AN EXPERIMENTAL GRAMMAR
FOR TRANSLATING ENGLISH TO JAPANESE

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1. Introduction

A computational approach for translating the sentences of one natural language to another has been reasonably well established by the basic method proposed by Satterthwaite (1965) and Tosh (1965). The method is based on the following paradigm.

Transform the input language strings into a deep syntactic structure for that language

IL $\rightarrow$ IL-DSS

Map from DSS in IL to a DSS for the target language

IL-DSS $\rightarrow$ TL-DSS

Then generate the target language strings from DSS of the TL

TL-DSS $\rightarrow$ TL

This report demonstrates the translation from English to Japanese by using the above paradigm where the deep syntactic
structure is semantic relations (SR). The semantic relations used here are linear expressions of a semantic network representation which describes a labelled dependency structure of a sentence (Simmons and Chester [1980]). See the Example below. The report uses their grammar, which transforms English sentences into SRs of English, as the first step in translating English to Japanese. The other two steps are implemented by the rule system developed by the author and described here. The whole translation process is illustrated below.

First transform English sentences into SRs of English by using Simmons and Chester's English grammar.

e.g. (THE GIANT ROCKET ROSE)

(RISE AE (ROCKET DET THE SIZE (GIANT) NBR SING SNTRL SUB) TNS PAST)

AE Affected Entity, DET Determiner, SIZE, NBR Number, SING Singular, TNS Tense, SNTRL Sentence Relation, SUB Subject

Second, map from SR of English into SR of Japanese by using a system of translation rules
e.g.
(RISE AE (ROCKET DET THE SIZE (GIANT) MBR SING SNTRL SUB) TNS PAST)

\[ \]

(AGARU AE (ROCKET POSTP WA SIZE (OHKII)) TNS PAST)

POSTP Postposition

Finally, generate Japanese sentences from the SR of Japanese by using a Japanese grammar

e.g.
(AGARU AE (ROCKET POSTP WA SIZE (OHKII)) TNS PAST)

\[ \]

(OHKII ROCKET WA AGATTA)

The following table shows a sketch of translation.

\[
\begin{array}{c}
\text{ENG-SNT} \quad \text{--(English grammar)--} \quad \text{SR (ENG)}
\end{array}
\]

\[
\begin{array}{c}
\text{JAP-SNT} \quad \text{<--(Japanese grammar)=} \quad \text{SR (JAP)}
\end{array}
\]

Table 1.1 Translation Scheme

Both the Japanese grammar and Translation rules developed here are written in MCPVR language, a first order logic restricted to Horn Clauses, written in LISP by Chester [1980].
2. Semantic Relations in V-2 Rocket Story

This section describes how the grammar works and its results, the semantic relations of both the English and the Japanese sentences in the V-2 Rocket narrative. The V-2 Rocket story was the subject of psychological and linguistic studies by Beauchamp (1980), and the version used here has been modified by Simmons and Chester. The Japanese version of the story was translated by the author.

The English text is given below.

A great black and yellow V-2 rocket forty-six feet long stood in a New Mexico desert. Empty it weighed five tons. For fuel it carried eight tons of alcohol and liquid oxygen.

Everything was ready. Scientists and generals withdrew to some distance and crouched behind earth mounds. Two red foils rose as a signal to fire the rocket.

With a great roar and burst of flame the giant rocket rose slowly and then faster and faster. Behind it trailed sixty feet of yellow flame. Soon the flame looked like a yellow star.

In a few seconds it was too high to be seen; radar tracked it as it sped upward to three-thousand mph. A few
minutes after it was fired the pilot of a watching plane saw it return. It plunged into earth forth miles from the starting point.

The Japanese translation of the text is given below.

46 feet no onkii kuroku kiiroi W-2 rocket wa NewMexico sabaku no naka ni tatteita. Kara de sore wa 5 ton no omosa ga atta. Henyo ni sore wa 8 ton no alcohol to ekitai sanso o tsunedeita.

Sotte wa dekita. Kagakusha to shogun wa tonkuni hanarete, dote no ushiro ni suwatta. 2 hon no akai honon ga rocket o uchiageru tame no aizu ni agatta.

Onkii oto to honon to tomo ni, onkii rocket wa yukuuri sosnichi dandan hayaku agatta. Sore wa ushiro ni 60 feet no kiiroi honon o hiita. Suguni honon wa kiiroi hosni ni mieta.

Su byon no nochii ni sore wa takasugite mienaku natta. Radar wa sore ga 3000 mph no hayasa made otta. Sore ga uchiagerarete kara su hun no nochii ni teisatsuki no pilot wa sore ga moderu tokoro o mita. Sore wa hassen chiten kara 40 mile no tokoro ni ochita.

The English grammar developed by Simmons and Chester produced the SRs of English listed in Table 2.1. The SRs of Japanese produced by the author's Japanese grammar.

The complete Japanese grammar for the sentences is presented in Appendix A. It is sectioned by Grammar rules and Lexical Assertions, which included wordclass, feature, archnames, etc. It has been debugged and runs in the HCPVRVR LISP language.
1. (STAND AE (ROCKET DET A SIZE (GREAT) COLOR (BLACK *AND (YELLOW)) TYPE (V-2) LGTH (LONG LGTH (FOOT QU (FORTY-SIX) NBR PL))) NBR SING SNTRL SUB) TNS PAST LOC (DESERT PREP IN DET A LOC (NEW-MEXICO) NBR SING))

2. (WEIGH AE (IT ST (EMPTY) NBR SING SNTRL SUB) TNS PAST MSR (TON QU (FIVE) NBR PL SNTRL OBJ))

3. (CARRY PU (FUEL PREP FOR NBR SING) AE (IT NBR SING SNTRL SUB) TNS PAST AE (ALCOHOL MSR (TON PREP OF QU (EIGHT) NBR PL) NBR SING SNTRL OBJ *AND (OXYGEN STATE (LIQUID) NBR SING)))

4. (BE AE (EVERYTHING NBR PL) TNS PAST ST (READY))

5. (WITHDRAW AGT (SCIENTIST NBR PL SNTRL SUB *AND (GENERAL NBR PL)))

TNS PAST LOC (DISTANCE PREP TO DET SOME NBR SING) *AND (CROUCH TNS PAST LOC (GROUND PREP BEHIND TYPE (EARTH NBR SING) NBR PL))

6. (RISE AE (FLAME QU (TWO) COLOR (RED) NBR PL SNTRL SUB) TNS PAST PU (SIGNAL PREP AS DET A PU (FIRE INF TO INS PRES AE (ROCKET DET THE NBR SING)) NBR SING))

7. (RISE AC (ROAR PREP WITH DET A SIZE (GREAT) NBR SING *AND (BURST SUBST (FLAME PREP OF NBR SING) NBR SING)) AE (ROCKET DET THE SIZE (GIANT) NBR SING) TNS PAST RATE (SLOWLY *THEN (FASTER *AND FASTER)))

8. (TRAIL LOC BEHIND INSTR (IT NBR SING SNTRL SUB) TNS PAST SUBST (FLAME MSR (FOOT PREP OF QU (SIXTY) NBR PL) COLOR (YELLOW) NBR SING SNTRL OBJ))

Table 2.1 Semantic Relations of Rocket story (English)
9. (LOOK TIME SOON
   AE (PLANE DET THE NBR SING SNTRL SUB)
   TNS PAST
   AP (STAR PREP LIKE DET A COLOR (YELLOW) NBR SING))
10. (BE TIME (SECOND PREP IN DET A QU (FEW) NBR PL)
    AE (IT NBR SING SNTRL SUB)
    TNS PAST
    HT (HIGH INTENS TO)
    RESULT (SEE INF TO AUX (BE TNS PRES) TNS PAST))
11. (TRACK INSTR (RADAR NBR SING SNTRL SUB)
     TNS PAST
     AE (IT NBR SING SNTRL OBJ)
     DUR (SPEED AE (IT NBR SING SNTRL SUB)
          TNS PAST
          DIR UPWARD
          RATE (MPH PREP TO)
          QU (THREE-THOUSAND) NBR PL))
12. (SEE TIME (AFTER TIME (MINUTE DET A QU (FEW) NBR PL)
       EVT (FIRE AE (IT NBR SING SNTRL SUB)
            AUX (BE TNS PAST) TNS PAST))
    AGT (PILOT DET THE *OF (PLANE PREP OF DET A
        INSTR* (WATCH TNS PRPRT)
        NBR SING SNTRL OBJ)
        NBR SING SNTRL SUB)
    TNS PAST
    AE (RETURN AE (IT NBR SING SNTRL SUB) TNS PRES))
13. (PLUNGE INSTR (IT NBR SING SNTRL SUB)
     TNS PAST
     *TO (EARTH PREP INTO NBR SING)
     LOC (*MILE QU (FORTY)
          LOC (POINT PREP FROM DET THE
               LOC (START TNS PRES) NBR SING)
               NBR PL))

=========================================================

Arcomnes:
Affectec Entity, DETerminer, SIZE, COLOR, TYPE, LENGTH,
Quantity, Numbec, Tense, LOCation, Measure, Purpose,
weight, PREposition, *AND (conjunction), STATE, AGent,
INFinite, Accompany, SUBstance, RATE, INSTRumEn, TIME,
*THEN (temporal conjunction), Height, INTENSifier, DURation,
RESULT, AUXiliary, DIRECTION, *OF(partof), SentenceRelation,
INSTR* (back link through instrument), *TO (direction to).
=========================================================

Table 2.1 Semantic Relations of Rocket Story(concluded)
1. (TATSU AE (ROCKET POSTP GA
   LGTH (NAGASA POSTP NO
   MSR (FEET POSTP NO QU (*46 FORM ORG))
   QU (*45 FORM ORG))
   SIZE (OKHII FORM ORG)
   COLOR (KUROI FORM CONT *AND(KIIOI FORM ORG))
   TYPE (V=2))
   LOC (HAKA POSTP NI
       LOC (SATAMU POSTP NO LOC (NEKEMEXICO)))
   AUX (IRU TNS PAST) TNS PAST)

2. (ARU AE (SURE POSTP WA) ST (KARA POSTP DE)
   WGT (OMUSA POSTP GA
   MSR (TON POSTP NO QU (*5 FORM ORG))
   TNS PAST)

3. (TSUMU AE (SURE POSTP WA) PU (SENRYO POSTP NI)
   AE (ALCOHOL POSTP O *AND(SANSO ST (EKITAII))
   MSR (TON POSTP NO QU (*8 FORM ORG))
   AUX (IRU TNS PAST) TNS PAST)

4. (DEKIRU AE (SUBETE POSTP GA) TNS PAST)

5. (HANAGERO AGT (KAGAKUSHA POSTP WA *AND (SHOGUN))
   LOC (TOHRIKI)
   *AND (SUWARU LOC (USHIRO POSTP NI LOC (DOTE POSTP NO))
   TNS PAST)
   FORM CONT TNS PAST)

6. (AGARU AE (HONOH POSTP GA
   MSR (HON POSTP NO QU (*2 FORM ORG))
   COLOR (AKAI FORM ORG))
   PU (AIZU POSTP NI
   PU (UCHIAGEKU POSTP NO POSTP TANE
   AE (ROCKET POSTP O) TNS PRES))
   TNS PAST)

7. (AGARU AC (TOMO POSTP NI
   *AND (OTO SIZE (OKHII FORM ORG) *AND (HONOH)))
   AE (ROCKET POSTP WA SIZE (OKHII FORM ORG))
   RATE (YUKKURI *AND (HAYAKU BARTE (Dandan)))
   TNS PAST)

Table 2.2 Semantic Relations of Rocket Story (Japanese)
8. (HIKU INSTR (SORE POSTP WA)
   LOC (USHIRO POSTP NI)
   AE (HONOH POSTP O
       MSR (FEET POSTP NO QU (*60 FORM ORG))
       COLOR (KIIROI FORM ORG))
  TNS PAST)

9. (MIERU TIME (SUGUNI)
    AE (HONOH POSTP WA)
    AP (KOGHI POSTP NI COLOR (KIIROI FORM ORG))
    TNS PAST)

10. (NARU TIME (NOCHI POSTP NI
      TIME (BYOH POSTP NO QU (SU FORM ORG))
    AE (ROCKET POSTP WA)
    HT (TAKAI INTENS (SUGUNI) FORM ORG)
    AP (MIERU FORM CONT MOD NEG TNS PRES)
    TNS PAST)

11. (DIKAKERU INSTR (RADAR POSTP WA)
    DUR (TASSURU POSTP WADE
    AE (ROCKET POSTP GA)
    SP (HAYASA POSTP NI
        MSR (**MPH POSTP NO QU(*3000 FORM ORG)))
        QU (**3000 FORM ORG)))
    TNS PAST)

12. (MIKU TIME (NOCHI POSTP NI
      TIME (HUN POSTP NO QU (SU FORM ORG))
    EVT (UCHIAGERU POSTP KARA AE (ROCKET POSTP GA
        AUX (RANERU TNS PRES) TNS PRES))
    AGT (PILOT POSTP WA OF* (TEISATSUKI POSTP NO))
    AE (TOKORO POSTP O
        EVT (MODORU AE (SORE POSTP GA) TNS PRES)
    TNS PAST)

13. (OCHIRU INSTR (SORE POSTP WA)
    LOC (TOKORO POSTP NI
        MSR (MILE POSTP NO
            LOC (CHITEN POSTP KARA TYPE (HASSHA))
            TYPE (HASSHA))
    TNS PAST)

Table 2.2 Semantic Relations of Rocket Story(concluded)
Corresponding SRs of each language reveal some similarities of the structure. We make use of the similarities to translate. Before translating SRs of English in the next section we will look at the symmetry of the Japanese grammar from recordings of a console session testing the grammar on sentences of the rocket story text. First we set a variable to the sentence to be analyzed, then we call the function TRY, which applies the Japanese grammar to that sentence. Then we pretty-print the output, ask for the time it takes, then reset the arguments of the variable to show that the same grammar generates the original sentence from the output SRs. Comments are inserted in the form <<...>>.

===
*(sprint st1)*

<< st1 contains a sentence to be parsed,>>

(S12 (*46 FEET NO NAGASA NO OHKII KUROKU KIROI V=2 ROCKET GA NEWMEXICO SABAKU NO NAKA NI TATTEITA)

X)

NIL

*(try st1)*

<< we call TRY to parse st1. The CONTINUE question tell us that 100 subquestions have been asked; if we respond no, the proof will be abandoned,>>

CONTINUE? *y

((S12 (*46 FEET NO NAGASA NO OHKII KUROKU KIROI V=2 ROCKET GA NEWMEXICO SABAKU NO NAKA NI TATTEITA) (TATSU AE (ROCKET POSTP GA LGTH (NAGASA POSTP NO MSR (FEET POSTP NO QU (*46 FOR w ORG))) SIZE (OHKII FORM ORG) COLOR (KUROI FORM CONT * AND ( KIROI FORM ORG)) TYPE (V=2)) LOC (NAKA POSTP NI LOC (SABAKU POSTP NO LOC (NEWMEXICO))) AUX (IRU TNS PAST) TNS PAST) NIL
**(sprint (car val))

<< Now we can look at the answer pretty-printed. VAL contains the answer.>>

(512 (*46 FEET NO NAGASA NO OKHII KUROKU KIIRUI V=2 ROCKET
GA NEW MEXICO SABAKU NO NAKA NI TATTEITA)
(TATSU AE
(ROCKET POSTP
GA
LGTH
(NAGASA POSTP
NO
MSR
(FEET POSTP
NO
QU
(*46 FORM ORG)))
SIZE
(OKHII FORM ORG)
COLOR
(KUROI FORM CONT *AND (KIIROI FORM ORG))
TYPE
(V=2))
LOC
(NAKA POSTP
NI
LOC
(SABAKU POSTP NO LOC (NEW MEXICO)))
AUX
(IKU THIS PAST)
THIS
PAST)
NIL)

NIL

<< Now we set J to (s12 x semantic-relation nil) by using VAL.>>

*(setq j (car (subst x (cadar val) val)))

(512 -X (TATSU AE (ROCKET POSTP GA LGTH (NAGASA POSTP NO MSR
(FEET POSTP NO QU (*46 FORM ORG))) SIZE (OKHII FORM ORG) CO
LOR (KUROI FORM CONT *AND (KIIROI FORM ORG)) TYPE (V=2)) LOC
NIL)
((NAKA POSTP NI LOC (SABAKU POSTP NI LOC (NEWMEXICO))) AUX (IRU TNS PAST) TNS PAST) NIL)

*(try 1)

<< we will TRY to generate the original sentence. >>

((S12 (*36 FEET NO NAGASA NO OHKII KUROKI KIROI V-2 ROCKET GA NEWMEXICO SABAKU NO NAKA NI TATTEITA) (TATSU AE (ROCKET POSTP GA LGTH (NAGASA POSTP NO MSR (FEET POSTP NO QU (*46 FOR ORG))) SIZE (OHKII FORM ORG) COLOR (KUROKI FORM CONT *AND (KIIROI FORM ORG)) TYPE (V-2)) LOC (NAKA POSTP NI LOC (SABAKU POSTP NO LOC (NEWMEXICO))) AUX (IRU TNS PAST) TNS PAST) NIL))

<< It generated the original sentence, showing the symmetry of the grammar. >>

*runtime
(0.60000000 SECS)

*(sprint st3)

(S13 (SORE WA NEHRYO NI 8 TON NO ALCOHOL TO EKITAI SANSO O TSUNDEITA)

X
X1)

NIL

<< we TRY ST3 to parse. >>

*(sprint (car (try st3)))

CONTINUE? *y
CONTINUE? *y

(S13 (SORE WA NEHRYO NI 8 TON NO ALCOHOL TO EKITAI SANSO O TSUNDEITA)

(TSUNU AE

(SORE POSTP *A)

RU

(NEHRYO POSTP NI)

AE

(ALCOHOL POSTP

O

*AND

(SANSO ST (EKITAI)))

MSR

(TON POSTP NO QU (*8 FORM ORG)))

AUX

(IRU TNS PAST)

TNS

PAST)
NIL
*NIL
*rt ime
(1.9490000 SECS)

<< We also try to retrieve the original sentence by substituting the variable x for the sentence but leaving its analysis as the second argument.>>
*(setq j (car (subst x (cadar val) val)))
(S13 X (TSUMU AE (SORE POSTP WA) PU (HENRYU POSTP NI) AE (ALCOHOL POSTP 0) *AND (SANSO ST (EKITAI)) M5R (TON POSTP NO QU (*8 FORM ORG))) AUX (IRU TNS PASTI TNS PASTI) NIL)

*(try j)
((S13 (SORE WA HENRYU NI *8 TON NO ALCOHOL TO EKITAI SANSO O TSUNEDEITA) (TSUMU AE (SORE POSTP WA) PU (HENRYU POSTP NI) AE (ALCOHOL POSTP 0) *AND (SANSO ST (EKITAI)) M5R (TON POSTP NO QU (*8 FORM ORG))) AUX (IRU TNS PASTI TNS PASTI) NIL))

*rt ime
(0.3290000 SECS)

=================================

The remainder of this session continues in Appendix C.
3. Translation Rules

Translation, or mapping rules, that transform SRs of English to get SRs of Japanese, consist of four parts. Top level procedures and structure transformation rules are shown in Table 3.1. Casename and vocabulary translation rules are given in Appendix B.

Of top level procedures, TRANSLATE tries to REPLACE the head of its SR, then calls TRANSPAIR to translate the SR's argument pairs (casename and its structure). TRANSPAIR first attempts to REPLACE, if any, casename's structure. REPLACE seeks vocabulary transformation rules in TRANSLATE, or casename transformation rules in TRANSPAIR.

Structure transformation rules are MEMPR, ADDPR, DEPAIR, and ADPAIR which are logic procedures used in each vocabulary and casename transformation. MEMPR checks to see if an argument pair is in the structure. DEPAIR deletes an argument pair from the
structure. ADDPR and ADPAIR add argument pairs into the structure.

=====================================================================

(1) Top Level Procedures

(((TRANSLATE (S * R) (S1 * R2))
  <
  (REPLACE S R (S1 * R1))
  (TRANSPAIR R1 (S1 * R1) R2))
((TRANSLATE X Y) < (ATOM* X) (REPLACE X NIL Y)))

(((TRANSPAIR (X V * R) (S1 * R1) (Y V2 * R2))
  <
  (REPLACE X V (Y * V1))
  (TRANSLATE V1 V2)
  (TRANSPAIR R (S1 * R1) R2))
((TRANSPAIR NIL X NIL)))

(((REPLACE X Y (U * Y1)) < (XPJP U Y Y1))
((REPLACE X NIL X))
((REPLACE X W (X * W))))

(2) Structure Transformation Rules

(((MEMPR (R Y) (R X * Z)))
(((MEMPR (R X) (U V * Z)) < (MEMPR (R X) Z)))

(((DEPAIR X NIL NIL))
((DEPAIR (X Y) (X Y * W))
((DEPAIR (X Y) (U V * W) (U V * Z)) < (DEPAIR (X Y) W Z)))

(((ADPAIR (R X) Y Y) < (MEMPR (R X) Y))
((ADPAIR (R X) NIL (R X)))
((ADPAIR (R X) V (R X * V))))

(((ADPAIR (R X) NIL (R X)))
((ADPAIR (R X) (U V * W) (U V * Z)) < (ADPAIR (R X) G Z)))

=====================================================================

Table 3.1 Translation Rules (part 1 and 2)
We will look at some features of the Japanese as we watch vocabulary and case transformation rules, which employ the above functions, **KEMP**, **DEPAIR**, **ADDPH**, and **ADPAIR**.

(1) Noun

Generally handling a noun is just replacing this noun with the Japanese counterpart, and deleting **NUMBER** and **DETERMINER** features (See the example ST1 below).

However, a countable noun when it has quantity in its structure is dealt quite differently. It requires a counting feature depending on each noun; thus it needs to change its structure (See the example ST6 in appendix D). All the countable nouns have this property, so that the all vocabulary rules must provide this feature.

A complex noun like "earth mounds", whose Japanese counterpart is only one noun, "dote", has also an interesting feature. The **TYPE** feature must be deleted from the structure whose head is "mound" when replacing "mound" with "dote". (See the example ST5 in appendix D.)

(2) Adjective
In the grammar, there are two forms of adjective: **ORIGINAL** and **CONTInuing**. Translating adjectives from English to Japanese requires two cases, whether it has *and or not. If it has *and, **FORM CONT** is added, otherwise **FORM ORG**, it is then translated with a lexical rule.

(3) Verb

In general, the verb can simply be replaced with the Japanese equivalent when there is Tense pair in the structure (See ST6). When there is *AND in the structure, however, **FORM CONT** is added (See ST5). An **AUXiliary may be added to the Japanese to indicate that the verb shows continuation of action** (See ST1, ST2).

(4) Preposition

Prepositions, indicating **LOCations**, may require complex mappings. When case name **LOCation** has a **PREPosition pair in it**, its head is replaced by this preposition, **POSTPosition** NI is added and the original LOC structure is embedded in this LOC, (See ST1 below) Afterwards the preposition will be replaced by a Japanese word.
Prepositions inside PURPOSE and APPEARANCE are just replaced by POSTPOSITION Mi. (See ST6, ST9 in Appendix D.) While these sentences show only a few examples of prepositional translation, their patterns prepare the way to handle other prepositions.

Translation examples are from the recordings of a console session. First we look at the original SRs of English, then we call TRY to translate them, by applying translation rules to the SRs and returning the translated SRs of Japanese. We pretty-print the output, and ask for RTIME. Comments appear in the same form <<....>>. The sample session follows below:

============================================
*st1
<< ST1 contains SR of English of the sentence 1 in rocket story. The variable U will be bound to the translated SRs.>>
(TRANSLATE (STAND AE (ROCKET DET A SIZE (GREAT) COLOR (BLACK *AND (YELLOW)) TYPE (V=2) LGTH (LONG MSR (FOOT QU (FORTY-SIX) NBR PL)) NBR SING SMTML SUB) THIS PAST LOC (DESERT PREP IN DET A LOC (NEWMEXICO) NBR SING)) U)
*(try st1)
<< We called TRY to translate ST1. Each CONTINUE questions 100 subquestions.>>
CONTINUE? *y
CONTINUE? *y
((TRANSLATE (STAND AE (ROCKET DET A SIZE (GREAT) COLOR (BLACK *AND (YELLOW)) TYPE (V=2) LGTH (LONG MSR (FOOT QU (FORTY-SIX) NBR PL)) NBR SING SMTML SUB) THIS PAST LOC (NEWMEXICO) NBR SING)) U)
(ROCKET DET  
A  
SIZE  
(GREAT)  
COLOR  
(BLACK *AND (YELLOW)))  
TYPE  
(V-2)  
LGTH  
(LOWG MSR  
(FOOT QU (FORTY-SIX) NBR PL))  
NBR  
SING  
SNTRL  
SUB  
)

(TNS PAST LOC  
(DESERT PREP IN  
DET A  
LOC  
(NEWMEXICO)  
NBR  
SING))  

(TATSU AE  
(ROCKET POSTP  
WA  
SIZE  
(OHKII FORM ORG)  
COLOR  

<< we pretty-print the output. see the following.  
verb (aux) transformation, ordinary noun,  
adjectives (both cases), preposition handling (LOC)  
including English word in changes into NAKA.  
also SNTRL SUB changes to POSTP WA.>>

*(sprint (car val))

(TRANSLATE (STAND AE  
(ROCKET DET  
A  
SIZE  
(GREAT)  
COLOR  
(BLACK *AND (YELLOW)))  
TYPE  
(V-2)  
LGTH  
(LOWG MSR  
(FOOT QU (FORTY-SIX) NBR PL))  
NBR  
SING  
SNTRL  
SUB)
(KUROI FORM
  CONT
  \*AND
  (KIIROI FORM ORG))
TYPE
  (V=2)
LGTH
  (NAGASA POSTP
    NO
    MSR
    (FEET POSTP
      NO
      QU
      (**46 FORM ORG))))
LOC
  (MABA POSTP
    NI
    LOC
    (SABAKU POSTP NO LOC (NEWMEXICO))))
AUX
  (IRU TNS PAST)
TNS
  PAST))
NIL
*rtime
(0.45500000 SECS)
  << It took real CPU time 0.455 secs.>>
*st3
(TRANSLATE (CARRY PU (FUEL PREP FOR NBR SING) AE (IT NBR SING SNTRL SUB) TNS PAST AE (ALCOHOL MSR (TOW PREP OF QU (EIGHT ) NBR PU) NBR SING \*AND (OXYGEN SI (LIQUID) NBR SING) SNTRL OBJ)) V)
*(sprint (car (try st3)))
CONTINUE? *y

<< Sentence 3 demonstrates the features following;
  Preposition handling (purpose) -- POSTP NI,
  SNTRL OBJ (AE) -- POSTP O .>>
(TRANSLATE (CARRY PU
  (FUEL PREP FOR NBR SING)
AE
  (IT NBR SING SNTRL SUB)
TNS
PAST
AE
(Alcohol
PREP OF QU (EIGHT) PR NBR PL)
NBR
SING
*NBR
(QUANT ST (LIQUID) NBR SING)
SWTRL
OBJ))

(TSUMU PU
(NEGRO POSTP NI)
AE
(SORE POSTP WA)
AE
(Alcohol POSTP
O
*MR
(TON POSTP NO QU (*8 FORM ORG))
*AND
(SANSO ST (EKITAI)))
AUX
(IRU TNS PAST)
TNS
PAST))

NIL

*time
(0.37500000 SECS)

=================================
The remainder of this session continues in Appendix D.
4. Conclusions

We have watched the method of translating from English to Japanese. Once we have an English grammar to parse English sentences into semantic relations, we can use the translation rules in Appendix B to map the SRs of English to those of Japanese and use the Japanese grammar in Appendix A to generate Japanese sentences from the SRs of Japanese.

Generally for translation between languages, a symmetric grammar (i.e., usable both for parsing and generation) for each language and a set of rules from terms of one language to those of the other one are required. In this report, two important things are the properties of symmetry and transferability. We do not need two programs for one language, one to parse the sentence into semantic relations and another to generate a sentence from the semantic relations. Because of the property of symmetry, we could translate Japanese to English by adding only translation rules, which could be constructed in the same fashion (maybe with
the help of the structure transformation rules) as the one presented here. An open research question is the possibility of symmetric translation rules. Can one translation grammar map SRs in both directions between a pair of languages?

Transferability of the structure of the SR between languages is also important. In section one, it was said that for the computational approach to translate, there should be deep structures for the sentences of each language. It is easier to use this method than to use direct sentence-to-sentence translation, because there are a lot of semantic differences on the sentence level while there are few on the semantic relation level.

However, there is still a problem with the Japanese grammar. It is not as general a grammar as the English one because the sentence structure (S11, S12, ...) allows only up to four phrases in one sentence and the modified noun phrase (MDNP) allows up to three level. They limit their entries. They should accept as many entries as possible. And a problem is also found in the translation rules. ST10 (It was too high to be seen.) is an example. Because of the language differences, Japanese say "It was so high that we could not see it." (a literal English
paraphrase of the Japanese), but Japanese do not say "It was too high to be seen." Translation rules, which only map SRs to SRs, become very complex. We need to perform deeper level translation.

For further research, a more general symmetric grammar of Japanese has to be developed and the translation has to be considered at a deeper conceptual level.
Appendix A. Japanese Grammar

(1) Grammar rules

(((S1 X Y R) < (S11 X Y R)))
(((S1 X Y R) < (S12 X Y R)))
(((S1 X Y R) < (S13 X Y R)))
(((S1 X Y R) < (S14 X Y R)))

(((S2 X (V1 *AND V2 , Q) R) <
  (S1 X (V1 , Q) R1)
  (S1 R1 V2 R)))

(((S3 X (V2 \ W V1 , Q) R) <
  (S1 X V1 (R1 , R2))
  (POSTP R1)
  (S1 R2 (V2 , Q) R3)
  (FEAT V1 X1)
  (FEAT V2 X2)
  (ARCVAL X2 X1 R1 W)))

(((S11 X (Z \ W1 V1 , Z1) R) <
  (PHR X V1 R1)
  (VP R1 (Z , Z1) R)
  (SEMP Z V1 \ W1)))

(((S12 X (Z \ W1 V1 \ W2 V2 , Z1) R) <
  (PHR X V1 R1)
  (PHR R1 V2 R2)
  (VP R2 (Z , Z1) R))
((SEMF Z V1 W1)
(SEMF Z V2 W2)))

(((S1) X (Z W1 V1 W2 V2 W3 V3 * Z1) R)
<
(PHR X V1 R1)
(PHR R1 V2 R2)
(PHR R2 V3 R3)
(VP R3 (Z * Z1) R)
(SEMF Z V1 W1)
(SEMF Z V2 W2)
(SEMF Z V3 W3)))

(((S14) X (Z W1 V1 W2 V2 W3 V3 W4 V4 * Z1) R)
<
(PHR X V1 R1)
(PHR R1 V2 R2)
(PHR R2 V3 R3)
(PHR R3 V4 R4)
(VP R4 (Z * Z1) R)
(SEMF Z V1 W1)
(SEMF Z V2 W2)
(SEMF Z V3 W3)
(SEMF Z V4 W4)))

(((PHR X Y R) < (NP X Y R)) ((PHR X Y R) < (ADV X Y R)))

(((NP X (Y POSTP W * Y1) R)
<
(NP1 X (Y * Y1) R1)
(PP R1 W R))
(((NP X (V1 POSTP W * AND V2 * Q) R)
<
(NP1 X (V1 * Q) (R1 * R2))
(CONJ R1)
(NP1 R2 V2 R3)
(PP R3 W R)))

(((NP1 (X Y * R) (Y W (X)) R)
<
(NOUN X)
(NOUN Y)
(FEAT X W))
(((NP1 (X * R) (X) R) < (NOUN X))
(((NP1 X W R) < (MDNP X W R))
(((NP1 X (W2 W W1 * Q) R)
<
(ADJP X V1 R1)
(NP1 R1 (V2 W Q) R)
(FEAT V1 W))

(((NP2 (X Y W R) (Y W (X)) R)
  <
  (NOUN X)
  (NOUN Y)
  (FEAT X W))
  
(((NP2 (X W R) (X R) < (NOUN X))
(((NP2 X (V2 W V1 W Q) R)
  <
  (ADJP X V1 R1)
  (NP2 R1 (V2 W Q) R)
  (FEAT V1 W))

(((MDNP X
  (V3 W2
   (V2 POSTP R3 W1 (V1 POSTP R1 W Q1) W Q2) W Q3) R)
  <
  (NP2 X (V1 W Q1) (R1 W R2))
  (MODARC V1 W1)
  (POSTP R1)
  (NP2 R2 (V2 W Q2) (R3 W R4))
  (MODARC V2 W2)
  (POSTP R3)
  (NP2 R4 (V3 W Q3) R))
  
(((MDNP X (V2 W1 (V1 POSTP R1 W Q1) W Q2) R)
  <
  (NP2 X (V1 W Q1) (R1 W R2))
  (MODARC V1 W1)
  (POSTP R1)
  (NP2 R2 (V2 W Q2) R))

))

(((ADVP (X Y W Z) (X W ANOD V1) R)
  <
  (ADV X)
  (CONJ Y)
  (ADVP Z V1 R))

(((ADVP (X W Y) (V1 W (X) W Q) R)
  <
  (ADV X)
  (ADVP Y (V1 W Q) R)
  (FEAT X W))

))
(((ADVP (x, y) (x, y) < (ADV X)))
  (((ADVP (x, y) (v1, y) (x2, q) y)
    <
    (ADV X X1 X2)
    (ADJP X1 (v1, q))
    (FEAT X2 w)))))

  (((ADJP (x, y) (x1 form Y1) *AND v1) R)
   <
   (ADJ X (X1 form Y1))
   (EQ Y1 CONT)
   (ADJP Y v1 r))

  (((ADJP (x, y) X1 Y) < (ADJP X X1))
   (((ADJP (x, y) (v1, w) (x, q) r)
     <
     (ADV X)
     (ADJP Y (v1, q) r)
     (FEAT X w))))

  (((PP (x, y) X Y) < (POSTP X))))

  (((PPTEST X (Y POSTP *W1, q) w)
    <
    (FEAT X X1)
    (FEAT Y Y1)
    (ARCVAL X1 Y1 *W1 w))))

  (((VP (x, y, z) (v2, w) v1, q) z)
    <
    (vV X V1)
    (vV Y (V2, q))
    (FEAT Y1 w))

  (((VP (x, y) X1 Y) < (vV X X1))
   (((VP (x, y) (v aux v1, q) y)
     <
     (VP B X1 X2)
     (vV X1 (v, q))
     (vBE X2 V1)))))

  (((VP B TATTEITA TATTA ITA))
   (((VP B TATTEITA TSUNDA ITA))
    (((VP B UCHIAGERARETE UCHIAGERU RARETE))
     (((VP B NIWEAKUNARU NIWAI NARU))))

  (((SEMPE X (Y, Y1) w) < (ADV X) (FEAT Y w))
   (((SEMPE X (Y, Y1) w) < (ADJP Y V1) (FEAT Y w))
    <
    (vBE X X2 V1))))
((SEMIXY < (PPTESTXY))))

(2) Lexical Assertions

(((NOUN NAGASA)))
(((NOUN V=2)))
(((NOUN ROCKET)))
(((NOUN NEWMEXICO)))
(((NOUN SABAKU)))
(((NOUN KARA)))
(((NOUN TON)))
(((NOUN OMOSA)))
(((NOUN HENRY)))
(((NOUN ALCOHOL)))
(((NOUN EKITAI)))
(((NOUN SANSU)))
(((NOUN JUMSI)))
(((NOUN KAGAKUSA)))
(((NOUN SHOGUN)))
(((NOUN DOTE)))
(((NOUN USHIRO)))
(((NOUN MAKAI)))
(((NOUN HONOH)))
(((NOUN SHINGO)))
(((NOUN AIZU)))
(((NOUN OTORI)))
(((NOUN PEET)))
(((NOUN HOSHI)))
(((NOUN RADAR)))
(((NOUN MPH)))
(((NOUN HAYASA)))
(((NOUN TEISATSUKI)))
(((NOUN PILOT)))
(((NOUN HASSHA)))
(((NOUN CHITEN)))
(((NOUN IKOKO)))
(((NOUN SORF)))
(((NOUN SUBOTE)))
(((NOUN ONI)))
(((NOUN YILE)))
(((NOUN BYON)))
(((NOUN NOCHI)))
(((NOUN HUN)))

(((ADJ OHKII (OHKII FORM ORG))))
((ADJ KIIROI (KIIROI FORM ORG)))
((ADJ AKAI (AKAI FORM ORG)))
((ADJ KUROI (KUROI FORM CONT)))
((ADJ *46 (*46 FORM ORG)))
((ADJ *5 (*5 FORM ORG)))
((ADJ *8 (*8 FORM ORG)))
((ADJ *2 (*2 FORM ORG)))
((ADJ *3000 (*3000 FORM ORG)))
((ADJ *60 (*60 FORM ORG)))
((ADJ *40 (*40 FORM ORG)))
((ADJ SU (SU FORM ORG)))
((ADJ TAKAI (TAKAI FORM ORG)))

(((ADV SUKOSHI)))
(((ADV SUGUNI)))
(((ADV YUKKURI)))
(((ADV DANDAN)))
(((ADV HAYAKU)))
(((ADV TAKASUGITE TAKAI SUGITE)))

(((POSTP NI)))
(((POSTP WA)))
(((POSTP GA)))
(((POSTP O)))
(((POSTP DE)))
(((POSTP MADE)))

(((POSTP NO)))
(((POSTP KARA)))

(((VV OCHITA (UCHIRU TNS PAST)))
(((VV HITA (MIKU TNS PAST)))
(((VV OTTA (OU TNS PAST)))
(((VV MIETA (MIERU TNS PAST)))
(((VV HIITA (HIKU TNS PAST)))
(((VV AGATTAA (AGARU TNS PAST)))
(((VV SHIATTAA (SHIARU TNS PAST)))
(((VV HATTA (HARU TNS PAST)))
(((VV ATTA (ARU TNS PAST)))
(((VV DEKITA (DEKIRU TNS PAST)))
(((VV UCHIAGERU (UCHIAGERU TNS PRES)))
(((VV TASSURU (TASSURU INS PRES)))
(((VV MODORU (MODORU TNS PRES)))
(((VV TATTA (TATSU TNS PAST)))
(((VV TSUNDA (TSUMU TNS PAST)))
(((VV HANAGERU (HANAGERU TNS PRES)))
(((VV TOMONAU (TOMONAU INS PRES)))

30
(((VV MIENAKU (MIERU FORM CONT MOD NEG TNS PRES)))
((VV OIKAKETA (OIKAKERU TNS PAST)))
((VV HANARETE (HANARERU FORM CONT TNS PAST)))
((VV TOMONAITTE (TOMONAU FORM CONT TNS PAST)))

(((VRE ITA (IRU TNS PAST)))
((VRE RARETE (RARERU TNS PRES)))

(((CONJ TO)) ((CONJ SOSHITE)))

(((MODARC Y W) < (FEAT Y Y1) (ARCNNAME Y1 W)))

(((ARCNNAME HUMAN POS))
((ARCNNAME DEV ASSOC))
((ARCNNAME LOC LOC))
((ARCNNAME MSR MSR))
((ARCNNAME LGTH LGTH))
((ARCNNAME WGT WGT))
((ARCNNAME POBJ ASSOC))
((ARCNNAME DGR DGR))
((ARCNNAME TIME TIME))
((ARCNNAME RATE RATE))

(((ARCVAL POSIT POBJ GA AE))
((ARCVAL POSIT LOC NI LOC))
((ARCVAL MSR ST DE ST))
((ARCVAL MSR WGT GA WGT))
((ARCVAL MSR POBJ WA AE))
((ARCVAL CO POBJ WA AE))
((ARCVAL CO POBJ NI PU))
((ARCVAL CO POBJ O AE))
((ARCVAL ST DGR GA AE))
((ARCVAL ST POBJ GA AE))
((ARCVAL ST TIME NI TIME))
((ARCVAL ST POBJ WA AE))
((ARCVAL MOVE HUMAN WA AGT))
((ARCVAL MOVE POBJ WA AE))
((ARCVAL MOVE LOC NI LOC))
((ARCVAL MOVE POBJ GA AE))
((ARCVAL MOVE POBJ NI PU))
((ARCVAL AC SOUND O AC))
((ARCVAL ACT LOC NI LOC))
((ARCVAL ACT POBJ WA INSTR))
((ARCVAL ACT POBJ O AE))
((ARCVAL AP POBJ WA AE))
((ARCVAL AP POBJ NI AP))

(((ARCVAL AP DEV WA INSTR)))
(((ARCVAL MOVE SP NI SP)))
(((ARCVAL AP HUMAN WA AGT)))
(((ARCVAL ACT POBJ GA INSTR)))
(((ARCVAL AP MOVE MADE OUR)))

(((FEAT DHKII SIZE))
(((FEAT KIROI COLOR))
(((FEAT AKAI COLOR))
(((FEAT KOROI COLOR))
(((FEAT SUGITE INTERS))
(((FEAT TAKAI HIT))
(((FEAT SUKOISHI DGR))
(((FEAT SUGUNI TIME))
(((FEAT YUKKURI RATE))
(((FEAT DANDAN DGR))
(((FEAT HAYAKU RATE))
(((FEAT NAGASA LGTH))
(((FEAT V-2 TYPE))
(((FEAT ROCKET POBJ))
(((FEAT NEWMEXICO LOC))
(((FEAT SARAKU LOC))
(((FEAT KARA ST))
(((FEAT TON MSR))
(((FEAT ODOSA AGT))
(((FEAT HENGYO POBJ))
(((FEAT ALCOHOL POBJ))
(((FEAT EKITAI ST))
(((FEAT SANSO POBJ))
(((FEAT JUMBI POBJ))
(((FEAT KAGAKUSA HUMAN))
(((FEAT SHOGUN HUMAN))
(((FEAT DOTE LOC))
(((FEAT USHIRO LOC))
(((FEAT NAKA LOC))
(((FEAT HONOH POBJ))
(((FEAT SHINGO POBJ))
(((FEAT AIZU POBJ))
(((FEAT OTOSOUND))
(((FEAT FEET MSR))
(((FEAT MUSHI POBJ))
(((FEAT RADAR DEV))
(((FEAT MPH RATE))
(((FEAT HAYASA SP))
(((FEAT TEISATSUKI POBJ))
(((FEAT PILOT HUMAN))
((FEAT HASSHA TYPE))
((FEAT CHITEN LOC))
((FEAT TOKORO LOC))
((FEAT MIKE MSR))
((FEAT SORE OBJ))
((FEAT SUBETE DGR))
((FEAT #46 QU))
((FEAT #5 QU))
((FEAT #6 QU))
((FEAT #2 QU))
((FEAT #60 QU))
((FEAT #3000 QU))
((FEAT #40 QU))
((FEAT BYOH TIME))
((FEAT NOCHI TIME))
((FEAT HUN TIME))
((FEAT SU QU))
((FEAT NON MSR))
((FEAT UCHIAGE ACT))
((FEAT #IRU AP))
((FEAT QU AP))
((FEAT #IRU AP))
((FEAT Hiku ACT))
((FEAT AGARU MOVE))
((FEAT SUGARU MOVE))
((FEAT ARU MSR))
((FEAT DEKIRU ST))
((FEAT UCHIAGE ACT))
((FEAT TASSRU MOVE))
((FEAT MOMORU ACT))
((FEAT TATSU POSIT))
((FEAT TSUKU CO))
((FEAT HANAMERU MOVE))
((FEAT TOMONAI ACO))
((FEAT DINACEWU AP))
((FEAT WENAI AP))
((FEAT MARU ST))
((FEAT (X : Y) +) < (FEAT X +)))
Appendix B, Translation Rules

(3) Case Transformation Rules

(((LOC JP LOC (w , y) (w , y))) < (MEMPR (PREP TO) y))
(((LOC JP LOC (w , y) (X POSTP N1 LOC (w , y1))))
   <
   (MEMPR (PREP X) y)
   (DEPAIR (PREP X) Y Y2)
   (ADOPR (POSTP NO) Y2 Y1)))

(((PU JP PU (w , y) (w , y1)))
   <
   (MEMPR (PREP X) Y)
   (DEPAIR (PREP X) Y Y2)
   (ADOPR (POSTP N1) Y2 Y1))
(((PU JP PU (w , y) (w , y1)))
   <
   (MEMPR (INF TO) Y)
   (DEPAIR (INF TO) Y Y2)
   (ADOPR (POSTP NO) Y2 Y3)
   (ADOPR (POSTP TAME) Y3 Y1))))

(((MSR JP MSR (# , y) (# , y1)))
   <
   (DEPAIR (PREP OF) Y Y2)
   (ADOPR (POSTP NO) Y2 Y1))))

(((AGT JP AGT (# , y) (w , y1)))
   <
   (MEMPR (SNTRL OBJ) Y)
   (DEPAIR (SNTRL OBJ) Y Y2)
   (ADOPR (SNTRL OBJ) Y2 Y1))
(((AGT JP AGT (w , y) (# , y1)))
   <

(MEMPR (SNTRL SUB) Y)
(DEPAIR (SNTRL SUB) Y Y2)
(ADOPP (SNTRL SUB) Y2 Y1)))

(((AE JP AE (w * Y) (w * Y1))
<
(MEMPR (SNTRL OBJ) Y)
(DEPAIR (SNTRL OBJ) Y Y2)
(ADOPR (SNTRL OBJ) Y2 Y1)))

(((AP JP AP (w * Y) (w * Y1))
<
(MEMPR (PREP X) Y)
(DEPAIR (PREP X) Y Y2)
(ADOPR (POSTP NI) Y2 Y1)))

(((SUBST JP SUBST (w * Y) (w * Y1))
<
(MEMPR (SNTRL OBJ) Y)
(DEPAIR (SNTRL OBJ) Y Y2)
(ADOPR (SNTRL OBJ) Y2 Y1)))

(((SNTRL JP POSTP Y Y1) < (POSTP Y Y1)))

(((POSTP SUB WA)) ((POSTP OBJP NI)) ((POSTP OBJP O)))

(4) Vocabulary Transformation Rules

(((IT JP SORE Y Y1) < (DEPAIR (NBR X) Y Y1)))

(((SOON JP SUGUNI Y Y))))

(((BLACK JP KUROI Y Y1))
<
(MEMPR (*AND X) Y)
(ADOPR (FORM CONT) Y Y1))

(((BLACK JP KUROI Y Y1) < (ADOPR (FORM ORG) Y Y1)))

(((GREAT JP OHKII Y Y1))
(<MEMPR (*AND X) Y)
  (ADDPR (FORM CONT) Y Y1))
(((GREAT JP CHIKII Y Y1) < (ADDPR (FORM ORG) Y Y1)))

(((YELLOW JP KIIROI Y Y1)
  <
  (MEMPR (*AND X) Y)
  (ADDPR (FORM CONT) Y Y1))
  ((YELLOW JP KIIROI Y Y1) < (ADDPR (FORM ORG) Y Y1)))

(((RED JP AKAI Y Y1)
  <
  (MEMPR (*AND X) Y)
  (ADDPR (FORM CONT) Y Y1))
  ((RED JP AKAI Y Y1) < (ADDPR (FORM ORG) Y Y1)))

(((FORTY-SIX JP *46 Y Y1) < (ADDPR (FORM ORG) Y Y1)))

(((EIGHT JP *8 Y Y1) < (ADDPR (FORM ORG) Y Y1)))

(((SIXTY JP *60 Y Y1) < (ADDPR (FORM ORG) Y Y1)))

(((DESSERT JP SABAKU Y Y1)
  <
  (DEPAIR (DET X) Y Y2)
  (DEPAIR (NBR X1) Y2 Y1)))

(((FUEL JP MENRYO Y Y1)
  <
  (DEPAIR (NBR X) Y Y2)
  (DEPAIR (DET X1) Y2 Y1)))

(((ALCOHOL JP ALCOHOL Y Y1)
  <
  (DEPAIR (NBR X) Y Y2)
  (DEPAIR (DET X1) Y2 Y1)))

(((OXYGEN JP SANSO Y Y1)
  <
  (DEPAIR (NBR X) Y Y2)
  (DEPAIR (DET X1) Y2 Y1)))

(((LIQUID JP EKITAI Y Y1) < (DEPAIR (DET X) Y Y1)))

(((TON JP TON Y Y1))
<
(DEPAIR (NBR X) Y Y2)
(MEMPR (QU X1) Y2)
(ADDPR (POSTP NO) Y2 Y1))

(((SCIENTIST JP KAGAKUSHA Y Y1)
<
(DEPAIR (NBR X) Y Y2)
(DEPAIR (DET X1) Y2 Y1))

(((GENERAL JP SHOGUN Y Y1)
<
(DEPAIR (NBR X) Y Y2)
(DEPAIR (DET X1) Y2 Y1))

(((DISTANCE JP TOHKUNI Y Y1)
<
(MEMPR (PREP TO) Y)
(DEPAIR (PREP TO) Y Y2)
(DEPAIR (NBR X) Y2 Y3)
(DEPAIR (DET X1) Y3 Y1))

(((HOUND JP DOTE Y Y1)
<
(MEMPR (TYPE X) Y)
(DEPAIR (TYPE X) Y Y2)
(DEPAIR (NBR X1) Y2 Y3)
(DEPAIR (DET X2) Y3 Y1))

(((FLAME JP HONOH Y Y1)
<
(DEPAIR (NBR X) Y Y2)
(DEPAIR (DET X1) Y2 Y1))

(((SIGNAL JP AIZU Y Y1)
<
(DEPAIR (NBR X) Y Y2)
(DEPAIR (DET X1) Y2 Y1))

(((FLARE JP HONOH Y Y1)
<
(MEMPR (QU (X)) Y)
(DEPAIR (NBR X1) Y Y2)
(DEPAIR (DET X2) Y2 Y3)
(CNTFEAT FLARE W)
(V X w1)
(DEPAIR QU (X)) Y3 Y4)
(ADDPR (MSR (W1 POSTP NO QU (X))) Y4 Y1))
((FLARE JP HONOH Y Y1))
<
(DEPAIR (NBR X) Y Y2)
(DEPAIR (DET X1) Y2 Y1)))

(((FOOT JP FEET Y Y1))
<
(DEPAIR (NBR X) Y Y2)
(MEMPR (QU X1) Y2)
(ADDPR (POSTP NO) Y2 Y1)))

(((LONG JP WAGASA Y Y1))
<
(MEMPR (MSR X) Y)
(ADDPR (POSTP NO) Y Y1)))

(((ROCKET JP ROCKET Y Y1))
<
(DEPAIR (DET X) Y Y2)
(DEPAIR (NBR X1) Y2 Y1)))

(((STAR JP HOSHI Y Y1))
<
(DEPAIR (NBR X) Y Y2)
(DEPAIR (DET X1) Y2 Y1)))

(((BEHIND JP USHIRO Y Y1) < (ADDPR (POSTP NI) Y Y1)))

(((IN JP NAKA Y Y1) < (ADDPR (POSTP NI) Y Y1)))

(((ON JP UE Y Y1) < (ADDPR (POSTP NI) Y Y1)))

(((STAND JP TATSU Y Y1))
<
(MEMPR (TNS X) Y)
(ADPAIR (AUX (IRU TNS X)) Y Y2)
(DEPAIR (TNS X) Y2 Y3)
(ADPAIR (TNS X) Y3 Y1)))

(((CARRY JP TSUMU Y Y1))
<
(MEMPR (TNS X) Y)
(ADPAIR (AUX (IRU TNS X)) Y Y2)
(DEPAIR (TNS X) Y2 Y3)
(ADPAIR (TNS X) Y3 Y1))

(((RISE JP AGARU Y Y1)
 <
 (MEMPR (TNS X) Y)
 (DEPAIR (TNS X) Y Y2)
 (ADPAIR (TNS X) Y2 Y1))))

(((FIRE JP UCHIAGERU Y Y1)
 <
 (MEMPR (TNS X) Y)
 (DEPAIR (TNS X) Y Y2)
 (ADPAIR (TNS X) Y2 Y1))))

(((WITHOKAN JP HANARERU Y Y1)
 <
 (MEMPR (TNS X) Y)
 (DEPAIR (TNS X) Y Y2)
 (MEMPR (#AND X1) Y2)
 (ADPAIR (FORM CONT) Y2 Y3)
 (ADPAIR (TNS X) Y3 Y1))))

(((TRAIL JP HIKU Y Y1)
 <
 (MEMPR (TNS X) Y)
 (DEPAIR (TNS X) Y Y2)
 (ADPAIR (TNS X) Y2 Y1))))

(((CROUCH JP SUMARU Y Y1)
 <
 (MEMPR (TNS X) Y)
 (DEPAIR (TNS X) Y Y2)
 (ADPAIR (TNS X) Y2 Y1))))

(((LOOK JP MIERU Y Y1)
 <
 (MEMPR (TNS X) Y)
 (DEPAIR (TNS X) Y Y2)
 (ADPAIR (TNS X) Y2 Y1))))

(((CNTFEAT ROCKET CNT1)) ((CNTFEAT FLARE CNT2)))

(((CNT1 X DAI)))

(((CNT2 ONE PON)) ((CNT2 TWO HON)) ((CNT2 THREE BON)))
Appendix C. Japanese Sentence Analysis

The following is a continuation of the recording session in section 2.

*(sprint st8)
(S13 (SORE WA USHIRO NI *60 FEET NO KIROI HONOH O HIITA)
    X
    X1)
NIL
<< We call TRY to parse sentence 8, and pretty-print the output.>>

*(sprint (car (try st8)))
CONTINUE? *y

(S13 (SORE WA USHIRO NI *60 FEET NO KIROI HONOH O HIITA)
    (HIKU INSTR
        (SORE POSTP WA)
        LOC
        (USHIRO POSTP N1)
        AE
        (HONOH POSTP O
            NSR
            (FEET POSTP NO QU (*60 FORM ORG))
            COLOR
            (KIROI FORM ORG))
    TNS
    PAST)
NIL)
NIL
#rtime
(0.872900000 SECS)
<< we set J to (S13 x semantic-relation nil) to show the
symmetry of the grammar again.>>

*(setq J (car (subst x (cadar val) val)))
(S13 -X (HIKU INSTR (SORE POSTP #A) LOC (USHIRO POSTP NI) AE
(HONOH POSTP O N5R (FEET POSTP NO QU (*60 FORM ORG)) COLOR
(KIROI FORM ORG)) TNS PAST) NIL).

*(try J)
((S13 (SORE #A USHIRO NI *60 FEET NO KIROI HONOH O HII TA) (HIKU INSTR (SORE POSTP WA) LOC (USHIRO POSTP NI) AE (HONOH POSTP O N5R (FEET POSTP NO QU (*60 FORM ORG)) COLOR (KIROI FORM ORG)) TNS PAST) NIL))

*rtime
(0.573000000 SECS)

*(sprint st9)
(S13 (SUGUNI HONOH #A KIROI HOSHI NI MIETA) X X1) nil
<< we TRY to parse sentence 9.>>

*(sprint (car (try st9)))
CONTINUE? #v

(S13 (SUGUNI HONOH #A KIROI HOSHI NI MIETA)
(MIERU TIME
 (SUGUNI)
 AE
 (HONOH POSTP #A)
 AP
 (HOSHI POSTP NI COLOR (KIROI FORM ORG))
 TNS
 PAST)
 nil)
 nil

*rtime
(0.948000000 SECS)

*(setq J (car (subst x (cadar val) val ))
(S13 -X (MIERU TIME (SUGUNI) AE (HONOH POSTP #A) AP (HOSHI POSTP NI COLOR (KIROI FORM ORG)) TNS PAST) NIL)
We show the symmetry of the grammar.

**(try 1)**

```
((S13 (SUGUNI HONOH WA KIROI HOSHI NI MIETA) (MIERU TIME (S
SUGUNI) AE (HONOH POSTP WA) AP (HOSHI POSTP NI COLOR (KIROI
FORM ORG)) TNS PAST) NIL))
```

*rtime

```
(0.10300000 SECS)
```

**(sprint st13)**

```
(S12 (SORE WA HASSHA CHITEN KARA #40 MILE NO TOKORO NI
OCHITA)
    
    (X
    (X1)
    NIL)
```

<< we TRY to parse sentence 13 and get pretty-print output.>>

**(sprint (car (try st13)))**

```
(S12 (SORE WA HASSHA CHITEN KARA #40 MILE NO TOKORO NI
OCHITA)
    
    (OCHIRU INSTR
    (SORE POSTP WA)
    LOC
    (TOKORO POSTP
     NI
     MSR
     (MILE POSTP
      NO
      LOC
      (CHITEN POSTP KARA TYPE (HASSHA))
      QU
      (#40 FORM ORG)))
    
    (TNS PAST)
    
    NIL)
```

*rtime

```
(0.18330000 SECS)
```

**(setq j (car (subst x (cadar val) val)))**

```
(S12 -X (OCHIRU INSTR (SORE POSTP WA) LOC (TOKORO POSTP NI
MSR (MILE POSTP NO LOC (CHITEN POSTP KARA TYPE (HASSHA)) QU
(#40 FORM ORG))) TNS PAST) NIL)
```
*(try 1)*

[((S12 (SORE WA HASSHA CHITEN KARA *40 MIILE NO TOKORD NI OCHI TA) OCHIRU INSTR (SORE POSTP WA) LOC (TOKORD POSTP NI MSR (MIILE POSTP NO LOC (CHITEN POSTP KARA TYPE (HASSHA)) QU (*40 FORM ORG)))) TNS PAST) NIL))

*rtime

(0.27400000 SECS)

<< That is the end of the session.>>
Appendix D. Translation Analysis

The following is the continuation of the recording session in section 3.

*st5
(TRANSLATE (WITHDRAW AGT (SCIENTIST NBR PL) *AND (GENERAL NBR PL) SNTRL SUB) TNS PAST LOC (DISTANCE PREP TO DET SOME NBR SING) *AND (CROUCH TNS PAST LOC (MOUND PREP BEHIND TYPE (EARTH NBR SING) NBR PL))) V)

*(script (car (try st5)))

CONTINUE? *y

<< We can see the following features from this example. Preposition (LOC) is different here, because of TO. DOTE (noun) is a composite form in Japanese. It consists of MOUND and TYPE earth in English. Verb contains *and in the structure transforms into Verb + TNS + FORM CONTINUING.>>

(TRANSLATE (WITHDRAW AGT
(SCIENTIST NBR
PL
*AND
(GENERAL NBR PL)
SNTRL
SUB)

TNS
PAST
LOC
(DISTANCE PREP TO DET SOME NBR SING)
*AND
(CROUCH TNS
PAST

44
LOC
(HEMID PREP
BEHIND)
TYPE
(EARTH NBR SING)
NBR
PL))

(HANARERU AGI
(KAGAKUSHI POSTP WA *AND (SHOGUN))
LOC
(TOMKUNI)
*AND
(SUWARU LOC
(UHRIU POSTP
NI
LOC
(DOTE POSTP NO))
TNS
PAST)
FORM
CONF
TNS
PAST))

NIL

*rtime
(0.57100000 SECs)

*st6
(TRANSLATE (RISE AE (FLARE QU (TWO) COLOR (RED) NBR PL SWIRL
SUP) TNS PAST PU (SIGNAL PREP AS DET A PU (FIRE INF TO TNS
PRES AE (ROCKET DET THE NBR SING)) NBR SING)) V)

*(sprint (car (try st6)))

CONTINUE? *y

<< we have the following features in this translation.>>
<< Noun + QU transforms Noun + #SR ( QU ) as described
in section 3.>>
<< Preposition in Purpose is changed into POSTP NI.>>

(TRANSLATE (RISE AE
(FLARE QU
(TWO)
COLOR
(RED)
NBR
PL
SNTRL
SUB

INS
PASI
PJ
_SYMBOL
(SIGNAL PREP
AS
DET
A
PJ
_SYMBOL
(FIRE INF
TJ
INS
PRES
AE
_SYMBOL
(ROCKET DET
THE
NBR
SING
SNTRL
OBJ))

NBR
SING))
_SYMBOL
(AGARU AE
_SYMBOL
(HONOH MSR
_SYMBOL
(HON POSTP ND QU (TWO))
_POSTP
_SYMBOL
(KA
_SYMBOL
(COLOR
_SYMBOL
(AKAI FORM ORG))

PJ
_SYMBOL
(AIZU POSTP
_SYMBOL
NI
_SYMBOL
PJ
_SYMBOL
(UCHIAGERU POSTP
_SYMBOL
TATE
_SYMBOL
POSTP
_SYMBOL
NO
_SYMBOL
AE
_SYMBOL
(ROCKET POSTP U))
_SYMBOL
INS
_SYMBOL
PRES))

INS
_SYMBOL
PAST))
NIL

*rtime
(0.40100000 SECS)

*st8
(TRANSLATE (TRAIL LOC BEHIND INSTR (IT NBR SING SNTRL SUB) TNS PAST SUBST (FLAME MSR (FOOT PREP OF QU (SIXTY) NBR PL) COLOR (YELLOW) NBR SING SNTRL OBJ)) V)

*(sprint (car (try st8)))

CONTINUE? *y

<< Following features are presented.>>
<< Preposition (LOC).>>
(TRANSLATE (TRAIL LOC
  BEHIND
  INSTR
  (IT NBR SING SNTRL SUB)
  TNS PAST
  SUBST
  (FLAME MSR
   (FOOT PREP OF QU (SIXTY) NBR PL)
   COLOR
   (YELLOW)
   NBR
   SING
   SNTRL
   OBJ))

(HIKU LOC
 (USHIRO POSTP NI)
 INSTR
 (SORE POSTP WA)
 SUBST
 (HONOH POSTP
  O
  MSR
  (FEET POSTP NO QU (*60 FORM ORG))
  COLOR
  (KIIROI FORM ORG))

TNS PAST))

NIL
time
(0.54300000 SECS)

*st9
(TRANSLATE (LOOK TIME SOON AE (FLAME DET THE NBR SING SNTRL SUB) TNS PAST AP (STAR PREP LIKE DET A COLOR (YELLOW) NBR SING)) v)

*(sprint (car (try st9)))

CONTINUE? *y

(TRANSLATE (LOOK TIME
SOON
AE
(FLAME DET THE NBR SING SNTRL SUB)
TNS PAST AP
(STAR PREP LIKE DET A COLOR (YELLOW) NBR SING))

MIERU TIME
(SUGUNI)
AE
(HONOH POSTP WA)
AP
(HOSHI POSTP NI COLOR (KIIROI FORM ORG))
TNS PAST))

NIL

*time
(0.22300000 SECS)

<< That is the end of the session.>>
bibliography


VITA

Takao Usui was born in Osaka, Japan, on August 20, 1954, the son of Koji Usui and Fusayo Usui. He was graduated from Kozu High School, Osaka, Japan, in 1973, and entered Kyoto University, Kyoto, Japan. In March, 1977, he received the degree of Bachelor of Science in Mathematics from Kyoto University and was employed as a system programmer by Hitachi Software Engineering Co.. In September, 1980, he was given a scholarship, entered the Graduate School of the University of Texas, and pursued a major in Computer Sciences.

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