Inteligentní systémy (TIL)

Přednáška 2

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Procedurální sémantika TIL

výraz

Smysl (procedura, *konstrukce*)

denotát
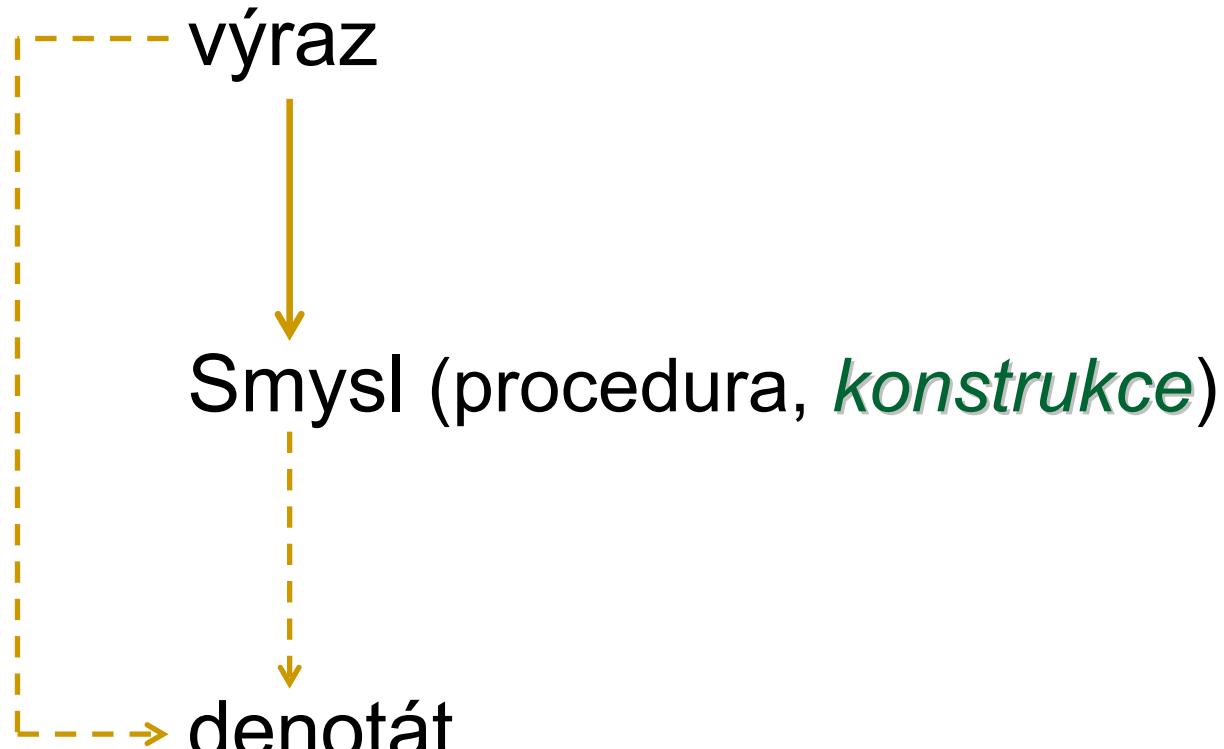
Ontologie TIL: rozvětvená hierarchie typů
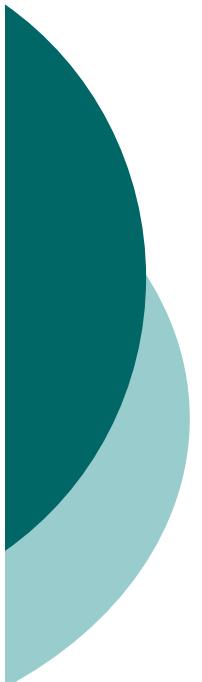
Extenzionální vs. intenzionální kontext

- Kdy je kontext extenzionální?
- Kontext je extenzionální, když v něm platí pravidla *substituce identit* a *existenční generalizace*
- A kdy tato pravidla platí?
- V extenzionálním kontextu
  - hmmm

TIL: *three kinds of context*

- *Hyperintensional*; *construction* of the denoted function is an object of predication
    - *Tom computes **Sin**(π)*
    - *Tom believes that the **Pope** is wise but does not believe that the Bishop of Rome is wise*

- *Intensional*; the denoted *function itself* is an object of predication
    - ***Sine** is a periodic function*
    - *Tom wants to become the **Pope***

- *Extensional*; *value* of the denoted function is an object of predication
    - ***Sin**(π) = 0*
    - *The **Pope** is wise.*

TIL Ontology (types of order 1)

(**non**-procedural objects)

- **Basic types**

  truth-values $\{T, F\}$ (o)

  universe of discourse $\{$individuals$\}$ (ι)

  times or real numbers (τ)

  possible worlds (ω)

- **Functional types** ($\beta\ \alpha_1 \ldots \alpha_n$)
  partial functions $(\alpha_1 \times \ldots \times \alpha_n) \to \beta$

(PWS-)intense, množiny, extense

- **(PWS-)intense** jsou *entity typu* $((\alpha\tau)\omega)$; zkracujeme $\alpha_{\tau\omega}$

- **Množiny** jsou objekty typu $(o\alpha)$ - charakteristické funkce

- **Extense** dané intense typu $\alpha_{\tau\omega}$ ve světě *w* a čase *t* je α-objekt

- **Binární Relace** jsou objekty typu $(o\alpha\beta)$ - charakteristické funkce dvojic

- **Binární vztahy** jsou objekty typu $(o\alpha\beta)_{\tau\omega}$

Nejdůležitější (PWS-)intense

- $\iota_{\tau\omega}$ - *individuový úřad* neboli *role*.
  - Je obsazován *nanejvýš jedním* individuem, označen výrazy jako „president ČR", „papež", „první člověk, který zaběhne 100 m pod 9 s", „Miss World 2005", …

- $(\mathrm{o}\iota)_{\tau\omega}$ - *vlastnost individuí*.
  - Označena výrazy jako „být studentem", „moudrý", „být vzdělaný a chytrý", apod.

- $\mathrm{o}_{\tau\omega}$ - *propozice*.
  - Označena oznamovacími větami jako „President ČR je Miloš Zeman", apod.

- $(\alpha\beta)_{\tau\omega}$ - *atributy*. Často typu $(\iota\iota)_{\tau\omega}$.
  - Označovány výrazy jako „prezident (něčeho)", „otec (někoho)", „teplota (něčeho)", apod.

Constructions

- *Variables x, y, p, w, t, … v*-construct

- *Trivialization* ^0C constructs C (of any type)
  - a *fixed pointer* to C and the *dereference* of the pointer.
  - In order to operate on C, C needs to be grabbed, or 'called', first. Trivialization is such a grabbing mechanism.

- *Closure* $[\lambda x_1 … x_n \ X] \quad \rightarrow (\beta \ \alpha_1 … \alpha_n)$
  $\qquad\qquad \alpha_1 \quad\ \alpha_n \ \ \beta$

- *Composition* $[F \quad X_1 … X_n] \rightarrow \beta$
  $\qquad\quad (\beta \ \alpha_1 … \alpha_n) \ \ \alpha_1 \qquad \alpha_n$

- *Execution* ^1X, *Double Execution* ^2X

TIL Ontology (higher-order types)

- ### *Constructions of order 1* ($*_1$)

  - $\rightarrow$ construct entities belonging to a type of order 1
  - / belong to $*_1$: *type of order 2*

- ### *Constructions of order 2* ($*_2$)

  - $\rightarrow$ construct entities belonging to a type of order 2 or 1
  - / belong to $*_2$: *type of order 3*

- ### *Constructions of order n* ($*_n$)

  - $\rightarrow$ construct entities belonging to a type of order $n \geq 1$
  - / belong to $*_n$: *type of order n + 1*

- ### *Functional entities*: $(\beta\ \alpha_1 \ldots \alpha_n)$ / belong to $*_n$

  (*n*: the highest of the types to which β, α_1, …, α_n belong)

  And so on, *ad infinitum*

explicit intensionalization and temporalization

- constructions of possible-world intensions directly encoded in the logical syntax:

$$\lambda w\, \lambda t\, [\ldots w \ldots t \ldots]$$

- $^0Happy \rightarrow (o\iota)_{\tau\omega}$; $^0Pope \rightarrow \iota_{\tau\omega}$

$$\lambda w\, \lambda t\, [^0Happy_{wt}\, {}^0Pope_{wt}] \rightarrow o_{\tau\omega}$$

- In any possible world (λw) at any time (λt):
  - Take the property of being happy (^0Happy)
  - Take the papal office (^0Pope)
  - Extensoinalize both of them ($^0Happy_{wt}$, $^0Pope_{wt}$)
  - Check whether the holder of the Papal office is happy at that w, t of evaluation ($[^0Happy_{wt}\, {}^0Pope_{wt}]$)

Metoda analýzy

1. Přiřadíme *typy* objektům, o kterých výraz *V* mluví, tj. objektům označeným podvýrazy výrazu *V* včetně *V* samotného.

2. *Spojujeme konstrukce* objektů ad 1) tak, abychom zkonstruovali objekt označený výrazem *V*.

   Přitom sémanticky jednoduchým výrazům přiřadíme *Trivializaci* označeného objektu

3. Provedeme *typovou kontrolu*.

Příklad: „Primátor Ostravy“

- Typy: *Primátor(něčeho)*/$(((\iota\iota)\tau)\omega)$ – zkr. $(\iota\iota)_{\tau\omega}$, *Ostrava*/$\iota$, *Primátor_Ostravy*/$((\iota\tau)\omega)$ – zkr. $\iota_{\tau\omega}$

- Syntéza: $\lambda w \lambda t\ [^0Primátor_{wt}\ ^0Ostrava]$

- Typová kontrola:

$\lambda w\ \lambda t\ [[[^0Primator\quad w]\ t]\ ^0Ostrava]$

$(((\iota\iota)\tau)\omega)\qquad \omega$

$((\iota\iota)\tau)\qquad \tau$

$(\iota\iota)\qquad \iota$

ι

$(\iota\tau)$

$((\iota\tau)\omega)\qquad$ zkráceně $\iota_{\tau\omega}$ (*individuový úřad*)
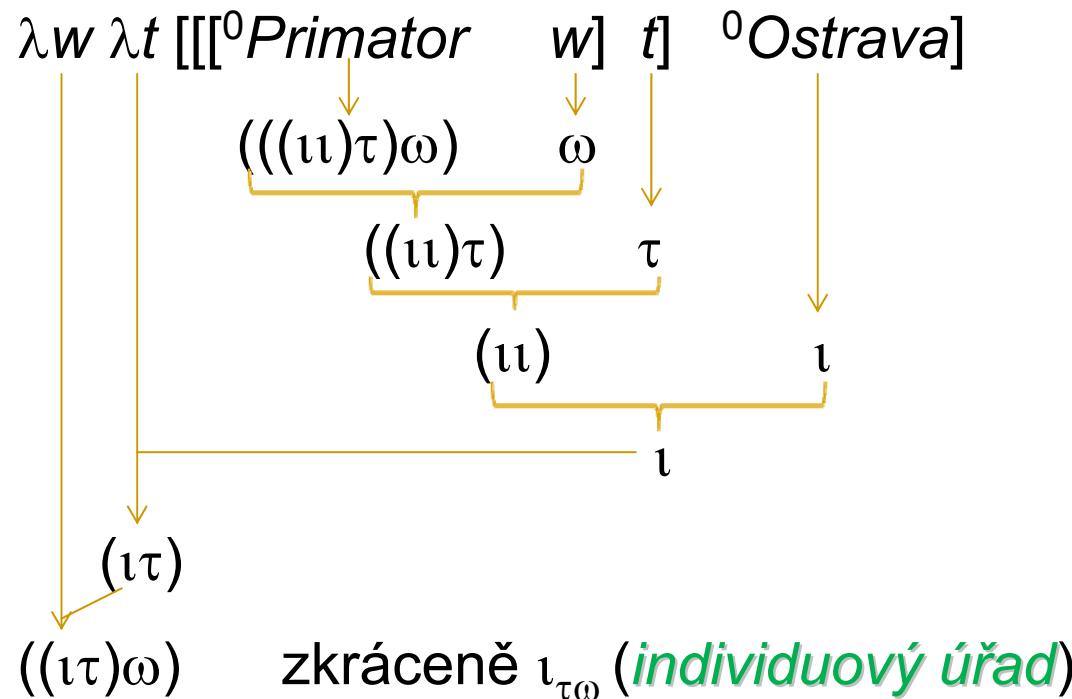
„Primátor Ostravy je bohatý"

- Typy: *Primátor(něčeho)*/$(\iota\iota)_{\tau\omega}$, *Ostrava*/$\iota$, *Primátor_Ostravy*/$\iota_{\tau\omega}$, *(Být)Bohatý*/$(o\iota)_{\tau\omega}$

- Syntéza:
$\lambda w \lambda t\ [^0Bohatý_{wt}\ \lambda w \lambda t\ [^0Primátor_{wt}\ ^0Ostrava]]_{wt}]$

- Typová kontrola (zkráceně):

$\lambda w\ \lambda t\ [[[^0Bohatý_{wt}\ \ \lambda w \lambda t\ [^0Primátor_{wt}\ ^0Ostrava]]_{wt}]$

$\qquad\qquad (o\iota) \qquad\qquad\qquad \iota$

$\qquad\qquad\qquad\qquad o$

$\quad (o\tau)$

$((o\tau)\omega)$ zkráceně $o_{\tau\omega}$ (*propozice*)

TIL vs. Montague's IL

- IL is an extensional logic, since the axiom of extensionality is valid:
  $$\forall x\,(Ax = Bx) \rightarrow A = B.$$

- This is a good thing. However, the price exacted for the simplification of the language (due to ghost variables) is too high;
  - the law of universal instantiation, lambda conversion and Leibniz's Law do not generally hold, all of which is rather unattractive.

- Worse, IL does *not validate the Church-Rosser 'diamond'*. It is a well-known fact that an ordinary typed λ-calculus will have this property. Given a term $\lambda x(A)B$ (the *redex*), we can simplify the term to the form $[B/x]A$, and *the order in which we reduce particular redexes does not matter*. The resulting term is uniquely determined up to α-renaming variables.

- TIL does not have this defect; it validates the Church-Rosser property though it works with *n-ary partial* functions
  - the functions of TY_2 are restricted to *unary total* functions (Schönfinkel)

TIL: *logical core*

- ***constructions*** + ***type hierarchy***
  (simple and ramified)

- The ramified type hierarchy organizes all higher-order objects: constructions (types $*_n$), as well as functions with domain or range in constructions.

- The simple type hierarchy organizes first-order objects: non-constructions like extensions (individuals, numbers, sets, etc.), possible-world intensions (functions from possible worlds) and their arguments and values.

Hyperintensionality

- was born out of a negative need, to block invalid inferences

  - Carnap (1947, §§13*ff*); there are contexts that are neither extensional nor intensional (attitudes)

  - Cresswell; any context in which substitution of necessary equivalent terms fails is hyperintensional

- Yet, which inferences are valid in hyperintensional contexts?

- How hyper are hyperintensions?

- **Which contexts are intensional / hyperintensional**?

- *TIL definition is positive*:
a context is *hyperintensional* if the very meaning *procedure* is an object of predication

Three kinds of context

- *hyperintensional context*: a meaning construction occurs *displayed*
  - so that the very *construction is an object of predication*
  - though a construction at least one order higher need to be executed in order to produce the displayed construction
- *intensional context*: a meaning construction occurs *executed* in order to produce a function *f*
  - so that *the whole function f is an object of predication*
  - moreover, the executed construction does not occur within another displayed construction
- *extensional context*: the meaning construction is *executed* in order to produce a particular value of the so-constructed function *f* at its argument
  - so that *the value of the function f is an object of predication*
  - moreover, the executed construction does not occur within another intensional or hyperintensional context.

Hyperintensionality

- *Extensional logic* of hyperintensions
- *Transparency*: no context is opaque
- The same (extensional) logical rules are valid in all kinds of context;
  - Leibniz's substitution of identicals, existential quantification even into hyperintensional contexts, …
- Only the types of objects these rules are applied at differ according to a context
- Anti-contextualism: constructions are assigned to expressions as their context-invariant meanings