Errors, Intentions, and Explanations – Feedback Generation for Language Tutoring Systems

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Overview

• A Vision
Overview

- A Vision
- Where we are?
Overview

• A Vision
• Where we are?
• Error Diagnosis and Ambiguity
Overview

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• Error Diagnosis and Ambiguity
• Dealing with Diagnostic Ambiguity
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- Dealing with Diagnostic Ambiguity
- Constraint-Based Error Diagnosis
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- Constraint-Based Error Diagnosis
- Late Hypothesis Selection
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- Structural Constraints
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• Constraint-Based Error Diagnosis
• Late Hypothesis Selection
• Structural Constraints
• Intentions for Hypothesis Selection
• Conclusions
A Vision

• having a system which . . .
  . . . facilitates goal-oriented interaction
  . . . encourages the student to *actively* produce language
  . . . puts few constraining limitations on language use
  . . . provides helpful feedback for the student to improve
A Vision

- clicking isn’t enough
A Vision

• clicking isn’t enough

Consequently, a session with one of the currently fashionable multimedia packages is like trying to learn to speak a foreign language from a tutor who is stone deaf . . .
A Vision

- clicking isn’t enough

Consequently, a session with one of the currently fashionable multimedia packages is like trying to learn to speak a foreign language from a tutor who is stone deaf …

The reason is that there exists no software intelligent enough to process ill-formed sentences other than by simply refusing them.
clicking isn’t enough

Consequently, a session with one of the currently fashionable multimedia packages is like trying to learn to speak a foreign language from a tutor who is stone deaf . . .

The reason is that there exists no software intelligent enough to process ill-formed sentences other than by simply refusing them.

BRIAN FARRINGTON (Eurocall 2000)
Where we are?

- We can provide helpful error explanations . . .
  - . . . under strong domain restrictions
  - . . . for language with limited lexical and grammar coverage
  - . . . using approximative linguistic knowledge
  - . . . making simplifying assumptions on error types and maximum error complexity

We know that . . .

- existing system solutions are too restricted
- explanation quality is sometimes poor
Where we are?

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  . . . under strong domain restrictions
  . . . for language with limited lexical and grammar coverage
  . . . using approximative linguistic knowledge
  . . . making simplifying assumptions on error types and maximum error complexity
- We know that . . .
  . . . existing system solutions are too restricted
  . . . explanation quality is sometimes poor
Where we are?

- We tend to neglect that . . .
  - . . . every explanation is targeted at a particular correction proposal
  - . . . the *only* criterion available to determine the optimum proposal is the "similarity" of the corrected to the original student solution
  - . . . "similarity" is relative to the knowledge captured by a particular model
  - . . . the quality of error descriptions depends on knowledge being available at the *right point in time*
Where we are?

- We believe that explanation quality could be improved by using . . .
  - . . . more precise linguistic descriptions
  - . . . strong support from extra-linguistic knowledge
  - . . . reference to the non-linguistic context
Where we are?

• We believe that explanation quality could be improved by using . . .
  . . . more precise linguistic descriptions
  . . . strong support from extra-linguistic knowledge
  . . . reference to the non-linguistic context

• We should become aware of the fact that . . .
  . . . the ideal point of reference is the intention of the learner.
Where we are?

- Why intentions?
Where we are?

- Why intentions?
  - language teacher use it routinely

Wolfgang Menzel: Errors, Intentions, and Explanations: Where we are?
Where we are?

• Why intentions?
  • language teacher use it routinely
  • it can be inferred
    • from past behaviour of the student
    • from domain knowledge
    • from the discourse context
Where we are?

- Why intentions?
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  - it can be inferred
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    - from domain knowledge
    - from the discourse context
  - it can be directly elicited from the student
    - e.g. asking "What did you want to say?"
    - can be communicated by linguistic and non-linguistic means
Where we are?

• Why intentions?
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  • it can be inferred
    • from past behaviour of the student
    • from domain knowledge
    • from the discourse context
  • it can be directly elicited from the student
    • e.g. asking "What did you want to say?"
    • can be communicated by linguistic and non-linguistic means
  • could provide a strong support for guiding the diagnosis
Error Diagnosis and Ambiguity

- ambiguity
Error Diagnosis and Ambiguity

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Error Diagnosis and Ambiguity

- ambiguity

LDOCE: 40 readings
Error Diagnosis and Ambiguity

- ambiguity

He painted the back twice.

LDOCE: 40 readings
He painted the back twice.

- ambiguity

LDOCE: 40 readings

syntax
He painted the back twice.

- ambiguity

LDOCE: 40 readings

+ world knowledge

syntax

part of a body
towards the back
player position
to support
surface of an object

go backwards
old liabilities
as before
past issues
He painted the back twice.

- ambiguity

LDOCE: 40 readings

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Error Diagnosis and Ambiguity

- language errors introduce additional ambiguity
Error Diagnosis and Ambiguity

- language errors introduce additional ambiguity
- example: spelling correction
Error Diagnosis and Ambiguity

- language errors introduce additional ambiguity
- example: spelling correction

*It is very kold in here.*
Error Diagnosis and Ambiguity

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*It is very kold in here.*

![Diagram showing word relationships with 'cold', 'kold', and various related words with 'syntax + world knowledge + domain knowledge'.]
Error Diagnosis and Ambiguity

• minimal error heuristics:
  prefer simpler correction proposals over more complex one
Error Diagnosis and Ambiguity

• minimal error heuristics:
  prefer simpler correction proposals over more complex one
  • can be misleading

*It is very kolds in here.

kolds $\rightarrow$ holds.
Error Diagnosis and Ambiguity

• minimal error heuristics: prefer simpler correction proposals over more complex one
  • can be misleading

  *It is very kolds in here.

  kolds → holds.

• error assumptions are even necessary for correct word forms if the utterance is syntactically inacceptable

  *It is very told in here.
Error Diagnosis and Ambiguity

- character-based correction proposals are rather poor explanations
  - no indication
  - what might have caused the error
  - how to avoid a similar error in the future
Error Diagnosis and Ambiguity

- character-based correction proposals are rather poor explanations
  - no indication
    - what might have caused the error
    - how to avoid a similar error in the future
- possible causes:
  - substitution or insertion of neighboring keys
  - phonetic similarity
  - interference from another language
Error Diagnosis and Ambiguity

- different *error perspectives*
  - the same error can be explained in different ways
  - introduces yet another type of diagnostic ambiguity
  - provides also additional criteria for hypothesis selection
Error Diagnosis and Ambiguity

- different *error perspectives*
  - the same error can be explained in different ways
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  - provides also additional criteria for hypothesis selection
- *kold → cold*:
  phonetic confusion is most plausible
Error Diagnosis and Ambiguity

• different perspectives might lead to differently complex error descriptions
  
  *It was there fault.

• no error assumption on a purely phonetic level

• character-based explanation with two substitutions
  
  → minimal error heuristics fails if phonetic similarity is ignored
Error Diagnosis and Ambiguity

- different perspectives might lead to differently complex error descriptions
  
  *It was there fault.

- no error assumption on a purely phonetic level
- character-based explanation with two substitutions
  - minimal error heuristics fails if phonetic similarity is ignored
  - cheaper character-based corrections available:
    - there → here
- do not remove the syntactic inconsistency
1. The necessity to consider erroneous input increases (local) ambiguity.
   - enumerating all possible correction possibilities is neither feasible nor desirable.
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   - enumerating all possible correction possibilities is neither feasible nor desirable.

2. Errors can be explained from different perspectives.
   - the perspective might influence the decision on the most plausible explanation
   - usually plausibility is a gradual notion
Dealing with Diagnostic Ambiguity

1. The necessity to consider erroneous input increases (local) ambiguity.
   - enumerating all possible correction possibilities is neither feasible nor desirable.

2. Errors can be explained from different perspectives.
   - the perspective might influence the decision on the most plausible explanation
   - usually plausibility is a gradual notion

3. Least effort corrections do not always yield satisfying error explanations.
4. The diagnosis procedure should be aware of alternative explanation/correction possibilities
   • the alternatives can be more plausible from another perspective.
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   - the alternatives can be more plausible from another perspective.

5. Considering an error might even be necessary if the input seems (locally) acceptable.
Dealing with Diagnostic Ambiguity

- huge number of error hypotheses even for relatively simple problems
Dealing with Diagnostic Ambiguity

- huge number of error hypotheses even for relatively simple problems
- needed: strong constraints to narrow down the space of possible alternatives
Dealing with Diagnostic Ambiguity

- huge number of error hypotheses even for relatively simple problems
- needed: strong constraints to narrow down the space of possible alternatives
- two approaches:
  1. artificially constrain the sublanguage
  2. use (dynamic) domain knowledge about the current state of affairs
Dealing with Diagnostic Ambiguity

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• two approaches:
  1. artificially constrain the sublanguage
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Dealing with Diagnostic Ambiguity

- two architectures
Dealing with Diagnostic Ambiguity

- two architectures
  1. late selection:
     - diagnosis produces an as large as possible set of potential error explanations
     - a subsequent selection step selects the most plausible ones

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Dealing with Diagnostic Ambiguity

- two architectures
  1. late selection:
     - diagnosis produces an as large as possible set of potential error explanations
     - a subsequent selection step selects the most plausible ones
  2. early integration:
     - the domain knowledge is directly integrated into the diagnosis procedure
     - guides it towards the most plausible explanation
Constraint-Based Diagnosis

- example: morpho-syntactic regularities
  - constraints model the compatibility of feature assignments
  - feature assignments need not be unique
Constraint-Based Diagnosis

- example: morpho-syntactic regularities
  - constraints model the compatibility of feature assignments
  - feature assignments need not be unique

- for *all* variable assignments find the constraints that are violated
- if an assignment with no constraint violations is found, signal "ok"
- else find the assignment with a minimum number of constraint violations
- output the explanation(s) connected to the violated constraint(s)
Constraint-Based Diagnosis

• an ambiguous diagnosis problem
Constraint-Based Diagnosis

• an ambiguous diagnosis problem

- These fish stinks
  - det: these
  - noun: fish
  - verb: stinks
  - number: plural
  - singular
  - plural
Constraint-Based Diagnosis

• an ambiguous diagnosis problem

\[
\text{not(number(det,noun))}
\]
Constraint-Based Diagnosis

• an ambiguous diagnosis problem

\[ \rightarrow \text{not}(\text{number(noun,verb)}) \]
Constraint-Based Diagnosis

- constraint system of English is rather impoverished
Constraint-Based Diagnosis

- constraint system of English is rather impoverished
- richer constraint systems in other languages
Constraint-Based Diagnosis

- constraint system of English is rather impoverished
- richer constraint systems in other languages
- e.g. German
  - subject-verb: person, number
  - noun phrase: number, gender, case
Constraint-Based Diagnosis

- constraint system of English is rather impoverished
- richer constraint systems in other languages
- e.g. German
  - subject-verb: person, number
  - noun phrase: number, gender, case
- e.g. Russian
  - subject-verb: person, number, gender
  - noun phrase: number, gender, case, animatedness
Constraint-Based Diagnosis

die Mädchen schläft

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Constraint-Based Diagnosis

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Constraint-Based Diagnosis

\[
\text{det} \quad \text{noun} \quad \text{verb}
\]

\[
die \quad Mädchen \quad schläft
\]

\[
fem \ sg \ nom \quad neut \ sg \ nom \ 3rd \quad sg \ 3rd
\]

\[
neut \ pl \ nom \quad neut \ pl \ nom \ 3rd \quad \ldots
\]

\[
\rightarrow \ not(\text{gender(det,noun)})
\]
Constraint-Based Diagnosis

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Constraint-Based Diagnosis

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Constraint-Based Diagnosis

- global consistency required
  - locally restricted constraint checking leads to incomplete diagnoses
Constraint-Based Diagnosis

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  - locally restricted constraint checking leads to incomplete diagnoses
- Schwind (1994): constraint checking within the scope of phrase structure rules
  - alternative (more plausible) diagnoses are lost
Constraint-Based Diagnosis

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Der Götter zürnen
Constraint-Based Diagnosis

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\[ \text{Der Götter zürnen} \]

Correct genitive case NP
Constraint-Based Diagnosis

- global consistency required
  - locally restricted constraint checking leads to incomplete diagnoses
- Schwind (1994): constraint checking within the scope of phrase structure rules
  - alternative (more plausible) diagnoses are lost

Der Götter zürnen

Der: correct genitive case NP
Götter: subject NP without nominative case
zürnen:
Constraint-Based Diagnosis

- global consistency required
  - locally restricted constraint checking leads to incomplete diagnoses
- SCHWIND (1994): constraint checking within the scope of phrase structure rules
  - alternative (more plausible) diagnoses are lost

\[ \text{Der Götter zürnen} \]

- correct genitive case NP
- subject NP without nominative case

- special treatment proposed
Constraint-Based Diagnosis

- **HOLLAND (1995)**
  - partial diagnoses trigger contingent errors
Constraint-Based Diagnosis

- **Holland** (1995)
  - partial diagnoses trigger contingent errors

  \[Wir \ \text{stehen} \ \text{auf} \ \text{die} \ \text{Berg}\]
Constraint-Based Diagnosis

- **HOLLAND** (1995)
  - partial diagnoses trigger contingent errors

  $$\text{Wir stehen auf die Berg}$$

  missing gender agreement
Constraint-Based Diagnosis

- **HOLLAND** (1995)
  - partial diagnoses trigger contingent errors

  \[\text{Wir stehen auf } \textcolor{red}{\textit{die Berg}}\]
  
  missing gender agreement

  \[\text{Wir stehen auf } \textit{der Berg}\]
Constraint-Based Diagnosis

- **HOLLAND** (1995)
  - partial diagnoses trigger contingent errors

\[ \text{Wir stehen auf die Berg} \]

missing gender agreement

\[ \text{Wir stehen auf der Berg} \]

NP must have dative case
Agreement in a German PP
Inflection in a Russian NP

Additional diagnostic capabilities:
- detection of erroneous inflection patterns

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Inflection in a Russian NP

- additional diagnostic capabilities:
  detection of erroneous inflection patterns
Constraint-Based Diagnosis

- alternative error perspective: fact errors
  - the student might have thought that "child" is not a singular form:
    
    \[ \text{not(value(noun,singular))} \]
• alternative error perspective: fact errors
  • the student might have thought that "child" is not a singular form:
    \[ \text{not(value(noun,singular))} \]
  • assuming the ignorance of lexical information
    • different view on the same error
    • sometimes yields more concise explanations
• alternative error perspective: fact errors
  • the student might have thought that "child" is not a singular form:
    \[ \text{not(value(noun,singular))} \]
• assuming the ignorance of lexical information
  • different view on the same error
  • sometimes yields more concise explanations
• performing a separate error simulation with lexical value assignment components
without an disambiguating context fact diagnoses are always ambiguous
Constraint-Based Diagnosis

- the two error perspectives are complementary
Constraint-Based Diagnosis

- the two error perspectives are complementary
- provide alternative information about an error
  - grammar rules vs. correction proposals
Constraint-Based Diagnosis

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- descriptions can be differently complex
Constraint-Based Diagnosis

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- both are required
Constraint-Based Diagnosis

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- Schwind (1994): rule errors only
the two error perspectives are complementary
provide alternative information about an error
grammar rules vs. correction proposals
descriptions can be differently complex
both are required
SCHWIND (1994): rule errors only
HEIFT (1999): fact errors only
Constraint-Based Diagnosis

- approach can be extended to
  - linear precedence regularities
  - co-occurrence constraints

within the limits of a fixed structural pattern
Constraints for a German PP
Constraint-Based Diagnosis

- flexible exercises
  - free lexical choice (within the limitations of the dictionary)
Constraint-Based Diagnosis

- flexible exercises
  - free lexical choice (within the limitations of the dictionary)
- highly precise diagnoses in limited exercises
  - diagnostic results can be used to retrieve alternative forms from the dictionary → correction proposals
  - explorative learning-by-doing experiments becomes possible
Constraint-Based Diagnosis

- flexible exercises
  - free lexical choice (within the limitations of the dictionary)
- highly precise diagnoses in limited exercises
  - diagnostic results can be used to retrieve alternative forms from the dictionary → correction proposals
  - explorative learning-by-doing experiments becomes possible
- no diagnostic bias
- multitude of diagnostic information
  - hypothesis selection required
  - selection can be sensitive to a didactic goal and / or the desires of the student
Late Hypothesis Selection

- system architecture
Late Hypothesis Selection

- system architecture

Structure
Identification
Late Hypothesis Selection

• system architecture

Structure Identification → Constraint-Based Diagnosis
Late Hypothesis Selection

- system architecture

Structure Identification → Constraint-Based Diagnosis → Hypothesis Selection
Late Hypothesis Selection

- System architecture

```
| Structure Identification | Constraint-Based Diagnosis | Hypothesis Selection | Feedback Generation |
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Late Hypothesis Selection

- selection heuristics
Late Hypothesis Selection

- selection heuristics
  - minimality
Late Hypothesis Selection

- selection heuristics
  - minimality
  - higher up in a syntactic structure:
    - better reflects the violated grammar rule
Late Hypothesis Selection

- selection heuristics
  - minimality
  - higher up in a syntactic structure:
    - better reflects the violated grammar rule
  - deeper down in a syntactic structure:
    - better indicates a correction possibility
Late Hypothesis Selection

• selection heuristics
  • minimality
  • higher up in a syntactic structure:
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  • deeper down in a syntactic structure:
    • better indicates a correction possibility
  • preference for constraint violations:
    • better reflects the violated grammar rule
Late Hypothesis Selection

- selection heuristics
  - minimality
  - higher up in a syntactic structure:
    - better reflects the violated grammar rule
  - deeper down in a syntactic structure:
    - better indicates a correction possibility
  - preference for constraint violations:
    - better reflects the violated grammar rule
  - preference for lexical error descriptions:
    - better indicates a correction possibility
Late Hypothesis Selection

- selection heuristics (cont.)
Late Hypothesis Selection

- selection heuristics (cont.)
  - conjunctive or disjunctive combinability:
    - results in more compact error descriptions
Late Hypothesis Selection

• selection heuristics (cont.)
  • conjunctive or disjunctive combinability:
    • results in more compact error descriptions
  • citation form preference:
    • explanations referring to the default case are more plausible
Late Hypothesis Selection

- selection heuristics (cont.)
  - conjunctive or disjunctive combinability:
    - results in more compact error descriptions
  - citation form preference:
    - explanations referring to the default case are more plausible
  - (L1 dependent) error type preference:
    - typical errors are more likely (e.g. gender in German)
Late Hypothesis Selection

• late selection is only possible for limited exercises
Late Hypothesis Selection

- late selection is only possible for limited exercises
- full enumeration of alternative hypotheses for more complex models is infeasible
  - direct integration of diagnosis and selection is necessary
Structural Constraints

- extending the idea of constraint retraction to syntactic structures
Structural Constraints

- extending the idea of constraint retraction to syntactic structures
- instead of having rules to construct hierarchical representations, use constraints to describe the space of possible structural descriptions
Structural Constraints

• extending the idea of constraint retraction to syntactic structures
• instead of having rules to construct hierarchical representations use constraints to describe the space of possible structural descriptions
• Constraint Dependency Grammar (MARUYAMA 1990)
Structural Constraints

- extending the idea of constraint retraction to syntactic structures
- instead of having rules to construct hierarchical representations use constraints to describe the space of possible structural descriptions
- Constraint Dependency Grammar (MARUYAMA 1990)
- initial space of hypotheses:
  - fully underspecified structural descriptions
  - every node modifies every other with all possible labels
  - containing all possible dependency trees for an utterance
Structural Constraints

- constraints license certain dependency edges or combinations thereof
  - dependency edges which violate a constraint can be removed from the space of structural hypotheses
Structural Constraints

- constraints license certain dependency edges or combinations thereof
  - dependency edges which violate a constraint can be removed from the space of structural hypotheses
- constraints can be weighted
  - edges which violate a constraint are deprecated not removed
  - parsing becomes a constraint optimization problem
- uncertain and preferential knowledge can be included
  - e.g. the subject usually precedes the object
Structural Constraints

Initial state of a parsing problem with three labels (DET, SUBJ, DOBJ)
Structural Constraints

\{X\} : DetNom : Det : 0.0 : X\uparrow\text{cat}=\text{det} \rightarrow X\uparrow\text{cat}=\text{noun} \land X\text{.label}=\text{DET}
Structural Constraints

Der Mann besichtigt den Marktplatz
Structural Constraints

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Structural Constraints

Der Mann besichtigt den Marktplatz

{X} : Root : Verb : 0.0 :
X↓cat=vfin → X↑cat=nil
Der Mann besichtigt den Markttag.
Structural Constraints

\{X,Y\} : Unique : General : 0.0 :
\ X\uparrow id = Y\uparrow id \rightarrow X.label \neq Y.label
Structural Constraints

Der Mann besichtigt den Markt.
Structural Constraints

\[
\{X,Y \} : \text{SubjAgr} : \text{Subj} : 0.0 : \\
X.\text{label}=\text{SUBJ} \land Y.\text{label}=\text{DET} \land X.\text{id}=Y.\text{id} \rightarrow Y.\uparrow\text{case}=Y.\downarrow\text{case}=\text{nom}
\]
Structural Constraints

Der Mann besichtigt den Markt

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Structural Constraints

- many constraints are defeasible
Structural Constraints

- many constraints are defeasible
- almost arbitrary input can be analysed
Structural Constraints

- many constraints are defeasible
- almost arbitrary input can be analysed
- constraint violations in the optimum solution can be interpreted as diagnoses
Structural Constraints

- many constraints are defeasible
- almost arbitrary input can be analysed
- constraint violations in the optimum solution can be interpreted as diagnoses
- modelling of transitive closures is only approximative
  - correction proposal cannot be derived reliably
Structural Constraints

- combination with error simulation in a two phase-diagnosis
Structural Constraints

- combination with error simulation in a two phase-diagnosis
- constraint-based error simulation
  - highly precise and supports multiple explanation perspectives
  - but requires a syntactic structure being given
Structural Constraints

- combination with error simulation in a two phase-diagnosis
- constraint-based error simulation
  - highly precise and supports multiple explanation perspectives
  - but requires a syntactic structure being given
- parsing as constraint optimization
  - (so far) no precise error diagnosis in transitive correctness conditions (like agreement)
  - but determines a syntactic structure
Structural Constraints

- combination with error simulation in a two phase-diagnosis
- constraint-based error simulation
  - highly precise and supports multiple explanation perspectives
  - but requires a syntactic structure being given
- parsing as constraint optimization
  - (so far) no precise error diagnosis in transitive correctness conditions (like agreement)
  - but determines a syntactic structure
- good synergy when used in combination
Structural Constraints

- system architecture
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- system architecture

![Diagram showing the system architecture with Constraint-Based Parser, Semantic Interpretation, Constraint-Based Diagnosis, Hypothesis Selection, and Feedback Generation]

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Structural Constraints

- semantic preferences, world knowledge and context information can be integrated into the optimisation process

\begin{verbatim}
in_front_of(church,marketplace).
left_of(church,parking_lot).
at(market_place,bakers)
count(church,1).
...
\end{verbatim}
Structural Constraints

- semantic preferences, world knowledge and context information can be integrated into the optimisation process

\[
\text{in\_front\_of(church,marketplace).}
\]
\[
\text{left\_of(church,parking\_lot).}
\]
\[
\text{at(market\_place,bakers)}
\]
\[
\text{count(church,1).}
\]

- if the ”world” contains just a single church, prefer the singular reading
Intentions for Hypothesis Selection

- Where does the constraining information come from?
Intentions for Hypothesis Selection

• Where does the constraining information come from?
• simplifying assumption: the obedient student
  • provide a scenario and a task
  • assume the student complies with the given limitations
    • static scenarios
    • dynamic scenarios
Intentions for Hypothesis Selection

- Where does the constraining information come from?
- simplifying assumption: the obedient student
  - provide a scenario and a task
  - assume the student complies with the given limitations
    - static scenarios
    - dynamic scenarios
- alternatively
  - let the student take the initiative
  - communicate with the student about her intentions
Intentions for Hypothesis Selection

- a static scenario: Meister Albrecht
Intentions for Hypothesis Selection

- a static scenario: Meister Albrecht

- (static) domain knowledge can be integrated into the error sensitive parsing
Intentions for Hypothesis Selection

- a static scenario: Meister Albrecht

- (static) domain knowledge can be integrated into the error sensitive parsing

- in rich scenarios the domain knowledge does not provide enough constraining information
Intentions for Hypothesis Selection

- a static scenario: Meister Albrecht

- (static) domain knowledge can be integrated into the error sensitive parsing

- in rich scenarios the domain knowledge does not provide enough constraining information

- dynamic scenarios allow to focus on the changing aspects of a scene (Reuer 2003)
Intentions for Hypothesis Selection

- strongest constraints could be derived from the intention of the student
Intentions for Hypothesis Selection

- strongest constraints could be derived from the intention of the student
- How to gain access to intentions?
Intentions for Hypothesis Selection

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• How to gain access to intentions?
  • verbal: asking back

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Intentions for Hypothesis Selection

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  - verbal: asking back
    
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  - non-verbal: select from a menu
Intentions for Hypothesis Selection

- more complex tasks
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  - the fridge
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- virtual world can become an alternative communication channel if the verbal communication breaks down
Conclusions

- available diagnostic techniques can produce a great variety of diagnostic information
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  → requires integrated system solutions