Synthesis of Gait Kinematics Using a Database

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1 Previous Works

Numerous researchers have investigated the correlation between body parameters (height, weight, etc) and human gait pattern by observing the gait patterns of subjects [1]. Typically, their analysis methods follow the subsequent process: first, extraction of several gait parameters (step length, gait period, etc) from the subjects' gait motions; second, determination of correlation between one or two body parameters with one or two gait parameters; finally, verification of effectiveness with statistic tools such as p-value or ANOVA. One simple example is that taller men have longer step lengths than shorted women.

2 Motivation

With the advanced motion capture systems, we can collect an extensive amount of data which contain not only gait parameters but also the gait kinematics (*time-series of joint motions*). Typical identification of correlation between one or two gait and body parameters only brings out a slice of the available information for the analysis and synthesis of gait motions. We have developed a novel methodology to generate a functional mapping or a "comprehensive correlation" between body parameters and the time-series of joint motions. With the functional mapping, we can predict an arbitrary person's gait kinematics by inputting his body parameters. Our statistics-based gait pattern synthesis method 1) does not require any model, so avoids the challenges associated with model simplifications, 2) does not need any cost function for optimization, which is critical in musculoskeletal analysis, and 3) can take into account the randomness associated with any gait data.

3 Own Approach

The creation of functional mapping from a large database requires a task of nonlinear regression. We adopted Gaussian Process Regression (GPR) algorithm [2], and its overall procedure is described in Figure 1. In our GP model, the mean function and the covariance function are determined as (1) and (2)

$$m(\mathbf{x}) = \nu_m \tag{1}$$

$$k(\mathbf{x}, \mathbf{x}') = \nu_0 \exp\left\{ -\frac{(\Delta\mathbf{b})^\top \Lambda_b (\Delta\mathbf{b}) + \lambda_t \Delta t^2}{2} \right\} + \nu_1 \delta(i, j) \tag{2}$$

where $\mathbf{b}$ is a vector indicating a subject's body parameters, and $\mathbf{t}$ is time index. $\Delta\mathbf{b}$ is defined as $\mathbf{b} - \mathbf{b}'$ and Δt is defined as $t - t'$. $\delta(i, j)$ is Kronecker delta function. Λ_b is a diagonal matrix. Hyperparameter set is defined as a set of $\nu_m, \nu_0, \nu_1, \Lambda, \lambda_t$, and determines the characteristics of GP. By selecting the hyperparameter set to maximize likelihood function, we can find the optimal GP model.

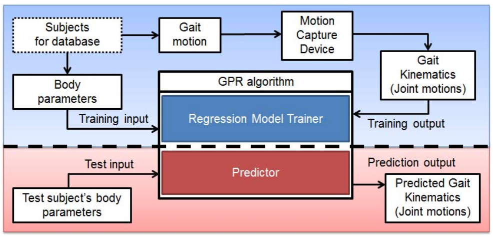

Figure 1: Outline of GPR algorithm for prediction of an arbitrary person's gait pattern

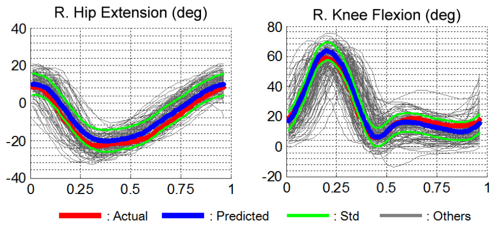

Figure 2: Sample prediction results. GPR prediction algorithm provides not only predicted time-series of joint motions but also its uncertainty values via standard deviation values.

4 Current and Best Possible Results

The ultimate goal is to be able to predict an arbitrary person's gait kinematics only by inputting his body parameters. We have developed a GPR model using gait kinematics data collected from 113 subjects. The predicted output of the model is the probabilistic distribution of joint motions (mean and standard deviation). Figure 2 shows sample results. The effectiveness of the algorithm was validated by a cross-validation method. The method enables a better understanding of human gait patterns, and also provides a novel and low-cost gait pattern generation method which may be helpful in developing controller for rehabilitation robots, and in computer graphics. The shortcoming of this statistics-based method, which is difficulty in gaining an insight into the physics and biomechanics of walking, can be addressed by combining physics-based models with the statistical methods.

Acknowledgement

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References

[1] Lelas et al. (2003) *Gait & posture*

[2] Rasmussen. (2006) *Gaussian processes for mach. learning*