Using KIV to Verify ASBRU Plans – Overview

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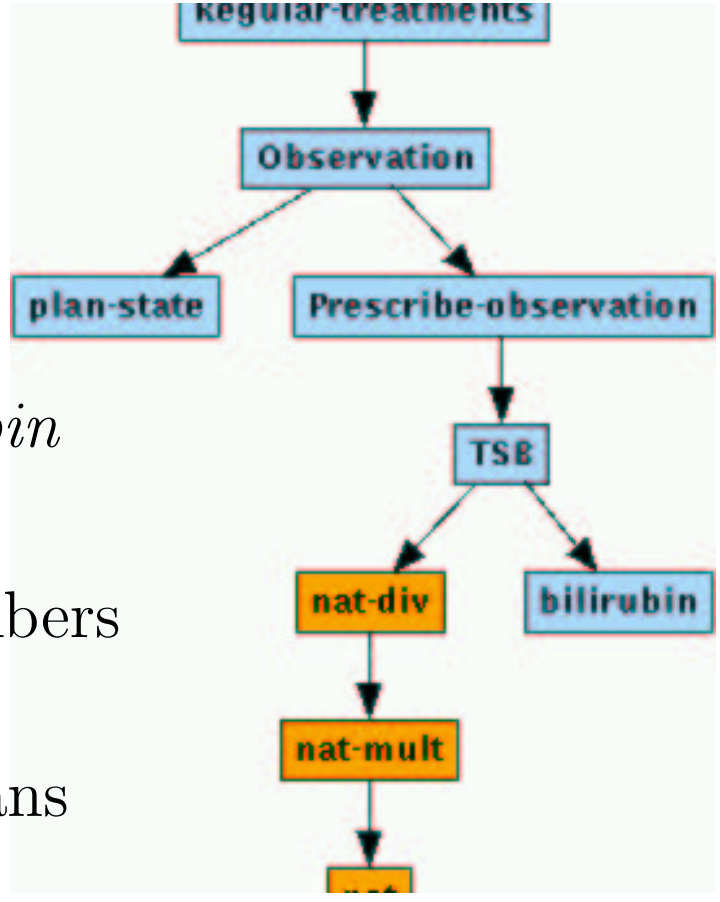
Example – ASBRU Plan

PLAN	Observation (1.4.2.1.5)
PREFERENCES	
INTENTIONS	`MAINTAIN INTERMEDIATE STATE` `bilirubin = observation`
CONDITIONS	**Filter:** `(bilirubin observation` `* [_,_] [0,_] [_,_] NOW)` **Abort:** `(bilirubin not observation` `* [_,_] [0,_] [_,_] NOW)`
EFFECTS	
PLAN BODY	**Prescribe-Observation**
COMMENTS	…

Specification – Overview

$\Rightarrow$ *Development graph*



- Data abstraction
  - ⋆ Qualitative bilirubin levels $\Rightarrow$ *bilirubin*
  - ⋆ Abstraction function $\Rightarrow$ *TSB*
- Quantitative TSB levels as natural numbers
  $\Rightarrow$ *library*
- Hierarchical specification of ASBRU plans
  $\Rightarrow$ *modularity*

Specification – Data Abstraction

- Abstract values of bilirubin
  $\Rightarrow$ Enumeration type *bilirubin*
- Abstraction function
  $\Rightarrow$ Function *get-bilirubin* in *TSB*

Abstraction table

age	TSB level	
	-12	...
⋮	⋮	...
25-48	observation	...
⋮	...	...

Predicate logic

$$25 \leq a \wedge a \leq 48 \wedge l < 12$$
$$\rightarrow \text{ get-bilirubin}(\text{set-age-level}(tsb, a, l))$$
$$= \text{observation}$$

Specification – ASBRU Plan

$\Rightarrow$ Specification *Observation*

- Parallel program
- Plan as procedure
- Filter precondition as **await** statement
- Abort condition as **break** statement
- Simple plan body

Atomic plan

$\Rightarrow$ Specification *Prescribe-observation*

- Duration is nondeterministic
- Manual activation as nondeterminism

Specification – Properties

- Termination

$$\begin{array}{lll} & \text{Observation\#}(;\text{tsb},\text{time},\text{Observation-state}), & \textit{System} \\ & \Box\ \text{time}'' = \text{time}' + 1 & \textit{Environment} \\ \vdash & \Box\ \text{get-bilirubin}(\text{tsb}) = \text{observation} \rightarrow \Diamond\ \textbf{last}; & \textit{Property} \end{array}$$

- Intention

$$\begin{array}{lll} & \text{Observation\#}(;\text{tsb},\text{time},\text{Observation-state}), & \textit{System} \\ & \text{Observation-state} = \text{considered} & \textit{Environment} \\ \vdash & \Box \quad \neg\ \textbf{last} \wedge \text{Observation-state} = \text{activate} & \textit{Property} \\ & \quad \rightarrow \text{get-bilirubin}(\text{tsb}) = \text{observation}; & \end{array}$$

$\Rightarrow$ Theorems in specification *Observation*

Specification – General Remarks

State

- Algebraic specifications
- Higher order logic
- Library of standard data types

Transition system

- Parallel programs
- Special ASBRU constructs
- Temporal logic

Important: modular structure

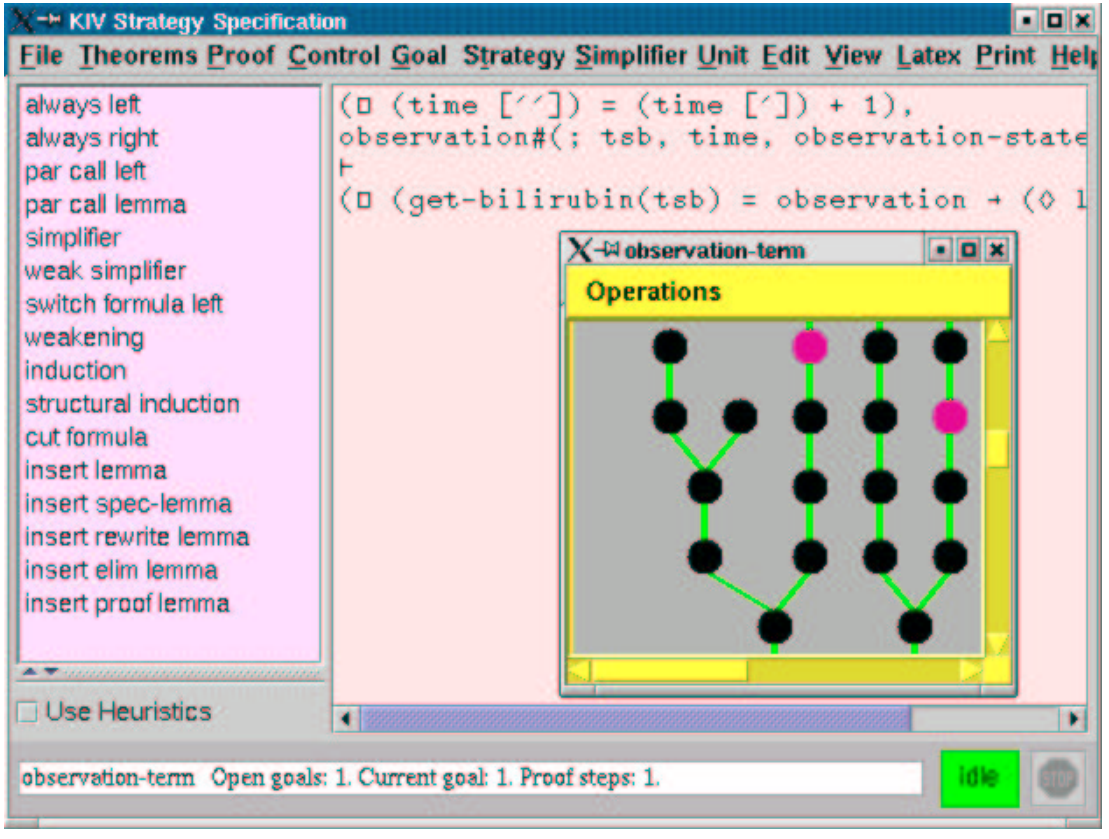
Verification

First step

Construct proof for *Prescribe-observation*
$\Rightarrow$ Prove lemma *prescribe-observation-term*

KIV environment

- Interactive verification
- Choose from set of applicable proof rules
- Proof tree represents progress



Verification – Principle

Proof principle

Symbolic Execution with a Little Induction

- Symbolic Execution
  1. Prove property for current state
  2. Execute one step of ASBRU plan
  3. Continue with next step
- Trace Induction

Modular Proofs

Assumption-Guarantee Proofs

Verification – Symbolic Execution

1. Prove property $\Diamond$ **last**
   $\Rightarrow$ *eventually right*
2. call procedure
   $\Rightarrow$ *par call left*
3. Execute first statement **skip**
   $\Rightarrow$ *cl* $\ll$*rule*$\gg$, *par chop left*
4. Apply environment assumption
   $\Rightarrow$ *always left*
5. Continue with next step
   $\Rightarrow$ *step*, *simplifier*

Prescribe-observation#(...),
$\Box$ Env $\vdash \Diamond$ **last**

skip; **var** ... **in await** ...,
$\Box$ Env $\vdash$ **last**, $\circ \Diamond$ **last**

var ... **in await** ...,
$\Box$ Env, PL $\vdash \Diamond$ **last**

Verification – Induction

Next statement is **await**, which may loop

loc . . . . **await** . . . ,

□ Env, PL ⊢ ◇ **last**

1. Generalisation
   ⇒ *weakening*
2. Induction
   ⇒ *trace induction*

loc . . . . l :- **await** . . . ,

□ Env, IndHyp ⊢ ◇ **last**

3. Execution of next step
   ⇒ . . .

loc . . . . l :- **await** . . . ,

□ Env, IndHyp, PL ⊢ ◇ **last**

4. ⇒ *apply trace induction*

Verification – Modular Proofs

await $\ldots;\ldots;$

break Prescribe-observation#$(\ldots);\ldots$ **if** $\ldots,$

$\ldots \vdash \Diamond$ **last**

1. Execute plan until call to sub plan is reached

   break Prescribe-observation#$(\ldots);\ldots$ **if** $\ldots,\ldots \vdash \Diamond$ **last**

2. Use lemma for sub plan
   $\Rightarrow$ *par call lemma*
3. Prove assumption of lemma

   break $\neg \Box\ time'' = time' + 1;\ldots$ **if** $\ldots,\ldots \vdash \Diamond$ **last**

4. Use guarantee of lemma

   break $\Diamond$ **last**$;\ldots$ **if** $\ldots,\ldots \vdash \Diamond$ **last**

Verification – Automation

Heuristics

Heuristics apply rules automatically

- Symbolic execution can be automated
- Induction can be partly automated

$\Rightarrow$ *Configure Heuristics*

Degree of Automation

- Work in progress
- Proofs fully automatic except
  - $\star$ generalisation and
  - $\star$ modular proofs

Verification – General Remarks

Features of KIV

- Strong proof support for higher order logic
- Automatic simplification
- High degree of automation
- Lemma administration
  - ⋆ Dependency analysis
  - ⋆ Change management
  - ⋆ Reuse of proofs
- Proof manipulation
  - ⋆ Graphical proof trees
  - ⋆ Pruning, backtracking
  - ⋆ Context sensitive rule selection