Editing and Constraining Kinematic Approximations of Dynamic Motion

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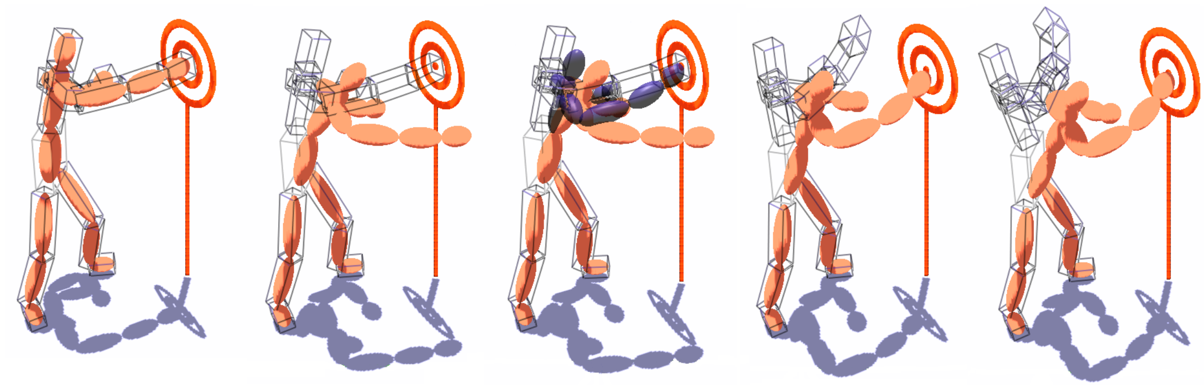

(a) (b) (c) (d) (e)

Figure 1: *Inverse Kinodynamics Approach Illustrating a Punch Scenario.*

1 Introduction

Physical simulation is now a robust and common approach to recreating reality in virtual worlds and is almost universally used in the animation of natural phenomena, ballistic objects, and character accessories like clothing and hair. Despite these great strides, the animation of primary characters continues to be dominated by the kinematic techniques of motion capture and above all traditional keyframing. Two aspects of a primary character in particular, skeletal and facial motion, are often laboriously animated using kinematics. There are perhaps three chief reasons for this. First, kinematics, unencumbered by physics, provides the finest level of control necessary for animators to breathe life and personality into their characters. Second, this control is direct and history-free, in that the authored state of the character, set at any point in time is precisely observed upon playback and its impact on the animation is localized to a neighborhood around that time. Third, animator interaction with the time line is WYSIWYG (what-you-see-is-what-you-get), allowing them to scrub to various points in time and observe the character state without having to playback the entire animation. Secondary dynamics can be overlaid on primarily kinematic character motion to enhance the visceral feel of their characters. But unfortunately compromise the second and third reasons animators rely on pure kinematic control.

2 Our Approach

We presents inverse kinodynamics (IKD), an animator friendly kinematic workflow that both encapsulates short-lived dynamics and allows precise space-time constraints. Kinodynamics (KD), defines the system state at any given time as the result of a kinematic state in the recent past, physically simulated over a short temporal window to the present. KD is a well suited kinematic approximation to animated characters and other dynamic systems with dominant kinematic motion and short-lived dynamics [Angelidis and Singh 2007]. Given a dynamic system, we first formulate an appropriate kinodynamic window size based on kinematically defined accelerations in the kinematic trajectory and physical properties of the system. We then present an inverse kinodynamics (IKD) algorithm, where a kinodynamic system can precisely attain a set of animator constraints at specified times. Our approach solves the IKD problem iteratively, and is able to handle full pose or end effector constraints at both position and velocity level, as well as multiple constraints in close temporal proximity. Our approach can also be used to solve position and velocity constraints on passive systems attached to kinematically driven bodies. We show IKD to be a compelling approach to the direct kinematic control of character, with secondary dynamics via examples of skeletal dynamics and facial animation.

We provide a short description of our results, referring to Figure 1 which shows snapshots of a character who has to punch a target. (a) shows the motion capture at the time of contact in both wire-frame and solid orange. (b) the solid orange character shows the KD state of the relaxed character, which fails to reach the target at the time of contact. (c) inverse kinematics produces the pose of the character in dark blue. (d) iteratively computing the error and modifying the kinematic trajectory produces a KD state which hits the target (orange). Here the modified motion capture pose is shown in wire-frame. (e) shows the result of using a smaller temporal width for the bell shaped correction curve, which results in more of an upper cut.

3 Conclusion and Future Work

In future work we would like to address the coupling of kinodynamic trajectories with fully dynamic environments via adaptive kinodynamic window sizes that are aware of collision events and other discontinuities in a full physical simulation. In summary, we propose the concept of Inverse Kinodynamics and present a first algorithm which opens up new possibilities for editing traditional keyframe animations that are augmented with secondary dynamics.

References

ANGELIDIS, A., AND SINGH, K. 2007. Kinodynamic skinning using volume-preserving deformations. In *Proceedings of the 2007 ACM SIGGRAPH/Eurographics symposium on Computer animation*, Eurographics Association, SCA '07, 129–140.