Modeling Humans & Animals
Physics-based Animation

Controller \( \mathbf{T} \) \( \rightarrow \) Physics Engine \( q, \dot{q} \)
Posture Control
Under actuated
Inherently unstable
\[
\begin{bmatrix}
F_{\text{rd}}^d \\
T_{\text{rd}}^d
\end{bmatrix} = k_p (q_b^d - q_b) + k_d (\dot{q}_b^d - \dot{q}_b) + k_f F
\]

\[
\begin{bmatrix}
I & I & \cdots & I \\
r_0 \times & r_1 \times & \cdots & r_m \times
\end{bmatrix}
\begin{pmatrix}
F_0 \\
F_1 \\
\vdots \\
F_m
\end{pmatrix}
= \begin{pmatrix}
F_B \\
T_B
\end{pmatrix}
\]

\[
\min (A\mathbf{x} - b)^T (A\mathbf{x} - b)
\]

subject to \( F_i^n \geq F_{\text{min}} \)

\(- \mu F_i^n \leq F_i^t \leq \mu F_i^n\)
\[ \tau = J^T F \]
Walking

• Described *temporally* in terms of stride duration and its two components per leg, swing time and stance time
Walking

• Described **temporally** in terms of stride duration and its two components per leg, swing time and stance time, and **spatially** in terms of foot placement locations
Foot Placement Control

d = d_f(v_d) + (v - v_d) \sqrt{\frac{h}{g}}
Foot Placement Control
Towards Increasingly Complex Motor Skills
## Quadrupedal Gaits

<table>
<thead>
<tr>
<th>Trot</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
</tr>
<tr>
<td>FR</td>
</tr>
<tr>
<td>FL</td>
</tr>
<tr>
<td>RL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Canter</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
</tr>
<tr>
<td>FR</td>
</tr>
<tr>
<td>FL</td>
</tr>
<tr>
<td>RL</td>
</tr>
</tbody>
</table>
Controller Parameterization

\[ h(t) \]

\[ d_f \]

\[ T \]
Motion Data
After Learning

walk
Locomotion Control for Legged Robots
Locomotion Control for Legged Robots
Physics simulation and sampling

Online Motion Synthesis Using Sequential Monte Carlo

Perttu Hämäläinen¹ Sebastian Eriksson¹ Esa Tanskanen¹ Ville Kyrki¹ Jaakko Lehtinen¹ ²

¹Aalto University ²NVIDIA Research


Part of the Future Game Animation project.

An example of emergent evasive behavior generated by our method.

https://mediatech.aalto.fi/publications/graphics/OnlineSMC/
Physics simulation and sampling

Online Control of Simulated Humanoids Using Particle Belief Propagation

Perttu Hämäläinen¹ Joose Rajamäki¹ C. Karen Liu²

¹Aalto University ²Georgia Tech


Part of the Future Game Animation project.

Our algorithm can handle complex balancing and manipulation tasks while adapting to user interactions. All our demonstrated movements emerge from simple cost functions without animation data or offline precomputation.

https://mediatech.aalto.fi/publications/graphics/C-PBP/
Physics simulation and sampling

https://github.com/deepmind/mujoco_mpc
Improving the biomechanical model

Flexible Muscle-Based Locomotion for Bipedal Creatures

SIGGRAPH ASIA 2013

Thomas Geijtenbeek
Michiel van de Panne
Frank van der Stappen
Learning new skills

Learning new skills

Learning to Get Up

Tianxin Tao, Matthew Wilson, Ruiyu Gou, Michiel van de Panne

University of British Columbia

Learning new skills

What is a VAE?

VAE without simulation

Creating variation from limited motion

What about performance?