Exact Parameterization for Precise Foot Placement

B. J. H. van Basten[1 †], S. A. Stüvel[1] and A. Egges[1]

[1]Games and Virtual World Group, Utrecht University, The Netherlands

Abstract

In many constrained environments, precise control of foot placement during character locomotion is crucial to avoid collisions and to ensure a natural locomotion. In this paper, we present a new exact parameterization technique based on foot steps that efficiently blends animations in a linear representation to guarantee exact control of foot placement. By concatenating these parameterized steps, we can generate highly-constraint stepping animations. Furthermore, because of a novel blend candidates selection strategy, soft constraints such as timing can also be taken into account.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Animation

1. Introduction

In games, characters constantly walk around the environment while trying to avoid obstacles. Therefore, generating animations of human walking has received a lot of attention during the past decades. In highly-constrained environments, such as narrow corridors or indoors, exact foot placement is crucial and different locomotion behavior such as side-stepping or walking backwards are required to realistically guide a character through such environments.

This animation problem is also known as the *stepping stone* problem. Given a set of query foot placements, called a *foot plan*, that contains temporal and spatial constraints, generate an animation that adheres to these constraints. In our problem setting, we consider the feet positions as *hard constraints* and feet orientation and temporal constraints as *soft constraints*. Not many techniques allow exact foot placement. Some use a global optimization [vdP97, SH07] that is often not suitable for real-time. Other techniques concatenate and modify existing clips of motion [CLS03, BPE10], possibly introducing more artifacts. We propose a novel parameterization technique that efficiently generates exact results.

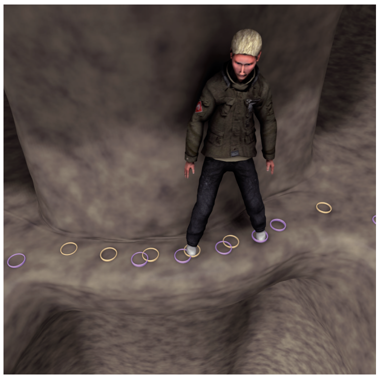

Figure 1: *In some environments, exact foot placement is very important. Our technique generates animations that exactly follow a desired foot plan.*

2. Method

Our system can be divided into an offline and online phase. In the offline phase, we create the data structures that allow for fast motion synthesis. In the online phase, these structures are queried to synthesise stepping motion.

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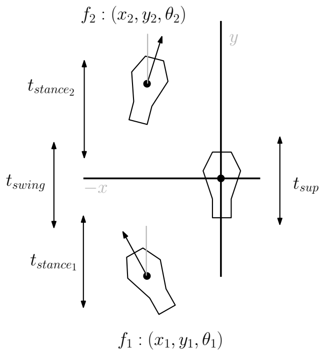

Figure 2: *We represent a foot step in S_{high} using 10 parameters.*

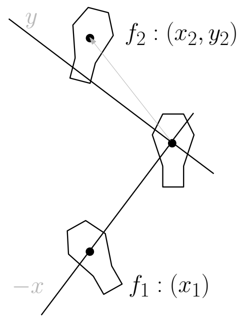

Figure 3: *We express the spatial properties of a step in S_{low} using 3 parameters.*

The offline phase consists of the following steps:

1. We automatically segment a corpus of motion data consisting of locomotion animation into clips of individual steps.
2. We represent these steps in a 10-dimensional parameter space S_{high} (See Figure 2).
3. We also represent the same steps in a 3-dimensional parameter space S_{low} using a Delaunay tetrahedralization with cross-pointers between corresponding steps (See Figure 3).

In the online phase the user or footstep planner supplies a query foot plan. Then, for each query step in this foot plan:

1. The query step is transformed to the lower-dimensional parameter representation.
2. We utilize S_{low} to rapidly find a set of blend candidates **B**. We extend the half-planes spanning the tetrahedron that contains the query step and localize all example steps in these infinite frustrums.
3. We evaluate the blend candidates in the higher-dimensional, more descriptive, parameter space S_{high} to also take soft constraints into account.
4. The final blend candidates are blended in the lower-dimensional space S_{low}, using a novel interpolation scheme that yields exact foot placement. By *positionally* interpolating the foot joints and recalculating the remaining joints (knee, toe), we can guarantee exact foot placement.
5. The generated step is aligned and fitted to the previous step.

3. Results

We tested our techniques on several foot plans. The query foot plan of Figure 1 consisted of 20 steps guiding the character along a narrow ridge, including a transition to side-stepping. In Figure 4, we used a foot plan extracted from recorded motion. On average, generation and concatenation of a single step takes 0.028 seconds ($\sigma = 0.02$ s.). The average duration of a single step was 0.59 seconds ($\sigma = 0.05$ s.) making this technique suitable for real-time applications.

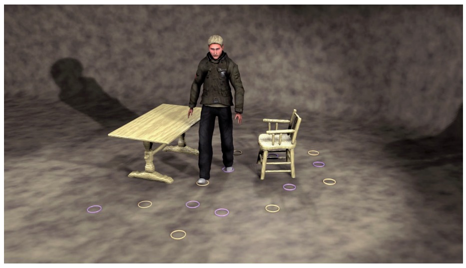

Figure 4: *An indoor foot plan, extracted from motion capture data.*

4. Conclusion

Our technique efficiently generates highly-constrained motion using a novel parameterization technique that yields exact results, in contrast to standard parameterization technique. Due to a novel blend candidates selection strategy, we also take into account soft constraints such as timing and foot orientation.

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