On the Identification and Use of Hierarchical Resources in Planning and Scheduling

Bernd Schattenberg

Susanne Biundo

University of Ulm

Overview

- Introduction
- Hybrid Planning
- Abstraction of Resources
  - Motivation
  - Modelling
  - Reasoning
- Planning with Hierarchical Resources
- Conclusions

Introduction

- Crisis management support:
  THW mission at the river Oder in ‘97
  - Consists of a great variety of tasks, covering
    - Logistics
    - Construction
    - Organization
  - 180 groups
    1562 workers
    >2 months mission

Introduction

- Application Characteristics:
  - Requires representation of procedural knowledge
  - Requires representation of resources like time, material, tools, and manpower
  - Makes use of hierarchies on activities and resources

Introduction

- Domain for interleaving planning and scheduling problems
- Meeting the requirements with integrated planning and scheduling
  - Integration of scheduling as additional plan modifications into a hybrid planning framework
  - Least commitment planning and scheduling strategy

Hybrid Planning

- Combining hierarchical task network (HTN) planning and operator based partial order causal link (POCL) techniques
  - Methods refine complex actions / tasks into networks, thereby defining a hierarchy on tasks
  - Actions carry pre- and post-conditions on all levels of abstraction
  - ... Details in (Biundo & Schattenberg ECP'01)

Hybrid Planning

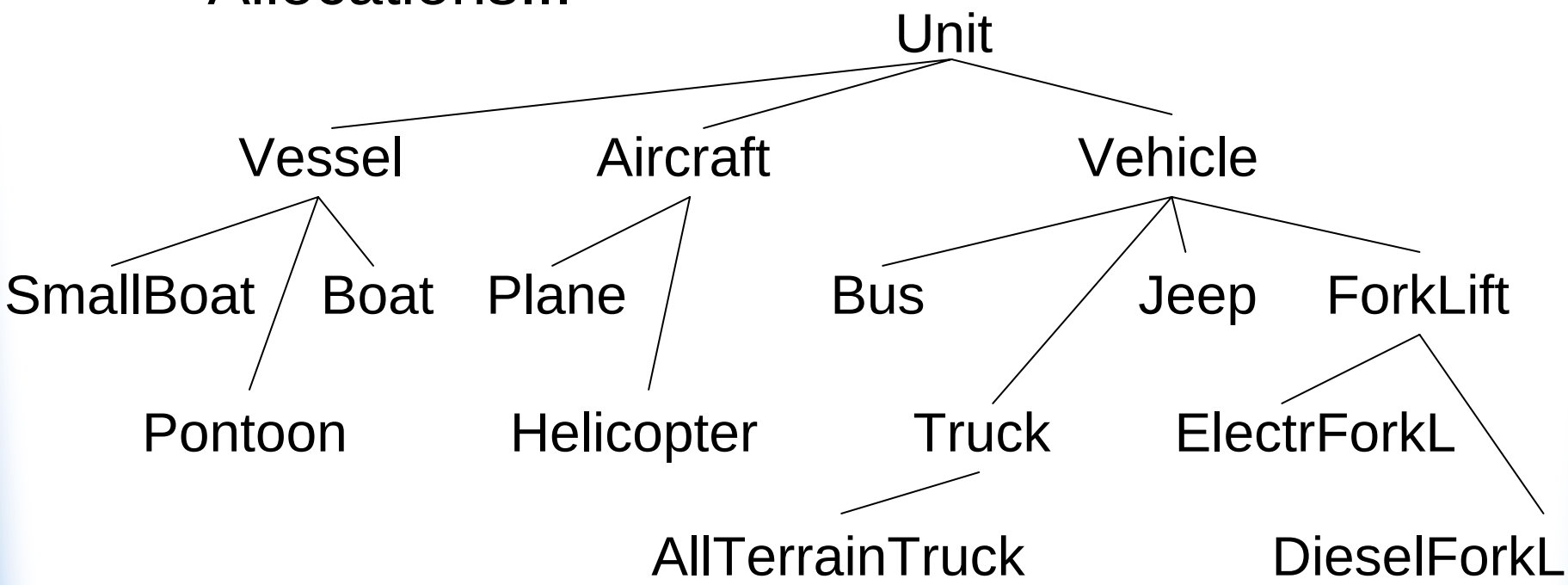
- Decomposition axioms relate conditions by defining a hierarchy on state descriptions, allowing for
  - Formal justification of HTN decomposition steps
  - POCL plan modifications which consider tasks on different levels of abstraction
    - Threat detection and resolution
    - Inserting new steps - flexible plan generation

Abstraction of Resources

- Resources integrated in the hybrid framework
- Identified types of abstraction
  - Subsumption & Aggregation
  - Qualification & Approximation
- Rationale:
  - Detect and resolve possible over-consumptions at any abstraction level
  - Guide the search towards “efficient” plans

Subsumption

- One resource specializes another
  - Sort hierarchy, e.g. transportation units
  - Allocations...



Subsumption

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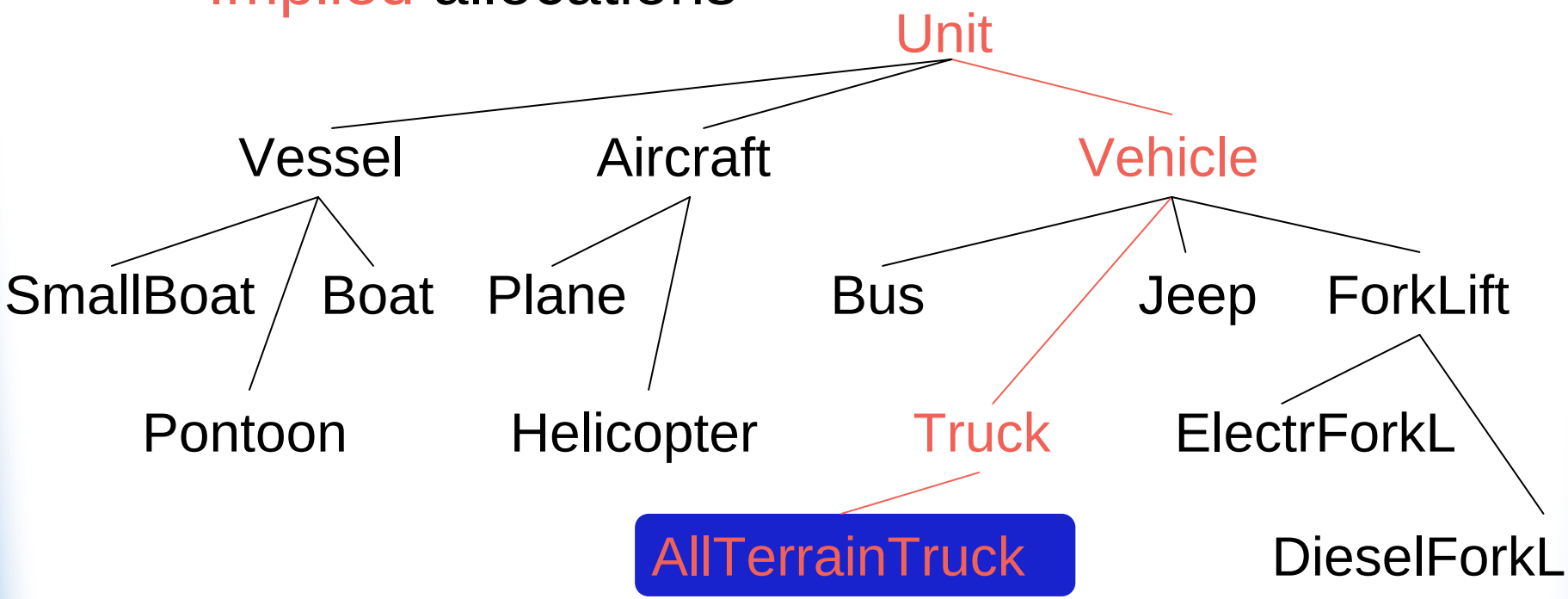

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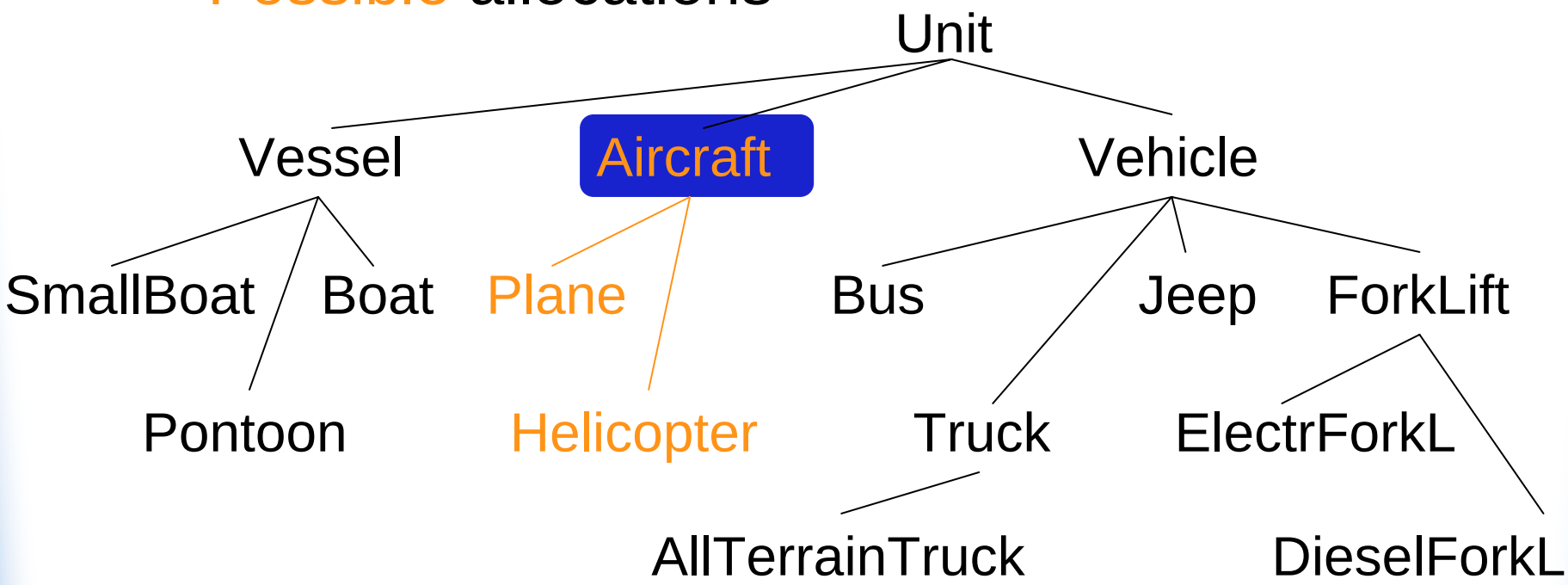


Subsumption

- Decomposition axioms relate abstract and concrete resources

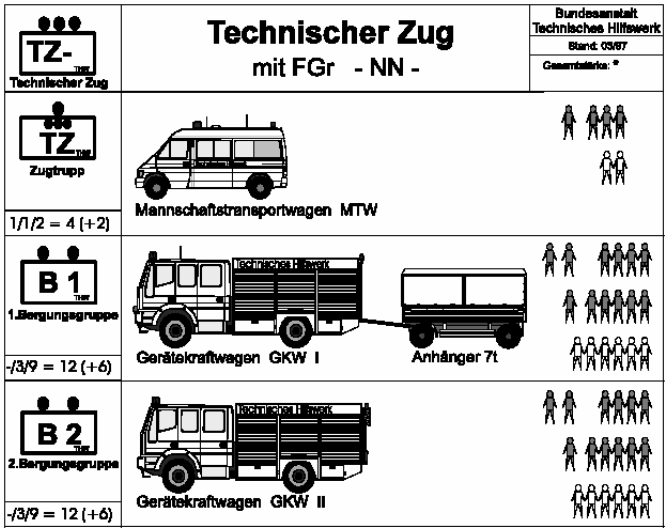
$$\text{At(Unit:u, Location:area)} \leftrightarrow$$
$$[\ \text{Standing-at(Vehicle:u, Location:area, Road:r)} \vee$$
$$\text{Aircraft-at(Aircraft:u, Location:area, Height:h)} \vee$$
$$\text{Boat-at(Boat:u, Location:area, Water-street:w)} \vee \ldots]$$

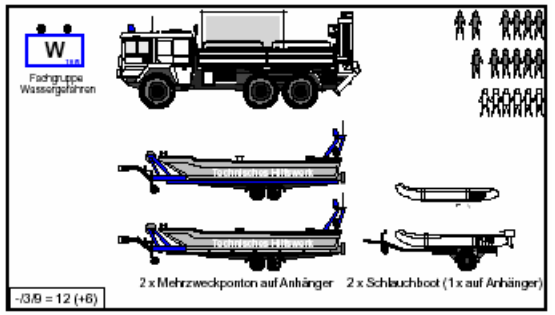
Aggregation

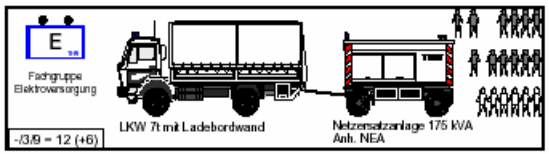
- Structural abstraction
  - Decomposition of resources into *independent* components
  - Used in many organizational structures, e.g. “technical platoon”
  - Here: combined with subsumption...

Aggregation

- ...Configuration depending on mission







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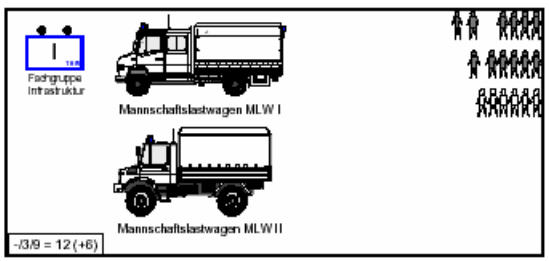
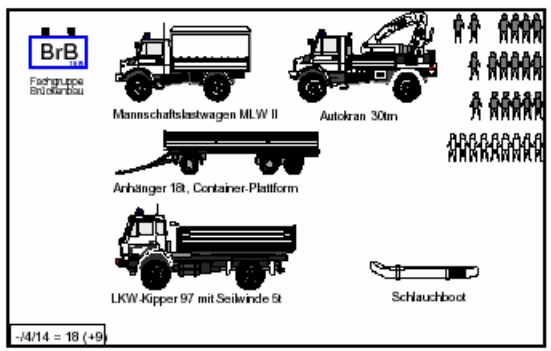
Extensions





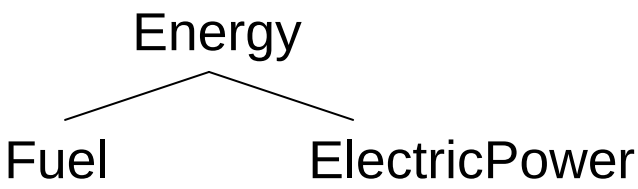
Aggregation

- Allocations of
  - aggregates imply allocating components
  - components may imply allocating aggregate
- Decomposition axioms justify aggregate allocations

Available(IPlatoon:p, Location:area) ↔
[Standing-at(Bus:mt, Location:area, Road:r) ∧
Standing-at(ATTruck:ml, Location:area, Road:r) ∧
Operational(RadioSet:rs, Location:area) ∧
= (Personnel,40) ∧…
∨…]

Approximation - Qualification

- Approximation: abstract resources estimate refinements
  - Intervals approximate their restrictions
  - ... possibly not monotonic
  - ... but at least pre-processing (sometimes)
- Qualified (numerical) resources are symbolic
  - “Causal preparation” of numerical reasoning
  - Putting a hierarchy on “uncomparable” scales



Planning with Hierarchical Resources

- Integrated Algorithm performs least commitment strategy
- Stepwise opportunistic schedule refinement (cf. IxTeT), combined with
- Stepwise plan refinement

Planning with Hierarchical Resources

Scheduling	Hybrid Planning
check for flaws	check for flaws
modify ordering by adding ordering constraints assigning time slots narrowing intervals	modify ordering by adding ordering constraints
	modify causal structure by adding causal links inserting new tasks expanding abstract tasks
assign resources to schedule variables	assign values to plan variables

Planning with Hierarchical Resources

Scheduling & Hybrid Planning

check for flaws

modify ordering by
adding ordering constraints
assigning time slots
narrowing intervals

modify causal structure by
adding causal links
inserting new tasks
expanding abstract tasks

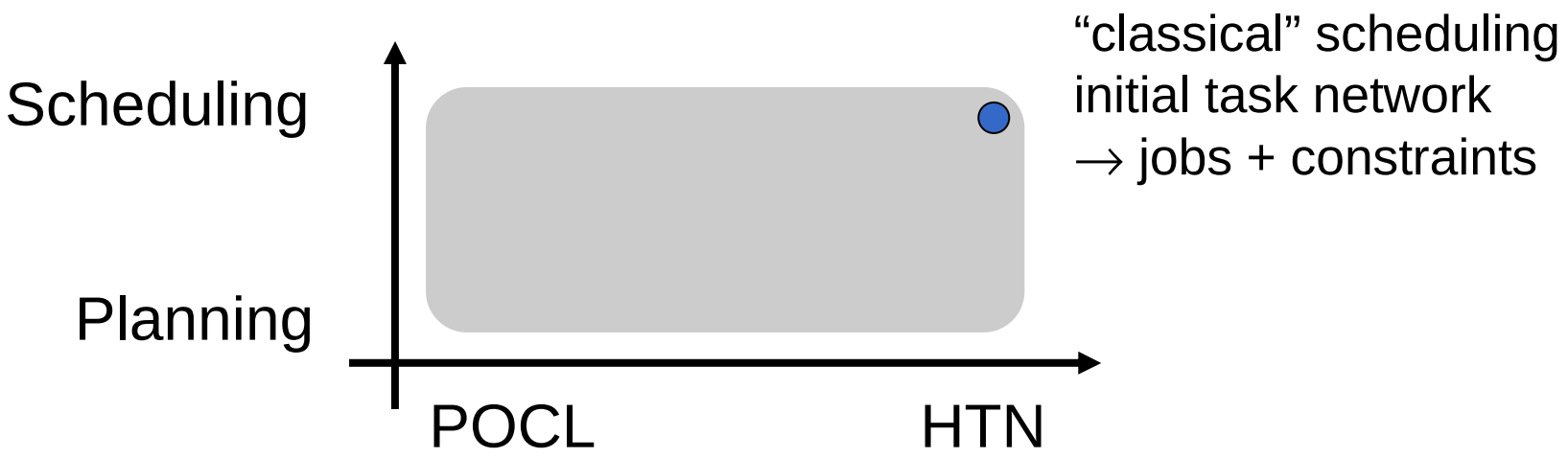
assign resources & values to variables

Reasoning about Resources

- ... now along the line of existing approaches
  - O-Plan's optimistic and pessimistic profiles (Drabble & Tate 1994) - sketched in the paper
  - IxTeT - especially dynamic resource hierarchy (Garcia & Laborie 1996)
  - ASPEN (Clement et al. ECP'01) - for some modeling cases
  - Recent developments in temporal and multi criteria planning (AIPS'02 workshops)
- Many techniques are applicable

Conclusions

- Identification and representation of different types of abstraction
- Flexible integration of hybrid planning and scheduling



Future Work

- Experiments with reasoning algorithms
- Identifying suitable p&s strategies
  - Precompilations of profiles
  - Guiding search towards “good plans”
- Multi-criteria reasoning