Center for Machine Translation

Direct Memory Access Translation
A Theory of Translation

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Abstract

Direct Memory Access Translation (DMTRANS) is a theory of translation in which translation is viewed as an integrated part of cognitive processing. In this paradigm, understanding in source language is a recognition of input in terms of existing knowledge in memory and integration of the input into the memory. Context of sentences are established as what is left in memory after understanding previous sentences (or a preceding part of a sentence) making the correct translation of contexually ambiguous sentences possible. Decisions made during translation are influenced by what is dynamically modified in memory through preceding recognitions. Since knowledge in memory is directly shared with the rest of cognition, during translation other cognitive processes such as inference can dynamically participate in the translation process.

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1 Introduction

The Direct Memory Access Translation (DMTRANS) is a new approach to machine translation currently researched at the Center for Machine Translation (CMT) of CMU. We claim that every part of cognition dynamically participates in translation (as in any other cognitive process) through shared memory, and that a translation system aiming at fully-autonomous machine translation should be designed with this in mind. This project is an experimental project currently being developed at the CMT as a new generation MT system and should not be confused with the ongoing CMU-MT project (Tomita&Carbonell[1987]).

The current implementation of DMTRANS uses the spreading activation model as a simulated parallel memory search[1] to recognize input in terms of the existing knowledge in memory. Similar approaches to understanding languages are found in Quillian[1969], Collins[1969], Fahlman[1979], Riesbeck&Martin[1985]. Related past works in this area include Hirst[1982], Hahn[1983], Yokoyama&Hanakata[1986], and Charniak[1986]. We prefer this method, because translation is performed directly through the network of memory, which makes dynamic interaction with other memory-related processes possible, and because all previously created memory structures can potentially participate in translation. DMTRANS extends and integrates theories of direct memory access understanding into translation with consideration of cross-cultural questions that accompany the attempt. We view translation as locating existing memory structures under the source language that the text is referring to and generating text that refers to these memory structures in the target language[2]. Often, a single memory structure is not shared by different languages and in that case, use of similar existing memory structures and explanation by surrounding memory structures replace direct generation from identified memory structures. Currently, the system is developed to translate between English and Japanese and is capable of understanding and generating fairly complex sentences between the two languages.

[1] A guided spreading activation is performed directly on the memory net and no modular syntactic analysis (Birnbaum[1986]) is done.

[2] Since understanding is done as accommodating input with already existing knowledge in memory (or past cases) we can also view DMTRANS as a kind of case-based translation theory.

2 Where most MT systems fail

2.1 Ambiguation – No choice over others

2.1.1 Syntactic Ambiguity

Because most MT systems do not understand what they are translating, they are incapable of making decisions based on the content of the material they are translating. For example, the famous structurally ambiguous examples such as "I saw a man with a telescope" and "The man left by the door rotted" may be handled by current systems by representing multiple interpretations of the input; however, this does not mean these systems are capable of handling garden path sentences, since none of these systems are capable of choosing the most correct interpretation over the others. Since inputs are translated sentence by sentence, virtually no contexual help is available during translation. This makes an autonomous translation extremely unlikely, because very often sentences can have multiple interpretations (most of which, humans are unaware of); without human assistance, such systems are incapable of selecting one interpretation over others[3]. Thus, being able to generate all possible interpretations of an input sentence does not automatically mean the system is capable of handling syntactically ambiguous sentences. We claim that the system should be able to select the correct interpretation (what speaker intended) in order to claim that it "handles" such a sentence. Unfortunately, most current MT systems fail in this task.

2.1.2 Semantic Ambiguity

By the same token, most MT systems fail in handling semantically ambiguous sentences. Consider the examples: "The quality of this paper is terrible" and "John gave Mary a punch". In the former example, the interpretation of paper should be different (for example, Japanese for 'thesis' and 'a sheet of paper' is different) according to what has been said before (or perhaps, visual perception of the situation may supply help). In the latter sentence, interpretation should be different again due to the context (Japanese for punch as PROPEL and punch as a drink is different). Again, being able to generate multiple interpretations of sentences does not mean the system is capable of handling semantically ambiguous sentences. The system instead should be able to choose appropriate interpretations.

[3]This problem is conspicuous when a sentence has a fairly complex structure including conjuncts. Consider "Show me the picture of lung with small cell carcinoma with magnification of ten and the brain with squamous cell carcinoma with magnification of five".

2.2 Ellipses, Anaphora, Indirect Speech Acts

2.2.1 Ellipses

In most MT systems, ellipsis in a sentence results in either no parse at all or output with missing slots. For example, in translating "kouryo suru to ittaga, totemo shinjigatai" ([he] said, [he] will consider [it], but [I] can hardly believe [it]) which is a typical Japanese sentence with missing subjects, most MT systems simply fail in filling in missing information[4]. Another example is "How often does squamous cell carcinoma metastasize to the brain? Lung? Large cell carcinoma?". Unless MT systems perform some strong inference at run-time, it is beyond their capacity to handle this phenomenon. Since few conventional MT systems are performing any kind of contexual inferences at runtime and normally the representation structures that are built during the translation of one sentence are either lost or not used in any meaningful way during the translation of other sentences, ellipses are hard problems for these systems. Actually, since filling in missing informations requires the understanding of text and the contexual knowledge, any inference that hopes to solve this problem needs to be memory based[5].

2.2.2 Anaphora

Anaphoric expressions are another kind of phenomenon that most MT systems fail to handle. Consider the example of "Musashi threw a long sword at the giant rat. It ate it." Current MT systems are satisfied with translating 'it' as 'it'[6]; however, this often creates problems: for example, Japanese does not prefer 'sore' (it) for animate objects whereas English refers to both animate and inanimate objects with 'it'. In some languages, the morphology of 'it' changes according to what it is referring to. In this sense, anaphora is another phenomenon most MT systems avoid. Even if the MT systems decide to output 'it' as 'it' unless they do so with knowing what 'it' is referring to, there is a danger of causing awful mistakes in translations even without noticing that they mis-translated the input.

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[4]Simple heuristics such as "assume the missing subject to be the subject of the former clause' does not work here.

[5]As opposed to rule based.

[6]As long as 'it' is translated as 'it' (perhaps 'sore' in Japanese), translation is treated as accurate in most systems.

2.2.3 Indirect Speech Acts

Virtually no current MT systems handle pragmatics. One typical area of such failure is indirect speech acts. At best, these systems output two possible interpretations of the utterances: the primary illocution and the secondary illocution, however, no preference for one over the other is made. A conference interpreter will take "Can you move over a little, your shoulder is blocking the picture" almost undoubtedly to be a request instead of a question. Without knowledge of what is it that the interpreter is translating, such an automatic choice is impossible. There are some systems that try to handle this problem through the use of phrasal lexicon; however, such attempts still suffer from the same question that they cannot decide whether to take the primary illocution or the secondary illocution. Unless the expressions of the indirect speech acts have become cliches and are always conventionally taken as the expressions for the secondary illocutions, such scheme will not solve this phenomenon[7]. Apparently that is not the case in most languages.

3 What DMTRANS can do

DMTRANS outperforms most systems in choosing an appropriate interpretation of sentences over others in accordance with contexts. DMTRANS does not even realize many of the unlikely interpretations of the text (just like humans do not realize unlikely interpretations of an input text). This is possible because sentences are always recognized in context in DMTRANS, by performing strong predictions based on what has been recognized previously.

3.1 Contexual Recognition of Concepts

In DMTRANS, the contexual recognition of concepts is performed through the use of lexically guided marker passing algorithm that implements spreading activations, conceptual predictions, and contexual markings.

3.1.1 A-Marker, P-Marker, and C-Marker

First, a brief view of the DMTRANS marker passing mechanism is in order. We have three kinds of markers[8] that are spread around in the memory network:

[7]Just as trying to solve idioms such as 'to kick the bucket' by a phrasal lexicon may not always work.

[8]A-Marker and P-Marker are due to Riesbeck&Martin, which describes a more detailed picture of the way these two markers are passed around in memory.

the Activation-Marker (A-Marker), the Prediction-Marker (P-Marker), and the Context-Marker (C-Marker). The A-Marker is to mark concepts (and the abstractions) that are being identified with inputs. The P-Marker is used to predict the next likely concept to be recognized, through knowledge of the possible sequences of concepts. The C-Marker is used to mark concepts that are likely to be input under a given context. When a word comes in, the word sends activation to (put an A-Marker on) a concept that the word is attached to and the activation is sent above the abstraction hierarchy in the network. The A-Marker contains[9] the source of activation to indicate which concept originated the activation. The P-Marker contains the origin of prediction of a concept that the P-Marker is put on. By the same token, C-Marker contains the origin of the contexual marking.

3.1.2 Concept Sequences and Refinements

Predictions are initially made (P-Markers are put) on all the first elements of concept sequences[10], and if a predicted concept receives activation (when A-Marker and P-Marker meet) then the next element of the concept sequence is predicted. A concept sequence is a sequence of concepts that represents an order of concepts that is unique to a language and is stored in root concepts[11]. When the last element of a concept sequence is activated, then the concept sequence is accepted and the associated root concept is recognized. When this happens, DMTRANS searches for (or creates if it does not exist yet) some concept underneath the root concept in the abstraction hierarchy that represents the specific input concept sequence. This is called 'concept refinement[12]' and with the concept refinement, the new specialization underneath the root concept gets activated (another spreading activation).

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[9]To be precise, A-Marker is a structure that contains the original source of activation (activated by lexical entry) and the information whether the activation was a lexical activation or a result of concept refinement. P-Marker contains the origin of the P-Marking (ie, the conceptual root concept) and the concept that immediately preceding the P-Marked concept. C-Marker is a structure that contains the contexual root concept (such as 'academic-conference') and the concept that triggered the C-Marking by receiving an activation (such as 'IJCAI-87').

[10]We use the term 'concept sequence' to represent some known sequence of concepts such as <feature, physical-object> which includes sequence of abstract concepts as in MOP components and also low level phrasal templates such as described by Becker[1975], Wilensky[1981], and Hovy[1986].

[11]Root concept is a concept that packages another concept in a structure, such as MOP. Verbs in a case-frame based lexicon are comparable structures.

[12]Concept refinement in DMTRANS is performed as a search in memory network for the concept that has links to specializations of the elements of the accepted concept sequence. Also, Lytinen discusses a rule-based version of concept refinement.

3.1.3 Contexual Marking

The C-Marker is stored in concepts called the contexual root concepts. Contexual root concepts are the concepts that influence the context of the text. Also these concepts are not necessarily the root concepts of the concept sequences. When the contexual root concepts receives activation they send C-Markers to associated concepts. Concepts such as 'academic-conference' are the contexual root concepts, and sends C-Markers to concepts including 'proceedings', 'thesis', etc[13]. This contexual marking mechanism helps to resolve ambiguities in texts especially when an input word has multiple meanings and also when the multiple interpretations of an input text may be solvable through the context that was established relatively recently[14]. When activation is spread upward in the abstraction hierarchy and if more than one route exist (such as two meanings for a word), then the route through the C-Marked concepts are chosen unless the route hits a higher level concept that indicates a contrary preference.

3.1.4 Examining Our Sample Translation

In order to demonstrate this mechanism, let us examine a short translation of a semantically (word-sense) ambiguous sentence: "John is at IJCAI-87. He said the quality of the paper is terrible" (Figure 1 & Appendix A.1[15]). Initially, all the first elements of concept sequences (indicated by <...>) are predicted. The first word "John" comes in and activates the concept 'John' (put A-Marker on it) then the A-Marker is sent upward until it hits the concept 'person' which is predicted by 'at-person-loc' as the first element of the sequence. Then the prediction is sent to 'is' which gets activated by receiving A-Marker from next input word "is". Then 'at' is predicted as the third element of the sequence which meets activation from the input "at". Then the prediction for 'location' is made. When the word "IJCAI-87" comes in, and activates 'IJCAI-87' and then 'location' ('IJCAI-87' has two immediate ancestors: 'academic-conference' and 'location') which was predicted as the last element of the concept sequence: <person is at location>, this concept sequence is accepted and the root-concept

[13]Generally, the recipient concepts of the C-Marker include: Participants of a MOP, concepts representing events, explanation-patterns attached to a MOP.

[14]Which is often the case with the ambiguities that most MT systems are currently avoiding to handle. When the context was not established relatively recently, ie, if the context is the result of larger conceptual framework, then the C-Marking may not always help. In such a case, the top-down predictions through the higher level MOP structures are more effective than the use of Context Marker passing.

[15]The memory network used in the examples uses the hierarchy described by Sakamoto,etal[1986] and are represented internally using Framekit+ (Carbonell&Joseph[1986]).

'at-person-loc' gets activated. Then the search is performed to find a specific concept under the root concept that indicates the input[16], and a concept refinement is conducted to get to 'at-John-IJCAI-87'. If this is not found, DMTRANS creates this concept as a specific episode of 'at-person-loc'. At the same time, since 'academic-conference' (activated by 'IJCAI-87') is a contexual-root concept it sends C-Markers to 'person-present-thesis', 'person-criticize-thesis', 'thesis', 'proceedings', etc.. When the next word "He" comes in, it sends activation upward and finds that the only male person activated in memory is 'John', and activates 'John' again; 'person' gets re-activated, which is predicted as the first element of 'mtrans-event', then "said" comes in and fits as the second element of the concept sequence attached to 'mtrans-event'. Likewise, "The quality of the paper is terrible" is accepted, being identified with the sequence <feature-type of object is feature-value> attached to 'object-description'.

3.1.5 Contexual Choices

One thing that happens is that when "paper" which is attached both to 'paper' and 'thesis' comes in, only 'thesis' sends activation upward because 'thesis' was C-Marked by 'academic-conference' and 'paper' was not marked. This choice is not challenged when 'mtrans-event' is accepted and is concept-refined to 'person-criticize-thesis-event', since this concept also supports the contexual interpretation of "paper"[17]. This way, understanding is left as activated memory structures representing 'at-John-IJCAI-87' and 'John-criticize-quality-of-thesis-event' that are instances of the refined concepts under accepted root concepts. Also, if two conflicting choices of a concept are marked by two C-Markers, the C-Marker put by the concept activated more recently gets preference. For example, in "John was writing a letter on a plane to IJCAI-87. The ink smeared. He said the quality of this paper is terrible" and in "John was printing a paper for IJCAI-87. The printer jammed. He said the quality of this paper is terrible", both 'paper' and 'thesis' are C-Marked by 'IJCAI-87'[18] and 'ink', 'IJCAI-87' and 'printer' respectively[19]. However, since, "ink" and "printer" both come after "IJCAI-87" in both cases, 'paper' is preferred over 'thesis' in both cases, and it gets activated. Unless these activations meet contradicting hypotheses elsewhere, 'paper' becomes the contextual interpretation of "paper".

[16]Concept refinement in DMTRANS is performed as a search for a node that packages the input recognized concept with links parallel to the links from the accepted root node to the elements of the accepted concept sequence.

[17]C-Marked by the same contexual root concept as 'thesis'.

[18]Actually, C-Marked by 'academic-conference' which was activated by 'IJCAI-87'.

[19]These three concepts trigger (activate) contexual-root concepts.

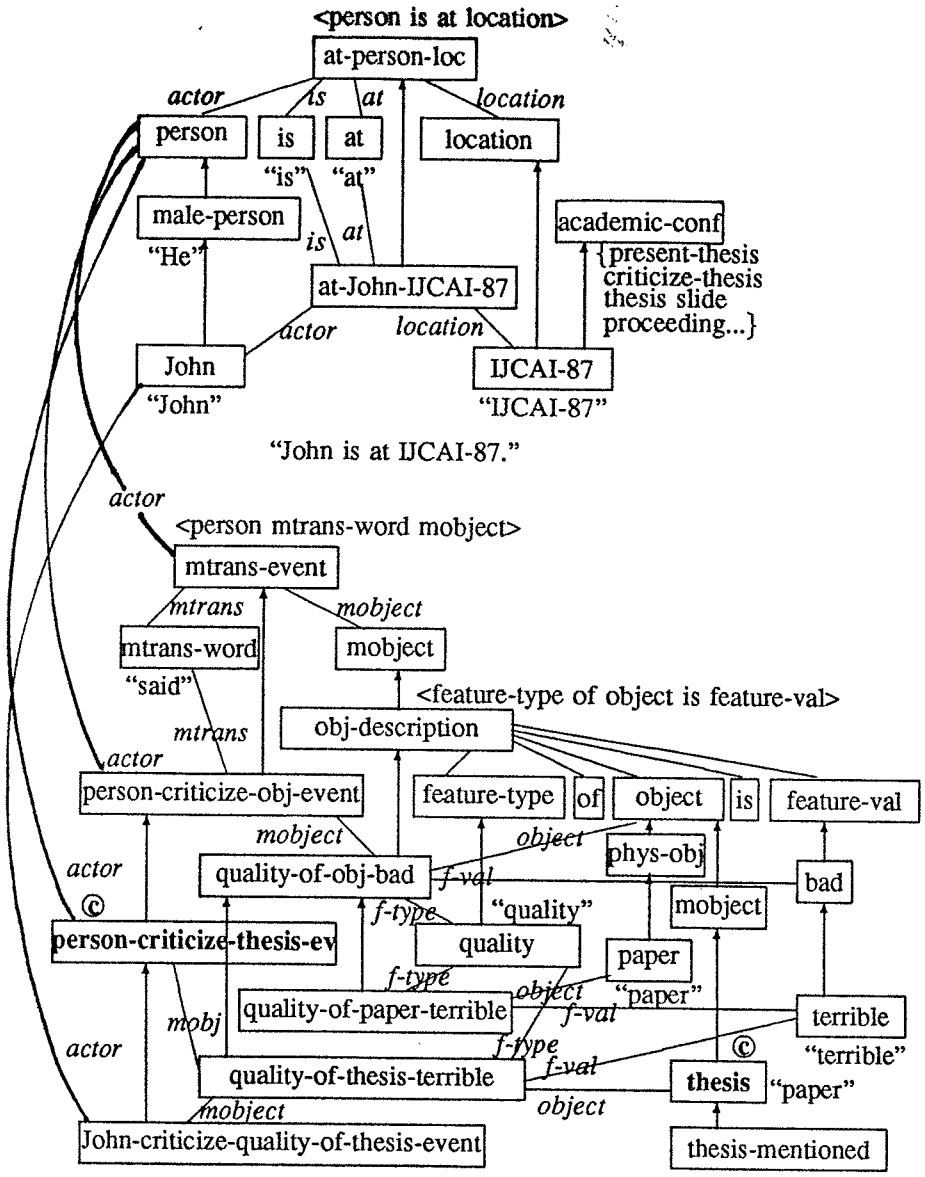

Figure 1: Concept refinement and context marking

3.2 Explanatory Generation

DMTRANS is capable of generating output through the mechanism of explanatory generation which can handle translation of culturally sensitive sentences and the concepts that do not have counterpart lexical entries in the target languages.

3.2.1 Multiple Concept Sequences

We have two different concept sequences stored in each root concept, one for English and one for Japanese[20]. Especially because they represent texts from different language families, the sequences are rarely the same; however, the roles are shared, it is because memory structures are independent of languages and the types of roles are inherent in the root concepts, not in the languages. Similar approaches are taken in Lytinen[1984]'s MOPTRANS and CMU's current generation MT system (Tomita&Carbonell). Both systems take advantage of shared memory structures for translation, the former using MOPs as the shared structure and the latter using case frames as the shared structure.

3.2.2 Generation Mechanism

Generation begins with the result of memory activation parsing from input in one language. For each concept refined nodes left in memory, we do the following. 1) Check at the lexical node for the refined concept in the target language and if a lexical entry is found, generate in accordance with templates stored with the concept and we are done. 2) If not, which is the often the case[21], we generate according to the stored concept sequence for the target language. That is to generate from the first element of the concept sequences (go back to 1 with the first element of the concept sequence). 3) Since not all concepts have sequence attached to it, search the abstraction hierarchy upward for abstraction of the refined concept which has concept sequences attached to it. 4) Get the sequence from this abstraction and then instantiate with the roles in the refined-concepts. Then from the first element of the instantiated concepts sequence, repeat from looking up lexical node again. If not found, repeat from the 2 again to explain this concept.

[20] Actually, we may have multiple concept sequences attached to a concept within a language instead of one for each languages

[21] This is the inherent uniqueness of the DMTRANS system, that the system does not halt even if the lexical entry is not found in the target language; instead DMTRANS tries to explain the concept through surrounding concepts in the memory network that have lexical entries in the target language.

3.2.3 Examining Our Sample Translation

One sample short translation is translating the Japanese sentence: "Gionshoja no kane no koe, shogyomujo no hibiki ari"[22] (Appendix A.2[23]) which is translated to be: "The sound of bell at Gionshoja has the tone of "shogyomujo" (impermanence of all phenomena in world)". The result of understanding by DMTRANS leaves the two concepts (instances) in memory that are: 'sound-of-bell-at-gionshoja' and 'exists-tone-of-shogyo-mujo'. In order to generate the first concept in English, it looks for the conceptual root concept above 'sound-of-bell-at-gionshoja' and finds 'sound-of-instrument' which has the sequence <sound of musical-instrument[24]> attached to it. We instantiate this sequence by the concepts packaged in 'sound-of-bell-at-gionshoja' and get <sound of bell-at-gionshoja>. By the same token, generate 'bell-at-gionshoja' by explaining it through the packaged concepts (that are neighbours in the linking relations) found in the concept sequences attached to the ancestor concepts and get <bell at gionshoja>. For the second concept left as the result of understanding: 'exists-tone-of-shogyo-mujo', we apply the same generation mechanism. First search the concept sequence attached to the ancestor of the 'exist-tone-of-shogyo-mujo' which is 'exists-feature-type-of-sound' and return <has the feature-type-of-sound> and instantiate it to be: <has the tone-of-shogyo-mujo>. Then generate 'tone-of-shogyo-mujo' explaining <tone of shogyo-mujo>. Here 'shogyo-mujo' is a concept peculiar to the Japanese culture (no corresponding English terms); however, since it is integrated into our memory network, it can be explained using the same generation mechanism. We get to its ancestor 'impermanence-of-all-phenomena' and return <impermanence of all phenomena> and generate this in English.

Note that DMTRANS outputs "shogyomujo" as "shogyomujo", and adds the explanation of the word in parentheses. This is because an English lexical entry for the concept representing 'shogyo-mujo' was not found in memory and we know that the phrase in parenthesis is the close meaning of the word "shogy-omujo". This mechanism is much more desirable than the behaviours of many current MT systems in which they either halt execution with input words without

[22] From *Heikemonogatari* written around 1210 (Sugita[1979]).

[23] The DMTRANS implementation at CMT is on IBM-RT using the CMU Common Lisp which currently lacks support for hiragana and chinese characters, and therefore, the text in Japanese is represented as the segmented ascii characters.

[24] Never mind even if the categorization of the 'bell at a Buddhist temple' to be a musical instrument sounds controversial. This is how we categorize in our memory network and the parser recognized accordingly. In other words, we could categorize the 'bell' to be something else and the same generation mechanism can handle the explanatory generation using the different definition of the concept.

corresponding target language vocabulary or simply output the original source words (without any attempts to explain). Since a concept may not be shared across languages, this type of translation happens often, especially in the cross-cultural context[25].

The strength of DMTRANS generation mechanism is that since generation is performed directly from the state of the memory network left as the recognition of the source text, ie, the understanding of the input text, it can generate the output in the target language using the concepts that are available in the target language and therefore, existence, or lack thereof, of the counterpart vocabularies for the input words does not change the performance of the translation.

3.3 Dynamic Interactions with the Rest of Cognition

Since translation is performed by directly accessing the memory network, other faculties of cognition can dynamically participate in translation. One example sentence here is "John threw an apple at the giant rat. It ate it". Whenever, a pronoun comes in as an input, DMTRANS tries to identify the object that is referred to[26]. In this example, the concept 'animal-ingest-object-event' gets activated by the input "it ate it". 'animal-ingest-object-event' is a MOP structure which is a kind of 'ingest-event'. It has two roles to be filled: Actor and Object. In order to determine the Actor, the inference mechanism is activated and it looks for activated concepts in memory that can be an Actor and finds 'giant-rat' to be a candidate given restrictions set forth by the MOP structure[27]. Then a search is made for concepts previously activated in memory that fit the requirements for Objects and 'apple' is selected to be an acceptable object of 'ingest-event'. This example only requires a minimum amount of work for deciding objects; however, this architecture allows for deeper inferences if necessary, such as utilizing causal relations stored in MOPs and eXplanation Patterns associated with higher level structures (Schank[1986])[28].

[25]The described explanatory generation mechanism works effectively in translation between English and Japanese, where a one to one match of concepts is often difficult to find due to the difference in the cultural contexts. Even words such as "river" and "kawa" (Japanese for river) which are normally substituted for one another without any further consideration, reveal difference in concepts attached to them, ie, the Japanese word "kawa" is normally associated with images of clear rapid streams. What about "kou" in Chinese?

[26]This is independent of the question whether to translate 'it' as 'it'. Even if we do, it is better to know what is referred by it with the reasons indicated before.

[27]If "John" is known to be a name of dog, we need more inference. Such as check the previously activated memory structure (propel-event) and infer where the apple is at now, etc..

[28]Actually, the understanding part of DMTRANS was originally designed as an integrated part of a case-based reasoning system to allow direct inference on input sentences.

3.4 A Translation system that learns

DMTRANS is capable of creating new concepts while translating, and is capable of learning new vocabulary for newly created concepts in a multi-lingual context. When a concept refinement is performed, if a specific concept representing the input sentence is not found underneath the accepted root concept, a new specialization is created. Also, the user of the system is asked to input the English and Japanese names (words) for the concept (or input phrase can simply be stored as a phrasal lexicon). By the same token, we can simply assert facts to be translated by DMTRANS and the system stores the assertion as well as it translates it as long as it is not incompatible with what it already knows. At the same time, the acquired concept is accessible from different contexts because of the hierarchical organization of memory (Schank[1982]) that implements MOP structures. This way DMTRANS implements dynamic memory as its memory network and is capable of learning while translating.

4 Conclusion

From a practical point of view, DMTRANS may be interesting because a lexically guided spreading activation mechanism is parallel in nature, and recent availability of massively parallel machines[29] makes it an appealing theory for machine translation, utilizing such parallel architectures. However, the impact of this theory is that translation is performed as an integrated part of cognition, cooperating with other faculties through memory. Most MT systems have failed in tackling contexually ambiguous sentences; however, in DMTRANS, with use of episodic and thematic memory, and also the C-Marker passing, performance with ambiguous sentences is significantly improved.

Explanatory generation handles culturally sensitive translations more effectively, especially when lexical entries in the target language are not available. Also, the dynamic participation of an inference mechanism contributes in handling phenomena such as anaphora, ellipses, and indirect speech acts. A future possibility is that we may supplement DMTRANS with other input output channels to make the system's abilities closer to those of human interpreters in handling questions of pragmatics, and also that we may introduce the notion of patterns of activations to our representational units[30] to represent and handle subtle semantic variations beyond the current level of contexual recognitions. In our understanding, memory is shared by all parts of cognition, and any cognitive

[29] Such as 'The Connection Machine' (Hillis[1985]).

[30] Such as the representation of frame-like structures in a neural nets by Touretzky&Geva[1987]

task including translation should be dynamically assisted by every faculty with direct access to the memory and the knowledge in the memory should be active and flexible from the micro-structure level upto the thematic patterns.

A Sample Runs of the DMTRANS

A.1 English-to-Japanese Translations

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* (eng '(John is at IJCAI-87. He said the quality of the paper is terrible.))

Initializing the concept sequence predictions..
Predicting first elements of concept sequences...

Input word: JOHN
 Lexical node(s): JOHN.
 Creating A-Marker: #S(MARKER SOURCE JOHN FROM LEX)
  activating JOHN
  activating MALE-PERSON
  activating PERSON
  activating HUMAN
  activating ANIMATE-OBJECT
  activating PHYSICAL-OBJECT
  activating OBJECT
  activating CATEGORY
 Concept sequence recognized: (PERSON MTRANS-WORD MENTAL-OBJECT)
 predicting next element of concept sequence: MTRANS-WORD
 Putting P-marker #S(MARKER SOURCE MTRANS-EVENT FROM JOHN) on MTRANS-WORD
 Concept sequence recognized: (PERSON IS AT LOCATION)
 predicting next element of concept sequence: IS
 Putting P-marker #S(MARKER SOURCE AT-PERSON-LOC FROM JOHN) on IS
  Removing prediction on PERSON predicted by AT-PERSON-LOC
  Removing prediction on PERSON predicted by MTRANS-EVENT

Input word: IS
 Lexical node(s): IS.
 Creating A-Marker: #S(MARKER SOURCE IS FROM LEX)
  activating IS
  activating NATURE&PROPERTY
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (PERSON IS AT LOCATION)
 predicting next element of concept sequence: AT
 Putting P-marker #S(MARKER SOURCE AT-PERSON-LOC FROM IS) on AT
  Removing prediction on IS predicted by AT-PERSON-LOC

Input word: AT
 Lexical node(s): AT.
 Creating A-Marker: #S(MARKER SOURCE AT FROM LEX)
  activating AT
  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (PERSON IS AT LOCATION)
 predicting next element of concept sequence: LOCATION
 Putting P-marker #S(MARKER SOURCE AT-PERSON-LOC FROM AT) on LOCATION
  Removing prediction on AT predicted by AT-PERSON-LOC

Input word: IJCAI-87
 Lexical node(s): IJCAI-87.
 Creating A-Marker: #S(MARKER SOURCE IJCAI-87 FROM LEX)
  activating IJCAI-87
```

```
   activating LOCATION
   activating SPACE&TOPOGRAPHY
   activating CATEGORY
  Last element of concept sequence: (PERSON IS AT LOCATION)
   activating ACADEMIC-CONFERENCE
  Contexual root node ACADEMIC-CONFERENCE activated.
  Performing contexual marking...
  Creating C-Marker: #S(MARKER SOURCE ACADEMIC-CONFERENCE FROM NIL)
  Putting C-marker #S(MARKER SOURCE ACADEMIC-CONFERENCE FROM IJCAI-87) on THESIS
  Putting C-marker #S(MARKER SOURCE ACADEMIC-CONFERENCE FROM IJCAI-87) on SLIDE
  Putting C-marker #S(MARKER SOURCE ACADEMIC-CONFERENCE FROM IJCAI-87) on PROCEEDING
  Putting C-marker #S(MARKER SOURCE ACADEMIC-CONFERENCE FROM IJCAI-87) on PERSON-CRI
  Putting C-marker #S(MARKER SOURCE ACADEMIC-CONFERENCE FROM IJCAI-87) on PERSON-PRE
   activating CONFERENCE
   activating SOCIAL-PHENOMENON
   activating PHENOMENON
   activating CATEGORY
  Concept sequence accepted trying refinements...
  Refined concept not found in memory..
  Creating a new concept..
  With definition: ((IS-A AT-PERSON-LOC) (PERSON JOHN) (IS IS) (AT AT)
                    (LOCATION IJCAI-87))
  PLEASE NAME THIS CONCEPT: at-John-ijcai-87

   Adding the link:  IS-A
   With the content: AT-PERSON-LOC
   Adding the link:  PERSON
   With the content: JOHN
   Adding the link:  IS
   With the content: IS
   Adding the link:  AT
   With the content: AT
   Adding the link:  LOCATION
   With the content: IJCAI-87
  Concept refined, new root of sequence: AT-JOHN-IJCAI-87
   Removing prediction on PERSON predicted by AT-PERSON-LOC
   Removing prediction on IS predicted by AT-PERSON-LOC
   Removing prediction on AT predicted by AT-PERSON-LOC
   Removing prediction on LOCATION predicted by AT-PERSON-LOC
  Resetting the first element predictions of accepted and
  aborted concept sequences with acceptance of: (PERSON IS AT LOCATION)
  Resetting prediction on the first element of sequence: PERSON
  Creating P-Marker: #S(MARKER SOURCE MTRANS-EVENT FROM INITIAL)
  Putting P-marker #S(MARKER SOURCE MTRANS-EVENT FROM INITIAL) on PERSON
  Resetting prediction on the first element of sequence: PERSON
  Creating P-Marker: #S(MARKER SOURCE AT-PERSON-LOC FROM INITIAL)
  Putting P-marker #S(MARKER SOURCE AT-PERSON-LOC FROM INITIAL) on PERSON
  Creating A-Marker: #S(MARKER SOURCE AT-JOHN-IJCAI-87 FROM ROOT)
   activating AT-JOHN-IJCAI-87
   activating AT-PERSON-LOC
   activating AT-OBJECT-LOC
   activating PHYSICAL-PHENOMENON
   activating PHENOMENON
   activating CATEGORY

Input word: HE
 Lexical node(s): HE.
 Creating A-Marker: #S(MARKER SOURCE HE FROM LEX)
Input is HE, and only activated (MALE-PERSON)
is JOHN.
Assuming HE to be JOHN.
  activating HE
  activating MALE-PERSON
  activating PERSON
  activating HUMAN
  activating ANIMATE-OBJECT
```

```
  activating PHYSICAL-OBJECT
  activating OBJECT
  activating CATEGORY
 Concept sequence recognized: (PERSON MTRANS-WORD MENTAL-OBJECT)
 predicting next element of concept sequence: MTRANS-WORD
 Putting P-marker #S(MARKER SOURCE MTRANS-EVENT FROM HE) on MTRANS-WORD
 Concept sequence recognized: (PERSON IS AT LOCATION)
 predicting next element of concept sequence: IS
 Putting P-marker #S(MARKER SOURCE AT-PERSON-LOC FROM HE) on IS
  Removing prediction on PERSON predicted by AT-PERSON-LOC
  Removing prediction on PERSON predicted by MTRANS-EVENT

Input word: SAID
 Lexical node(s): SAID.
 Creating A-Marker: #S(MARKER SOURCE SAID FROM LEX)
  activating SAID
  activating MTRANS-WORD
  activating MTRANS
  activating ACT
  activating ACTION
  activating CATEGORY
 Concept sequence recognized: (PERSON MTRANS-WORD MENTAL-OBJECT)
 predicting next element of concept sequence: MENTAL-OBJECT
  utting P-marker #S(MARKER SOURCE MTRANS-EVENT FROM SAID) on MENTAL-OBJECT
  Removing prediction on MTRANS-WORD predicted by MTRANS-EVENT

Input word: THE
 Lexical node(s): THE.
 Creating A-Marker: #S(MARKER SOURCE THE FROM LEX)
  activating THE

Input word: QUALITY
 Lexical node(s): QUALITY.
 Creating A-Marker: #S(MARKER SOURCE QUALITY FROM LEX)
  activating QUALITY
  activating FEATURE-TYPE
  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (FEATURE-TYPE OF OBJECT IS FEATURE-VALUE)
 predicting next element of concept sequence: OF
 Putting P-marker #S(MARKER SOURCE OBJ-DESCRIPTION FROM QUALITY) on OF
  Removing prediction on FEATURE-TYPE predicted by OBJ-DESCRIPTION

Input word: OF
 Lexical node(s): OF.
 Creating A-Marker: #S(MARKER SOURCE OF FROM LEX)
  activating OF
  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (FEATURE-TYPE OF OBJECT IS FEATURE-VALUE)
 predicting next element of concept sequence: OBJECT
 Putting P-marker #S(MARKER SOURCE OBJ-DESCRIPTION FROM OF) on OBJECT
  Removing prediction on OF predicted by OBJ-DESCRIPTION

Input word: THE
 Lexical node(s): THE.
 Creating A-Marker: #S(MARKER SOURCE THE FROM LEX)
  activating THE

Input word: PAPER
 Lexical node(s): (PAPER THESIS).
 Multiple meaning exist: (PAPER THESIS).
 THESIS C-Marked, choosing it as the contexual interpretation...
 Creating A-Marker: #S(MARKER SOURCE THESIS FROM LEX)
```

```
*** This activation confirms the current context: ACADEMIC-CONFERENCE
    which was established by the activation of: IJCAI-87.
  activating THESIS
  activating INTELLECTUAL-PRODUCT
  activating MENTAL-OBJECT
  activating OBJECT
  activating CATEGORY
 Concept sequence recognized: (FEATURE-TYPE OF OBJECT IS FEATURE-VALUE)
 predicting next element of concept sequence: IS
 Putting P-marker #S(MARKER SOURCE OBJ-DESCRIPTION FROM THESIS) on IS
  Removing prediction on OBJECT predicted by OBJ-DESCRIPTION

Input word: IS
 Lexical node(s): IS.
 Creating A-Marker: #S(MARKER SOURCE IS FROM LEX)
  activating IS
  activating NATURE&PROPERTY
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (FEATURE-TYPE OF OBJECT IS FEATURE-VALUE)
 predicting next element of concept sequence: FEATURE-VALUE
 Putting P-marker #S(MARKER SOURCE OBJ-DESCRIPTION FROM IS) on FEATURE-VALUE
  Removing prediction on IS predicted by OBJ-DESCRIPTION

Input word: TERRIBLE
 Lexical node(s): TERRIBLE.
 Creating A-Marker: #S(MARKER SOURCE TERRIBLE FROM LEX)
  activating TERRIBLE
  activating BAD
  activating FEATURE-VALUE
  activating CONDITION
  activating ATTRIBUTE
  activating CATEGORY
 Last element of concept sequence: (FEATURE-TYPE OF OBJECT IS FEATURE-VALUE)
 Concept sequence accepted trying refinements...
 Refined concept not found in memory..
 Creating a new concept..
 With definition: ((IS-A OBJ-DESCRIPTION) (FEATURE-TYPE QUALITY) (OF OF)
                   (OBJECT THESIS) (IS IS) (FEATURE-VALUE TERRIBLE))
 PLEASE NAME THIS CONCEPT: quality-of-thesis-terrible

 Appropriate location to add the new concept is
 immediately below THESIS-DESCRIPTION
  Adding the link:  IS-A
  With the content: THESIS-DESCRIPTION
  Adding the link:  FEATURE-TYPE
  With the content: QUALITY
  Adding the link:  OF
  With the content: OF
  Adding the link:  OBJECT
  With the content: THESIS
  Adding the link:  IS
  With the content: IS
  Adding the link:  FEATURE-VALUE
  With the content: TERRIBLE
 Concept refined, new root of sequence: QUALITY-OF-THESIS-TERRIBLE
  Removing prediction on FEATURE-TYPE predicted by OBJ-DESCRIPTION
  Removing prediction on OF predicted by OBJ-DESCRIPTION
  Removing prediction on OBJECT predicted by OBJ-DESCRIPTION
  Removing prediction on IS predicted by OBJ-DESCRIPTION
  Removing prediction on FEATURE-VALUE predicted by OBJ-DESCRIPTION
 Resetting the first element predictions of accepted and
 aborted concept sequences with acceptance of: (FEATURE-TYPE OF OBJECT IS
                                                FEATURE-VALUE)
 Resetting prediction on the first element of sequence: FEATURE-TYPE
 Creating P-Marker: #S(MARKER SOURCE OBJ-DESCRIPTION FROM INITIAL)
```

```
 Putting P-marker #S(MARKER SOURCE OBJ-DESCRIPTION FROM INITIAL) on FEATURE-TYPE
 Creating A-Marker: #S(MARKER SOURCE QUALITY-OF-THESIS-TERRIBLE FROM ROOT)
  activating QUALITY-OF-THESIS-TERRIBLE
  activating THESIS-DESCRIPTION
  activating OBJ-DESCRIPTION
  activating OTHER-MENTAL-OBJECT
  activating MENTAL-OBJECT
  activating OBJECT
  activating CATEGORY
 Last element of concept sequence: (PERSON MTRANS-WORD MENTAL-OBJECT)
 Concept sequence accepted trying refinements...
 Refined concept not found in memory..
 Creating a new concept..
 With definition: ((IS-A MTRANS-EVENT) (PERSON JOHN) (MTRANS-WORD SAID)
                   (MENTAL-OBJECT QUALITY-OF-THESIS-TERRIBLE))
 PLEASE NAME THIS CONCEPT: John-criticize-quality-of-thesis-event

 Appropriate location to add the new concept is
 immediately below PERSON-CRITICIZE-THESIS
  Adding the link:  IS-A
  With the content: PERSON-CRITICIZE-THESIS
  Adding the link:  PERSON
  With the content: JOHN
  Adding the link:  MTRANS-WORD
  With the content: SAID
  Adding the link:  MENTAL-OBJECT
  With the content: QUALITY-OF-THESIS-TERRIBLE
 Concept refined, new root of sequence: JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT
  Removing prediction on PERSON predicted by MTRANS-EVENT
  Removing prediction on MTRANS-WORD predicted by MTRANS-EVENT
  Removing prediction on MENTAL-OBJECT predicted by MTRANS-EVENT
 Resetting the first element predictions of accepted and
 aborted concept sequences with acceptance of: (PERSON MTRANS-WORD MENTAL-OBJECT)
 Resetting prediction on the first element of sequence: PERSON
 Creating P-Marker: #S(MARKER SOURCE MTRANS-EVENT FROM INITIAL)
 Putting P-marker #S(MARKER SOURCE MTRANS-EVENT FROM INITIAL) on PERSON
 Resetting prediction on the first element of sequence: PERSON
 Creating P-Marker: #S(MARKER SOURCE AT-PERSON-LOC FROM INITIAL)
 Putting P-marker #S(MARKER SOURCE AT-PERSON-LOC FROM INITIAL) on PERSON
 Creating A-Marker: #S(MARKER SOURCE JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT FROM R(
  activating JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT
  activating PERSON-CRITICIZE-THESIS
*** This activation confirms the current context: ACADEMIC-CONFERENCE
    which was established by the activation of: IJCAI-87.
  activating MTRANS-EVENT
  activating EVENT
  activating PHYSICAL-PHENOMENON
  activating PHENOMENON
  activating CATEGORY
 ... ALL DELAYED EXCUTED ...
 Final concepts: (AT-JOHN-IJCAI-87 JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT)
(AT-JOHN-IJCAI-87 JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT)

* (generate)

BEGIN GENERATION
 Generation from the current memory with concepts:
 (AT-JOHN-IJCAI-87 JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT)

English for the input concept:
 Returning ENGLISH for AT-JOHN-IJCAI-87 ... No lexical entry.
 Explanatory generating non-lexical concept: AT-JOHN-IJCAI-87
 Retrieving the concept sequence from root concept:
 (PERSON IS AT LOCATION)
 Reordering the packaged concepts under this sequence:
 (JOHN IS AT IJCAI-87)
```

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    Returning ENGLISH for JOHN ... Lexical entry found: JOHN.
    Returning ENGLISH for IS ... Lexical entry found: IS.
    Returning ENGLISH for AT ... Lexical entry found: AT.
    Returning ENGLISH for IJCAI-87 ... Lexical entry found: IJCAI87.
     JOHN IS AT IJCAI87

   Japanese for the input concept:
    Returning JAPANESE for AT-JOHN-IJCAI-87 ... No lexical entry.
    Explanatory generating non-lexical concept: AT-JOHN-IJCAI-87
    Retrieving the concept sequence from root concept:
    (PERSON IS LOCATION AT EXIST)
    Reordering the packaged concepts under this sequence:
    (JOHN IS IJCAI-87 AT EXIST)
    Returning JAPANESE for JOHN ... Lexical entry found: JIYON.
    Returning JAPANESE for IS ... Lexical entry found: WA.
    Returning JAPANESE for IJCAI-87 ... Lexical entry found: 87-NENDO-IJICAI.
    Returning JAPANESE for AT ... Lexical entry found: NI.
    Returning JAPANESE for EXIST ... Lexical entry found: IRU.
     JIYON WA 87-NENDO-IJICAI NI IRU

  English for the input concept:
    Returning ENGLISH for JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT ... No lexical entry
    Explanatory generating non-lexical concept: JOHN-CRITICIZE-QUALITY-OF-THESIS-EVEN
    Retrieving the concept sequence from root concept:
    (PERSON MTRANS-WORD MENTAL-OBJECT)
    Reordering the packaged concepts under this sequence:
    (JOHN SAID QUALITY-OF-THESIS-TERRIBLE)
    Returning ENGLISH for JOHN ... Lexical entry found: JOHN.
    Returning ENGLISH for SAID ... Lexical entry found: SAID.
    Returning ENGLISH for QUALITY-OF-THESIS-TERRIBLE ... No lexical entry.
    Explanatory generating non-lexical concept: QUALITY-OF-THESIS-TERRIBLE
    Retrieving the concept sequence from root concept:
    (FEATURE-TYPE OF OBJECT IS FEATURE-VALUE)
    Reordering the packaged concepts under this sequence:
    (QUALITY OF THESIS IS TERRIBLE)
    Returning ENGLISH for QUALITY ... Lexical entry found: QUALITY.
    Returning ENGLISH for OF ... Lexical entry found: OF.
    Returning ENGLISH for THESIS ... Lexical entry found: PAPER.
    Returning ENGLISH for IS ... Lexical entry found: IS.
    Returning ENGLISH for TERRIBLE ... Lexical entry found: TERRIBLE.
     JOHN SAID QUALITY OF PAPER IS TERRIBLE

  Japanese for the input concept:
    Returning JAPANESE for JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT ... No lexical
    Explanatory generating non-lexical concept: JOHN-CRITICIZE-QUALITY-OF-THESIS-EVENT
    Retrieving the concept sequence from root concept:
    (PERSON IS1 MENTAL-OBJECT MTRANS-WORD)
    Reordering the packaged concepts under this sequence:
    (JOHN IS1 QUALITY-OF-THESIS-TERRIBLE SAID)
    Returning JAPANESE for JOHN ... Lexical entry found: JIYON.
    Returning JAPANESE for IS1 ... Lexical entry found: WA.
    Returning JAPANESE for QUALITY-OF-THESIS-TERRIBLE ... No lexical entry.
    Explanatory generating non-lexical concept: QUALITY-OF-THESIS-TERRIBLE
    Retrieving the concept sequence from root concept:
    (OBJECT OF FEATURE-TYPE IS2 FEATURE-VALUE)
    Reordering the packaged concepts under this sequence:
    (THESIS OF QUALITY IS2 TERRIBLE)
    Returning JAPANESE for THESIS ... Lexical entry found: RONBUN.
    Returning JAPANESE for OF ... Lexical entry found: NO.
    Returning JAPANESE for QUALITY ... Lexical entry found: SHITSU.
    Returning JAPANESE for IS2 ... Lexical entry found: GA.
    Returning JAPANESE for TERRIBLE ... Lexical entry found: HIDOI.
    Returning JAPANESE for SAID ... Lexical entry found: TOIITTA.
     JIYON WA RONBUN NO SHITSU GA HIDOI TOIITTA
GENERATION-COMPLETE
*
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A.2 Japanese-to-English Translations

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* (jap '(Gionshoja no kane no koe shogyomujo no hibiki ari))

Initializing the concept sequence predictions..
Predicting first elements of concept sequences...

Input word: GIONSHOJA
 Lexical node(s): GIONSHOJA.
 Creating A-Marker: #S(MARKER SOURCE GIONSHOJA FROM LEX)
  activating GIONSHOJA
  activating TEMPLE
  activating BUILDING-STRUCTURE
  activating INANIMATE-OBJECT
  activating PHYSICAL-OBJECT
  activating OBJECT
  activating CATEGORY
 Concept sequence recognized: (OBJECT OF FEATURE-TYPE IS2 FEATURE-VALUE)
 predicting next element of concept sequence: OF
 Putting P-marker #S(MARKER SOURCE OBJ-DESCRIPTION FROM GIONSHOJA) on OF
  activating LOCATION
  activating SPACE&TOPOGRAPHY
  activating CATEGORY
 Concept sequence recognized: (LOCATION OF PHYSICAL-OBJECT)
 predicting next element of concept sequence: OF
 Putting P-marker #S(MARKER SOURCE PHYS-OBJ-AT-LOC FROM GIONSHOJA) on OF
  Removing prediction on LOCATION predicted by PHYS-OBJ-AT-LOC
  Removing prediction on OBJECT predicted by OBJ-DESCRIPTION

Input word: NO
 Lexical node(s): OF.
 Creating A-Marker: #S(MARKER SOURCE OF FROM LEX)
  activating OF
  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (OBJECT OF FEATURE-TYPE IS2 FEATURE-VALUE)
 predicting next element of concept sequence: FEATURE-TYPE
 Putting P-marker #S(MARKER SOURCE OBJ-DESCRIPTION FROM OF) on FEATURE-TYPE
 Concept sequence recognized: (LOCATION OF PHYSICAL-OBJECT)
 predicting next element of concept sequence: PHYSICAL-OBJECT
 Putting P-marker #S(MARKER SOURCE PHYS-OBJ-AT-LOC FROM OF) on PHYSICAL-OBJECT
  Removing prediction on OF predicted by PHYS-OBJ-AT-LOC
  Removing prediction on OF predicted by OBJ-DESCRIPTION

Input word: KANE
 Lexical node(s): BELL.
 Creating A-Marker: #S(MARKER SOURCE BELL FROM LEX)
  activating BELL
  activating MUSICAL-INSTRUMENT
  activating ARTIFICIAL-SUBSTANCE
  activating INANIMATE-OBJECT
  activating PHYSICAL-OBJECT
  activating OBJECT
  activating CATEGORY
 Last element of concept sequence: (LOCATION OF PHYSICAL-OBJECT)
 Concept sequence recognized: (MUSICAL-INSTRUMENT OF SOUND)
 predicting next element of concept sequence: OF
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```
Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM BELL) on OF
Concept sequence recognized: (MUSICAL-INSTRUMENT OF SOUND)
predicting next element of concept sequence: OF
Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM BELL) on OF
 Removing prediction on MUSICAL-INSTRUMENT predicted by SOUND-OF-INSTRUMENT
 Removing prediction on MUSICAL-INSTRUMENT predicted by SOUND-OF-INSTRUMENT
Concept sequence accepted trying refinements...
Refined concept not found in memory..
Creating a new concept..
With definition: ((IS-A PHYS-OBJ-AT-LOC) (LOCATION GIONSHOJA) (OF OF)
                  (PHYSICAL-OBJECT BELL))
PLEASE NAME THIS CONCEPT: bell-at-Gionshoja

Appropriate location to add the new concept is
immediately below BELL-AT-LOC
 Adding the link:  IS-A
 With the content: BELL-AT-LOC
 Adding the link:  LOCATION
 With the content: GIONSHOJA
 Adding the link:  OF
 With the content: OF
 Adding the link:  PHYSICAL-OBJECT
 With the content: BELL
Concept refined, new root of sequence: BELL-AT-GIONSHOJA
 Removing prediction on LOCATION predicted by PHYS-OBJ-AT-LOC
 Removing prediction on OF predicted by PHYS-OBJ-AT-LOC
 Removing prediction on PHYSICAL-OBJECT predicted by PHYS-OBJ-AT-LOC
Resetting the first element predictions of accepted and
aborted concept sequences with acceptance of: (LOCATION OF PHYSICAL-OBJECT)
Resetting prediction on the first element of sequence: LOCATION
Creating P-Marker: #S(MARKER SOURCE PHYS-OBJ-AT-LOC FROM INITIAL)
Putting P-marker #S(MARKER SOURCE PHYS-OBJ-AT-LOC FROM INITIAL) on LOCATION
Creating A-Marker: #S(MARKER SOURCE BELL-AT-GIONSHOJA FROM ROOT)
 activating BELL-AT-GIONSHOJA
 activating BELL-AT-LOC
 activating PHYS-OBJ-AT-LOC
 activating PHYSICAL-OBJECT
 activating OBJECT
 activating CATEGORY
 activating BELL
 activating MUSICAL-INSTRUMENT
 activating ARTIFICIAL-SUBSTANCE
 activating INANIMATE-OBJECT
 activating PHYSICAL-OBJECT
 activating OBJECT
 activating CATEGORY

Input word: NO
 Lexical node(s): OF.
 Creating A-Marker: #S(MARKER SOURCE OF FROM LEX)
  activating OF
  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (MUSICAL-INSTRUMENT OF SOUND)
 predicting next element of concept sequence: SOUND
 Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM OF) on SOUND
 Concept sequence recognized: (MUSICAL-INSTRUMENT OF SOUND)
 predicting next element of concept sequence: SOUND
 Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM OF) on SOUND
  Removing prediction on OF predicted by SOUND-OF-INSTRUMENT
  Removing prediction on OF predicted by SOUND-OF-INSTRUMENT

Input word: KOE
 Lexical node(s): SOUND.
 Creating A-Marker: #S(MARKER SOURCE SOUND FROM LEX)
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 activating SOUND
 activating PHYSICAL-PHENOMENON
 activating PHENOMENON
 activating CATEGORY
 activating OTHER-MENTAL-OBJECT
 activating MENTAL-OBJECT
 activating OBJECT
 activating CATEGORY
Last element of concept sequence: (MUSICAL-INSTRUMENT OF SOUND)
Last element of concept sequence: (MUSICAL-INSTRUMENT OF SOUND)
Concept sequence accepted trying refinements...
Refined concept not found in memory..
Creating a new concept..
With definition: ((IS-A SOUND-OF-INSTRUMENT)
                  (MUSICAL-INSTRUMENT BELL-AT-GIONSHOJA) (OF OF) (SOUND SOUND))
PLEASE NAME THIS CONCEPT: sound-of-bell-at-Gionshoja

 Adding the link:  IS-A
 With the content: SOUND-OF-INSTRUMENT
 Adding the link:  MUSICAL-INSTRUMENT
 With the content: BELL-AT-GIONSHOJA
 Adding the link:  OF
 With the content: OF
 Adding the link:  SOUND
 With the content: SOUND
Concept refined, new root of sequence: SOUND-OF-BELL-AT-GIONSHOJA
 Removing prediction on MUSICAL-INSTRUMENT predicted by SOUND-OF-INSTRUMENT
 Removing prediction on OF predicted by SOUND-OF-INSTRUMENT
 Removing prediction on SOUND predicted by SOUND-OF-INSTRUMENT
Resetting the first element predictions of accepted and
aborted concept sequences with acceptance of: (MUSICAL-INSTRUMENT OF SOUND)
Resetting prediction on the first element of sequence: MUSICAL-INSTRUMENT
Creating P-Marker: #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL)
Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL) on MUSICAL-INS
Resetting prediction on the first element of sequence: MUSICAL-INSTRUMENT
Creating P-Marker: #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL)
Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL) on MUSICAL-INS
 Removing prediction on MUSICAL-INSTRUMENT predicted by SOUND-OF-INSTRUMENT
 Removing prediction on OF predicted by SOUND-OF-INSTRUMENT
 Removing prediction on SOUND predicted by SOUND-OF-INSTRUMENT
Resetting the first element predictions of accepted and
aborted concept sequences with acceptance of: (MUSICAL-INSTRUMENT OF SOUND)
esetting prediction on the first element of sequence: MUSICAL-INSTRUMENT
reating P-Marker: #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL)
Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL) on MUSICAL-INS
Resetting prediction on the first element of sequence: MUSICAL-INSTRUMENT
Creating P-Marker: #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL)
Putting P-marker #S(MARKER SOURCE SOUND-OF-INSTRUMENT FROM INITIAL) on MUSICAL-INS
Creating A-Marker: #S(MARKER SOURCE SOUND-OF-BELL-AT-GIONSHOJA FROM ROOT)
 activating SOUND-OF-BELL-AT-GIONSHOJA
 activating SOUND-OF-INSTRUMENT
 activating SOUND
 activating PHYSICAL-PHENOMENON
 activating PHENOMENON
 activating CATEGORY
 activating OTHER-MENTAL-OBJECT
 activating MENTAL-OBJECT
 activating OBJECT
 activating CATEGORY

Input word: SHOGYOMUJO
 Lexical node(s): SHOGYO-MUJO.
 Creating A-Marker: #S(MARKER SOURCE SHOGYO-MUJO FROM LEX)
  activating SHOGYO-MUJO
  activating IMPERMANENCE-IN-WORLD
  activating FEATURE-TYPE
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  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (FEATURE-TYPE OF SOUND)
 predicting next element of concept sequence: OF
 Putting P-marker #S(MARKER SOURCE FEATURE-TYPE-OF-SOUND FROM SHOGYO-MUJO) on OF
  Removing prediction on FEATURE-TYPE predicted by FEATURE-TYPE-OF-SOUND

Input word: NO
 Lexical node(s): OF.
 Creating A-Marker: #S(MARKER SOURCE OF FROM LEX)
  activating OF
  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (FEATURE-TYPE OF SOUND)
 predicting next element of concept sequence: SOUND
 Putting P-marker #S(MARKER SOURCE FEATURE-TYPE-OF-SOUND FROM OF) on SOUND
  Removing prediction on OF predicted by FEATURE-TYPE-OF-SOUND

Input word: HIBIKI
 Lexical node(s): TONE.
 Creating A-Marker: #S(MARKER SOURCE TONE FROM LEX)
  activating TONE
  activating SOUND
  activating PHYSICAL-PHENOMENON
  activating PHENOMENON
  activating CATEGORY
  activating OTHER-MENTAL-OBJECT
  activating MENTAL-OBJECT
  activating OBJECT
  activating CATEGORY
 Last element of concept sequence: (FEATURE-TYPE OF SOUND)
 Concept sequence accepted trying refinements...
 Refined concept not found in memory..
 Creating a new concept..
 With definition: ((IS-A FEATURE-TYPE-OF-SOUND) (FEATURE-TYPE SHOGYO-MUJO)
                   (OF OF) (SOUND TONE))
 PLEASE NAME THIS CONCEPT: tone-of-shogyo-mujo

  Adding the link:  IS-A
  With the content: FEATURE-TYPE-OF-SOUND
  Adding the link:  FEATURE-TYPE
  With the content: SHOGYO-MUJO
  Adding the link:  OF
  With the content: OF
  Adding the link:  SOUND
  With the content: TONE
 Concept refined, new root of sequence: TONE-OF-SHOGYO-MUJO
  Removing prediction on FEATURE-TYPE predicted by FEATURE-TYPE-OF-SOUND
  Removing prediction on OF predicted by FEATURE-TYPE-OF-SOUND
  Removing prediction on SOUND predicted by FEATURE-TYPE-OF-SOUND
 Resetting the first element predictions of accepted and
 aborted concept sequences with acceptance of: (FEATURE-TYPE OF SOUND)
 Resetting prediction on the first element of sequence: FEATURE-TYPE
 Creating P-Marker: #S(MARKER SOURCE FEATURE-TYPE-OF-SOUND FROM INITIAL)
 Putting P-marker #S(MARKER SOURCE FEATURE-TYPE-OF-SOUND FROM INITIAL) on FEATURE-
 Creating A-Marker: #S(MARKER SOURCE TONE-OF-SHOGYO-MUJO FROM ROOT)
  activating TONE-OF-SHOGYO-MUJO
  activating FEATURE-TYPE-OF-SOUND
  activating FEATURE-TYPE
  activating ATTRIBUTE-NAME
  activating ATTRIBUTE
  activating CATEGORY
 Concept sequence recognized: (FEATURE-TYPE OF SOUND)
 predicting next element of concept sequence: OF
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 Putting P-marker #S(MARKER SOURCE FEATURE-TYPE-OF-SOUND FROM TONE-OF-SHOGYO-MUJO)
 Concept sequence recognized: (FEATURE-TYPE-OF-SOUND EXIST2)
 predicting next element of concept sequence: EXIST2
 Putting P-marker #S(MARKER SOURCE EXISTS-FEATURE-TYPE-OF-SOUND FROM TONE-OF-SHOGYC
  Removing prediction on FEATURE-TYPE-OF-SOUND predicted by EXISTS-FEATURE-TYPE-OF-
  Removing prediction on FEATURE-TYPE predicted by FEATURE-TYPE-OF-SOUND

Input word: ARI
 Lexical node(s): EXIST2.
 Creating A-Marker: #S(MARKER SOURCE EXIST2 FROM LEX)
  activating EXIST2
  activating EXIST
  activating PHYSICAL-PHENOMENON
  activating PHENOMENON
  activating CATEGORY
 Last element of concept sequence: (FEATURE-TYPE-OF-SOUND EXIST2)
 Concept sequence accepted trying refinements...
 Refined concept not found in memory..
 Creating a new concept..
 With definition: ((IS-A EXISTS-FEATURE-TYPE-OF-SOUND)
                   (FEATURE-TYPE-OF-SOUND TONE-OF-SHOGYO-MUJO) (EXIST2 EXIST2))
 PLEASE NAME THIS CONCEPT: exists-tone-of-shogyo-mujo

  Adding the link:  IS-A
  With the content: EXISTS-FEATURE-TYPE-OF-SOUND
  Adding the link:  FEATURE-TYPE-OF-SOUND
  With the content: TONE-OF-SHOGYO-MUJO
  Adding the link:  EXIST2
  With the content: EXIST2
 Concept refined, new root of sequence: EXISTS-TONE-OF-SHOGYO-MUJO
  Removing prediction on FEATURE-TYPE-OF-SOUND predicted by EXISTS-FEATURE-TYPE-OF-
  Removing prediction on EXIST2 predicted by EXISTS-FEATURE-TYPE-OF-SOUND
 Resetting the first element predictions of accepted and
 aborted concept sequences with acceptance of: (FEATURE-TYPE-OF-SOUND EXIST2)
 Resetting prediction on the first element of sequence: FEATURE-TYPE-OF-SOUND
 Creating P-Marker: #S(MARKER SOURCE EXISTS-FEATURE-TYPE-OF-SOUND FROM INITIAL)
 Putting P-marker #S(MARKER SOURCE EXISTS-FEATURE-TYPE-OF-SOUND FROM INITIAL) on FE
 Creating A-Marker: #S(MARKER SOURCE EXISTS-TONE-OF-SHOGYO-MUJO FROM ROOT)
  activating EXISTS-TONE-OF-SHOGYO-MUJO
  activating EXISTS-FEATURE-TYPE-OF-SOUND
  activating EXISTS-FEATURE-TYPE
  activating PHENOMENON
  activating CATEGORY
 ... ALL DELAYED EXCUTED ...
 Final concepts: (SOUND-OF-BELL-AT-GIONSHOJA EXISTS-TONE-OF-SHOGYO-MUJO)
(SOUND-OF-BELL-AT-GIONSHOJA EXISTS-TONE-OF-SHOGYO-MUJO)
* (generate)

BEGIN GENERATION
 Generation from the current memory with concepts:
 (SOUND-OF-BELL-AT-GIONSHOJA EXISTS-TONE-OF-SHOGYO-MUJO)

English for the input concept:
 Returning ENGLISH for SOUND-OF-BELL-AT-GIONSHOJA ... No lexical entry.
 Explanatory generating non-lexical concept: SOUND-OF-BELL-AT-GIONSHOJA
 Retrieving the concept sequence from root concept:
 (SOUND OF MUSICAL-INSTRUMENT)
 Reordering the packaged concepts under this sequence:
 (SOUND OF BELL-AT-GIONSHOJA)
 Returning ENGLISH for SOUND ... Lexical entry found: SOUND.
 Returning ENGLISH for OF ... Lexical entry found: OF.
 Returning ENGLISH for BELL-AT-GIONSHOJA ... No lexical entry.
 Explanatory generating non-lexical concept: BELL-AT-GIONSHOJA
 Retrieving the concept sequence from root concept:
 (PHYSICAL-OBJECT AT LOCATION)
 Reordering the packaged concepts under this sequence:
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(BELL AT GIONSHOJA)
Returning ENGLISH for BELL ... Lexical entry found: BELL.
Returning ENGLISH for AT ... Lexical entry found: AT.
Returning ENGLISH for GIONSHOJA ... Lexical entry found: GIONSHOJA.
 SOUND OF BELL AT GIONSHOJA

Japanese for the input concept:
 Returning JAPANESE for SOUND-OF-BELL-AT-GIONSHOJA ... No lexical entry.
 Explanatory generating non-lexical concept: SOUND-OF-BELL-AT-GIONSHOJA
 Retrieving the concept sequence from root concept:
 (MUSICAL-INSTRUMENT OF SOUND)
 Reordering the packaged concepts under this sequence:
 (BELL-AT-GIONSHOJA OF SOUND)
 Returning JAPANESE for BELL-AT-GIONSHOJA ... No lexical entry.
 Explanatory generating non-lexical concept: BELL-AT-GIONSHOJA
 Retrieving the concept sequence from root concept:
 (LOCATION OF PHYSICAL-OBJECT)
 Reordering the packaged concepts under this sequence:
 (GIONSHOJA OF BELL)
 Returning JAPANESE for GIONSHOJA ... Lexical entry found: GIONSHOJA.
 Returning JAPANESE for OF ... Lexical entry found: NO.
 Returning JAPANESE for BELL ... Lexical entry found: KANE.
 Returning JAPANESE for OF ... Lexical entry found: NO.
 Returning JAPANESE for SOUND ... Lexical entry found: KOE.
  GIONSHOJA NO KANE NO KOE

English for the input concept:
 Returning ENGLISH for EXISTS-TONE-OF-SHOGYO-MUJO ... No lexical entry.
 Explanatory generating non-lexical concept: EXISTS-TONE-OF-SHOGYO-MUJO
 Retrieving the concept sequence from root concept:
 (HAS THE FEATURE-TYPE-OF-SOUND)
 Reordering the packaged concepts under this sequence:
 (HAS THE TONE-OF-SHOGYO-MUJO)
 Returning ENGLISH for HAS ... Lexical entry found: HAS.
 Returning ENGLISH for THE ... Lexical entry found: THE.
 Returning ENGLISH for TONE-OF-SHOGYO-MUJO ... No lexical entry.
 Explanatory generating non-lexical concept: TONE-OF-SHOGYO-MUJO
 Retrieving the concept sequence from root concept:
 (SOUND OF FEATURE-TYPE)
 Reordering the packaged concepts under this sequence:
 (TONE OF SHOGYO-MUJO)
 Returning ENGLISH for TONE ... Lexical entry found: TONE.
 Returning ENGLISH for OF ... Lexical entry found: OF.
 Returning ENGLISH for SHOGYO-MUJO ... No lexical entry.
 Explanatory generating non-lexical concept: SHOGYO-MUJO
 Retrieving the concept sequence from root concept:
 (IMPERMANENCE-OF-ALL-EVENTS IN WORLD)
 Reordering the packaged concepts under this sequence:
 (IMPERMANENCE-OF-ALL-EVENTS IN WORLD)
 Returning ENGLISH for IMPERMANENCE-OF-ALL-EVENTS ... No lexical entry.
 Explanatory generating non-lexical concept: IMPERMANENCE-OF-ALL-EVENTS
 Retrieving the concept sequence from root concept:
 (IMPERMANENCE OF ALL PHENOMENA)
 Reordering the packaged concepts under this sequence:
 (IMPERMANENCE OF ALL PHENOMENA)
 Returning ENGLISH for IMPERMANENCE ... Lexical entry found: IMPERMANENCE.
 Returning ENGLISH for OF ... Lexical entry found: OF.
 Returning ENGLISH for ALL ... Lexical entry found: ALL.
 Returning ENGLISH for PHENOMENA ... Lexical entry found: PHENOMENA.
 Returning ENGLISH for IN ... Lexical entry found: IN.
 Returning ENGLISH for WORLD ... Lexical entry found: WORLD.
  HAS THE TONE OF "SHOGYOMUJO" (IMPERMANENCE OF ALL PHENOMENA IN WORLD)

Japanese for the input concept:
 Returning JAPANESE for EXISTS-TONE-OF-SHOGYO-MUJO ... No lexical entry.
 Explanatory generating non-lexical concept: EXISTS-TONE-OF-SHOGYO-MUJO
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 Retrieving the concept sequence from root concept:
 (FEATURE-TYPE-OF-SOUND EXIST2)
 Reordering the packaged concepts under this sequence:
 (TONE-OF-SHOGYO-MUJO EXIST2)
 Returning JAPANESE for TONE-OF-SHOGYO-MUJO ... No lexical entry.
 Explanatory generating non-lexical concept: TONE-OF-SHOGYO-MUJO
 Retrieving the concept sequence from root concept:
 (FEATURE-TYPE OF SOUND)
 Reordering the packaged concepts under this sequence:
 (SHOGYO-MUJO OF TONE)
 Returning JAPANESE for SHOGYO-MUJO ... Lexical entry found: SHOGYOMUJO.
 Returning JAPANESE for OF ... Lexical entry found: NO.
 Returning JAPANESE for TONE ... Lexical entry found: HIBIKI.
 Returning JAPANESE for EXIST2 ... Lexical entry found: ARI.
  SHOGYOMUJO NO HIBIKI ARI
GENERATION-COMPLETE
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