TectoMT:
Deep-Syntactic Machine Translation

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Motivation

TectoMT

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TectoMT was one of the **worst** systems in WMT2015.

TectoMT is **difficult** to train for a new language pair.

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Chimera **won** EN→CS WMT 2013–2015.

Chimera = Moses + TectoMT + Depfix

Motivation

TectoMT	✔			✔		✔		✔	53.5
Moses	✔		✔		✔			✔	57.7
Moses+TectoMT	✔		✔	✔			✔		59.2
% of reference tokens	44.7	32.9	8.6	**4.5**	3.6	**3.5**	1.4	0.8	100

adapted from Tamchyna and Bojar, ACL 2015

TectoMT translations are very different from phrase-based systems
(8% of reference tokens are only in TectoMT).

TectoMT is **essential** for Chimera's success.

Motivation

TectoMT was one of the **worst** systems in WMT2015.

TectoMT is **difficult** to train for a new language pair.

BUT

TectoMT is **essential** for Chimera's **success**.

We have many plans for improving TectoMT.

TectoMT is now **less difficult** to adapt:

prototypes of CS→EN, EN↔ES, EN↔NL, EN↔PT, EN↔EU

created within the QTLeap project. (+JA→CS, CS→RU)

Future: Universal Dependencies and Udapi.

TectoMT info (inspired by Mikel's talk)

TectoMT

- started in 2005, Charles University in Prague as FLOS**A**S software:-), https://github.com/ufal/treex
- best fit for **un**related languages with difficult structural transfer or morphologically rich l.
- same problem as Apertium: using XML, but only for the native data format
- OOP API (instead of *nix pipeline)
- both rule-based and statistical parts
- community: your chance;-)

Outline

- TectoMT (MT system) vs. Treex (NLP framework)
- Demo translation step by step
- Annotation of translation errors
- Details
  - Hidden Markov Tree Models (HMTM)
  - Combining dictionaries
  - Maximum Entropy dictionary
- Examples of translation

TectoMT vs. Treex

2005 ... 2011

NLP framework
TectoMT

MT system
TectoMT

- lemmatization
- tagging
- parsing

Main author:
Zdeněk Žabokrtský

multi-purpose NLP framework
Treex

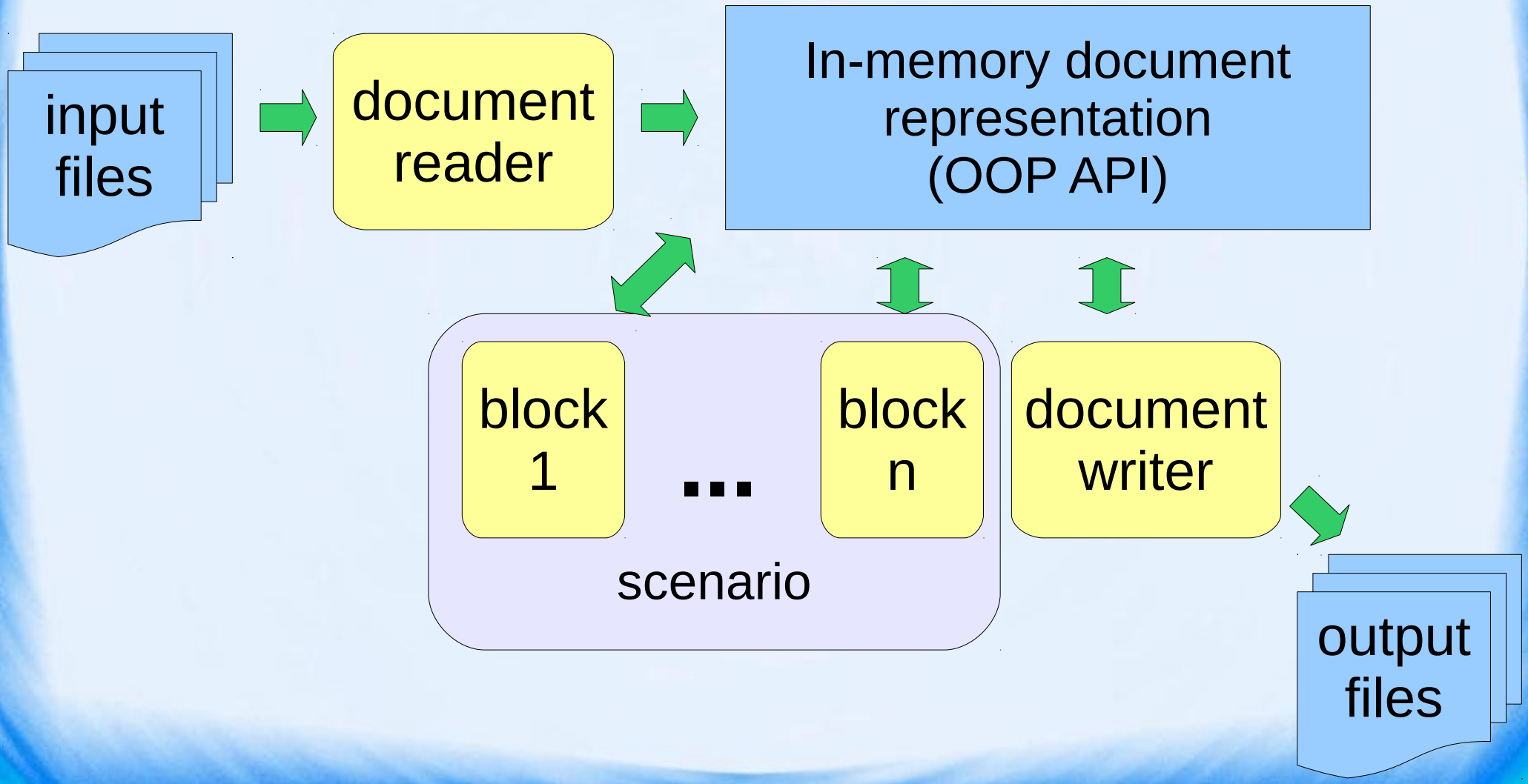
MT system
TectoMT

- lemmatization
- tagging
- parsing

- coreference
- CzEng analysis
- named entity r.
- SMT preproc.
- PEDT preprocessing
- treebank conversions
- alignment (word,tree)
- etc.

Treex architecture

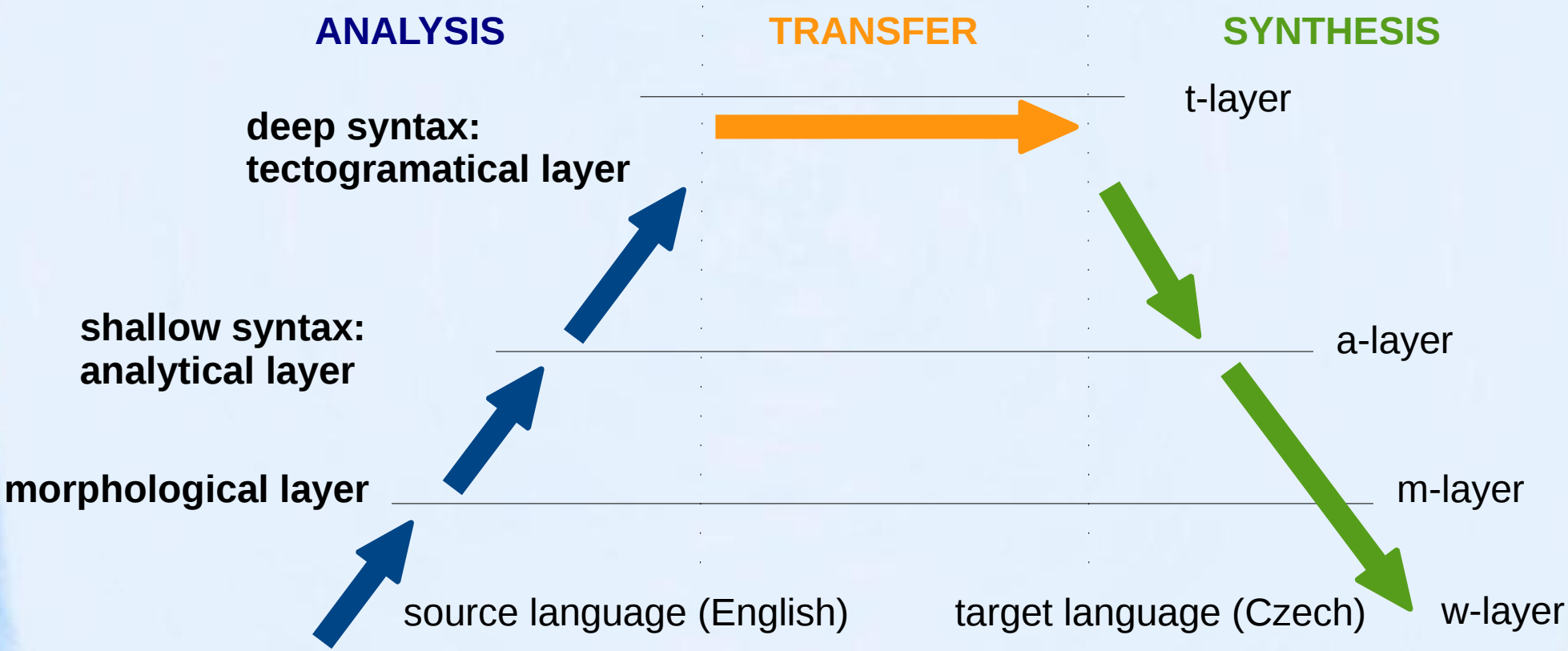
TectoMT



Translation scheme

TectoMT

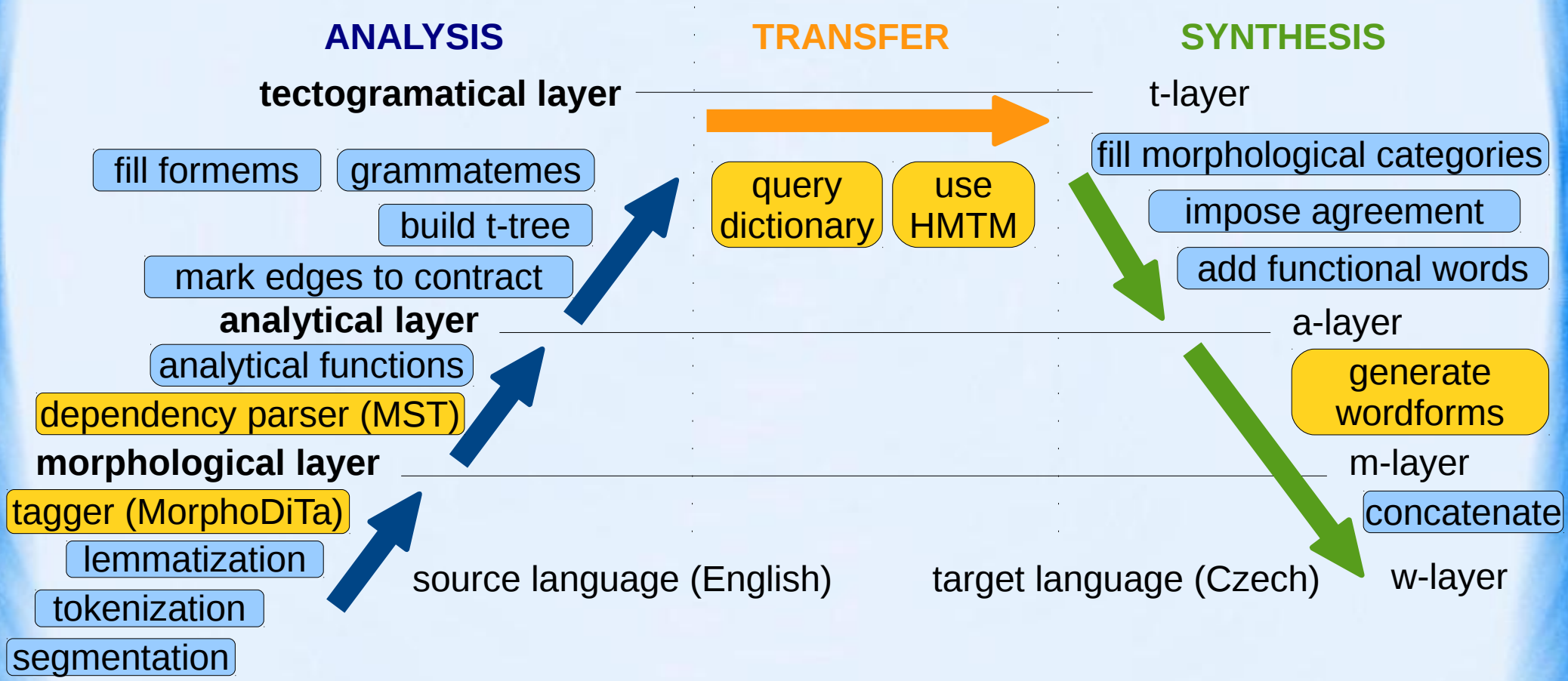
transfer over the tectogrammatical layer



Translation scheme

TectoMT

rule based & statistical blocks



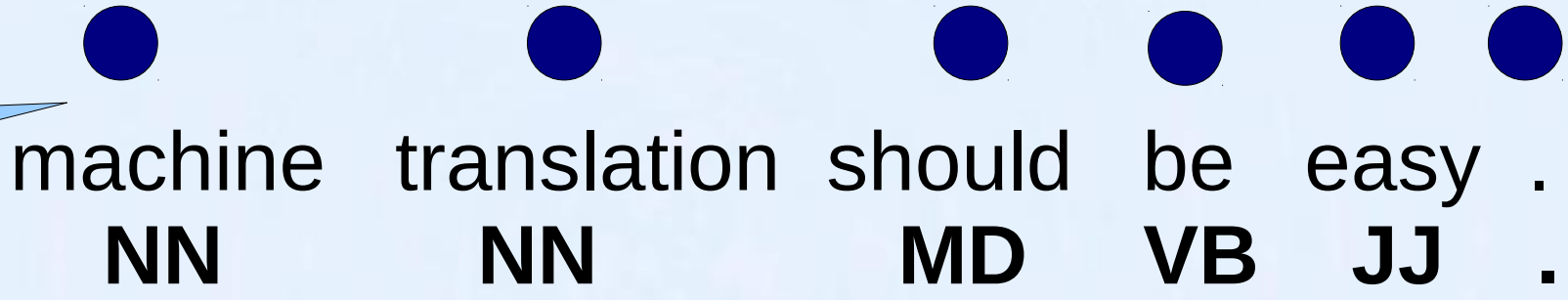
Demo Translation – Analysis

TectoMT

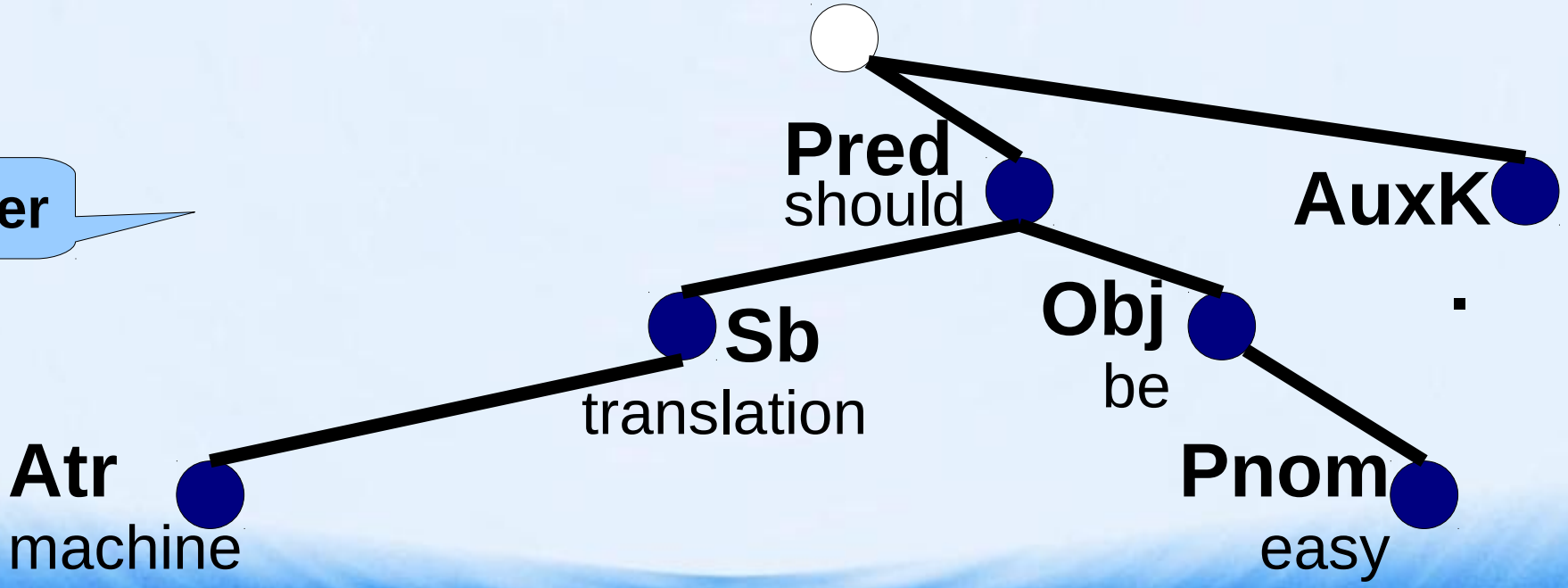
raw text

Machine translation should be easy.

m-layer



a-layer



Demo Translation – Analysis

TectoMT

raw text

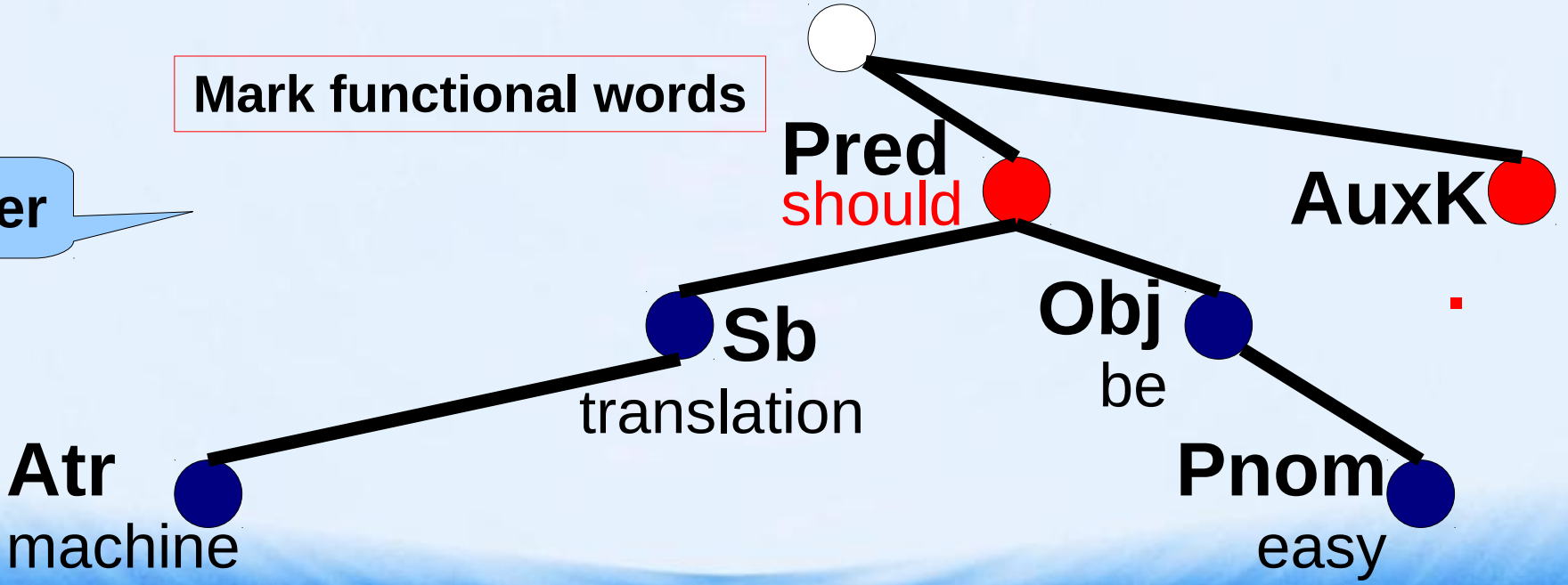
Machine translation should be easy.

m-layer

machine	translation	should	be	easy	.
NN	**NN**	**MD**	**VB**	**JJ**	**.**

a-layer

Mark functional words



Demo Translation – Analysis

TectoMT

raw text

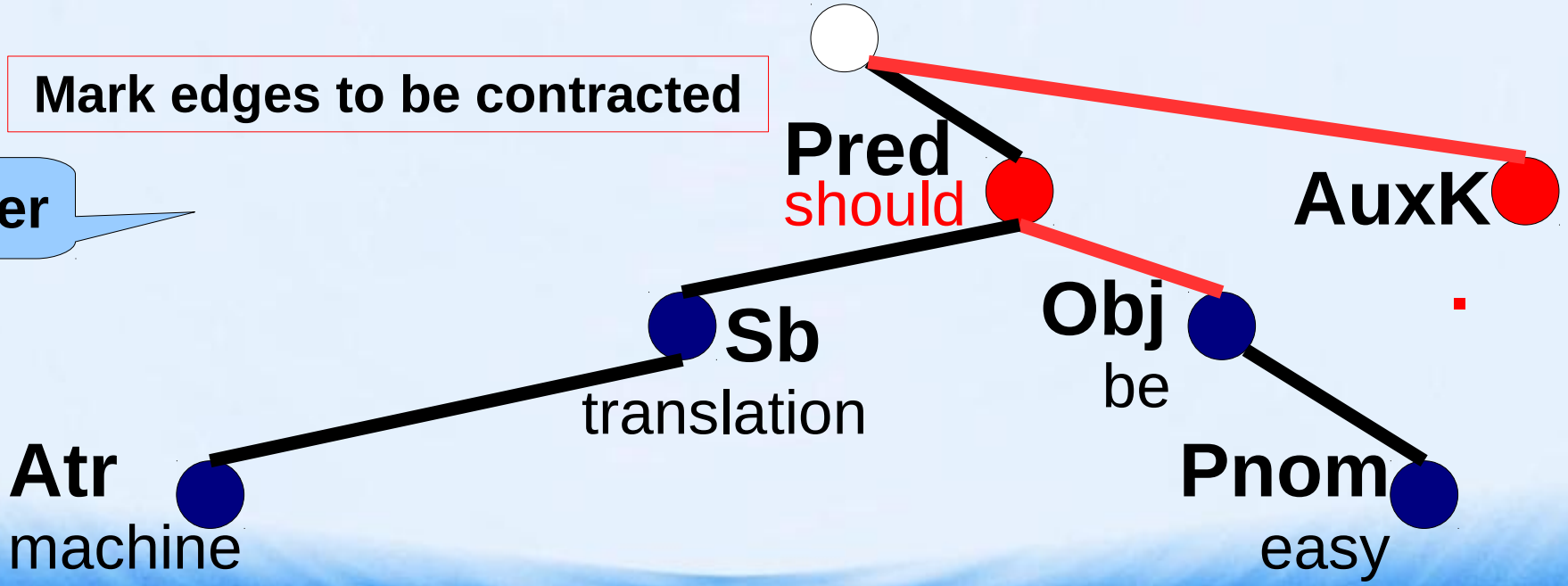
Machine translation should be easy.

m-layer

machine	translation	should	be	easy	.
NN	**NN**	**MD**	**VB**	**JJ**	**.**

Mark edges to be contracted

a-layer



Demo Translation – Analysis

TectoMT

raw text

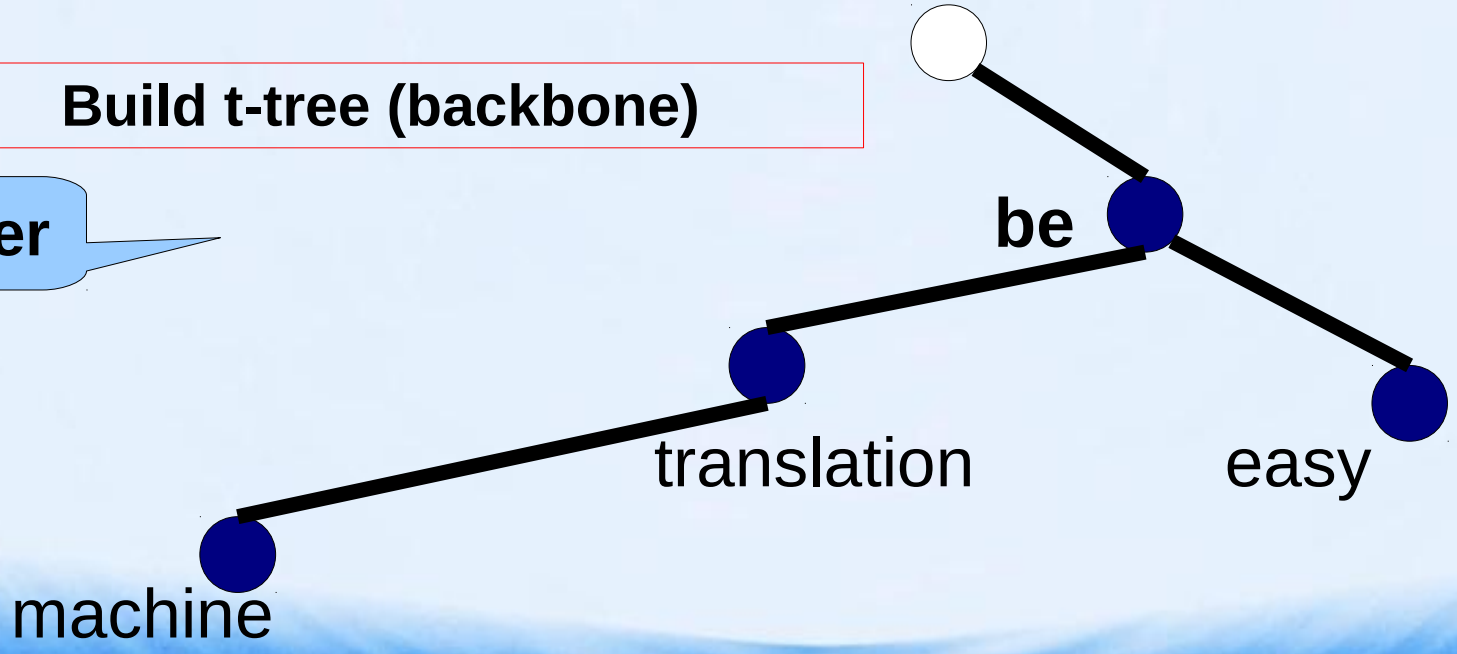
Machine translation should be easy.

m-layer

machine	translation	should	be	easy	.
NN	**NN**	**MD**	**VB**	**JJ**	**.**

Build t-tree (backbone)

t-layer



Demo Translation – Analysis

TectoMT

raw text

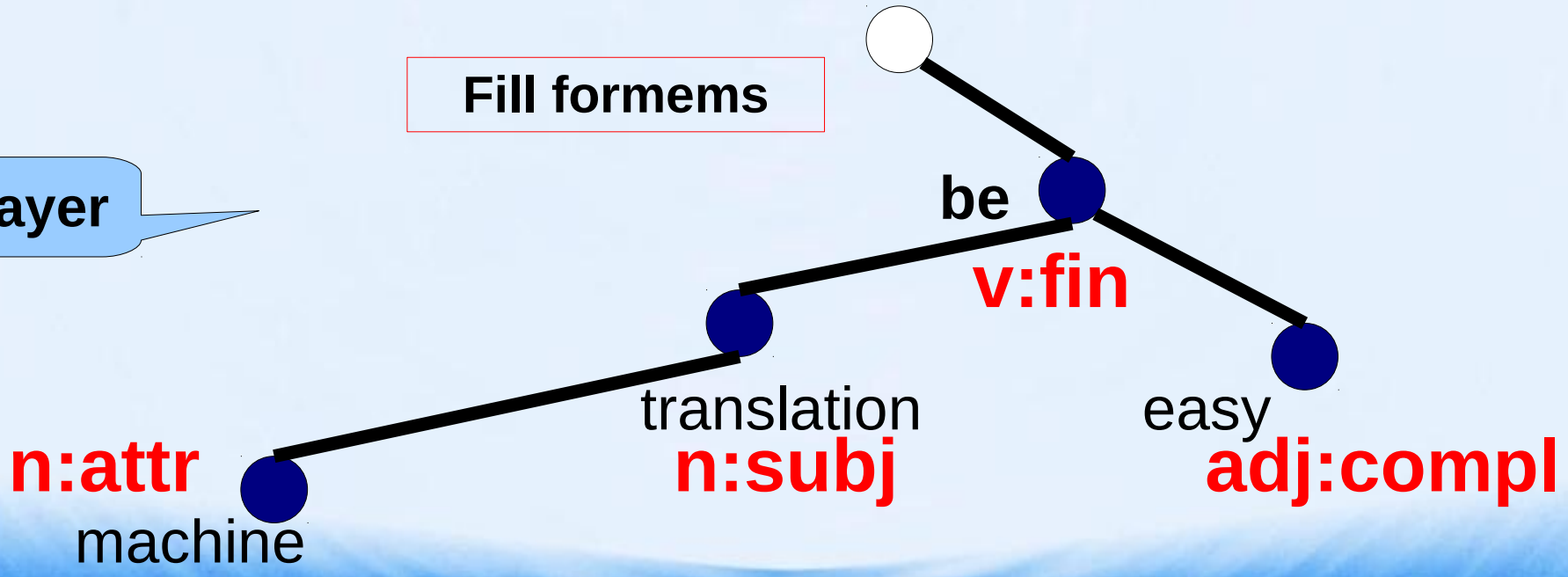
Machine translation should be easy.

m-layer

machine	translation	should	be	easy	.
NN	**NN**	**MD**	**VB**	**JJ**	**.**

t-layer

Fill formems



Demo Translation – Analysis

TectoMT

raw text

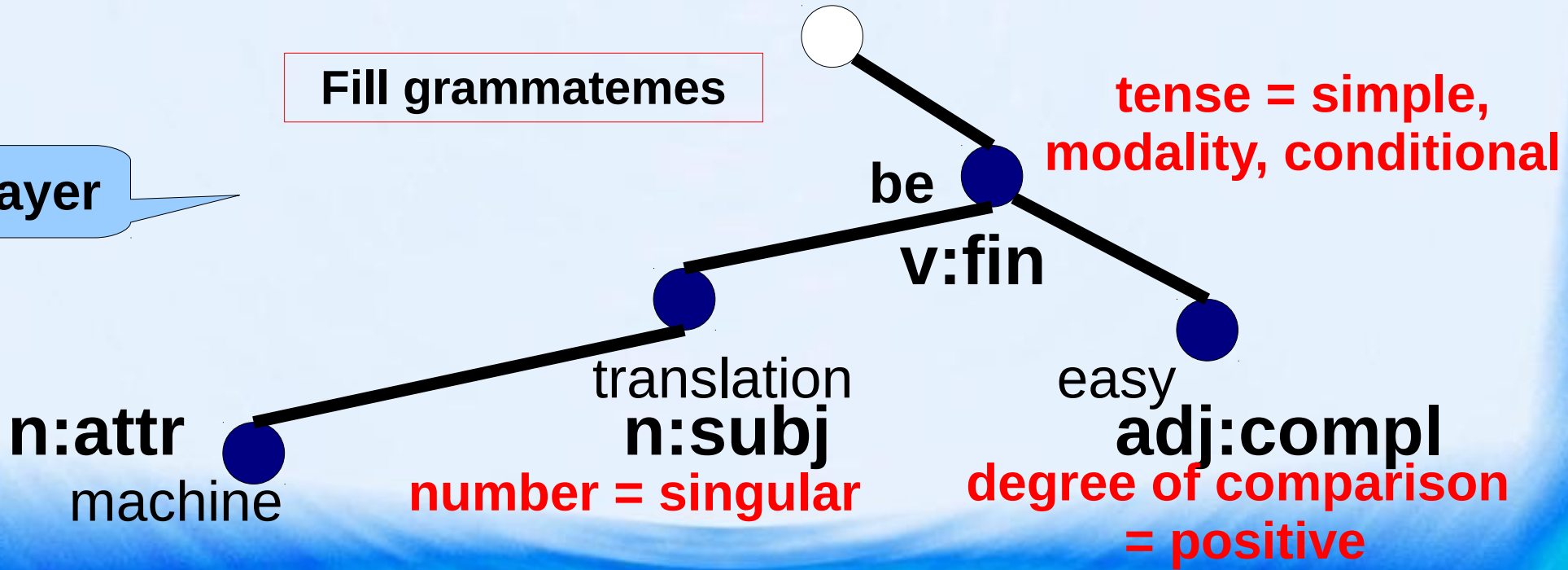
Machine translation should be easy.

m-layer

machine	translation	should	be	easy	.
NN	**NN**	**MD**	**VB**	**JJ**	**.**

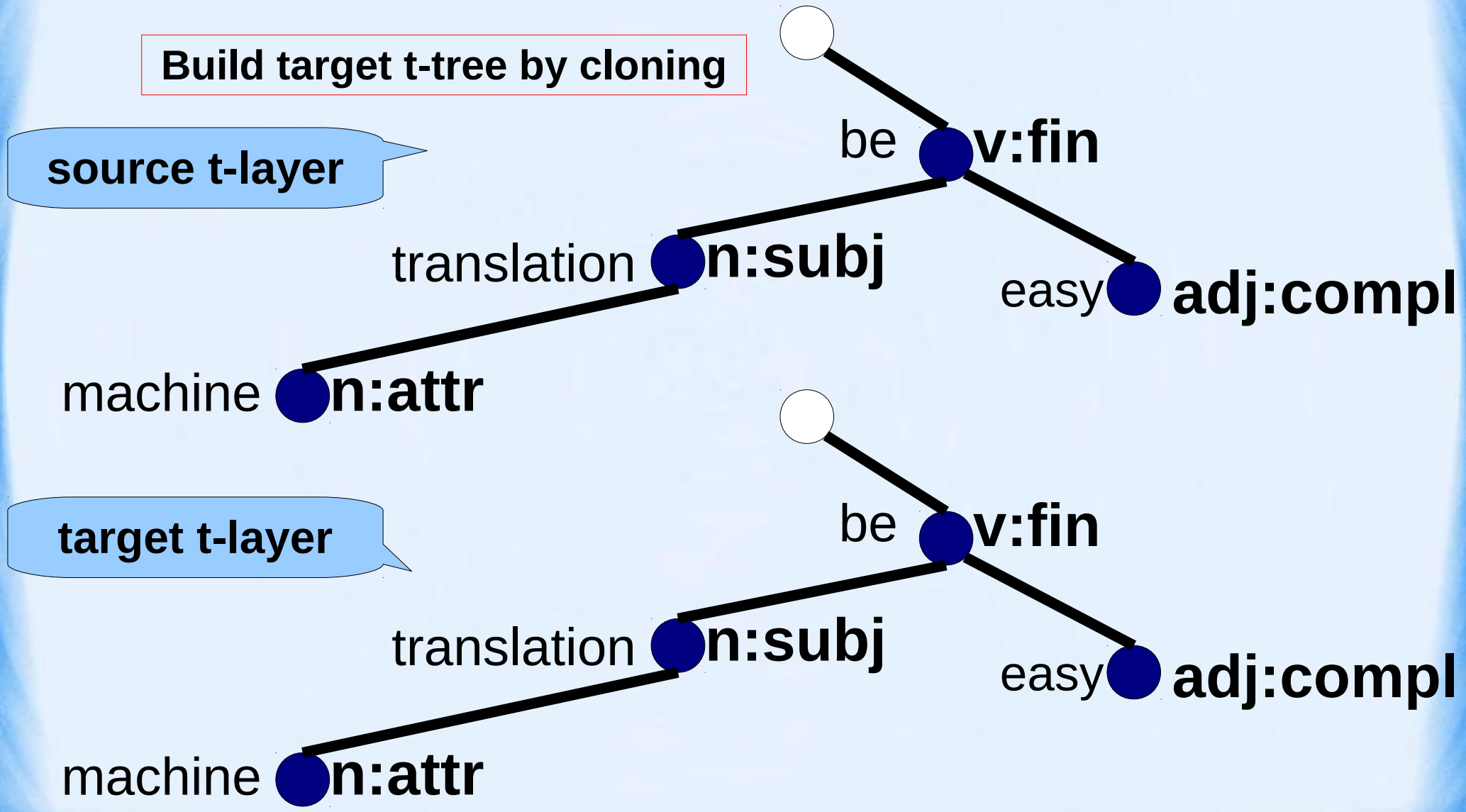
t-layer

Fill grammatemes



Demo Translation – Transfer

TectoMT

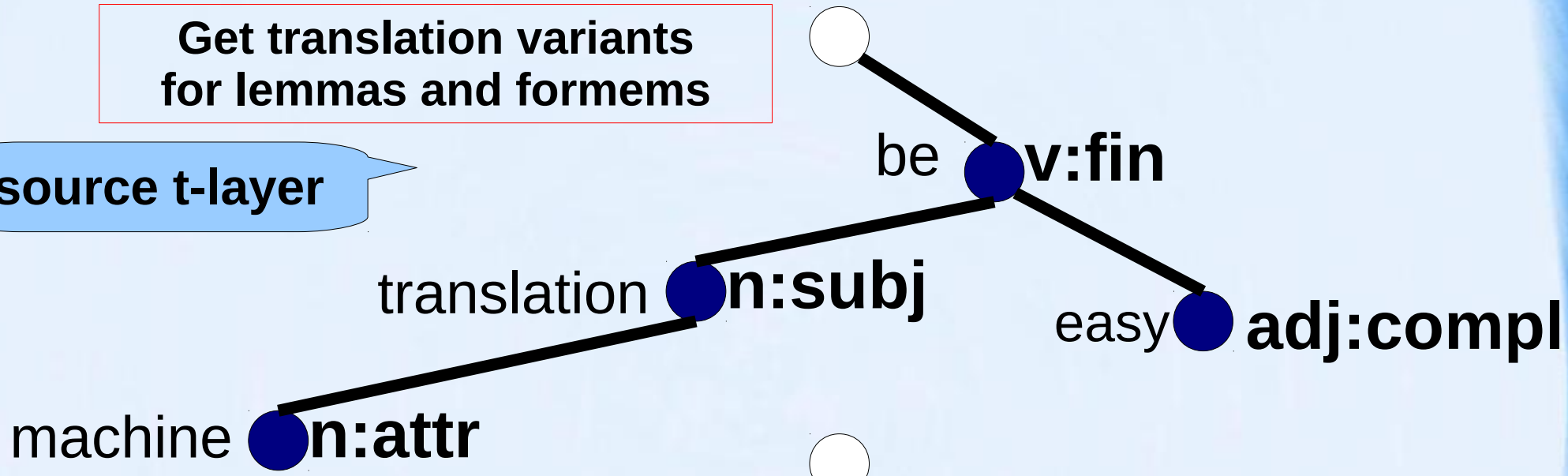


Demo Translation – Transfer

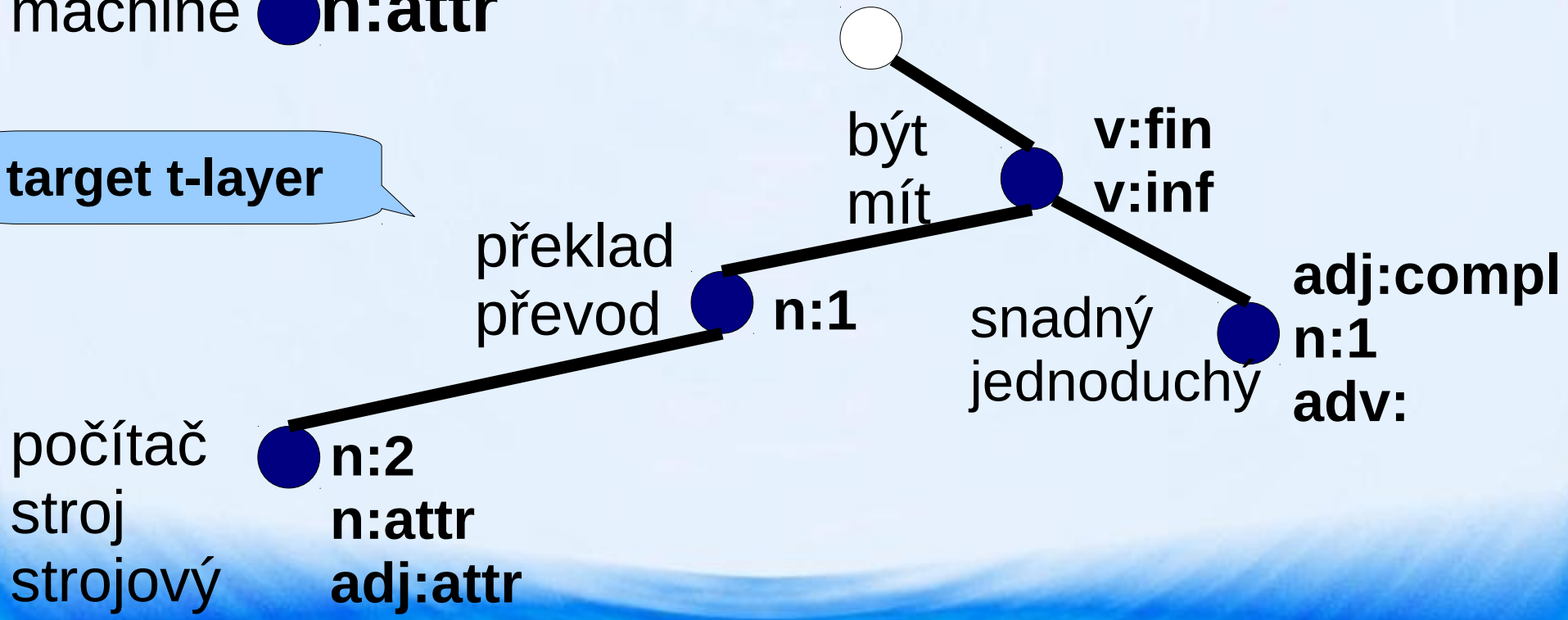
TectoMT

Get translation variants for lemmas and formems

source t-layer



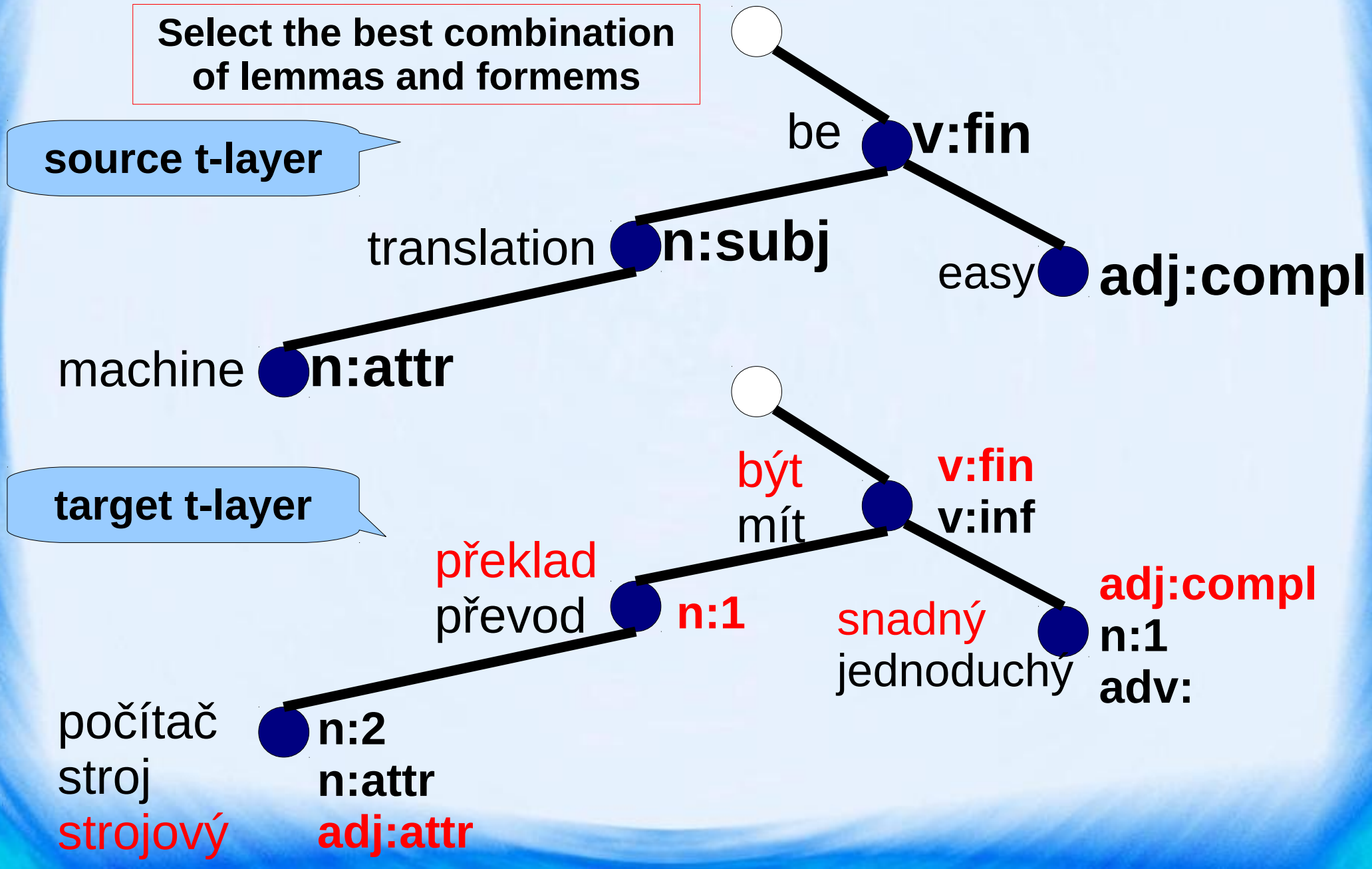
target t-layer



Demo Translation – Transfer

TectoMT

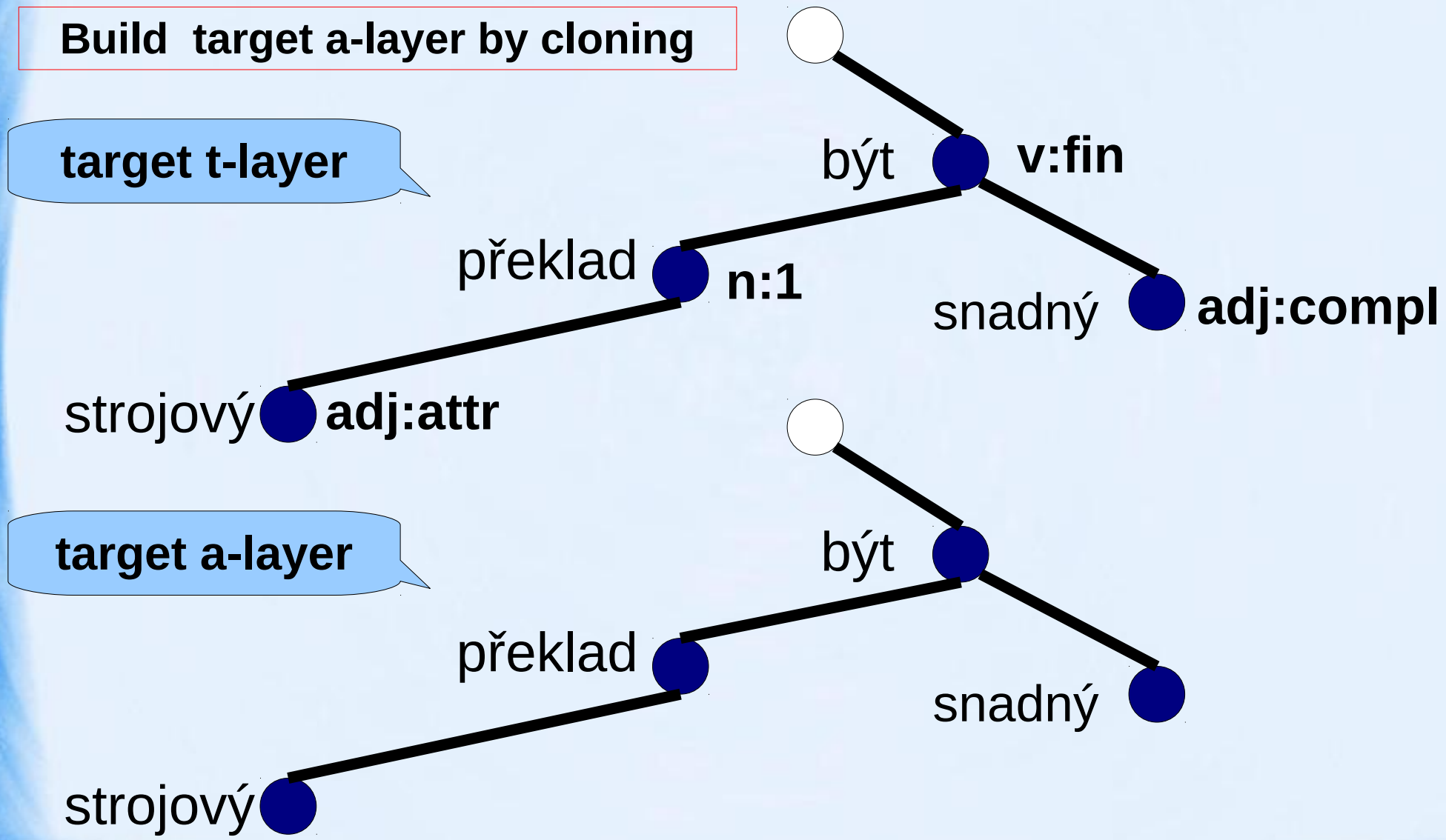
Select the best combination of lemmas and formems



Demo Translation – Synthesis

TectoMT

Build target a-layer by cloning

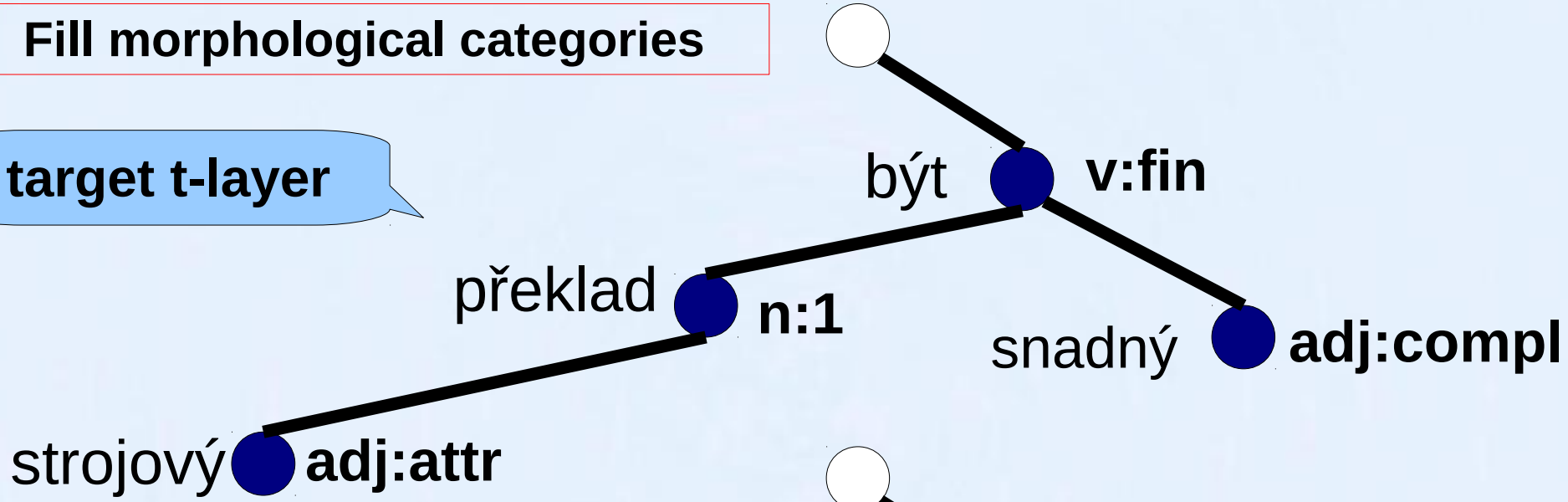


Demo Translation – Synthesis

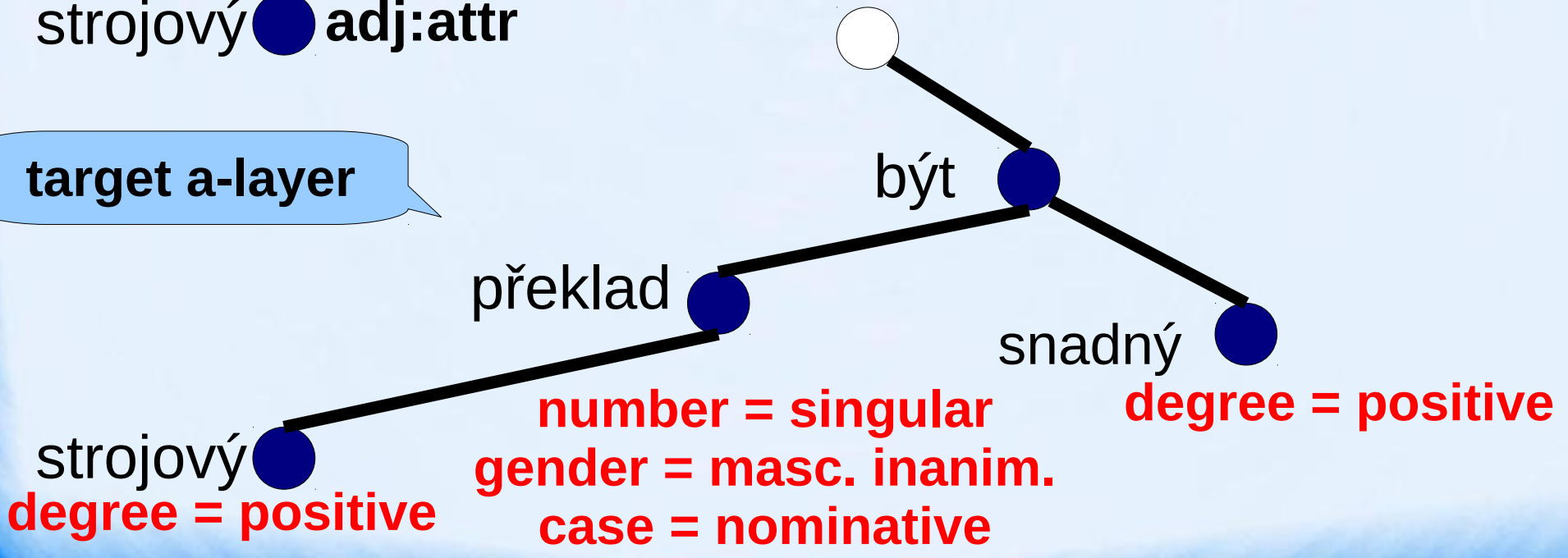
TectoMT

Fill morphological categories

target t-layer

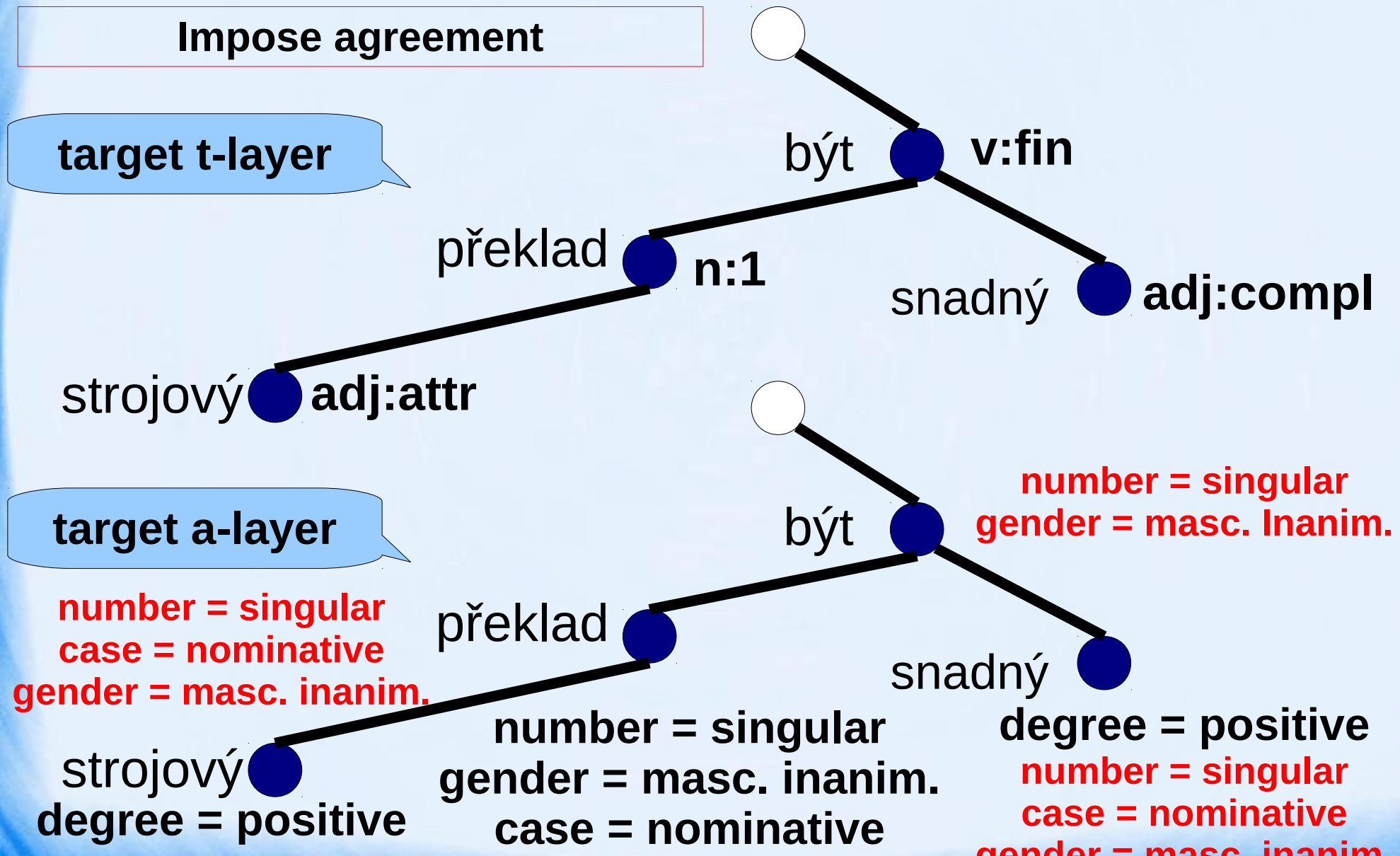


target a-layer



Demo Translation – Synthesis

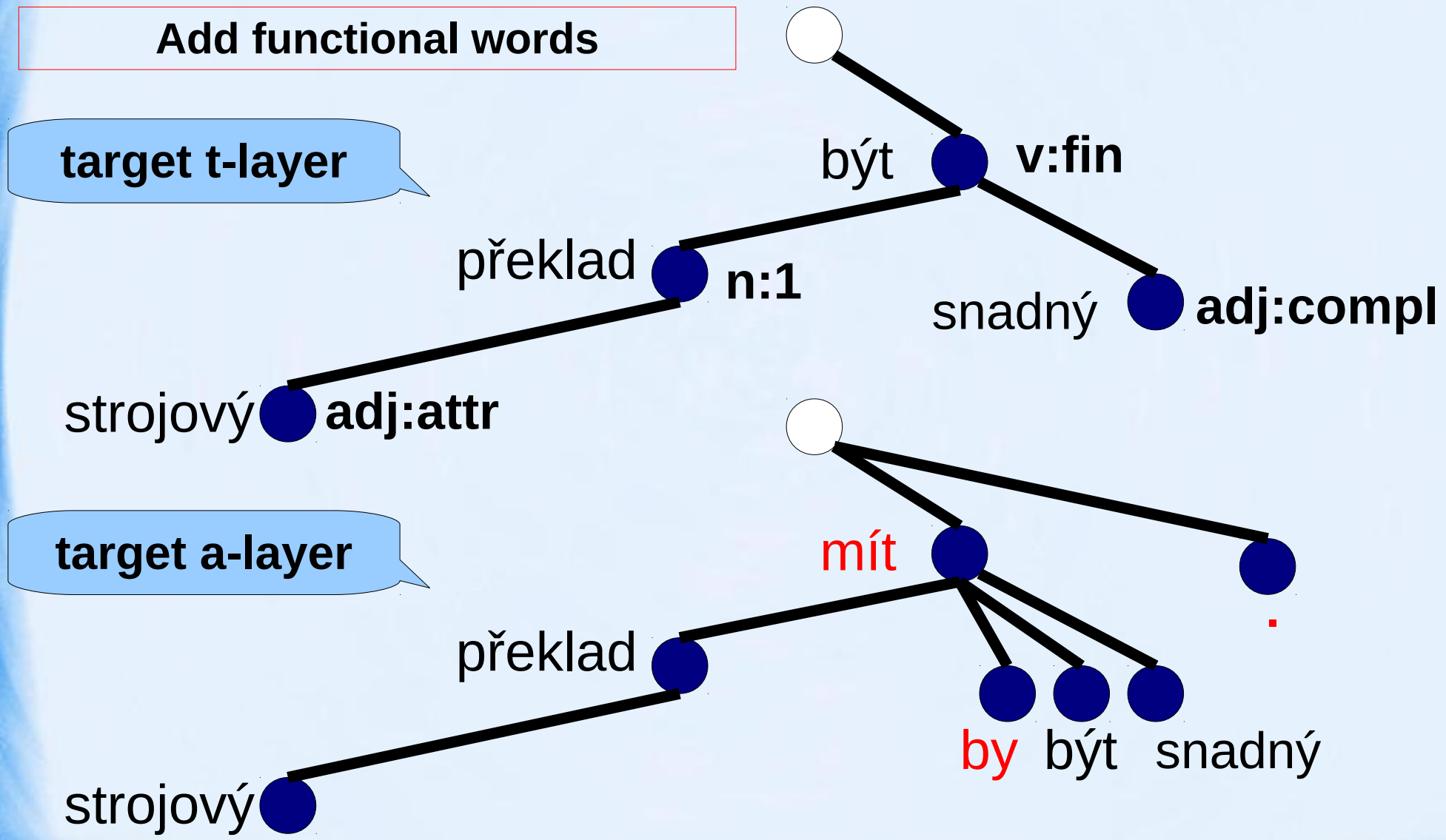
TectoMT



Demo Translation – Synthesis

TectoMT

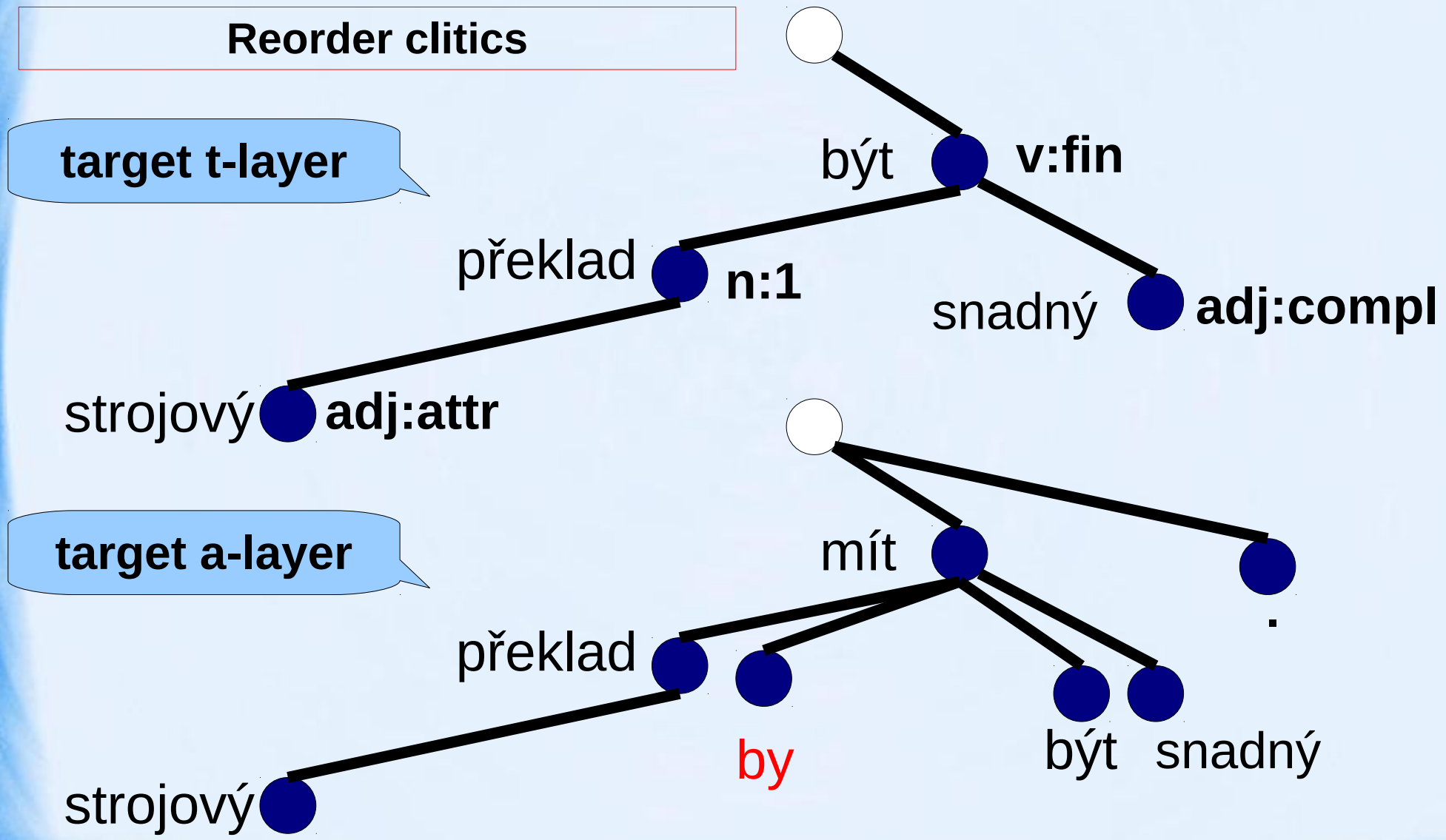
Add functional words



Demo Translation – Synthesis

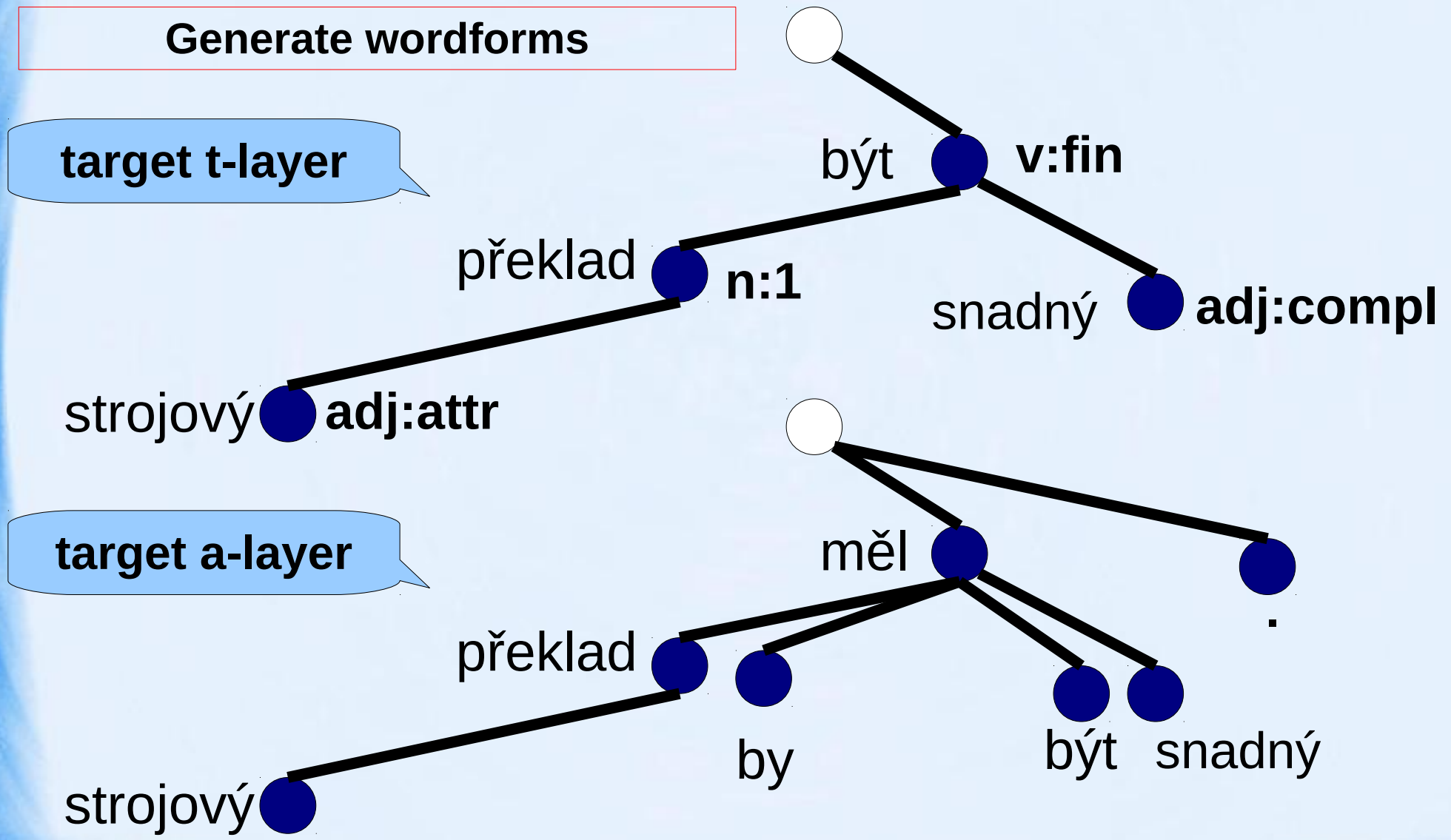
TectoMT

Reorder clitics



Demo Translation – Synthesis

TectoMT

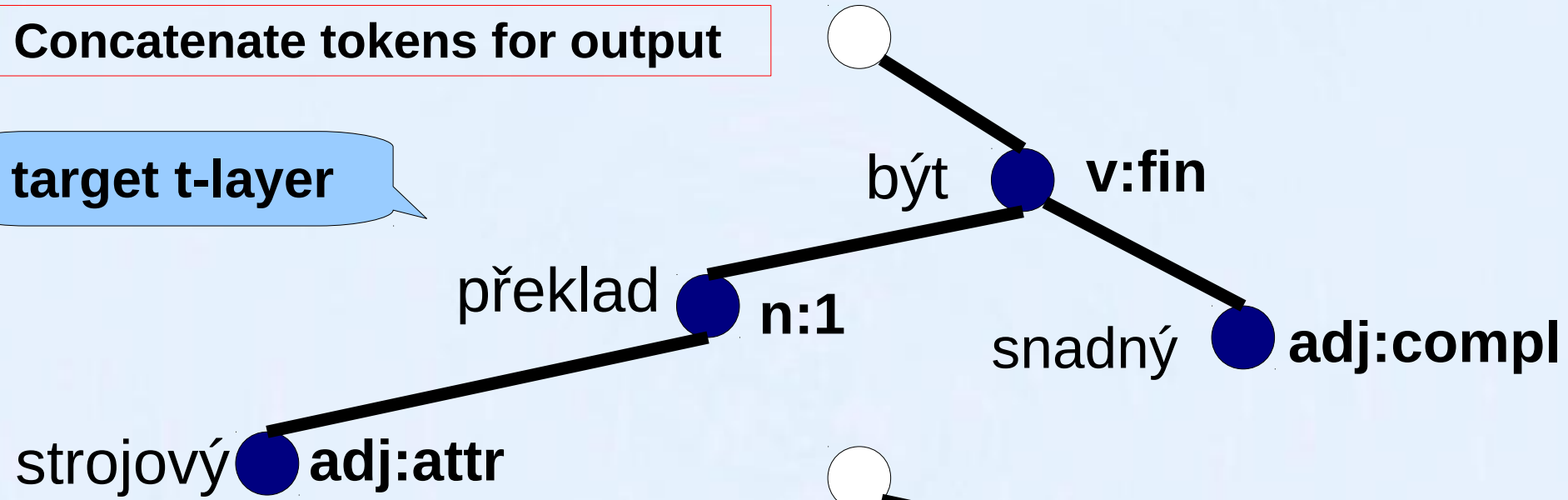


Demo Translation – Synthesis

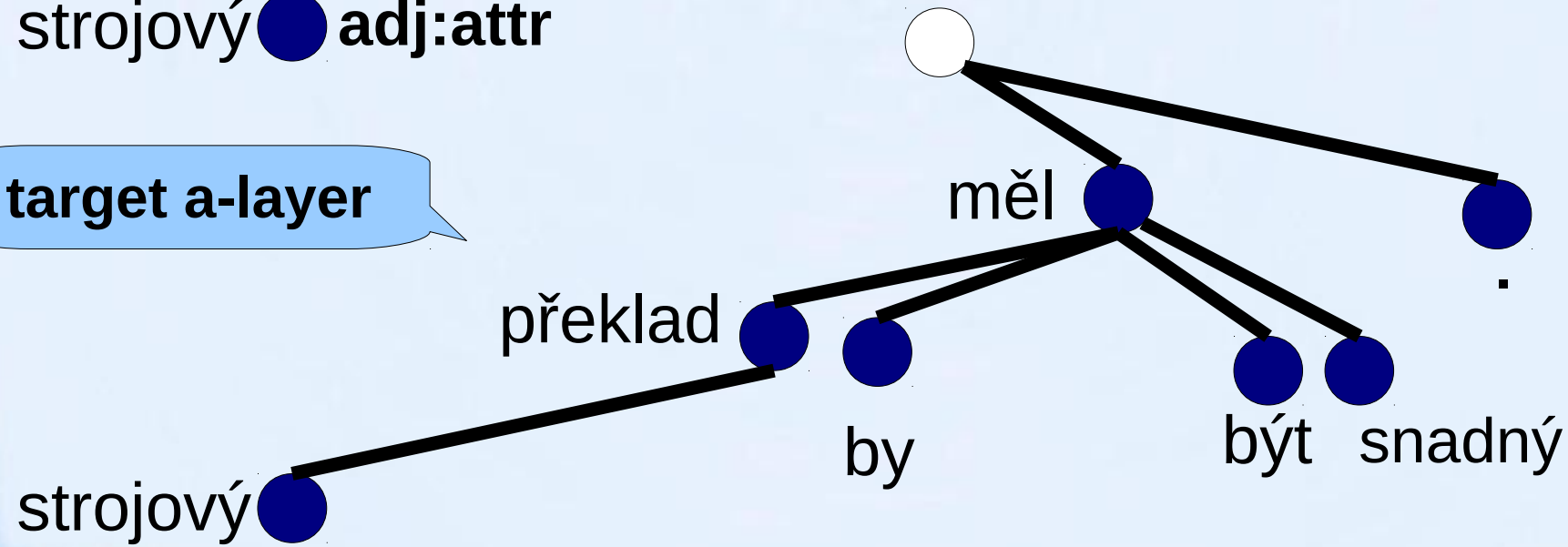
TectoMT

Concatenate tokens for output

target t-layer



target a-layer



Strojový překlad by měl být snadný.

Demo Translation – Real Scenario

TectoMT

MORPHOLOGY:
ResegmentSentences
Tokenize
NormalizeForms
FixTokenization
TagMorce
FixTags
Lemmatize

NAMED ENTITIES:
StanfordNamedEntities
DistinguishPersonalNames

A-LAYER:
MarkChunks
ParseMST
SetIsMemberFromDeprel
RehangConllToPdtStyle
FixNominalGroups
FixIsMember
FixAtree
FixMultiwordPrepAndConj
FixDicendiVerbs
SetAfunAuxCPCoord
SetAfun

T-LAYER:
MarkEdgesToCollapse
MarkEdgesToCollapseNeg
BuildTtree
SetIsMember
MoveAuxFromCoordToMembers
FixTlemmas
SetCoapFunctors
FixEitherOr
FixIsMember
MarkClauseHeads
MarkPassives
SetFunctors
MarkInfin
MarkRelClauseHeads
MarkRelClauseCoref
MarkDspRoot
MarkParentheses
SetNodetype
SetGrammatemes
SetFormeme
RehangSharedAttr
SetVoice
FixImperatives
SetIsNameOfPerson
SetGenderOfPerson
AddCorAct
FindTextCoref

TRANSFER:
CopyTtree
TrLFPhrases
TrLFJointStatic
DeleteSuperfluousTnodes
TrFTryRules
TrFAddVariants
TrFRerank
TrLTryRules
TrLAddVariants
TrLFNumeralsByRules
TrLFilterAspect
TransformPassiveConstructions
PrunePersonalNameVariants
RemoveUnpassivizableVariants
TrLFCompounds
CutVariants
RehangToEffParents
TrLFTreeViterbi
RehangToOrigParents
CutVariants
FixTransferChoices
ReplaceVerbWithAdj
DeletePossPronBeforeVlastni
TrLFemaleSurnames
AddNounGender
MarkNewRelClauses
AddRelpronBelowRc
ChangeCorToPersPron
AddPersPronBelowVfin
AddVerbAspect
FixDateTime
FixGrammatemesAfterTransfer
FixNegation
MoveAdjsBeforeNouns
MoveGenitivesRight
MoveRelClauseRight
MoveDicendiCloserToDsp
MovePersPronNextToVerb
MoveEnoughBeforeAdj
MoveJesteBeforeVerb
FixMoney
OverridePpWithPhraseTr
FindGramCorefForReflPron
NeutPersPronGenderFromAntec
ValencyRelatedRules
SetClauseNumber
TurnTextCorefToGramCoref

SYNTHESIS TO A-LAYER:
CopyTtree
DistinguishHomonymous.
ReverseNumberNounDep.
InitMorphcat
FixPossessiveAdjs
MarkSubject
ImposePronZAgr
ImposeRelPronAgr
ImposeSubjpredAgr
ImposeAttrAgr
ImposeComplAgr
DropSubjPersProns
AddPrepos
AddSubconjs
AddReflexParticles
AddAuxVerbCompoundPassive
AddAuxVerbModal
AddAuxVerbCompoundFuture
AddAuxVerbConditional
AddAuxVerbCompoundPast
AddClausalExpletivePronouns
ResolveVerbs
ProjectClauseNumber
AddParentheses
AddSentFinalPunct
AddSubordClausePunct
AddCoordPunct
AddAppositionPunct
ChooseMlemmaForPersPron
GenerateWordforms
MoveCliticsToWackernagel
DeleteSuperfluousPrepos
DeleteEmptyNouns
VocalizePrepos
CapitalizeSentStart
CapitalizeNamedEntities.
FillTagFromMorphcat

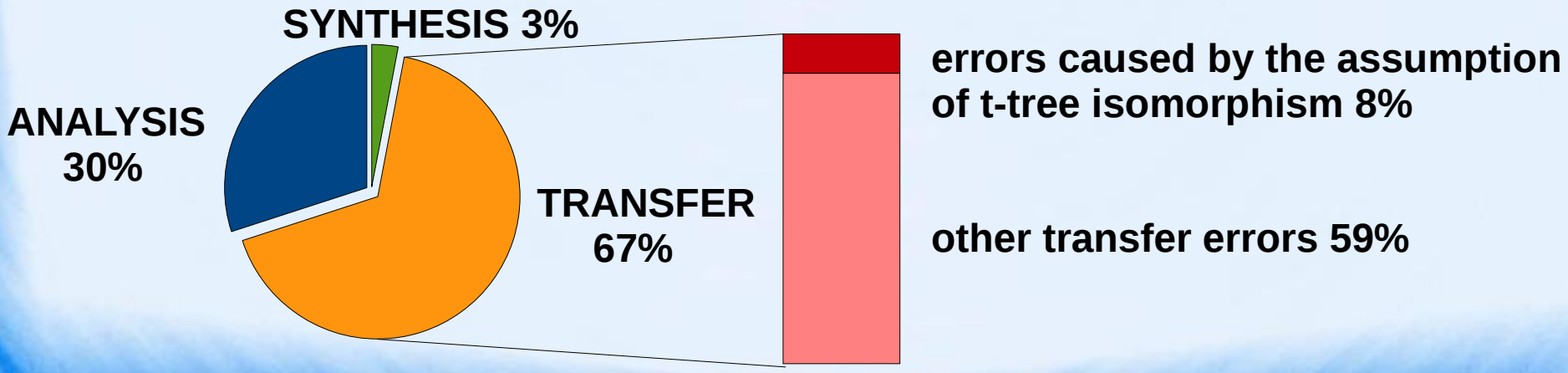
SYNTHESIS TO TEXT:
ConcatenateTokens
ApplySubstitutions
DetokenizeUsingRules
RemoveRepeatedTokens
NormalizePunctuationForWMT

Annotation of Translation Errors

TectoMT

sample of 250 sentences, 1463 errors in total

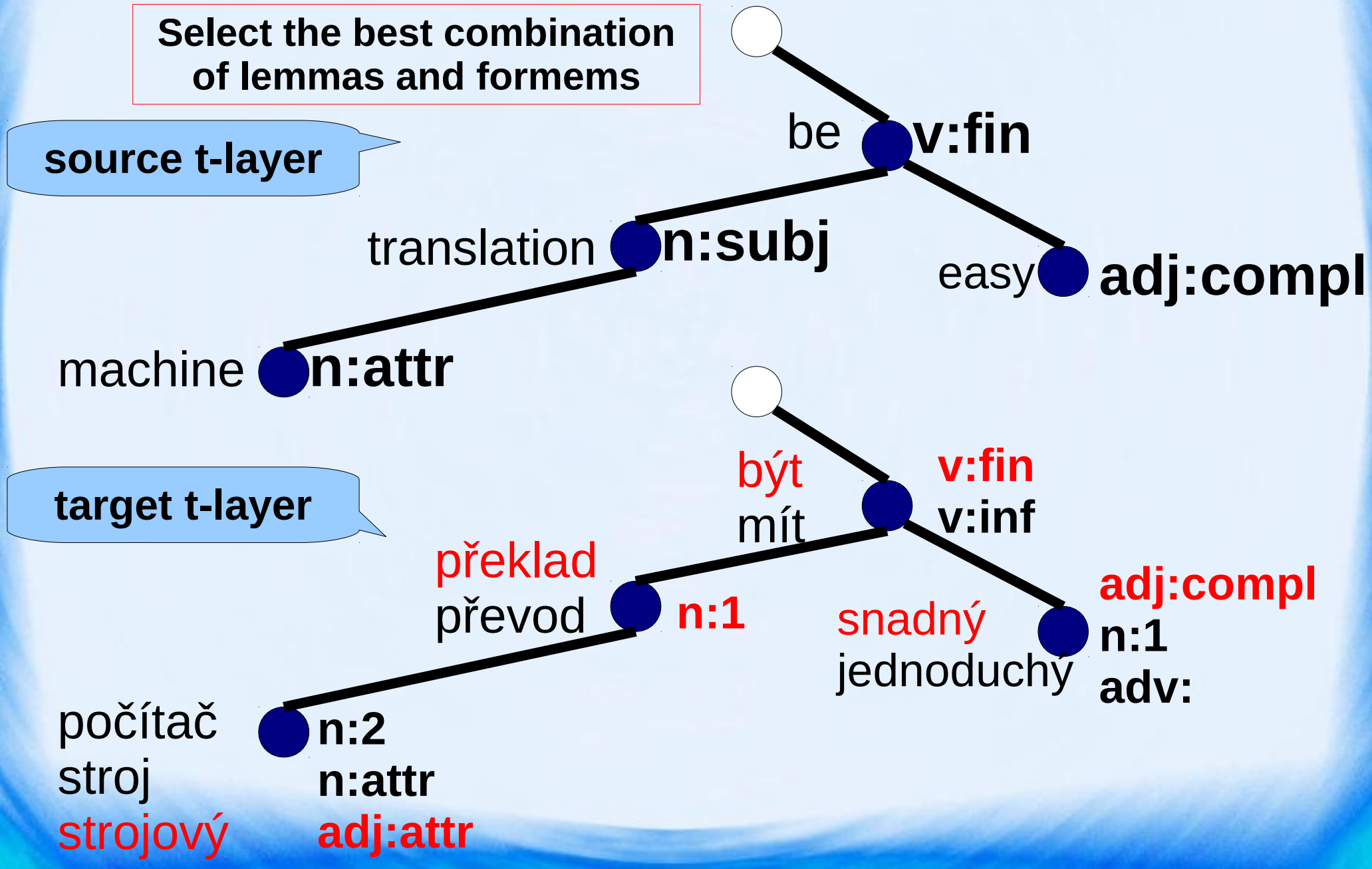
Type	lemma, formeme, gram., w. order,...
Subtype	gram: gender, person, tense,...
Seriousness	serious, minor
Circumstances	coordination, named entity, numbers
Source	tok, lem, tagger, parser, tecto, trans, x, syn, ?



HMTM – Motivation

TectoMT

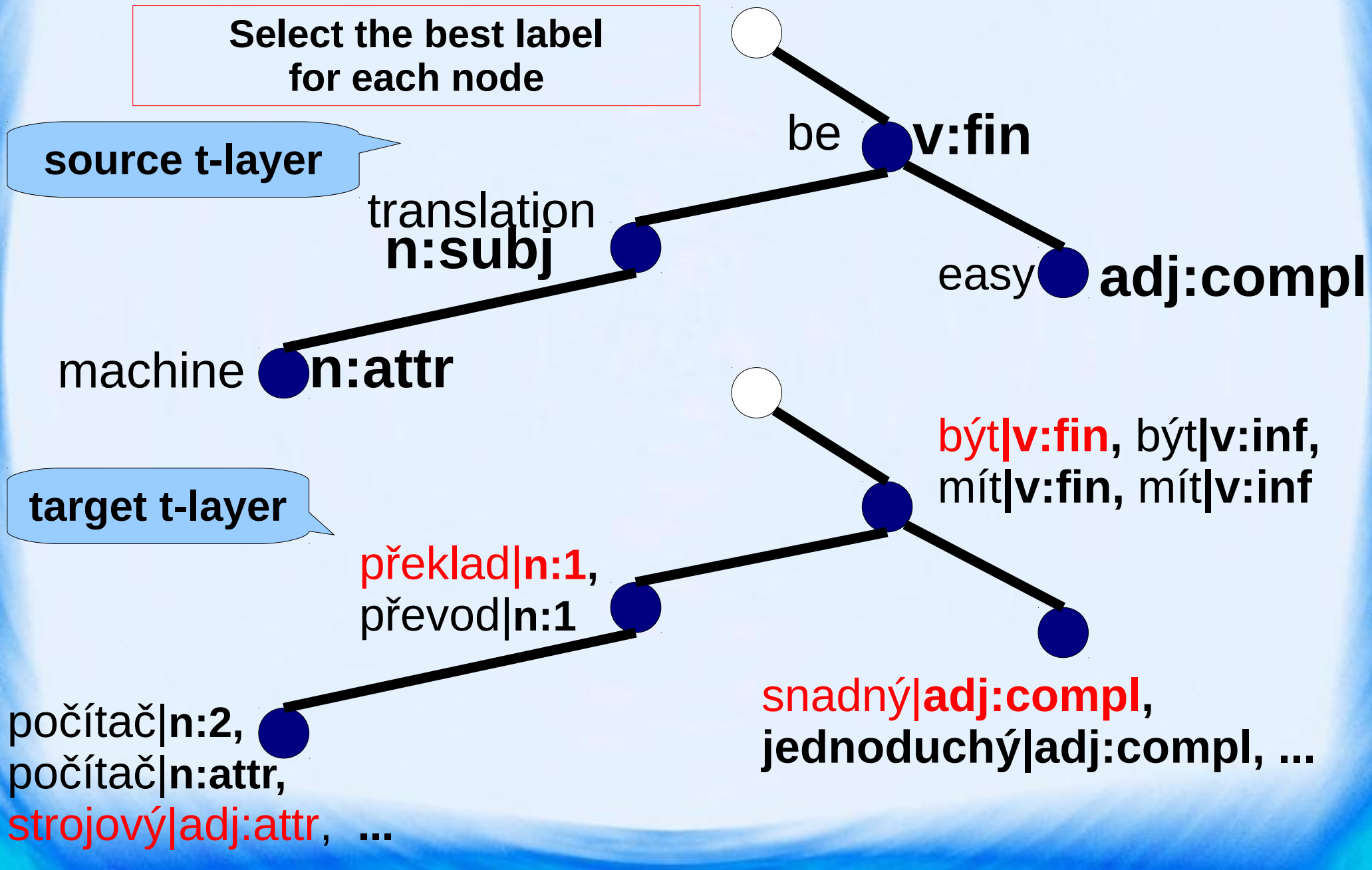
Select the best combination of lemmas and formems



HMTM – Motivation

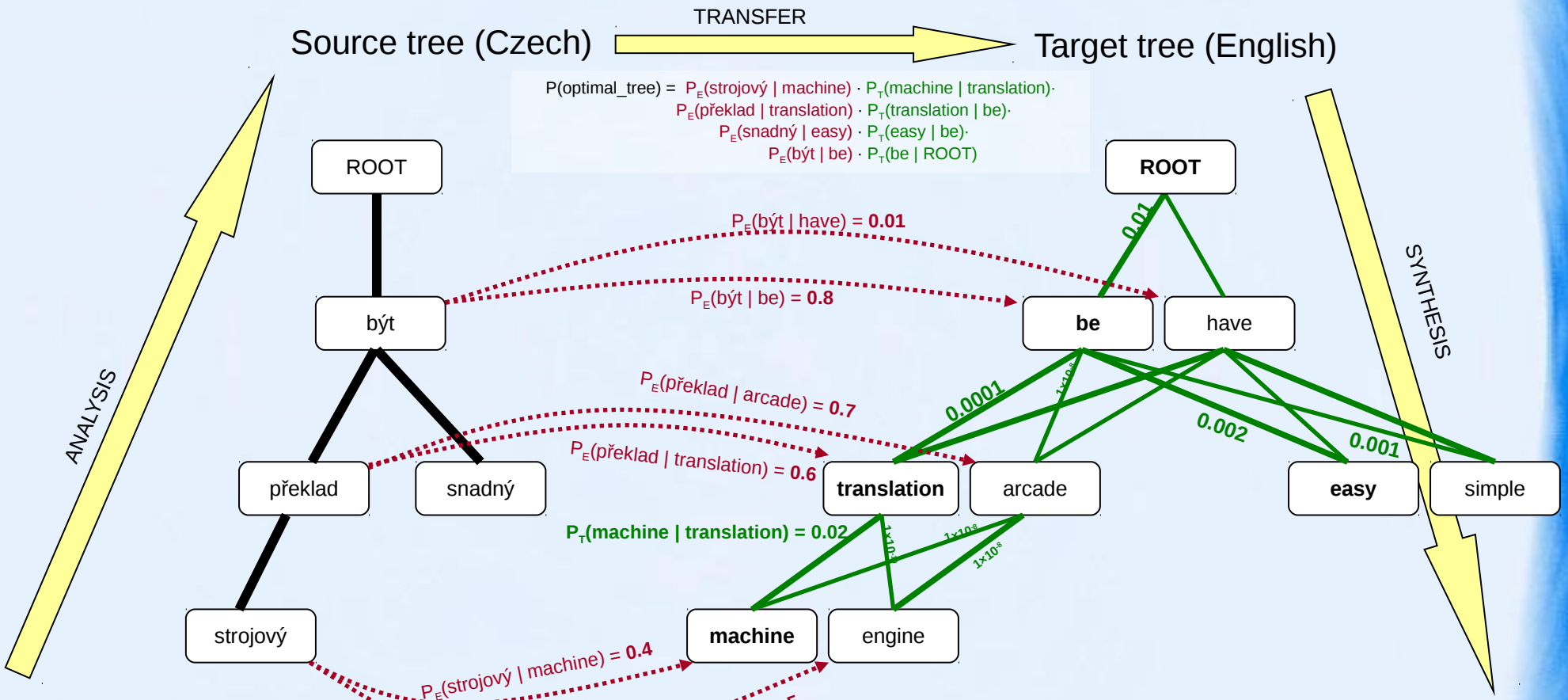
TectoMT

Select the best label for each node



HMTM in MT

TectoMT



Source sentence:
Strojový překlad by měl být snadný.

Target sentence:
Machine translation should be easy.

P_E(source | target) … emission probabilities … **translation model**

P_T(dependent | governing) … transition probabilities … **target-language tree model**

Combining Dictionaries

TectoMT

- new general interface (for lemmas and formems)

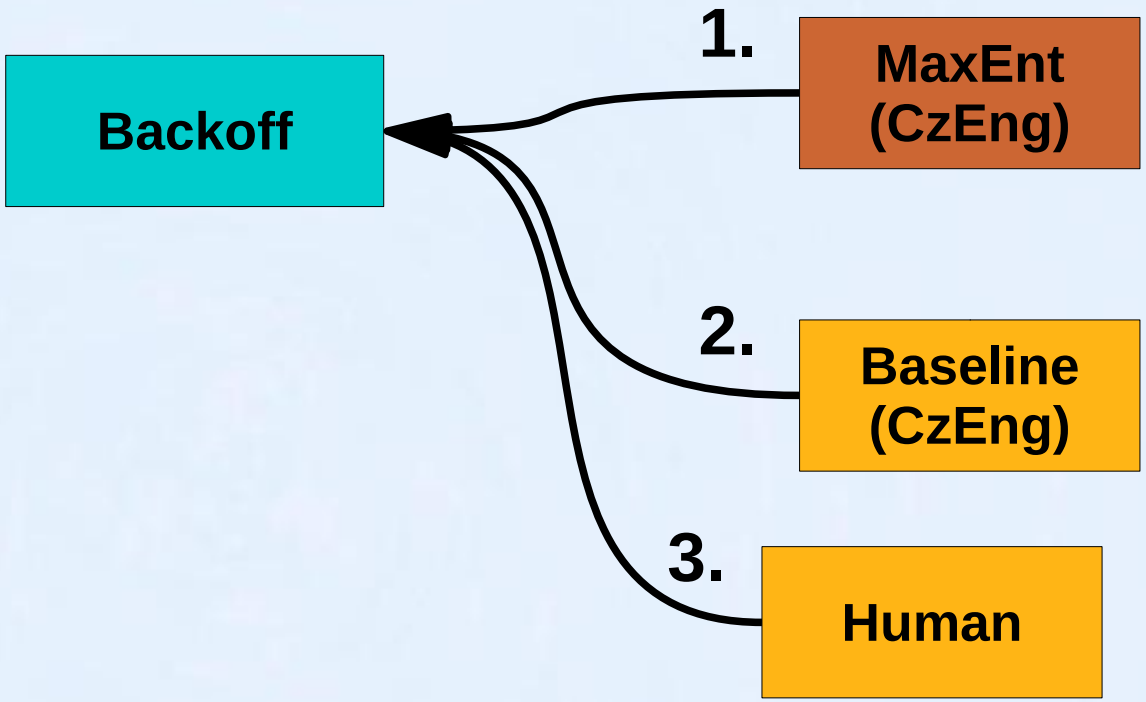
  `$dict->get_translations($input_label, $features)`

  returns a list of translation variants including probabilities
- OOP style, dictionary constructor can take another dictionary (or more) as a parameter → hierachy
- Four basic types of dictionaries:

Static plain	loaded from a file „lemma → lemma“
Context	loaded from a file „lemma,features → lemma“
Derivational	translations derived dynamicaly, input dictionary
Combinaional	combination of more input dictionaries

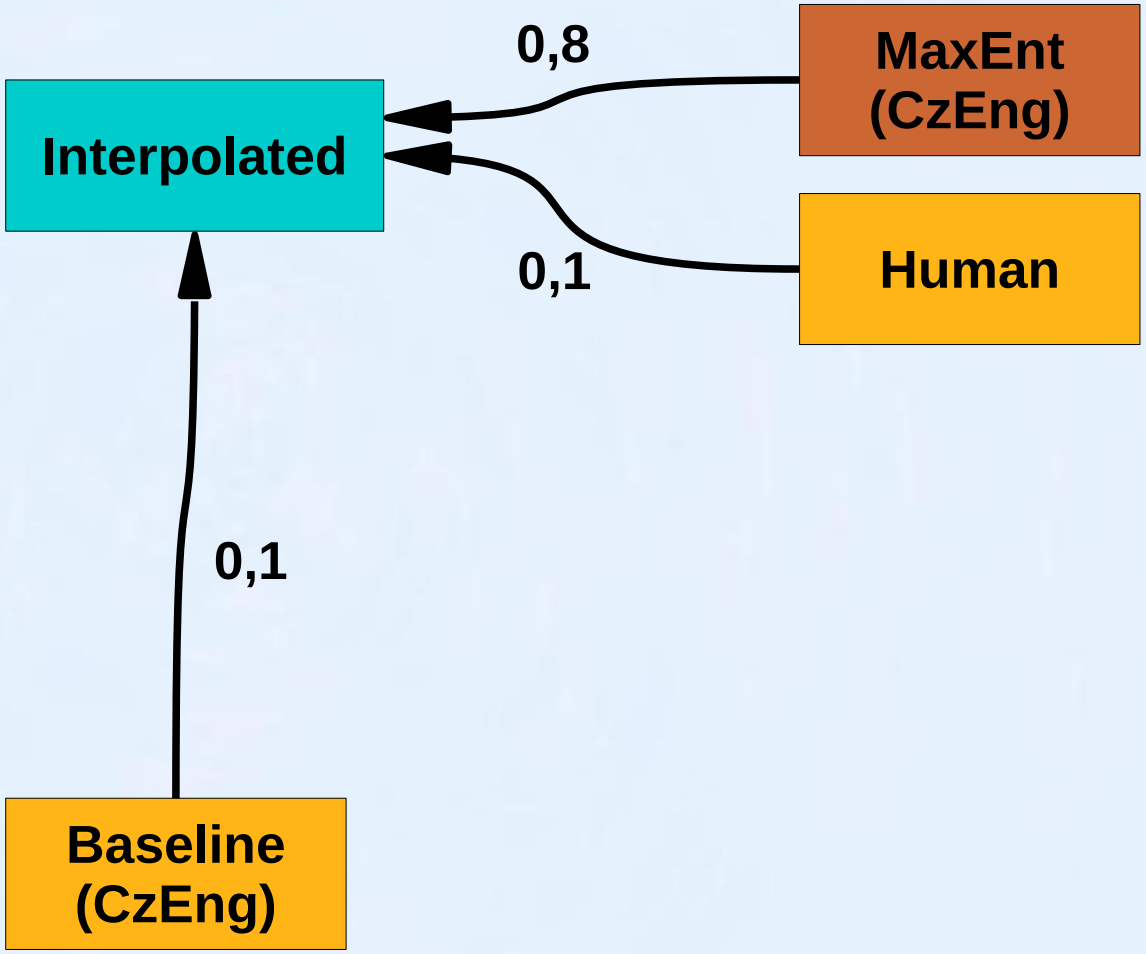
Hierarchy of lemma dictionaries

TectoMT



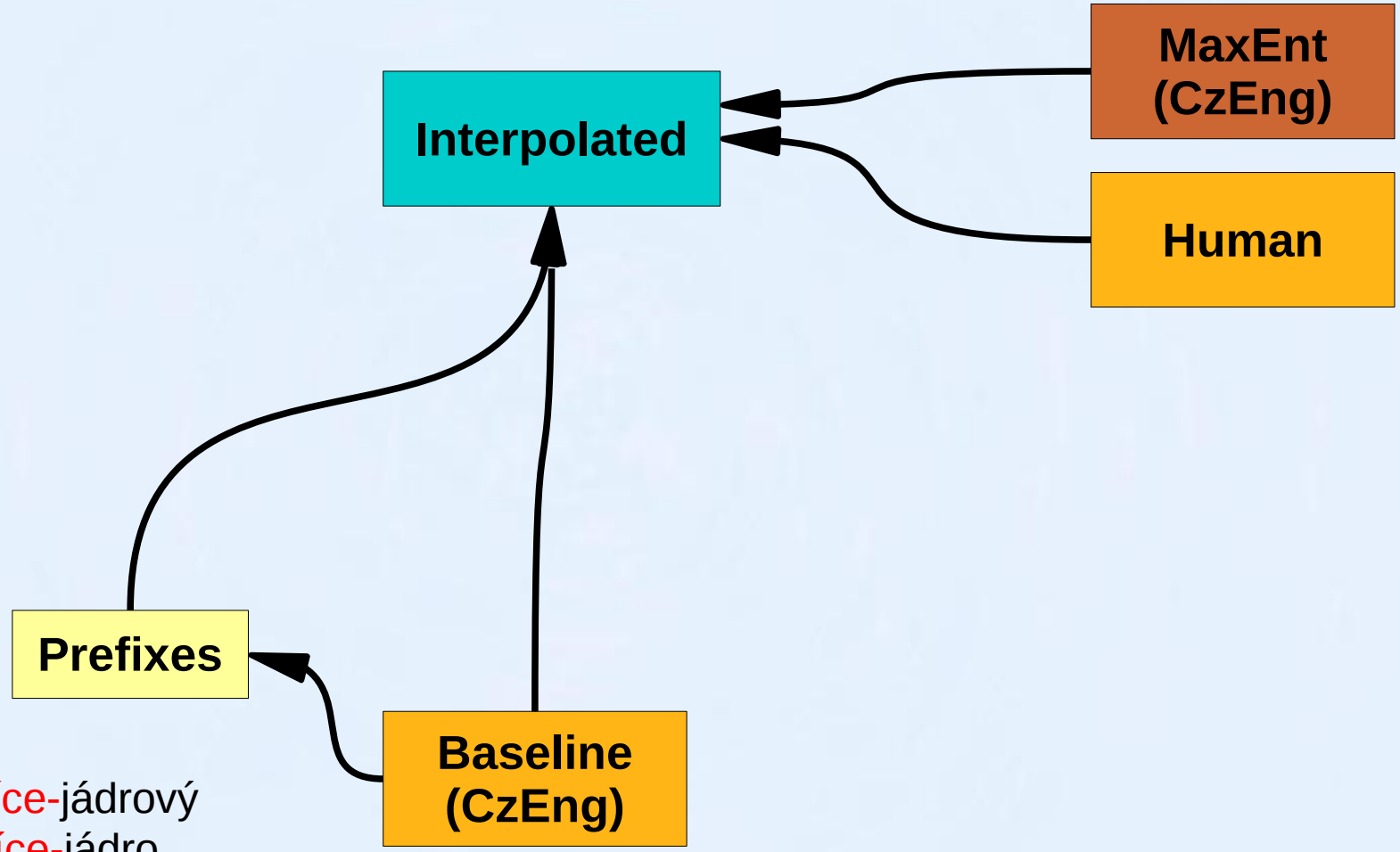
Hierarchy of lemma dictionaries

TectoMT



Hierarchy of lemma dictionaries

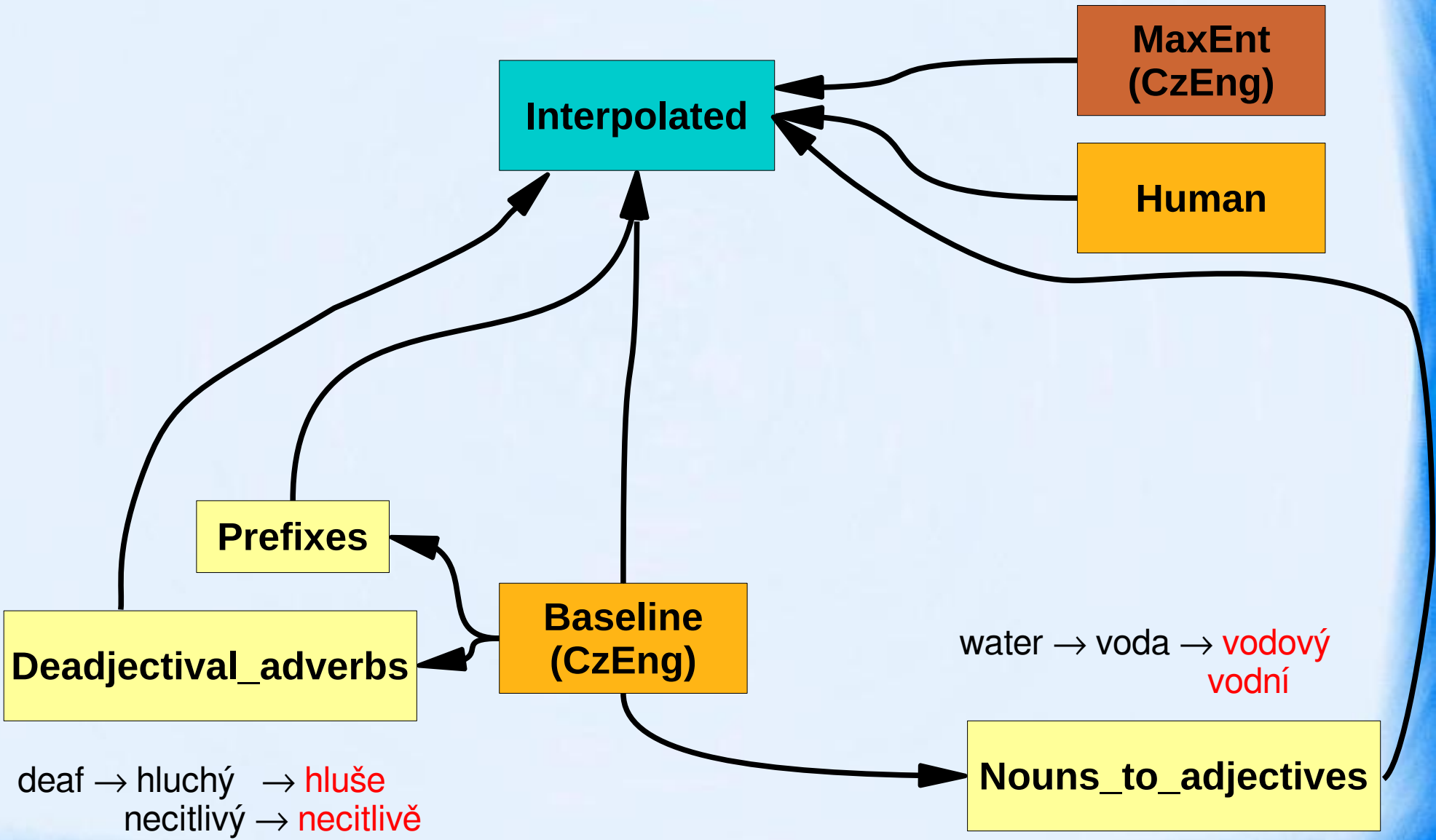
TectoMT



multi-core → více-jádrový
více-jádro
multi-jádrový
multi-jádro

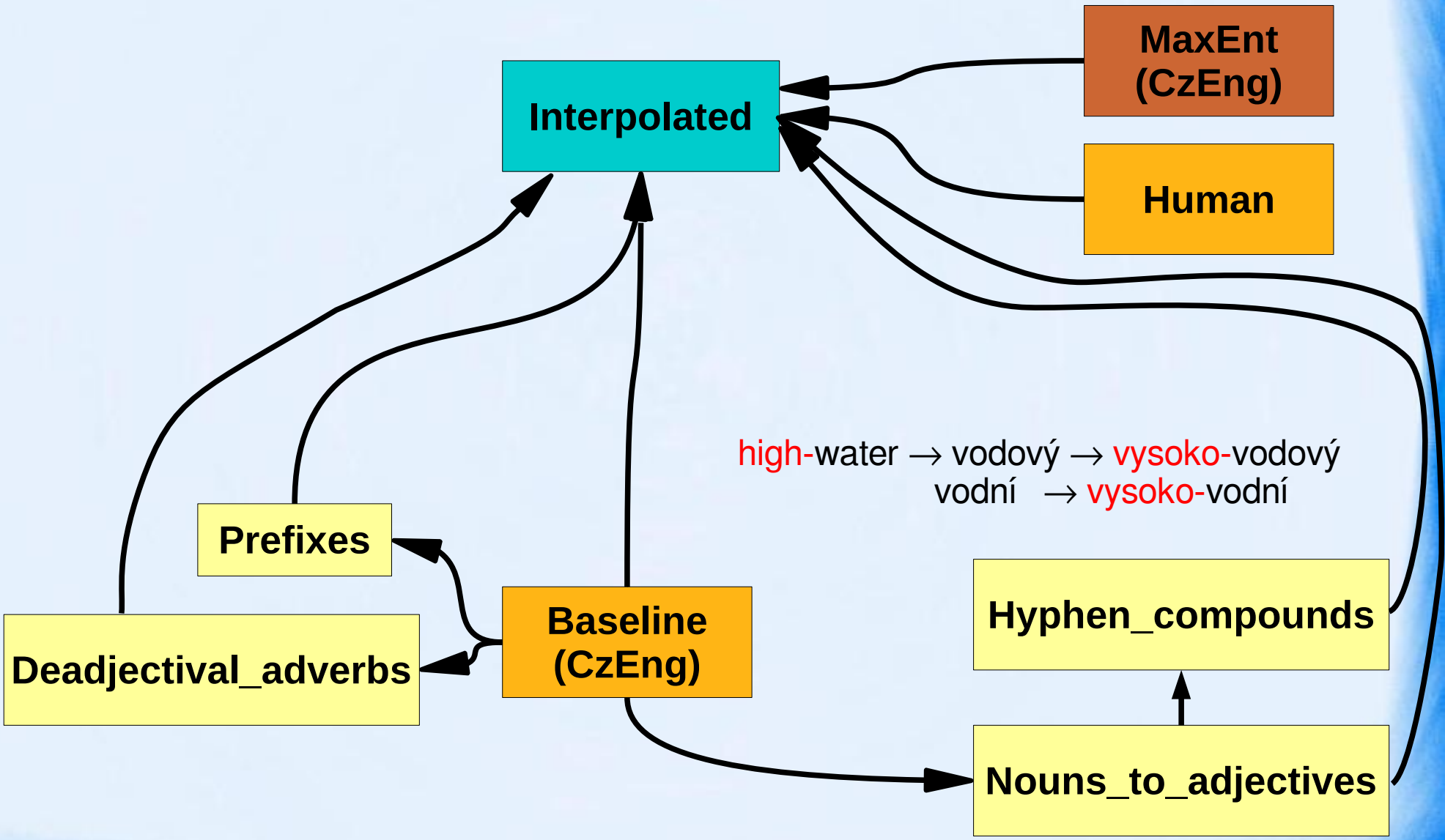
Hierarchy of lemma dictionaries

TectoMT



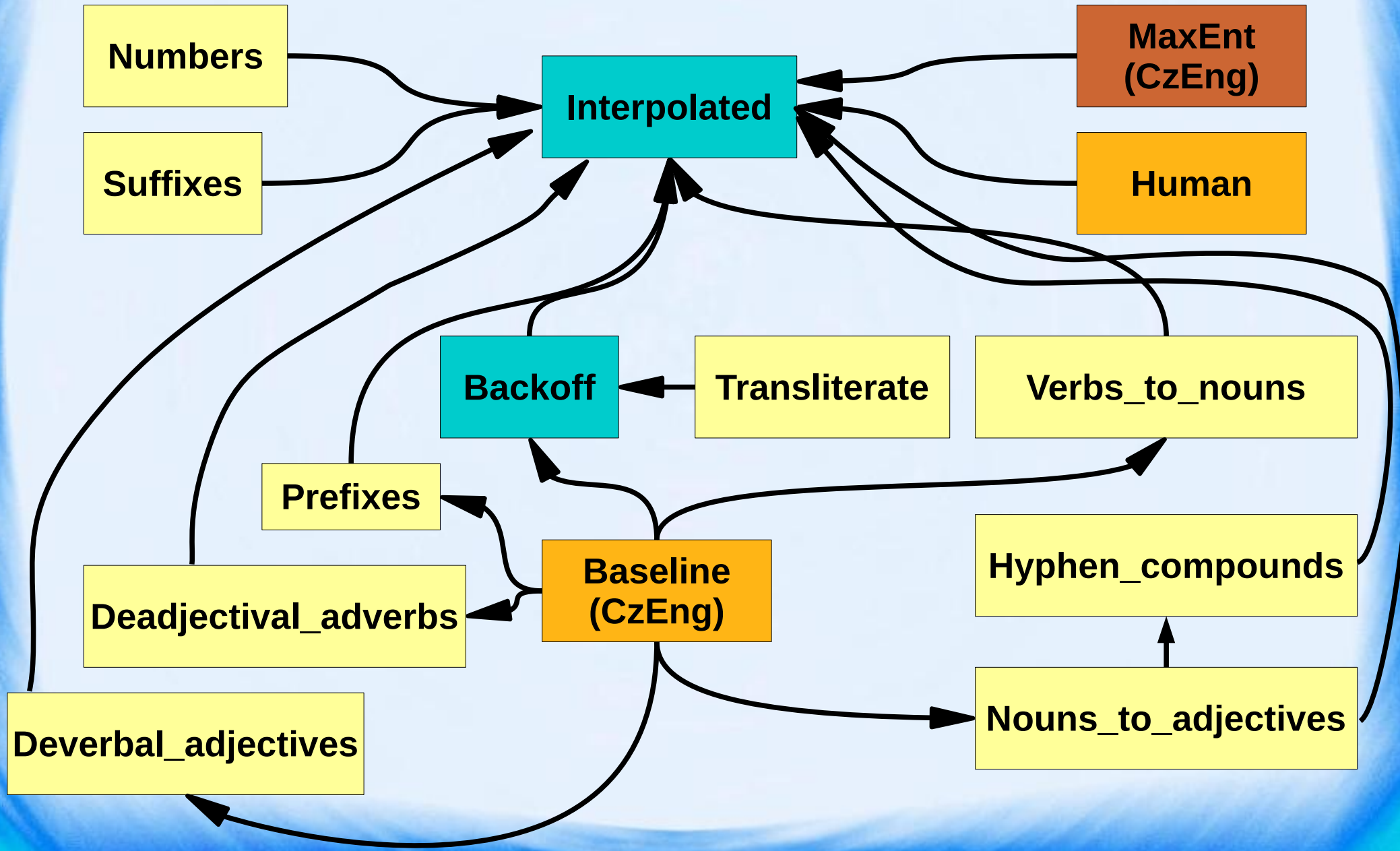
Hierarchy of lemma dictionaries

TectoMT



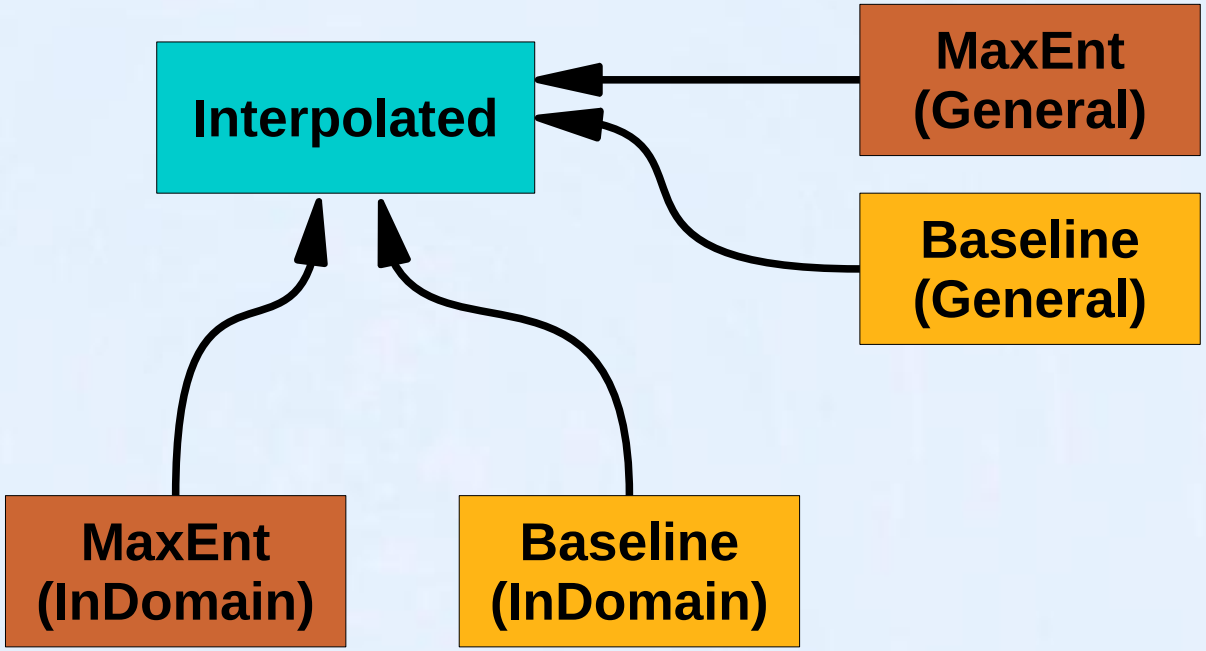
Hierarchy of lemma dictionaries

TectoMT



Domain adaptation
by TM interpolation

TectoMT




```
T2T::TrLAddVariantsInterpol   model_dir=data/models/translation/en2nl   models='
    static     0.5   20150217_tlemma.static.gz
    maxent     1.0   20150217_tlemma.maxent.gz
    static     0.5   IT/20150725_batch1a-tlemma.static.gz
    maxent     1.0   IT/20150725_batch1a-tlemma.maxent.gz'
```

Maximum Entropy Dictionary

TectoMT

Baseline Dictionary

$$p(y|x) = \frac{count(x, y)}{count(x)}$$

- Maximum likelihood estimates (from the training sections of CzEng)
- Pruned by thresholds on *p(x|y)* and *p(y|x)*
- No context used
  x = source lemma
  y = target lemma

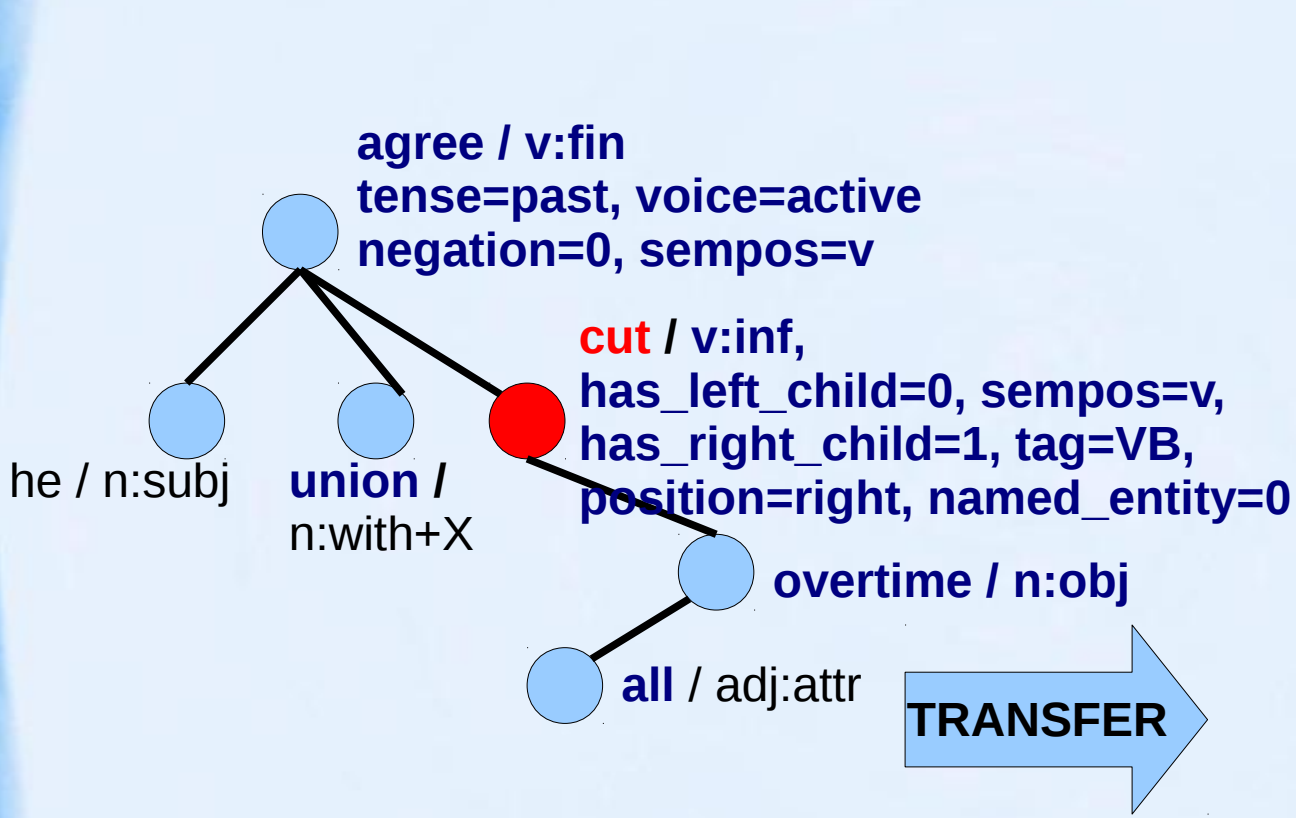
MaxEnt Dictionary

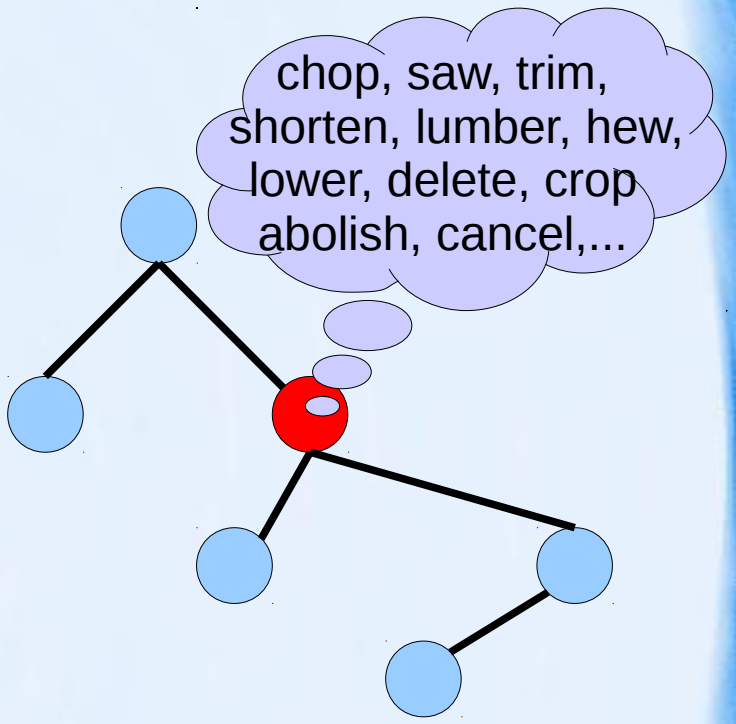
$$p(y|x) = \frac{1}{Z(x)} \exp \sum_i \lambda_i f_i(x, y)$$

- One MaxEnt model for each source lemma (same training data as for the Baseline Dict.)
- Interpolated with Baseline Dict. (due to pruning)
- Context features used (x = source context)
  - local tree context
  - local linear context
  - morphological & syntactic categories
  - ...

Maximum Entropy Dictionary

TectoMT





ANALYSIS

SYNTHESIS

He agreed with the unions to cut all overtime.

Dohodl se s odbory na zrušení všech přesčasů.

Examples of Translation (2009)

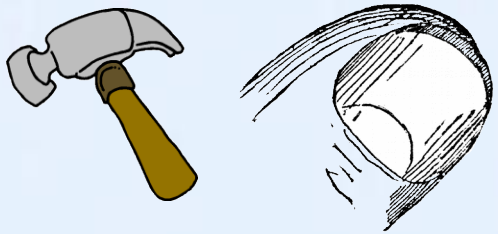
TectoMT

A miss by an inch is a miss by a mile.

Slečna palec je slečna miliónu.

I'd rather be a hammer than a nail.

Spíše bych byl kladivo než nehet.

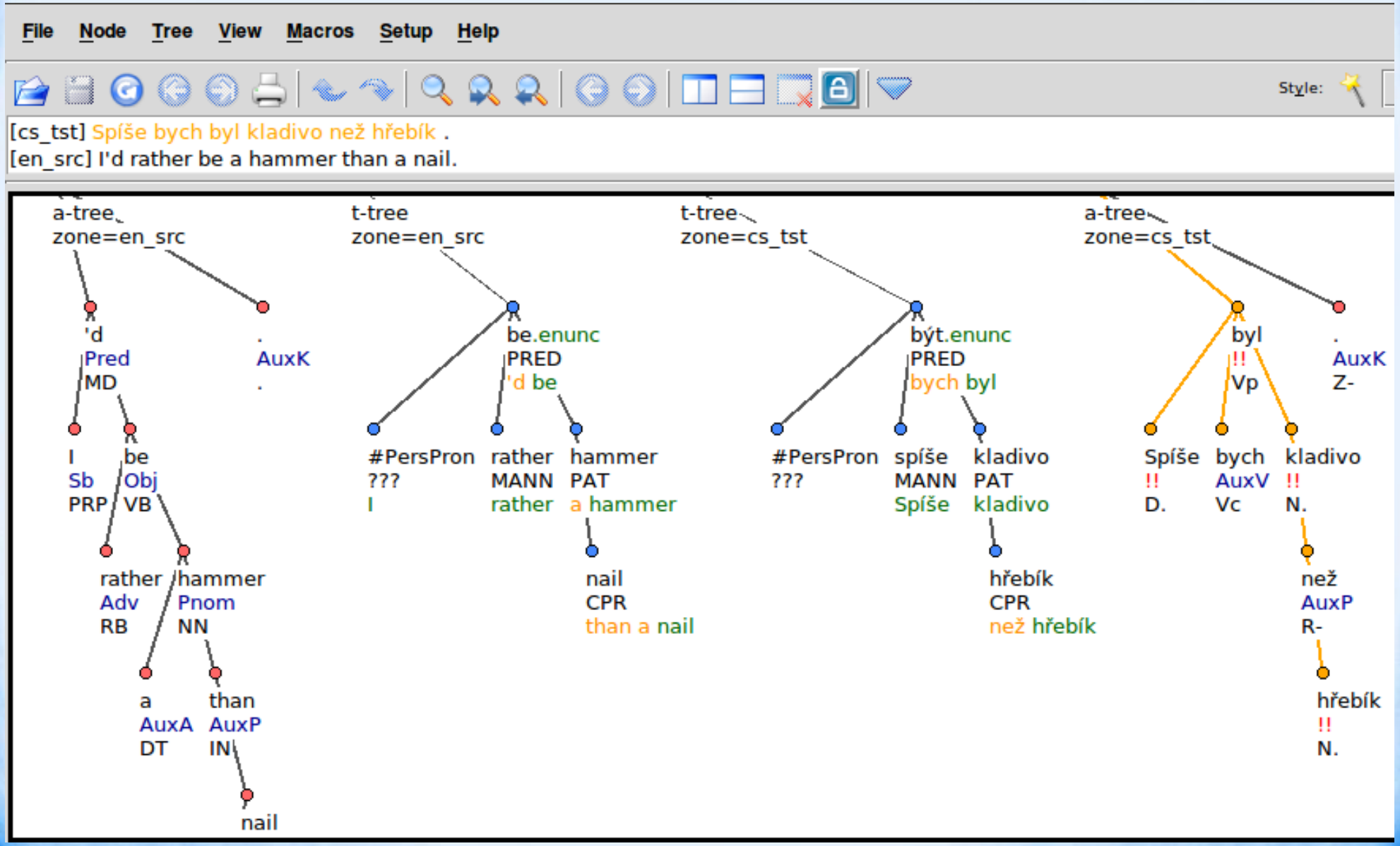


A bird in the hand is worth two in the bush.

Pták v ruce je cenný dvakrát v Bushovi.

Example of Translation (2011)

TectoMT



Sample of MaxEnt Features

input_label=nail

output_label=hřebík#N (metal nail)

child_formeme_n:in+X=1	1.64483855116042
is_member=1	1.30042900630692
child_formeme_v:fin=1	1.04422203176176
next_node_tlemma=down	0.838961007712912
is_capitalized=1	0.792130821958927
position=right	0.747785245407306
tense_g=post	0.744919903760696
voice_g=active	0.659489975893991
prev_node_tlemma=drive	0.655357850937254
parent_capitalized=1	0.622953832124697
formeme=n:from+X	0.599348506643414
prev_node_tlemma=hammer	0.592276691427986
child_tlemma_few=1	0.553464629114697
child_tlemma_remove=1	0.546698831608057
sempos=n.denot	0.504719359514573
next_node_tlemma=and	0.502529618088752
formeme_g=v:until+fin	0.491064112122981
child_tlemma_rusty=1	0.428884558837039
tag_g=VBP	0.422967377093101
next_node_tlemma=screw	0.344701934524519
...	

output_label=nehet#N (fingernail or toenail)

child_formeme_n:poss=1	1.32717038827268
child_tlemma_finger=1	1.07509772743853
child_formeme_n:of+X=1	0.982021327950337
position=left	0.886912864256063
prev_node_tlemma=black	0.770671304450658
child_tlemma_broken=1	0.761077744287099
child_formeme_v:attr=1	0.700099311992958
formeme=n:at+X	0.674547829214778
formeme_g=n:attr	0.673367412957367
child_tlemma_long=1	0.673158400394094
next_node_tlemma=file	0.600496248030202
child_tlemma_false=1	0.584236638145312
prev_node_tlemma=false	0.584236638145312
number=sg	0.563056142428995
formeme=n:obj	0.533943098032196
formeme=n:by+X	0.528852315800188
...	

Cooperation is welcome

- Exploit English a-layer or t-layer for your project (e.g. extra features/factors for Moses)
- Adapt TectoMT for a new langauge pair
- Contribute to Udapi (successor of Treex)
  - just use it, report GitHub issues etc.
  - improve the Python and Java (or Perl) implementation
  - implement new blocks or tool wrappers
  - design Deep Universal Dependencies
- Suggest a better transfer algorithm (treelets)

Thank you

TectoMT