

EVALUATION OF THE CONTACT FORCE BETWEEN TWO RIGID BODIES USING KINEMATIC DATA ONLY

R. VAN HULLE, C. SCHWARTZ, V. DENOËL, J.-L. CROISIER, B. FORTHOMME, O. BRÛLS
LABORATORY OF HUMAN MOTION ANALYSIS, UNIVERSITY OF LIÈGE, BELGIUM

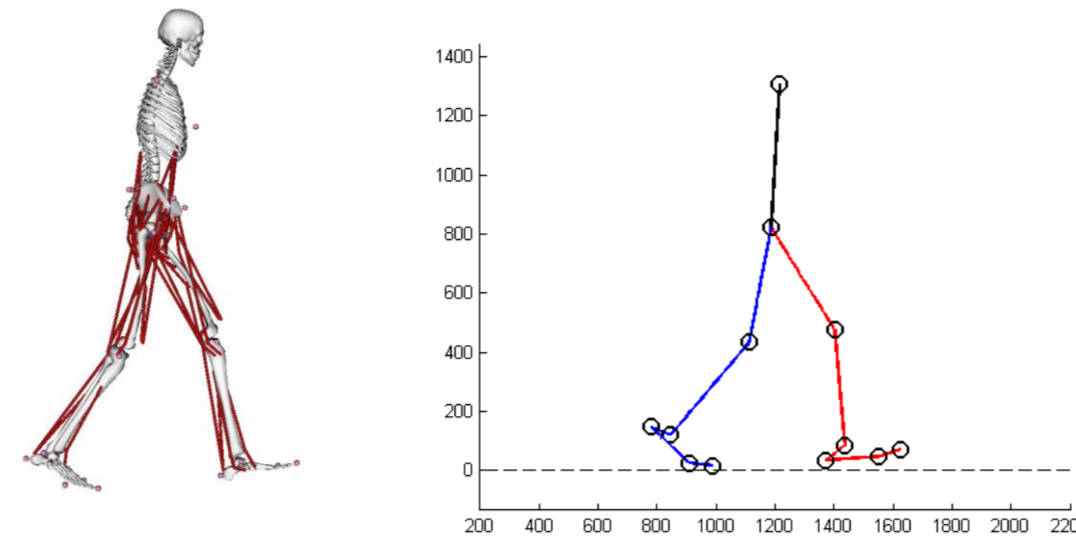
Usual evaluation of foot contact forces in motion analysis

Experimental measurement: force platform



Advantages: reliable results

Flaws: number of steps limited by the number of force plates



Numerical estimation: Koopman's method

Advantages: easy to implement

Flaws: single contact point foot model, approximation when atypical/pathological gait

$$F_R = f \sum_{i=1}^{N_s} m_i (\dot{x}_i - g)$$

$$F_L = (1 - f) \sum_{i=1}^{N_s} m_i (\dot{x}_i - g)$$

Objective

Develop a general numerical method able to deal with multiple contact points

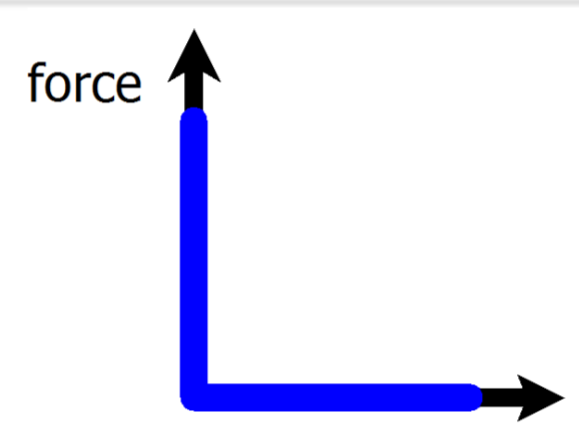
Methods

Simple Equations of Motion

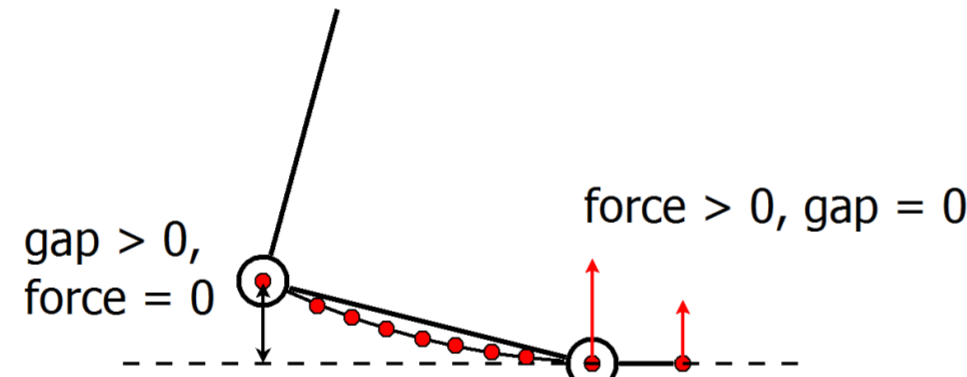
$$\begin{cases} M\ddot{q}(t) + g_q^{B,T}(q)\lambda^B - f(q) = 0 \\ g^B(q) = 0 \end{cases}$$

M , the mass matrix;
 q , the coordinates;
 g^B , the bilateral constraints;
 λ^B , the Lagrange multipliers associated to the bilateral constraints;
 f , the external forces.

Adding unilateral constraints



The foot is not allowed to penetrate the ground.
No information on the compliance of the foot is required, only its position.

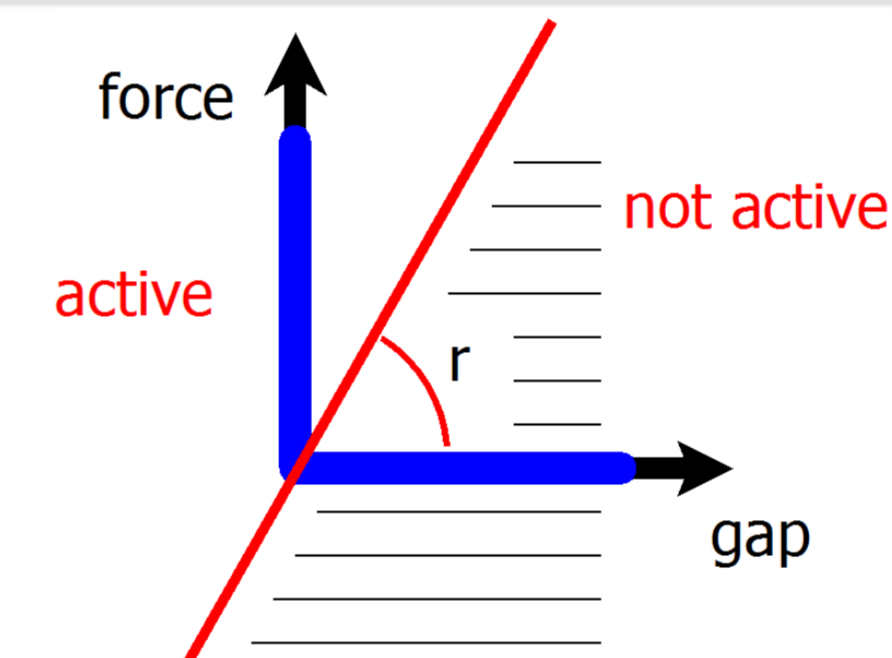


New Equations of Motion

$$\begin{cases} M\ddot{q}(t) + g_q^{B,T}(q)\lambda^B + g_q^{U,T}(q)\lambda^U - f(q) = 0 \\ g^B(q) = 0 \\ 0 \leq g^U \perp \lambda^U \geq 0 \end{cases}$$

g^U , the unilateral constraints;
 λ^U , the Lagrange multipliers associated with the unilateral constraints.

Determination of contact status



Criterion based on penetration and estimated contact force.

Solving Equations of Motion

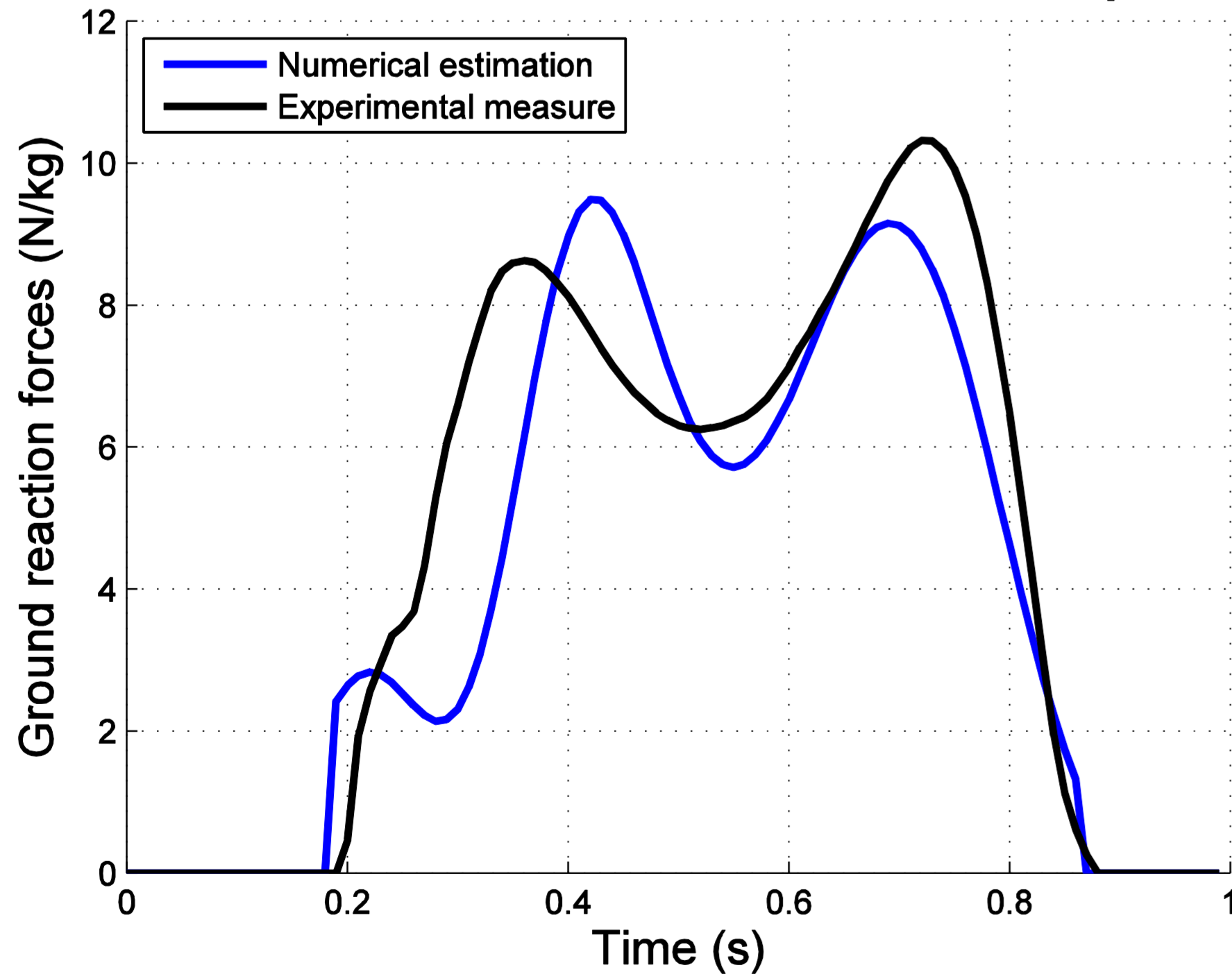
The problem might be under- or overdetermined depending on the number of active contact points.

The indetermination is handled using the Least-square Method.

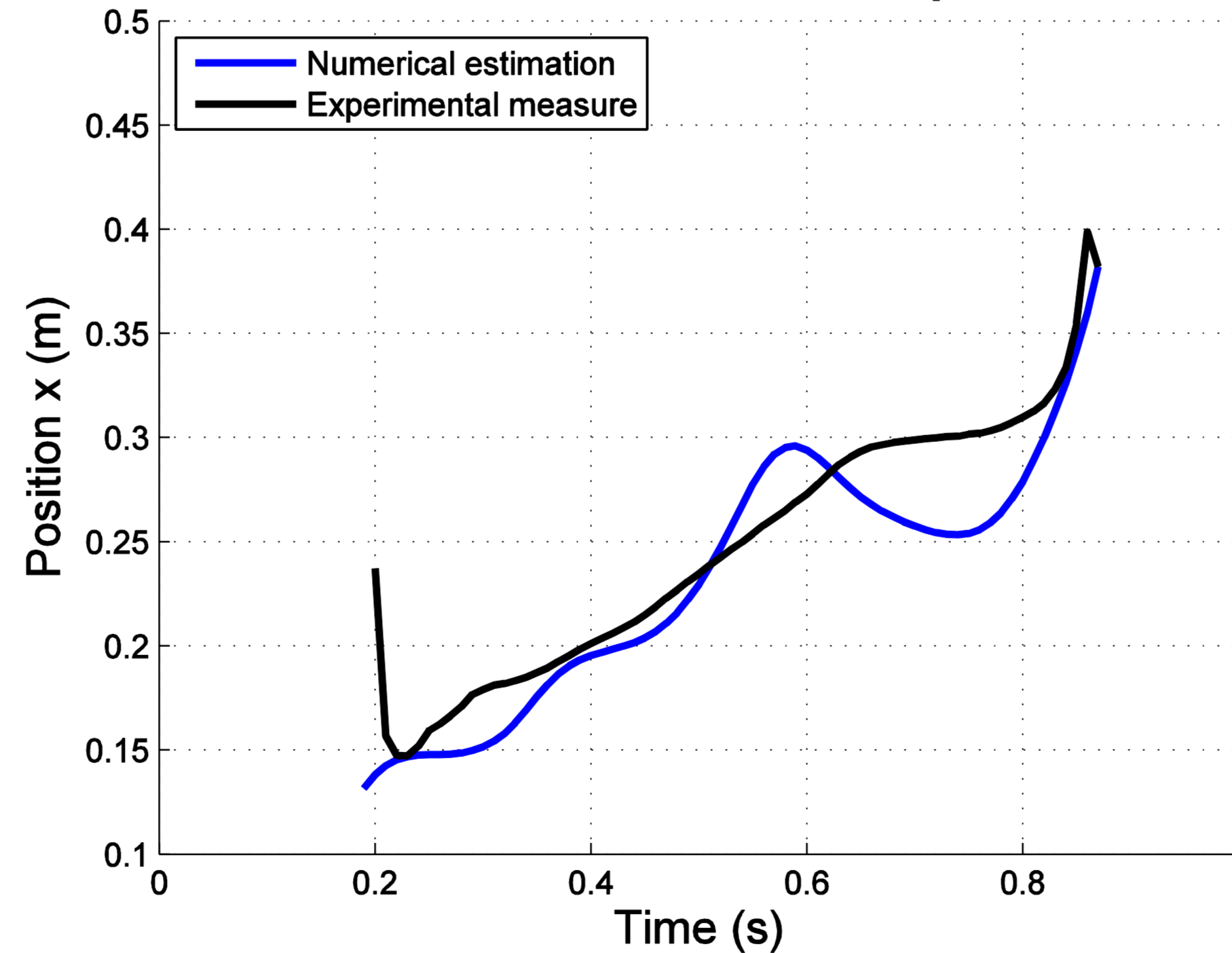
λ^U gives the ground reaction forces.

Results

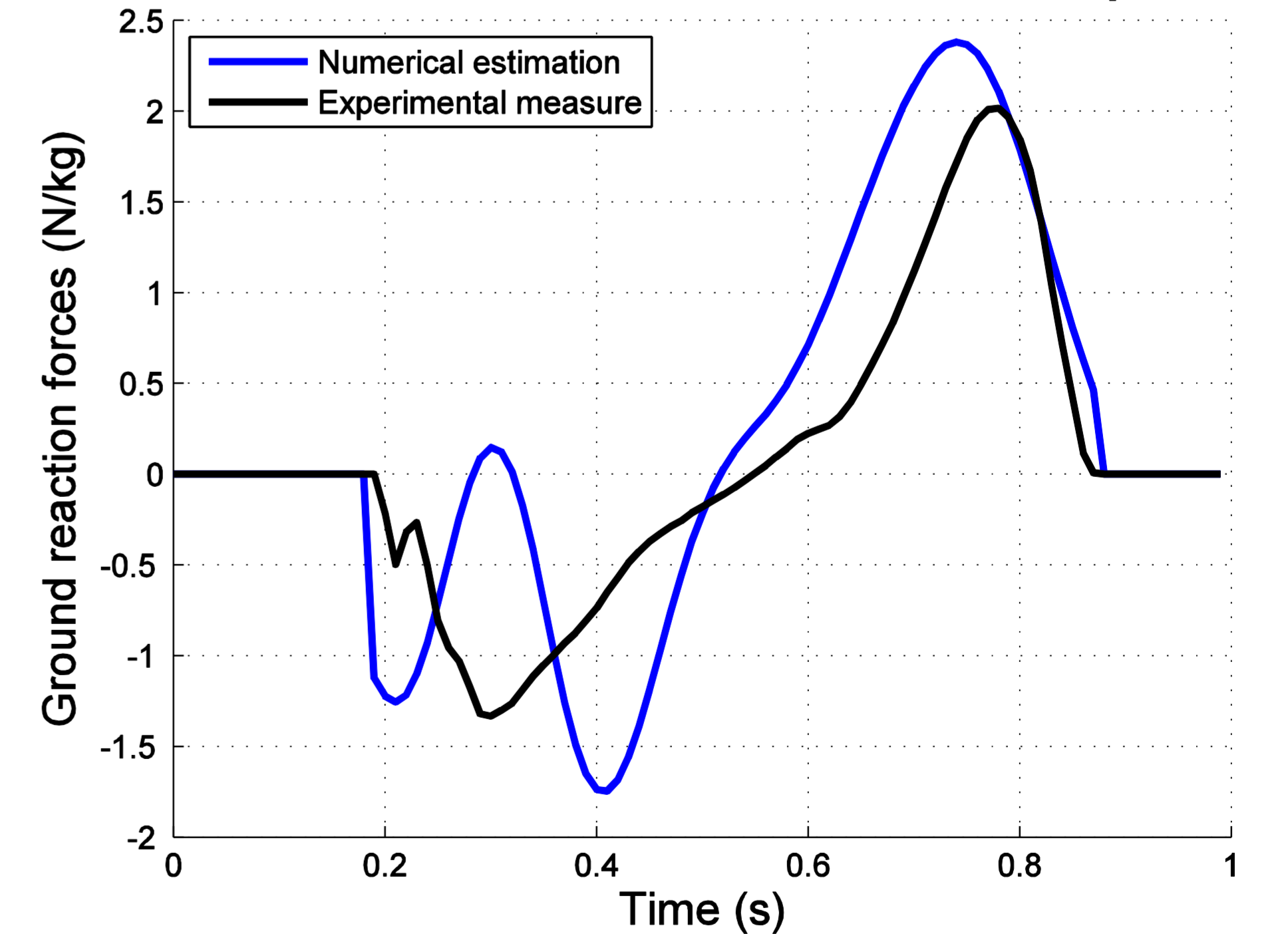
Ground reaction force: vertical component



Position of the centre of pressure



Ground reaction force: fore-aft component

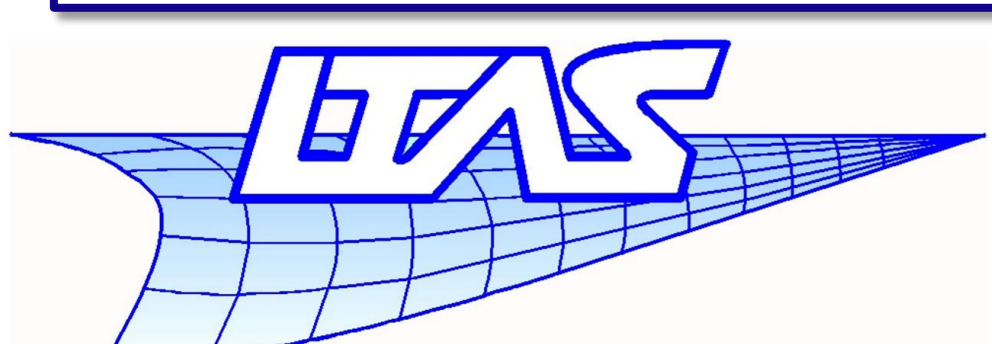


Conclusion

Preliminary but encouraging results

Easy to implement: no information on the compliance is required, only kinematic and geometric data

General method for multiple contact points: healthy and pathological gait, running, treadmill, etc.



University of Liège, Belgium
Aerospace & Mechanical Engineering Department
Multibody and Mechatronic Systems - www.ltas-mms.ulg.ac.be

University of Liège, Belgium
Faculty of Applied Sciences, Faculty of Medicine
LAMH - <http://labos.ulg.ac.be/lamh/>



Contact: Romain Van Hulle, ✉ romain.vanhulle@ulg.ac.be, ☎ +32 4 366 91 13