A hybrid dynamic motion prediction method with collision detection

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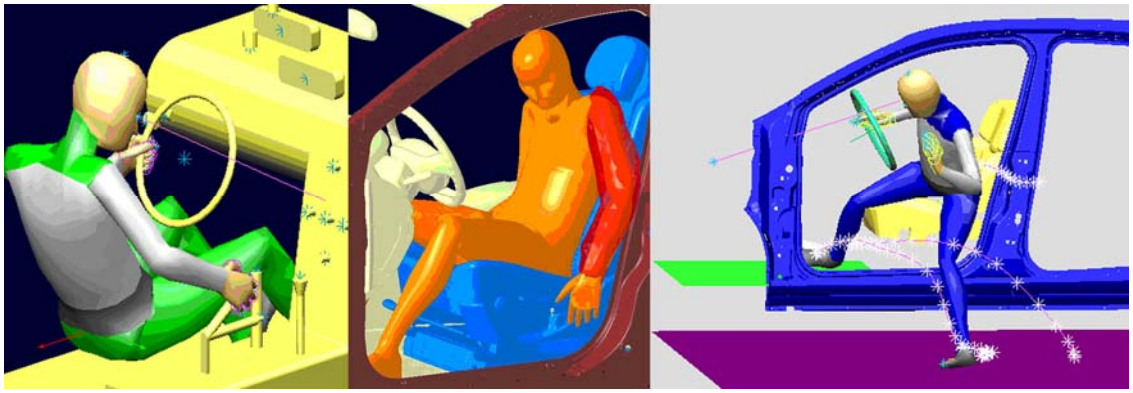
Introduction

- Integration of DHMs in product design



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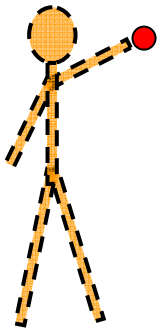
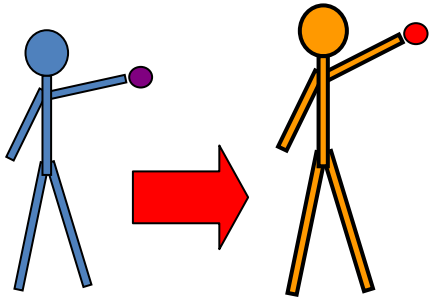
- Human motion prediction:
  - To simulate the interaction of different user populations with a variety of environments
  - Aims: realism and representativeness

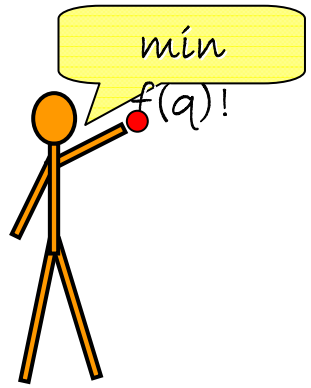
Motion prediction methods

- Data-based
  - Resemble reference motion

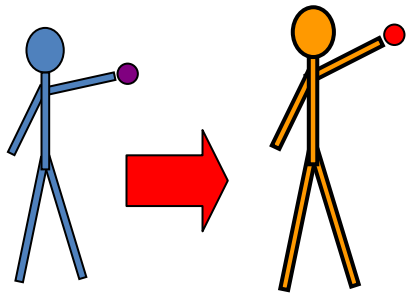




- Knowledge-based
  - Follow motion control law

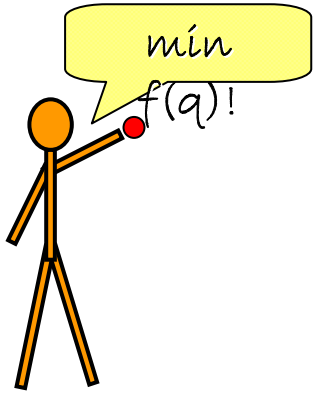


Data-based methods



- Currently only kinematic
- Reference motion from database
- Modification to meet new goals
- Advantages:
  - Intrinsic realism of reference motion
  - Suitable for complex task-oriented motions
- Drawbacks:
  - Only predict tasks in database

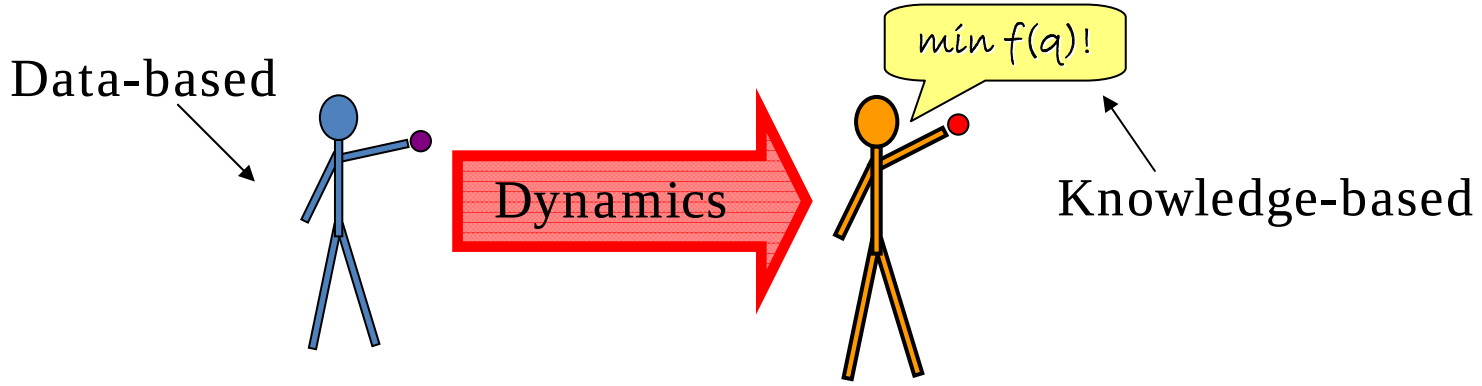
Knowledge-based methods



- Currently also dynamic
- No reference
- Realism through motion control law
- Advantages:
  - Theoretically applicable to any task
- Drawbacks:
  - Appropriate motion control law is difficult to identify

Novel prediction method

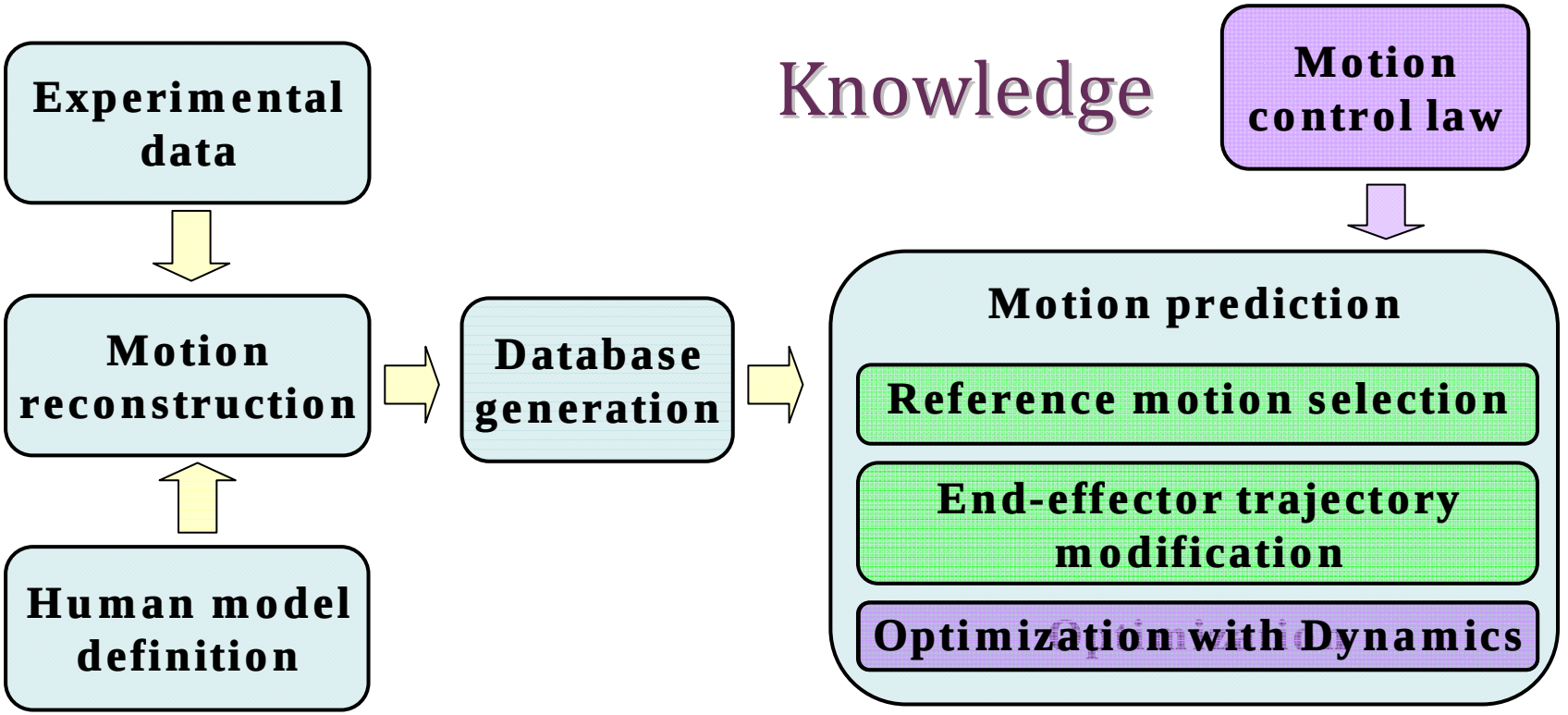
- Hybrid dynamic motion prediction method: data-based & knowledge-based



Applied to the prediction of a clutch-pedal depression

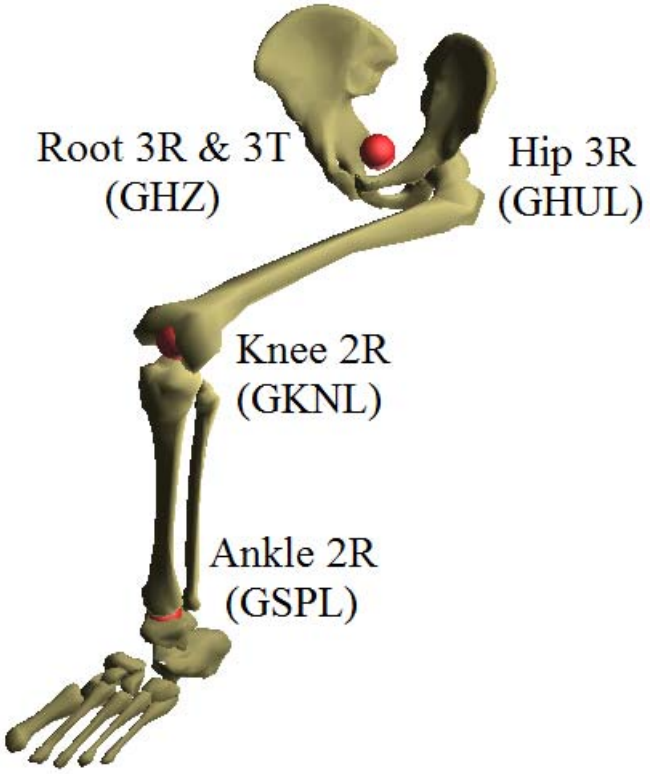
Methodology

Data-based prediction



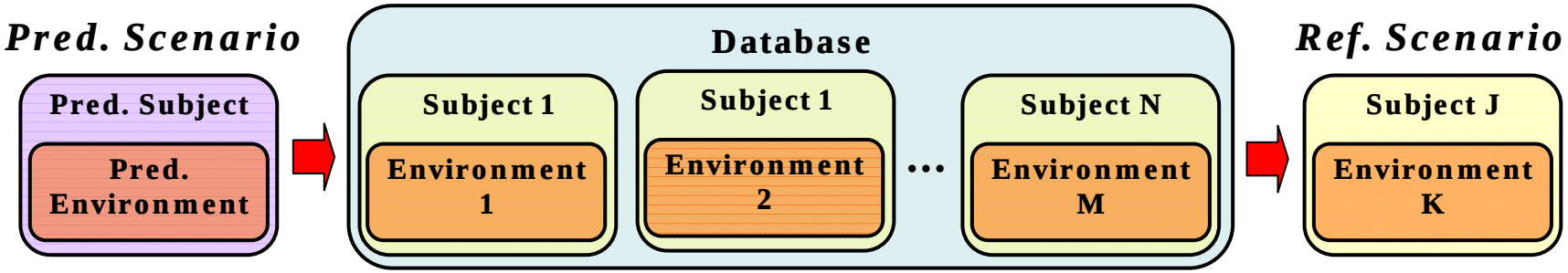
Human model definition

- Multi-body model
- Left leg:
  - 4 segments
    - Pelvis
    - Thigh
    - Shank
    - Foot
  - 13 DoFs
    - 10 rotations
    - 3 translations
- RAMSIS specifications
- Described with relative coordinates

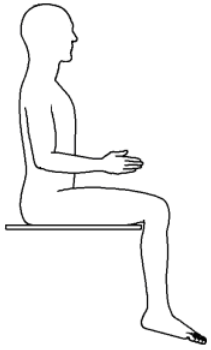


Reference motion selection

- Resemblance in scenarios

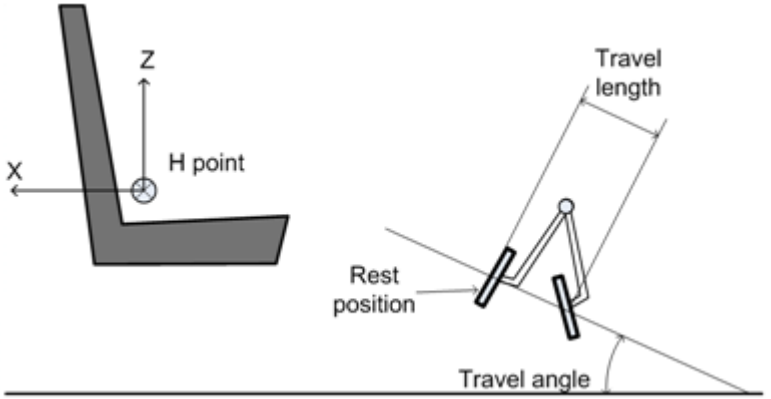


- Subject data



  - Gender
  - Age
  - Stature
  - Weight

- Environment data

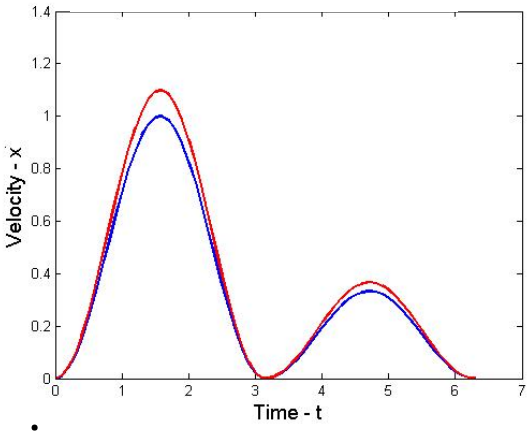


End-effector trajectory modification

- Reference and prediction scenarios are different

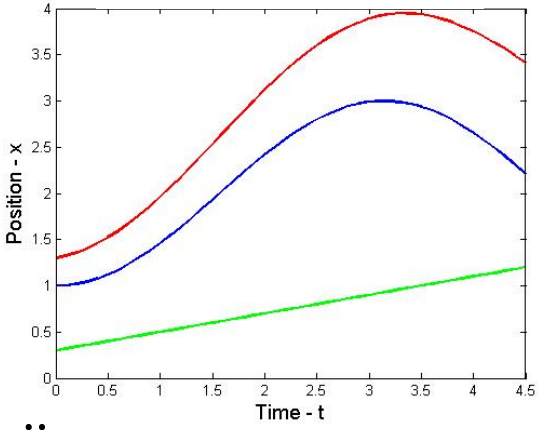
- Modification of reference trajectory to meet new goals
  - 2 methods (Zhang 2002):

Velocity proportional



$$\dot{\hat{x}} = c_1 \dot{x} \Rightarrow \hat{x} = c_1 x + c_2$$

Acceleration preserving



$$\ddot{\hat{x}} = \ddot{x} \Rightarrow \hat{x} = x + c_1 t + c_2$$

Dynamic prediction

- Predicted motion must:
  - Fulfill new goals
  - Resemble reference motion
  - Follow dynamic motion control law
  - Ensure dynamic equilibrium of DHM

Relates frames one another

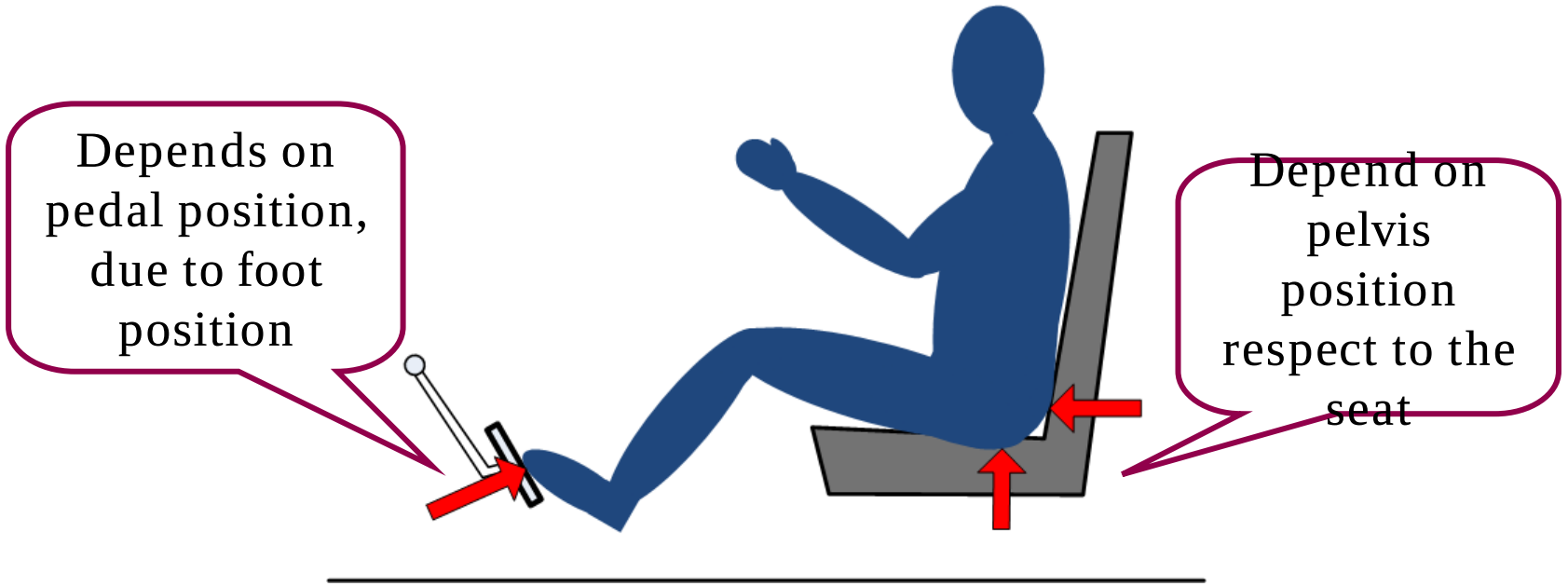
- B-spline representation of DoF profiles
  - Motion considered as a whole (not per-frame)

Optimization

- Design variables: B-spline control points
- Constrained optimization
  - Objective function
    - Resemble reference DoF profiles
    - Resemble modified end-effector trajectory
    - Follow motion control law: resemble reference joint power profiles (Pasciuto et al., 2010)
  - Constraints
    - Fulfill new goals
    - Ensure dynamic equilibrium of DHM

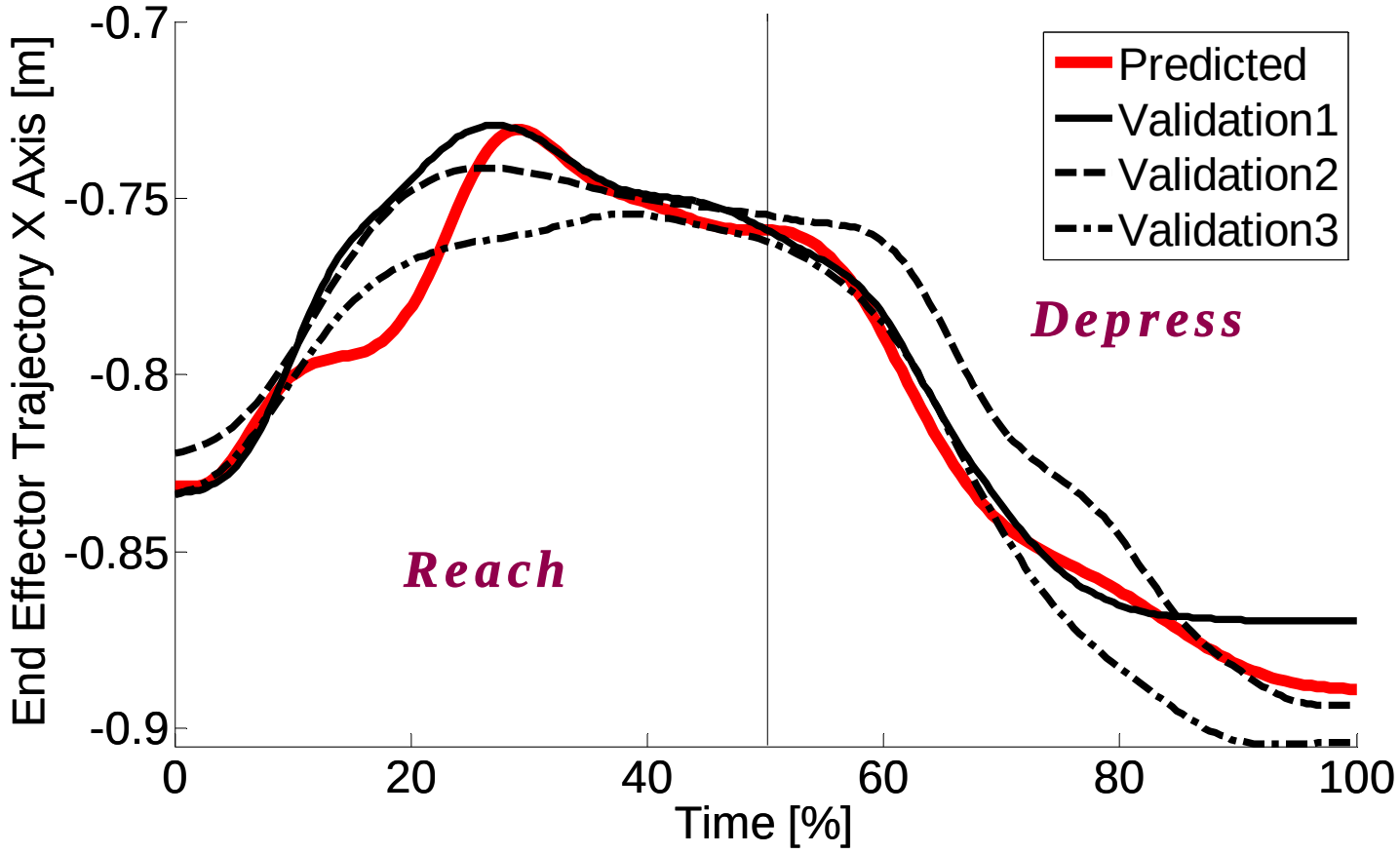
Collision detection

- To evaluate external contact forces
- Environment reacts with a force according to the position and velocity of the DHM



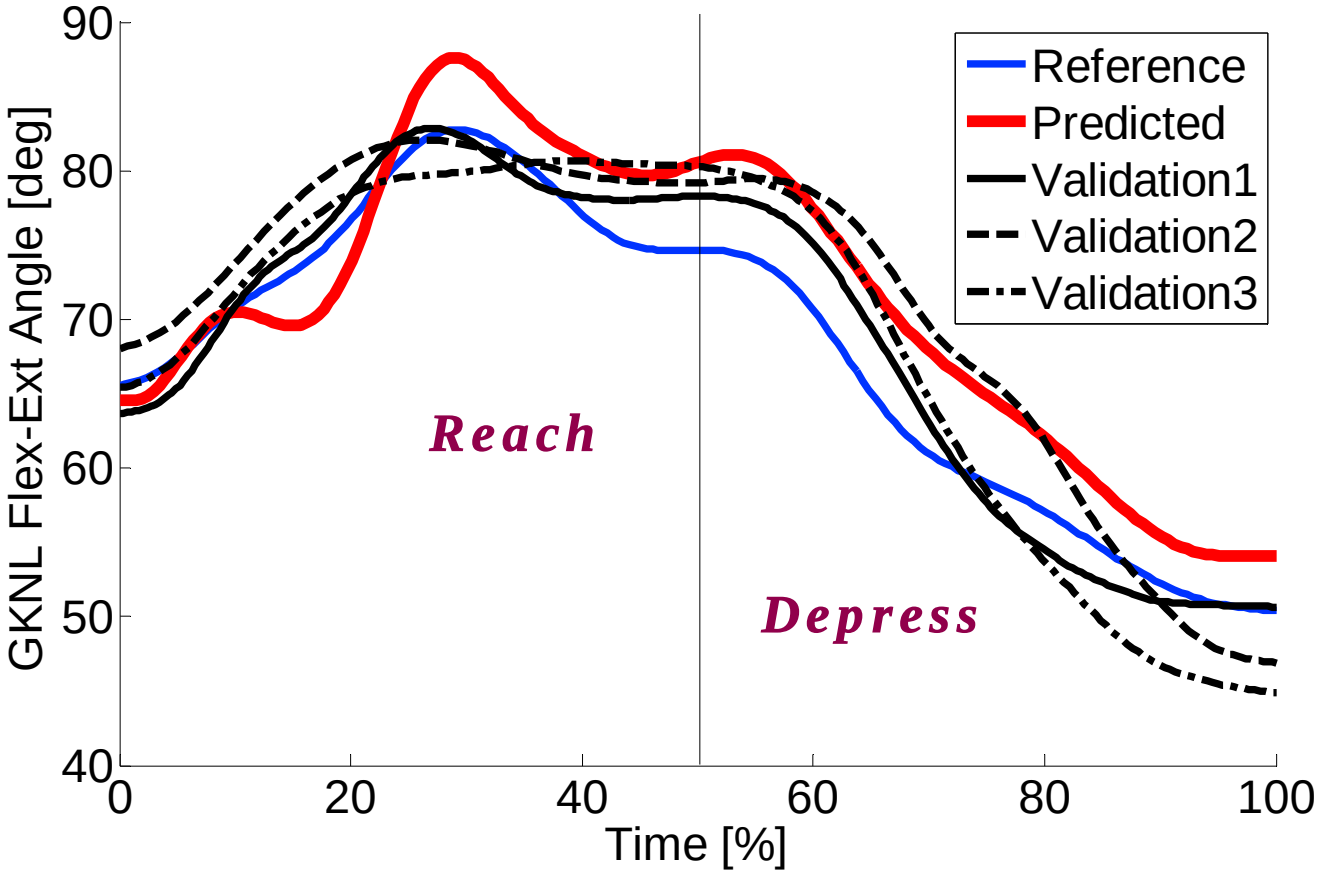
Results (I)

- End-effector trajectory



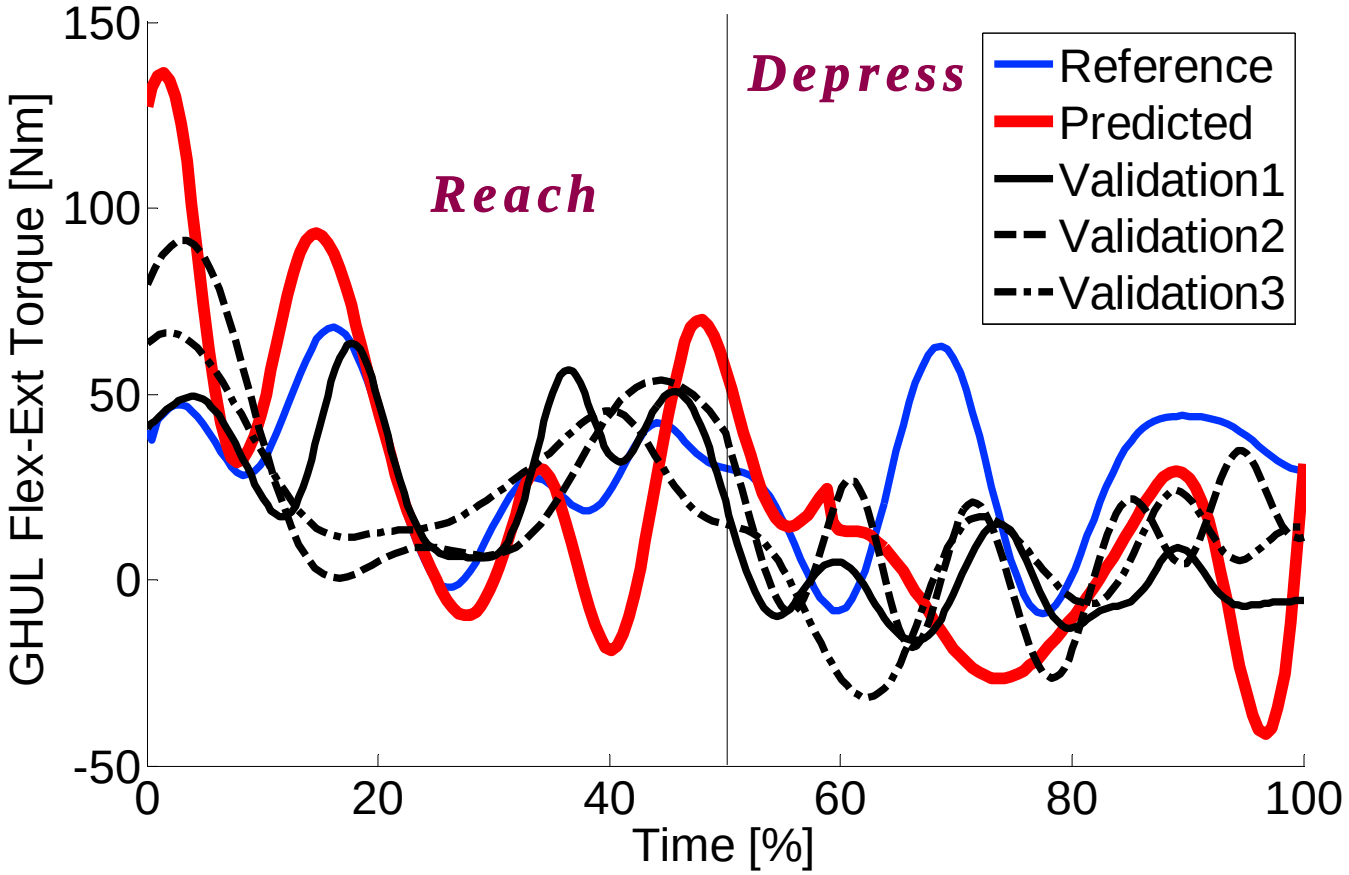
Results (II)

- Knee flexion-extension joint angle profile



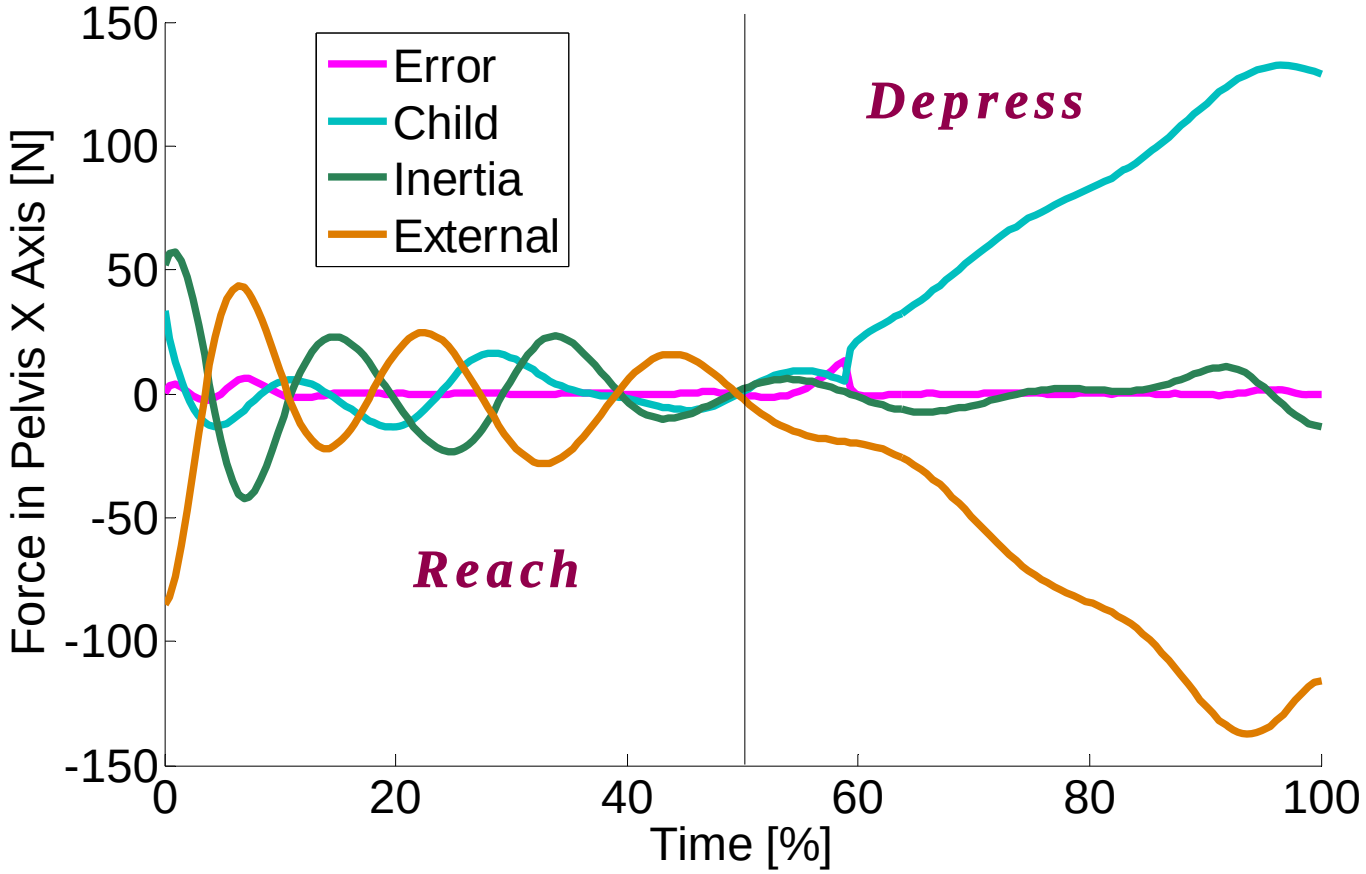
Results (III)

- Hip flexion-extension joint torque profile



Results (IV)

- Forces acting on the pelvis



Conclusions

- Hybrid method for dynamic motion prediction
  - Combines data-based and knowledge-based methods
  - Dynamics: ensures equilibrium
- Collisions
  - Detects and models collisions between DHM and environment
- Validation
  - Compared against 3 repetitions of the motion carried out in the prediction scenario

Acknowledgements

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Thank you for your attention!

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