Neuromusculoskeletal Simulation by Interfacing OpenSim with NEST

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Florian Walter
Technical University of Munich
Department of Informatics
Robotics and Embedded Systems

Motivation & Goals

Motivation

• Spinal reflex circuits are among the simplest building blocks of the nervous system
• Simulation of basic reflexes as a first step towards an integration of musculoskeletal modeling and neural motor control

Goals

• Implementation of a spiking neuron model of the monosynaptic stretch reflex
• Connect this model to a musculoskeletal simulator

Image Credit:
http://www.backpain-guide.com/Chapter_Fig_Folders/Ch05_Anatomy_Folder/OverallSpine.html
http://www.newhealthadvisor.com/Neuromuscular-Junction.html
Earlier Work

Neuromuscular Simulation of the Biceps Stretch Reflex by Sreenivasa et al. (2013)

- Simulation with pools of Integrate-and-Fire Neurons is connected to a realistic musculoskeletal simulation
- Neural architecture based on the spine
  - Two motor neurons pools control biceps and triceps
  - Two sensory neuron pools encode velocities of biceps and triceps
  - One pool of interneurons for inhibitory disynaptic connections
- Neural and musculoskeletal parameters are derived from experimental results

Background: Monosynaptic Spinal Reflexes

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NEST

Overview
- Spiking neural network simulator for point neuron models
- Neural networks can be defined in Python using PyNEST or PyNN and in the native Simulation Language Interpreter (SLI)

Technical Details
- Source code freely available (GNU Public License)
- Runs on POSIX compatible operating systems (i.e. not on Windows)

OpenSim

Overview
- Musculoskeletal modelling and simulation environment
- Mainly designed for offline motion analysis in medical applications
  - Compute muscle forces
  - Simulate muscle transfer surgeries
  - Visualize and analyze motion tracking data
- Built-in support for different Hill-type muscle models (Thelen, Millard)
- Computes both forward and inverse kinematics and dynamics
- Musculoskeletal models freely available

Applications
Rehabilitation, Orthopedics, Robotics, Ergonomics, Performance, Design
OpenSim – Example: Gait Analysis

OpenSim – Example: Analysis
OpenSim – Technical Details

OpenSim GUI
- Graphical Windows application for configuration, visualization and analysis
- Closed-source

OpenSim API
- Backend for implementing new simulations and for modelling biological structures
- Works also in stand-alone mode without the GUI
- Can be augmented with new controllers and analysis tools
- Based on C++
- Source code is available and compiles on all major operating systems

Conclusions of the Initial Evaluation
- An interface between NEST and OpenSim requires to translate between Python and C++
- The OpenSim GUI cannot be used to set parameters and control the simulation
- Simulations can only be computed offline, which means that no real-time visualization is available
- The huge model database and the sophisticated simulation framework support will enable highly realistic biomechanical experiments
Current State

- Spinal Reflex Circuit Model
- Model Parameter Adaption
- Musculoskeletal Arm Model (included in OpenSim)
- OpenSim-NEST Interface

Outlook

- Evaluate the implemented reflexes in a virtual biomechanical experiment
- Integrate the results as a new experiment into the Neurorobotics Platform
- Implement and evaluate the neural simulation of spinal reflexes on Myorobotics
- Combine reflexes with cerebellar control
- ...
References


Thank You!

www.neurorobotics.net

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