CONSTRAINT-BASED DIAGNOSIS OF GRAMMATICAL FAULTS

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Constraint propagation techniques are applied to the diagnosis of certain classes of grammatical faults. Although being of hardly more than typical toy problem size and complexity this novel approach involves significant improvements in diagnostic precision and explanatory quality as compared with previous solutions. It has been successfully incorporated into a natural language training environment and tested on a number of exercises of definitely practical relevance.

1 INTRODUCTION

Diagnosis of student mistakes and misconceptions certainly should be considered one of the crucial issues in the design of intelligent tutoring systems for language learning. Although student modelling components and adaptive teaching strategies doubtlessly are indispensable if stupid and boring system behaviour is to be avoided, fault diagnosis remains to be the primary question. At least in a domain such as natural language where well established standards of correctness and acceptability are common, both the modelling of the learning progress and the determination of appropriate steps in the further course of teaching depend decisively on the diagnostic capabilities of the system. These capabilities turn out to be not only the most prominent evaluation criterion but additionally are an important prerequisite for flexible and diversified language training.

Knowledge to be used by systems for fault diagnosis may well be organized in quite different ways certainly best characterized by the kind of work load distribution between the author of the knowledge on the one hand and the system's diagnostic component on the other:

(A) All the knowledge about possible faulty or correct situations is stated explicitly, thus rendering inferential capabilities of the diagnosis component superfluous. Diagnosis is reduced to merely identifying the particular instance in a list of possible solutions.

(B) The knowledge base contains generalizations (rules and facts) for classes of different situations, where rules intended to describe faulty situations are properly marked to invoke appropriate error messages if needed. Diagnosis then is a (usually nondeterministic) search to identify the set of rules matching the given situation best.

(C) The knowledge base contains only first priciples, that is, knowledge about correct situations or, in more general terms, knowledge about structure, function and behaviour of the application domain (Reiter, 1987). Diagnosis becomes a nonmonotonic reasoning procedure which tries to derive error descriptions from a model of correctness ("deep-modelled" or "model-based" diagnosis).

Traditional approaches to computer assisted language learning belong to the first category. They heavily rely on the central assumption that the author of a teaching exercise could be able to anticipate the bulk of mistakes possibly made by a student. Helpful explanations can only be expected, if the tutoring system is supplied with a collection of adequate responses to all the different errors and error combinations which eventually might occur in real training sessions, a demand which hardly can be met in any realistic natural language environment. Most efforts are spent into devising sensible teaching aids despite the absence of appropriate diagnostic techniques. The author is forced to concentrate on single teaching programs without almost any chance to generalize from his results and to reuse parts of it in other contexts later.

In order to avoid the cumbersome process of coding the data needed for each single exercise, a number of proposals towards a first generation of intelligent systems for second language learning have been offered. Most of them try to generalize from single error instances to knowledge about typical *rule* violations by attaching failure classes to observable symptoms via more or less surface-oriented rules. Properly marked, these mal-rules are included into the grammar and, if a reasonable coverage is attempted, both the difficulties in gathering a representative collection of possible mistakes as well as the danger of "bloating" the grammar are obvious.

Thus far, only very few system developments attempt to depart from the necessity to anticipate student errors (e.g. Fum, Giangrandi, and Tasso (1988)). The idea of devising flexible and error sensitive parsing strategies for some kind of context-free grammar rules attracts most attention (Barchan, Woodmansee, and Yazdani, 1986; O'Brien, 1988; Mellish, 1989). In contrast to these approaches the techniques reported in this paper follow quite another direction: instead of trying to diagnose wrong applications of complex grammar rules, it simply handles errors as violations of very elementary *correctness constraints*. This, of course, by no means implies the claim that almost all the problems of parsing ill-formes input can be solved on such a basis. Though, despite its obvious limitations the approach allows to define a good number of limited areas, where model-based techniques can be used to design sensible training aids for the purpose of language learning. A first investigation into the problem of diagnosing consistency violations has shown that a strictly deep-modelled and extremely precise diagnostic procedure can be devised, which provides a sound basis for the generation of comprehensible explanations (including proposals for a proper solution), for a valuation of the learning progress and for an adaptive determination of the further training strategy.

2 CONSISTENCY CONSTRAINTS

Consistency constraints to be used as a basis for diagnosing students' faults are expressed in a quite common way as binary predicates which hold over structured feature sets of syntactically related word forms (source and destination). Feature values, as usual, are attached to word forms via the dictionary or a morphological analysis. To specify the kind of features relevant to a specific correctness condition the binary correctness predicates are augmented by a third argument:

agree[⟨**source**⟩,⟨**destination**⟩,⟨**feature**⟩].

Source and destination uniquely denote positions in an (e.g. artificially fixed) structural description of an utterance, say, noun and determiner of a typical German noun phrase which have to agree (among others) with respect to case:

agree[**det**,**noun**,**case**].

This correctness predicate defines a symmetrical relation between the equivalent parts of the two feature structures involved. Another type of agreement predicates is needed to account for agreement between *different* features of two structures. One example are selectional demands of a source to be matched with the corresponding properties of a destination, another is given by predicates coping e.g. with the distinction between the different gender values belonging to stem and ending of German possessive pronouns.

Source and destination are treated as variables which receive their initial value binding from the dictionary of the system. In favour of an efficient diagnosis procedure feature structures are restricted to tuples of sets, where set elements are treated as *alternative value assignments*. This corresponds to a typical frame structure with morpho-syntactic features (gender, case, etc.) indicating the slots. Somewhat simplified, the instantiation of the variables **det** and **noun** to the German NP *die Schlüssel* (engl.: *the keys*) yields the following value assignments:

gender[**det**,**{femin}**] ∧ **number**[**det**,**{sing}**] ∧ **case**[**det**,**{nom,acc}**]
gender[**det**,**{masc,femin,neutr}**] ∧ **number**[**det**,**{plur}**] ∧ **case**[**det**,**{nom,acc}**]

gender[**noun**,**{masc}**] ∧ **number**[**noun**,**{sing}**] ∧ **case**[**noun**,**{nom,dat,acc}**]
gender[**noun**,**{masc}**] ∧ **number**[**noun**,**{plur}**] ∧ **case**[**noun**,**{nom,gen,acc}**]

A basically different type of predicates does not specify a source but instead gives a condition to be fulfilled by the destination:

restrict[⟨**destination**⟩,⟨**condition**⟩].

This type is always used when the source of a constraint cannot or should not be given explicitly. To achieve a uniform treatment, internally the *restrict*-predicates are converted into ordinary agreement-predicates for an artificially created feature expression at a nowhere source (indicated by ***):

restrict[noun,case={acc}] $\rightarrow$ **agree[***,noun,case]** $\wedge$ **case[***,{nom}].**

A single training exercise usually is described by a number of correctness predicates which can be combined to form a simple *constraint network*. The arcs in this network represent correctness predicates and the connected nodes are identified by the source and destination arguments. For example, the formation of German prepositional phrases for locations (dative case) and directions (accusative case) which – according to the fixed structural pattern

pattern = (preposition determiner adjective noun)

are to be inserted into sentences like

Das Geld habe ich ... gelegt. (engl: *I put the money ....*)

or given as an answer to questions like

Wohin habe ich das Geld gelegt? ... (engl.: *Where did I put the money? ...)*

Here, the network consists of five nodes and 16 edges. All the nodes correspond to word forms in the student's response, but depending on the sentence context only a subset of exactly four nodes (e.g. (prep-4 det adj noun)) is instantiated to the incoming word forms:

restrict[prep-3,cat={prep}]
restrict[prep-3,select={location}]
restrict[prep-4,cat={prep}]
restrict[prep-4,select={direction}]
restrict[noun,cat={noun}]
restrict[det,cat={art,poss-p,dem-p}]
restrict[adj,cat={adj}]
agree[prep-3,noun,case]
agree[prep-4,noun,case]
agree[noun,det,case]
agree[noun,det,number]
agree[noun,det,gender]
agree[noun,adj,case]
agree[noun,adj,number]
agree[noun,adj,gender]
agree[det,adj,inflectional-degree].

Without any difficulty the priciples of consistency descriptions can be extended to a more unusual class of consistency relations which hold *within* particular word forms of an inflected language. These relations refer to the *internal agreement* between the stem and the ending of a single form. Since some German noun stems - in addition to the usual distinctions according to gender and inflectional type - carry an explicit number flag (Umlaut) there are at least the following three consistency constraints to be considered

agree[noun-stem,noun-ending,gender]
agree[noun-stem,noun-ending,inflectional-type]
agree[noun-stem,noun-ending,number].

Combined with the ordinary external constraints these conditions will enable the system to e.g. detect student errors which may have a deeper reason in an overgeneralized application of basic inflectional schemata to some more idiosyncratic cases or to find supporting evidence for a particular external constraint violation.

Very interesting applications for internal agreement conditions can be found in some slavonic languages (e.g. Russian). Their inflectional system not only is a comparatively rich one but additionally depends on unconventional features like stress and animatedness.

3 STRUCTURAL CONSTRAINTS

Traditional grammar formalisms usually embed *structural constraints* implicitly into a framework of rather complex rules. Accordingly, the desired information cannot be used in a constraint-based diagnosis procedure, which requires constraints to be given explicitly. Ordinary context free rules of the type

$$\mathbf{S} \rightarrow \mathbf{NP}\ \mathbf{VP}$$

contain only a single type of explicit information, namely dominance relations between the element on the left hand side and the elements of the right hand side. Besides this, the rule implicitly contains different additional conditions regarding

1. the linear order of constituents (the NP has to precede the VP) and
2. the omissibility of constituents (both of them are obligatory).

This hidden information better becomes visible if the original rule is reformulated in a first order notation (Pereira and Shieber, 1987)

$$\forall\ \mathbf{x}.\ \forall\ \mathbf{y}.\ \forall\ \mathbf{z}.\ \mathbf{s[z]} \rightarrow \mathbf{np[x]} \wedge \mathbf{vp[z]} \wedge \mathbf{append[x,y,z]}$$

where the ordering constraint is given explicitly by the **append** predicate, whereas the obligatory demand results from the conjunctive connector between the **np** and **vp** predicates. The implicitness of these constraints is probably illustrated best by the considerable difficulties to express ordering or omissibility *variations* without enumerating them. Hence, existing natural language constraints cannot be stated directly but have to be spreaded across a list of alternative rules, each of which stands for an individual variant. This, of course, makes it rather difficult to diagnose respective constraint violations.

In order to transform ordering and omissibility constraints into an explicit form, an order-free and disjunctive reading of dominance rules is required

$$\mathbf{A} \rightarrow \{\mathbf{B}_1, \mathbf{B}_2, ..., \mathbf{B}_n\}.$$

Here, the set notation is intended to indicate the basic fact that

1. all elements on the right hand side are optional (at least one of them must be present) and
2. the selected elements may occur in arbitrary order.

A rule of this kind can be interpreted equally well as a disjunction of elementary and independent (local) dominance relations $\mathbf{dom}[\mathbf{A},\mathbf{B}_x]$

$$\mathbf{or}[\mathbf{dom}[\mathbf{A},\mathbf{B}_1], \mathbf{dom}[\mathbf{A},\mathbf{B}_2], ..., \mathbf{dom}[\mathbf{A},\mathbf{B}_n]]$$

or in a shorthand notation

$$\mathbf{or}[\mathbf{B}_1, \mathbf{B}_2, ..., \mathbf{B}_n].$$

Obviously, such a rule overgenerates for almost every purpose. In order to restrict it to the desired degree *cooccurrence constraints* are given by additional propositional expressions, e.g. as alternatives (exor), implication (if) or equivalence (iff) of dominance relations. A dominance relation can be made obligatory, if it is simply specified as a single element in the conjunction of constraints. Hence, by choosing a purpose specific specification of constraints optionality or obligatoriness can easily be expressed as special cases. In the simple noun phrase

NP → **{det,adj,noun}**

the determiner and the noun can be indicated as being obligatory by adding the constraint

and[det,noun]

whereby the adjective remains optional.

A more ambitious example is provided again by the German local prepositional phrase

pp → **{prep-3,prep-3-det,det,adv,adj,noun}.**

In addition to the usual dative prepositions (**prep-3**) it allows the fusion of preposition and determiner (**prep-3-det**) which is very common not only in spoken German (*an + dem = am*, *in + das = ins*, etc.). The additional constraints

exor[prep-3,prep-3-det]
or[adj,noun]

iff[prep-3,det]
if[adv,adj]

require a prepositional phrase to contain one and only one preposition and exactly one determiner, independently of being fused or not. Adjective and noun both are optional (but not simultaneously) and the admissibility of an attributive adverb depends on the existence of the modified adjective.

To describe the omissibility of dominated nodes (e.g. for the determiner) simple logical conditions (e.g. for the presence or absence of certain semantic features) may be included into the set of constraints.

To model *ordering constraints* in an explicit way too, precedence relations between dominated nodes are required. A similar approach has first been used in the GPSG framework (Gazdar et al., 1985). For the purpose of constraint-based diagnosis it can be slightly extended to allow absolute constraints like

last[noun] (the noun of a NP takes the last position)

in addition to the relative ones

precedes[adv,adj] (the adverb is placed in front of the Adjective)

Apparently, this simple formal framework is far from being sufficient to write complex grammars. Nevertheless, it can serve to build tiny (but non-trivial) specialized grammars covering e.g. simple types of main or subordinate clauses, extended noun phrases with left and/or right attributes etc. which then meet the rather strong preconditions for an application of constraint-based diagnosis techniques.

4 DIAGNOSIS

The diagnosis component has been designed as a highly specialized system for constraint propagation through a network. In accordance with the requirements of the application domain the procedure is restricted to handle discrete, non-numerical values only. Additionally it supports very few, carefully selected data types and respective constraint relations for them.

According to the fundamental distinction between (a) rules (consistency and structural constraints) and (b) facts (feature values from the dictionary, position numbers from the input sequence, etc.) two types of misconceptions have to be distinguished: *rule violations* and *factual faults*. Diagnosis, accordingly, is carried out in two steps: a procedure for constraint inference (following the terminology proposed by Davis (1987)) where rule violations are diagnosed and a subsequent, extended label inference which is able to detect and localize factual faults. Each predicate in the network is repeatedly applied to its variables and the values at the source and the destination are updated according to specific propagation conventions. Propagation (locally) terminates if it results in the transmission of an empty value set.

A solution proposed by the student can be considered a valid one if the network finally reaches a global state of quiescence with non-empty value sets at all network variables. Otherwise an error has been detected and different hypotheses have to be tried in order to localize the fault precisely. To achieve this goal, logical negations of different predicates (agreement or ordering demands, initial value bindings, etc.) are tried for assimilation into the network. Each negated predicate can then be interpreted as an error hypothesis (suspecting the student did ignore exactly that particular constraint or those value bindings) and its consequences are followed up around the network. Theoretically this kind of reasoning is motivated by a closed world assumption (Reiter, 1978). Technically it is achieved by simply continuing constraint propagation with modified propagation conventions. Given, for example, the faulty German NP **des Schlüssel* (engl.: *the key*) the inference procedure fails to assimilate simultaneously

agree[noun,det,number] and **agree[noun,det,case]**

because of the initial variable binding

$$\begin{array}{l}\textbf{case[det,\{gen\}]} \wedge \textbf{number[det,\{sing\}]} \wedge \ldots \\ \textbf{case[noun,\{nom,dat,acc\}]} \wedge \textbf{number[noun,\{sing\}]} \wedge \ldots \\ \textbf{case[noun,\{nom,gen,acc\}]} \wedge \textbf{number[noun,\{plur\}]} \wedge \ldots ,\end{array}$$

but the rule error diagnosis succeeds in assimilating either

$\neg$ **agree[noun,det,number]** or $\neg$ **agree[noun,det,case]**,

hence establishing two independent rule error hypotheses and (locally) removing the inconsistency from the network.

Equally well the diagnosis is able to assimilate the "negated" value bindings

$$\begin{array}{l}\neg\ \textbf{case[noun,\{nom,dat,acc\}]} \wedge \textbf{number[noun,\{sing\}]} \wedge \ldots \\ \leftrightarrow\ \textbf{case[noun,\{gen\}]} \wedge \textbf{number[noun,\{sing\}]} \wedge \ldots\end{array}$$

or

$$\begin{array}{l}\textbf{case[noun,\{nom,gen,acc\}]} \wedge \neg\ \textbf{number[noun,\{plur\}]]} \wedge \ldots \\ \leftrightarrow\ \textbf{case[noun,\{nom,gen,acc\}]} \wedge \textbf{number[noun,\{sing\}]} \wedge \ldots\end{array}$$

thereby simulating two different factual faults of the student.

Because of the uniquely defined position numbers of an input word form, violations of *linear ordering constraints* can be detecded locally without any difficulty. Hence, the diagnosis of deviant orderings is concerned only with the simulation of factual faults. If, for instance, the input string **der Tisch große* (engl.: **the table big*) is associated with the initial value binding

position[det,1]
position[adj,3]
position[noun,2]

a constraint violation between the adjective and the noun is detected

$\neg$ **precedes[adj,noun]**.

The factual fault diagnosis yields the following value assignments

$\neg$ **position[adj,{3}]** $\wedge$ $\neg$ **position[noun,{2}]**
$\leftrightarrow$ **position[adj,{1,2}]** $\wedge$ **position[noun,{1,3}]**,

which can be simplified further by subsequent constraint applications which result in the only possible correction proposal

position[adj,{2}] $\wedge$ **position[noun,{3}].**

Cooccurrence constraints do have a special status. This is caused by the boolean nature of their value domain (the word form is present in the input string or not) which renders the use of value alternatives senseless. Nevertheless the diagnosis is not trivial, since it has to consider (a) that a cooccurrence violation may have several reasons (e.g. an alternative may be violated because of both arguments present or both missing) and (b) that the transitivity property of certain constraints is to be respected.

In all these cases the diagnostic procedure clearly profits from the specifics of the application domain where in contrast to domains dealing with possibly infinite sets of numerical values the complement of a value set turns out to be a sensible restricted value set again and without any difficulty can be used in the further course of reasoning.

The search carried out is exhaustive with respect to solutions containing a minimum number of negated predicates. In particular, the diagnosis component is able to detect multiple faults as well as alternative diagnostic readings (which are quite common in natural language applications).

Rule violations and factual faults are simulated independently in order to yield distinct error descriptions which interpret a mistake both in terms of rule violations and in terms of factual faults. Compared with a mixed simulation this sometimes results in slightly more complex diagnostic results. More important, however, was the observation that although a mixed simulation is considerably more expensive, "mixed" results usually turned out to be almost unexplainable.

5 GENERATING ERROR EXPLANATIONS

Under normal circumstances the primary results obtained by the diagnosis procedure are not directly suited for the purpose of error explanation. Most error descriptions are much too complex to be verbalized immediately. To avoid verbose and uncomprehensible explanations, some simple *generalization schemata* based on pattern matching can be used to aggregate elementary descriptions by emphasizing the different parts. Hence, the two competing diagnoses for the consistency example above can be compressed and verbalized as

Missing number or case agreement between determiner and noun.

Another possibility to reduce the complexity of diagnostic results is the selection among alternative error descriptions. This task is an integral part of several steps of the diagnosis procedure. It always tries to reduce the number of concurrent error descriptions to a single one. By using a global simplicity criterion the diagnosis procedures for both rule violations and factual faults select on the minimal number of primary errors per error description. Since error generalization again may influence the explanatory complexity, its results in turn are subject to a minimal-number-of-errors decision.

A second important criterion for error selection is the purpose (defined by the intended teaching strategy) for which error descriptions are derived. According to the basic distinction between rule violations and factual faults, two different diagnostic views on a particular error can be supported: (i) indicating the regularities not captured by the student and (ii) showing the mistaken facts which is always equivalent to giving a hint where to correct the utterance best.

Hitherto existing experiences show a constraint violation and/or an error "higher up" in a hierarchical syntactic representation of the utterance best suited to rather exactly pinpoint the conceptual mistake. On the other hand a factual fault and/or an error "deeper down" in a syntactic tree better points at the existing possibilities for an improvement of the partially wrong solution.

Sometimes these different views may differ substantially. This situation is given, for instance, if in the second consistency example above a student inserts the *directional* prepositional phrase *auf den großen Tisch* (engl.: *on the big table*) instead of a *local* one required by the context. In this case the uppermost constraint violation could be verbalized e.g. as

The complete prepositional phrase is of wrong case.

whereas the bottom factual fault directly gives a repair suggestion:

Try to correct the determiner!

If necessary, certain classes of factual faults may be suppressed, because they result in doubtful correction proposals (e.g. in a given semantic context a gender-of-the-noun error can hardly be repaired by simply exchanging the noun in question).

In any case the generation of error explanations has to take care of the transitivity of most constraints. Given the distorted linear ordering **der Tisch sehr große* (engl.: **the table very big*) an explanation like

The adjective has to be placed in front of the noun.

might be somewhat confusing, although it exactly reflects the only one ordering constraint violated

$\neg$ **precedes[adj,noun]**.

More useful could be the verbalization of the transitive closure

Adverb and adjective have to be placed in front of the noun.

6 INITIAL VALUE BINDING

Constraint propagation techniques ultimately require all necessary values being bound to the variables of the constraint network *before* any inferencing can be carried out. Accepting unrestricted input, this demand is equivalent with the necessity to have some kind of parsing result already *in advance* of the diagnosis procedure to start. Shifting almost all constraining information from traditional syntactic rules into explicit, but refutable constraints makes parsing an increasingly difficult enterprise. Whereas for models with only a single dominance rule (like in the example for the prepositional phrase above) a value binding procedure can be realized very easily, multiple rule models are facing enormous efficiency problems, since valuable information usually used to reduce the search space has been lost.

With the basic definition of dominance to be a disjunctive combination of potential dominance relations, a grammar can be interpreted as an OR-tree and structural identification (parsing) becomes a procedure of attaching all the word forms occurring in the input sequence to corresponding leaves of the grammar tree. This, of course, restricts practical solutions to finite trees, i.e. nonrecursive dominance relations. For nonrecursive relations the search space becomes finite but remains nevertheless extremely large. Even for very small grammars many combinations of possible attachments exist, each of which stands for a separate constraint satisfaction problem, which to solve normally requires a combinatorial procedure again.

Accordingly, a reduction of the search space has to be achieved by means of different heuristics:

1. Certain compatibility constraints which are unlikely to be violated by the student (e.g. two prepositions in a single prepositional phrase) can be made implicit. In that case, they cannot be negated and consequently cannot be used for explanatory purposes. They, however, may well be used to exclude senseless word form attachments.

   Since this heuristics often applies for clearly alternative dominance relations, the tree of dominance possibilities gets an implicit or/exor-structure. A very similar technique can be applied for optional subordinated constituents, where the subordinated constituent should be accepted only, if at least something of of the dominating constituent has been identified.

2. Useless permutations may be excluded during the attachment by maximising a locality measure. This heuristics fails systematically in case of certain embedded constituents, where it prefers to attach e.g. a determiner to the embedded noun phrase instead of assigning it to the more distant noun.

3. A reuse of partial results can be facilitated by a clustering of functionally different constituents (Subject, Object, etc.) according to their structural equivalence (NP, PP, etc.).

4. A data driven best first analysis should be tried.

For simple grammars of modest complexity these heuristics usually reduce the ambiguity of attachment to a few readings which remain to be passed to the consistency check. Since even very simple grammars often are quite sufficient for language learning purposes, indeed a kind of restricted, but nevertheless useful parsing system mainly based on constraint satisfaction techniques can be devised. This at least allows to considerably soften the strong limitations imposed by e.g. a fixed syntactic pattern. Considering however the rapidly growing search space required for more complex models, an extension of the approach to the level of a language covering grammar obviously seems not feasible.

7 CONCLUSIONS

Although it is connected with a number of interesting advantages, constraint-based diagnosis clearly should not be considered the *sine qua non* of future tools for language instruction. Based on the very idea of a closed world, it is by definition limited to the rather narrow domains of knowledge about natural language which allow a highly reliable and complete description of the necessary correctness conditions. In such domains the constraint-based approach provides a very precise diagnostic procedure which in particular is well suited

- to produce comprehensible error explanations and repair suggestions,
- to diagnose multiple faults,
- to obtain different readings of an error and
- to support different views on a student's mistake.

The diagnostic results for the consistency examples above are precise to a degree which allows the retrieval of the correct solution(s) directly from the dictionary by means of the value sets computed during factual fault simulation. The same holds for linear ordering constraints where possible permutations are generated from the diagnostic results. Despite this extremely tough correctness citerion and extensive testing no instance of diagnostical misbehaviour has been detected thus far. This unexpectedly high reliability of system responses facilitates unconventional approaches to language teaching in supplement to traditional strategies. In particular student driven experimentation (as discussed for procedural aspects of language learning in Zock, Sabah, and Alviset (1986)) becomes possible, where the student is asked to infer language regularities using the explanations elicited from the system on a trial-and-error basis.

Based on the priciples described a prototype system for single rule systems has been realized which integrates the diagnosis procedure into a simple learning environment. Besides the guiding advice of a sentential context additional measures have been taken to avoid the student feeling uneasy about the limitations of the exercise. Using a menu-based input mode it becomes possible not only to inspect the dictionary at run time but also to select appropriate word forms from it. Thus a quick and convenient interaction facility is offered and the student is encouraged to construct his solution in a toy kit manner from the available stock of word forms.

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