Motion-based ground reaction forces and moments prediction method in a moving frame: a pilot study

Louise Demestre, François May, Pauline Morin, Guillaume Nicolas, Nicolas Bideau, Georges Dumont, Charles Pontonnier

Motion-based ground reaction forces and moments prediction method in a moving frame: a pilot study

L. Demestre[1], F. May[1], P. Morin[1], G. Nicolas[2], N. Bideau[2], G. Dumont[1], C. Pontonnier[1]
[1]Univ Rennes, CNRS, Inria, IRISA – UMR 6074, F-35000 Rennes, France
[2]Univ Rennes, Inria, Laboratoire M2S, F-35000 Rennes, France
Email: louise.demestre@ens-rennes.fr

Summary

A motion-based method to predict ground reaction forces and moments (GRF&M) in a moving and/or non-horizontal frame has been developed. The motion of a subject located on a moving hand pallet truck has been recorded. The moving structure has been equipped with a force platform to compare predicted and measured GRF&M.

Introduction

Inverse dynamics methods are widely used in motion analysis studies to compute joint torques. The ground reaction forces and moments are required to solve the dynamic equilibrium of the subject studied. Measuring the GRF&M reduce the ecological aspect and constraint the movement area. Motion-based prediction methods are used to circumvent this limitation. All the existing methods regard the ground as a static and horizontal surface. In this abstract, an existing prediction method [1] is improved to expand its application to external forces coming from mobile and/or non-horizontal structures.

Methods

The force platform is composed of a 6-dofs force sensor (MCS10 5kN, 5000Hz, HBM) located between two steel plates. The motion capture data were recorded using an optoelectronic system (200 Hz, Qualisys). 43 reflective markers were placed on standardized anatomical landmarks of the human subject and 3 markers on the upper surface of the force platform. The force platform was laid down on a hand pallet truck. During a trial, the subject stood on the force platform, squatted once then successively lifted up each foot. During the subject's movement, an investigator pulled the hand pallet truck.

The GRF&M were predicted at each frame following two steps: contact detection and forces distribution. Firstly, a moving frame linked to the force platform was created using the 3D displacement of the 3 markers placed on it. Relative position and velocity thresholds between the moving contact surface and a set of discrete contact points under the subject's feet were tested. Secondly, the external forces applied on each prediction point were minimized with respect to the dynamic equilibrium of the subject [1]. This method has been implemented in the CusToM Matlab toolbox [2].

Results and Discussion

A comparison between predicted and measured force on vertical direction (FZ) and moment on antero-posterior direction (MY) for a sample trial is presented below (Figure 1):

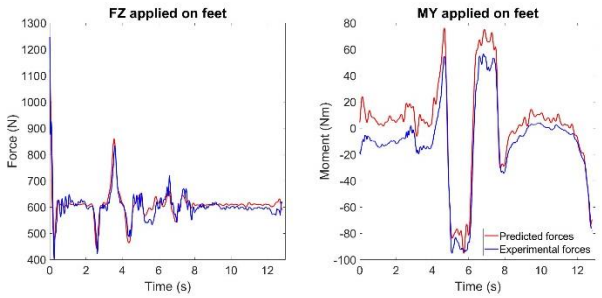

Figure 1: Predicted (red) and measured (blue) FZ (left) and MY (right) applied on feet.

The RMSE errors between predicted and measured GRF&M curves for this trial are presented in the table below (Table 1). They are of the same order of magnitude as those obtained from the initial CusToM method [1]. The prediction method in moving frame presented here seems to open new applications to the initial one keeping the same accuracy. Nevertheless, more subjects and structure movements must be studied to draw suitable conclusion about this new method.

Conclusions

A motion-based GRF&M prediction method in a moving and/or non-horizontal frame has been proposed. Preliminary results shows that this new method is promising and needs to be evaluated with more subjects and more challenging structure motions. Such a method may be useful for many applicative studies in sports or ergonomics.

References

[1] A. Muller, et al. (2020). *IEEE T Bio-Med Eng*, **67**(2): 344-352.
[2] A. Muller, et al. (2019). *J. Open Source Softwa*. **4**(33):92

Table 1: RMSE errors between predicted and measured forces (FX, FY, FZ) and moments (MX, MY, MZ) curves as a function of time

Component	FX	FY	FZ	MX	MY	MZ
RMSE	14.7 N	30.9 N	27.5 N	9.5 N.m	14.7 N.m	1.0 N.m