RAMBLING-TREMBLING DECOMPOSITION IN TWO DIMENSIONS

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INTRODUCTION

Rambling-trembling decomposition of the center of pressure (CoP) trajectory (Zatsiorsky, Duarte 1999, 2000) is based on the idea that during quiet standing the body sways for two reasons: the migration of the reference point with respect to which the equilibrium is maintained (rambling, R) and the deviation away from that point (trembling, T). So far, the RT decomposition was performed in only one plane, either anterior-posterior (AP) or medio-lateral (ML). The technique of the RT decomposition is based on determining the so-called instant equilibrium point (IEP), the CoP position at the instance when the horizontal ground reaction force (GRF), either F_{AP} or F_{ML}, equals zero. The IEPs for the AP and ML body sway usually do not coincide and it is not clear how the RT decomposition can be performed for the CoP trajectory on the supporting surface.

The goals of this study are: (1) To develop a method of the RT decomposition of the CoP trajectory in the plane. (2) To study the relations between the R and T fractions of the CoP trajectory in the plane and the shear ground reaction forces. Note, that when RT decomposition is performed in either AP or ML direction the involved variables (forces, displacements) are scalars. When the analysis is performed in the plane the forces and displacements are 2-D vectors.

METHODS

Seven subjects (3 males, 4 females) participated in this study. Their age was 29.4±7.5 years, their height 173±6 cm and their mass 70±18 kg. None of these subjects has any known historical postural disorder. Subjects were asked to stand on a force plate (model AMTI OR6-7-1000), with a comfortable feet width, and to maintain their posture during one minute. Subjects were barefoot and with eyes open. The ground reaction forces were recorded at a sampling frequency of 200 Hz on a personal computer using a 12 bit AD board. A low pass Butterworth filter (4^{th} order, zero lag, cut off frequency = 8 Hz) was applied to the ground reaction forces (Zatsiorsky, Duarte 1999). The CoP coordinates were computed from these data (Zatsiorsky, Duarte 2000).

The following definition was accepted: the IEP is a CoP position on the plane at the instant when the norm of a horizontal force vector is zero. The IEPs were identified as the points where the magnitude of the shear force was in a local minimum, under 5% of the maximal shear force recorded during the trial. The R trajectory was estimated by interpolating the IEP points, using 3D cubic cardinal splines (2 coordinates and the time). The T component was defined as the 2D vectors of the deviation of the CoP from the R trajectory.

A canonic correlation procedure was used in order to investigate the correlation between the shear forces and the T trajectory, which are both 2D variables (vectors). The principle was to study the correlation between two uni-dimensional canonic variables (F and T), made by linear combinations of the elements of the original two-dimensional variables (F_x, F_y and T_x, T_y, respectively):

$$F=a1\cdot F_x+b1\cdot F_y; \quad T=a2\cdot T_x+b2\cdot T_y;$$

The coefficients of the linear combinations are adjusted in order to find the highest correlation between the two canonic variables. In this case, in order to go back to the original vectors variables, the set of coefficients {ai,bi} that corresponds to the highest correlation has been interpreted as angles: αi=atan2(bi,ai). Thus, the difference $\alpha 1-\alpha 2$ indicates the orientation of the T vectors relative to the shear forces vector obtained for the highest canonical correlation. The same procedure was applied to study the correlation between the shear force and the R vectors.

RESULTS AND DISCUSSION

Figure 1 illustrates the results obtained for a typical subject. The R trajectory is, as expected, well smoother than the CoP trajectory. Note the similarity of the shear force and the T vectors. The results of the canonical correlation, displayed in the Table 1, confirm this visual impression. The shear force and the T component are highly correlated. Moreover, their preferential orientation is not different of zero, which means that the vectors are aligned. On the other hand, the correlation between the shear force and the T component is relatively poor.

Table 1: Canonical correlation between the shear force vectors and the T and R vectors.

	T trajectory	R trajectory
correlation	**0.84** ± *0.06*	**0.26** ± *0.06*
$\alpha 1-\alpha 2$ (°)	**1.0** ± *10.6*	**177.7** ± *27.0*

The results of the planar RT decomposition extend previously obtained data for the unidirectional decompositions. They confirm the idea that the CoP trajectory is composed by the migration of an attracting point (rambling) and the oscillations around the R trajectory (trembling).

The results also indicates that the loops typically observed in the CoP trajectories (cf. numbers displayed in Figure 1) are mainly due to the trembling component, that are commonly considered as arising due to elastic restoring forces.

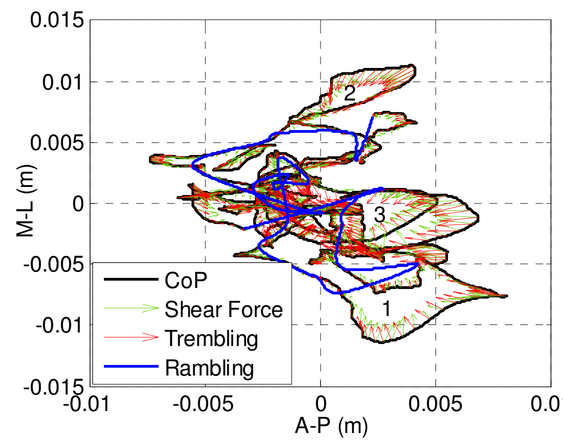

Figure 1: 2D representation of the CoP trajectory, the Rambling trajectory, and the Trembling and shear forces vectors for a typical subject.

SUMMARY/CONCLUSIONS

This study proposes an extension of the decomposition of the CoP into the Rambling and Trembling components to a 2-D case. A high correlation between the trembling component of the CoP migration and the shear forces (both of them are vectors) was observed.

REFERENCES

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ACKNOWLEDGEMENTS

This study was supported by NIH grants NS035032 and AR048563.