

Constraint-based Manipulations for Precise Interactions in Virtual Environments

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Framework of Constraint-Based Manipulations

The absence of constraints when interacting with virtual objects is one of the major limitations in current Virtual Reality (VR) applications. Without constraints, it is difficult to perform precise interactive manipulations in virtual environments. In this work, constraint-based manipulations are realized for precise interactions in the VR environment. The framework of constraint-based manipulations is shown in figure 1. For every object in the virtual environment, such as feature elements, features, or parts, an event list is regarded as the attribute of this object and is attached to the object. An action list is connected to every event in the event list of the object. This action list shows the actions that will be executed as soon as the event occurs. The

constraint-based manipulations are realized by these basic interactive events and the actions that are performed when these events occur. Examples for the basic interactive events are the grasping event, the moving event, and the dropping event. The grasping event has an action for acquiring the current allowable motions of an object that is attached to it. An action for recognizing the constraints between objects is attached to the moving event and the dropping event. As soon as a user grasps an object, the grasping event occurs and the current allowable motions of this object are derived from the constraint-based model through constraint solving. The constraint-based manipulations are acquired by constraining the 3D hand movements to the allowable motions. This is done by transferring 3-D

German Abstract

Virtual Reality (VR) Technologien kommen zunehmend auch im Bereich CAD zum Einsatz. Ein Problem stellen dabei die in der VR verwendeten 3D Eingabegeräte dar, da sie für viele CAD Anwendungen nicht präzise genug sind. Ein möglicher Ansatz zur Verbesserung der Eingabegenauigkeit ist die Verwendung von Nebenbedingungen, durch die der Freiheitsgrad des Benutzer bei der Manipulation von virtuellen Objekten sinnvoll eingeschränkt wird. Dabei werden die Nebenbedingungen für jedes Objekt innerhalb von Matrizen gespeichert, die erlaubte Translationen und Rotationen definieren. Ein Vergleich der Matrizen mit den Eingabedaten ermöglicht die Erkennung und Kontrolle ungenauer Interaktionen. Die visuelle Darstellung der erlaubten Manipulationen für Objekte, die bewegt werden, liefert eine weitere Hilfestellung für den Benutzer.

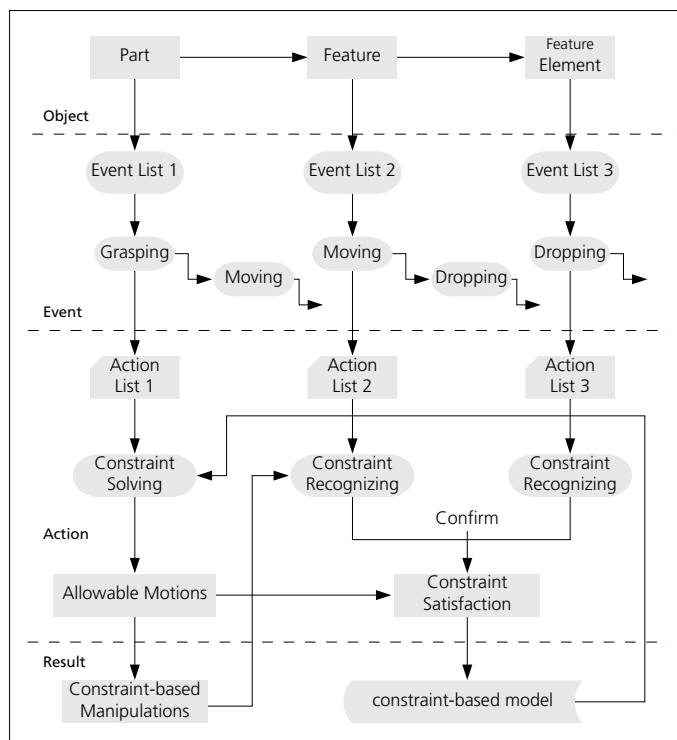


Figure 1: The framework of constraint-based manipulations

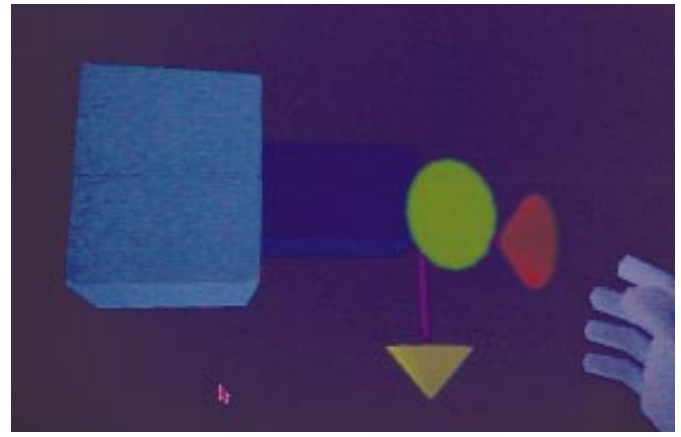
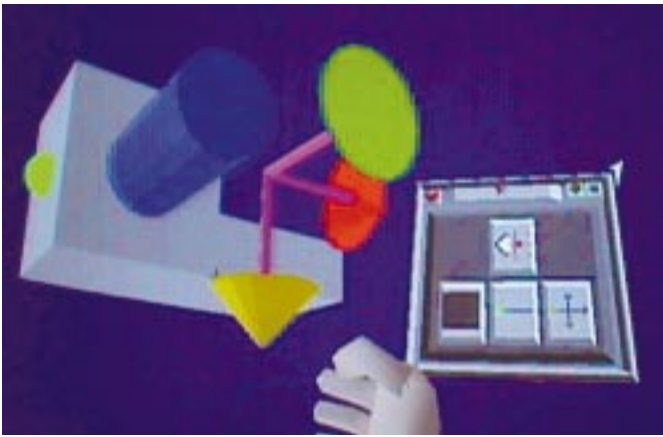


Figure 2: Visual cues for constraint-based manipulations

motion data from the 3-D input devices into the allowable motions of the object. Once a constraint is recognized during the constraint recognition process, it will be highlighted and awaits the user's confirmation. Once it is confirmed, the recognized constraint will be carried out precisely under the current allowable motions of the object and inserted into the constraint-based model. The constraint further restricts the subsequent motions of the object.

Representation and Derivation of Allowable Motions

Allowable motion is represented as the following matrix:

$$\begin{bmatrix} T_x & R_x & T_{x \min} & T_{x \max} & R_{x \min} & R_{x \max} \\ T_y & R_y & T_{y \min} & T_{y \max} & R_{y \min} & R_{y \max} \\ T_z & R_z & T_{z \min} & T_{z \max} & R_{z \min} & R_{z \max} \end{bmatrix}$$

where T_x , T_y , and T_z are linear translations along X axis, Y axis, Z axis respectively and R_x , R_y , and R_z are the rotations about X axis, Y axis, Z axis respectively. The values of these elements in the matrix are either 0 or 1. Integer 1 indicates an allowable motion in the direction along the corresponding principal axis. Integer 0 indicates the motion that is not allowable in the axial direction. $T_{x \min}$ and $T_{x \max}$ are the minimum and maximum values of the translation along the X axis, $T_{y \min}$ and $T_{y \max}$ along the Y axis, and $T_{z \min}$ and $T_{z \max}$ along the Z axis. $R_{x \min}$ and $R_{x \max}$ are the minimum and maximum values of the

rotation about the X axis, $R_{y \min}$ and $R_{y \max}$ about the Y axis, and $R_{z \min}$ and $R_{z \max}$ about the Z axis. If the translation or rotation along some axis is not allowed, the corresponding minimum and maximum values are zero.

Allowable motions are derived from the constraint-based model through constraint solving. For example, when a grasping event occurs for an object, the action is interpreted by a constraint solver as requesting the remaining degrees of freedom (DOFs) of this object. If there is one constraint applied on the object, the allowable motion matrix can be directly derived from the remaining DOFs of the object. For multiple constraints, the final matrix can be derived from the incremental intersections of the allowable motion matrices corresponding to each of the constraints. The incremental intersections are realized through Boolean operations of the corresponding elements located on the first and second columns in each allowable motion matrix that corresponds to each constraint and also the intersections of the intervals between the minimum and maximum values of the translations or rotations.

Visual Cues for Constraint-Based Manipulations

Visual cues are given to the user to obtain the desired constraint-based manipulations by visualizing the allowable motions of an object. As shown in figure 2, a

coordinate frame with a set of allowable motion flags and other visual cues are used to display the allowable motion information. The origin of the coordinate frame is located nearby the manipulated object and the three axes represent the X, Y and Z axis respectively. The normal arrow at the end of each axis indicates a translation along the axis and the inverse arrow at the end of each axis indicates a rotation around the axis.

Point of contact

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