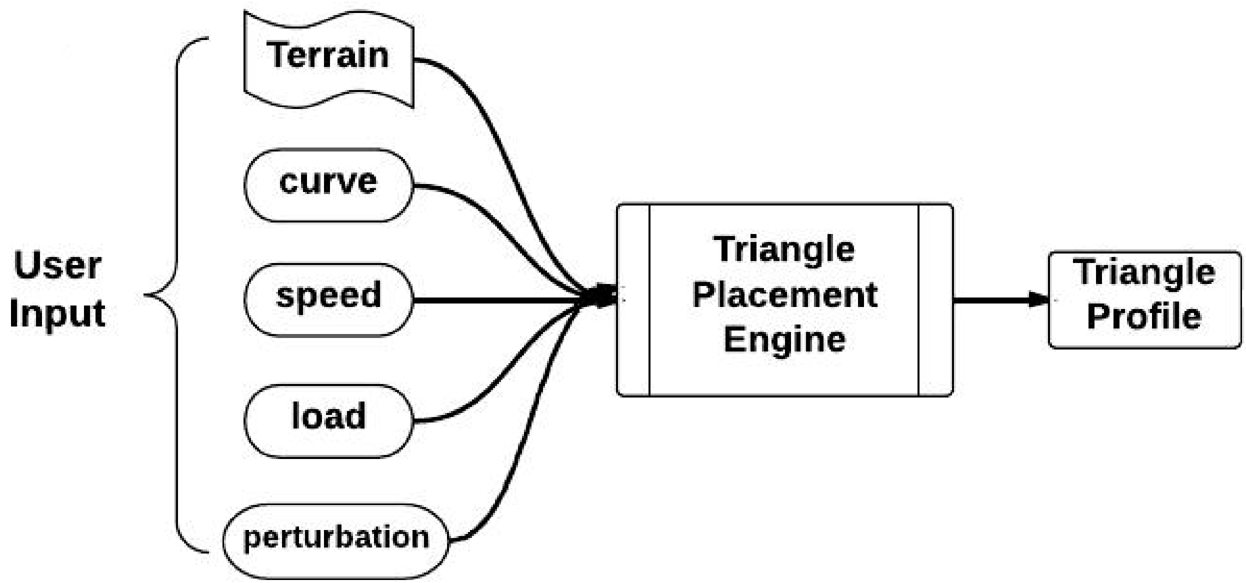
– Fast and Efficient

Fixed Gait Pattern

Distributed Nervous System

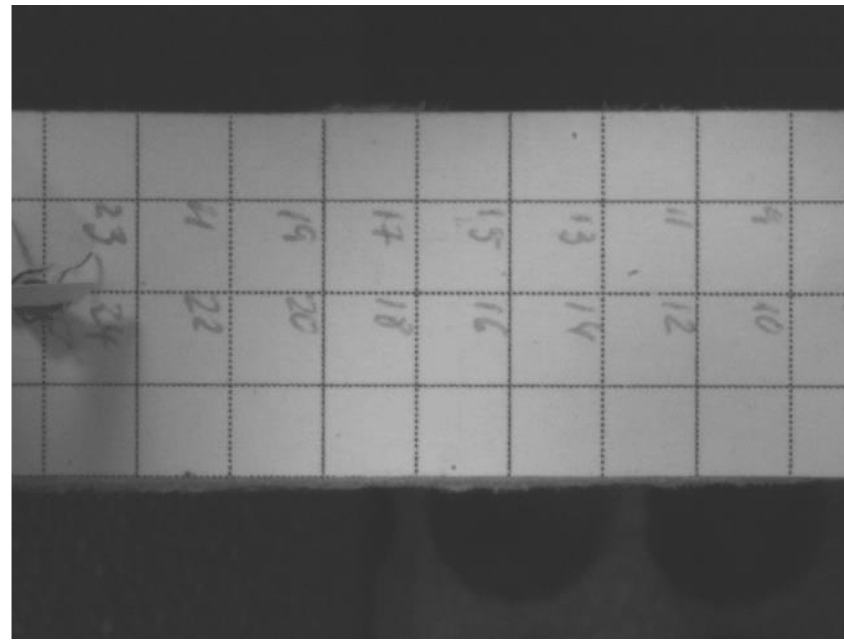


Triangle Placement Engine



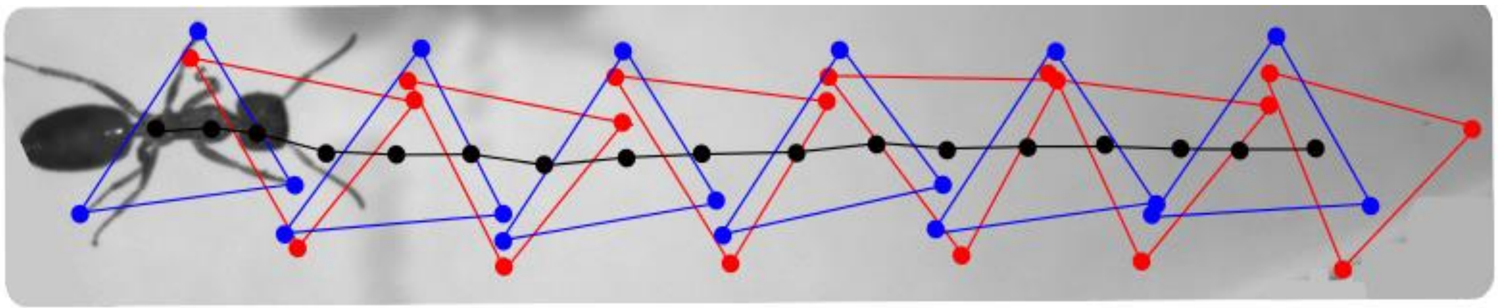
Animator is able to specify a trajectory and other settings, the supporting triangles are automatically placed on the terrain.

Capture in the lab

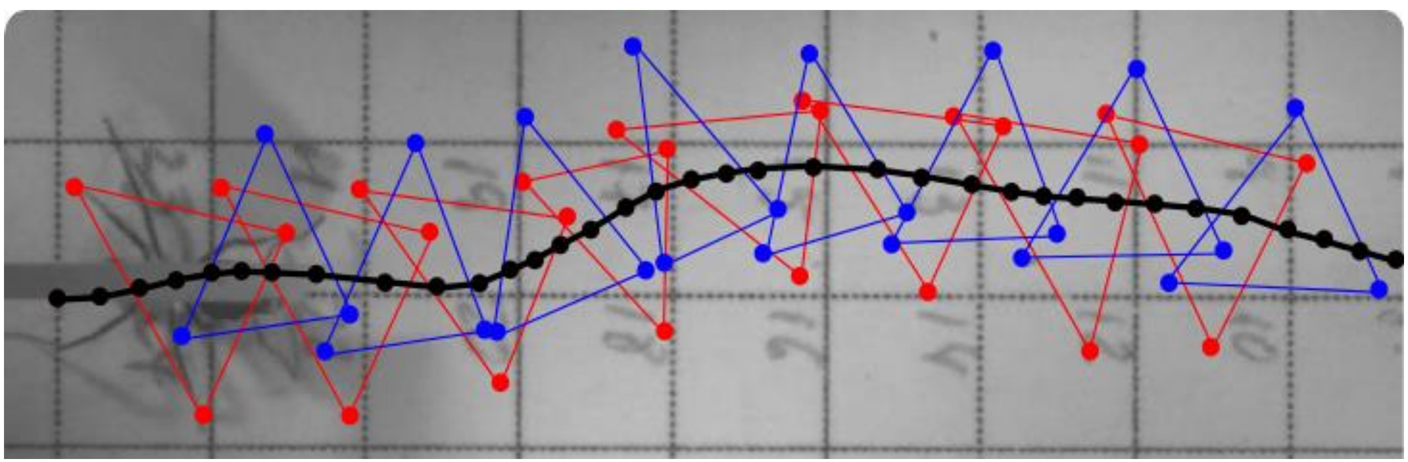


Videos are provided by collaborators from University of Cambridge and University of Freiburg.

Triangle Placement Engine

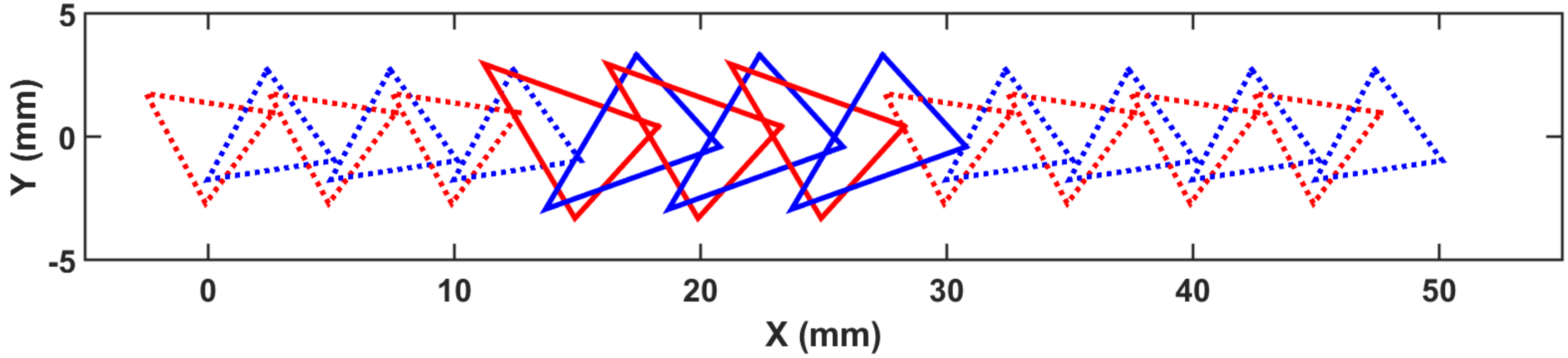


(a) Walking on a straight path



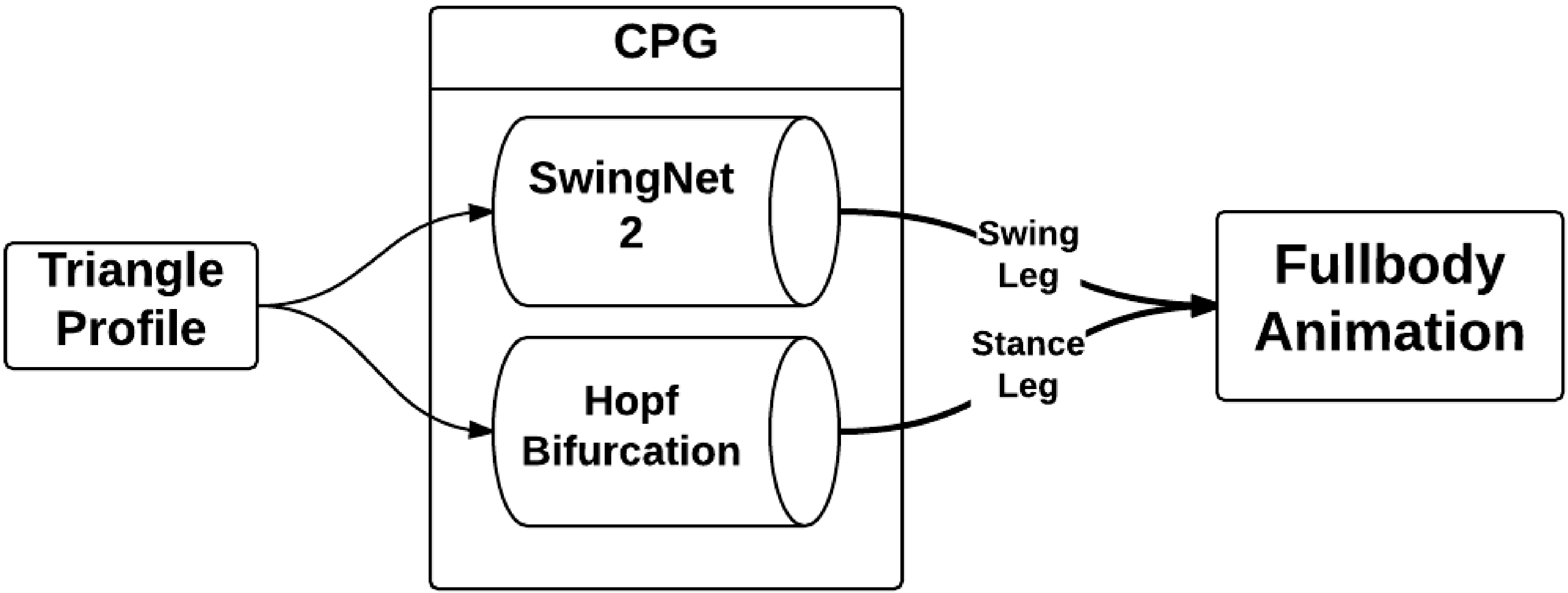
(b) Walking on a curve path

Triangle Placement Engine

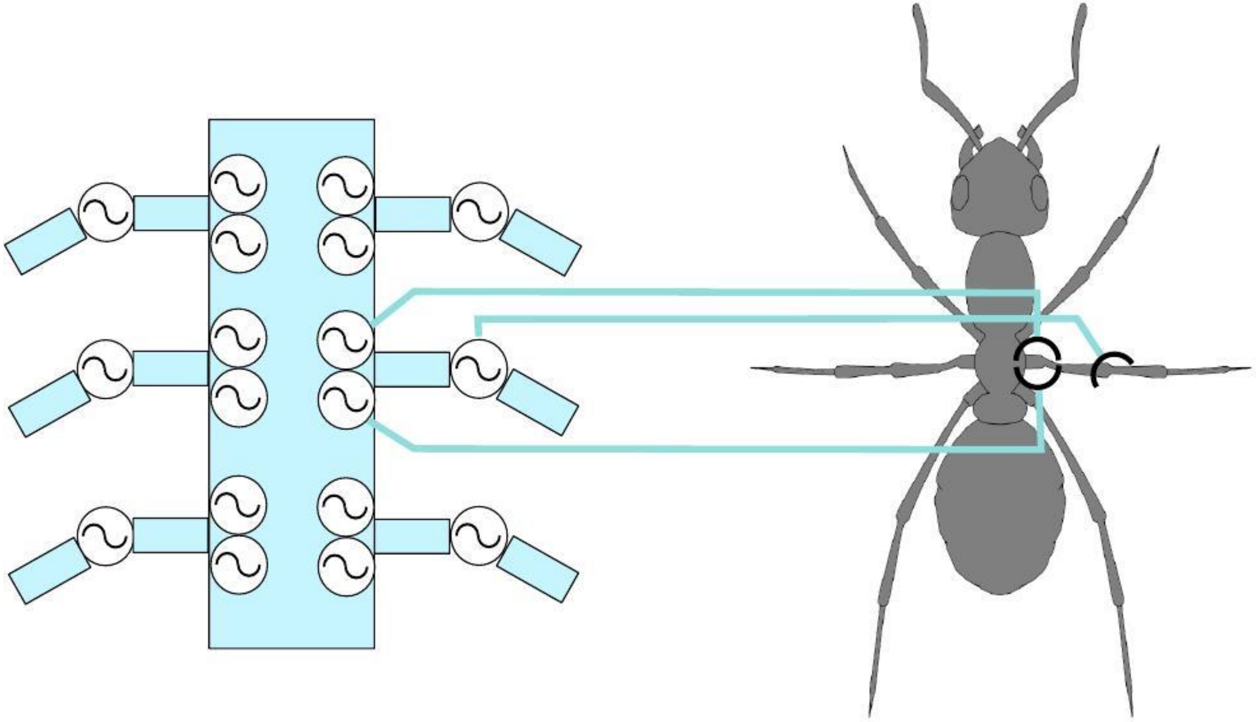


When the ant encounters some perturbations, the supporting triangle is enlarged to improve the stability.

CPG Controller



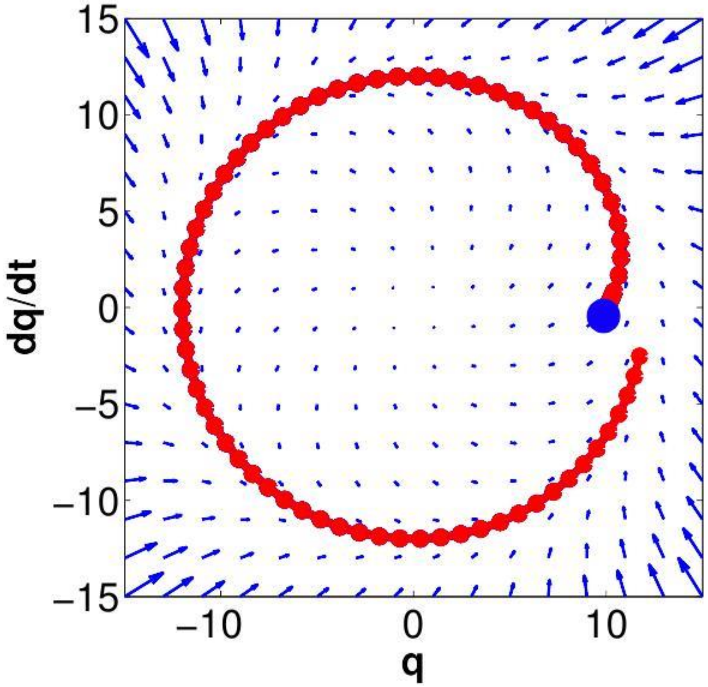
Biological Inspirations



The controller is modelled as a network of neural oscillators, and each joint is controlled by a neural oscillator (Ordinary Differential Equation).

CPG Controller

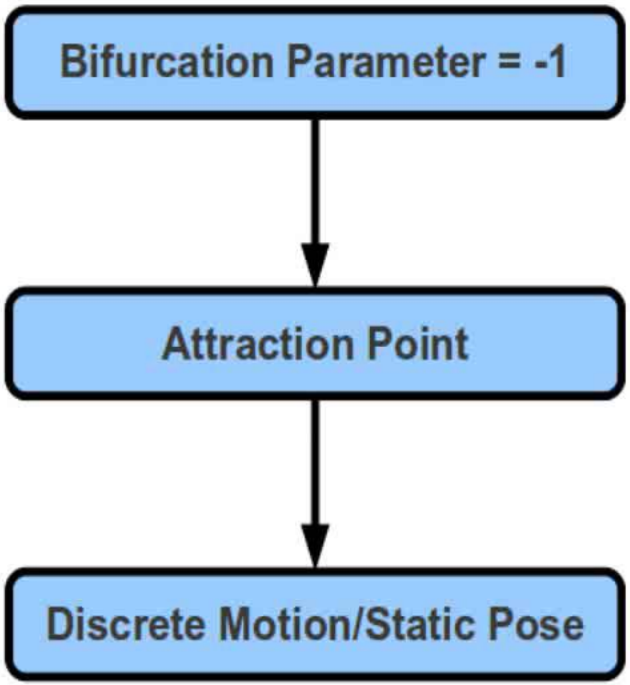
$$\begin{pmatrix} \dot{\mathbf{q}} \\ \ddot{\mathbf{q}} \end{pmatrix} = \begin{bmatrix} -\lambda(\frac{\mathbf{q}^2+\dot{\mathbf{q}}^2}{\rho^2} - \sigma) & -\omega(t) \\ \omega(t) & -\lambda(\frac{\mathbf{q}^2+\dot{\mathbf{q}}^2}{\rho^2} - \sigma) \end{bmatrix} \begin{pmatrix} \mathbf{q} \\ \dot{\mathbf{q}} \end{pmatrix}$$

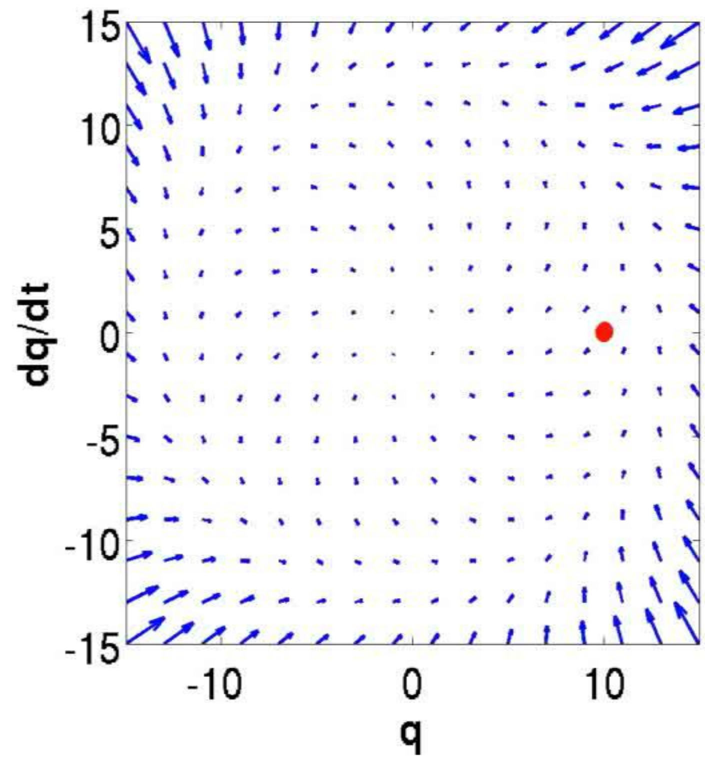


- ρ - amplitude
- Φ - phase difference
- ω - frequency
- $\overline{q}$ - average offset

These parameters are controlled to perform the specific behavior and will be optimized in later part – Controller Look-up Table.

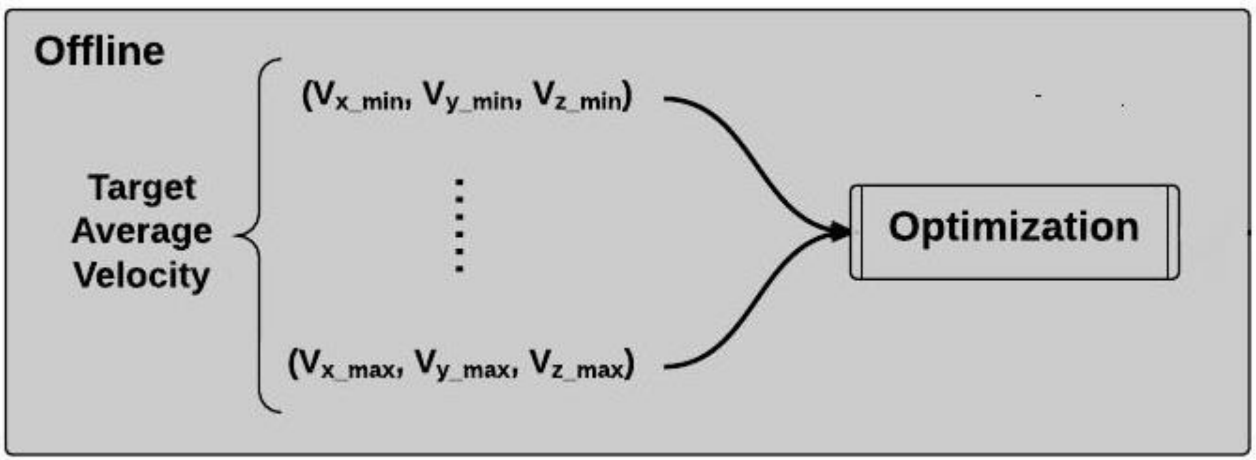
Hopf Bifurcation





Controller Look-up Table

Triangle Profiles → CLUT → CPG Parameters



CLUT is pre-computed offline and enquired during runtime, with the target velocity as input

Optimization Objective Functions

- **Minimize the differences between the target and simulated velocity in this stride**

$$E_t = \sum_i (\nu_{target} - \nu_{simulation})^2$$

- **Constrain the movements on the lateral and vertical directions**

$$E_d = \sum_i (||y_i - y^*||^2 + ||z_i - z^*||^2)$$

- **Ensure the continuity of velocity direction**

$$E_v = \sum_i ||\mathrm{v}_i||^2, if\ \mathrm{v}_i \cdot \mathrm{v}_{target} < 0$$

Result & Demo

Future Directions

- Sophisticated Model
  - Control: Spiking Neurons
  - Actuator: Muscles
- Social Behavior (Collective Transport)
- Interaction with Nature through *Evolution*

Thank you for Listening!
Questions?

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