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Deformation, Parameterization and Analysis of a Single Locomotion Cycle

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Introduction

We present preliminary results of a framework that can synthesize parameterized locomotion with controllable quality from simple deformations over a single step cycle. Our approach enforces feet constraints per phase in order to appropriately perform motion deformation operations, resulting in a generative and controllable model that maintains the style of the input motion. The method is lightweight and has quantifiable motion quality related to the amount of deformation used. It only requires a single cycle of locomotion. An analysis of the deformation is presented with the quantification of the valid portion of the deformed motion space, informing on the parameterization coverage of the deformable motion cycle.

Method

The system relies on a self-concatenating motion cycle. Firstly, the structure of the cycle is defined. Then, deformations are applied over the root position and orientation, and any foot related error that the transformation introduces is fixed accordingly. We can then analyze and precompute the space of deformations in order to limit the space that maintains a desired quality.

Cycle corrections

Each foot has four different states: *Flying, Landing, Supporting* and *Departing*. By using blending operations on the transitory stages, we ensure motion continuity during deformation operations. Each foot cycle goes as follows:

- Flying
- Landing
- Supporting
- Departing

These four stages are inspired by human performances, whenever a change of speed or direction happens, a slight movement over the initial contact of the step can be observed, giving us the *Landing* phase. The *Supporting* phase is necessary to maintain consistency over the walk, and the *Departing* phase eliminates any discontinuity in position and speed.

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Deformations

Deformations are applied over the root position and orientation. We consider the root as the joint to which the hips and spine are connected in any humanoid skeleton. Each cycle M_R is represented as a vector of 3D representations of the root position and orientation $\rho_i = \{x_i, z_i, \theta_i\}$, θ_i represents the yaw of the character and $\{x_i, z_i\}$ its projected position on the floor. Then, the full motion is represented by $M_R = \{\rho_i\}$ with $i \in \{0, \ldots, N\}$ where N is the number of frames the cycle contains. We perform three kinds of deformations:

- **Rotation**. A 2D rotation of ϕ is applied to $\{x_i, z_i\}$ and added ϕ to θ_i.
- **Translation** or **Speed**. The translation at time t will be $\{x_i, z_i\} - \{x_{i-1}, z_{i-1}\}$ where i represents the corresponding frame at time t. The resulting path is stretched or compressed reaching a different position.
- **Orientation**. The value of ϕ is added to θ_i. The orientation of the character changes but it follows the same path.

The motion clip begins and ends at the flying stage of the right foot, and contains all the described stages for each foot. When large deformations are imposed, a number of problems arise and specific metrics are used to determine the quality of each deformation.

Analysis

When large deformations are imposed, a number of problems arise. We run the following evaluations on a 37 frame motion clip consisting of one single, self-concatenating walk cycle:

IK If the distance from the IK goal to the hip is greater than the distance from the hip to the end-effector, a solution will never be found. We quantify the error by measuring the sum of the distance errors whenever the IK cannot reach the exact solution (after a set threshold the deformed motion is discarded). This gives us a quality inversely proportional to the IK error.

Continuity The second problem when dealing with IK is to ensure continuity over subsequent frames independently corrected with IK. Instead of relying on specific IK formulations our approach discards the deformations that generate discontinuous motions.

Collision Finally, some of the deformations will cause the legs to collide with each other, and collision detection is required to reject these cases. The legs are represented as capsules for fast collision determination.

Our overall analysis highlights the danger areas in which the deformations generate too much error. In this way every cycle used for the locomotion can be analyzed during modeling phase in order to obtain optimal results on the trade-off between quality and parameterization coverage.