2. OVERVIEW

Though our chosen problem domain is simple, it illustrates interesting robotics topics. First, our system must describe cutting out a part, and the connection types in its problem domain, from a logical level (asserting that a connection exists) down to spatial relations between physical objects.

Second, our system must capture structural constraints on arrangements and the implications of cutting actions. Our robot needs to know that pizzas can be cut into slices of a given shape, that slices cannot be put together into a pizza again, but that we do consider them an "Assembly" if they lie in a fan pattern on a plate.

Third, we need to track what entities exist in the robot's environment. Some entities are physical objects (for example slices), but it is convenient to consider arrangements of objects as being entities as well: for example, a fan of pizza slices, all lying on the same plate, are an "Assembly" that the robot can deliver to a customer.

Fourth, the problem of object identity after changes in form. For example, after cutting out the first slice, we still think of the resulting object as the same pizza. Another aspect of this problem is handling violations on structural constraints on arrangements. Removing the middle slice from an Assembly changes it into another arrangement type (in an Assembly, the slices should make up a fan).

Finally, the results of the robot's reasoning queries must produce action parameters: where to cut, where to put an object.

Fig. 2 shows a sketch of our system. A geometric level handles queries about obtaining trajectories for cutting, checking connection types between objects, obtaining object poses to establish a connection type. This level also defines some auxiliary annotations to assist in its reasoning. The mereotopologic layer handles queries about what cuts are necessary to separate parts out of physical objects, and about arrangements of physical objects and the structural constraints on them. It uses a spatial grammar to describe arrangements in terms of part and connection types. The task level receives the customer orders, and issues queries to the underlying levels in order to generate plans and actions for the robot.

The world state is described by the poses of the physical objects that the robot can perceive; these are the primitive entities. Further entities can be asserted by the task and mereotopological layers. The task layer asserts "ghost" entities that are needed to fulfill an order (they need not be initially associated to physical objects). The mereotopological layer asserts entities when physical objects are arranged in certain ways; to avoid proliferation, it only asserts an entity when it is maximal. Either layer can vote to remove an asserted entity when it is no longer needed (task layer) or no longer embodied in a collection of physical objects (mereotopological layer), but both must agree before removal occurs.

3. RELATED WORK

Learning control parameters for cuts, given a quality measure such as time taken, was tackled by [2]. Cut location, or deciding whether a cut is necessary, was not in the scope of that research.

Cutting as a "microworld" for common-sense reasoning appears in [3], which gives two formal theories for the cutting of solid objects. Formal theories of parthood and connection (mereotopology) are overviewed in [4], spatial grammars in [5]. We extend the previous work by insisting on action parameter production for a robot, and on spatial grammar parsing and its application to planning.

Our approach is related to general purpose common-sense reasoning, which includes reasoning about geometric and physical properties and interactions [6], and that formal methods applied to reasoning about assemblies have seen application for automatic generation of customizable furniture models [7].

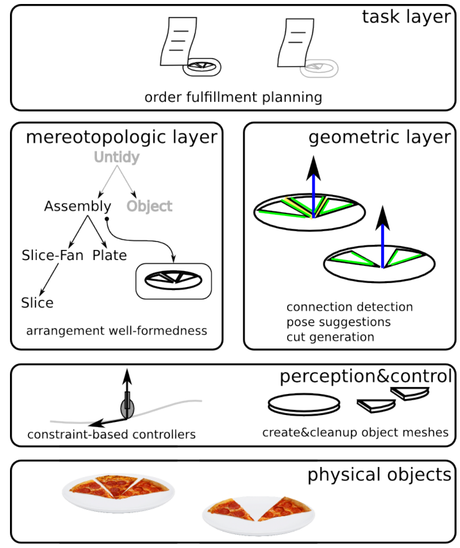

Figure 2: The layers of our system. The geometric layer annotates models of objects with information useful to analyze connections and suggest placements and cuts. The mereotopologic layer ensures arrangements of objects obey structural constraints. The task layer creates plans to fulfill customer orders and queries underlying levels.

4. CONCLUSION

We describe a robotic system able to reason about generating new parts out of materials it has at its disposal, and arrange those parts into assemblages that obey structural constraints.

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