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A novel definition of the ZMP via screw theory

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A motivation on the fields of biomechanics and humanoid robots is to analyze the dynamic balance. Vukobratovic and Juricic computed the resultant ground reaction force to legged machine and the point was defined as the zero-moment point (ZMP). Since then, ZMP has long been used for checking balance of legged robots. Popovic, et al. discussed the correlations of the three important ground reference points: ZMP, foot rotation indicator (FRI) and centroidal moment pivot (CMP) using a realistic human model and gait data. Firnami and Park proposed a method for quantifying the imbalance state by means of the center of pressure (CoP) and the ZMP. A new screw-based approach has been proposed for calculating the ZMP of body motions. Using screw method, the ZMP is defined by the intersection of the screw axis ($0) and the plane z=0. However, the conventional definition of ZMP is respect to the world coordinates, whereas the definition of our ZMP is according to the new frame with the z-axis lies along the axis of $0. The validity of the proposed approach is demonstrated by evaluating the whole-body dynamics over the course of a 25-second sequence of continuous motions performed by a professional martial arts practitioner. The results demonstrate that the magnitudes of the forces/moments are reasonable. Comparing the results obtained from the conventional method and the screw method for the ZMP locations over the 752 timeframes, the differences between two sets are small. Thus, two ZMP tracks nearly overlapped. The conventional ZMP definition is applicable for humanoid robots with big foot-print for stabilizing; whereas our ZMP definition is best suitable for body motion analyzing such as tiptoe contacting during ice skating, ballet etc. The screw-based ZMP calculation may be a better method for tracking or controlling tiptoe dynamic balancing conditions without big foot-print.

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