English Research Express@NCKU Volume 29 Issue 4 - June 5, 2015
[http://research.ncku.edu.tw/re/articles/e/20150605/4.html]

Dynamic Balance Control for Biped Robot Walking Using Sensor Fusion, Kalman Filter, and Fuzzy Logic

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IEEE Transactions on Industrial Electronics, Vol. 59, No. 11, pp. 4394-4408, Nov. 2012.

In the field of studying biped locomotion for humanoid robot, Zero Moment Point (ZMP) is the most famous and powerful theorem for designing the gait pattern of biped robot. Through analyzing the trajectory of ZMP, the walking stability of the gait pattern can be derived when designing the robot locomotion. On the other hand, we can modulate a proper ZMP trajectory as the reference trajectory to design a basic gait pattern, and use a Fuzzy Logic Controller (FLC) to follow the desired ZMP trajectory to achieve the dynamic balance control for different walking condition. In this study, an adjustable ZMP trajectory model and the fuzzy motion controller with sensor fusion technique are proposed.

According to ZMP theorem, if the ZMP is located in the safe region of the polygon formed by the supporting soles when walking, then the robot can walk stably without falling down. Thus, among the recent research [1-4], when single supporting phase (SSP) the ZMP is set as a fix point, which is the center of the supporting sole, it is the most intuitive way to design the reference ZMP trajectory. This kind of ZMP trajectory is in fact not similar to human being, because the reaction force generated when the swing sole contact the ground is hardly absorbed and the legs of the robot is not as flexible as legs of human. Therefore, this study proposes an adjustable piecewise continuous function to modulate the reference ZMP trajectory. Fig.1 shows the fixed ZMP trajectory used in previous research and the adjustable ZMP trajectory proposed in this study. With the desired ZMP trajectory, the basic gait pattern can be generated [5].

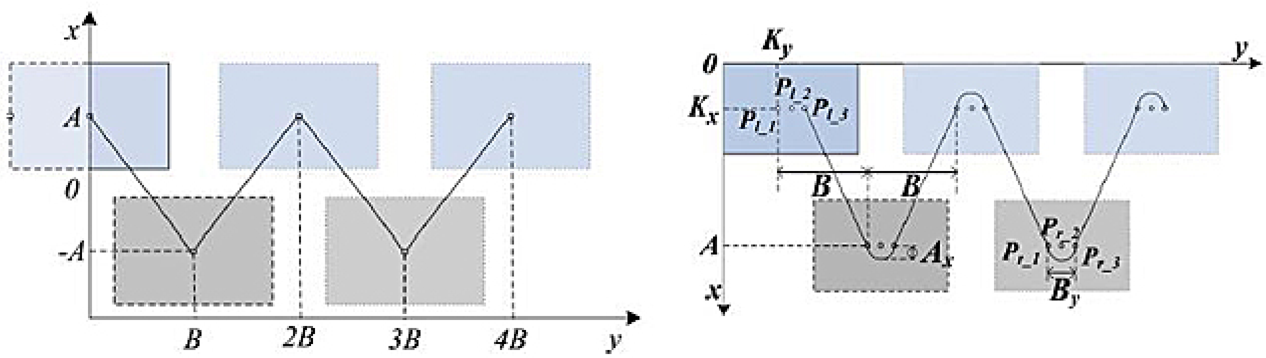

Fig.1 Fixed ZMP trajectory (left) and adjustable ZMP trajectory (right).

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With the desired ZMP trajectory, the fuzzy motion controller can be designed. In order to make robot be capable of walking on the different ground materials and different slope, the inputs of the controller are chosen as the inclination of the robot trunk, the error between the desired ZMP trajectory and actual ZMP trajectory, and the change rates of these two parameters. Fig. 2 depicts the block diagram of the proposed dynamic balance control

(DBC) method. It can be seen that the inputs of fuzzy motion controller are measured by force sensors for ZMP and accelerometer for inclination, and these signals are processed by a Kalman filter, which is considered as a sensor fusion block in this study. Fig. 3 illustrates the definitions of the fuzzy sets to the inclination angle. Fig. 4 illustrates the definitions of the fuzzy sets to the ZMP location.

Through the proposed ZMP planning model and DBC, the biped robot can walk stably on the carpet and on a plank. Moreover, the robot can walk on slopes with different inclination angles.

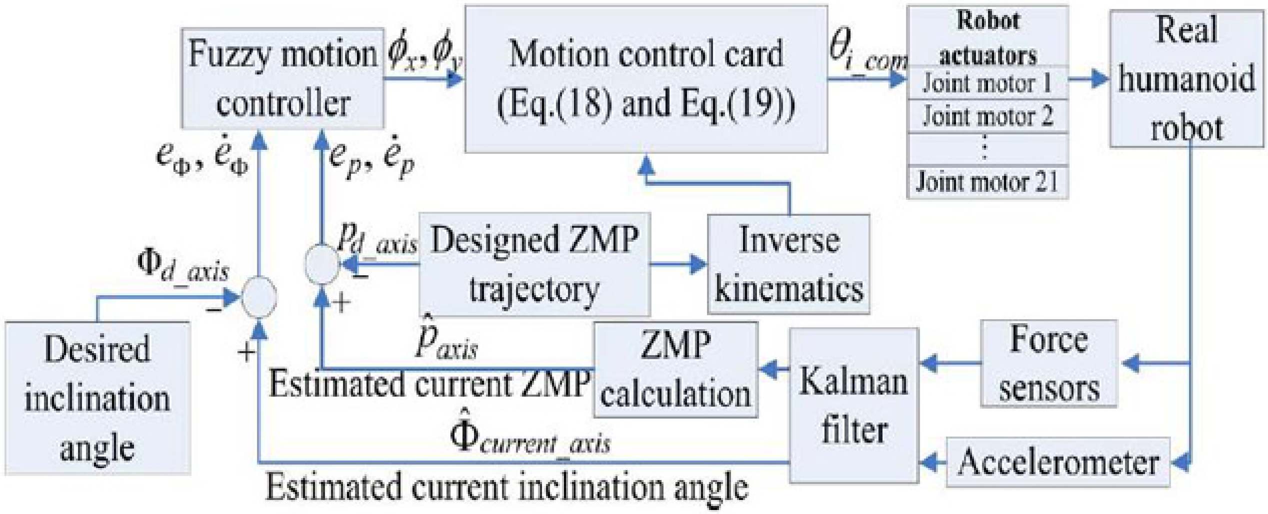

Fig. 2 Illustration of DBC.

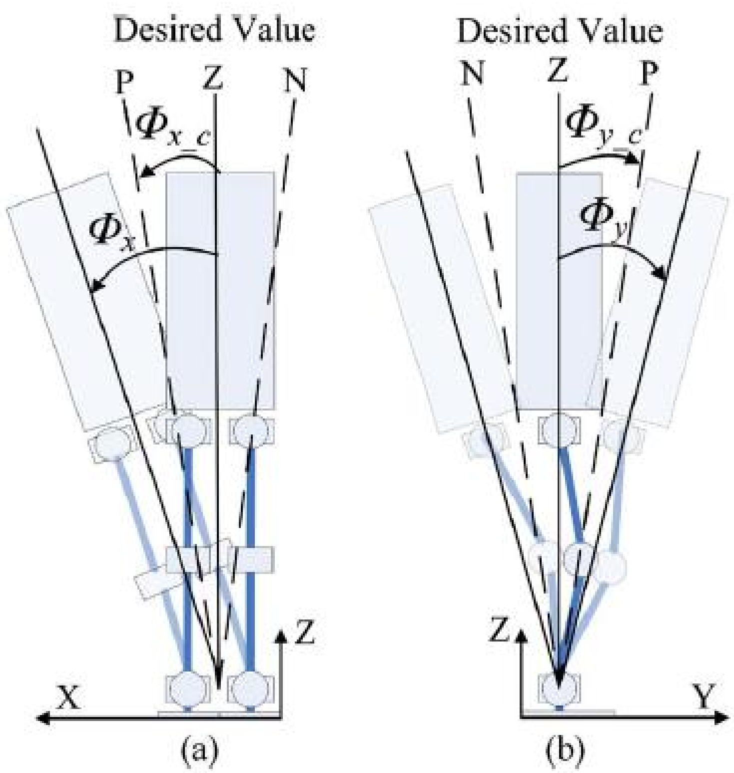

Fig. 3 Diagrams and the fuzzy sets to the inclination angle in (a) lateral plane and (b) sagittal plane.

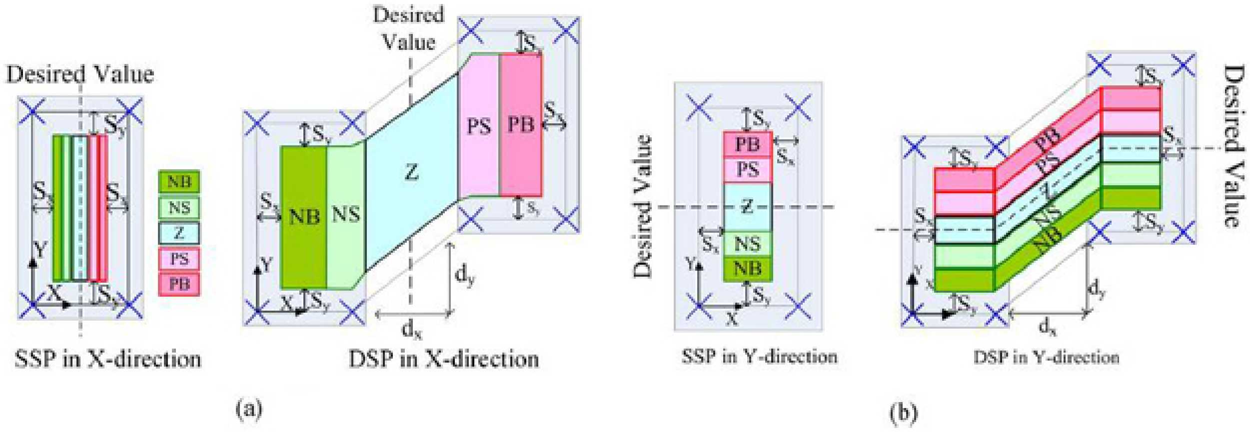

Fig. 4 Diagrams and the fuzzy sets to the ZMP location in (a) X-direction and (b) Y-direction.

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