The coupling of gaze and gait when walking over real-world rough terrain

Jonathan Samir Matthis*[1] & Mary Hayhoe*[2]
* Center for Perceptual Systems, University of Texas at Austin
[1] matthis@utexas.edu [2] hayhoe@utexas.edu

1 Introduction

Many essential aspects of the steady-state walking over flat, obstacle-free terrain arise from the interaction between the underlying neuromechanical dynamics of the body and the goal of minimizing the energetic cost of locomotion. However, when walking over more complex terrain such as a rocky trail, environmental impediments may render the preferred gait cycle unsafe or undesirable. In such environments, a key role of the visual system is to allow a walker to adjust the ongoing energetically-optimized gait cycle in order to accommodate upcoming complex terrain. This abstract presents a new study in continuation of an ongoing research project centered on the question – How do the biomechanics of bipedal gait shape the visual control of foot placement when walking over complex terrain?

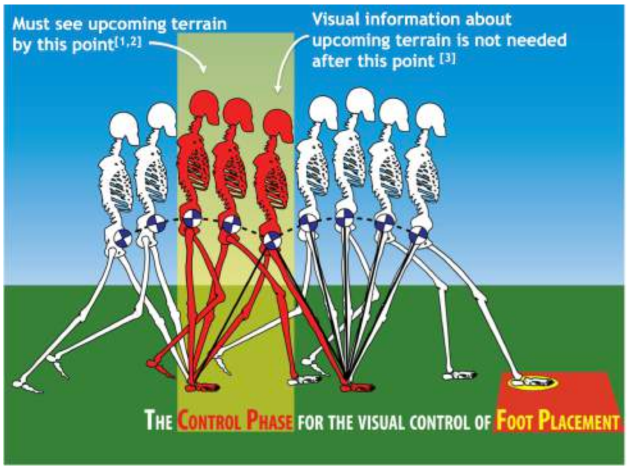

Figure 1: Summary of previous studies [1-4].

2 Background

Previous studies investigated the way that visual information about upcoming terrain is used to guide foot placement (Figure1, [1-4]). These studies utilized a lab-based motion capture system synchronized with an LCD projector which displayed virtual obstacles and targets on the ground. In a series of related experiments, the timing of the visibility of this terrain was manipulated in order to determine the phase of the gait cycle that terrain must be visible to allow the accurate control of foot placement in complex terrain. Theoretical consideration of the physical dynamics of the bipedal gait cycle allowed us to predict the effects of availability or deprivation of visual information about target/obstacle location during different phases of the gait cycle. The results of these studies reveal that there is a critical control phase for the visual control of foot placement that occurs during the latter half of the preceding step (Figure 1). Providing subjects with visual information about a target foothold for ~250ms during this critical control phase resulted in stepping accuracy that was equivalent to a Full Vision condition where the target was visible for the entire trial and superior to conditions when the target was visible for twice as long during a different phase of the gait cycle [4].

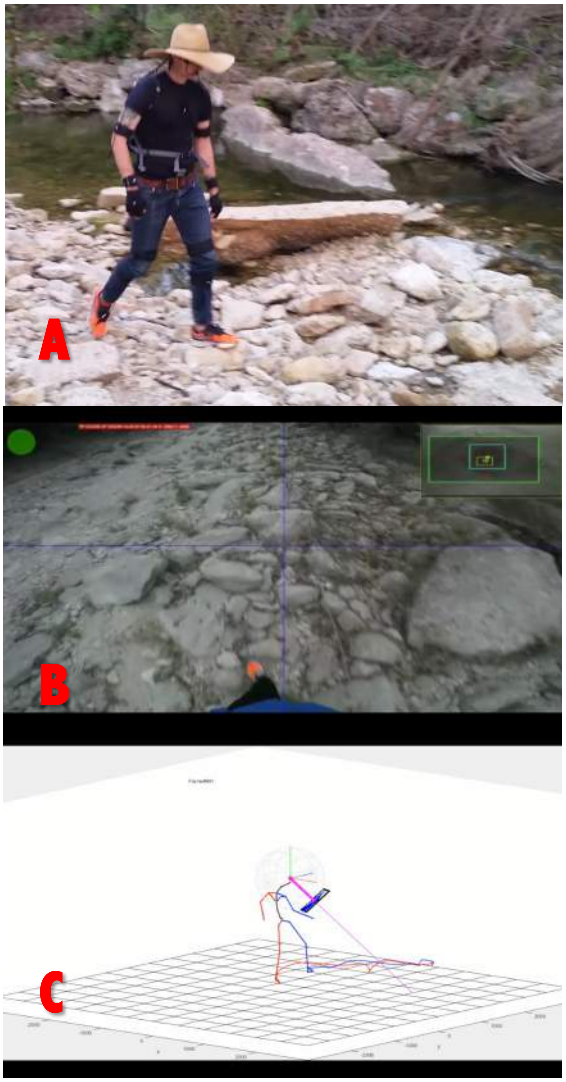

Figure 2: (A) Subjects wore an IMU-based motion capture suit and mobile eye tracker. (B) Subjects fixations (blue crosshairs) were recorded in screen pixel coordinates. (C) Gaze vectors (pink line) from the eye tracker were recast into the geocentric coordinate system used by the motion capture system to investigate coupling between the gait cycle and fixations to the terrain around upcoming footholds.

3 Present Study

In the present study, the results of the previous lab-based experiments are used to provide a theoretical framework within which to investigate the control of gaze during locomotion over real-world rough terrain. Subjects walked over several types of rough terrain of varying difficulty, ranging from a rocky, dried-out creek bed (Figure 2A), to a flat path of loose gravel, to an empty parking lot. Subjects' wore an untethered, full-body IMU-based motion capture suit that recorded the 3D position and orientation of the body in a geocentric reference frame. In addition, subjects' eye movements were recorded using a backpack based mobile eye tracking system (Figure 2B). The recorded fixation data from the eye tracker were recast into 3D spherical coordinates and then rotated according the orientation quaternion output from the head-mounted IMU in order to situate the gaze data from the screen pixel-based coordinate system of the eye tracker into the world-centered reference frame of the motion capture data (Figure 2C).

Gaze fixations relative to the terrain around upcoming foothold locations were analyzed relative to the phase of the gait cycle during which the fixations were made. We found that there is a coupling between the timing of fixations to upcoming footholds and the phase of the gait cycle. This coupling was affected both by the difficulty of the terrain and the cognitive load, which was manipulated by the performance of a secondary visual task. Non-terrain-related fixations made in service of this secondary task were also coupled to the gait cycle, suggesting that attentional allocation during locomotion is also shaped by the physical dynamics of bipedal gait.

References

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