How to synthesize posture and movement with inverse dynamics

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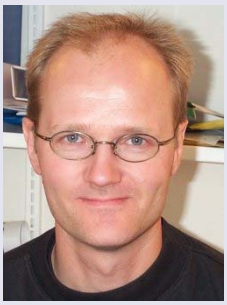
Presenters



John Rasmussen
(Presenter)

Arne Kiis
(Host)

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Q&A Panel

- Søren Tørholm & Michael Damsgaard.
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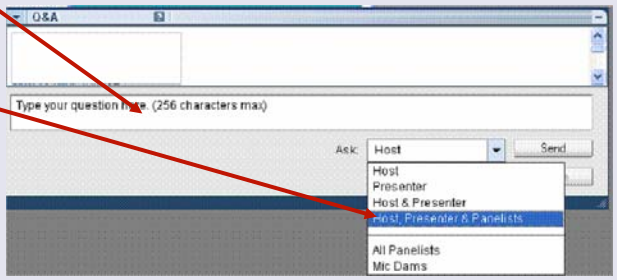

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1/3: Background and Methods

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Background

- We have very detailed and increasingly reliable models.
- We hope they can reduce the need for experiments with humans.
- Prediction of human behavior in the form of posture and movement prediction is needed for many applications.
- Without this, we are still stuck with experiments.

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Background

- Inverse dynamics is usually perceived as requiring posture, movement and **all external forces as input**.
- Movement synthesis is usually perceiv as affiliated with forward dynamics only.
- Outstanding example: Synthesis of Ga Anderson and Pandy.
- It turns out that inverse dynamics
  - Can compute interface forces
  - Can synthesize movement
  - May be more computationally efficient.

Popular misconception but not the topic of this presentation

Focus of this presentation

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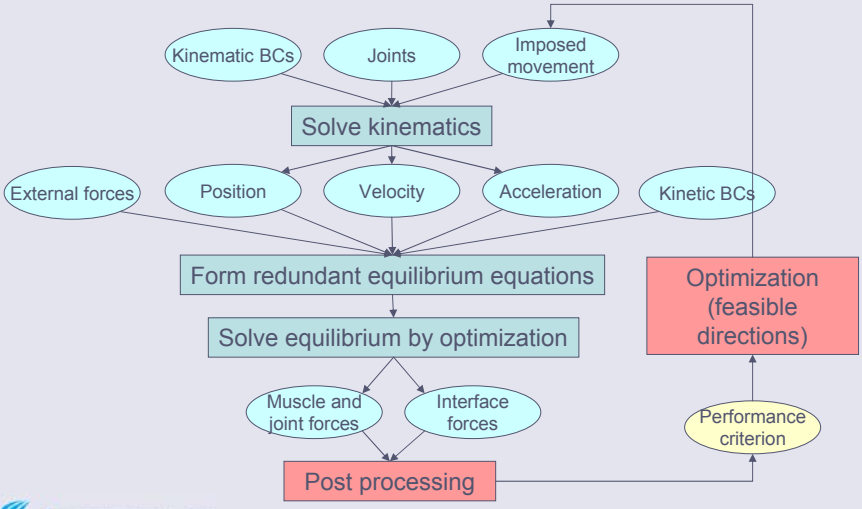
Inverse- Inverse Dynamics



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Optimization

Ergonomic design optimization:

$$\underset{\text{environment}}{\text{Minimize}}\ f(\text{Posture/movement}, \text{environment})$$

Posture/movement optimization:

$$\underset{\text{Posture/movement}}{\text{Minimize}}\ f(\text{Posture/movement}, \text{environment})$$

Combined optimization:

$$\underset{\text{Posture/movement, environment}}{\text{Minimize}}\ f(\text{Posture/movement}, \text{environment})$$

Notice the combined formulation only works if we can reasonably presume that posture, movement and the ergonomic quality of the environment can be optimized with the same objective function, *f*.

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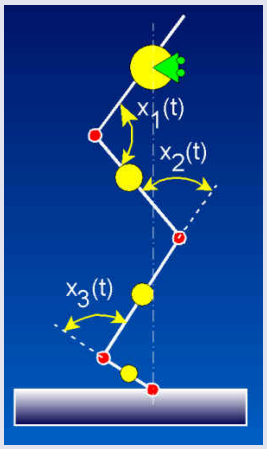
Some old results give us hope

- An early 2-D model (1999):
  9 muscles in each leg.
- Movement prediction of a squat jump.
- Joint angles described as Hermite polynomials.
- Design variables are polynomial coefficients.
- Objective function: Jump height.
- Please see results here:
  www.anybody.aau.dk/Examples/SquatJump.htm



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This type of problem works well

- Optimized GRF resembles measurements by Bobbert & van Ingen Schenau (1988).
- Optimized movement produces a realistic initial counter-action.
- Initial jump height ≈ 0
- Final jump height = 123 mm.
- Animations here:
  www.anybody.aau.dk/Examples/SquatJump.htm

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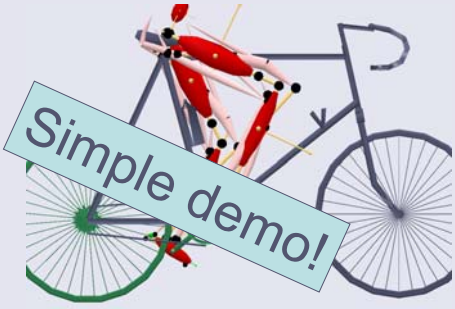
Pedaling

- Simple 2-D bicycle model.
- 9 muscles in each leg.
- Assumptions:
  - Constant crank velocity
  - Pelvis fixed on saddle (no upper body)
  - Mechanical output constrained.
- Variables:
  - Crank torque profile (Fourier series)
  - Ankle angle variation (Fourier series)



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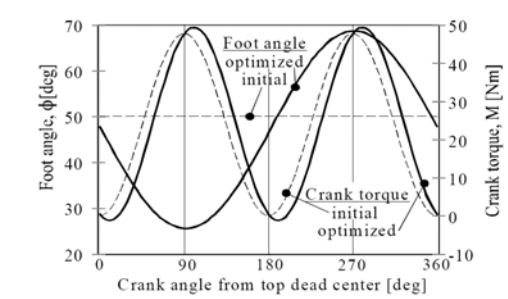
Movement prediction

- Real ankle movement pattern nicely reproduced by optimization.
- Several objective functions produce similar results:
  - Max efficiency
  - Min fatigue
  - Min muscle trauma.



Rasmussen, J., Damsgaard, M., Christensen, S.T. (2000):

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2/3: More complex models

- Much more detailed models are now available.
- We want to apply this to daily movements.
- Eventually we would like to do egress (getting out of a car), but we start with simpler examples.

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Standing posture prediction

- Standing model with 500+ muscles.
- 79 kinematic degrees of freedom.
- 5 design variables:
  - Ankle angle
  - Hip angle
  - Pelvis/thorax angle
  - GH flexion
  - GH abduction
- Symmetric posture presumed.
- Objective function: **Minimize maximum muscle activity in percent of MVC**
  → Minimum fatigue.

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Initial:
23.2% of MVC

Optimized:
19.8% of MVC

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Shoulder bag: 10 kg

Initial
34.2% of MVC

Final
31.5% of MVC

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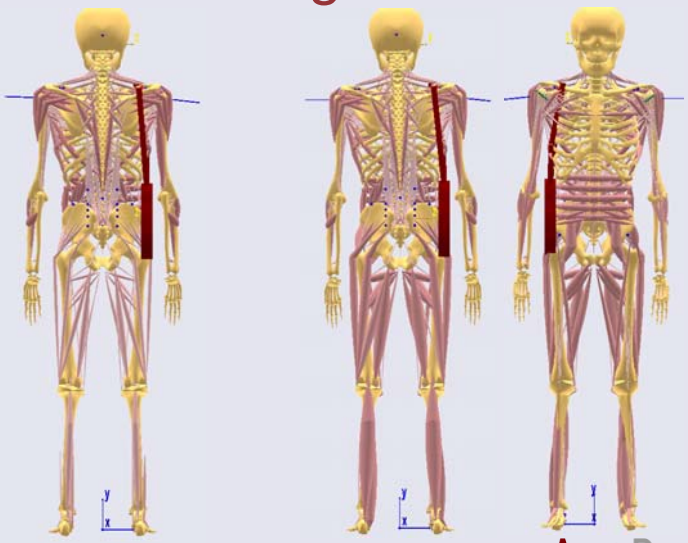
30 kg

Initial
50.3% of MVC



Final: 45.0% of MVC

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3/3: Conclusions

- The method seems to work when we know the criterion →Squat jump
- Different but reasonable criteria produce similar results →Pedaling
- Posture prediction based on minimum fatigue shows reasonable results but needs further validation.
- More complex movement prediction (such as egress) remains to be attempted.

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Online resources

- AnyBody Technology
  www.anybodytech.com
  - Free demo licenses
  - Tutorials and documentation
  - Replay of webcasts
  - Further info: Email: anybody@anybodytech.com
- The AnyBody Research Project
  www.anybody.aau.dk
  - Public domain library of body models and applications
  - Publications – many for direct download.

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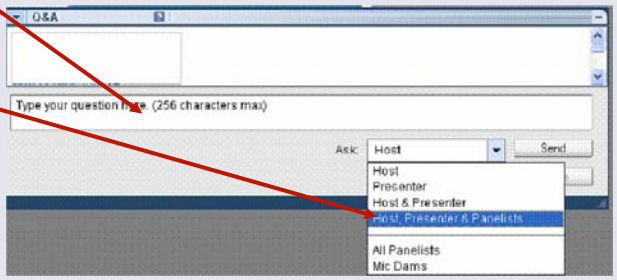

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Forthcoming webcasts

- 4 October 2006:
  Validation of musculoskeletal models
- 20 November 2006:
  The seated human model

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