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COMPUTATIONAL TRACKING OF 'NEW' VS 'GIVEN' INFORMATION: IMPLICATIONS FOR SYNTHESIS OF INTONATION

Merle Horne and Christer Johansson

INTRODUCTION

Researchers on Swedish prosody have been aware for some time of the consequences the referential status of words has as regards sentence intonation (Bruce 1977, Gårding & House 1985). In Bruce's work, for example, the 'new/given' parameter was used in order to trigger focal accents on different words in test sentences. In the pair of sentences in (1a-b), the presence of the word *nunnor* 'nuns' in (1a) leads to its deaccentuation in (1b), where it is repeated (i.e. 'contextually coreferent'), and to the assignment of a focal accent on *långa* 'tall' instead (see the dashed line contour in Figure 1 where the rightmost H on *långa*, following the word accent H*L, corresponds to the focal component of the accentual pattern):

(1) a. Vad vill man lämna för några nunnor$_i$?
'What nuns$_i$ does one want to leave?'
b. Man vill lämna några LÅNGA nunnor$_i$.
'One wants to leave some TALL nuns$_i$'

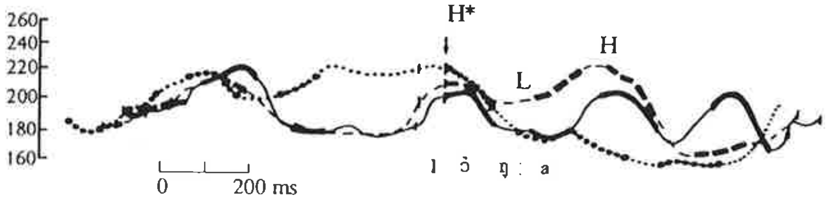

Figure 1. *The effect of the placement of sentence accent. Fo-contours of full sentences with accent II-words. The line-up point is at the CV-boundary of the stressed syllable in långa. (Key to interpretation of contours:____ man vill lämna några långa NUNNOR, – – – man vill lämna några LÅNGA nunnor, ... man vill LÄMNA några långa nunnor) (Bruce 1977:42)*

The knowledge of the role played by coreference in conditioning the placement of focal accent patterns was also included in an algorithm for assigning levels of sentence stress in English (Horne 1988) reproduced below as Figure 2. According to the model, it is required that words be marked as 'new' or 'given' before they are processed by the Fo generator which then uses this information in order to assign them appropriate fundamental frequency contours.

More recent work on the development of interfaces to prosody components for English text-to-speech systems has begun to show the results of efforts to take into account contextual factors that condition intonational patterning. Hirschberg (1990) for example has attempted to implement fragments of Grosz & Sidner's (1986) model of discourse by modelling aspects of their 'attentional state', in particular the notion of a 'stack' of focus spaces. These have been represented by a stack of morpheme roots ('lemmas') which is updated at certain fixed intervals, e.g. at paragraph boundaries. Words figuring in this stack are thus not accented by the text-to-speech rules. Youd & House (1991) also keep track of mentioned roots in an 'accessibility table' in their work on modelling information in the restricted area of a telephone dialogue system for flight information. Our own current research efforts are being directed towards further developing modelling of the different kinds of contextual information which have implications for the generation of intonation in Swedish and English.

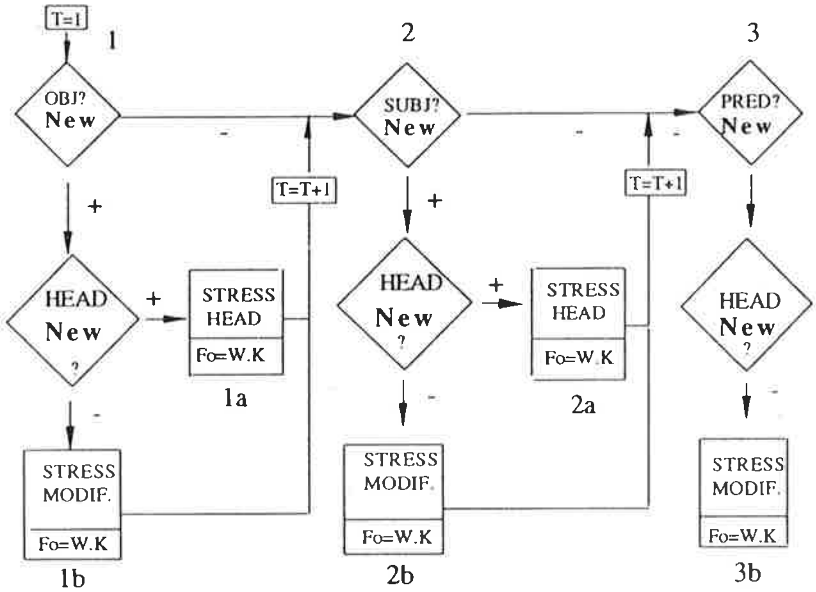

Figure 2. *Model for assigning sentence stress levels to constituents on the basis of grammatical functions and the new/given status of lexical items. The input to the model is a given sentences (S). Stress levels are realized as pitch (Fo) according to the equation Fo=W·K, where Fo here refers to the width of a register, W designates the mean width of the widest register used by a given speaker within a sentence and K is a variable ranging over a number of prominence levels defined as fractions of this widest register. In previous work, the values assumed by K were 1, 0.75 and 0.5, respectively. The box T=T+1 is a counter which adds 1 each time a stress level has been assigned.. T is used in determining the coefficient K: If T=1, K=1; if T=2, K=0.75; and if K=3, K=0.5. The diagram is to be read as follows: Check to see if there is a Predicate Complement. If there is one, check and see if the head is new information with respect to the preceding part of the text. If this condition is met, stress the head, assigning it a level of stress where Fo=W·K (1a). If the head constitutes given information, assign the modifier stress instead (1b). Go to the Subject (2) and repeat the same routine, and then go to the Predicate (3), again repeating the same routine.*

MODELLING OF 'NEW' VS 'GIVEN' INFORMATION

Lexical relationships

Our current research goals is aimed at being able to computationally model the different kinds of contextual phenomena that can affect a particular word's status in a text with respect to the parameter 'new/given'. This involves being able to track, in addition to relations based on morphological identity such as in the work of Hirschberg and Youd & House mentioned above, more complex identity of sense relations that are used in situations of anaphora in order to refer back to an already-mentioned item, e.g synonymy, hyponymy and part-whole relations (Allerton 1978, Lyons 1977). All these different types of 'cohesive devices' (Halliday & Hasan 1976, Morris & Hirst 1991) that are used in situations of anaphora in order to express textual giveness (coreference) are important to model for purposes of intonation generation since they lead to the assignment of nonfocal accents on anaphoric lexical words (see Horne & Johansson 1991). In summary, these anaphoric devices include the following :

.Reiteration using a morphologically identical form:

E.g.: see (1a-b).

.Reiteration using a previously mentioned morpheme with a different inflexional/derivational ending:

E.g.: *Marie tycker att vi borde investera i en Saab*$_a$ *men jag måste erkänna att jag faktiskt inte tycker om Saabar*$_a$,

'Marie thinks that we should invest in a Saab$_a$, but I must admit that I really don't like Saabs$_a$'.

.Reiteration by means of a synonym:

E.g.: *Ingvar tror att en skattehöjning är möjlig*$_k$, *men Carl säger att en sådan åtgärd inte är på något sätt genomförbar*$_k$.

'Ingvar thinks that a tax-rise is possible$_k$, but Carl says that such a measure is not at all feasable$_k$'.

.Reiteration by means of a superordinate term:

E.g.: *Min son vill ha en tax*$_m$, *men jag är inte säker på att han är gammal nog att ta hand om en hund*$_m$.

'My son wants a dachshund$_m$, but I am not sure he is old enough to take care of a dog$_m$'.

In addition to the above morphological and lexical relationships, there are always a number of pragmatically (situationally) 'given' terms (Chafe 1974, Firbas 1979) which have to be accounted for :

E.g.: in the context of the Swedish stockmarket, the word for Swedish currency, *kronor*, 'crowns' always constitutes given information and is consequently not assigned a focal accent.

Restricted texts

In an attempt to computationally model the above kinds of textual phenomena and implement them in a referent-tracking program which marks words as either New or Given, we have chosen to study restricted texts dealing with the Stockholm stock market. This has been done for a number of reasons. In the first place, since one is dealing with a limited area of the lexicon, one can avoid problems of polysemy since one needs only represent those lexical relations that are present in this particular type of text. Furthermore, since these texts report mainly concrete facts concerning changes in the status of stocks and bonds, there is not the problem of modelling complicated relations such as inferences that are common in more complex texts. In what follows, we will describe how the program works.

Dealing with morphologically inflected forms

Determining whether a word has been mentioned previously is complicated by the use of inflectional forms in languages like Swedish and English. A way to get around this is to use a truncation procedure (due to B. Brodda) that finds the common stem and the remainders of the two words to be compared (e.g. *Saab* in *Saab-en* 'the Saab' and *Saab-ar* 'Saabs'. Morphological identity is then defined as existence of the two remainders which are valid endings in the language. These endings are supplied in a table which can be altered before the use of the program, thus making the program more flexible. The procedure saves one from using a lexicon to compare inflected forms of the same word, but of course it is not a method which will give a 100% guarantee that the words really refer to the same meaning — this is a much harder problem which is usually not solved by representing the surface forms. For example, the Swedish word *man* can mean both 'man' and 'mane'. In a context where both senses are permitted, the word would be marked falsely when used with a different sense for the first time. However, since we are dealing with a very restricted area of the Swedish lexicon, the probability of such cases of polysemy occurring is almost null.

The morphological truncation method which is used is simple, reliable and gives a good result considering that the method only uses graphic information. In this system, two words, X and Y, are said to have the same stem if and only if they match, character by character from left to right, with the remainders X1 and Y1. X1 and Y1 are both stored in the table of possible endings. This is probably the simplest form of the equality function when the comparison has to deal with simple inflection. The method can be further elaborated but for specific purposes it is probably adequate.

Dealing with superordinate relationships

The second important function in distinguishing new from given information is to find out if *an example of* the word has been mentioned before, i.e. if the word being checked is a superordinate term with respect to a previously occurring word. For this purpose a hierarchy ordered by the generality of the words is constructed. The more general a word is the higher up in the hierarchy it will be. See Figure 3.

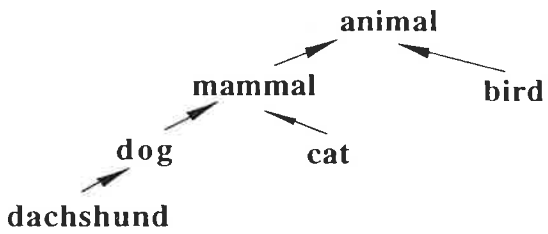

Figure 3. *Example of a superordinate hierarchy reflecting the lexical relation 'is an example of'.*

The hierarchy describes what is an example of what. The relation between the nodes is called 'is an example of', a relation which can be noted to be transitive. For example, to prove that *dachshund* is an example of *animal*, the following procedure is taken: *dachshund* is an example of *dog* which is an example of *mammal* which is an example of *animal*.

The hierarchical information of the domain which we want to cover is stored as a collection of 'is an example of' relations that translates into a forest of hierarchical, multi-branch trees where each node has exactly one parent or no parent at all. The structure could possibly be elaborated into a 'many parents' structure which would lead to a wider search space and a more complicated algorithm. For the purpose of exploring limited domains, the 'one parent' structure might prove to be the best choice.

The hierarchical structure is implemented as a look up table where each entry consists of the 'stem' form and the parent in its stem form. Therefore the stems of words must be found in order to be able to perform the look up function in an efficient manner. Currently this is done by subtracting the longest possible ending from the word to be looked up.

The current program allows one to look back in the text 60 words when tracking a word's potential coreferent. In summary then, if the word being checked for its 'new'/'given' status occurs within the 60-word window, it is marked as (G)iven;

otherwise as N(ew). A word is marked as Given if it has either morphological identity with a word in the window or a hierarchical (superordinate) relation to a word in the window.

One problem with the current structure is that loops within the trees are not allowed which implies that, among other things, synonymy relations can not be described within the current structure. However, the synonymy problem can be solved by having a special table of synonymous word pairs.

The algorithm

The program for tracking coreference relations is described below in a meta programming language in order to explain the logic of the algorithm. The superordinate hierarchy is implemented as a large hash table where each node contains a key word and a target word. (A hash table is a table where the position of the word in the table can be determined from a numerical code that can be derived from the characters of the word).

X Is an example of Y is defined as:
  Look up the stem of X in **the hash table**
    if its **target** does not exist
    then X is not an example of Y
    else if its target has the same stem as Y
    then X Is an example of Y
    else Is its target an example of Y ?

InList (i.e. memory with 'given' terms) is defined as:
    if the Word has the Same Stem as another Word in Memory
    then InList is true
    else if there exists an Example of Word in Memory
    then Inlist is true;
    otherwise InList is false.

New or Given is defined as:
  for all Words in a text **do**

    [**if** InList(Word) is true
    then the Word is 'Given'
    else the Word is 'New';
    Insert The Word in The List]

The complexity of the algorithm

The complexity of the algorithm depends on how many words are in memory and how many levels in the hierarchies that must be searched. The time complexity of the Same Stem function is assumed to be constant. Let N be the number of words in the text and M the size of the memory and H the maximum depth of the hierarchical trees and K a constant which is proportional to the time to perform a primitive comparison (Same Stem comparison), then the time complexity can be expressed by $T(N) \leq K*H*M*N$. Note that K*H*M is a constant entity, which might be quite large.In the test system we had $H \approx 5$ and $M=60$ and $N \approx 500$, and the time was approximately 1.5 minutes on a Machintosh II/fx. To increase speed, but possibly decrease quality, we could shorten the length of the limited memory list and thus decrease the constant factor.

An example of the tracking procedure

In order to illustrate in more detail how the program tracks referents and marks words as New or Given, we can use the following text where coreference relations are indicated with identical subscripts (component morphemes of compounds have been separated by a +):

Stockholms$_{a}$ fond+börs$_{b}$ general+index$_{c}$ slutade$_{d}$ på torsdagen$_{e}$ på 858,8, en uppgång$_{f}$ med marginella 0,02 procent$_{g}$ jämfört med onsdagens$_{h}$ slut$_{d}$+index$_{c}$. Kurs$_{c}$+utvecklingen$_{i}$ över dagen$_{e}$ betecknades som oregelbunden.

Kurs$_{c}$+stegringar i AGA$_{j}$ och Astra$_{k}$ fick bransch$_{j,k}$+index$_{c}$ för kemi$_{j}$- och läkemedel$_{k}$ att bli bästa bransch$_{j,k}$ med en uppgång$_{f}$ på 1,6 procent$_{g}$.Förlorare var övrig industri$_{j,k}$ och handels+företag$_{j,k}$, som föll med 2,6 respektive 1,9 procent$_{g}$.Köp+kurserna$_{c}$ steg i 52 bolag$_{j,k}$, föll i 80 medan 189 låg kvar på onsdagens$_{h}$ slut$_{d}$+nivåer$_{c}$.

TRANSLATION: Stockholm's$_{a}$ stock exchange$_{b}$ general index$_{c}$ closed$_{d}$ on Thursday$_{e}$ at 858.8, a marginal increase$_{f}$ of 0.02 percent$_{g}$ compared with Wednesday's$_{h}$ closing$_{d}$ index$_{c}$. The rate$_{c}$ development$_{i}$ during the day$_{e}$ was described as irregular.

Rate$_{c}$ increases$_{f}$ in AGA$_{j}$ and Astra$_{k}$ made the trade index$_{c}$ for chemicals$_{j}$ and drugs$_{k}$ to be the best line of business$_{j,k}$ with an increase$_{f}$ of 1.6 percent$_{g}$. The losers were the remaining industrial and trading companies$_{j,k}$, which fell by 2.6 and 1.9 percent$_{g}$, respectively. The buying rates$_{c}$ rose in 52 companies$_{j,k}$, fell in 80, while 189 remained at Wednesday's$_{h}$ closing$_{d}$ levels$_{c}$.

The output of the program is the text where the words are marked for their status as either N(ew) or G(iven):

STOCKHOLMS(N) FONDBÖRS(N) GENERALINDEX(N) SLUTADE(N) PÅ(N) TORSDAGEN(N) PÅ(G) 858_8(N), EN(G) UPPGÅNG(N) MED(N) MARGINELLA(N) 0_02(N) PROCENT(N) JÄMFÖRT(N) MED(G) ONSDAGENS(N) SLUTINDEX(N). KURSUTVECKLINGEN(N) ÖVER(N) DAGEN(G) BETECKNADES(N) SOM(N) OREGELBUNDEN(N). KURSSTEGRINGAR(N) I(N) AGA(N) OCH(N) ASTRA(N) FICK(N) BRANSCHINDEX(N) FÖR(G) KEMI (G) OCH(N) LÄKEMEDEL(G) ATT(N) BLI(N) BÄSTA(N) BRANSCH(G) MED(G) EN(G) UPPGÅNG(G) PÅ(G) 1_6(N) PROCENT(G). FÖRLORARE(N) VAR(N) ÖVRIG(N) INDUSTRI(G) OCH(G) HANDELSFÖRETAG(N), SOM(G) FÖLL(N) MED(G) 2_6(N) RESPEKTIVE(N) 1_9(N) PROCENT(G). KÖPKURSERNA(N) STEG(N) I(G) 52(N) BOLAG(G), FÖLL(G) I(G) 80(N) MEDAN(N) 189(N) LÅG(N) KVAR(N) PÅ(G) ONSDAGENS(N) SLUTNIVÅER(N).

Comments on the output

In the first sentence, the last word *slutindex* 'closing index' (a compound) should be analysed as Given information, since its component morphemes are mentioned earlier, i.e. *slutade* 'closed' and *index* 'index'. At the present time, however, we do not have the possibility of recognizing the morphological make-up of Swedish compounds. This is a procedure that will be incorporated in the program in the future. The word *dagen* 'the day' is correctly marked as Given since it refers back to *torsdagen* 'Thursday'. This is accomplished by using both morphological and lexical information. First, the program includes the lexical hierarchy (hyponymy relation) that holds between the word *dag* and the more specific terms *vardag* 'weekday' and *helgdag* 'weekend day' as well as the superordinate relation between these latter words and the specific days of the week, *måndag, tisdag, onsdag*, etc. (see Fig. 4). Thus in checking for a previous occurrence of a word which is coreferent to *dagen*, the algorithm will first come to the word *onsdagens* 'Wednesday's'. The two words are first compared for morphological root identity, and when this is not found, the superordinate relationships between *dagen* and *onsdagens* are checked. Since *dag* is superordinate to *onsdag* in the hierarchy, *dagen* will be marked as Given information by the algorithm. Note that it is not in fact *onsdagen* that *dag* refers back to but rather *torsdag*. But since *onsdagens* is checked before *torsdagen*, it is the former word that the program recognizes as a coreferent to *dagen*. Thus, *dagen* is marked correctly as G(iven) but on the basis of the wrong antecedent! Of course, the algorithm would eventually have found the correct antecedent since *torsdagen* occurs within the 60-word window. However, as soon as a coreference relationship is found between the current word and a previously occurring word, the tracking procedure is stopped and the program goes on to the next word.

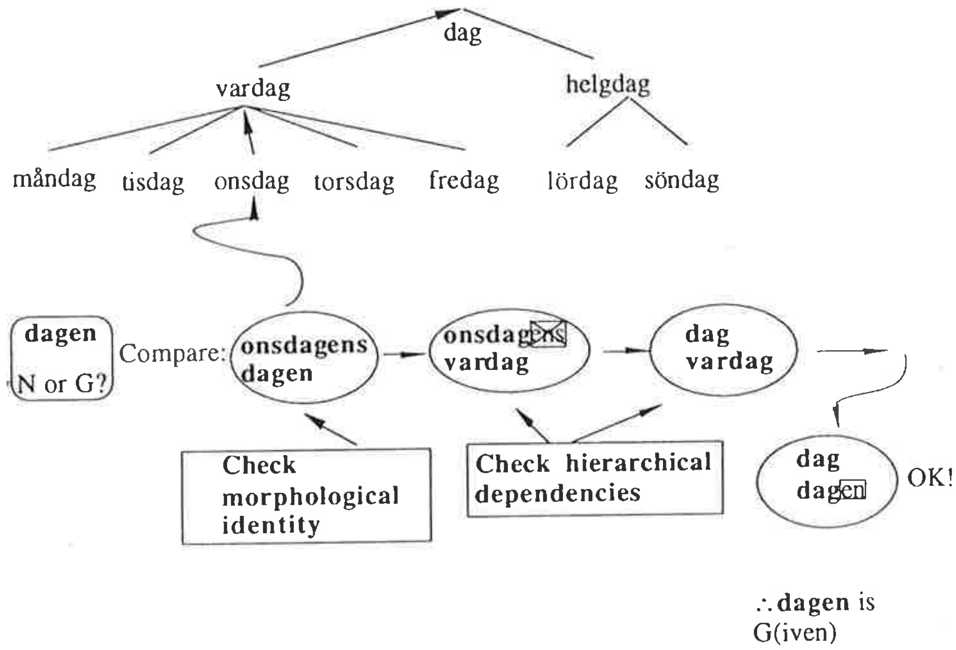

Figure 4. *Schematic illustration of the procedure involved in determining the Given status of the word dagen. The program first compares the words dagen and onsdagen for morphological identity. When this is not found, the algorithm searches through the hierarchical relations to see whether dagen stands in a superordinate relation with respect to onsdagens. When this is determined by checking though the lexical hierarchies, dagen is marked as G(iven).*

In the third sentence, *kemi-och läkemedel* 'chemicals and drugs' is marked by the referent-tracking algorithm as G(iven) since it is a superordinate term in relationship to *AGA* and *Astra* which is used anaphorically to refer back to them. *Bransch* 'branch' is also marked as G(iven) since it is also a superordinate term, both with respect to *AGA* and *Astra* and to *kemi-och läkemedel*. In the fourth sentence, *industri* is also marked as G(iven) since it refers back to *bransch*. These hierarchical relations, as well as others illustrated in Figure 5 are modelled in the program by the relationship 'is an example of' mentioned above.

Prosodic reflexes of the New/Given distinction

The prosodic consequences that can be expected assuming the lexical patterning discussed above are that speakers will assign the phrase *AGA och Astra* à focal accent (i.e. a H(igh) after the word-accent (see Bruce 1977), since it constitutes new information; however, when referring back to the specific companies by means of superordinate terms, i.e. *kemi-och läkemedel, branch, industri,* non-focal accents are called for. In order to illustrate this interaction between New/Given information and focal/

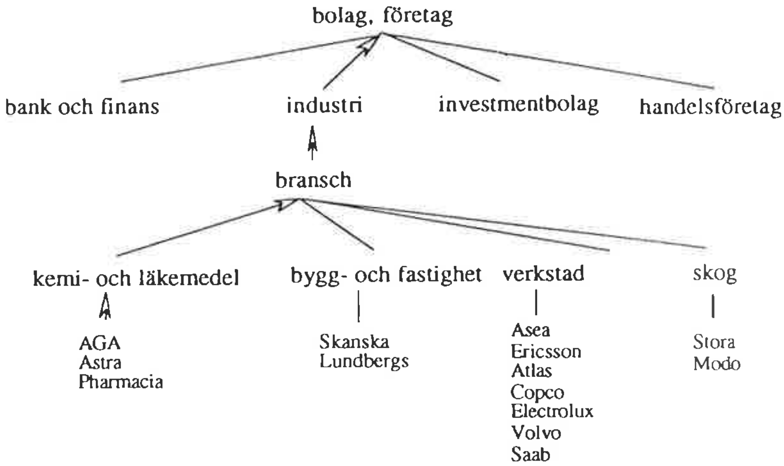

Figure 5. *A partial superordinate hierarchy of individual Swedish companies and the classes which they are members of. At the bottom of the tree are the names of specific companies which are dominatd by the terms designating the classes the particular companies are grouped into as regards financial transactions on the stock market*

non-focal accents, we present in Figure 6 intonational patterns produced by a speaker of Stockholm Swedish for the phrases under consideration. In Figure 6a, *Astra*, an Accent 2 word, is assigned a focal accent marking the New status of the information within the phrase *AGA och Astra*. Figure 6b shows a non-focal Accent 2 on the compound *kemi-och läkemedel* which refers back to the companies *AGA* and *Astra*. In Figure 6c, the Fo contour for *bransch* is presented. As in the preceding case, *bransch* also exhibits a non-focal accent since it refers back anaphorically to *kemi-och läkemedel.*

Implications for text-to-speech

In the commerically available INFOVOX text-to-speech system for Swedish with a prosodic component based on Carlson & Granström (1973, 1986) and Bruce & Granström (1989), the Fo generator produces default Focal accents on the last word in an intonational phrase. (An intonational phrase boundary corresponds roughly to a comma or a full-stop in the written text.) Thus it is not possible to automatically produce the contour in Figure 6c, for example, which has a non-final focal accent on *bästa*. Figure 7 illustrates the output of the default text-to-speech prosody rules for this phrase which does not exhibit any focal accent since it does not come at the end of an intonational phrase. In Figure 8, we have reproduced the intonation curve for *bästa bransch* that would be produced by the text-to-speech system if the algorithm discussed here were implemented and a non-final focal accent were assigned to *bästa*. This contour shown was generated by hand assigning *bästa* a level of prominence equal to #7# on a possible scale of 0-9 pitch levels available in the system. If one compares this output with that produced by the Swedish speaker in Figure 6c, it is seen that the text-to-speech rules are capable of generating a very natural intonation contour if they have recourse to the type of lexical information that we are attempting to model. Our goal is thus to be able to use the algorithm described above to first of all mark words as Given versus New. With this information, one can then specify in the intonation rule component that the last word in an intonational phrase constituting New information is assigned a focal accent.

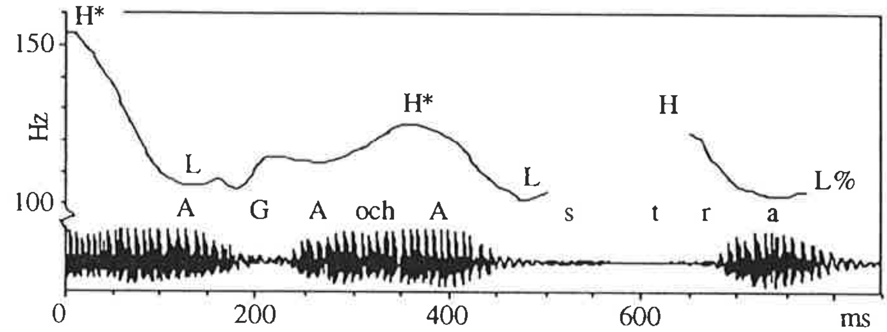

Figure 6a. *Fo pattern associated with the phrase AGA och Astra (New information). Both words are assigned Accent 2 (H*L). Astra is also assigned a 'focal' H in its final syllable.*

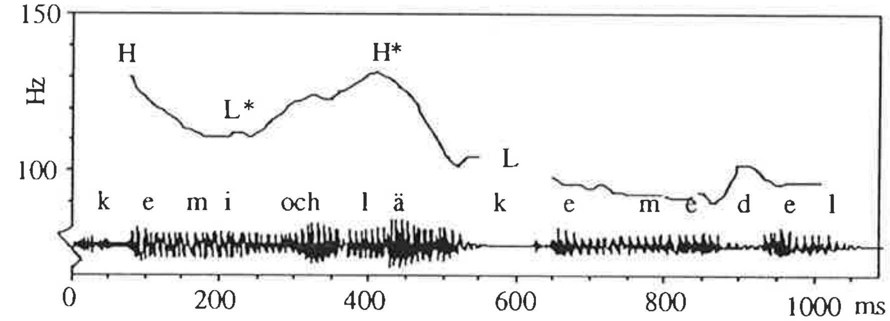

Figure 6b. *Fo pattern on kemi och läkemedel 'chemicals and drugs' (Given information). Kemi exhibits a non-focal HL* accent pattern as does the compound word läkemedel (H*L).*

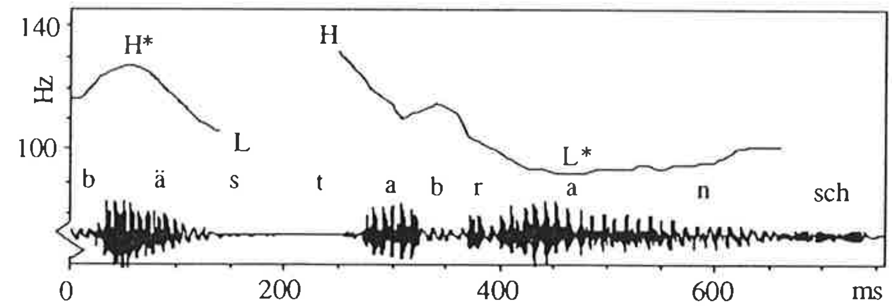

Figure 6c. *Fo pattern on bästa bransch 'best branch' where bästa constitutes New information and bransch Given information. Bästa, an Acc. 2 (H*L) word, is thus associated with a focal H in its final syllable. Bransch, an Acc.1 word is not, however, associated with a focal H.*

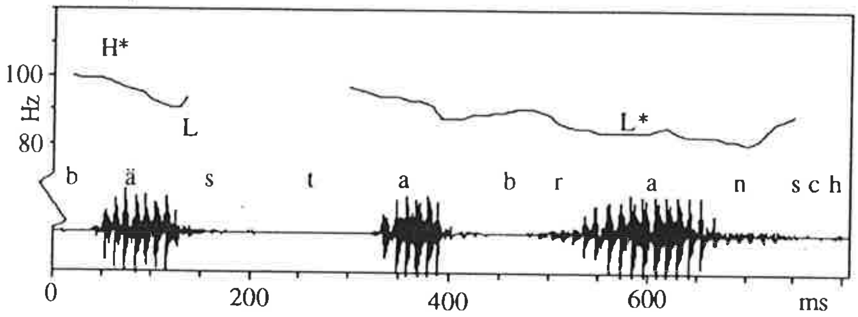

Figure 7. *Fo contour for the phrase bästa bransch produced by the default INFOVOX text-to-speech rules. No focal accent is generated on bästa since it is not the final word of an intonational phrase.*

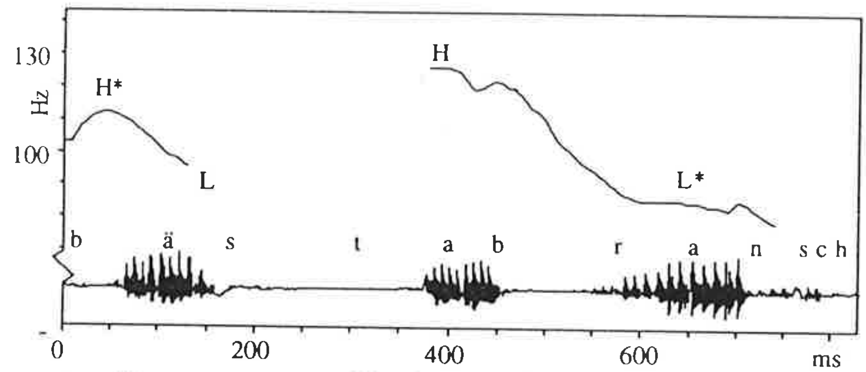

Figure 8. *Fo contour generated by the INFOVOX prosody component on bästa branch by hand-assigning bästa a focal accent 2.*

For the final sentence in the text above the algorithm marks the compound *slutnivåer* as New information despite the fact that both its component morphemes have been mentioned previously (*slut-* has as its antecedents *slut-* in *slutindex* and *slut-* in *slutade* and *nivåer* has as its antecedent the hyponym *index*). Thus, *slutindex* should be marked as Given information on the basis of these morpholgical and lexical factors and the word *onsdags* should rather be assigned a focal accent. However, as was noted above, the referent tracking procedure does not at present have recourse to the internal strucutre of compounds and consequently the program cannot recognize when a compound should be assigned Given status unless of course it is identical to a previous occurrence of the same compound. The consequences for the generation of appropriate intonation contours are thus quite severe if one cannot correctly analyse compounds into their component morphemes. For instance, with *slutnivåer* marked wrongly as New, the contour in Figure 9 with a focal accent on *slutnivåer* would be generated by the Fo generator in the text-to-speech prosody rules. With *onsdagens* marked as New, however, and *slutnivåer* as Given, the contour in Figure 10 would instead be generated with a focal accent on *onsdag(en)s* and a nonfocal Accent 2 compound contour on *slutnivåer*, a more natural intonation in this context. Incidently, the reason *onsdagens* should be focussed in this case is, we hypothesize, due to a pragmatic condition that dictates that a focal or contrastive accent is placed on any week-day that is not the same day as that of the actual stockmarket report (in this case *torsdag* 'Thursday').

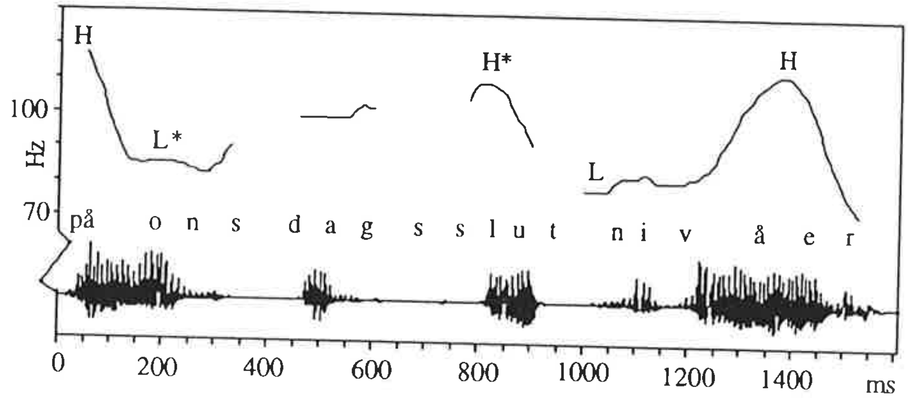

Figure 9. *Default Fo contour produced by the default INFOVOX prosody rules for the phrase onsdagens slutinivåer with a focal accent on the compound (H*LH). This corresponds to the case where slutinivåer is marked as New (wrongly in this context).*

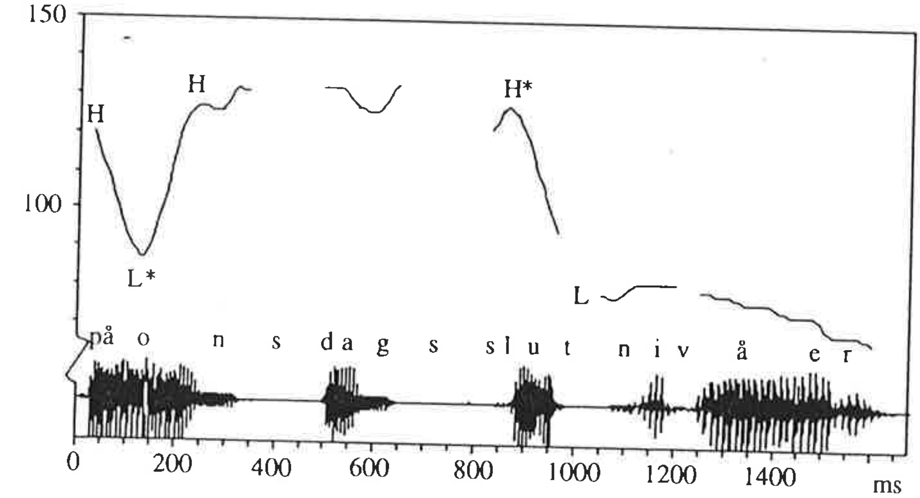

Figure 10. *Contour which would be generated on the phrase onsdag(en)s slutnivåer were the compound marked as Given by the referent-tracking program. Onsdags would then be assigned a focal Accent 1 (HL*H) and slutnivåer non-focal Accent 2 (H*L).*

CONCLUSIONS

The coreferent tracking algorithm described above is quite simple and computationally tractable. Although it has linear time complexity, the results are quite promising for accuracy in finding New vs. Given information. Speed is, of course, needed for practical reasons if the information is to be implemented in an interface to a text-to-speech system.

Currently there is no lexicon involved in the development of the algorithm, although the hierarchical structure modelling the superordinate relations of the domain can be viewed as a kind of lexical information. In the comparison of words we have used a 'morphological' approach instead of a lexicon approach to find out if two word-forms have the same stem. Consequently, we risk marking some words wrongly. Many of these cases would require parsing and semantic analysis, as well as a richly marked lexicon to be analyzed correctly. Moreover, we risk not identifying potential cases of morphological identity where the root is suppletive, e.g. *bok — böck-er* 'book — book-s'. Thus, a lexicon will be necessary in the future for two reasons: first, in order to be able to analyse compound words into their component morphemes so that one can search for their respective antecedents (e.g. *slut+index* discussed above), and second, in order to be able to recognize morphological identity involving derivational processes (*stiga* (v)'to rise'/*stegring* (n) 'rise') and suppletive roots (*falla* 'to fall'/*föll* 'fell').

In subsequent stages in the development of the interface, this contextual information will be united with syntactic information obtained from a parser which will be able to identify phrasal heads and attributes. With these two kinds of information, it will be possible to assign words appropriate levels of pitch prominence in a manner resembling the algorithm in Figure 1.

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