Modellierung von Alltagsunterstützung als hybride Planungsdomäne: Eine Fallstudie

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Motivation and Outline

- In the context of the Transregional Collaborative Research Centre SFB/TRR 62 "Companion-Technology for Cognitive Technical Systems"
- Extension of demonstration scenario 1
- Modeling of multiple problem instances based on one domain model in order to check its adequacy
- Modeling guidelines

Hybrid Planning

POCL Planning

- Causal reasoning
- Least commitment

HTN Planning

- Procedural knowledge
- Top-down refinement

Hybrid Planning

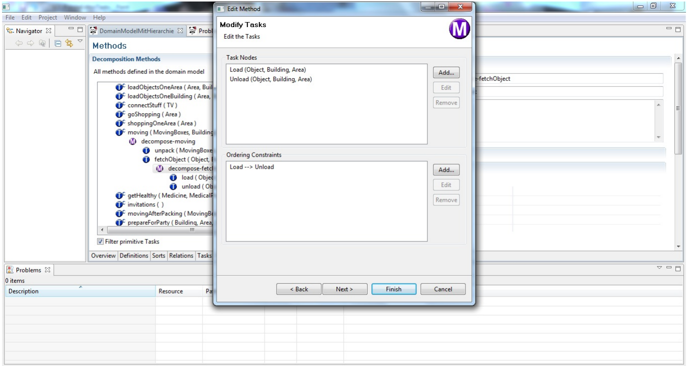
- Powerful technology for solving complex real world problems
- Suitable for planning for humans
- Knowledge-rich plans

Hybrid Planning Framework

- Logical Language $\mathscr{L} = \langle Z, <, R, C, V, L \rangle$
- Tasks $t = \langle pre, post \rangle \in \mathscr{T}$ with $\mathscr{T} = \mathscr{T}_{primitive} \dot{\cup} \mathscr{T}_{abstract}$
- Plans $P = \langle PS, \prec, VC, CL \rangle$
- Decomposition methods $m = \langle t, VC_m, P \rangle \in \mathscr{M}$
- Domain model $\mathscr{D} = \langle \mathscr{L}, \mathscr{T}, \mathscr{M} \rangle$
- Planning problems $\pi = \langle \mathscr{D}, P_{initial} \rangle$

PANDA Editor

Domain model and problem instances were modeled using PANDA Editor



Edit Method

Modify Tasks

Edit the Tasks

Task Nodes

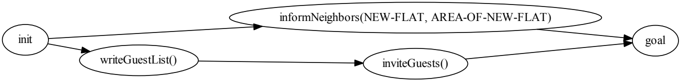
Load (Object, Building, Area)
Unload (Object, Building, Area)

Ordering Constraints

Load --> Unload

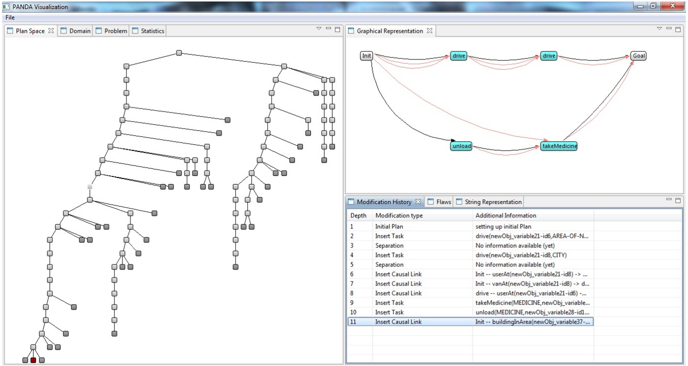
PANDA$_2$

- Domain model was tested using PANDA$_2$
- Different algorithms and heuristics
- Generates plans
- Multiple output-options



Tool for Visualizing the Explored Search Space

Visual and textual representation of all plans, which were generated during the planning process



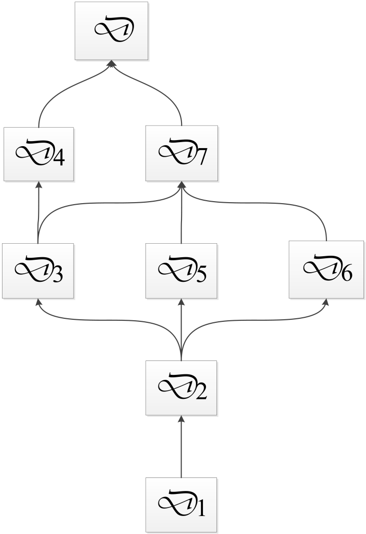
Depth	Modification type	Additional Information
1	Initial Plan	setting up initial Plan
2	Insert Task	drive(newObj_variable21-id6,AREA-OF-N...
3	Separation	No information available (yet)
4	Insert Task	drive(newObj_variable21-id8,CITY)
5	Separation	No information available (yet)
6	Insert Causal Link	Init -- userAt(newObj_variable21-id8) -> ...
7	Insert Causal Link	Init -- vanAt(newObj_variable21-id8) -> d...
8	Insert Causal Link	drive -- userAt(newObj_variable21-id6) -...
9	Insert Task	takeMedicine(MEDICINE,newObj_variable...
10	Insert Task	unload(MEDICINE,newObj_variable28-id1...
11	Insert Causal Link	Init -- buildingInArea(newObj_variable37-...

Modeling Guidelines

- Plausibility: real world relations, properties and tasks
- “Physics” instead of solutions
- Reasonable level of details
- Wide variety of real life aspects instead of detailed modeling
- Bottom-up modeling
- Incremental expansion

Diagram of the Domain Model $\mathscr{D}$

- $\mathscr{D}_1$: Driving between different places
- $\mathscr{D}_2$: Transporting objects
- $\mathscr{D}_3$: Shopping
- $\mathscr{D}_4$: Diseases
- $\mathscr{D}_5$: Moving into a new apartment
- $\mathscr{D}_6$: Installing the home theater
- $\mathscr{D}_7$: Housewarming party



Overview of the Domain Model $\mathscr{D}$

- 15 sorts
- 30 relations
  - 24 flexible Relations
  - 6 rigid Relations
- 40 tasks
  - 22 primitive Tasks
  - 18 abstract Tasks
- 27 decomposition methods
- On average 1.5 decompositions methods per abstract task

Excerpt of the Domain Model $\mathscr{D}$ (1/4)

- Driving from *?Area1* to *?Area2* in $\mathscr{D}_1$:

$$drive(?Area1, ?Area2) = \langle pre, post \rangle \in \mathscr{T}_{primitive}$$

$$pre = \{userAt(?Area1), vanAt(?Area1)\}$$

$$post = \{userAt(?Area2), vanAt(?Area2), \neg userAt(?Area1), \neg vanAt(?Area1)\}$$

Excerpt of the Domain Model $\mathscr{D}$ (2/4)

- Fetching an *?Object* in $\mathscr{D}_2$:

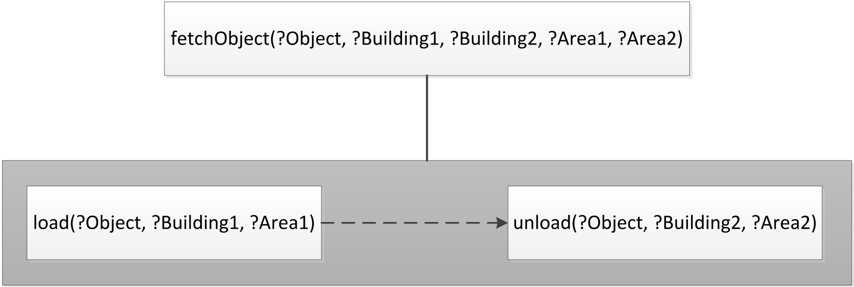
$$fetchObject(?Object, ?Building1, ?Building2, ?Area1, ?Area2) =$$

$$\langle pre, post\rangle \in \mathscr{T}_{abstract}$$

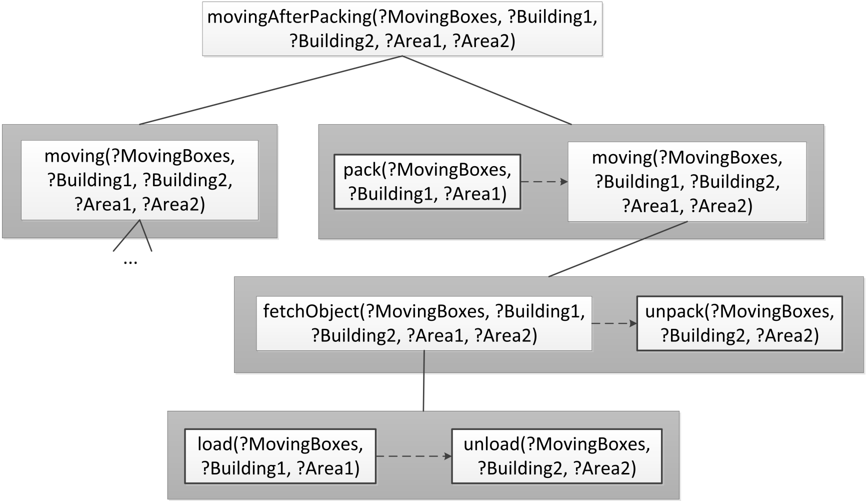
$$\begin{aligned} pre &= \{userAt(?Area1), vanAt(?Area1), \neg inVan(?Object), \\ &\quad inBuilding(?Object, ?Building1), \\ &\quad buildingInArea(?Building1, ?Area1), \\ &\quad buildingInArea(?Building2, ?Area2)\} \\ post &= \{\neg inVan(?Object), inBuilding(?Object, ?Building2), \\ &\quad \neg inBuilding(?Object, ?Building1)\} \end{aligned}$$

Fetching an *?Object* consists of loading and unloading it

Excerpt of the Domain Model $\mathscr{D}$ (3/4)


fetchObject(?Object, ?Building1, ?Building2, ?Area1, ?Area2)
load(?Object, ?Building1, ?Area1)
unload(?Object, ?Building2, ?Area2)

Excerpt of the Domain Model $\mathscr{D}$ (4/4)


movingAfterPacking(?MovingBoxes, ?Building1, ?Building2, ?Area1, ?Area2)

moving(?MovingBoxes, ?Building1, ?Building2, ?Area1, ?Area2)

...

pack(?MovingBoxes, ?Building1, ?Area1)

moving(?MovingBoxes, ?Building1, ?Building2, ?Area1, ?Area2)

fetchObject(?MovingBoxes, ?Building1, ?Building2, ?Area1, ?Area2)

unpack(?MovingBoxes, ?Building2, ?Area2)

load(?MovingBoxes, ?Building1, ?Area1)

unload(?MovingBoxes, ?Building2, ?Area2)

Lessons Learned - Modeling the Real World

- Avoiding inconsistent states by
  - explicit modeling of negative effects
  - symmetric effects, e.g., *connected*(*?Device1*, *?Device2*) and *connected*(*?Device2*, *?Device1*)
- Coarsening from real circumstances
- Limitations because of
  - no universal quantifier
  - no possibilities of modeling transitivity
- Leveraging language elements
- Modeling in terms of real life aspects instead of problems

Lessons Learned - Bottom-Up Approach

- Separation of modeling physics and procedural knowledge
- Risk of modeling one's own solution
- Everyone has procedural knowledge about everyday life

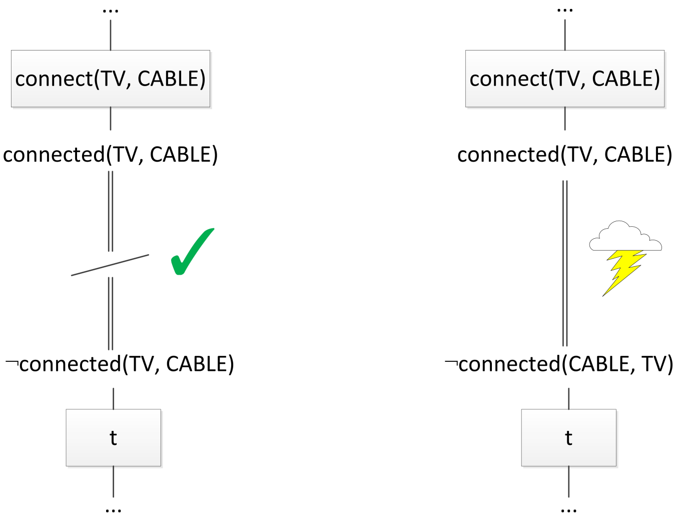
Lessons Learned - Incremental Expansion

- Successive expansion of a core domain model
- Keeping track of the domain model because every element is assigned to one domain model fragment
- Focusing on one aspect
- Easier to test
- Risk of appearance of undesirable interactions between domain model fragments
- Advantages more distinct in bigger domain models

Summary

- Domain model that provides multiple aspects of everyday life
- Modeling guidelines were very helpful
- Incremental expansion is very recommendable
- Many more interesting possible expansions, for example
  - multiple persons
  - consuming gasoline
  - aspects of time

Symmetric Effects (1/3)



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connected(TV, CABLE)

✓

¬connected(TV, CABLE)

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...

...

connect(TV, CABLE)

connected(TV, CABLE)

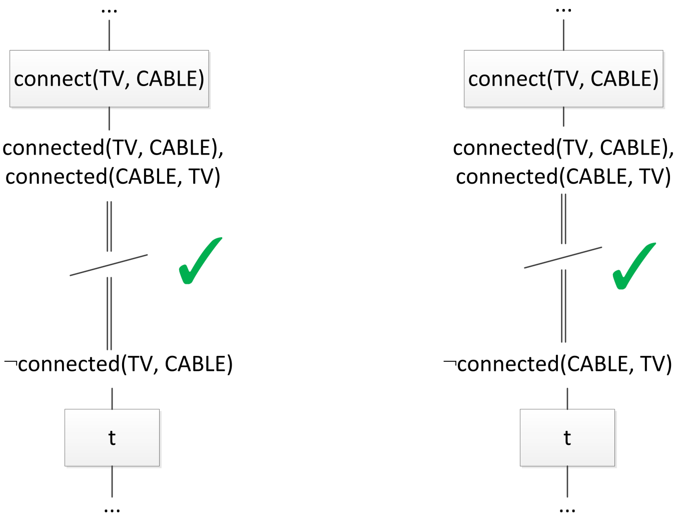
⚡

¬connected(CABLE, TV)

t

...

Symmetric Effects (2/3)



...

connect(TV, CABLE)

connected(TV, CABLE),
connected(CABLE, TV)

✓

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...

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connect(TV, CABLE)

connected(TV, CABLE),
connected(CABLE, TV)

✓

¬connected(CABLE, TV)

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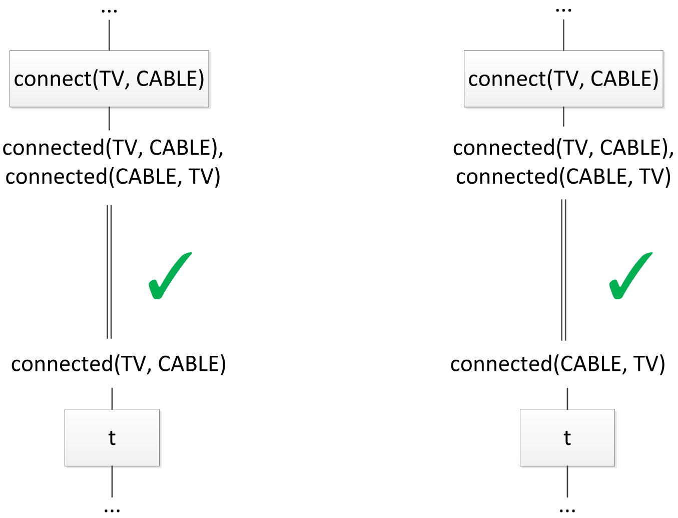
Symmetric Effects (3/3)



...

connect(TV, CABLE)

connected(TV, CABLE), connected(CABLE, TV)

✓

connected(TV, CABLE)

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connect(TV, CABLE)

connected(TV, CABLE), connected(CABLE, TV)

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