Reactive responses of legs and arms to an unanticipated sudden drop of ground during human walking

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1 Motivation and State of the Art

Maintaining balance during locomotion is one of the most important tasks for both human beings and humanoids. In general, balance performance during walking includes two parts: trunk posture and gait stability (Fig. 1). We can modulate trunk posture by exerting torque on hip and shoulder joints. For example, Maus et al. show that a highly reduced conceptual walking model can achieve and maintain trunk posture stability by modulating hip torque according to leg force [1]. From the study on conceptual models we know that foot placement (attack angle) strategy is critical for achieving gait stability [2], [3]. Meanwhile, foot placement can be considered as the result of swing leg movement, which could also affect trunk posture. Thus, in order to find out the role of legs and arms in keeping balance during walking, here we investigate how legs and arms react to an unanticipated sudden drop of ground perturbation.

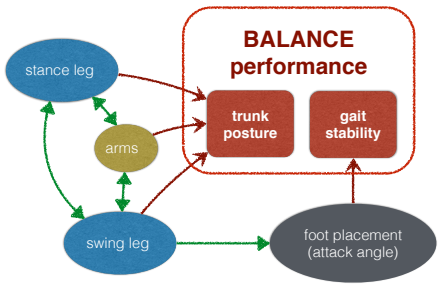

Figure 1: Factors which could affect human balance performance during walking.

2 Our Approach

In the experiment, subjects were asked to walk on an instrumented track (2m wide, 6m long). There are three force plates embedded in the center of the track (Fig. 2). The force plate in the middle is mounted on a movable platform. The platform will drop 10cm if the vertical force acting on the movable platform is over 30N.

3 Current Results

For now, we just have one young healthy subject (male, 24 years old, body mass 74.9kg, body height 1.76m) participated in the experiment. The preliminary results (11 trials, Fig. 3) show that shoulder torques are quite small compares to hip torques. Despite at the beginning of the touch down, stance leg (perturbed leg) hip toque is smaller than the swing leg (unperturbed leg).

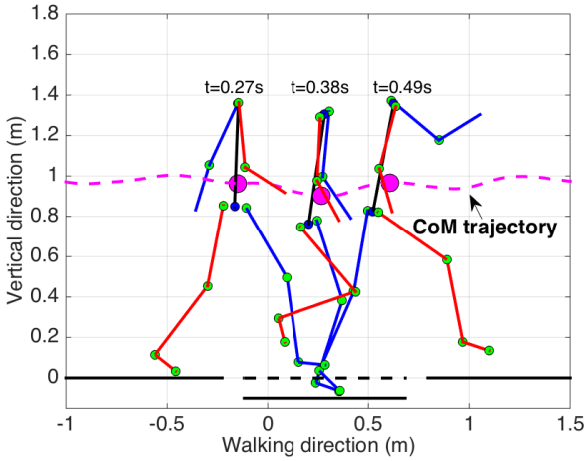

Figure 2: Stick figure extracted from one experiment trial.

4 Best Possible Outcome

Based on the experiment results, the best possible outcome is a human-like balance control strategy which combines swing leg, stance leg and arms control. This could be the key to improve dynamic walking behavior of current humanoids. In addition, it could also help us design new prosthesis and exoskeletons which can help human beings deal with perturbations better.

References

[1] H.-M. Maus, S. W. Lipfert, M. Gross, J. Rummel, and A. Seyfarth, "Upright human gait did not provide a major mechanical challenge for our ancestors." *Nature communications*, vol. 1, no. 6, p. 70, Jan. 2010.

[2] J. Pratt, J. Carff, S. Drakunov, and A. Goswami, "Capture point: A step toward humanoid push recovery," in *Humanoid Robots, 2006 6th IEEE-RAS International Conference on*, Dec 2006, pp. 200–207.

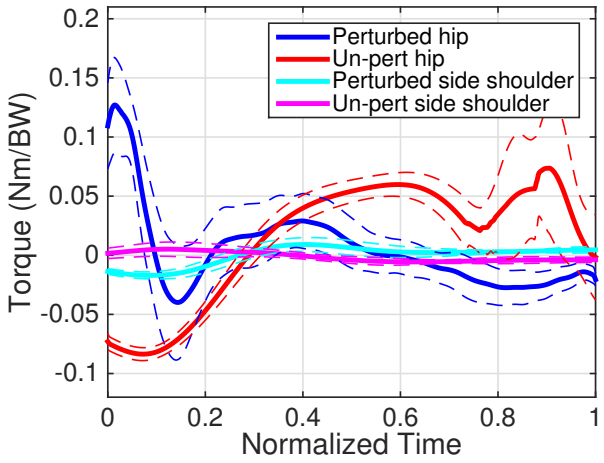

Figure 3: Joint torque curves during perturbed step. Dash line indicate the standard deviation. Normalized time '0' and '1' denotes the touch-down and toe-off of perturbed leg.

[3] A. Seyfarth, H. Geyer, and H. Herr, "Swing-leg retraction: a simple control model for stable running," *Journal of Experimental Biology*, vol. 206, no. 15, pp. 2547–2555, 2003.