Automatic Animation Generation of a Teleoperated Robot Arm

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Abstract.
In this paper we describe the Automatic Task Demonstration Generator (ATDG), a system implemented into a software prototype for teaching the operation of a robot manipulator deployed on the International Space Station (ISS). The ATDG combines the use of path planning and camera planning to take into account the complexity of the manipulator, the limited direct view of the ISS exterior, and the unpredictability of lighting conditions in the workspace. The path-planning algorithm not only avoids obstacles in the workspace as is normal for a path-planner, but in addition takes into account the position of corridors for safe operations and the placement of cameras on the ISS. The camera planner is then invoked to find the right arrangement of cameras to follow the manipulator on its trajectory. This allows the on-the-fly production of useful and pedagogical task demonstrations to help the student carry out tasks involving the manipulation of the robot on the ISS. Even if the system has been developed for robotic manipulations, it could be used for any application involving the filming of unpredictable complex scenes.

1 Introduction

The Space Station Remote Manipulator (SSRMS) is an articulated robot arm mounted on the international space station (ISS). The SSRMS is a key component of the ISS, used in the assembling, the maintenance and the repair of the station, and also for moving payloads from visiting shuttles. Astronauts operate the SSRMS through a workstation located inside one of the ISS compartments. The workstation has an interface with three monitors, each connected to a camera placed at a strategic location of the ISS. There are a total of 14 cameras on the ISS. Making the right camera choices for each of the three monitors available in the robotic workstation is essential for the operator to have a good awareness of the space when manoeuvering the arm. Operators manipulating the SSRMS on orbit receive support from ground operations. Part of this support consist in visualizing and validating manoeuvres before they are actually carried out.

In order to improve the ground support operations on the SSRMS, we have developed the automatic task demonstration generator (ATDG), which generates 3D animations that demonstrate how to perform a given task with the SSRMS. The ATDG is integrated within the RObot MANipulation Tutoring System (Roman Tutor) [5], a simulator for the command and control of the SSRMS (Figure 1).

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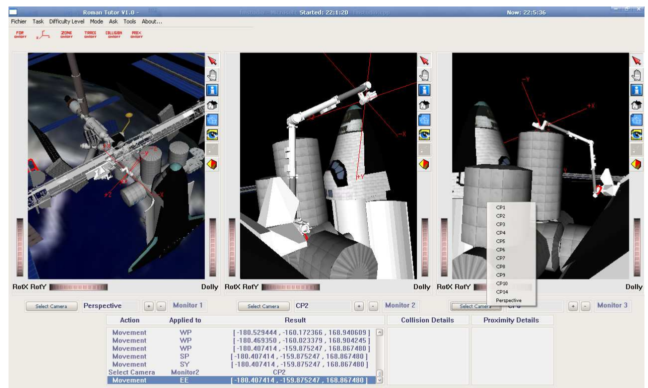

Figure 1. Roman Tutor Student Interface

Filming a trajectory of the SSRMS is a particular case of the problem of automatic movie generation. Previous approaches can be generally classified into constraint satisfaction methods and idiom-based approaches. Constraint-satisfaction methods [2] work at the level of the frame. Given a set of constraints about the objects to appear in the frame, they find the camera parameters that best satisfy these constraints. Idiom-based approaches [4] are based on cinematography principles. They establish a formalization of these principles to reduce the large search space produced by the many degrees of freedom the camera has in each frame of the animation.

A key difference between these applications and ours is that in their case, they have a detailed script of the animation at the design phase, with well identified scenes and corresponding semantics. Hence, constraints for the placement of objects and the types of camera shots for different scenes are specified off-line at the design phase. In our case, the trajectory for the SSRMS has to be generated online, depending on the task at hand; we do not have a script specifying beforehand all the scenes of interest and how they should be filmed. Our main contribution is to actually explain how idiom-based approaches can be adapted to filming complex robot arm trajectories by integrating an automated segmentation of the trajectory into scenes depending on some spatial and cognitive task specifications. Another difference between previous approaches and ours deals with the nature of the domain. A number of general-purpose rules have been developed in the literature constraining the types of camera shots used for filming people or animated characters. These rules do not apply when the object being filmed is an articulated arm, so we had to introduce more appropriate ones.

2 ATDG - Automatic Task Demonstration Generator

The ATDG system takes as input a start and a goal configuration for the SSRMS. It generates a movie demonstrating how to move the SSRMS from the start to the goal configuration. The ATDG algorithm sequentially performs the following steps:

1. Calls the path-planner to compute the trajectory from the start to the goal configuration
2. Segments the trajectory into scenes
3. Calls the camera planner to plan the shots on the scenes

The path-planner implements the FADPRM algorithm introduced by Belghith *et al.* [3] which takes into account collisions and visibility constraints. Collisions are treated as hard constraints on trajectories that must be avoided at any cost, whereas visibility constraints are handled as preferences among desirable trajectories. This approach generates safe collision-free trajectories such that the robot is visible at all times from one or more of the cameras.

In order to categorize the movements performed by the SSRMS and decompose them into scenes and shoot them correctly using specific idioms, it was necessary to add new information to the trajectory provided by the FADPRM path planner. This new information takes the form of a geometric decomposition of the workspace. The trajectory found by the path-planner is mapped within these geometric decompositions to produce a series of corridors. Each of these corridors corresponds to a specific scene category. A list of idioms is associated with each category of scene as in the normal idiom-based animation generation. This geometric decomposition and the choice of idioms for each scene category is done manually by a domain expert. We plan to construct a complete module that will automatically generate these decompositions from the actual state of the ISS including, among others, the geometry of the workplace, visibility constraints and luminosity.

The trajectory mapped within the succession of corridors is then passed to the camera planner. For each portion of the path in a single corridor, the camera planner will try to select the best suitable idiom. The selection of the best idiom in each corridor depends on the quality of the rendering and takes into account the cinematic principles guaranteeing continuity between shots and then consistency of the final movie.

In ATDG, each shot in the idiom is distinguished by three key attributes: shot type, camera placement mode, camera zooming mode.

Shot Types Five shot types are currently defined in the ATDG System: Static, GoBy, Pan, Track and Pov. A Static shot for example is done from a static camera when the robot is in a constant position or moving slowly. Whereas in a Track shot, a camera follows the robot and keeps a constant distance from it.

Camera Placements For each shot type, the camera can be placed in five different ways according to some given line of interest: External, Parallel, Internal, Apex and External II. Currently, we take the trajectory of the robot's center of gravity as the line of interest which allows filming of a number of many typical manoeuvres. For larger coverage of manoeuvres, additional lines of interest will be added later.

Zoom modes For each shot type and camera placement, the zoom of the camera can be in five different modes: Extreme Close up, Close up, Medium View, Full View and Long View.

Figure 2 shows an idiom illustrating the anchoring of a new component on the ISS. It starts with a Track shot following the robot while moving on the truss. Then, another Track shot showing the rotation of one joint on the robot to align with the ISS structure. And finally a Static shot focusing on the anchoring operation.

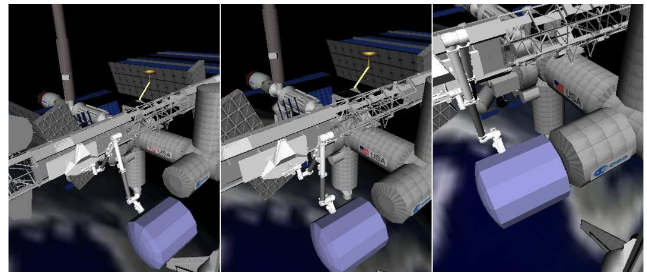

Figure 2. Idiom to film the SSRM anchoring a component on the ISS

In DCCL [4], idioms are specified using planning operators, so that the sequence of shots is generated by a planner. We follow a similar approach but use a different planner and another idiom specification language. In our case, we specify idioms in the Planning Definition Language (PDDL 3.0) and use the TLPlan system [1]. Intuitively, a PDDL operator specifies preferences about shot types in time and in space depending on the robot manoeuver. Parsing the trajectory of the robot mapped within the corridors designating the successive scenes performed, the planner will try to find a succession of shots that captures the best possible idioms. The planner also takes into account the cinematic principles to ensure consistency of the resulting movie. Idioms and cinematic principles are in fact encoded in the form of temporal logic formulas within the planner.

3 Conclusion and Future work

We have introduced a heuristic technique for segmenting the robot trajectory and an approach for defining idioms for robot manoeuvres, allowing us to adapt idiom-based approaches for the automatic filming of robot manipulations. As we are using the TLPlan system, this framework also opens up interesting avenues for developing efficient search control knowledge for this particular application domain and possibly for learning it. There are widespread expectations that the TLPLan and the planning techniques it incorporates are useful in real world applications and ATDG is one of the first examples.

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