

# Integrating Spatial and Conceptual Knowledge in Virtual Assembly

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The CODY<sup>1</sup> *Virtual Constructor* is a knowledge based system for the interactive assembly of complex aggregates on a virtual assembly bench[1]. In our testbed scenario, the user can assemble a toy airplane and similar constructs from parts of a construction kit, such as bolts, blocks, and bars (see figure 1). The user can inspect the graphics scene from different perspectives and change the blocks' configuration by way of verbal instructions, e.g., "*Attach the long bolt to the top of the undercarriage.*"<sup>2</sup> When processing user instructions, the Virtual Constructor accesses the geometric scene descriptions to evaluate spatial expressions ("*the top of*"), as well as additional conceptual representations containing knowledge about the currently assembled aggregates ("*undercarriage*"). The spatial information contained in the visualized scene is not only exploited for instruction processing though: the airplane's subassemblies usually require their parts to be arranged in a specific way, for example, the airplane wings must be attached *crosswise* to the fuselage; or, the wheels of the undercarriage must be in *parallel* planes. On the one hand, spatial information is necessary to adequately describe the airplane's assembly groups. On the other hand, this information can be inferred from the scene descriptions. Thus, the spatial knowledge of the geometric scene descriptions needs to be integrated with the conceptual knowledge representations.

The background knowledge of the Virtual Constructor is defined in four knowledge bases. The first one contains the building blocks' generic geometry models. They define the building blocks' wire frame models, center of gravity, and prototypical orientation. They also define the relative positions and orientations of the objects' connection *ports*. A second knowledge base defines several qualitative spatial relations over the geometry models, such as *parallel<sub>x</sub>*, *orthogonal<sub>x</sub>*, and *touches*. A third knowledge base defines conceptual knowledge about the building blocks and their connection ports. Finally, a fourth knowledge base defines the airplane's structured assembly groups as well as the specific *roles* the building blocks can assume in assembly groups. For example, a BOLT assumes the role of an AXLE when it is part of a HALFAXLESYSTEM.

The concept definition formalism builds on the semantic network language ERNEST [3], and the terminological language for part-of hierarchies introduced

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<sup>2</sup> Translation of original German input.

in [2]. Concepts for assembly groups are defined by their parts and part-part-(pp-)constraints describing necessary relations between them. We distinguish between *logical* constraints, e.g., connection which require, when tested, corresponding relations to be asserted between part representations, and *geometric* constraints, e.g.,  $parallel_x$  that trigger tests in the geometry models directly.

Concept: UNDERCARRIAGE

is-a: ASSEMBLYGROUP

part "has-left-halfaxlesystem": HALFAXLESYSTEM

part "has-right-halfaxlesystem": HALFAXLESYSTEM

part "has-block": UNDERCARRIAGEBLOCK

pp-constraint connection "has-block" "has-left-halfaxlesystem"

pp-constraint connection "has-block" "has-right-halfaxlesystem"

pp-constraint  $parallel_x$  "has-left-halfaxlesystem" "has-right-halfaxlesystem"

Dynamic conceptual descriptions are kept in working memory and linked to their corresponding geometry models. Whenever objects are composed on the virtual assembly bench, new connection relations are inferred from the geometry models and propagated along the part-of structure in the data base. First, unstructured aggregate representations are created and matched against the model knowledge base. Then, new representations for recognized assembly groups are created and new roles are assigned to their parts accordingly. Figure 1 exemplifies the effectiveness of the geometric constraint  $parallel_x$  in the above concept definition. In the middle, an undercarriage was recognized. On the right, a complex aggregate which is not an undercarriage is depicted that consists of the same parts, but with the geometric constraint  $parallel_x$  violated.

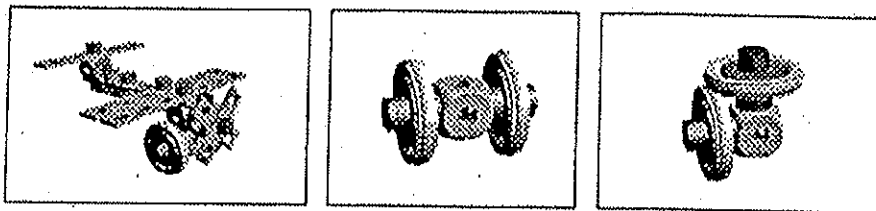


Fig. 1. a) Assembled toy airplane b) undercarriage c) no undercarriage

## References

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