

# SCONE: Open Source Software for Predictive Simulation of Biological Motion

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## I. INTRODUCTION

Even though individual branches of neuroscience and biomechanics have produced a wealth of knowledge of the components comprising biological motion, the fundamental question of how the neural, muscular and skeletal systems operate together to produce efficient and purposeful motion remains largely unanswered. Real-world experimentation is not ideal for gaining a higher-level understanding of biological motion, as experimental setups are often challenging to conceive and limited in scope, while relevant data are often unavailable or coarse-grained.

Fortunately, neuromusculoskeletal simulations provide an animal-friendly alternative that does not have these limitations. They can *predict* motion by optimizing model parameters to perform a given task optimally, according to high-level objectives such as energy efficiency and pain avoidance. Not only do these predictive simulations enable helpful real-world applications – such as optimizing assistive devices *in silico* or predicting treatment outcome – they permit fundamental *what-if?* questions, allowing researchers to investigate the effects of individual model parameters on the motion as a whole.

Despite having shown great promise [1]–[3], the number of studies that have successfully employed predictive simulations of biological motion is limited. A main contributing factor is complexity: besides expertise in neurological and musculoskeletal modeling, researchers require knowledge and understanding of optimization theory, as well as advanced software development skills to tie these components together. Even successful projects often do not lead to fruitful collaboration and follow-up research, due to lack of structure and documentation of the resulting code-base.

SCONE [4] is a free, open source initiative designed to help overcome these obstacles.

## II. SOFTWARE OVERVIEW

SCONE is a fully featured software framework that allows researchers to perform, analyze and reproduce custom predictive simulations of biological motion. Features include:

- A user-friendly graphical user interface for developing, optimizing, and analyzing predictive simulations (Fig. 1).
- Support for any existing OpenSim model [5].
- Optional support for additional dynamics simulation software through a custom C++ API.

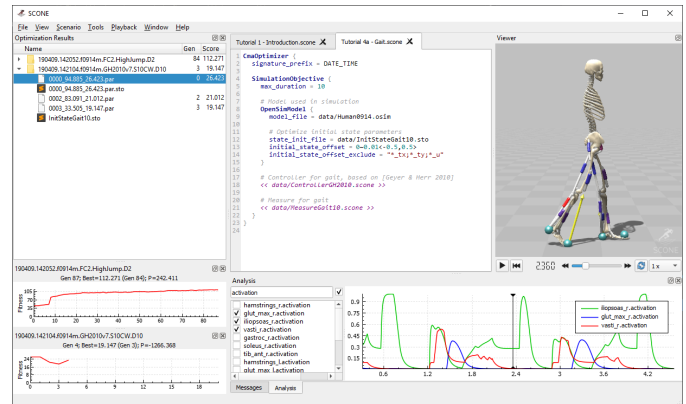


Fig. 1. The SCONE User Interface

- Support for a wide range of parameterized controllers using the modular control system or through scripting.
- Support for custom objective functions, based on predefined components or through scripting.
- Both model and control parameters can be optimized simultaneously using *Covariance Matrix Adaptation* [6].
- On-line tutorials and examples to help you get started.

## III. LICENSE AND AVAILABILITY

SCONE is freely available for download under the terms of the GNU Public License. See <https://scone.software> for more details, funding and acknowledgements.

## REFERENCES

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