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Planning Motions in Motion

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Abstract

Editing recorded motions to make them suitable for different sets of environmental constraints is a general and difficult open problem. In this paper we solve a significant part of this problem by modifying full-body motions with an interactive randomized motion planner. Our method is able to plan motions for specified linkages of an animated character in synchrony with the full-body motions affecting the same character and at the same time avoid collisions with dynamic obstacles. We demonstrate the effectiveness of our method with two important applications: (a) motion correction (to remove collisions) and (b) synthesis of realistic object manipulation sequences on top of locomotion.

1. Introduction

We introduce a new motion editing approach that combines keyframed motions with motion planning in order to produce realistic animations of characters manipulating objects in dynamic environments. As an example, Figure 1a shows a walking character manipulating an umbrella so that it can walk through the two posts without hitting them. The motion of the character's arm was synthesized interactively by our planner on top of the original locomotion.

Our approach is based on a *Rapidly-Exploring Random Tree* (RRT) planner in its bidirectional version [KL00]. To address synchronization with external motion controllers and moving obstacles we extend this planner by including time as one more dimension in the search. The inclusion of the time dimension in a motion planner has already been proposed in Robotics [HKLR02] however in this work we present for the first time the combination of keyframed and planned sequences in order to achieve manipulation combined with locomotion.

2. Synchronized Motion Planner

We represent the character as an articulated figure composed of hierarchical joints. A motion affecting the character is defined as a time-varying function $m(t)$ over a given time interval $I \subset \mathbb{R}$. In order to take into account dynamic environments, moving objects are required to be parameterized by the same time parameter $t \in I$, and a function $w(t)$ is used to set the state of the world to the desired time t.

The motion planner is then configured to affect only the desired joints of the character (for example the arm or leg joints). Our planner is based on a bidirectional RRT extended to support landmarks with monotone time parameters. Two search trees are initialized with initial and goal configurations at specified initial and goal times. The trees are iteratively expanded by adding valid configuration landmarks towards random samples. Each configuration can only be added to one of the trees if the monotone time condition is preserved, otherwise the configuration is invalid and discarded. In addition, only configurations which are collision-free at states $w(t)$ and $m(t)$ can be added, where $t \in I$ is the time component of the landmark being considered. Other validity constraints, such as joint limits, are also included.

3. Applications and Results

We have integrated the described planner in the DANCE animation system [SFNTH05]. Multiple arms and leg targets can be specified and solved by our planner interactively. Targets can be dynamic and/or attached to any objects or body parts. Characters can be instructed to grab, drop and move objects. Several tasks can be specified simultaneously and synchronized with arbitrary keyframe motions applied to the characters.

Motion Correction Our planner introduces an effective way

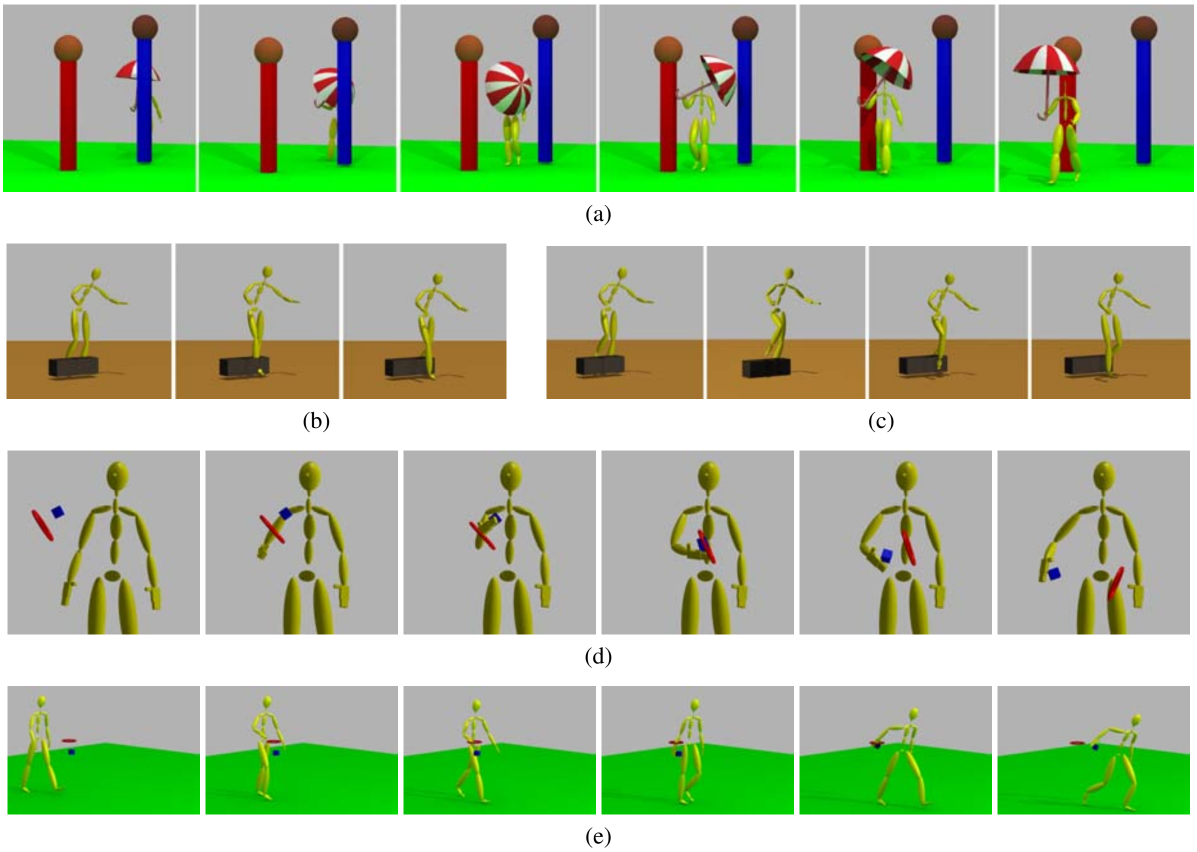

Figure 1: *Examples of motion correction (a-c) and grasping of a dynamic object (d,e).*

to correct portions of motions that are found to produce collisions with new objects in the environment or with new objects attached to the character.

For solving this kind of problem, we define times t_{init} and t_{goal} such that interval $[t_{init}, t_{goal}]$ spans the problematic period of the motion. The problem is then solved by planning a new synchronized path for the problematic limb between configurations $m(t_{init})$ and $m(t_{goal})$. If the planner is successful, the result will be a collision-free motion that is used to replace m during interval $[t_{init}, t_{goal}]$. See Figures 1a-c for some examples.

Object Manipulation For solving object manipulation tasks with moving characters we first specify a hand target h on the object to be grasped at the desired time t_b. We use Inverse Kinematics to determine a configuration $ik(h, t_b)$ that reaches the hand target with the desired end-effector and that is annotated to be executed at time t_b. We then determine times t_a and t_c such that $t_a < t_b < t_c$, and the problem is solved in two steps: first a synchronized path is planned between configurations $m(t_a)$ and $ik(h, t_b)$ and then a second path is planned between $ik(h, t_b)$ and $m(t_c)$. See Figures 1d,e for examples.

References

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