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Animation Planning for Virtual Mannequin Cooperation

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Abstract

We present a brief overview of an algorithm to automatically compute animations for virtual mannequins cooperating to move bulky objects in cluttered environments. The main challenge is to deal with 3D collision avoidance while preserving the believability of the agents behaviors. To accomplish the coordinated task, a geometric and kinematic decoupling of the system is proposed. This decomposition enables us to plan a collision-free path for a reduced system, then to animate locomotion and grasp behaviors in parallel, and finally to clean up the animation from residual collisions. These three steps are applied consecutively making use of different techniques such as probabilistic path planning, locomotion controllers, inverse kinematics and path planning for closed-kinematic mechanisms.

1. Introduction

In this work we cope with developing an automated motion strategy for the cooperation of two or more virtual mannequins that transport an object in a 3-dimensional cluttered environment (Figure 1). The motivation is mainly supported by offline applications such as PLM (Product lifecycle management), e.g. maintenance and operation in industrial facilities. The mannequins are considered to be either human figures with walking capabilities or virtual mobile robots.

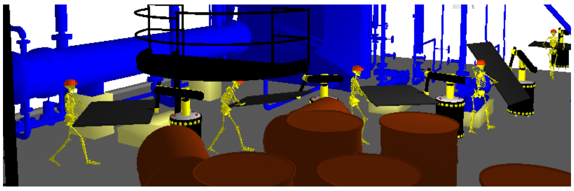

Figure 1: *The agents deal with several obstacles while cooperatively transporting a large plate.*

We show how to model the global task within a single system that gathers all the degrees of freedom of the agents and the object. This system is automatically built by computing a so-called *"reachable cooperative space"*. Then three consecutive steps are performed:

1. **Plan** a collision-free trajectory for a reduced system.
2. **Animate** locomotion and manipulation DOFs.
3. **Tune** the generated motions to avoid residual collisions.

These steps are applied by making use of a probabilistic motion planner to compute the collision-free paths; motion controllers adapted for each kind of mannequin for both, locomotion and grasp behaviors and path planning algorithms for closed kinematic chains to deal with coordinated manipulation. Our contribution is thus, to address all these approaches in a single scheme and at the same time deal with 3D collision avoidance.

2. Behavior-based kinematic model

The system DOFs are decomposed in groups according to the main task they are sensed to perform. In this way, the control and description of the task is simplified. The system contains three groups of DOFs (Figure 2a): locomotion, grasp and mobility. The *Locomotion* DOFs are the ones involved mainly in the steering of the mannequin in the environment. The *Grasp* DOFs are in charge of the manipulation task, i.e. the arms of the mannequins. The *Mobility* DOFs allow a complementary posture control.

3. Reachable cooperative space

To attain cooperation between the mannequins a description of the space where the object can be manipulated is needed.

For a single virtual mannequin, the space is defined by its arms inherent inverse kinematics. The *reachable cooperative space* is represented by the intersection of all the individual spaces. In the case of large objects (Figure 2b), we consider the object as the end effector of the arms kinematic chain for each mannequin. The reachable spaces are automatically approximated with the *spherical shells* technique.

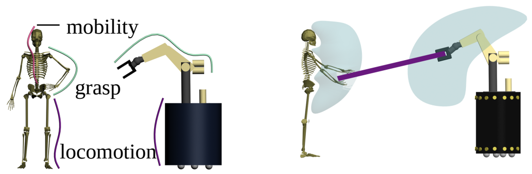

Figure 2: (a) *models DOF decomposition* (b) *illustration of the reachable cooperative space.*

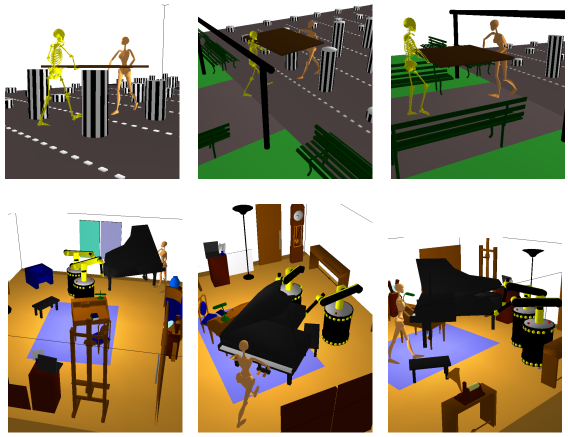

Figure 3: *Two different animations automatically generated with our algorithm.*

4. Algorithm

Given the user-defined initial and final configurations of the system in the 3D environment and velocity and acceleration constraints. The first step is thus to plan a collision-free trajectory for the locomotion DOFs as well as for the object DOFs. For this, a probabilistic roadmap method is applied [KSLO96]. As local paths, Bezier curves of third degree are computed for the human mannequin. For the object and the mobile robots, a straight line segment in their respective configuration spaces is used.

To animate locomotion DOFs (pelvis and legs) and mobility DOFs (spine and head), we have adopted a locomotion controller based on motion capture blending techniques [PLS03]. To synthesize the coordinated manipulation motions, an inverse kinematics algorithm adapted for each kinematic chain labeled as grasp DOFs (the human mannequin and the robot arms) is used [TGB00].

To solve the possible residual collision along the animated sequence, a local deformation of either the mobility (spine-head) or grasp (arms-object) kinematic chains until a valid random collision-free configuration is reached. Thereafter, a warping method is computed to preserve the smoothness of the animation. Considering the case of collisions involving the grasp DOFs, a local planner based on closed kinematic chains is used [CSL02].

After these stages, if there are no collision-free configurations found, the trajectory generated in the planning stage is invalidated and a new one is searched.

5. Experiments

Figure 3 shows some examples solved by our algorithm. The planner has been tested on a workstation Sun-Blade-100 with a 500MHz UltraSparc-IIe processor and 512 MB RAM. The number of polygons in the different environments and the time taken to compute the examples (averaged over 100 runs) were 44,392/14.1 sec for 204 frames and 19,077/6.4 sec. with 151 frames for the columns and the living-room respectively.

6. Conclusion

We presented an approach to plan and synthesize collision-free motions for virtual mannequins handling a bulky object in a 3D environment. To accomplish this coordinated task, a geometric and kinematic decoupling of the system is proposed. This decomposition enables us to plan a collision-free path for a reduced system, then to animate the locomotion and grasp behaviors in parallel and finally to clean up the animation from residual collisions. Future work includes extending the planner to handle more complicated instances of this problem involving several mannequins and movable objects. Work should also be done in order to obtain a larger set of motions for our virtual mannequins. We intend to achieve this by incorporating simulation-based approaches in our global planning framework.

Videos of this work can be obtained at www.laas.fr/RIA/RIA-research-motion-character.html

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