the intersection such that we overestimate or underestimate the volume already enclosed. Using surface splines, the computation is fast enough to allow the real time animation shown in Figure 6. Here the volume is kept constant and the fill height is recomputed, yielding design feedback while the containing shape is interactively deformed.

6.2 Mass matching

As a second example, we determine the point of instability of a gripper placed on a table top. Here the free parameter is the opening angle α and the condition is that the projection of the center of mass $m(\mathbf{x})$ comes to lie on the table edge E, i.e.

$$\text{find } \alpha \text{ such that} \quad m(\mathbf{x}((\alpha, \mathbf{u})) \subset E.$$

Bisection with a call to the mass computing module rather than the volume module solves the problem. The sequence of computations is animated in Figure 7. Note that as α varies the blend between finger and body changes. Therefore the standard engineering approach of decomposing the gripper into a fixed and a moving part and adding their respective centers of mass to compute the center of mass of the whole object yields a less accurate result.

6.3 Inertia matching

The inertia tensor $\mathcal{I}$ is a positive definite, symmetric matrix. As pointed out in Section 5, its eigenvectors and eigenvalues can be used, together with the center of mass, to define a frame that is unique if the eigenvalues are distinct. Matching inertia frame can thus be used as a quick, first approximation to determine an unknown rigid motion by which an object is displaced with respect to a reference position (see e.g. [19]). For example, Figure 8 shows the input data of a successful object registration, where a cloud of measured points from a physical object and a surface model of this object are to be brought in agreement by a rigid motion, computed as an affine transformation relating the inertia frames of the two entities. In our limited experience, this method worked very well even when the sampled points were not exactly on

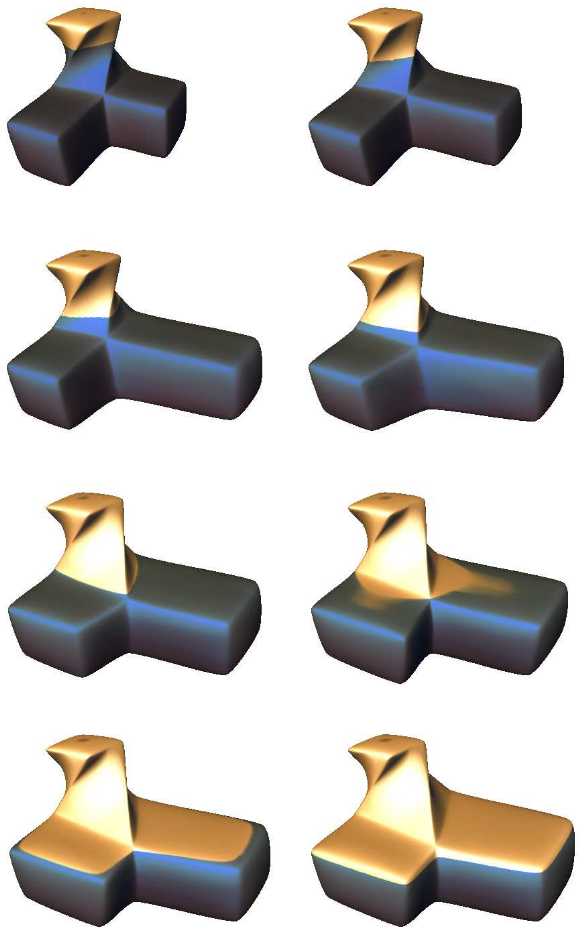

Figure 6: Deformation of the container object alters the fill height for a constant fill volume.