Kinematic Parameterization of Natural Slope Walking

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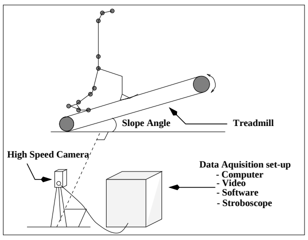
1 Motivation

Our objective is to parameterize the salient kinematic features of natural walking gait on ascending and descending slopes as a function of the slope angle. Although level walk has been a topic of intense study, slope walking is surprisingly under-studied. This is in spite of the fact that graded surfaces are frequently encountered in everyday life [1] and are often the cause of accidents. Most of the reported work in this subject considers only a few slopes and the global conclusions were thus drawn from a relatively sparse dataset [2] [3] [4] [6]. Our approach is novel in the sense that we study gait on a large range of slopes ($-13°$ to $+13°$) with only $1°$ difference between successive slopes.

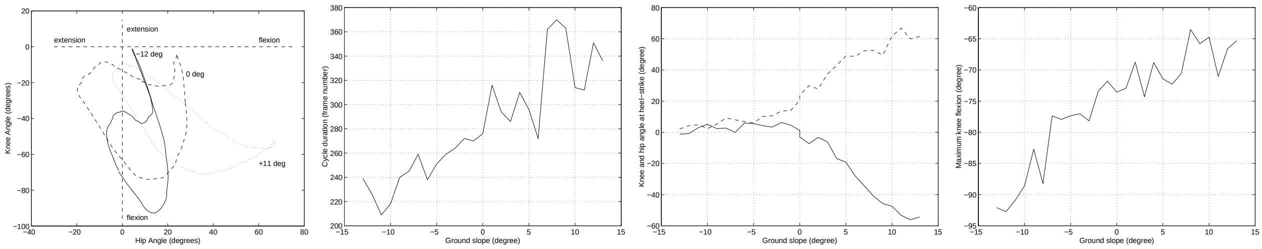
2 Method



We collected sagittal plane position data of retro-reflective markers attached to the traditionally used bony landmarks of two healthy treadmill-habituated male subjects with a video camera. The treadmill speed was adjusted so that the subjects could walk with their natural gaits. After each run, consisting of several datasets from the same slope, the treadmill inclination was changed without any pre-specified order to prevent any anticipatory gait by the subjects. The marker position data were subsequently smoothed using a Butterworth filter and the inter-segmental angles were extracted from them. For this particular paper only the hip and the knee angles are relevant.

3 Results

The evolution of several gait features were studied for parameterization. A representative of the results are shown in the following set of figures. The first figure exhibits the substantial change in the forms of the hip-



knee cyclograms. The cyclograms in the figure correspond to $-12°$, level walk, and $+11°$ slopes. The results are similar to those found by [5]. The cyclograms corresponding to $-12°$ and $+11°$ are interesting for the prominent presence and absence, respectively, of the ground impact stage. The time period of walk cycle has a monotonically increasing trend with respect to the ground slope as shown in the second figure. The next figure presents the evolutions of the heel-strike knee angle and the heel-strike hip angle with respect to ground slope. We observe the interesting phenomenon that one curve is almost the mirror-reflection of the other. The last figure shows the monotonic evolution of the maximum knee flexion angle with respect to the ground slope.

4 Discussion

This study provides us with a straightforward route to the parameterization of slope walking gait. We may start, for instance, by fitting the above curves with linear, piecewise linear or quadratic functions. Please note that the significant fluctuations in the plots are partly due to the fact that the walk cycles were not extracted with any signal processing technique but were obtained visually from smoothed data. Appropriate segmentation techniques are expected to improve the results.

References

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