Logical Analysis of Czech Sentence with TIL

Aleš Horák

Faculty of Informatics, Masaryk University

Botanická 68a, CZ-602 00 Brno, Czech Republic

E-mail: hales@fi.muni.cz

http://www.fi.muni.cz/~hales/disert/

Outline

- logical analysis, TIL
- Expression-Meaning Relationship, Concept
- Logical Analysis of NL Sentences
- conclusions

Logical Analysis in TIL (NTA$_2$)

- based on *compositionality principle*
- aim: prepare input for *TIL Inference Machine*
- description of *Knowledge Base Representation*
- in cooperation with Leo hadacz

TIL — Transparent Intensional Logic

Tichý, P., *The Foundations of Frege's Logic*, de Gruyter, Berlin, New York, 1988.

- logical system suitable as a meaning surrogate (intensions, possible worlds, temporal and modal variability)
- parallel to Montague's logic, TIL has greater expressivity
- typed λ-calculus logic with particular epistemic framework
- *basic types* = $\{\iota, o, \tau, \omega\}$, (individuals, truth values, real numbers or time moments and possible worlds); *other types*: functions or higher rank types ($\iota_{\tau\omega}$ – individual role, $(o\iota)_{\tau\omega}$ – class of individuals or property, $(o\alpha\beta)_{\tau\omega}$ – intensional relation between object of types α and β, $*_n$ – class of constructions of order n,...)
- constructions – λ-calculus formulae with specific modes of constructions (trivialization).
- inference rules for TIL are well defined
- Normal Translation Algorithm (NTA)

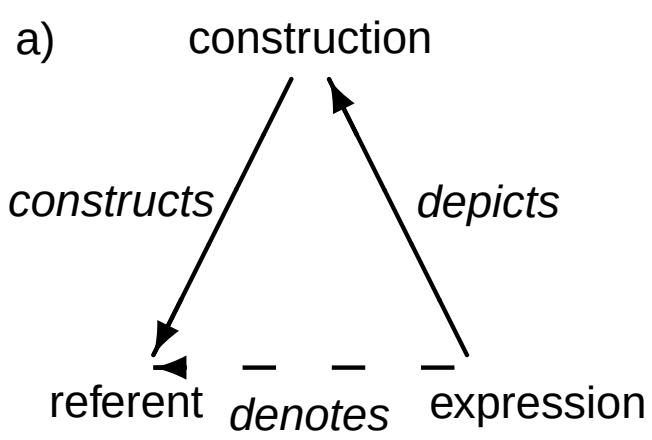
- logical analysis, TIL

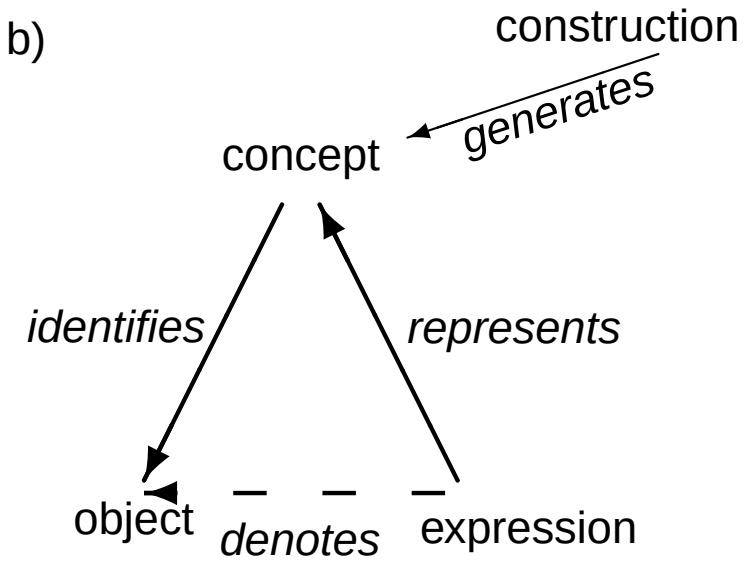
⇒ Expression-Meaning Relationship, Concept

- Logical Analysis of NL Sentences
- conclusions

Expression-Meaning Relationship in TIL

a) the expression-meaning relation in TIL and b) with Materna's conceptual approach.





enhancements:

- construction normal form
- new definition of concept

Concept

concept motivations:

(a) when constructing a higher-order object (e.g. a propositional attitude), we cannot make a difference between quasi-identical constructions in place of the argument.

(b) the meaning sustainer must follow the Functionality Principle

- (Materna's) CONCEPT — class of closed quasi-identical constructions (generated by one of them, a CONCEPT$*$)
- *concept normal form* — represents class of α- and β-equivalent constructions of an object
- **Claim**: normal forms of CONCEPTS$*$ are isomorphic with CONCEPTS
- newly defined *concept* — normal form of an CONCEPT$*$ (which *points* to the concept)

- logical analysis, TIL
- Expression-Meaning Relationship, Concept

$\Rightarrow$ Logical Analysis of NL Sentences

- conclusions

Logical Analysis of NL Sentences

- Verb Phrase
- Noun Phrase
- Sentence Building
- Folding of Constituents
- Special Compound
- Questions and Imperatives

Attributive and Episodic Verbs

verbs:

1. *attributive* — ascribe a property to the subject, timeless

   ‘Radnice stojí na náměstí.’ (‘The town hall stands in the square.’)

   $$\lambda w \lambda t [\textbf{stojící\_na\_náměstí}_{wt} \textbf{radnice}]$$

2. *episodic* — express actions (*episodes*)

   - event — conjunction of basic propositions (primary properties) and a time proposition . . . π
   - episode — class of events that are pairwise variants (differ in time proposition) . . . $(o\pi)$. Episode can have a *protagonist* — *by*-relation individual is in *does*-relation to a class of episodes if the individual currently takes leading role in one of the episodes

     ‘Petr zpívá.’ (‘Peter sings.’)

     $$\lambda w \lambda t [\textbf{Does}_{wt} \textbf{Petr zpívá}_{w}]$$

Episodic Verbs — Verbal Object and Verb

- verbal object — world-dependent linkage between a *labour episode* and an *upshot episode* . . . $(o(o\pi)(o\pi))_\omega$
  1. *achievement* verbs — labour episode and upshot episode are disjoint (‘zabít králíka’ or ‘uvařit oběd’ (‘to kill a rabbit’, ‘to make a dinner’))
  2. *performance* verbs — labour episode does not differ from upshot episode (‘zpívat Ódu na radost’ or ‘chodit’ (‘to sing the Ode to Joy’, ‘to walk’))
- verb — function that assigns a verbal object to its arguments $\ldots(o(o\pi)(o\pi))_\omega\xi_1\ldots\xi_n$

  verb ‘zničit’ (‘to kill off’) — zničit$/(o(o\pi)(o\pi))_\omega\iota$

  verbal object ‘zničit krtka’ (‘to kill off the mole’)

  — $[\textbf{zničit Krtek}]\ldots(o(o\pi)(o\pi))_\omega$.

Verb Aspect

aspect$=\left\{\begin{array}{l} X \text{ is in } \textit{imperfective} \text{ a. to verb } V \text{ — } X \text{ is } \textit{engaged} \text{ in } V\text{-ing} \\ X \text{ is in } \textit{perfective} \text{ a. to } V \text{ — } X \text{ has just } \textit{completed } V\text{-ing} \end{array}\right.$

Imp/Perf — world-dependent operation between instantiated verb and object denoted by the present tense expression

present tense expression ‘zpívá’ (‘sings’) $\longrightarrow$ zpívá$/\big(o(o\pi)\big)_\omega$

$$\lambda w \lambda t \big[\textbf{Does}_{wt}\textbf{Petr}\,\big[\textbf{Imp}_{w}\textbf{zpívat}_{w}\big]\big]$$

Verb Tense

- *present tense*

  ‘Petr nakupuje v supermarketu.’ (‘Peter goes shopping into a supermarket.’)

  (a) ‘Peter is shopping in a supermarket right now.’

$$\lambda w\lambda t\left[\textbf{Prog}_{wt}\lambda w\lambda t(\exists x)\left[\left[\textbf{Does}_{wt}\ \textbf{Petr}\left[\textbf{Imp}_{w}\left[\textbf{Nv}\ x\right]_{w}\right]\right]\ \wedge\ \left[\textbf{SM}_{wt}\ x\right]\right]\right]$$

  (b) ‘Peter has been shopping in a supermarket.’

$$\lambda w\lambda t\left[\textbf{Pf}_{t}\left[\textbf{Onc}_{w}\left[\textbf{Does}_{wt}\ \ldots\right]\right]\ \textbf{Anytime}\right]$$

- *future and past tense* — time-dependent relation between $(o(o\tau))$-objects and $(o\tau)$-objects (time span belongs to acceptable classes of time moments as obtained by the frequency modification of the proposition’s chronology)

$$\textbf{P}\Big(<\text{frequency adverb}>\big(<\text{proposition}>\big),\ <\text{reference time span}>\Big)$$

Active and Passive Voice

‘Krtek je zničen.’ (‘The mole is killed off.’)

function K $\leftarrow \lambda x[\textbf{Perf}_w[\textbf{zničit}\, x]_w]$ that takes individual x to class of all episodes which represent the killing off of x in world w

function Pass that takes (at t) object K to class of individuals that are killed off in w at t.

$$\lambda w \lambda t \left[\left[\textbf{Pass}_t \lambda x \left[\textbf{Perf}_w [\textbf{zničit}\, x]_w \right] \right] \textbf{Krtek} \right]$$

Adverbial Modification

adverbial phrase:

1. *locational* AP — property of verbal object
2. *temporal* AP — analysed with verb tense
3. *modal* AP — property of verbal object
4. *causal* AP — relationship between the proposition containing the AP and another underspecified proposition

$$\ldots (\exists p) \Big[\textbf{kvůli}_{wt}\, p\, \lambda w \lambda t \big[\textbf{Does}_{wt} \textbf{Petr} \big[\textbf{Perf}_{w} \textbf{odstěhovat\_se}_{w} \big] \big] \wedge$$
$$\wedge \big[\textbf{About}\, p\, \textbf{Karel} \big] \Big] \ldots$$

Auxiliary and Modal Verbs

- ‘mít’, ‘být’ (‘to have’ (in the auxiliary meaning usually not translated) and ‘to be’)

  ‘Petr má chřipku.’ (‘Peter is ill with influenza.’)

  $$\lambda w \lambda t [\textbf{mít\_chřipku}_{wt}\ \textbf{Petr}]$$

- ‘muset’, ‘smět’, ‘moci’ (‘to have to’ (must), ‘to be allowed to’ (may), ‘to be able to’ (can))

  — relation between an individual (or a class of individuals) and a class of episodes

  ‘Petr musí zničit krtka.’ (‘Peter must kill off the mole.’)

  $$\lambda w \lambda t \left[\textbf{Must}_{wt}\ \textbf{Petr} \left[\textbf{Perf}_{w} [\textbf{zničit Krtek}]_{w} \right] \right]$$

Verb Valency

levels of verb frame representation:

1. syntactic surface structure:

   dávat něco$_{\text{non-human.NP, accus., no prep.}}$ někomu$_{\text{human.NP, dat., no prep.}}$

2. semantic function:

   dávat Patiens Addressee

3. meaning function:

   dávat$/\left(o\left(o\pi\right)\left(o\pi\right)\right)_{\omega}\iota\iota$ $\quad x\ldots\iota \quad y\ldots\iota : s_{wt}y, s\ldots\left(o\iota\right)_{\tau\omega}$

translation from syntactic structure to meaning function

a valency expression:

- a *noun group*
- an *adverbial phrase*
- a *subordinate clause*
- an *infinitive*

Noun Analysis

‘pes, člověk’ (‘dog’, ‘human’)	$x \ldots \iota$: **pes**$_{wt}x$, pes$/(o\iota)_{\tau\omega}$	individual from class of individuals
‘prezident’ (‘president’)	prezident$/\iota_{\tau\omega}$	individual role
‘volitelnost’ (‘eligibility’)	volitelnost$/(o\iota_{\tau\omega})_{\tau\omega}$	property of individual role
‘výška’ (‘height’)	výška$/(\tau\iota)_{\tau\omega}$	a quantity
‘výrok’, ‘tvrzení’ (‘statement’, ‘assertion’)	$p \ldots *_\pi$: **výrok**$_{wt}p$, výrok$/(o*_\pi)_{\tau\omega}$	construction of proposition from the class of constructions of proposition
‘válka’, ‘smích’, ‘zvonění’ (‘war’, ‘laughter’, ‘ringing’)	válka$/(o(o\pi))_\omega$	class of episodes — activity that corresponds to a verb
‘leden’, ‘podzim’ (‘January’, ‘autumn’)	leden$/(o(o\tau))$	classes of time moments — time intervals

Adjective Modifier

‘červené jablko’ (‘a red apple’)

$x \ldots \iota$: **jablko**$_{wt}x \wedge$ **červený**$_{wt}x$

‘malý slon’ (‘a small elephant’)

$x \ldots \iota$: $\left[\textbf{malý}_{wt}\textbf{slon}\right] x$

‘zářivě červené jablko’ (‘a brightly red apple’)

$x \ldots \iota$: **jablko**$_{wt}x \wedge \left[\textbf{zářivě}_{wt}\textbf{červený}_{wt}\right] x$

Prepositional Noun Phrase

meaning of PNP $=$ { part of verbal object; as meaning of adverbial phrase

basic classification — according to the preposition

‘Praha’[a] . . . . . **Praha** . . . ι

‘byt v Praze’[a] . . . . . $x \ldots \iota$: **byt**$_{wt}x \wedge [\mathbf{v}^1{}_{wt}\mathbf{Praha}]_{wt}x$

‘bydlet v Praze’[a] . . . $v \ldots (o(o\pi)(o\pi))$: $v \subset$ **bydlet**$_w \wedge [\mathbf{v}^2{}_{wt}\mathbf{Praha}]_w v$

[a] ‘Prague’, ‘an apartment in Prague’, ‘to live in Prague’

NP attachment

1. *apposition*

   ‘chudák matka’ (‘poor mother’)

   $$x \ldots \iota : \textbf{chudák}_{wt} x \wedge \textbf{matka}_{wt} x$$

2. *prepositional attachment*

3. *genitive construction* (as argument or property)

   ‘výška’[a] . . . . . **výška** . . . $(\tau\iota)_{\tau\omega}$

   ‘postava’[a] . . . . . $y \ldots \iota$: $\textbf{postava}_{wt} y$

   ‘výška postavy’[a] . . . $x \ldots \tau$: $x = [\textbf{výška}_{wt} y] \wedge \textbf{postava}_{wt} y$

   ‘dno řeky’[b] . . . $x \ldots \iota$: $(\exists y)[\textbf{dno}_{wt} x \wedge \textbf{řeka}_{wt} y \wedge \textbf{Of}_{wt} x\, y]$

[a] ‘height’, ‘person’, ‘height of a person’

[b] ‘a river bed’

Pronoun and Proper Name

- conception of pragmatic meaning of *pragmatically anchored expressions* (Materna, 1998)

  ‘Já vidím Janu’ (‘I can see Jane.’)

  $$\lambda w \lambda t \Big[\textbf{Does}_{wt}\, Já \big[\textbf{Imp}_{w} \big[\textbf{vidět}\ Jana \big]_{w} \big] \Big]$$

  $Já, Jana \ldots \iota$

- interrogative pronoun — questions or relative clauses
- indefinite and negative pronoun — existentional quantifier and negation

Numeral and Quantificational Phrase

Deset labutí $\lambda x[$ Petr sleduje na obloze x $]$[a] (*a)

Přesně sedm much $\lambda x[$ Honza zabil x jednou ranou $]$[b] (**a)

$[$ Honza zabil s jednou ranou $] \wedge s = [$přesně sedm much$]$[c] (**b)

$[$ Petr sleduje na obloze s $] \wedge s = [$deset labutí$]$[d] (*b)

---

[a] Ten swans $\lambda x[$Peter watches x overhead$]$

[b] Exactly seven flies $\lambda x[$Jack has killed x at a single blow$]$

[c] $[$Jack has killed s at a single blow$] \wedge s = [$exactly seven flies$]$

[d] $[$Peter watches s overhead$] \wedge s = [$ten swans$]$

Compound Constituents

Sentence Building

- subordinate clauses
- coordinate clauses

Folding of Constituents

- lists of constituents

Special Compound

- extensions (numbers, date, time, . . .)

Questions

match $x : C$

x . . . object or variable, C construction

both construct (or are) one and the same object

kinds of attitudes to proposition:

Yes/No

Je Petr vyšší než Karel? (Is Peter taller than Charles?)

Petr je vyšší než Karel. (Peter is taller than Charles.)

$x \ldots o : C_{1wt}$

True : C_{1wt}

Questions — cont.

Wh-

Která hora je nevyšší na světě? (Which mountain is the highest in the world?)

Mount Everest je nevyšší hora na světě. (Mount Everest is the highest mountain in the world.)

$s \ldots o\iota : C_{2wt}$

$\{\text{Mount\_Everest}\} : C_{2wt}$

Expl

Proč je Marie smutná? (Why is Mary sad?)

Marie je smutná, protože je Petr nemocný. (Mary is sad, because Peter is ill.)

$p \ldots \pi : \textbf{Expl}_{wt} C_3$

$\lambda w \lambda t [\textbf{nemocný}_{wt} \textbf{Petr}]^{a} : \textbf{Expl}_{wt} C_3$

[a] 'ill','Peter'

Imperatives

Imper

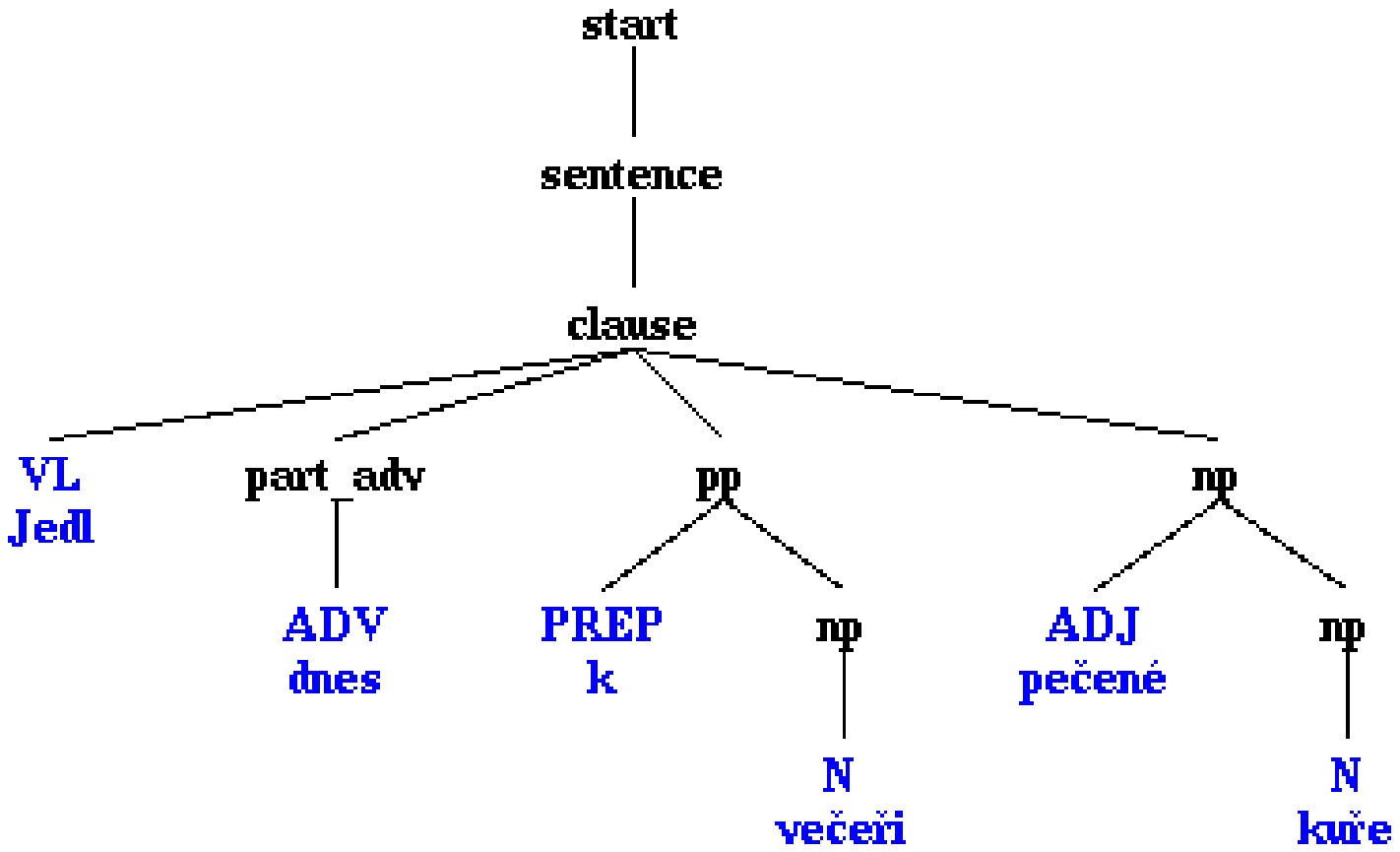
Petře, uvař oběd! (Peter, make lunch!)

Petr uvaří oběd. (Peter will make lunch.)

command (indicative sentence) that makes C_{4wt} to be True.

Example — derivation tree

An example of resulting derivation tree for sentence '`Jedl dnes k večeři pečené kuře.`' (*He ate a roast chicken for dinner today.*)



Example — logical analysis

evaluation of `rule_schema` for `np` 'pečené kuře'

```
4, 6, -npnl -> .{ left_modif } np .: k1gNnSc145
agree_case_number_gender_and_propagate OK
rule_schema: 2 nterms, 'lwtx(awtx(#1) and awtx(#2))'
And constrs, Abstr and Exi vars are just gathered
1 (1x1) constructions:
```

$\lambda w_2 \lambda t_3 \lambda x_4([\textbf{pečený}_{w_2 t_3}, x_4] \wedge [\textbf{kuře}_{w_2 t_3}, x_4]) \ldots (o\iota)_{\tau\omega}$

```
And constrs: none added
Exi vars: none added
```

Example — logical analysis (cont.)

evaluation of `verb_rule_schema` for the whole clause

`verb_rule_schema: 3 groups`

`no acceptable subject found: supplying an inexplicit one`

`inexplicit subject: k3xPgMnSc1,k3xPgInSc1:` $On \ldots \iota$

`Clause valency list: jíst <v>#1:(1)hA-#2:(2)hPTc1, ...`

`Verb valency list: jíst <v>#2:hH-#1:hPTc4ti`

`Matched valency list: jíst <v>#2:(1)hH-#1:(2)hPTc4ti`

`time span:` λt_{12}**dnes**$_{tt_{12}} \ldots (o\tau)$

`frequency:` **Onc** $\ldots ((o(o\tau))\pi)_{\omega}$

`verbal object:` $x_{15} \ldots (o(o\pi)(o\pi))$

`present tense clause:`

$\lambda w_{17}\lambda t_{18}(\exists i_{10})(\exists x_{15})(\exists i_{16})([$**Does**$_{w_{17}t_{18}}, On, [$**Imp**$_{w_{17}}, x_{15}]] \wedge$
$[$**večeře**$_{w_{17}t_{18}}, i_{10}] \wedge [$**pečený**$_{w_{17}t_{18}}, i_{16}] \wedge [$**kuře**$_{w_{17}t_{18}}, i_{16}] \wedge x_{15} =$
$[$**jíst**$, i_{16}]_{w_{17}} \wedge [[$**k**$_{w_{17}t_{18}}, i_{10}]_{w_{17}}, x_{15}]) \ldots \pi$

`clause:`

$\lambda w_{19}\lambda t_{20}[$**P**$_{t_{20}}, [$**Onc**$_{w_{19}}, \lambda w_{17}\lambda t_{18}(\exists i_{10})(\exists x_{15})(\exists i_{16})([$**Does**$_{w_{17}t_{18}}, On, [$**Imp**$_{w_{17}}, x_{15}]]$
$\wedge [$**večeře**$_{w_{17}t_{18}}, i_{10}] \wedge [$**pečený**$_{w_{17}t_{18}}, i_{16}] \wedge [$**kuře**$_{w_{17}t_{18}}, i_{16}] \wedge x_{15} =$
$[$**jíst**$, i_{16}]_{w_{17}} \wedge [[$**k**$_{w_{17}t_{18}}, i_{10}]_{w_{17}}, x_{15}])], \lambda t_{12}$**dnes**$_{tt_{12}}] \ldots \pi$

Conclusions

- the mettagrammar formalism for syntactic analysis
- implementation of a fully competitive parser for Czech
- comparison of TIL to other semantic representations
- new definition of concept
- Normal Translation Algorithm
  - first exact algorithm of such extent
  - new analysis of most phenoma in Czech