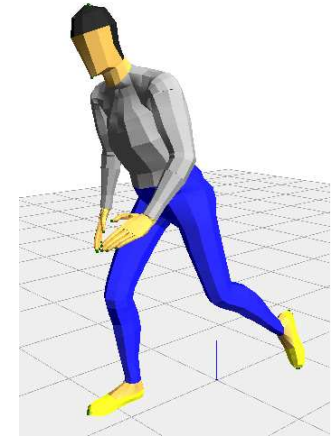




*Ninth International Symposium on the
3D Analysis of Human Movement*



Joint forces and moments calculation for a 3D whole body model during complex movements

*Application to the balance recovery movement
following a support surface translation*

Th. ROBERT^{(1) (2)}, L. CHEZE⁽¹⁾, R. DUMAS⁽¹⁾, J-P. VERRIEST⁽¹⁾

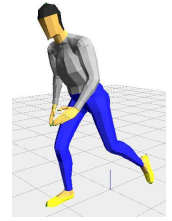


(1) **L**aboratoire de **B**iomécanique et **M**odélisation **H**umaine (**LBMH**)



(2) **L**aboratoire de **M**écanique des **C**ontact et des **S**olides (**LaMCoS**)

Objectives

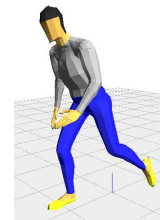


■ Objectives of the study:

- To calculate the joint forces and moments during balance recovery movements performed by volunteers.
- To obtain reference data for balance recovery analysis.

■ Consequences:

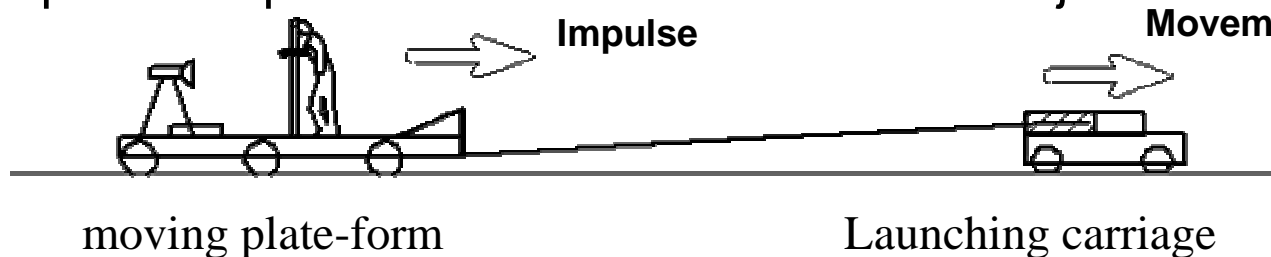
- Use of 3D whole body model
- Accuracy:
 - Sufficient to differentiate the movement strategies.
 - Convergence of direct dynamics computation is not needed.



Movements studied

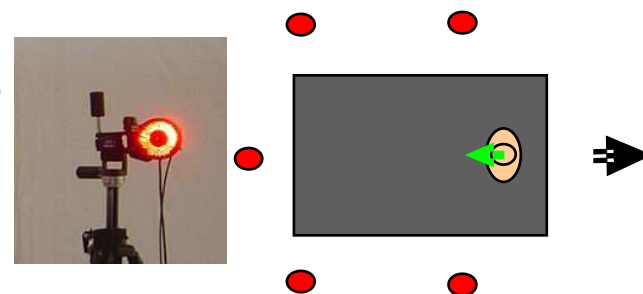
■ Overview of the experiment

- Principle : The platform is moved without the subject's knowledge



- Measurement :

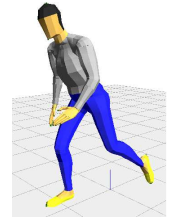
- Kinematics: 5 cameras MOTION ANALYSIS®
50 reflective markers



- Dynamics: Loads at each interface between the subject and its environment



Movements studied



■ Examples of movement

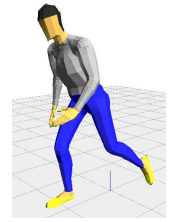


2 m/s² (0,2 g)



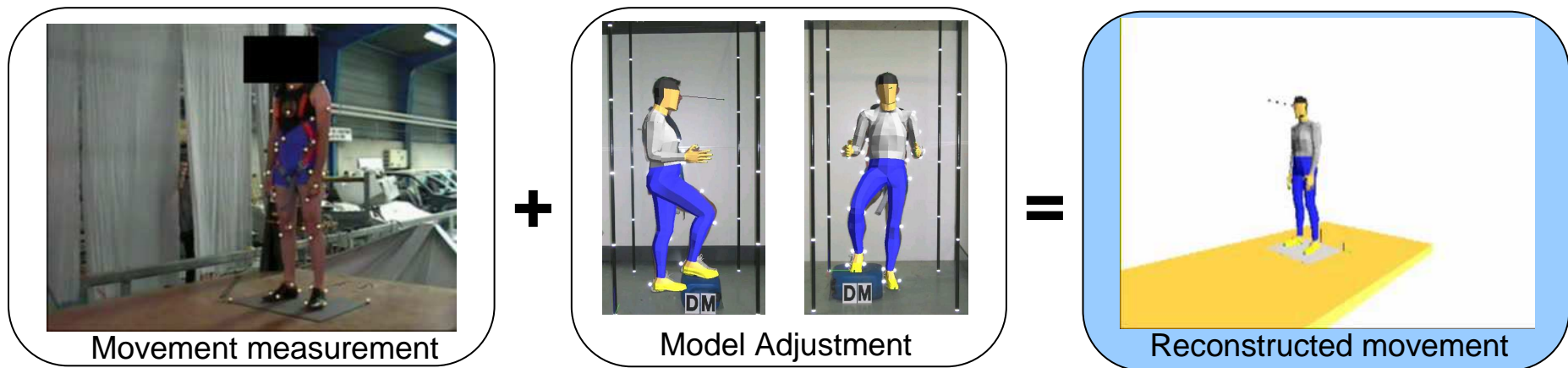
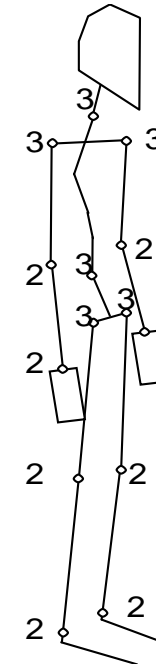
10 m/s² (1 g)

Methods

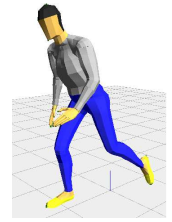


■ Movements reconstruction :

- Use of a numerical dummy (15 segments - 40 dof)
(Verriest 98)
- Semi global algorithm

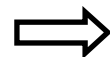


Methods

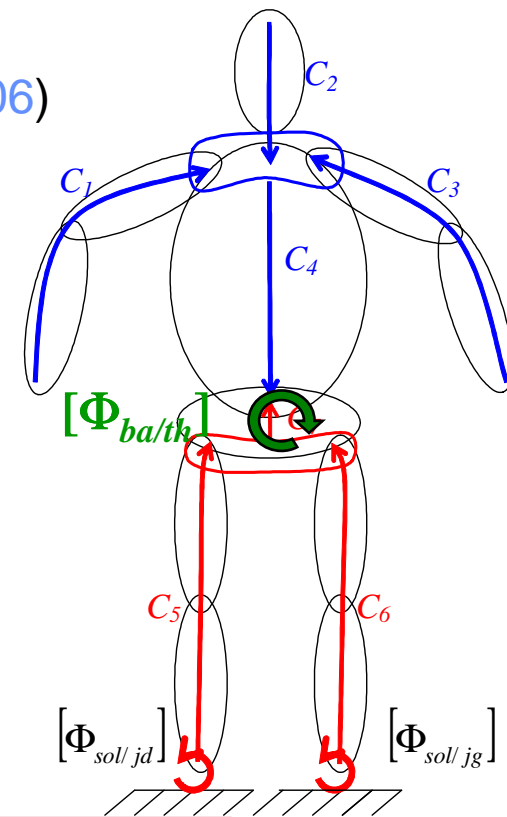


■ Inverse dynamics algorithm :

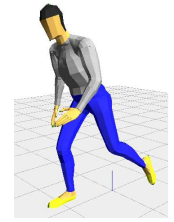
- Newton-Euler recursive algorithm
- Homogeneous matrix => robustness (Dumas 06)
- External loads measured
- 3D Model, 11 segments
- 2 calculation strategies



Consistency of the results can be estimated



1st step : classical hypotheses unsatisfying

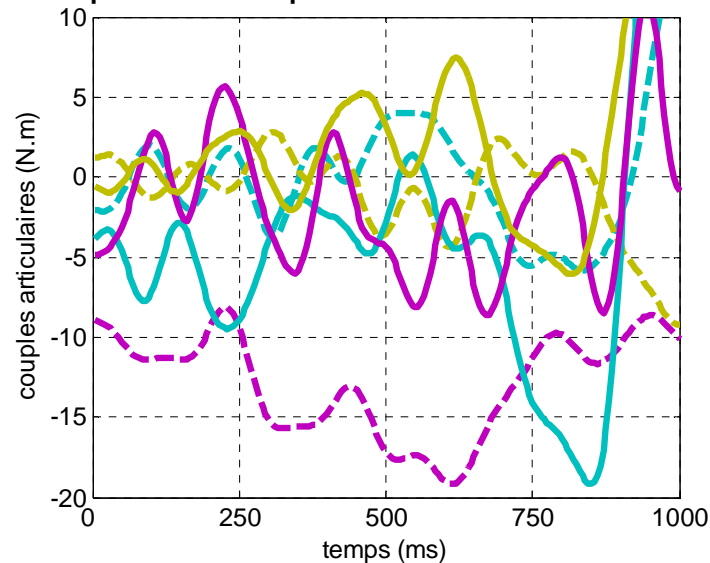


■ Method:

- BSIPs estimations : DeLeva (De Leva 96)
- Accelerations :
 - Term to term derivation
 - Classical filtering (Butterworth, 2nd order, manually adjusted)

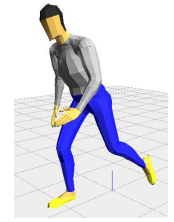
■ Results:

comparison of pelvis→thorax moments



⇒ Unsatisfying

2nd step: improvements



■ Sensibility Analysis:

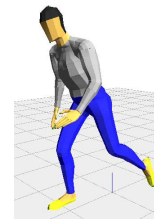
- Critical
 - Force plates loads (Fx Fy)
 - Angular accelerations
 - Position of the centers of mass
- Non Influent
 - Masses and Inertias
 - Angles for the distal joints

■ Improvements :

- BSIPs estimation ([Dumas 06](#))

	CoM-CoP (mm)	
	A/P	M/L
DeLeva	26.3 ± 7.6	5.3 ± 5.5
Dumas	-16.9 ± 7.4	4.7 ± 5.7

- Derivation of the kinematical data
 - Fc automatically adjusted: Residual Analysis ([Winter 90](#), [Silva 04](#))
 - Coherence of the derivative matrices



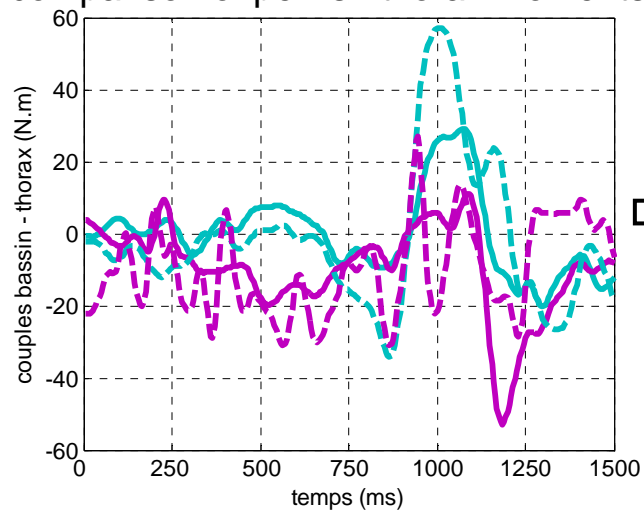
2nd step: improvements

■ Influence of the modifications:

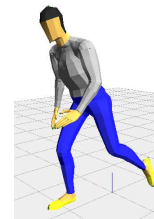
difference of mean gap between pelvis – thorax loads

Modifications	FX	FY	FZ	MX	MY	MZ
BSIPs	0.6	-1.4	-3.6	-0.5	-19.5	-1.4
Coherence of matrixes	0.4	0.0	0.4	0.1	0.0	0.0
Fc automatic	-0.1	-1.2	-1.1	-0.7	-1.0	-0.4

■ Results: comparison of pelvis→thorax moments



⇒ Consistent but noisy

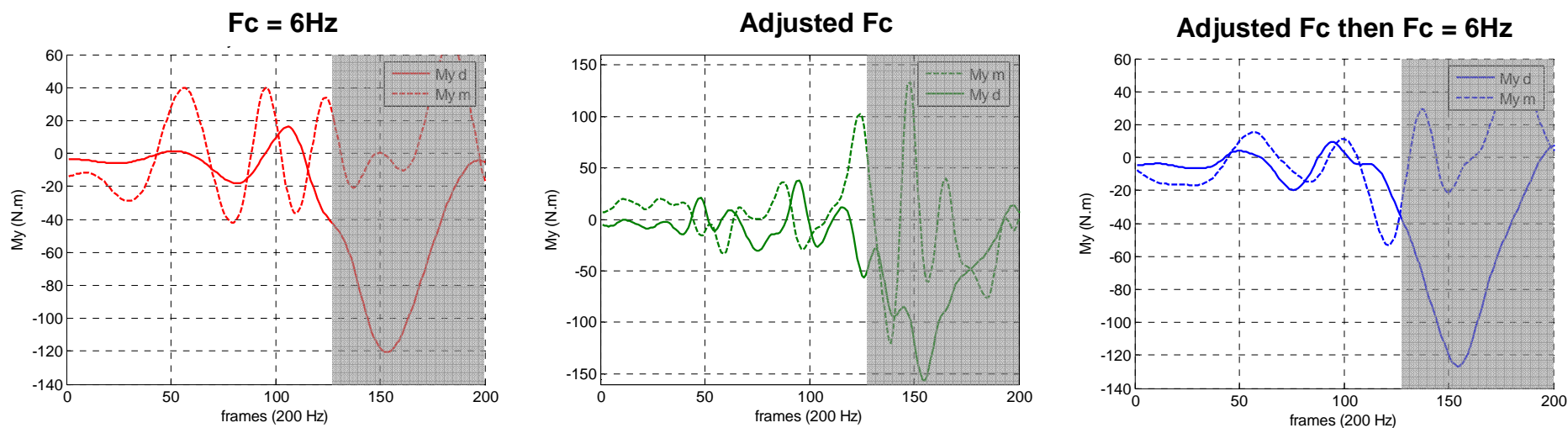


Validation

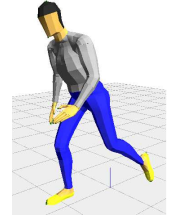
■ Noise treatment:

- Frequency analysis:
 - frequencies of noise are present in movements.
 - → too low Fc would suppress noise AND movement information
- Treatment:
 - 1/ calculation using adjusted Fc
 - 2/ then re-filter dynamical results

■ Results:



Conclusions



- Classical methods are not well adapted

- Importance of:
 - Positions of the CoM (!)
 - Derivation techniques

- Calculation in 2 steps:
 - Dynamical calculation (adjusted F_c)
 - Then, noise reduction

- Underlying conclusions:
 - Evaluate the results consistency (!)
 - Possibility to obtain consistent results using simple methods.