

# Künstliche Intelligenz – Übung 13

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# Organizational

## Personal information

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PGP encrypted mails are preferred!

my PGP fingerprint:

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# Use the forum!

Please use the forum

(as always: [https:](https://fsi.cs.fau.de/forum/144-Kuenstliche-Intelligenz)

[//fsi.cs.fau.de/forum/144-Kuenstliche-Intelligenz](https://fsi.cs.fau.de/forum/144-Kuenstliche-Intelligenz))

for questions, where you feel like someone else might also be interested in the answer!

# Homework 11

## Problems 11.3 - common error(s)

$$\frac{\mathbf{A}}{\forall X. \mathbf{A}} \forall I^*$$

$$\frac{\forall X. \mathbf{A}}{[\mathbf{B}/X](\mathbf{A})} \forall E$$

$$[[c/X](\mathbf{A})]^1$$

$$\frac{[\mathbf{B}/X](\mathbf{A})}{\exists X. \mathbf{A}} \exists I$$

$$\frac{\exists X. \mathbf{A} \quad \begin{array}{c} \vdots \\ \mathbf{C} \end{array}}{\mathbf{C}} \exists E^1$$

\* means that  $\mathbf{A}$  does not depend on any hypothesis in which  $X$  is free.

- ▶ forall intro:  $X$  must not occur **freely** in an open Hypothesis
- ▶  $c$  is a constant in the exists elim!
- ▶ ( $c$  is fresh in the exists elim, meaning it should not occur anywhere above) (not sure whether this is true for the Calculus used here, but still best practice!)

# Homework 12

## Howto skip the first annoying part of $CNF^1$

1. Put a  $\neg$  in front of your formula and label it with  $T$

2. “Drag” the  $\neg$  thorough all quantifiers (using the definitions of  $\forall, \exists$ )

3. Replace variables bound by existential quantifiers with skolem functions with skolem functions depending on all variables that are bound by a forall quantifier on the left side of the respective existential quantifier

4. drop all  $\forall$

### Example:

$$(0) \exists X \forall Y. A(X, Y)$$

$$(1) \neg \exists X \forall Y. A(X, Y)^T$$

$$(2) \forall X \exists Y. \neg A(X, Y)^T$$

$$(3) \forall X. [f(X)/Y] (\neg A(X, Y))^T$$

$$(3) \forall X. \neg A(X, f(X))^T$$

$$(4) \neg A(X, f(X))^T$$

# Howto skip the first annoying part of $CNF^1$

Obviously, the formula has to be in **prenex normal form!** (all quantifiers at the beginning)

Convince yourself, why the last slide works!  
(multiple application of the rules of the slides + definitions of  $\forall, \exists$ )

for details: see [https://fsi.cs.fau.de/dw/\\_media/pruefungen/hauptstudium/ki1-summary-ws1819.pdf](https://fsi.cs.fau.de/dw/_media/pruefungen/hauptstudium/ki1-summary-ws1819.pdf) page 6

# First-Order Resolution

Some tips:

- ▶ Train to do the **whole** task on paper and under time pressure!  
How? Draw a “tree” for the second part! (see: blackboard)
- ▶ (skolem) functions without parameters are constants!
- ▶ common misconception: see forum <https://fsi.cs.fau.de/forum/thread/17024-Resolution-popular-error>
- ▶ remember the second Rule:

$$\frac{A^T \vee C \quad B^F \vee D \quad \sigma = \text{mgu}(A, B)}{\sigma(C) \vee \sigma(D)}$$

$$\frac{A^\alpha \vee B^\alpha \vee C \quad \sigma = \text{mgu}(A, B)}{\sigma(A) \vee \sigma(C)}$$

# First-Order Tableaux

Some tips:

- ▶ (skolem) functions without parameters are constants!
- ▶ if  $\forall X.A^F$  then you have to introduce a **skolem-function**, not a variable!

# STRIPS

See lecture: we require that  $add\_a \cap del\_a = \emptyset$

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So in many of your solutions Emptyt<sub>p</sub> had  $\{Jug_p(n)\}$  as the pre-list and allowed for  $n = 0$ .

The action then adds  $\{Jug_p(0)\}$ , and deletes  $\{Jug_p(n)\}$  which means it may delete  $\{Jug_p(0)\}$  if  $n = 0$ !

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Think about it in a sequential way:

We first check "pre", then add "add" and then delete "del", so be careful not to reverse your own actions!

To fix that, you could specify in your del list, not to remove certain facts!

## Example 1

$P :$

$RobotX(n), 0 \leq n \leq 5$

$RobotY(n), 0 \leq n \leq 5$

$Marked_{x,y}(b), b \in \{true, false\}, 0 \leq x, y \leq 5$

$I :$

$\{RobotX(0), RobotY(0), Marked_{x,y}(false) \text{ for all } 0 \leq x, y \leq 5\}$

$G :$

$\{Marked_{5,5}(true)\}$

$A :$  (only small example)

**Forall**  $0 \leq X, X_{new} \leq 5$  **and**  $|X - X_{new}| = 1$  :  $Walk_{X,X_{new}}$  :  
pre:  $\{RobotX(X)\}$  add:  $\{RobotX(X_{new})\}$  del:  $\{RobotX(X)\}$

**Forall**  $0 \leq X, Y \leq 5$  :  $Mark_{X,Y}$  :

pre:  $\{Marked_{X,Y}(false), RobotX(X), RobotY(Y)\}$

add:  $\{Marked_{X,Y}(true)\}$  del:  $\{Marked_{X,Y}(false)\}$

## Example II – a little bit different

$P :$

$RobotX(n), 0 \leq n \leq 5$

$RobotY(n), 0 \leq n \leq 5$

$Marked_{x,y}, 0 \leq x, y \leq 5$

$I :$

$\{RobotX(0), RobotY(0)\}$

$G :$

$\{Marked_{5,5}\}$

$A :$  (only small example)

**Forall**  $0 \leq X, X_{new} \leq 5$  **and**  $|X - X_{new}| = 1$  :  $Walk_{X,X_{new}}$  :  
pre:  $\{RobotX(X)\}$  add:  $\{RobotX(X_{new})\}$  del:  $\{RobotX(X)\}$

**Forall**  $0 \leq X, Y \leq 5$  :  $Mark_{X,Y}$  :

pre:  $\{RobotX(X), RobotY(Y)\}$

add:  $\{Marked_{X,Y}\}$  del:  $\{\}$

## Differences?

- ▶ Example II shows that *Marked* can be realized without a boolean value, the sheer presence of a fact is enough here
- ▶ Example II uses the properties of mathematical sets
- ▶ Example II allows for applying *Mark*, even if the field is already marked (adding an already existing element to a **set** does nothing)
- ▶ Both are valid i.e. in the exam/assignments, you yourself can make your life easier/harder

## Popular(?) Error

- ▶ if / else constructions are only allowed if you define conditions on the **parameters**

Example (similar to homework, but only fractions!):

status	example
OK	add: $\{Jug_p(x + y)\}$ if $x + y \leq p$ $\{Jug_p(p)\}$ else
NOT OK	del: $\{Jug_p(z)\}$ if $Jug_p(z) \in Currentfacts$ $\{\}$ else
NOT OK	add: $\{Jug_p(z)\}$ if $Jug_p(z) \in Currentfacts \wedge z \neq 0$ $\{\}$ else

## Exam preparation: Questions & etc

Questions?