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.

System Implementation

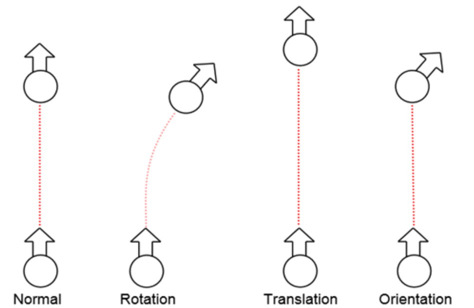
Deformations are applied over the root position and orientation, and any broken feet constraints introduced by the transformation are fixed with IK and blending operations.

Each foot has four different stages:

- **Flying**
- **Landing**
- **Supporting**
- **Departing**

These four stages are observed in real 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 during the walk, and the *Departing* phase eliminates any discontinuity in position and speed.

Deformations



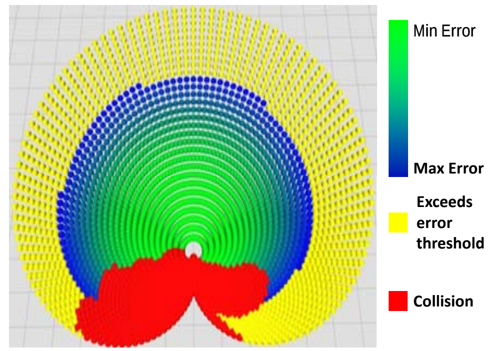
Deformations are applied over the root position and orientation. Each cycle M_R is represented as a 3D vector representation of the root position and orientation $\rho_i = \{x_i, z_i, \theta_i\}$, where θ_i represents the yaw rotation of the character and $\{x_i, z_i\}$ its projected position on the floor.

We currently perform three types of deformation:

- **Rotation**. A 2D rotation of ρ is applied to $\{x_i, z_i\}$ and added ρ 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 ρ 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



We have run the following metrics 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 measure 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 locomotion can be analyzed during modeling phase in order to obtain optimal results for the trade-off between quality and parameterization coverage.

Results and Applications

Example of two end poses of a straight step deformed to turn left. The example on the left also includes a stretching deformation. The supporting foot will always stay on its original position and orientation while the moving foot trajectory is deformed together with the root joint.

Our overall method can be applied to a number of tasks:

Real Time Control. We can map joystick or keyboard controls to deformations that remain inside the desired quality region, achieving intuitive control with ensured quality of motion.

Path Following. We can deform the locomotion to follow any desired path. Motion quality can be controlled by limiting path curvature during path generation.

Path Planning. Using the proposed analysis, we have a space that can be used for sampling. This is the starting point of several motion planning schemes.

While our preliminary results focus on a single motion cycle, a collection of deformable cycles can be used to address complex behaviors.