English Error Correction: A Syntactic User Model Based on Principled "Mal-Rule" Scoring

Kathleen F. McCoy
Christopher A. Pennington
Computer and Information Sciences Department and
Applied Science and Engineering Laboratories
University of Delaware / A.I.duPont Institute
Newark, DE 19716

Linda Z. Suri
Central Institute for the Deaf
818 S. Euclid
St. Louis, MO 63110

Abstract

We discuss a user model which can be tailored to different types of users in order to identify and correct English language errors. It is presented in the context of a written English tutoring system for deaf people who use American Sign Language.

Our approach to identifying the errors is to augment a standard grammar of English with a set of error productions (mal-rules) which expand the grammar accepted by the parser. We use a scoring mechanism to activate and initialize a subset of possible mal-rules for a given user. The scoring mechanism is affected by two major user modeling components. The first component is a static model of the first language which can be used to identify places where language transfer might take place. The second component is more dynamic and is based on a model of second language acquisition, zeroing in on aspects that may be causing current difficulties.

We motivate and explain the components of our model and then show how it can be generalized to other language assistance applications.

Introduction

In this paper we discuss a user model which can be tailored to different types of users to identify errors in written English. The user model (and method of identifying errors) is used in two very different applications:

- A written English tutoring system for people who are deaf American Sign Language (ASL) users learning written English as a second language.[1]
- A (word-based) communication device for people whose physical disability makes it difficult to communicate in an understandable fashion. The device allows the user to "select" a telegraphic message and converts it into a full English sentence.

Here we concentrate on the syntactic phase of processing and describe a user model for determining how the input differs from standard English. Our approach to identifying language errors which have syntactic and/or morphological manifestations[2] is to augment a standard grammar of English with a set of error productions (mal-rules) (Sleeman 1982),(Weischedel, Voge, & James 1978) which expand the grammar accepted by the parser to include the expected variations. The mal-rules are annotated to indicate the errors that they capture.

Problems that must be faced include (1) what mal-rules to include in the grammar, and (2) since it is likely that several parses of the input will be possible (i.e., some containing mal-rules and some not, some using different mal-rules than others), how does the system decide which parse is the "correct" one? We propose that a mal-rule scoring mechanism be used to select the most reasonable parse (and to order the alternatives). The scores for the individual mal-rules will be based on several factors and somewhat dependent on the application. The major component of the scoring mechanisms consist of two parts. One part is rather static and captures features of the expected language. The second part is more dynamic and can be thought of as zeroing in on specific aspects of the first model. For instance, in the context of a second language learning program the two models are the following:

1. a model of the user's first language – this will help identify places where language transfer might take place
2. the level of acquisition of the second language – this parameter is dependent on the individual and should be updated over time. It helps identify which aspects of the first language might be causing current difficulties.

In the case of the communication device expecting telegraphic speech, the more static model captures differences between telegraphic input and standard English. The dynamic model is closer to a model of first language acquisition which captures how this language might be expected to change as the user becomes more proficient. It also captures user's preferences as they become accustomed to the device.

In this paper we describe our overall approach to error identification in the context of a Computer Assisted Language Learning (CALL) tool for learning English as a second language. We make our analysis concrete by relying on examples from the application of American Sign Language (ASL) users learning written English. This tool is called ICICLE (Interactive Computer Identification and Correction of Language Errors). While we motivate our user model and the components of the scoring mechanism in the context of the ICICLE project, we argue that a similar analysis could hold for other second language learning applications as well. In addition, we show how the user model could generalize

[1] It should be noted that ASL is a language whose structure is very different from that of English.

[2] Several common errors require semantic and discourse information for recognition. Here we concentrate on errors that can be recognized syntactically.

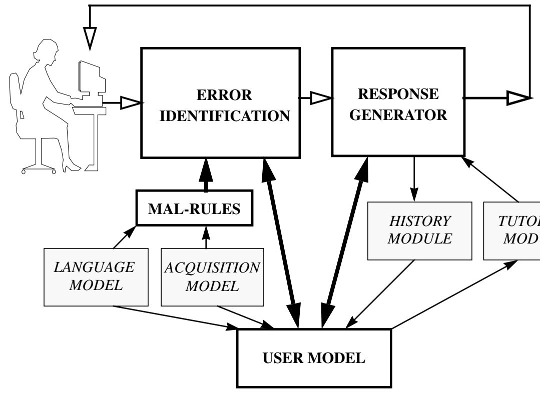

Figure 1: ICICLE Overall System Design

for totally different applications (such as the communication device mentioned earlier).

Writing Tool for Deaf Students

The problem of deaf literacy has been well-documented and affects every aspect of deaf students' education. Since data on writing skills is not well documented, we note that the reading comprehension level of deaf students is considerably lower than that of their hearing counterparts, "... with about half of the population of deaf 18-year-olds reading at or below a fourth grade level and only about 10% reading above the eighth grade level..."(Strong 1988). We have undertaken a project designed to act as a "writing tutor" for deaf students acquiring written English. We envision a system that will analyze a text written by a deaf student, identify errors in the text, and engage the student in a tutorial dialogue aimed at some subset of the errors identified.

Figure 1 contains a block diagram of the overall system under development. In this paper we concentrate on the *error identification* phase. In the ICICLE system, the input/feedback cycle begins when the user enters a portion of text into the computer. The user's text is first processed by the error identification component which is responsible for tagging all errors found in a given input (some subset of these errors will be corrected in detail by the response generator). At present, error identification processes one sentence of input at a time. It first does a syntactic parse of the sentence using the grammar of English augmented with error production rules called mal-rules. Each mal-rule is annotated to indicate the type of error it is intended to recognize. This expanded grammar is used to produce a syntactic parse of the input. If several possible parses are found, the system must choose the one that best accounts for the input. The scoring mechanism described in this paper will be crucial for this task. As indicated in the figure, the mal-rule scoring is dependent on the first language model and a model of the acquisition of English as a second language. These two models are motivated below. If one of the syntactic mal-rules was used in the parse, the sentence and the annotations from the mal-rule used will be passed to the *response generator*. The identification component must also contain semantic rules and discourse information. These may also add annotations for the response generator.

After all analyses have been completed, the text, along with the error results and annotations from error rules, will be passed to the response generator. The generator component processes this information, along with data from the user model (only a portion of which is described in this paper) and possibly the history module, in order to decide which errors to correct in detail and how each should be corrected (including what language level[3] should be used in any required instruction). The response generator must also select an appropriate tutoring strategy. Finally, the responses are displayed to the user who then has an opportunity to enter corrections to the text and have it re-checked. During the system processing, history information about the user is kept and updated.

While the overall system user model contains various characteristics useful for different portions of the processing, in this paper we focus on the error identification phase of the processing and on the type of user model required in this phase. We argue that that model must capture potential places of language transfer and also account for the user's errors changing over time as they acquires written English. It should be noted that these aspects of the user model are also crucial for the response generator portion of the system.

Common Errors in the Written English of People who are Deaf

A major claim of our work is that a model of the first language should be included as a component in a user model responsible for identifying errors in the production of a second language. This model should indicate places where (both positive and negative) language transfer may occur. This claim is made on the basis of an analysis of writing samples[4] collected from a number of different schools and organizations for the deaf, concentrating on proficient ASL signers.[5] Table 1 contains the error taxonomy we derived from the analysis of about 80 writing samples. Also included in the table is the number of sentences (out of 370) which contained at least one deviation which could be explained by each classification. These numbers are based on a subset of the analyzed samples (21 samples, 3490 words) which were added into a database that we developed to aid in statistical analysis of our findings. The intention of the numbers is to show the relative frequencies of the various error classes to judge their overall significance (but note that if a class occurred multiple times in a sentence it was only

[3] While in theory instruction in ASL might be useful, the generation of ASL is well beyond the scope of this work.

[4] Other researchers (e.g., (Power & Quigley 1973), (Quigley, Wilbur, & Montanelli 1976), (Russell, Quigley, & Power 1976), (Quigley, Power, & Steinkamp 1977), (Kretschmer Jr. & Kretschmer 1978), (Quigley & Paul 1984)) studied errors in deaf writing. Our work differs in that we attribute many errors to language transfer (LT) between ASL and written English as is explained below.

[5] We would like to thank John Albertini of the National Technical Institute for the Deaf (NTID), Bob McDonald of Gallaudet University, Lore Rosenthal of the Pennsylvania School for the Deaf, George Schellum (formerly) of the Margaret S. Sterck School, and MJ Bienvenu of the Bicultural Center for helping us gather writing samples.

counted once). See (Suri 1993) for further discussion of the counting method and problems encountered when counting errors.

Table 1: Error Taxonomy

- **NP and VP Conjunctions**: 18
  - Omitted conjunction: 10
  - Inappropriate conjunction: 7
  - Extra conjunction: 1
- **Inappropriate sentential conjunction:** 2
- **Prepositions**: 79
  - Omitted preposition: 27
  - Inappropriate preposition: 35
  - Extra Preposition: 17
- **Determiners**: 92
  - Omitted determiner: 49
  - Inappropriate determiner or determiner formation: 17
  - Extra Determiner: 26
- **Incorrect Subject-Verb Agreement**: 14
- **Tense and Aspect**: 95
  - Dropped Tense: 6
  - Extra Auxiliary: 7
  - Missing Auxiliary: 2
  - Incorrect Modal: 3
  - Missing Modal: 2
  - Extra Modal: 1
  - Other tense/aspect problems: 74
- **BE, HAVE (non-Auxiliary)**: 28
  - Omitted BE: 18
  - Lack of BE/HAVE distinction: 10
- **Other Omitted Main Verbs**: 15
- **Incorrect Main Verbs**: 13 (Poor lexical choice)
- **Relative Clauses**: 26
  - Relative pronoun deletion: 5
  - Resumptive pronoun: 1
  - Incorrect WH-relative pronoun: 4
  - Other: 16
- **Mixing up English words or phrases which share a single ASL sign**: 24
- **Adjective and Adverb Problems**: 27
  - Incorrect Adjective Choice: 3
  - Incorrect Adjective Formation: 13
  - Mixing up Adjectives and Adverbs: 2
  - Incorrect Adjective Order: 1
  - Missing Adjective: 2
  - Other Adverb Problems: 6
- **Incorrect Number on Noun**: 36
- **Problems with Noun Formation** : 6
- **Problems with Referent Formation** : 5
- **Pronouns**: 25
  - Incorrect pronoun choice (including pleonastic): 12
  - Inappropriate pronoun use (where full definite descriptions are required): 11
  - Lack of pronoun use (overuse of definite descriptions): 2
- **Pleonastic Pronoun Problems**: 20
  - Object Deletion: 4
  - Subject Deletion: 8
  - Incorrect Pleonastic Pronoun: 5
  - Other Pleonastic Pronoun Problems: 3
- **Redundancy Problems**: 7
- **Other Problems that may be related to Focus/Discourse Structuring**: 76
  - Noun Phrase Omission (subject: 16; object: 15): 31
  - Problems carrying over general/specific description strategies: 6
  - Structuring Problems with "because": 9
  - Other (may be related to topic-comment structures, or verbs of ASL): 25
  - Other: 5
- **Other Inappropriate Ellipses**: 10
- **Run-on Sentences**: 8
- **Idioms, word choice, hard to define problems**: 36

Characterizing and Explaining the Deviations in Terms of LT

While the taxonomy is useful for a writing tool specific to this population, we would like a general explanation for the errors. Not only would this allow us to both predict more error classes and provide information to include in a tutorial correction[6], but a general explanation might carry over to writing tools for different populations as well. Our analysis indicates that language transfer (LT) can account for many of the errors found (Suri 1993). This finding allows us to view ICICLE as a tool that can be used for learning English as a second language with ASL being the first language.

The term Language Transfer has been used to refer to the influence of knowledge of one language (L1) in the production and/or comprehension of a second language (L2). Transfer may be positive (in the sense that it may speed the acquisition of the L2), however it may also result in deviations in L2 production in places where the L1 and L2 differ. While the existence of LT has been a rather controversial subject over the years (see (McLaughlin 1987),(Gass & Selinker 1983),(Suri 1991)), much recent research has provided convincing evidence of LT (see (McLaughlin 1987), (Gass 1984), (Gass & Selinker 1983)).

Given that transfer has been documented between spoken languages, one might ask whether or not LT could occur between ASL (a visual-gestural language) and written English. At first glance, transfer may seem surprising since the components of ASL grammar and written English grammar are very different (Stokoe, Jr. 1960), (Baker & Padden 1978), (Padden 1982), (Hoffmeister & Shettle 1983), (Klima & Bellugi 1979), (Bellman, Poizner, & Bellugi 1983). ASL grammar components include sign order, morphological modulations of signs, and non-manual behavior which occurs simultaneously with the manual signs (Baker & Cokely 1980), (Liddell 1980), (Padden 1981), (Kegl & Gee 1983), (Ingram 1978), (Baker 1980). Written English grammar components include word order, morphological modulations of words, and punctuation, but nothing that clearly corresponds to the simultaneous non-manual behavior found in ASL. On the surface, the fact that ASL and written English occur in different modalities seems problematic as well. However, there is evidence that ASL is processed similarly to spoken languages (e.g., (Sacks 1990)).

A Characterization of LT. Because of the differences (in grammar and modality) between ASL and English, we have attempted to abstractly characterize how languages could differ in a way which is independent of the grammar components. We have identified several ways in which languages may differ which might lead to (negative) transfer by looking at language on a *feature* by *feature* basis.

- Two languages may differ in *when* they mark a particular feature. As a result the marking of that feature in the L2 may seem redundant in the first language. For example, in ASL it is usual to establish tense at the beginning of a discourse segment or time frame, and then not to mark it again until the time frame changes. Of course, in English, tense is marked (on the verb) in every finite clause. So, marking tense in every finite clause in English may seem redundant to an ASL signer. Transfer of such a feature (i.e., when to mark tense) might explain omission errors (in this case, of tense markings) in the L2.

- Two languages may differ in *how* they mark a feature. For example, in ASL, Yes/No questions are distinguished from declarative statements with non-manual markers (facial expression and body shifts). This is radically different from the word order changes which typically mark Yes/No questions in written English. Thus LT might

[6]Recall that the mal-rules have associated annotations to be used in response generation.

explain errors in Yes/No question formation by an ASL user.

- Languages differ in regard to requiring morphological changes or additional lexical items for strictly syntactic reasons. For example, English requires a subject-verb agreement marking (an "s") on most verbs in the present tense when the subject is third-person-singular. This morphological marking often conveys no extra information. The situation with regard to subject-verb agreement is more complex in ASL; when subject-verb agreement is marked, it involves a radically different marking than the agreement marking of English, and the marking is (generally) not empty of informational content. This may explain omissions of the morphological marking ("s") on these verbs in the written English of proficient ASL signers.
- As with any two languages, English often has two or more words or phrases which correspond to a single ASL sign (or sign sequence), and vice versa. For example, ASL uses the same sign (i.e., lexical item) for "other" and "another". Thus, LT might explain why an ASL learner of written English may have difficulty learning which word ("other" or "another") to use in English.

Examples of Error Classes Attributable to LT. Many of the error classes uncovered in our analysis follow from one (or more) of the above categories of differences between ASL and written English. We illustrate our analysis by providing a few examples of the error classes, explaining how each could be captured by our characterization above. (More detail on ASL, LT, and their effects on deaf writing can be found in (Suri 1991),(Suri 1993).)

Conjunctions: Omitted Conjunction

- "He taught _ directed, for almost 30 years . . ."[7]

While researchers have identified several kinds of conjunctive markings in ASL ((Padden 1981), (Baker-Shenk 1988)), there are many places where an explicit lexical item marking conjunction would be required in English, but not in ASL. For instance, conjoined verbs do not require an explicit separate lexical item (Fant 1983). Therefore, it is not surprising that an ASL signer would omit 'and' between (the final and next-to-final) conjoined verbs in written English. This omission could be the result of the marking seeming redundant or radically different to an ASL signer.

Incorrect Subject-Verb Agreement

- "*My brother like* to go..."

In ASL, not all verbs mark subject agreement for person and number. For certain verbs (some directional and classifier verbs) subject agreement is indicated by a change in handshape, a change in movement, or (rarely) the use of an overt NP where it would not normally be needed (Padden 1981). However, there is a large class of verbs in ASL which do *not* vary in form for person and number of the subject (see (Padden 1981)). In addition, some directional verbs vary in form according to the person and number of the *object* (Baker & Cokely 1980), (Fant 1983).

That subject-verb agreement is a syntactic constraint in English, coupled with the difference in *when* and *how* agreement is marked in the two languages, might explain deviations in how subject-verb agreement is marked in the written English of ASL signers.

Tense and Aspect

- "We *went* to see Senator Biden's office ... Then we *go to see* the Vietnam memorial ...."
- "Many students rather *live* at college, than *living* at home." (Possible Correction: *"Many students would rather live at college than live at home."*)

In our data we found missing and incorrect tense markings, and missing and incorrect aspect markings. These might be explained by differences between when and how ASL and English mark tense and aspect (see (Klima & Bellugi 1979), (Baker-Shenk 1988), and the text above).

BE, HAVE: Omitted or Lack of Distinction

- "Once the situation changes they _ different people."
- "... some birth controls *are* side-effect." (Possible Correction: *"... have side-effects..."*)

In some situations, ASL signers might fingerspell the word "be"; however, generally the idea of being is conveyed through the use of a topic-comment structure. That is, generally, a topic is set up, and then properties are attributed to the topic (the topic and comment are distinguished non-manually). Because the idea of being is conveyed in English in a *radically different* manner than in ASL, it is not surprising if it takes time for an ASL signer to learn to use a lexical item (for "to be") to convey the idea of being. While ASL does include a "have" sign, it is often omitted if it can be assumed from the context.

Mixing up English words or phrases which share a single ASL sign

- "Somehow, *I am interesting in ASL* and I want to learn it."

A single sign in ASL corresponds to both "interesting" and "interested."

Sample Analysis Summary. Our work in this area has included an analysis of writing samples from deaf writers who are proficient in ASL. The analysis supports the hypothesis that these people are using the natural and beneficial strategy of building on their ASL knowledge when acquiring English. Our findings revealed that many of the error classes (perhaps as much as 76% of those found in our initial sample analysis) could be attributed to Language Transfer (LT) from ASL to English, if LT is defined in the way that we suggest. However, we do not claim that every instance of an error class could be explained by LT necessarily arises from LT. There are other factors at work as well.

Mal-Rules and Second Language Acquisition

Our characterization of language transfer (and subsequent sample analysis) greatly influences our user model for error analysis. In particular, we propose that the model of the first

[7]**Note:** "_" is used to mark places where we think the writer has omitted one or more words from the corresponding correct English sentence.

language be represented according to "features" such as we described in our analysis. At the same time, we suggest that a set of mal-rules be used to capture the surface realizations of these features.

As a simple example, consider the error class "subject-verb agreement." In English, generally a +s marking on a present-tense verb is required for third person singular subjects. A mal-rule to handle errors of this feature would fire when the +s verb marking was not present. This mal-rule would also be annotated to indicate what the rule was intended to capture.

The Dynamic User Model: Acquisition of a Second Language

The user model that we have described so far captures (at equal likelihood) all potential places of language transfer. However, every student will not always make every error invited by language transfer. In addition, the set of errors made by a student will most likely change over time as the second language is acquired. Yet, the set of errors should not change randomly. In particular, a student will probably acquire certain features of the L2 before others. We would therefore expect more errors in constructions that the student is "ready" to acquire since a student would know enough to use the new constructions but not enough to use them correctly and consistently.

The dynamic aspect of our user model draws on work in language learning research dealing with order of acquisition, and on language assessment, to adjust the scores on our mal-rules to errors expected due to the student's current level of L2 acquisition.[8] The system should choose those errors that are within the users range of development given his/her current competence (Vygotsky 1986), (Rueda 1990). A primary goal of this work is to develop a consistent and theoretically sound model that can be used to evaluate each user's English language proficiency. This profile will be used to help determine a preferred interpretation when either the error or its underlying cause is ambiguous (e.g., when results from error identification suggest more than one possible correction for a single error).

There is considerable linguistic evidence that the acquisition order of language features is relatively consistent and fixed (Ingram 1989), (Dulay & Burt 1974), (Bailey, Madden, & Krashen 1974). In fact, a stronger version of this statement is one of the central tenets of universal grammar theory (see for example, (Hawkins 1991) and (Keenan & Hawkins 1987)). These findings have become the foundation for the development of a language assessment model called SLALOM ("Steps of Language Acquisition in a Layered Organization Model").

The basic idea behind SLALOM is to divide the English language (the L2 in our case) into a set of feature hierarchies (e.g., morphology, types of noun phrases, types of relative clauses) according to their relationships and complexity. Then features of similar complexity are grouped into lay-

[8]We note that this model is also of major importance in the response generation phase of ICICLE. The response should focus on those aspects of written English that the user is in the process of acquiring.

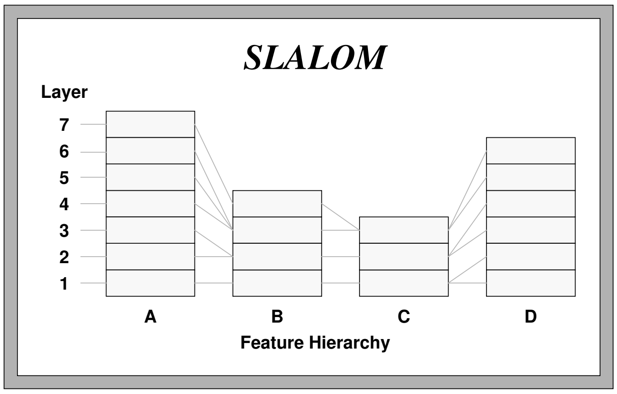

Figure 2: Language Complexity in SLALOM

ers representing stereotypical "levels" of language ability.[9] Layers allow a system using this model to make reasonable default inferences when little knowledge is available. For example, if the user has not expressed a language feature before, the system can assume its acquisition level based on other features that are "known". Figure 2 is a conceptual diagram of what the assessment model will look like.

Each feature hierarchy is ordered according to complexity. So, assume A represents the morphology hierarchy: plurals are generally acquired before irregular past tense forms, so plurals might be at some Layer *X* while irregular past tense would be at Layer *X+2*. If adjective noun clauses appear at about the same time as irregular past tense forms then they might be positioned at Layer *X+2* in Feature Hierarchy D. Since separate hierarchies may contain different numbers of features, it is likely that some of the layers will be collapsed for certain hierarchies. Most of the evidence for the cross-hierarchical groupings are based on statistics and educational "grade" expectations. Possibilities for defining the default levels can be found in (Lee 1974) and (Crystal 1982). It is expected that a combination of existing assessment tools will be needed to ensure adequate coverage of all English language features.

Using SLALOM. We anticipate that SLALOM will initially outline the typical steps of second language acquisition. This model will then be tailored to the needs of individual users via a series of filters (one for each user characteristic that might alter the initial generic model). For instance, it is possible that the specific features of the user's L1 will affect the rate or order of acquisition of the L2. In particular, one would expect features shared in the L1 and L2 to be acquired more quickly than those which are not (due to positive language transfer). Also, difficulties encoded within the error taxonomy would be reflected here as well.

For example, the developmental model alone might order the acquisition of construction-1 before the acquisition of construction-2. However, an L1 filter might change this order of acquisition because construction-2 has an analog in

[9]Note the similarity to (Chin 1989) in the Unix domain. Our grouping, however, is motivated by language acquisition literature.

Figure 3: Scoring Mal-Rules in Context of SLA

ASL which would allow it to be transferred. Thus, a filter which alters the content of the model based on a model of the user's L1 is anticipated. Another possible filter has to do with how much and what kind of formal instruction the user has had in written English. For example, if the formal program stressed subject-verb agreement, this feature might already be acquired while others before it in the original model might still remain problematic.

In developing the language learning model and its filters, we plan to compare our initial model (to be derived from acquisition literature) with the writing samples that we have already collected.[10] We also plan to seek input from English teachers of deaf students. We would like to collect samples of teachers' corrections, and compare these to the models that will have been hypothesized.

We anticipate that the initial placement of the user in SLALOM will be based on an analysis of the first input sample. The system must take note of which constructs seem to be used correctly in the sample, which constructs the user is attempting to use but with some problems, and which constructs are missing from or used incorrectly in the sample. Once this initial determination is made, further input from the user and feedback given during the correction and tutorial phases could cause the system to update the user's "profile" in the model.

Summary of the two models proposed for Second Language Acquisition (SLA)

While we have described our model in the context of ASL users learning English, we view our model as being general enough to model the errors found in *any* second language acquisition task. The proposal put forth here is that the general system will have encoded many mal-rules capturing differences in several dimensions of features. The model of the first language (and where it differs from English which is the language being acquired) would indicate which of these rules should be active for a particular application. The SLALOM model would dynamically identify where current errors are likely to be made.

Figure 3 shows how the information from these various sources affect the mal-rule scores (and thus the error identification). Using this model in a tutor for the acquisition of English given a different first language would simply require replacing the (first) language model and changing the "filters" in the SLALOM model appropriately. Recall that our language model indicates the first language properties on a feature by feature basis. This will allow many of the features used in the description of one language to be carried over to the features of another.[11] For example, Chinese has many features in common with ASL. It generally does not have articles, subject-verb agreement, or the kind of tense marking found in English. Thus we propose that an application of our CALL system for native Chinese students might include many of the same mal-rules as are included in our ASL-based tutor because the features used in the language model would be the same for the two different CALL applications.

Often literature in second language acquisition and in education looks at writing samples in a holistic fashion rather than considering individual linguistic features of the first and second languages. Thus these approaches may fail to identify transfer of specific features. However, our method allows us to take advantage of the common features and distinctions between a pair of languages when looking for language transfer. This allows us to consider shared mal-rules (features) between several applications.

The General User Model Strategy

We have explained the user model scoring in terms of second language acquisition, but it is also a useful model for a communication tool designed for people with severe speech and motor impairments (SSMI). Many people with SSMI use augmentative communication devices with speech synthesis or text output to help them communicate; however, the rate of communication is typically very slow (on the order of 2-10 words per minute) (Foulds 1980). Because of this and other factors, augmentative communication users often develop telegraphic language patterns from an early age. In addition, certain cognitive or educational difficulties can result in an incomplete knowledge of English structure and grammar, resulting in language variations as diverse as inverted word ordering.

The communication tool we are working on uses a natural language processing technique termed Compansion (compression-expansion) that expands telegraphic input into syntactically and semantically well-formed sentences (Demasco & McCoy 1992). For example, given the input *John go store yesterday*, our prototype augmentative communication system using Compansion might produce "John went to the store yesterday."[12] Of course, there are several difficulties in successfully providing accurate and complete interpretations (see (McCoy *et al.* 1994) for an overview of the Compansion system).

One of the phases of processing in Compansion is a "word order" parser that can be thought of as accepting a variant of standard English which captures the telegraphic speech (and/or word order variations) expected from the users'.

[10]Note that we have collected writing samples with some user information for the authors of each sample. While our analysis so far has been restricted to proficient ASL signers, samples from other deaf writers might help us determine what the ASL "influence" filter (for example) might look like since it would apply to one group of samples but not to another.

[11]In other words, the resulting mal-rules may be shared by several second language acquisition applications.

[12]Our prototype uses a word-based communication system. The expansion thus represents a 3 keystroke savings.

Figure 4: User Models as Viewed from Two Applications

Thus, one can think of the telegraphic speech as containing "errors"; a basic issue is the ability to detect multiple errors in an ill-formed input. In addition, there may be potentially ambiguous interpretations of what those errors are, so properly identifying the errors is a major step. For example, `John gone to the store` could be incorrect because of a wrong past tense form ("John went to the store") or a missing auxiliary verb ("John had gone to the store"). Often, the combination of these factors will generate a whole set of possible corrections. Deciding which correction is the most appropriate can be very difficult. For example, `The girl like John` appears to have a subject-verb agreement error and could be corrected as "The girls like John" or "The girl likes John". However, for certain augmentative communication users, it could also be interpreted as "The girl was liked by John" or "The girls were liked by John." In some instances, the best suggestion for correction may be partially dependent on a specific user's language patterns.

A user model and scoring mechanism analogous to those of ICICLE can provide a principled and efficient way of making these decisions, especially since many of the implementational mechanisms can remain the same. Specifically, in Figure 4 we see a parallel scheme for the organization of the how the user models can be described for both ICICLE and Compansion.

Instead of an error taxonomy based on language transfer, Compansion would rely on an error taxonomy that encodes the language variations attributable to telegraphic usage patterns and other errors (e.g., word order inversion) commonly found in the utterances of augmentative communication users. These errors would also be expressed as an active subset of mal-rules, even as those for ICICLE were. In fact, it is interesting to note that there is a significant group of active mal-rules that both Compansion and ICICLE have in common (e.g., "be" deletion); of course, the mal-rules would have different annotations and weightings attached to them. However, this does provide an elegant implementational strategy. We are currently planning on developing this approach within the framework of a probabilistic context-free grammar mechanism (Charniak 1993), (Allen 1995).

In a similar manner, Compansion would utilize a model of first language acquisition (implemented in SLALOM) analogous to the second language acquisition model in ICICLE. This provides us with the same inferencing strengths as well as a dynamic assessment model of the user's language proficiency. It also gives us the ability and knowledge to provide literacy instruction for augmentative communication users through corrective feedback and the future tutoring module. Finally, in both systems, the ultimate goal is to flexibly adapt to each individual's unique stylistic and idiosyncratic language patterns over time. The more accurate our profile of the user becomes, the better we will be able to both correct errors efficiently and provide the most appropriate feedback in our explanatory responses.

Conclusion

We have introduced components of a general user model to be used in the context of various language assistance applications. The model consists of a static model of the expected language (represented on a feature by feature basis) and a dynamic model that represents how a language might be acquired over time. Together these models affect scores on a set of grammar rules which are used to produce a "best interpretation" of the user's input.

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