# Moment-Based parameterization of evolving cyclograms on gradually changing slopes


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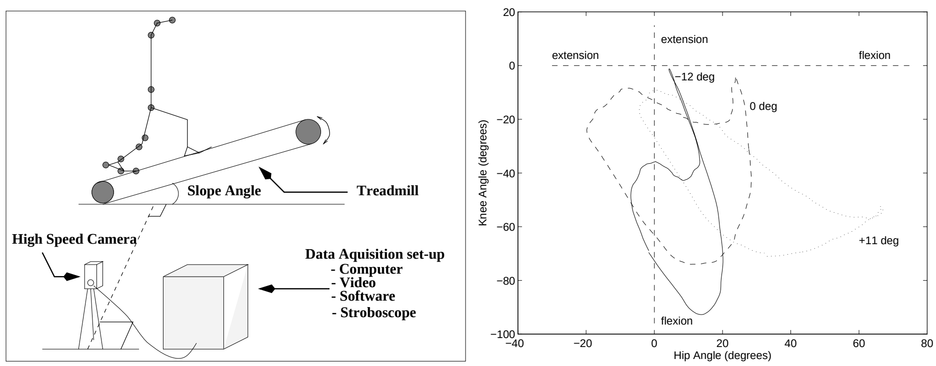
## Abstract


The problem under study is the parameterization of a series of gradually evolving cyclograms with a small number of feature descriptors. The descriptors we selected are the geometric moments of the cyclograms. The thesis of the work is that the gradual evolution of gait on inclined planes, which is manifested by the progressive shape change of these closed-contour curves, can be tracked by observing the evolution of the moment parameters. Parameterization of cyclograms has several useful applications including the quantification of normal gait and the diagnosis of pathological gait.

The cyclograms considered in this study were obtained from natural human walk on a variable-inclination treadmill with slope varying from $-13°$ to $+13°$ at each $1°$ interval. Although in this work we limit ourselves to planar cyclograms consisting of hip angle and knee angle, the described method is fairly general in nature and may be used without restriction for any closed curve such as the phase diagrams and the moment-angle diagrams. Moreover, the method can be extended to higher dimensions and thus we can treat cyclograms involving three or more joint angles.

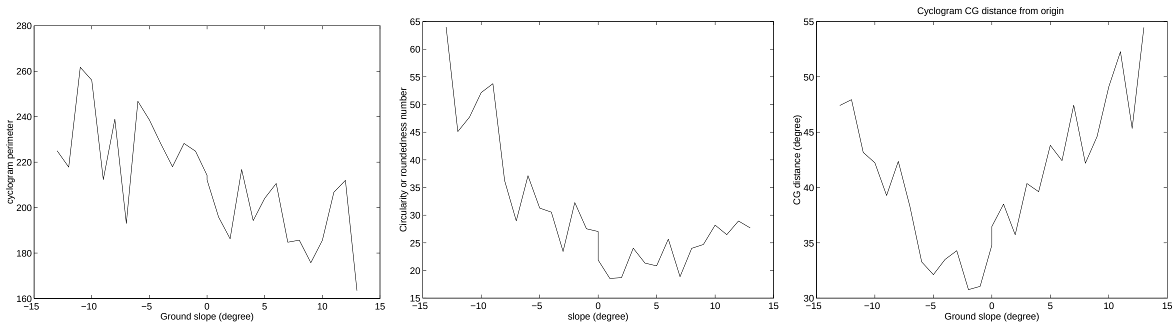
Moment-based identification of physical objects from their images is a topic of active research in the field of pattern recognition. We perform the necessary adaptations of these techniques to make them suitable for our purpose.

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 as seen in Fig. 1(a). 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. Fig. 1(b) exhibits the substantial change in the forms of the hip-knee cyclograms. The results are similar to those found by [4].


(a) (b)

Figure 1: a)Experimental set-up. b) Superimposed hip/knee cyclograms obtained from $-12°$, $0°$, and $+11°$ slopes.




(a) Evolution of cyclogram perimeter

(b) Evolution of the roundedness number

(c) Evolution of center-of-gravity distance

Figure 2: Evolution of several cyclogram parameters as a function of the slope

In order to compute the arc-length based moments of the cyclograms we considered that the contours are physically analogous to thin wire loops with uniform mass distribution. Although it has its own defects, the arc-length based moments are more useful to us than the traditional area-based moments [1]. The two-dimensional moments of order $(p+q)$ of a curve of length $L$ is expressed as [3], $M_{pq} = \int_0^L x^p y^q dl$, where the curve is represented in the $xy$-plane. Since, in practice, the cyclograms are constructed from discrete data points, the above equations become summations rather than integrals. It can be shown that the cyclogram perimeter, $P = M_{00}$, the position of the center of gravity, $x_{CG} = \frac{M_{10}}{M_{00}}$, $y_{CG} = \frac{M_{01}}{M_{00}}$, and its principal orientation directions can be obtained from the moments $M_{20}, M_{11}$ and $M_{02}$. Many other parameters can be calculated as well from the moments[1].

As shown in Fig. 2(a) the cyclogram perimeter (in degree) has a clear decreasing trend relative to the ground slope. Fig. 2(b) shows the *circularity factor* or the *roundedness number* [2] given by $\frac{(perimeter)^2}{area}$, as a function of slope. The evolution of the distance of the CG of the cyclograms with the ground slope is presented in Fig. 2(c). We have performed a systematic study of the dependence of a range of moment-based features of the cyclograms on the ground slope.

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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