The Hierarchical Woodworking Domain

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Abstract
The Woodworking domain is one of the classical benchmark domains in the canon of the International Planning Competition. This paper describes our hierarchical take on it.

Introduction
The hierarchical Woodworking domain models workflows in a workshop setting. Wooden boards are cut into parts of required sizes, which are planed, smoothened, and finally painted in specified colours and qualities. The various spray and varnish paints thereby require different preparation treatments of the respective wooden surface. Combinations of these process steps into proper workflows are provided by the decomposition methods.

The main causal interactions on a task level occur when some of the heavier workshop tools abrade the surface of wooden items, thereby undoing previous treatment steps. Other minor planning-sub-problems emerge when some of the machinery involved only allows for processing one item at a time. In its current version, this merely imposes limitations on possible plan linearisations but may become subject to plan optimization for resource-aware planners.

The Woodworking domain has been introduced as a benchmark to the planning community in 2008 for IPC 6. We have developed a hierarchical version of it in order to analyse planning strategy designs for hybrid planning systems using landmarks (Elkawkagy et al. 2012; Bercher, Keen, and Biundo 2014) and this domain model has finally been translated into the current, purely hierarchical version.

This short description focuses on the design decisions that led to the hybrid planning domain model for the formal framework introduced by Biundo and Schattenberg (2001) and Schattenberg (2009), that means, on the specifics of adding hierarchical features to a non-hierarchical domain model (cf. the work by Pragst et al. (2014)).

Mechanics of the Model
The type hierarchy of Woodworking establishes three main categories of objects: the wooden targets of creative handicraft (woodobj), workshop machines (machine), and a general object type. Wooden objects can be either boards or parts with the latter being obtained from the former by cutting them out. The type object is the most general type and an entry point for declaring constants representing specific wood materials, colours, and the like.

Regarding the state-variant features, most of the predicates describe the processing states of the processed wooden objects. This includes the following:
- unused₂part
- colour₂part.acolour
- boardsize₂board.aboardsize
- wood₂woodobj.wood
- treatment₂part.treatmentstatus
- available₂woodobj
- surfacecondition₂woodobj.surface

State features built from unused and available serve as semaphore, respectively book-keeping implementations for the pre-defined pool of part and wooden object constants. E.g., once a wooden object is used in a process step as a part, i.e., if a process step objective is assigned the respective constant, that very part constant is taken from the pool of available constants by negating its unused property. As a side effect of this technique, the wood property has to be passed on from the raw board (for which it’s technically unchangeable) to its processed part artefact.

While the rest of the above state features is straightforward with more intuitive semantics, the following state-invariant relations require some examination:
- machinepresent
- hascolourmachine.acolour
- goalsize₂part.apartsize
- boardsize_successor₂boardsize.aboardsize
- grindtreatmentchange₂treatmentstatus, treatmentstatus
- is_smoothsurface
- containspart₂board, part

Machine_present denotes the availability of mobile workshop machines and corresponds to availability of wooden objects – of course, machines are not used up in the process. Similarly, colour is used to describe painted parts, while hascolour represents the colour a respective workshop machine has at its disposal.

Sizes and treatment states are modeled by explicitly stating the available constants in a problem description. On these values, a simple symbolic computation is axiomatised implicitly in the task specifications: Parts, the process target objects, can have a goalsize of small, medium or
large. On the other hand, boards, i.e. the process source materials, are described via the state-variant boardsize, which is supposed to have at least three discrete values. The board size symbols are arranged according to the facts over the boardsize_successor predicate. The rationale is now a very high-level abstraction of a wood-cutting process, in which small sized parts reduce the board size by one boardsize_successor, medium sized ones by two, and large sized ones by three.

Please note that the current version of the hierarchical Woodworking domain, as does its non-hierarchical origin, does not yet support a re-use of the remaining boards after a part has been cut from them. Furthermore, the intention behind contains_part was unfortunately not documented, as it had not been used in any domain element.

The remaining physics of surface treatment by grinding (levels of removing varnish from wooden surfaces) is represented by the grind_treatment_change in a similar way like what we have shown for board sizes.

Regarding action specifications, the following operation for varnishing a part by means of immersion can serve as a common example for the domain:

```prolog
(:action do_immersion_varnish
 :parameters (?p - part
  ?m - immersion_varnisher
  ?c - acolour
  ?s - surface)
 :precondition
 (and (available ?p)
  (has_colour ?m ?c)
  (surface_condition ?p ?s)
  (treatment ?p untreated))
 :effect
 (and (not (treatment ?p untreated))
  (treatment ?p varnished)
  (colour ?p ?c)))
```

On this level of abstraction, processing consists of colouring a wooden part with all causal interactions delegated to the expansion methods. The methods themselves implement the different process variants by combining related tasks into modular subroutines. Please note that the decomposition hierarchy does not impose semantic restrictions on the solution space.

Properties of the Model

The domain is partially ordered and acyclic. It contains six abstract tasks, 13 primitive tasks, and 14 methods, where each task has between two and four methods. The IPC set contains 30 problem instances of various degrees of hardness. The first eleven instances were modeled by hand by the authors and are relatively easy with maximal shortest solution lengths of 15 steps. The remaining problem instances were created by a random generator, written by Gregor Behnke (based on an existing one for the original domain). The hardest instance has a shortest solution with 178 steps. Using the grounder by Behnke et al. (2020), we can report that the number of ground primitive and abstract tasks as well as decomposition methods ranges from a few dozen for the lower first (smaller) problem instances until 87,680 primitive tasks, 120,819 abstract tasks, and 592,235 decomposition methods for the largest problem instance.

References