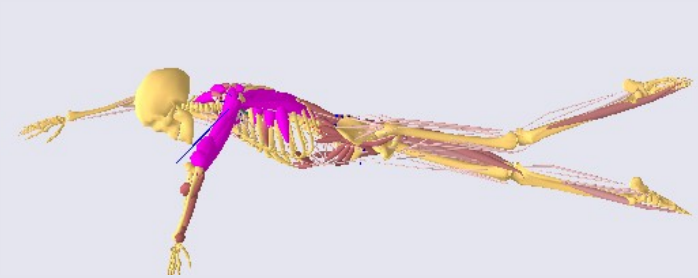
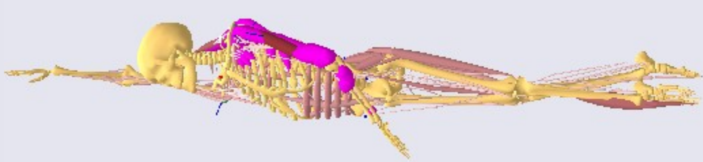
Development of a Musculoskeletal Simulator for Swimming

Motomu Nakashima





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Presenters

Motomu Nakashima
(Presenter)

Søren Tørholm
(Host)

John Rasmussen
(Panelist)

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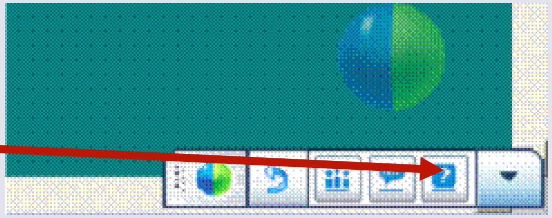
Q&A Panel



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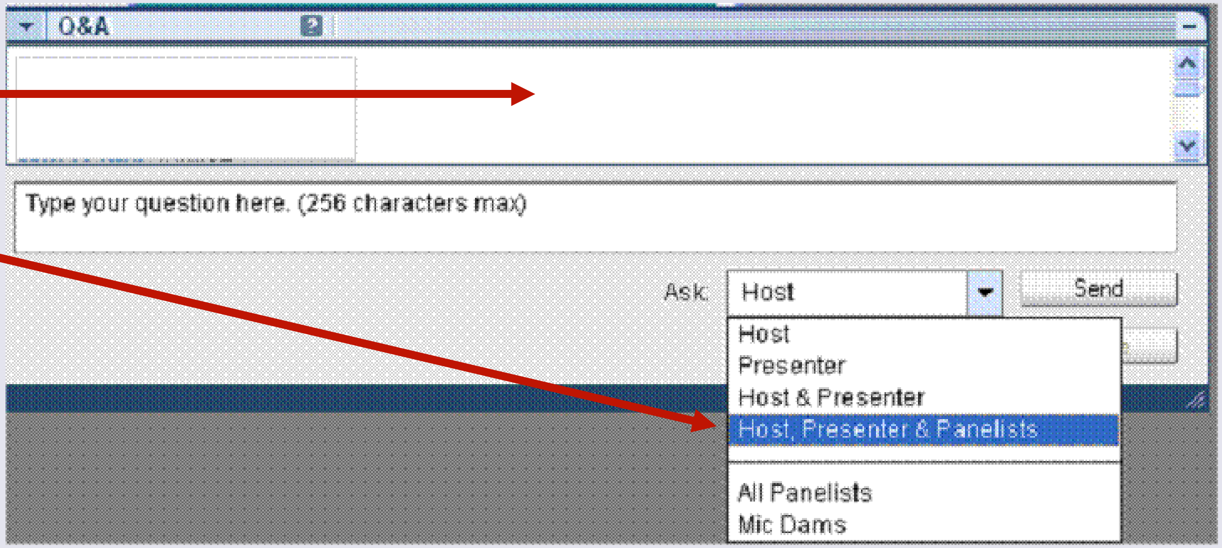

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Self Introduction (1)

- Motomu Nakashima
  - Doctor of Mechanical Engineering (1995)
  - Associate Professor
  - Tokyo Institute of Technology
  - Graduate School of Information Science and Engineering
  - Department of Mechanical Environmental Informatics (teaching mechanical engineering)

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Self Introduction (2)

- Present research fields
  - Biomechanics
    - Swimming
    - Skydiving
    - Sports injury
  - Sports Engineering
    - Developing new instruments for sports

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Today’s topic

1. Title: “Development of a musculoskeletal simulator for swimming”
2. Mainly done by Mr. Yugo Motegi, as his master thesis.
3. Presented at the International Symposium on Computer Simulation in Biomechanics (ISCSB2007) in Taiwan on the last June.
4. The manuscript of the paper is available at the SWUM’s website:

http://www.swum.org/

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Questions, it is ok to ask

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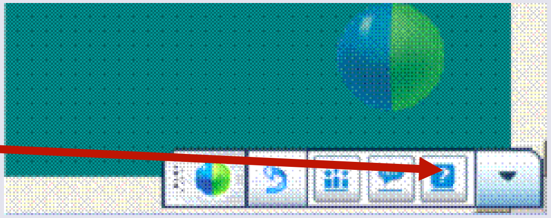

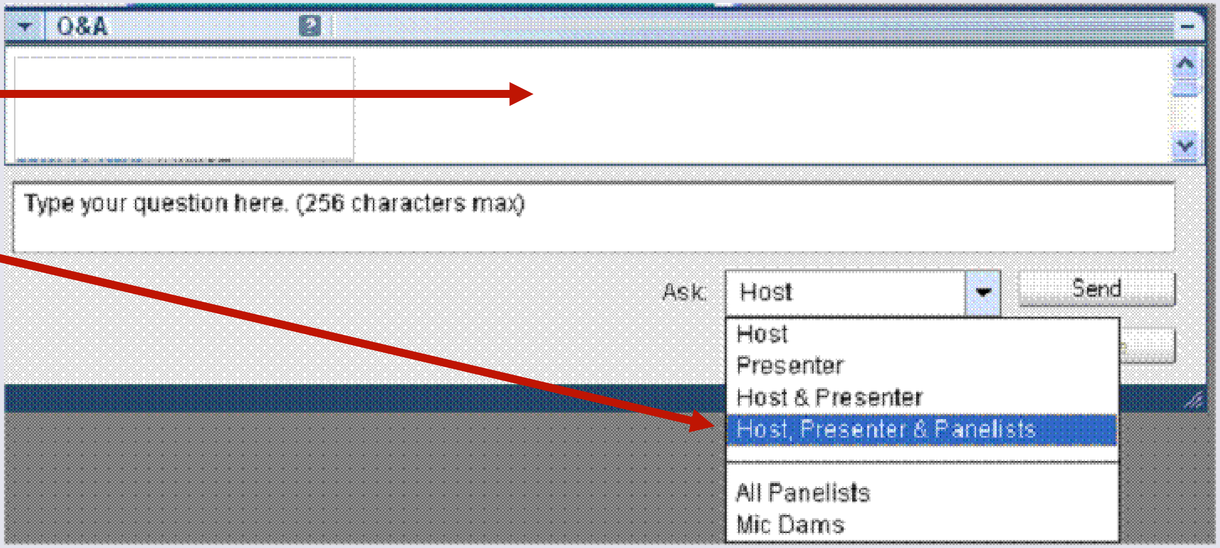

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- Introduction (Background and Objectives)
- SWUM (and Swumsuit)
- AnyBody Modeling System
- Integrating SWUM and AnyBody
- Demos and simulation results
- Comparison with EMG results
- Concluding remarks
- Q and A

Introduction (Background)

- There have been no studies of the musculoskeletal analysis for swimming although it will provide very useful information for the athlete swimmer's training and coaching.
- The reason of this is that the external force (fluid force) acting on the whole body as the input to the musculoskeletal analysis was difficult to obtain so far.
- The authors have recently developed a simulation model SWUM (SWimming hUman Model) which enables to calculate fluid force acting on the whole body.

Introduction (Objectives)

- To develop a full-body musculoskeletal simulator, by integrating SWUM and musculoskeletal model (AnyBody Modeling System).
- To conduct the musculoskeletal analysis of swimming.
- To examine the validity of the simulator by comparing the simulation results with EMG results in a previous study.

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"SWUM" (and its implemented software "Swumsuit")

- Human body : 21 segments as truncated elliptic cones
- Relative body motion is given.
- The fluid force is modeled and computed without solving flow for each part of the body.
- By time-integrating EOM for the whole human body, the absolute motion, fluid force, and so on are obtained as outputs.
- You can obtain information about SWUM at its website: http://www.swum.org/
- Swumsuit is a free software available on the website.

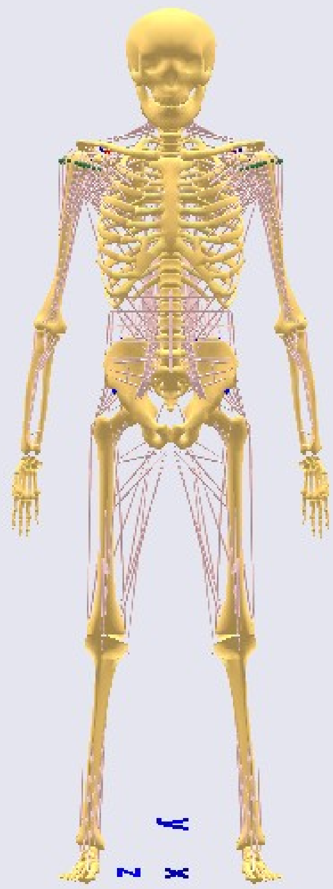
Simulation example (Crawl stroke)

Movies are available at the SWUM's website: http://www.swum.org/

Contents

AnyBody Modeling System

- Input : body motion and external forces
- Output : muscle activity
- All Input data are described in AnyScript (Object oriented programming language).
- Full-body model with 458 muscles was used.
- Version 2.0.



AnyBody's Full-body model

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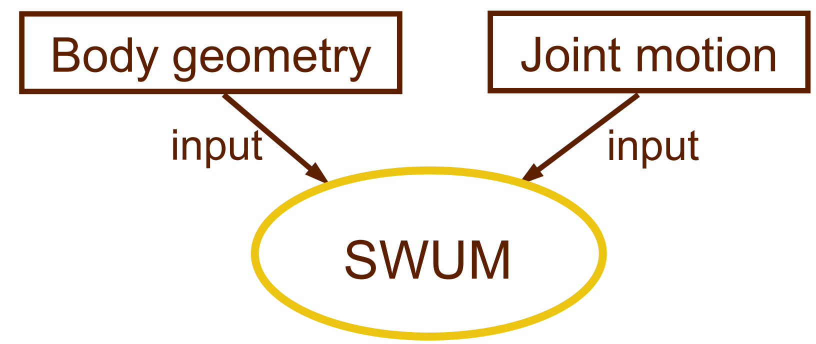
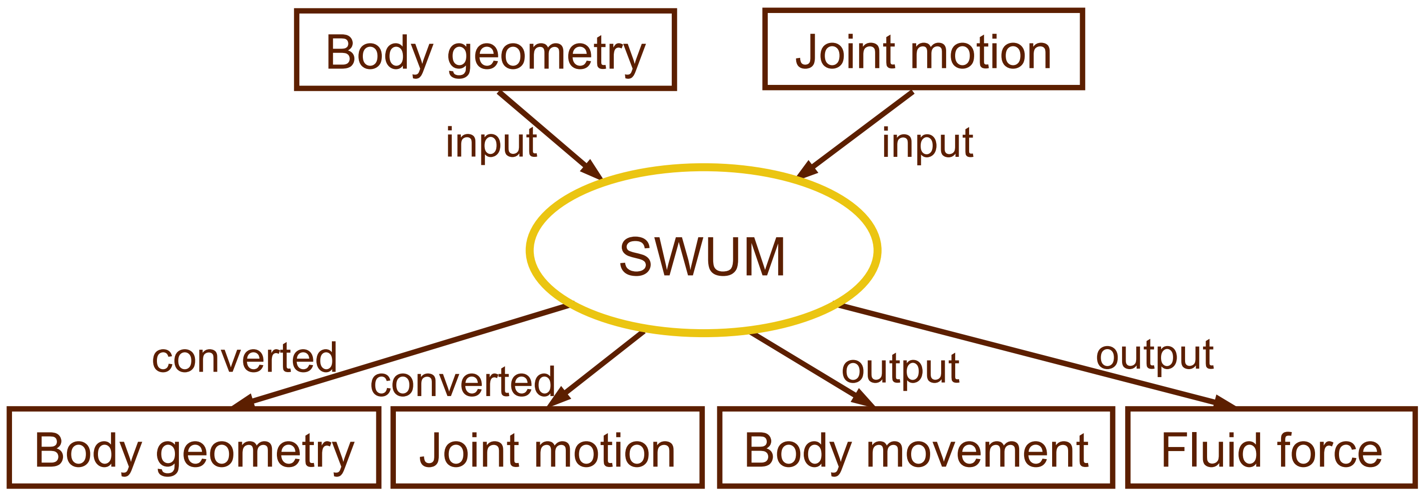
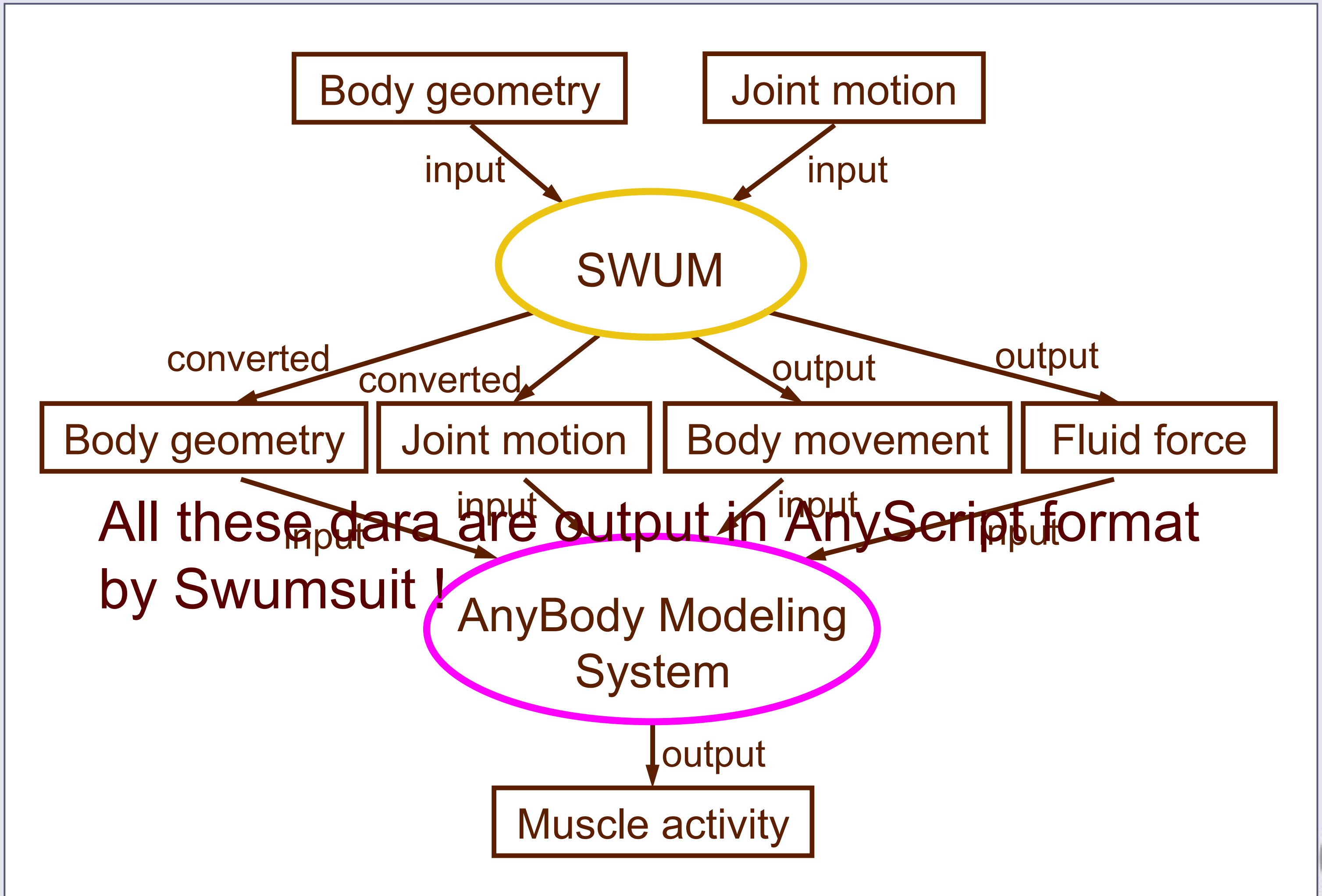
Integrating SWUM and AnyBody (1) Whole data flow



Integrating SWUM and AnyBody (1) Whole data flow



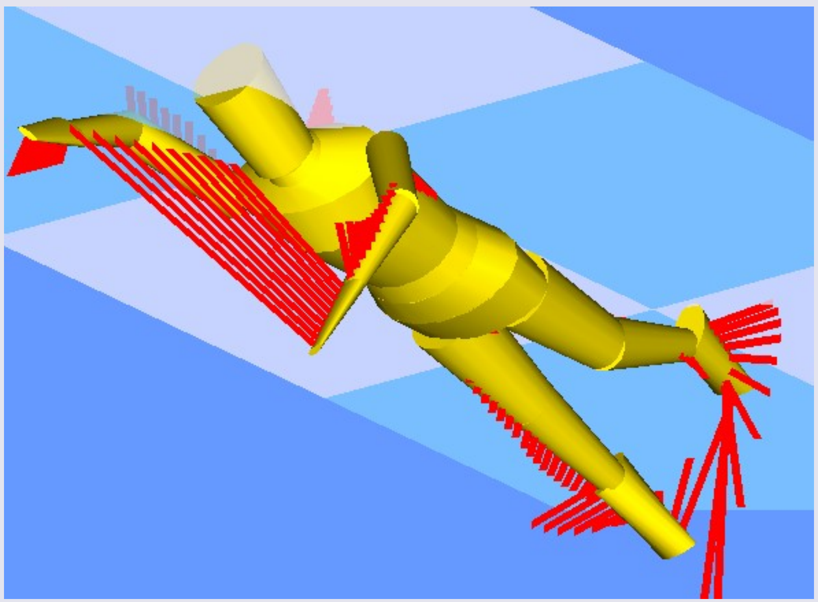
Integrating SWUM and AnyBody (1) Whole data flow



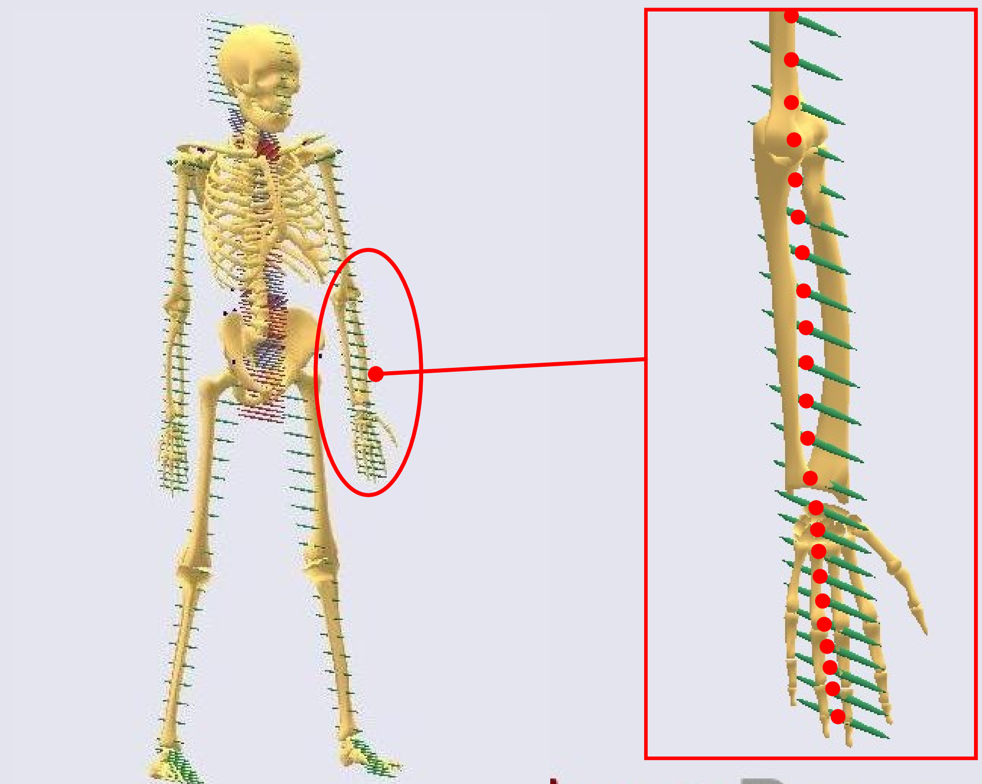
All these dara are output in AnyScript format by Swumsuit !

Integrating SWUM and AnyBody (2) Fluid force

- Fluid force, which is calculated at each part of the body in SWUM, is input to AnyBody for 210 points.



Fluid force in SWUM



Fluid force acting points in AnyBody

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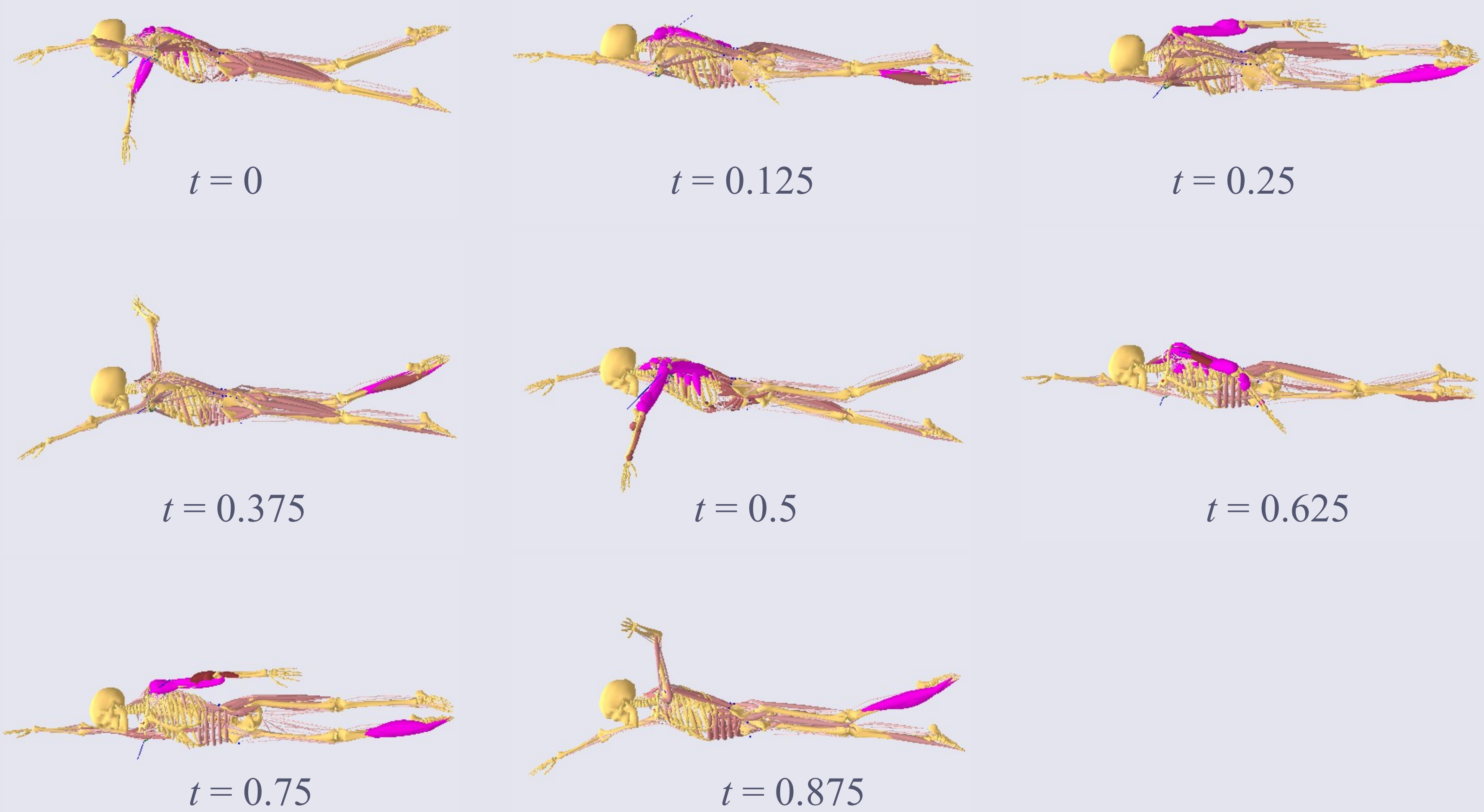
Live demo of the developed simulator

Simulation results

- Specifications
  - Crawl stroke
    - Swimming motion (joint motion) was created based on a movie of an actual swimmer, who was an Olympic finalist.
    - Swimming speed : 1.2 m/s (not full-strength)
    - Stroke cycle : 2.0 sec
  - Body geometry: AnyBody's original model

Simulation results of Crawl Stroke



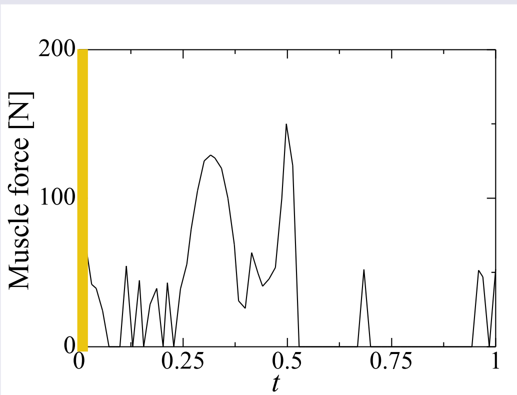
t is time non-dimensionalized by stroke cycle.

Animations are available at http://www.swum.org/

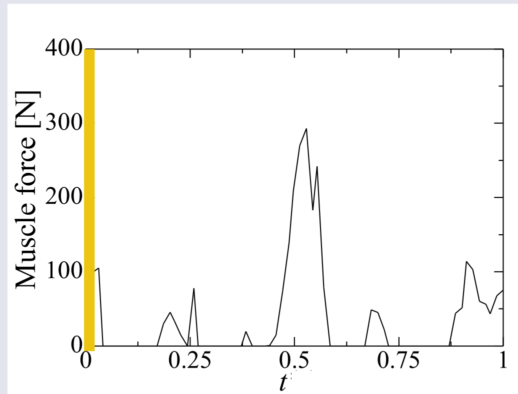
ANYBODY TECHNOLOGY

Simulation results (Muscle force around left arm)

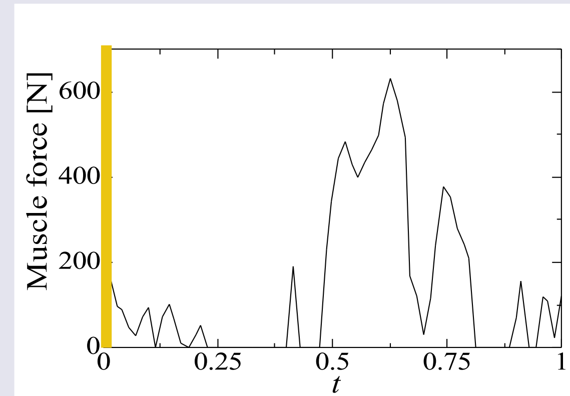
- Entry phase (Hand’s entry to the water)



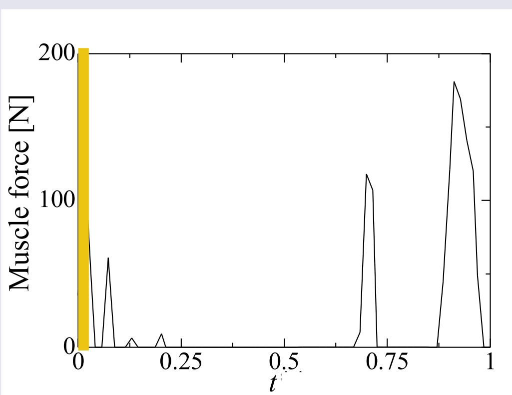
Pectoralis major



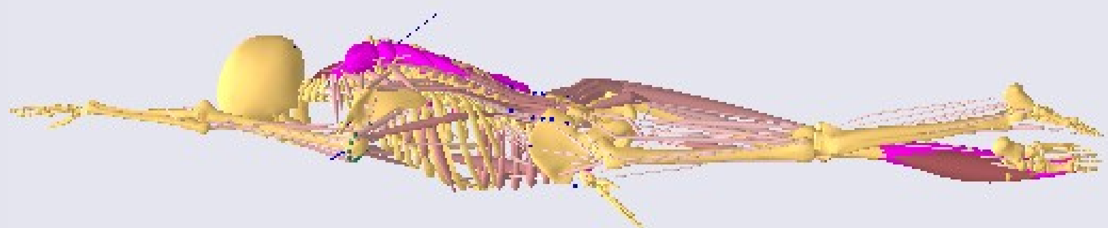
Latissimus dorsi



Triceps brachii

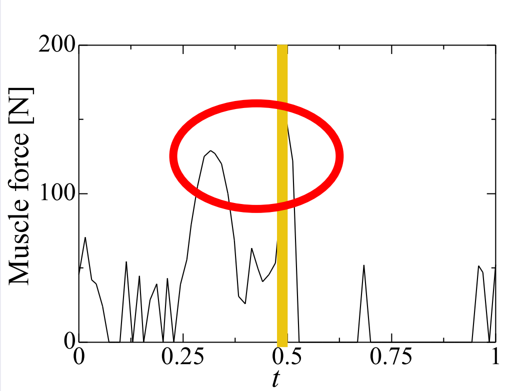


Anterior deltoid

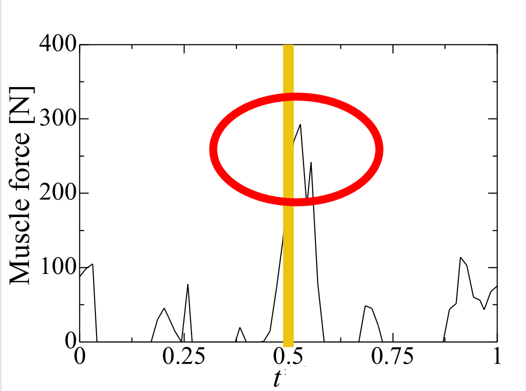


Simulation results (Muscle force around left arm)

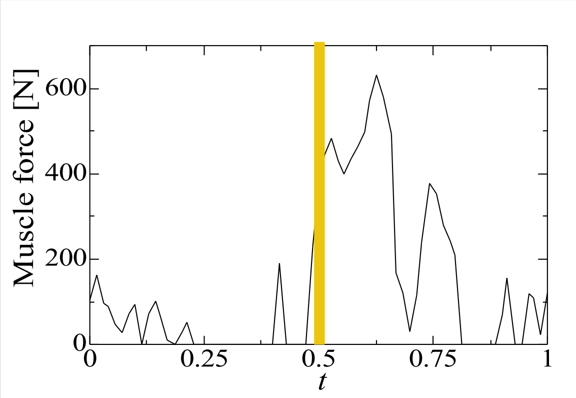
- Pull phase (Pulling the water)



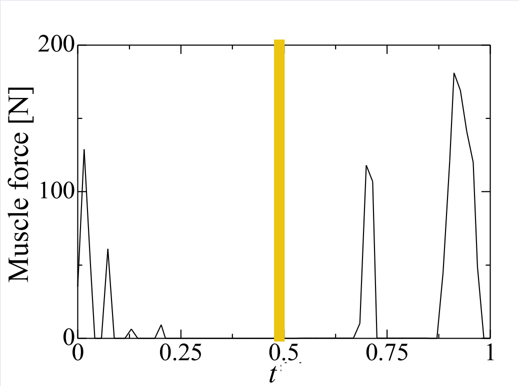
Pectoralis major



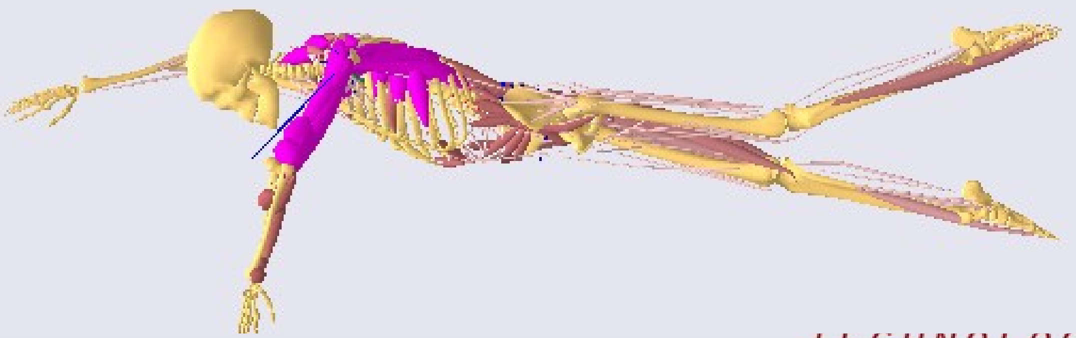
Latissimus dorsi



Triceps brachii



Anterior deltoid



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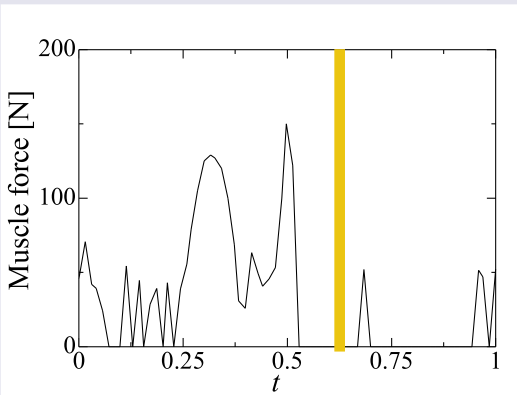
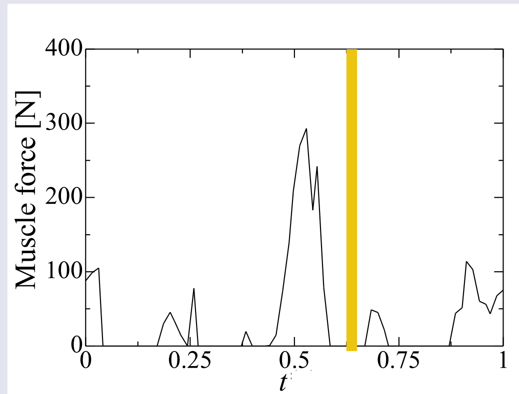
Simulation results (Muscle force around left arm)

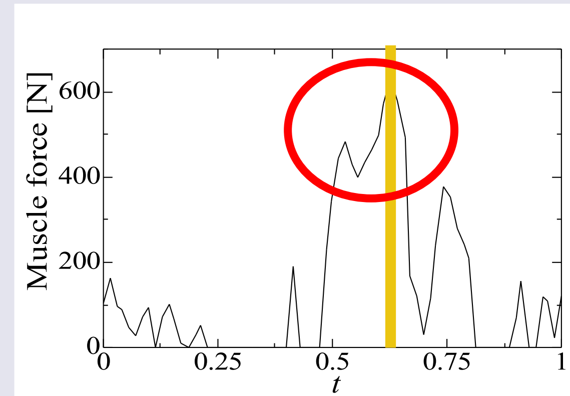
- Push phase (Pushing the water)



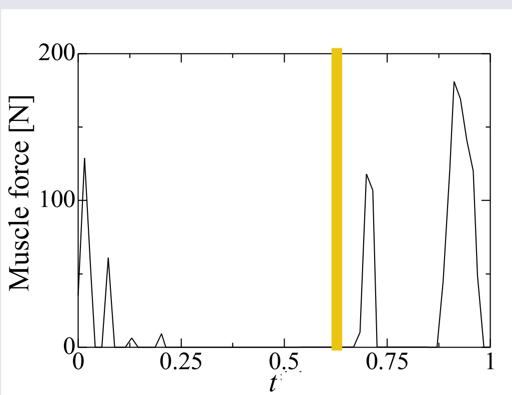
Pectoralis major



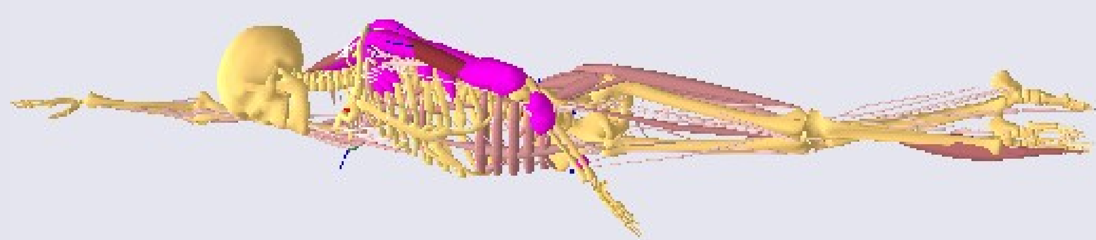
Latissimus dorsi



Triceps brachii



Anterior deltoid



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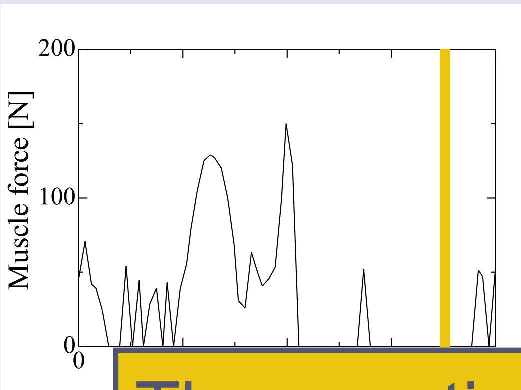
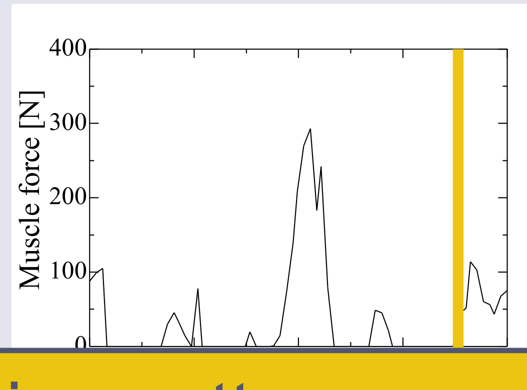
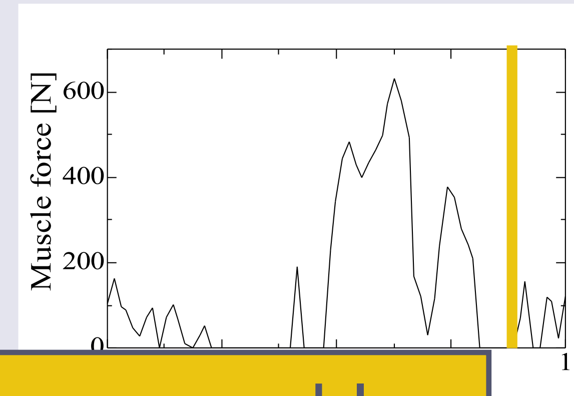
Simulation results (Muscle force around left arm)

- Recovery phase (Arm outside the water)







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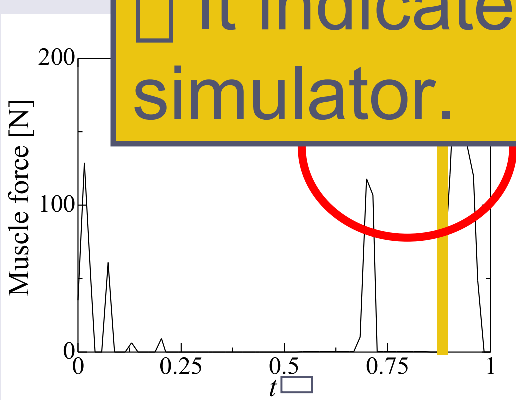
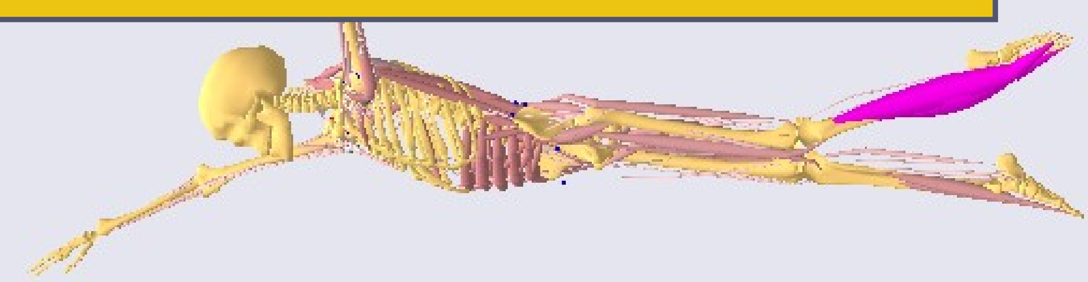
These activation patterns seem reasonable.
□ It indicates a certain validity of the simulator.



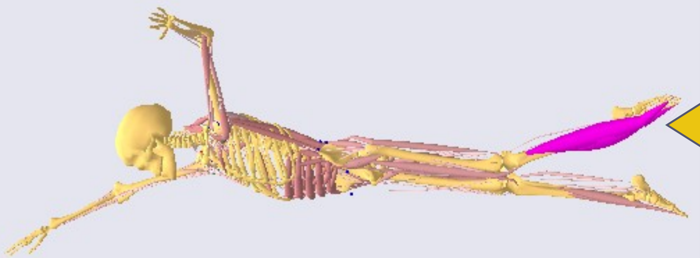
Anterior deltoid



Summary of the results

- Seems reasonable for upper limbs.
- Tibialis anterior is unnaturally activated.

  → problem of muscle model, which should be fixed in the future study.



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Simulation results of other three strokes

Breaststroke

Backstroke

Butterfly stroke

All animations are available at http://www.swum.org/

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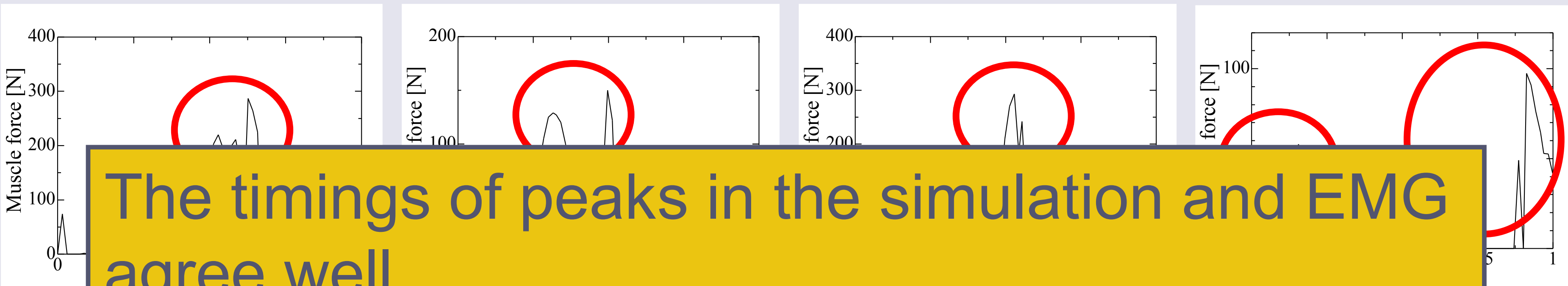
Comparison with EMG for muscles around shoulder

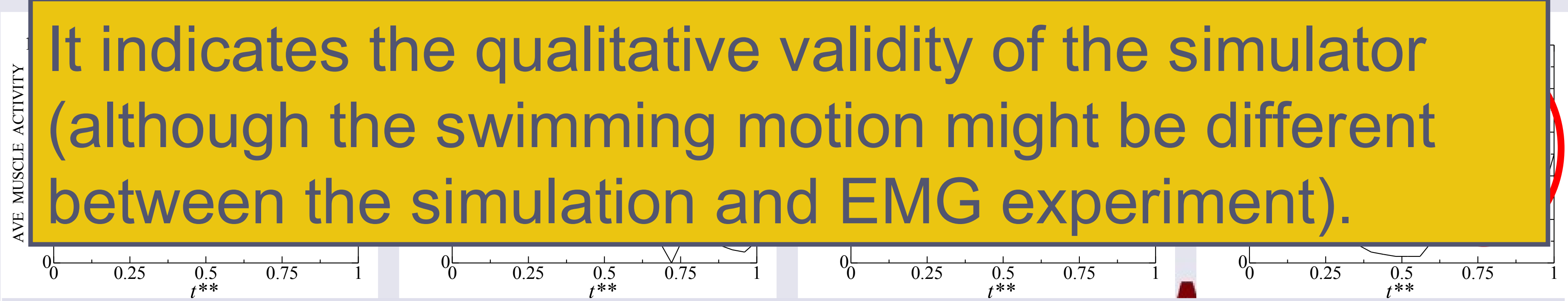
- Simulation



The timings of peaks in the simulation and EMG agree well.

Posterior deltoid Pectoralis major Latissimus dorsi Trapezius

- EMG (measured by [illegible]nk et al. (1991))



It indicates the qualitative validity of the simulator (although the swimming motion might be different between the simulation and EMG experiment).

Posterior deltoid Pectoralis major Latissimus dorsi Trapezius

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Concluding remarks

- A musculoskeletal simulator for swimming was developed.
- Good agreement between the simulation and EMG indicates the qualitative validity of this simulator.
- Future study will include a more detailed comparison by measuring the swimming motion and EMG simultaneously for the same swimmer.

Thank you for your kind attention.