Logik für Informatiker
Logic for computer scientists

What comes next?

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Beyond first-order logic

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- partial function logic: $D(f(x))$ ("$f(x)$ is defined")
- higher-order logic: $\forall f : s \to t \ldots, \forall p : Pred(t) \ldots$

$$\begin{aligned}
&\forall u \forall v (Path(u, v) \leftrightarrow \\
&\quad \forall R\ \ \{[\forall x \forall y \forall z (R(x, y) \wedge R(y, z) \to R(x, z)) \\
&\qquad\qquad \wedge \forall x \forall y (DirectWay(x, y) \to R(x, y))] \\
&\qquad\qquad\qquad\qquad \to R(u, v)\})
\end{aligned}$$

Modal and temporal logics

- modal logic:
  $\Box P$ ("necessarily P") and $\Diamond P$ ("possibly P")
  Other readings of $\Box P$:
  It ought to be that P
  It is known that P
  It is provable that P
  Always P (temporal logic)

- temporal logic: $\Box P$ ("always in the future, P"), $\Diamond P$ ("sometimes in the future, P"), and $\bigcirc P$ ("in the next step, P")
  e.g. $\Box bank\_account > 0$ (very unrealistic)

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- dynamic logic:
  $[p]P$ ("after every run of program p, P holds")
  $<p> P$ ("after some run of program p, P holds")

More exotic modal logics

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- logics for security, e.g. ABLP: $A\ controls\ P$ ("agent A has the permission to perform action P")

Logics for knowledge representation/semantic web

- description logics, e.g. $\mathcal{ALC}$:
  $Elephant \doteq Mammal \sqcap \exists bodypart.Trunk \sqcap \forall color.Grey$
  abbreviates
  $$\forall x[Elephant(x) \leftrightarrow (Mammal(x) \wedge \exists y(bodypart(x,y) \wedge Trunk(y)) \wedge \forall z(color(x,z) \rightarrow Grey(z)))]$$

Multi-valued logics

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- object constraint logic (OCL)
  (for UML — the unified modeling language)

```
-- Managers get a higher salary than employees
inv Branch2:
  self.employee->forall(e | e <> self.manager
    implies self.manager.salary > e.salary)
```

Multi-valued logics (cont'd)

- fuzzy logic: truth values in the interval $[0,1]$ correspond to different degrees of truth (e.g. Peter is quite tall, is tall, is very tall)

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- linear logic (resource-bounded logic)

  $A \otimes A \vdash B$

  (we can prove B when we are allowed to use A twice)

Why do we need so many logics?

- different aspects of the complex world / of software systems
- one "big" logic covering everything would be too clumsy
- good news: most of the logics are based on propositional or first-order logics
- most of the logics have central notions in common

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- A notion of language (or vocabulary of symbols, or signature)
- A syntax for sentences
- A notion of model
- A notion of satisfaction, i.e. $M \models P$ (read: "M satisfies P", or "P holds in M")
- A calculus $\mathcal{T} \vdash P$ (read "P is provable from $\mathcal{T}$)

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  $\mathcal{T} \not\vdash P$ for some P
- soundness of the calculus: $\mathcal{T} \vdash P$ implies $\mathcal{T} \models P$
- (sometimes) completeness: $\mathcal{T} \models P$ implies $\mathcal{T} \vdash P$

Multi logic systems

- The central notions common to all logics can be axiomatized
- Based on this meta-notion, multi-logic systems can be defined
- In Bremen, we also develop multi-logic tools

Next semester

Modal logic for computer scientists

Evaluation of this course

Please (anonymously) fill out the questionaire and return it to us! (MZH 6. Ebene, Postfach 99)

Abgabe der restlichen Übungsaufgaben

bis 11. Februar 2008