XLE:
Grammar Development Platform
Parser/Generator/Rewrite System

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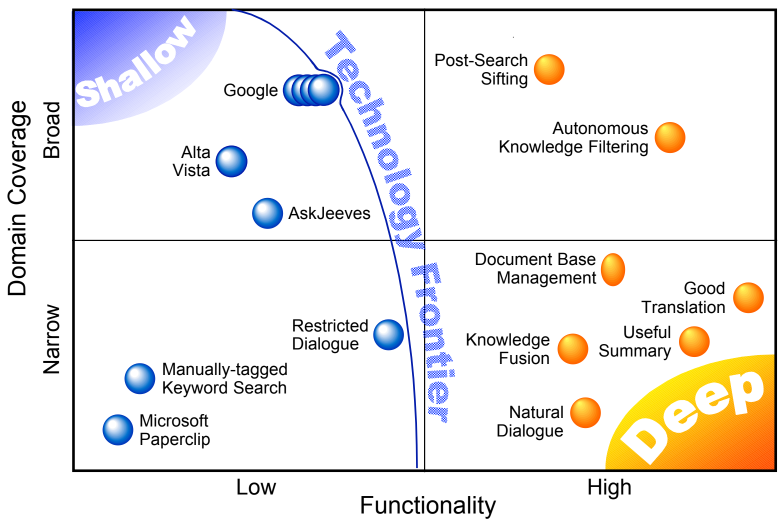
Outline

- What is a deep grammar and why would you want one?
- XLE: A First Walkthrough
- Robustness techniques
- Generation
- Disambiguation
- Applications:
  - Machine Translation
  - Sentence Condensation
  - Computer Assisted Language Learning (CALL)
  - Knowledge Representation

Applications of Language Engineering



Deep grammars

- Provide detailed syntactic/semantic analyses
  - HPSG (LinGO, Matrix), LFG (ParGram)
  - Grammatical functions, tense, number, etc.

    Mary wants to leave.

    subj(want~1,Mary~3)
    comp(want~1,leave~2)
    subj(leave~2,Mary~3)
    tense(leave~2,present)
- Usually manually constructed

Why would you want one?

- Meaning sensitive applications
  - overkill for many NLP applications
- Applications which use shallow methods for English may not be able to for "free" word order languages
  - can read many functions off of trees in English
    - » subj: NP sister to VP
    - » obj: first NP sister to V
  - need other information in German, Japanese, etc.

Deep analysis matters… if you care about the answer

Example:

A delegation led by Vice President Philips, head of the chemical division, flew to Chicago a week after the incident.

Question: Who flew to Chicago?

Candidate answers:

~~*division*~~ ~~*head*~~ ~~*V.P. Philips*~~	~~closest noun~~ ~~next closest~~ ~~next~~	shallow but wrong
delegation	furthest away but Subject of *flew*	deep and right

Why don't people use them?

- Time consuming and expensive to write
  - shallow parsers can be induced automatically from a training set
- Brittle
  - shallow parsers produce something for everything
- Ambiguous
  - shallow parsers rank the outputs
- Slow
  - shallow parsers are very fast (real time)
- Other gating items for applications that need deep grammars

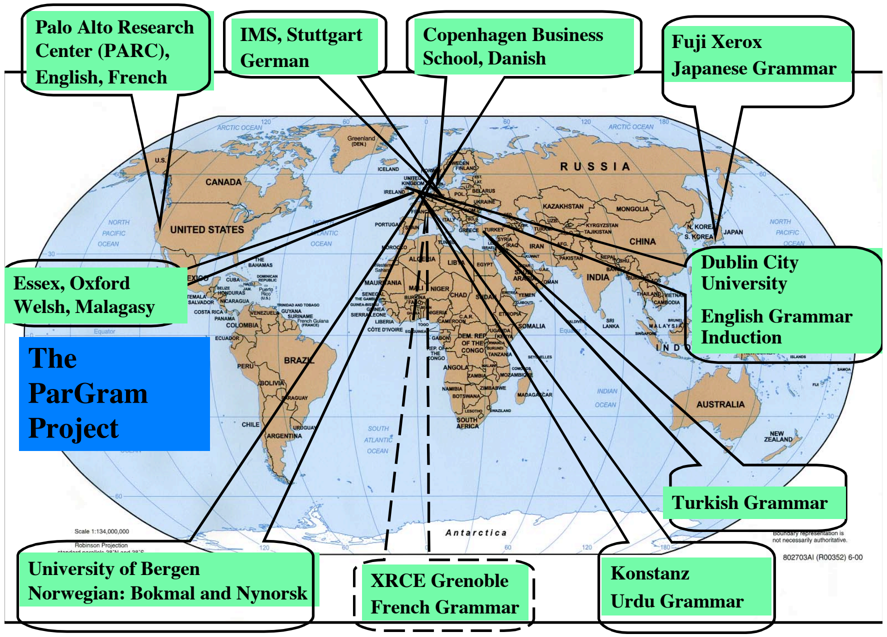
Why should one pay attention now?

New Generation of Large-Scale Grammars:

- Robustness:
  - Integrated Chunk Parsers
  - Bad input always results in some (possibly good) output
- Ambiguity:
  - Integration of stochastic methods
  - Optimality Theory used to rank/pick alternatives
- Speed: comparable to shallow parsers
- Accuracy and information content:
  - far beyond the capabilities of shallow parsers.

XLE at PARC

- Platform for Developing Large-Scale LFG Grammars
- LFG (Lexical-Functional Grammar)
  - Invented in the 1980s
    (Joan Bresnan and Ronald Kaplan)
  - Theoretically stable ⇔ Solid Implementation
- XLE is implemented in C, used with emacs, tcl/tk
- XLE includes a **parser**, **generator** and **transfer** component.



Project Structure

- Languages: English, Danish, French, German, Japanese, Malagasy, Norwegian, Turkish, Urdu, Welsh
- Theory: Lexical-Functional Grammar
- Platform: XLE
  - parser
  - generator
  - machine translation
- Loose organization: no common deliverables, but common interests.

Brief Project History

- 1994: English, French, German
  - Solidified grammatical analyses and conventions
  - Expanded, hardened XLE
- 1999: Norwegian
- 2000: Japanese, Urdu
  - Optimality Theory Integrated
- 2002: Danish
  - MT component (rewrite system)
- 2005: Welsh, Malagasy
- 2006: Turkish
  - Work on integrating knowledge representation/ontologies

Grammar Components

Each Grammar contains:

- Annotated Phrase Structure Rules (S --> NP VP)
- Lexicon (verb stems and functional elements)
- Finite-State Morphological Analyzer
- A version of Optimality Theory (OT):

  used as a filter to restrict ambiguities
  and/or parametrize the grammar.

The Parallel in ParGram

- Analyze languages to a degree of abstraction that reflects the common underlying structure (i.e., identiy the subject, the object, the tense, mood, etc.)
- Even at this level, there is usually more than one way to analyze a construction
- The same theoretical analysis may have different possible implementations
- The ParGram Project decides on common analyses and implementations (via meetings and the feature committee)

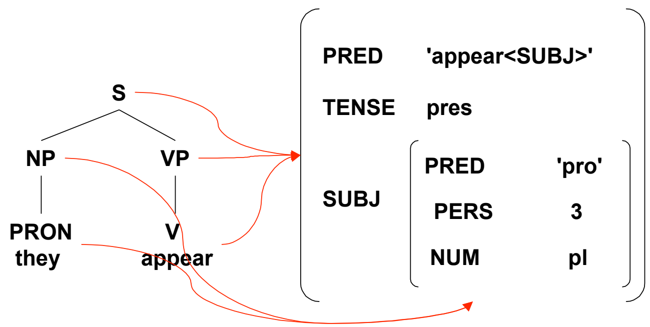
The Parallel in ParGram

- Analyses at the level of c-structure are allowed to differ (variance across languages)
- Analyses at f-structure are held as parallel as possible across languages (crosslinguistic invariance).
- **Theoretical Advantage**: This models the idea of UG.
- **Applicational Advantage**: machine translation is made easier; applications are more easily adapted to new languages (e.g., Kim et al. 2003).

Basic LFG

- Constituent-Structure: tree
- Functional-Structure: Attribute Value Matrix

universal



Examples

- Free Word Order (Warlpiri) vs. Fixed

(1) kurdu-jarra-rlu kapala maliki
child-Dual-Erg Aux.Pres dog.Abs
wajipili-nyi wita-jarra-rlu
chase-NonPast small-Dual-Erg
'The two small children are chasing the dog.'

- Passives
- Auxiliaries

Grammar components

- Configuration: links components
- Annotated phrase structure rules
- Lexicon
- Templates
- Other possible components
  - Finite State (FST) morphology
  - disambiguation feature file

Basic configuration file

```
TOY ENGLISH CONFIG (1.0)
ROOTCAT S.
FILES .
LEXENTRIES (TOY ENGLISH).
RULES (TOY ENGLISH).
TEMPLATES (TOY ENGLISH).
GOVERNABLERELATIONS SUBJ OBJ OBJ2 OBL COMP XCOMP.
SEMANTICFUNCTIONS ADJUNCT TOPIC.
NONDISTRIBUTIVES NUM PERS.
EPSILON e.
OPTIMALITYORDER
    NOGOOD.
----
```

Grammar sections

- Rules, templates, lexicons
- Each has:
  - version ID
  - component ID
  - XLE version number (1.0)
  - terminated by four dashes ----
- Example

```
STANDARD ENGLISH   RULES   (1.0)

----
```

Syntactic rules

- Annotated phrase structure rules

```
Category --> Cat1: Schemata1;
             Cat2: Schemata2;
             Cat3: Schemata3.

 S --> NP: (^ SUBJ)=!
           (! CASE)=NOM;
       VP: ^=!.
```

Another sample rule

```
                                  "indicate comments"
VP --> V: ^=!;                    "head"
       (NP: (^ OBJ)=!             "() = optionality"
            (! CASE)=ACC)
       PP*: ! $ (^ ADJUNCT).      "$ = set"
```

VP consists of:
- a head verb
- an optional object
- zero or more PP adjuncts

Lexicon

- Basic form for lexical entries:

```
word Category1 Morphcode1 Schemata1;
     Category2 Morphcode2 Schemata2.

walk V * (^ PRED)='WALK<(^ SUBJ)>';
     N * (^ PRED) = 'WALK' .

girl  N * (^ PRED) = 'GIRL'.

kick  V * { (^ PRED)='KICK<(^ SUBJ)(^ OBJ)>'
           |(^ PRED)='KICK<(^ SUBJ)>'}.

the   D * (^ DEF)=+.
```

Templates

- Express generalizations
  - in the lexicon
  - in the grammar
  - within the template space

No Template

```
girl N * (^ PRED)='GIRL'
         { (^ NUM)=SG
           (^ DEF)
          |(^ NUM)=PL}.
```

With Template

```
TEMPLATE: CN = { (^ NUM)=SG
                 (^ DEF)
                |(^ NUM)=PL}.
girl N * (^ PRED)='GIRL' @CN.
boy N * (^ PRED)='BOY' @CN.
```

Template example cont.

- Parameterize template to pass in values

```
CN(P) = (^ PRED)='P'
          { (^ NUM)=SG
          (^ DEF)
           |(^ NUM)=PL}.
```

```
girl N * @(CN GIRL).
boy N * @(CN BOY).
```

- Template can call other templates

```
INTRANS(P) = (^ PRED)='P<(^ SUBJ)>'.
TRANS(P) = (^ PRED)='P<(^ SUBJ)(^ OBJ)>'.
OPT-TRANS(P) = { @(INTRANS P) | @(TRANS P) }.
```

Parsing a string

- create-parser demo-eng.lfg
- parse "the girl walks"

Walkthrough Demo

Outline: Robustness

Dealing with brittleness

- Missing vocabulary
  - you can't list all the proper names in the world
- Missing constructions
  - there are many constructions theoretical linguistics rarely considers (e.g. dates, company names)
- Ungrammatical input
  - real world text is not always perfect
  - sometimes it is really horrendous

Dealing with Missing Vocabulary

- Build vocabulary based on the input of shallow methods
  - fast
  - extensive
  - accurate
- Finite-state morphologies

  falls -> fall +Noun +Pl

  fall +Verb +Pres +3sg
- Build lexical entry on-the-fly from the morphological information

Building lexical entries

- Lexical entries

-unknown N XLE @(COMMON-NOUN %stem).
+Noun N-SFX XLE @(PERS 3).
+Pl N-NUM XLE @(NUM pl).

- Rule

Noun -> N N-SFX N-NUM.

- Structure

[PRED 'fall'
NTYPE common
PERS 3
NUM pl]

Guessing words

- Use FST guesser if the morphology doesn't know the word
  - Capitalized words can be proper nouns
    Saakashvili -> Saakashvili +Noun +Proper +Guessed
  - *ed* words can be past tense verbs or adjectives
    fumped -> fump +Verb +Past +Guessed
    fumped +Adj +Deverbal +Guessed

Using the lexicons

- Rank the lexical lookup
  1. overt entry in lexicon
  2. entry built from information from morphology
  3. entry built from information from guesser
     » quality will depend on language type
- Use the most reliable information
- Fall back only as necessary

Missing constructions

- Even large hand-written grammars are not complete
  - new constructions, especially with new corpora
  - unusual constructions
- Generally longer sentences fail

Solution: Fragment and Chunk Parsing

- Build up as much as you can; stitch together the pieces

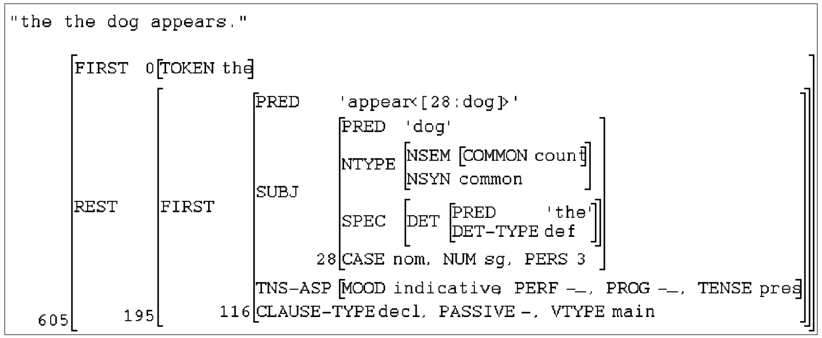
Grammar engineering approach

- First try to get a complete parse
- If fail, build up chunks that get complete parses
- Have a fall-back for things without even chunk parses
- Link these chunks and fall-backs together in a single structure

Fragment Chunks: Sample output

- the the dog appears.
- Split into:
  - "token" *the*
  - sentence "*the dog appears*"
  - ignore the period

F-structure



Ungrammatical input

- Real world text contains ungrammatical input
  - typos
  - run ons
  - cut and paste errors
- Deep grammars tend to only cover grammatical input
- Two strategies
  - robustness techniques: guesser/fragments
  - disprefered rules for ungrammatical structures

Harnessing Optimality Theory

- Optimality Theory (OT) allows the statement of preferences and dispreferences.
- In XLE, OT-Marks (annotations) can be added to rules or lexical entries to either prefer or disprefer a certain structure/item.

  `+Mark` = preference

  `Mark` = dispreference
- The strength of (dis)preference can be set variably.

OT Ranking

- **Order of Marks**: Mark3 is preferred to Mark4

  `OPTIMALITYORDER Mark4 Mark3 +Mark2 +Mark1.`

- **NOGOOD Mark:** Marks to the left are always bad. Useful for parametrizing grammar with respect to certain domains

  `OPTIMALITYORDER Mark4 NOGOOD Mark3 +Mark2 +Mark1.`

- **STOPPOINT Mark:** slowly increases the search space of the grammar if no good solution can be found (multipass grammar)

  `OPTIMALITYORDER Mark4 NOGOOD Mark3 STOPPOINT Mark2 STOPPOINT Mark1.`

Rule Annotation (O-Projection)

- Common errors can be coded in the rules

  mismatched subject-verb agreement

  ```
  Verb3Sg = { (^ SUBJ PERS) = 3
              (^ SUBJ  NUM) = sg
            | @(OTMARK BadVAgr) }
  ```
- Disprefer parses of ungrammatical structure
  - tools for grammar writer to rank rules
  - two+ pass system

Robustness via Optimality Marks

Demo

Ungrammatical Sentences

english.lfg (Tokenizer, FST Morphology)

Girls walks.

The the dog appears.

Robustness Summary

- Integrate shallow methods
  - morphologies (finite state)
  - guessers
- Fall back techniques
  - fragment grammar (chunks)
  - disprefered rules (OT)

Generation Outline

- Why generate?
- Generation as the reverse of parsing
- Constraining generation (OT)
- The generator as a debugging tool
- Generation from underspecified structures

Why generate?

- Machine translation

  Lang1 string -> Lang1 fstr -> Lang2 fstr -> Lang2 string
- Sentence condensation

  Long string -> fstr -> smaller fstr -> new string
- Question answering
- Grammar debugging

Generation: just reverse the parser

- XLE uses the same basic grammar to parse and generate
  - Parsing: string to analysis
  - Generation: analysis to string
- Input to Generator is the f-structure analysis
- Formal Properties of LFG Generation:
  - Generation produces Context Free Languages
  - LFG generation is a well-understood formal system (decidability, closure).

Generation: just reverse the parser

- Advantages
  - maintainability
  - write rules and lexicons once
- But
  - special generation tokenizer
  - different OT ranking

Restricting Generation

- Do not always want to generate all the possibilities that can be parsed
- Put in special OT marks for generation to block or prefer certain strings
  - fix up bad subject-verb agreement
  - only allow certain adverb placements
  - control punctuation options
- GENOPTIMALITYORDER
  - special ordering for OT generation marks that is kept separate from the parsing marks
  - serves to parametrize the grammar (parsing vs. generation)

Generation tokenizer

- White space
  - Parsing: multiple white space becomes a single TB

    John   appears. -> John TB appears TB . TB

  - Generation: single TB becomes a single space (or nothing)

    John TB appears TB . TB -> John appears.

    *John   appears   .

Generation tokenizer

- Capitalization
  - Parsing: optionally decap initially

    They came -> they came

    Mary came -> Mary came

  - Generation: always capitalize initially

    they came -> They came

    *they came
- May regularize other options
  - quotes, dashes, etc.

Generation morphology

- Suppress variant forms
  - Parse both *favor* and *favour*
  - Generate only one

Morphconfig for parsing & generation

STANDARD ENGLISH MOPRHOLOGY (1.0)

TOKENIZE:
P!eng.tok.parse.fst G!eng.tok.gen.fst

ANALYZE:
eng.infl-morph.fst G!amerbritfilter.fst
G!amergen.fst

Reversing the parsing grammar

- The parsing grammar rules can be used directly as a generator
- Adapt the grammar rule set with a special OT ranking GENOPTIMALITYORDER
- Why do this?
  - parse ungrammatical input
  - have too many options: one f-structure corresponds to many surface strings

Ungrammatical input

- Linguistically ungrammatical
  - They walks.
  - They ate banana.
- Stylistically ungrammatical
  - No ending punctuation: They appear
  - Superfluous commas: John, and Mary appear.
  - Shallow markup: [NP John and Mary] appear.

Too many options

- All the generated options can be linguistically valid, but too many for applications
- Occurs when more than one string has the same, legitimate f-structure
- PP placement:
  - In the morning I left.   I left in the morning.

Using the Gen OT ranking

- Generally much simpler than in the parsing direction
  - Usually only use standard marks and NOGOOD
    no STOPPOINT
  - Can have a few marks that are shared by several constructions
    one or two for dispreferred
    one or two for prefered

Example: Comma in coord

```
COORD(_CAT) = _CAT: @CONJUNCT;
              (COMMA: @(OTMARK GenBadPunct))
              CONJ
              _CAT: @CONJUNCT.
```

GENOPTIMALITYORDER GenBadPunct NOGOOD.

parse: They appear, and disappear.
generate: without OT: They appear(,) and disappear.
with OT: They appear and disappear.

Example: Prefer initial PP

```
S --> (PP: @ADJUNCT)
      NP: @SUBJ;
      VP.
VP --> V
       (NP: @OBJ)
       (PP: @ADJUNCT @(OT-MARK GenGood)).
```

GENOPTIMALITYORDER NOGOOD +GenGood.

parse: In the morning they appear.

generate: without OT: In the morning they appear.
They appear in the morning.

with OT: They appear in the morning.

Generation commands

- XLE command line:
  - regenerate "They appear."
  - generate-from-file my-file.pl
  - (regenerate-from-directory, regenerate-testfile)
- F-structure window:
  - commands: generate from this fs
- Debugging commands
  - regenerate-morphemes

Debugging the generator

- When generating from an f-structure produced by the same grammar, XLE should always generate
- Unless:
  - OT marks block the only possible string
  - something is wrong with the tokenizer/morphology

    regenerate-morphemes: if this gets a string

    the tokenizer/morphology is not the problem
- XLE has generation robustness features
  - seeing what is added/removed helps with debugging

Underspecified Input

- F-structures provided by applications are not perfect
  - may be missing features
  - may have extra features
  - may simply not match the grammar coverage
- Missing and extra features are often systematic
  - specify in XLE which features can be added and deleted
- Not matching the grammar is a more serious problem

Creating Paradigms

- Deleting and adding features within one grammar can produce paradigms
- Specifiers:
  - set-gen-adds remove "SPEC"

    set-gen-adds add "SPEC DET DEMON"
  - regenerate "NP: boys"

    { the | those | these | } boys

    etc.

Generation for Debugging

- Checking for grammar and lexicon errors
  - **create-generator english.lfg**
  - reports ill-formed rules, templates, feature declarations, lexical entries
- Checking for ill-formed sentences that can be parsed
  - parse a sentence
  - see if all the results are legitimate strings
  - **regenerate “they appear.”**

Regeneration example

% regenerate "In the park they often see the boy with the telescope."

parsing {In the park they often see the boy with the telescope.}

4 solutions, 0.39 CPU seconds, 178 subtrees unified

{They see the boy in the park|In the park they see the boy} often with the telescope.

regeneration took 0.87 CPU seconds.

Regenerate testfile

- regenerate-testfile
- produces new file: testfile.regen
  - sentences with parses and generated strings
  - lists sentences with no strings
  - if have no Gen OT marks, everything should generate back to itself

Summary: Generation and Reversibility

- XLE parses and generates on the same grammar
  - faster development time
  - easier maintenance
- Minor differences controlled by:
  - OT marks
  - FST tokenizers

Demo Generator

Ambiguity Outline

- Sources of Ambiguity:
  - Alternative c-structure rules
  - Disjunctions in f-structure description
  - Lexical categories
- XLE's display/computation of ambiguity
  - Packed representations
  - Dependent choices
- Dealing with ambiguity
  - Recognize legitimate ambiguity
  - OT marks for preferences
  - Shallow Markup/Tagging
  - Stochastic disambiguation

Ambiguity

- Deep grammars are massively ambiguous
- Use packing to parse and manipulate the ambiguities efficiently
- Trim early with shallow markup
  - fewer parses to choose from
  - faster parse time
- Choose most probable parse for applications that need a single input

Syntactic Ambiguity

- Lexical
  - part of speech
  - subcategorization frames
- Syntactic
  - attachments
  - coordination
- Implemented system highlights interactions

Lexical Ambiguity: POS

- verb-noun

  I saw her duck.

  I saw [NP her duck].

  I saw [NP her] [VP duck].
- noun-adjective

  the [N/A mean] rule

  that child is [A mean].

  he calculated the [N mean].

Morphology and POS ambiguity

- English has impoverished morphology and hence extreme POS ambiguity
  - leaves: leave +Verb +Pres +3sg
    leaf +Noun +Pl
    leave +Noun +Pl
  - will: +Noun +Sg
    +Aux
    +Verb +base
- Even languages with extensive morphology have ambiguities

Lexical ambiguity: Subcat frames

- Words often have more than one subcategorization frame
  - transitive/intransitive
    I broke it./It broke.
  - intransitive/oblique
    He went./He went to London.
  - transitive/transitive with infinitive
    I want it./I want it to leave.

Subcat-Rule interactions

- OBL vs. ADJUNCT with intransitive/oblique
  - He went to London.

```
[ PRED 'go<(^ SUBJ)(^ OBL)>'
  SUBJ [PRED 'he']
  OBL  [PRED 'to<(^ OBJ)>'
        OBJ  [ PRED 'London']]]
[ PRED 'go<(^ SUBJ)>'
  SUBJ [PRED 'he']
  ADJUNCT { [PRED 'to<(^ OBJ)>'
             OBJ  [ PRED 'London']]}]
```

OBL-ADJUNCT cont.

- Passive *by* phrase
  - It was eaten by the boys.

```
[ PRED    'eat<(^ OBL-AG)(^ SUBJ)>'
  SUBJ    [PRED 'it']
  OBL-AG  [PRED 'by<(^ OBJ)>'
           OBJ  [PRED 'boy']]]
```

  - It was eaten by the window.

```
[ PRED     'eat<NULL(^ SUBJ)>'
  SUBJ     [PRED 'it']
  ADJUNCT { [PRED 'by<(^ OBJ)>'
             OBJ  [PRED 'boy']]}]
```

OBJ-TH and Noun-Noun compounds

- Many OBJ-TH verbs are also transitive
  - **I took the cake. I took Mary the cake.**
- The grammar needs a rule for noun-noun compounds
  - **the tractor trailer, a grammar rule**
- These can interact
  - I took the grammar rules
  - **I took [NP the grammar rules]**
  - **I took [NP the grammar] [NP rules]**

Syntactic Ambiguities

- Even without lexical ambiguity, there is legitimate syntactic ambiguity
  - PP attachment
  - Coordination
- Want to:
  - constrain these to legitimate cases
  - make sure they are processed efficiently

PP Attachment

- PP adjuncts can attach to VPs and NPs
- Strings of PPs in the VP are ambiguous
  - **I see the girl with the telescope.**
    I see [the girl with the telescope].
    I see [the girl] [with the telescope].
- This ambiguity is reflected in:
  - the c-structure (constituency)
  - the f-structure (ADJUNCT attachment)

PP attachment cont.

- This ambiguity multiplies with more PPs
  - **I saw the girl with the telescope**
  - **I saw the girl with the telescope in the garden**
  - **I saw the girl with the telescope in the garden on the lawn**
- The syntax has no way to determine the attachment, even if humans can.

Ambiguity in coordination

- Vacuous ambiguity of non-branching trees
  - this can be avoided
- Legitimate ambiguity
  - old men and women

    old [N men and women]

    [NP old men] and [NP women]
  - I turned and pushed the cart

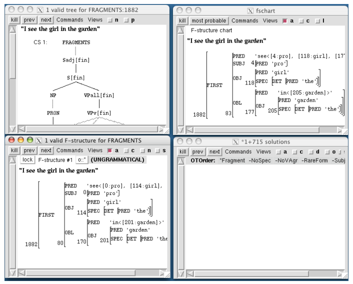
    I [V turned and pushed] the cart

    I [VP turned] and [VP pushed the cart]

Grammar Engineering and ambiguity

- Large-scale grammars will have lexical and syntactic ambiguities
- With real data they will interact resulting in many parses
  - these parses are legitimate
  - they are not intuitive to humans
- XLE provides tools to manage ambiguity
  - grammar writer interfaces
  - computation

XLE display

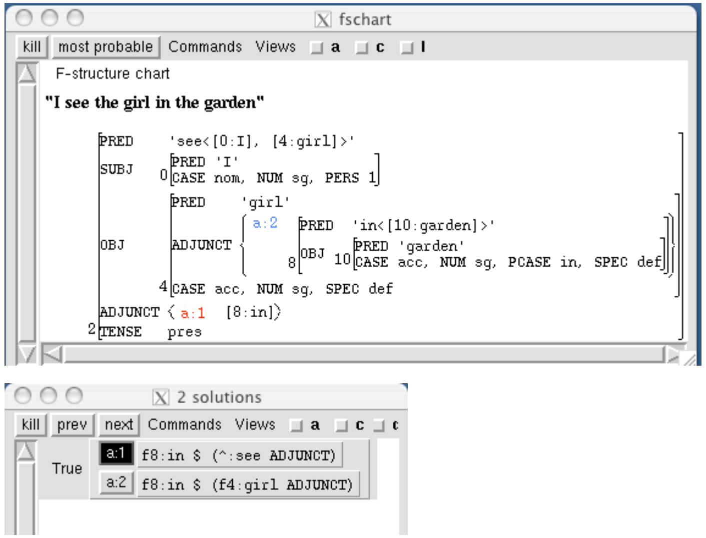


- Four windows
  - c-structure (top left)
  - f-structure (bottom left)
  - packed f-structure (top right)
  - choice space (bottom right)
- C-structure and f-structure “next” buttons
- Other two windows are packed representations of all the parses
  - clicking on a choice will display that choice in the left windows

Example

- I see the girl in the garden
- PP attachment ambiguity
  - both ADJUNCTS
  - difference in ADJUNCT-TYPE

Packed F-structure and Choice space



Sorting through the analyses

- "Next" button on c-structure and then f-structure windows
  - impractical with many choices
  - independent vs. interacting ambiguities
  - hard to detect spurious ambiguity
- The packed representations show all the analyses at once
  - (in)dependence more visible
  - click on choice to view
  - spurious ambiguities appear as blank choices
    - » but legitimate ambiguities may also do so

XLE Ambiguity Management

The sheep liked the fish.

How many sheep?
How many fish?

Options multiplied out

The sheep-sg liked the fish-sg.
The sheep-pl liked the fish-sg.
The sheep-sg liked the fish-pl.
The sheep-pl liked the fish-pl.

Options packed

The sheep {sg | pl} liked the fish {sg | pl}

Packed representation is a "free choice" system
- Encodes all dependencies without loss of information
- Common items represented, computed once
- Key to practical efficiency

Dependent choices

Das Mädchen {nom | acc} sah die Katze {nom | acc}
The girl saw the cat

Again, packing avoids duplication … but it's wrong
It doesn't encode all dependencies, choices are not free.

~~*Das Mädchen-nom sah die Katze-nom*~~	*bad*
Das Mädchen-nom sah die Katze-acc	*The girl saw the cat*
Das Mädchen-acc sah die Katze-nom	*The cat saw the girl*
~~*Das Mädchen-acc sah die Katze-acc*~~	*bad*

Who do you want to succeed?
I want to succeed John — *want intrans, succeed trans*
I want John to succeed — *want trans, succeed intrans*

Solution: Label dependent choices

~~*Das Mädchen-nom sah die Katze-nom*~~ — *bad*
Das Mädchen-nom sah die Katze-acc — The girl saw the cat
Das Mädchen-acc sah die Katze-nom — The cat saw the girl
~~*Das Mädchen-acc sah die Katze-acc*~~ — *bad*

Das Mädchen { p:*nom* / ¬p:*acc* } *sah die Katze* { q:*nom* / ¬q:*acc* }

$$\varphi = (p \wedge \neg q) \vee (\neg p \wedge q)$$

- Label each choice with distinct Boolean variables p, q, etc.
- Record acceptable combinations as a Boolean expression φ
- Each analysis corresponds to a satisfying truth-value assignment
  (free choice from the true lines of φ's truth table)

Ambiguity management: Shallow markup

- Part of speech marking as filter
  I saw her duck/VB.
  - accuracy of tagger (very good for English)
  - can use partial tagging (verbs and nouns)
- Named entities
  - <company>Goldman, Sachs & Co.</company> bought IBM.
  - good for proper names and times
  - hard to parse internal structure
- Fall back technique if fail
  - slows parsing
  - accuracy vs. speed

Chosing the most probable parse

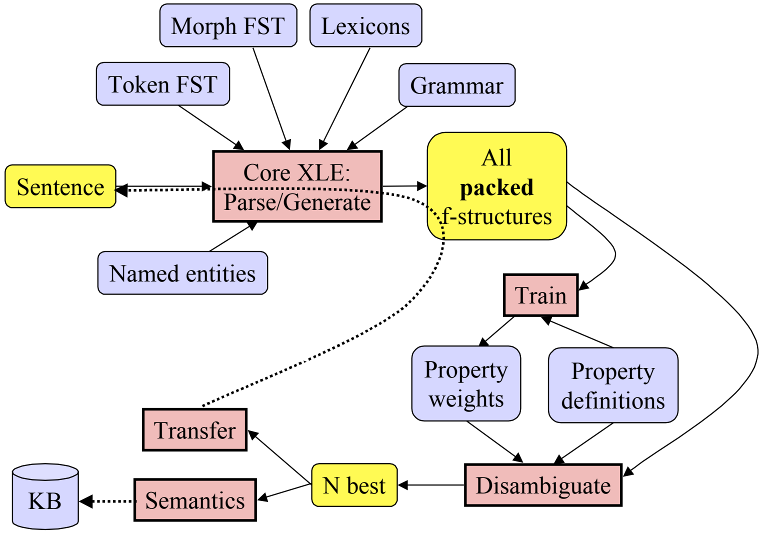
- Applications may want one input
- Use stochastic methods to choose
  - efficient (XLE English grammar: 5% of parse time)
- Need training data
  - partially labelled data ok
    [NP-SBJ They] see [NP-OBJ the girl with the telescope]

Demo
Stochastic Disambiguation

Applications — Beyond Parsing

- Machine translation
- Sentence condensation
- Computer Assisted Language Learning
- Knowledge representation

XLE related language components



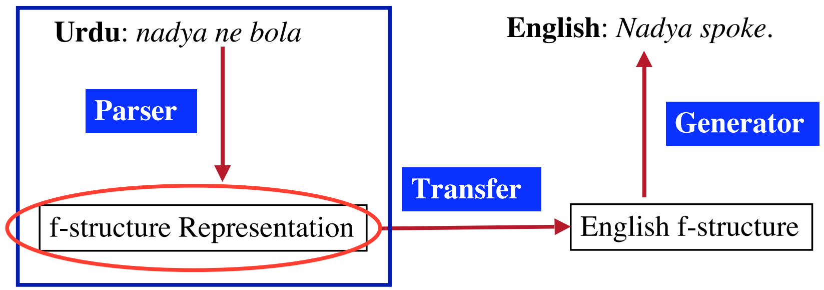
Machine Translation

- The Transfer Component
- Transferring features/F-structures
  - adding information
  - deleting information
- Examples

Basic Idea

- Parse a string in the source language
- Rewrite/transfer the f-structure to that of the target language
- Generate the target string from the transferred f-structure

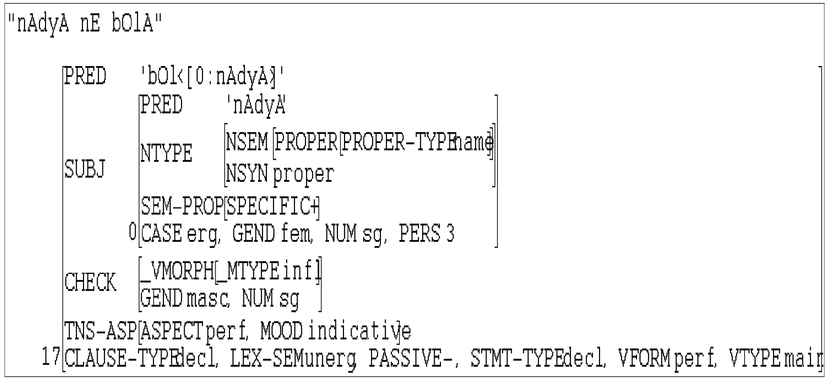
Urdu to English MT



from Urdu structure …

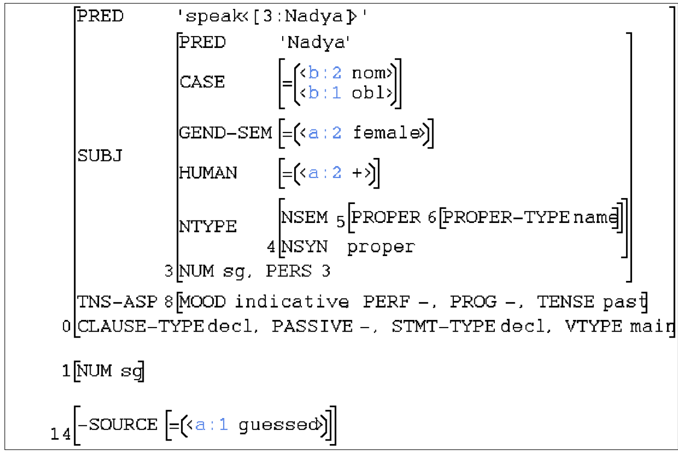
parse: *nadya ne bola*

Urdu f-structure



… to English structure

Urdu f-structure → **Transfer** → English f-structure



→ **Generator**

English:
Nadya spoke.

The Transfer Component

- Prolog based
- Small hand-written set of transfer rules
  - Obligatory and optional rules (possibly multiple output for single input)
  - Rules may add, delete, or change parts of *f*-structures
- Transfer operates on packed input and output
- Developer interface: Component adds new menu features to the output windows:
  - transfer this f-structure
  - translate this f-structure
  - reload rules

Sample Transfer Rules

Template

```
verb_verb(%Urdu, %English) ::
  PRED(%X, %Urdu), +VTYPE(%X,%main) ==>
                PRED(%X,% English).
```

Rules

```
verb_verb(pI,drink).
verb_verb(dEkH,see).
verb_verb(A,come).
```

```
%perf plus past, get perfect past
  ASPECT(%X,perf), + TENSE(%X,past) ==>
        PERF(%X,+), PROG(%X,-).
%only perf, get past
  ASPECT(%X,perf) ==> TENSE(%X,past), PERF(%X,-),
                PROG(%X,-).
```

Generation

- Use of *generator as filter* since transfer rules are independent of grammar
  - not constrained to preserve grammaticality
- Robustness techniques in generation:
  - Insertion/deletion of features to match lexicon
  - For fragmentary input from robust parser grammatical output guaranteed for separate fragments

Adding features

- English to French translation:
  - English nouns have no gender
  - French nouns need gender
  - Solution: have XLE add gender

    the French morphology will control the value
- Specify additions in configuration file (xlerc):
  - set-gen-adds add "GEND"
  - can add multiple features:

    set-gen-adds add "GEND CASE PCASE"
  - XLE will *optionally* insert the feature

Note: Unconstrained additions make generation undecidable

Example

The cat sleeps. -> Le chat dort.

```
[ PRED 'dormir<SUBJ>'
  SUBJ  [ PRED 'chat'
          NUM   sg
          SPEC  def ]
  TENSE present ]
```

```
[ PRED 'dormir<SUBJ>'
  SUBJ  [ PRED 'chat'
          NUM   sg
          GEND masc
          SPEC  def ]
  TENSE present ]
```

Deleting features

- French to English translation
  - delete the GEND feature
- Specify deletions in xlerc
  - set-gen-adds remove "GEND"
  - can remove multiple features

    set-gen-adds remove "GEND CASE PCASE"
  - XLE *obligatorily* removes the features

    no GEND feature will remain in the f-structure
  - if a feature takes an f-structure value, that f-structure is also removed

Changing values

- If values of a feature do not match between the input f-structure and the grammar:
  - delete the feature and then add it
- Example: case assignment in translation
  - set-gen-adds remove "CASE"
    set-gen-adds add "CASE"
  - allows dative case in input to become accusative
    e.g., exceptional case marking verb in input language but regular case in output language

Machine Translation

MT Demo

Sentence condensation

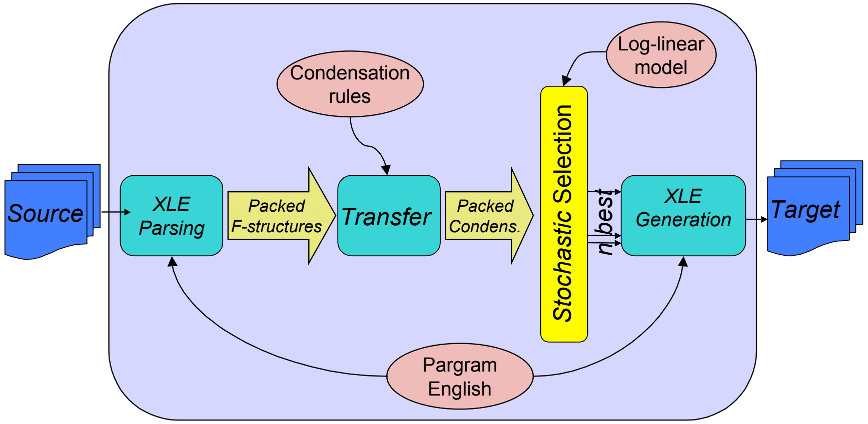
- Goal: Shrink sentences chosen for summary
- Challenges:
  1. Retain *most salient information* of input
  2. and *guarantee grammaticality* of output
- Example:
  Original uncondensed sentence
  A prototype is ready for testing, and Leary hopes to set requirements for a full system by the end of the year.

  One condensed version
  A prototype is ready for testing.

Sentence Condensation

- Use:
  - XLE's transfer component
  - generation
  - stochastic LFG parsing tools
  - ambiguity management via packed representations
- Condensation decisions made on *f-structure* instead of context-free trees or strings
- Generator guarantees grammatical well-formedness of output
- Powerful MaxEnt disambiguation model on transfer output

Condensation System



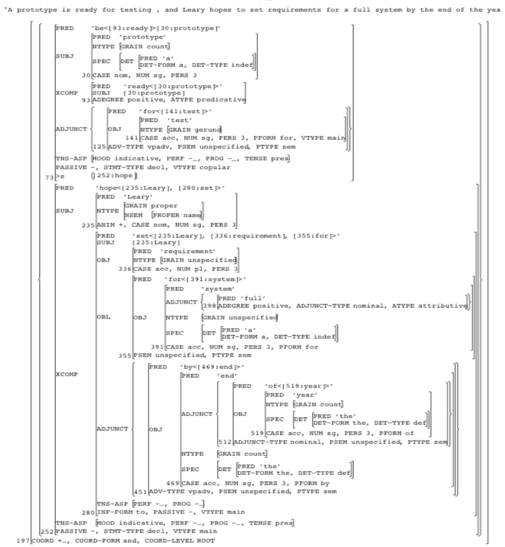
Simple combination of reusable system components

Sample Transfer Rules: sentence condensation

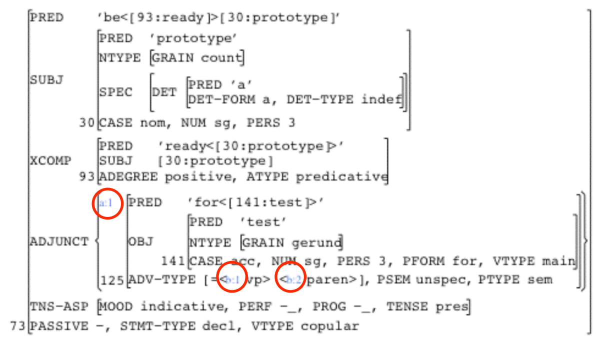
+ADJUNCT(%X,%AdjSet), in-set(%Adj,%AdjSet),
-ADJUNCT-TYPE(%Adj,neg) ?=> del-node(%Adj).

- Rule optionally removes a non-negative adjunct Adj by deleting the fact that Adj is contained within the set of adjuncts AdjSet associated with expression X.
- Rule-traces are added automatically to record relation of transfered *f*-structure to original *f*-structure for stochastic disambiguation.

One *f*-structure for Original Sentence



Packed alternatives after transfer condensation



Selection <a:1,b:1>

```
"A prototype is ready for testing."

   [PRED     'be<[93:ready]>[30:prototype]'
   |         [PRED  'prototype'
   |         |NTYPE [GRAIN count]
   |SUBJ     |SPEC  [DET [PRED 'a'
   |         |           DET-FORM a, DET-TYPE indef]]
   |      30 [CASE nom, NUM sg, PERS 3]
   |         [PRED   'ready<[30:prototype]>'
   |XCOMP    |SUBJ   [30:prototype]
   |      93 [ADEGREE positive, ATYPE predicative]
   |         {[PRED  'for<[141:test]>'
   |ADJUNCT  { |     [PRED  'test'
   |         { |OBJ  |NTYPE [GRAIN gerund]
   |         { |  141[CASE acc, NUM sg, PERS 3, PFORM for, VTYPE main]
   |         {125[ADV-TYPE vpadv, PSEM unspecified, PTYPE sem]}
   |TNS-ASP  [MOOD indicative, PERF -_, PROG -_, TENSE pres]
 73[PASSIVE -, STMT-TYPE decl, VTYPE copular]
```

Selection <a:2>

```
"A prototype is ready."

   [PRED     'be<[93:ready]>[30:prototype]'
   |         [PRED  'prototype'
   |         |NTYPE [GRAIN count]
   |SUBJ     |SPEC  [DET [PRED 'a'
   |         |           DET-FORM a, DET-TYPE indef]]
   |      30 [CASE nom, NUM sg, PERS 3]
   |         [PRED   'ready<[30:prototype]>'
   |XCOMP    |SUBJ   [30:prototype]
   |      93 [ADEGREE positive, ATYPE predicative]
   |TNS-ASP  [MOOD indicative, PERF -_, PROG -_, TENSE pres]
 73[PASSIVE -, STMT-TYPE decl, VTYPE copular]
```

Generated condensed strings

All grammatical!

A prototype is ready.

A prototype is ready for testing.

Leary hopes to set requirements for a full system.

A prototype is ready and Leary hopes to set requirements for a full system.

A prototype is ready for testing and Leary hopes to set requirements for a full system.

Leary hopes to set requirements for a full system by the end of the year.

A prototype is ready and Leary hopes to set requirements for a full system by the end of the year.

A prototype is ready for testing and Leary hopes to set requirements for a full system by the end of the year.

Transfer Rules used in Most Probable Condensation <a:2>

- Rule-traces in order of application
  - r13: Keep of-phrases (*of the year*)
  - r161: Keep adjuncts for certain heads, specified elsewhere (*system*)
  - r1: Delete adjunct of first conjunct (*for testing*)
  - r1: Delete adjunct of second conjunct (*by the end of the year*)
  - r2: Delete (rest of) second conjunct (*Leary hopes to set requirements for a full system*),
  - r22: Delete conjunction itself (*and*).

Condensation discussion

- Ranking of system variants shows *close correlation between automatic and manual evaluation*.
- *Stochastic selection of transfer-output crucial*: 50% reduction in error rate relative to upper bound.
- *Selection of best parse for transfer-input less important*: Similar results for manual selection and transfer from all parses.
- *Compression rate around 60%:* less aggressive than human condensation, but shortest-string heuristic is worse.

Computer Assisted Language Learning (CALL) Outline

- Goals
- Method
- Augmenting the English ParGram Grammar via OT Marks
- Generating Correct Output

XLE and CALL

- Goal: Use large-scale intelligent grammars to assist in grammar checking
  - identify errors in text by language learners
  - provide feedback as to location and type of error
  - generate back correct example
- Method: Adapt English ParGram grammar to deal with errors in the learner corpus

XLE CALL system method

- Grammar: Introduce special `UNGRAMMATICAL` feature at f-structure for feedback as to the type of error
- Parse CALL sentence
- Generate back possible corrections
- Evaluated on developed and unseen corpus
  - i. accuracy of error detection
  - ii. value of suggestions or possible feedback
  - iii. range of language problems/errors covered
  - iv. speed of operation

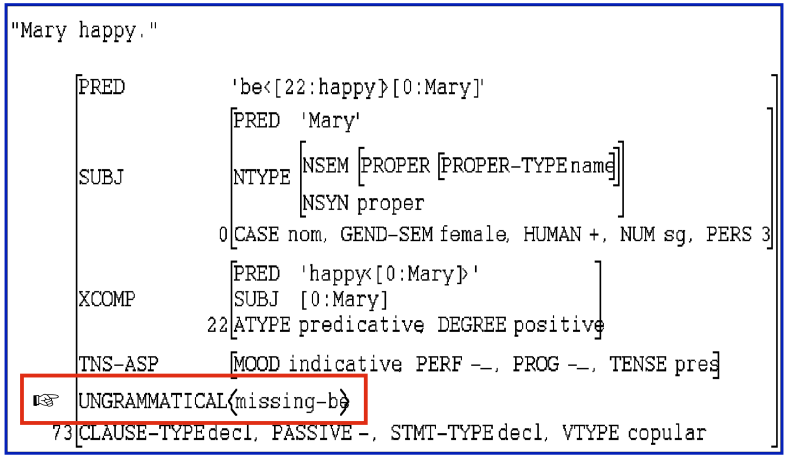
Adapting the English Grammar

- The standard ParGram English grammar was augmented with:
  - OT marks for ungrammatical constructions
  - Information for feedback: Example: Mary happy.

    UNGRAMMATICAL {missing-be}

    top level f-structure
- Parametrization of the generator to allow for corrections based on ungrammatical input.

F-structure: Mary happy.



Example modifications

- Missing copula (Mary happy.)
- No subj-verb agreement (The boys leaves.)
- Missing specifier on count noun (Boy leaves.)
- Missing punctuation (Mary is happy)
- Bad adverb placement (Mary quickly leaves.)
- Non-fronted wh-words (You saw who?)
- Missing *to* infinitive (I want disappear.)

Using OT Marks

- OT marks allow one analysis to be prefered over another
- The marks are introduced in rules and lexical entries

  @(OT-MARK ungrammatical)
- The parser is given a ranking of the marks
- Only the top ranked analyses appear

OT Marks in the CALL grammar

- A correct sentence triggers no marks
- A sentence with a known error triggers a mark ungrammatical
- A sentence with an unknown error triggers a mark fragment
- no mark < ungrammatical < fragment
  - the grammar first tries for no mark
  - then for a known error
  - then a fragment if all else fails

F-structure: Boy happy.

```
"Boy happy."

   [PRED          'be<[35:happy]>[15:boy]'
   |              [PRED          'boy'
   |              |NTYPE         [NSEM [COMMON count]]
   |SUBJ          |              [NSYN common       ]
   |              |UNGRAMMATICAL {missing-determiner}
   |            15[CASE nom, NUM sg, PERS 3
   |              [PRED  'happy<[15:boy]>'
   |XCOMP         |SUBJ  [15:boy]
   |            35[ATYPE predicative  DEGREE positive
   |TNS-ASP       [MOOD indicative  PERF -_, PROG -_, TENSE pres]
   |UNGRAMMATICAL {missing-be}
 86[CLAUSE-TYPE decl, PASSIVE -, STMT-TYPE decl, VTYPE copular]
```

Generation of corrections

- Remember that XLE allows the generation of correct sentences from ungrammtical input.
- Method:
  - Parse ungrammatical sentence
  - Remove UNGRAMMATICAL feature for generation
  - Generate from stripped down ungrammatical f-structure

Underspecified Generation

- XLE generation from an underspecified f-structure (information has been removed).
- Example: generation from an f-structure without tense/aspect information.

John sleeps (w/o TNS-ASP)

→ All tense/aspect variations

```
John
{ { will be
    |was
    |is
    |{has|had} been}
  sleeping
 |{{will have|has|had}|} slept
 |sleeps
 |will sleep}
```

CALL Generation example

- parse "Mary happy."
  generate back:
  Mary is happy.

- parse "boy arrives."
  generate back:
  { This | That | The | A } boy arrives.

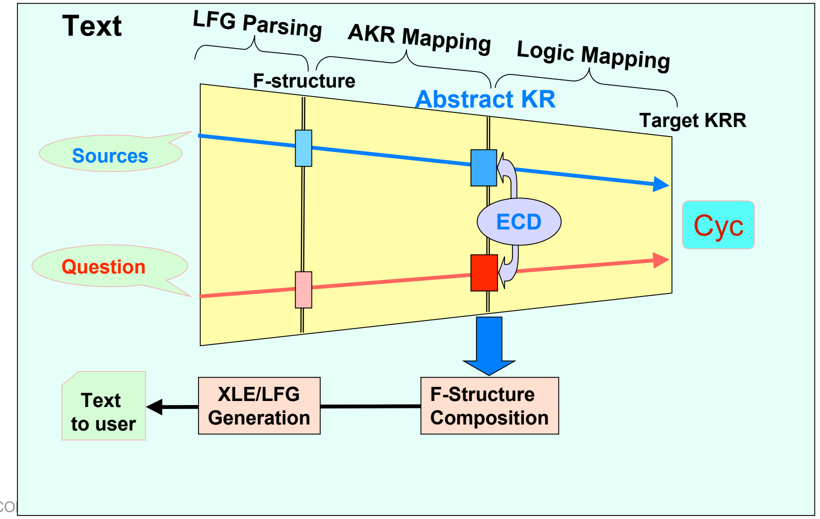
CALL evaluation and conclusions

- Preliminary Evaluation promising:
  - Word 10 out of 50=20% (bad user feedback)
  - XLE 29 out of 50=58% (better user feedback)
- Unseen real life student production
  - Word 5 out of 11 (bad user feedback)
  - XLE 6 out 11 (better user feedback)

Knowledge Representation

- From Syntax to Semantics
- From Semantics to Knowledge Representation
- Text Analysis
- Question/Answering

Text – KR – Text



Rewrite Rules for KR mapping

All operate on packed representations:

- F-structure to semantics
  - Semantic normalization, verbnet roles, wordnet senses, lexical class information
- Semantics to Abstract Knowledge Representation (AKR)
  - Separating conceptual, contextual & temporal structure
- AKR to F-structure
  - For generation from KR
- Entailment & contradiction detection rules
  - Applied to AKR

Semantic Representation
Someone failed to pay

```
in_context(t,  past(fail22))
in_context(t,  role(Agent,  fail22,  person1))
in_context(t,  role(Predicate,  fail22,  ctx(pay19)))
in_context(ctx(pay19),  cardinality(person1,  some))
in_context(ctx(pay19),  role(Agent,  pay19,  person1))
in_context(ctx(pay19),  role(Recipient,  pay19,  implicit_arg94))
in_context(ctx(pay19),  role(Theme,  pay19,  implicit_arg95))

lex_class(fail22,  [vnclass(unknown),  wnclass(change),
                temp-rel,  temp_simul,  impl_pn_np,  prop-attitude])
lex_class(pay19,  [vnclass(unknown),  wnclass(possession)])),
word(fail22,  fail,  verb,  0,  22,  t,  [[2505082],  [2504178],  …,  [2498138]])
word(implicit_arg:94,  implicit,  implicit,  0,  0,  ctx(pay19),  [[1740]])
word(implicit_arg:95,  implicit,  implicit,  0,  0,  ctx(pay19),  [[1740]])
word(pay19,  pay,  verb,  0,  19,  ctx(pay19),
            [[2230669],  [1049936],  …,  [2707966]])
word(person1,  person,  quantpro,  0,  1,  ctx(pay19),
            [[7626,  4576,  …,  1740]])
```

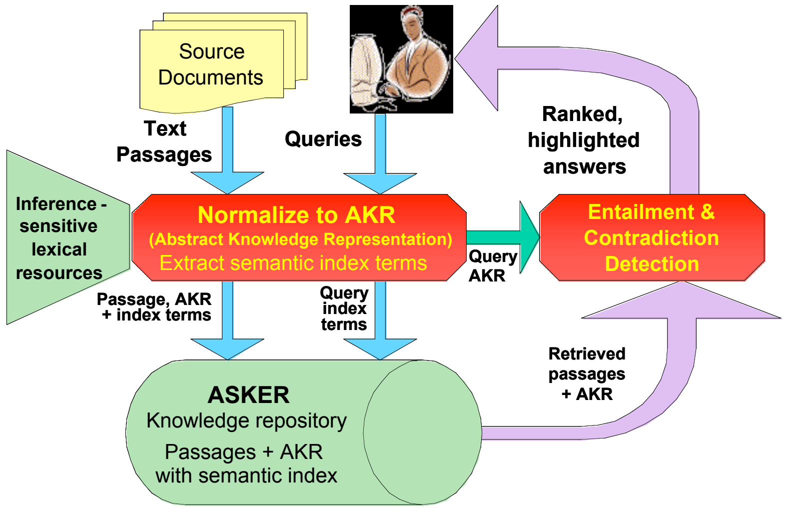

AKR
Someone failed to pay

Conceptual Structure:
```
    subconcept(fail22, [[2:2505082], [2:2504178], …, [2:2498138]])
    role(Agent, fail22, person1)
    subconcept(person1,  [[1:7626,  1:4576,  …,  1:1740]])
    role(cardinality_restriction, person1, some)
    role(Predicate, fail22, ctx(pay19))
    subconcept(pay19, [[2:2230669], [2:1049936], …, [2:2707966]])
    role(Agent, pay19, person1)
```

Contextual Structure:
```
    context(t)       context(ctx(pay19))
    context_lifting_relation(antiveridical, t, ctx(pay19))
    context_relation(t, ctx(pay19), Predicate(fail22))
    instantiable(fail22, t)
    uninstantiable(pay19, t)
    instantiable(pay19, ctx(pay19))
```

Temporal Structure:
```
    temporalRel(startsAfterEndingOf, Now, fail22)
    temporalRel(startsAfterEndingOf, Now, pay19)
```


Semantic Search Architecture



Entailment & Contradiction Detection

1. Map texts to packed AKR
2. Align concept & context terms between AKRs
3. Apply entailment & contradiction rules to aligned AKRs
   1. eliminate entailed facts
   2. flag contradictory facts
4. Inspect results
   1. Entailment = all query facts eliminated
   2. Contradiction = any contradiction flagged
   3. Unknown = otherwise

- Properties
  - Combination of positive aspects of graph matching (alignment) and theorem proving (rewriting)
  - Ambiguity tolerant

ECD: Illustrative Example

- "*A little girl disappeared*" entails "*A child vanished*"
- A trivial example
  - Could be handled by a simpler approach (e.g. graph matching)
  - Used to explain basics of ECD approach

Representations

AKR: *A little girl disappeared.*		AKR: *A child vanished*
context(t), instantiable(disappear4, t) instantiable(girl3, t) temporalRel(startsAfter, Now, disappear4) role(Theme, disappear4, girl3) role(cardinality_restriction, girl3, sg) subconcept(disappear4, [[422658], …, [220927]]) subconcept(girl3, [[9979060…1740], [9934281…9771976…1740], …, [9979646…1740]])	→	context(t), instantiable(vanish2, t) instantiable(child1, t) temporalRel(startsAfter, Now, vanish2) role(Theme, vanish2, child1) role(cardinality_restriction, child1, sg) subconcept(vanish2, [[422658], …, [2136731]]) subconcept(child1, [[9771320, …1740], [9771976, …1740], …, [9772490, …, 1740]])

Contextual, temporal and conceptual subsumption indicates entailment

Alignment

- Align terms based on conceptual overlap

***TABLE of possible Query-Passage alignments ***

vanish2	[1.0–disappear4, 0.0–little1, 0.0–girl3]
child1	[0.78–girl3, 0.0–little1, 0.0–disappear4]
t	[1.0–t]

```
subconcept(vanish2,
        [[422658], …, [2136731]])
subconcept(disappear4,
        [[422658], …, [220927]])
```

- Determined by subconcepts
  - Degree of hypernym overlap

```
subconcept(child1,
        [[9771320, …1740],
         [9771976, …1740],
         …, [9772490, …, 1740]])
subconcept(girl3,
        [[9979060…1740],
         [9934281…9771976…1740],
         …, [9979646…1740]])
```

vanish:2 = disappear:4 on sense 1

child:1 $\subset$ girl:3 on sense 2

Impose Alignment & Label Facts

girl3 // child1
disappear4 // vanish2

P-AKR: *A little girl disappeared.*	Q-AKR: *A child vanished*
P:context(t) P:instantiable(vanish2, t) P:instantiable(child1, t) P:temporalRel(startsAfter, Now, vanish2) P:role(Theme, vanish2, child1) P:role(cardinality_restriction, child1, sg) P:role(subsective, child1, little1) P:subconcept(little1, [[1443454…], …]) P:subconcept(vanish2, [[422658], …, [220927]]) P:subconcept(child1, [[9979060…1740], [9934281…9771976…1740], …, [9979646…1740]])	Q:context(t), Q:instantiable(vanish2, t) Q:instantiable(child1, t) Q:temporalRel(startsAfter, Now, vanish2) Q:role(Theme, vanish2, child1) Q:role(cardinality_restriction, child1, sg) Q:subconcept(vanish2, [[422658], …, [2136731]]) Q:subconcept(child1, [[9771320, …1740], [9771976, …1740], …, [9772490, …, 1740]])

- Combined P-AKR and Q-AKR used as input to entailment and contradiction transfer rules

Entailment & Contradiction Rules

- Packed rewrite rules that
  - Eliminate Q-facts that are entailed by P-facts
  - Flag Q-facts that are contradicted by P-facts
- Rule phases
  - Preliminary concept subsumption
  - Refine concept subsumption via role restrictions
  - Entailments & contradictions from instantiable / uninstantiable facts
  - Entailments & contradictions from other relations

Preliminary Subsumption Rules

- Example rules:

e.g. "girl" and "child"

Q:subconcept(%Sk, %QConcept)
P:subconcept(%Sk, %PConcept)
{%QConcept ⊂ %PConcept}
==>
prelim_more_specific(%Sk, P).

e.g. "disappear" and "vanish"

Q:subconcept(%Sk, %QConcept)
P:subconcept(%Sk, %PConcept)
{%QConcept = %PConcept}
==>
prelim_more_specific(%Sk, mutual).

- Apply to subconcept facts to give:

prelim_more_specific(vanish2, mutual)
prelim_more_specific(child1, P)

Role Restriction Rules

- Example rules:

"little girl" more specific than *"child"*

prelim_more_specific(%Sk, %PM)
{ member(%PM, [P, mutual]) }
P:role(%%, %Sk, %%)
-Q:role(%%, %Sk, %%)
==>
more_specific(%Sk, P).

- Rules apply to give: more_specific(child1, P)
  more_specific(vanish2, P)

Instantiation Rules

- Remove entailed instantiabilities and flag contradictions:

Q-instantiability entailed	*Q-uninstantiability contradicted*
more_specific(%Sk, P), P:instantiable(%Sk, %Ctx) Q:instantiable(%Sk, %Ctx) ==> 0.	more_specific(%Sk, P), P:instantiable(%Sk, %Ctx) Q:uninstantiable(%Sk, %Ctx) ==> contradiction.

ECD Summary

- Combination of graph matching and inference on deep representations
- Use of transfer system allows ECD on packed / ambiguous representations
  - No need for early disambiguation
  - Passage and query effectively disambiguate each other
- ECD rules currently geared toward very high precision detection of entailments & contradictions

Semantic/AKR Indexing

- ECD looks for inferential relations between a question and a candidate answer
- Semantic/AKR search retrieves candidate answers from a large database of representations
- Text representations are indexed by
  - Concepts referred to
  - Selected role relations
- Basic retrieval from index
  - Find text terms more specific than query terms
  - Ensure query roles are present in retrieved text

Semantic/AKR Indexing

- Semantic/AKR search retrieves candidate answers from a large database of representations
  - Simple relevance retrieval (graph/concept subsumption)
    A girl paid. Did a child pay?
    - » Text term more specific than query term
- Inferentially enhanced retrieval
  - Recognizing when text terms need to be less specific than query
    Someone forgot to pay. Did everyone pay?
    - » Text term is less specific than query term
  - Looser matching on roles present in text
- Retrievals are then fed to ECD module

Semantic Lexical Resources

- Semantics/KR applications require additional lexical resources
  - use existing resources when possible
  - XLE transfer system incorporates basic database to handle large lexicons efficiently
- Unified (semantic) lexicon
  - Ties existing resources to XLE lexicons (WordNet, VerbNet, ontologies, …)
  - Additional annotation of lexical classes (*fail* vs *manage*, *believe* vs *know*)
  - Used in mapping f-structures to semantics/AKR

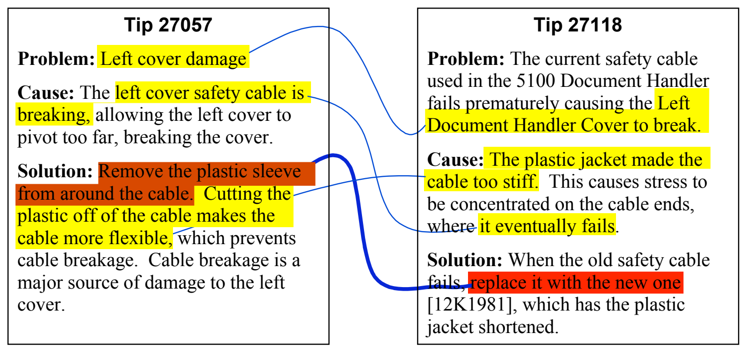
- **Demo**
- **AKR and ECD**

Advancing Open Text Semantic Analysis

- Deeper, more detailed linguistic analysis
  - Roles, concepts, normalization of f-structures
- Canonicalization into tractable KR
  - (un)instantiability
  - temporal relations
- Ambiguity enabled semantics and KR
  - Common packing mechanisms at all levels of representation
  - Avoid errors from premature disambiguation

Driving force: Entailment & Contradiction Detection (ECD)

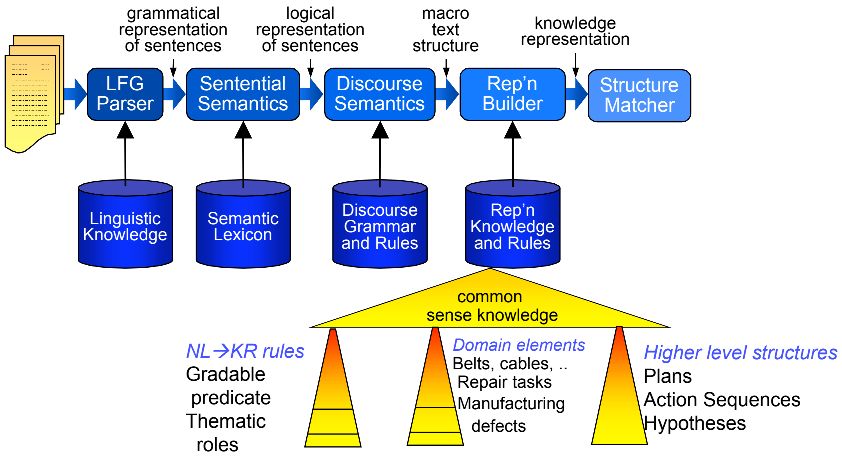
ECD and Maintaining Text Databases



Maintain quality of text database by identifying areas of redundancy and conflict between documents

Deep, canonical, ambiguity-enabled semantic processing is needed to detect entailments & contradictions like these.

Architecture for Document ECD



XLE: Summary

- XLE
  - parser (tree and dependency output)
  - generator (reversible parsing grammar)
  - powerful, efficient and flexible rewrite system
- Grammar engineering makes deep grammars feasible
  - robustness techniques
  - integration of shallow methods
- Ordered rewrite system to manipulate grammar output

XLE: Applications

- Many current applications can use shallow grammars
- Fast, accurate, broad-coverage deep grammars enable extensions to existing applications and new applications
  - semantic search
  - summarization/condensation
  - CALL and grammar checking
  - entity and entity relation detection
  - machine translation

XLE: Applications

- Powerful methods that allow innovative solutions:
  - Integration of shallow methods (chunking, statistical information)
  - Integration of optimality marks
  - rewrite system
  - innovative semantic representation

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- Many of the publications in the bibliography are available from our websites.

- Information about XLE (including link to documentation):
  http://www.parc.com/istl/groups/nltt/xle/default.html

Bibliography

XLE Documentation:
http://www2.parc.com/isl/groups/nltt/xle/doc/xle_toc.html

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