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

\[ \text{IL} \rightarrow \text{IL-DSS} \]

Map from DSS in IL to a DSS for the Target Language

\[ \text{IL-DSS} \rightarrow \text{TL-DSS} \]

Then generate the Target Language strings from DSS of the TL

\[ \text{TL-DSS} \rightarrow \text{TL} \]

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

\[ \text{e.g.} \quad (\text{THE GIANT ROCKET ROSE}) \]

\[ \begin{array}{c}
\text{V} \\
\text{(RISE AE (ROCKET DET THE SIZE (GIANT) NBR SING SNTRL SUB) TNS PAST)}
\end{array} \]

\text{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) NBR 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.

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

ENG-SNT  --(English grammar)--> SR (ENG)

!    

(Japanese grammar)  -> SR (JAP)

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

Table 1.1 Translation Scheme

Both the Japanese grammar and Translation rules developed
here are written in HCPRVR 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 Beaugrande (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 flares 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 forty miles from the starting point.

The Japanese translation of the text is given below.

46 feet no onkii kuroku kiroi W-2 rocket wa NewMexico sabaku no haka ni tatteita. Kara de sore wa 5 ton no omosa ga atta. Nebyo ni sore wa 8 ton no alcohol to exitai sanso o tsundeita.
Subete wa dekita. Kagakusha to shogun wa tonkuni hanareta, dote no ushiro ni suwatta, 2 hon no akai honoh ga rocket o uchiageru tame no aizu ni agatta.
Onkii oto to honoh to tomo ni, onkii rocket wa yakkuri sosnite dandan hayaku agatta. Sore wa ushiro ni 60 feet no kiroi honoh o niita. Suguni honoh wa kiroi hoshi ni mieta.
Su byon no nochi ni sore wa takasugite mienaku natta. Radar wa sore ga 3000 moh no hayasa made otta. Sore ga uchiagerarete kara su hun no nochi ni teisatsuki no pilot wa sore ga moderu tokoro o mita. Sore wa hassha 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 SKs 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, arcname, etc. It has been debugged and runs in the HCPRVR LISP language.
1. (STAND AE (ROCKET DET A SIZE (GREAT) COLOR (BLACK) AND (YELLOW)) TYPE (V=2) LGTH (LONG LGTH (FOOT QU (FORTY-SEVEN) 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 (MOUND PREP BEHIND TYPE (EARLY NBR SING) NBR PL))

6. (RISE AE (FLARE 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 (GIGANT) 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 (Flame Det the NBR Sing SNTRL SUB)
TNS PAST
AP (Star Prep like Det A Color (Yellow) NBR Sing)

10. (He Time (Second Prep In Det A Qu (Few) NBR PL)
AE (It NBR Sing SNTRL SUB)
TNS PAST
HT (High Intens Too)
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 PrpRI)
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 (*Here Qu (Forty)
Loc (Point Prep From Det The
Loc (Start TNS Pres) NBR Sing)
NBR PL))

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

Arctypes:
Affected Entity, DETERminer, SIZE, COLOR, TYPE, LENGTH,
Quantity, Number, Tense, LOCATION, Measure, Purpose,
Weight, Preposition, *AND (conjunction), STATE, AGENT,
INFinitive, ACCompany, SUBstance, RATE, INSTRUMENT, TIME,
*THEN (temporal conjunction), Height, INTENSifier, DURATION,
RESULT, AUXiliary, DIRECTION, *OF(partOf), SENTence Relation,
INSTR* (back link through instrument), *TO (direction to).
============================================

Table 2.1 Semantic Relations of Rocket Story(concluded)
1. (TATSU AE (ROCKET POSTP GA
   LGIH (NAGASA POSTP NO
     MSR (FEET POSTP NO QU (*46 FORM ORG))
     QU (*46 FORM ORG))
   SIZE (OHKII 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 (IRU TNS PAST) TNS PAST)

2. (AKU AE (SURE POSTP AA) ST (KARA POSTP DE)
   WGT (DORSA POSTP GA
     MSR (TON POSTP NO QU (*5 FORM ORG)))
   TNS PAST)

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

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

5. (HANARERU AGT (KAGAKUSA POSTP WA *AND (SHOGUN))
   LOC (TOKKUNI)
   *AND (SUWARI LOC (OSHIRO 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 (AIKU POSTP NI
   PU (UCHIAGERU POSTP NO POSTP TAME
   AE (ROCKET POSTP O) TNS PRES))
   TNS PAST)

7. (AGARU AC (TOMO POSTP NI
   *AND (OT) SIZE (OHKII FORM ORG) *AND (HONOH))))
   AE (ROCKET POSTP WA SIZE (OHKII FORM ORG))
   RATE (YUKKURI *AND (HAYAKU RATE (DANDAN)))
   TNS PAST)

Table 2.2 Semantic Relations of Rocket Story (Japanese)
8. (MIRU INSTR (SORE POSTP WA))
   LOC (USHIRO POSTP NI)
   AE (HONOH POSTP O)
   MSR (FEET POSTP NO QU (*60 FORM ORG))
   COLOR (KIROI FORM ORG))
   TNS PAST)
9. (MIERU TIME (SUGUNI))
   AE (HONOH POSTP WA)
   AP (HOSHI POSTP NI COLOR (KIROI FORM ORG))
   TNS PAST)
10. (MARU TIME (NOCHI POSTP NI)
    TIME (BYOH POSTP NO QU (SU FORM ORG)))
    AE (ROCKET POSTP WA)
    HT (TAKAI INTENS (SUGITE) FORM ORG)
    AP (MIERU FORM CONT MOD NEG TNS PRES)
    TNS PAST)
11. (OKAKERU INSTR (RADAR POSTP WA))
    DUR (TASSURU POSTP MADE
    AE (ROCKET POSTP GA)
    SP (HAYASA POSTP NI
    MSR (MPS POSTP NO QU(*3000 FORM ORG)))
    QU (*3000 FORM ORG)))
    TNS PAST)
12. (KIRU TIME (NOCHI POSTP NI
    TIME (HUN POSTP NO QU (SU FORM ORG))
    EVT (UCHIAGERU POSTP KARA AE (ROCKET POSTP GA)
    AUX (OCHIAGERU TNS PRES) TNS PRES))
    AGT (PILOT POSTP WA OF* (TEISATSUKI POSTP NO))
    AE (TOKORD POSTP O
    EVT (MODORU AE (SORE POSTP GA) TNS PRES)
    TNS PAST)
13. (OCHIRU INSTR (SORE POSTP WA))
    LOC (TOKORD 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 SRSs of each language reveal some similarities of the structure. We make use of the similarities to translate. Before translating SRSs 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 SRSs. Comments are inserted in the form <<...>>.

=======
*(print st1)
<< st1 contains a sentence to be parsed,>>
(S12 (*46 FEET NO NAGASA NO OHKII KUROKU KIIROI V=2 ROCKET GA NEWMEXICO SABAKU NO NAKA NI TATTEITA)
  X
  X1)
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 KIIROI 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 M ORG))) SIZE (OHKII FORM ORG) COLOR (KUROKU 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
(*time
(0.77300000 SECS)
<< It took real CPU time 0.773 secs in UCI LISP, MCPRVR
DEC 2050 K110.>>

*(sprint (car val))
<< Now we can look at the answer pretty-printed. VAL contains the answer.>>

(S12 (*46 FEET NO NAGASA NO OHKII KUROKI KIIRUI 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 FORM ORG)))
SIZE
(OHKII FORM ORG)
COLOR
(KUROKI FORM CONT *AND (KIIRUI FORM ORG))
TYPE
(V=2))

LOC
(NAKA POSTP
NI
LOC
(SABAKU POSTP NO LOC (NEWMEXICO)))

AUX
(IRU INS PAST)
TNS
PAST)
NIL)

NIL
<< Now we set J to (S12 x semantic-relation nil) by using VAL.>>

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

(S12 -X (TATSU AE (ROCKET POSTP GA LGTH (NAGASA POSTP NO MSR
(FEET POSTP NO QU (*46 FORM ORG))) SIZE (OHKII FORM ORG) CO-
LOR (KUROKI FORM CONT *AND (KIIRUI FORM ORG)) TYPE (V=2)) LOC
(NAKA POSTP NI LOC (SABAKU POSTP NO LOC (NEWMEXICO))) AUX (IRU TNS PAST) TNS PAST) NIL

*(try 1)

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

((S12 (*46 FEET NO NAGASA NO OHKII KUROKU KIIROI V=2 ROCKET GA NEWMEXICO SABAKU NO NAKA NI TATEITAI) (TATSU AE (ROCKET POSTP GA LGTH (NAGASA POSTP NO MSR (FEET POSTP NO QU (*46 FOR M ORG))) SIZE (OHKII FORM ORG) COLOR (KUROKU 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.>>

*rttime
(0.60000000 SECS)

*(sprint st3)

(S13 (SORE WA NENRYO NI *8 TON NO ALCOHOL TO EKITAI SANSO O TSUNDEITAI)

X

X1)

NIL

<< We TRY ST3 to parse.>>

*(sprint (car (try st3)))

CONTINUE? *y

CONTINUE? *y

(S13 (SORE WA NENRYO NI *8 TON NO ALCOHOL TO EKITAI SANSO O TSUNDEITAI)

(TSUMU AE

(SORE POSTP WA)

PU

(NENRYO POSTP NI)

AE

(ALCOHOL POSTP O

*AND

(SANSO ST (EKITAI))

MSR

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

AUX

(IRU TNS PAST)

TNS

PAST)
<< 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 (WENRYO POSTP NI) AE (ALCOHOL POSTP O) *AND (SANSO ST (KEITAI)) *MR (TON POSTP NO QU (*8 FORM ORG))) AUX (IRU TNS PAST TNS PAST) NIL)

*(try j)
(((S13 (SORE WA WENRYO NI *8 TON NO ALCOHOL TO KEITAI SANSO O TSUNDEITA) (TSUMU AE (SORE POSTP WA) PU (WENRYO POSTP NI) AE (ALCOHOL POSTP O) *AND (SANSO ST (KEITAI)) *MR (TON POSTP NO QU (*8 FORM ORG))) AUX (IRU TNS PAST TNS PAST) NIL))

*rtime
(0,32900000 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 S1 (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)) < (X JP U Y Y1))
 (((REPLACE X NIL X))
 (((REPLACE X W (X * W)))))

(2) Structure Transformation Rules

(((MEMPR (R X) (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)))

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

(((ADPAIR (R X) NIL (R X)))
 (((ADPAIR (R X) (U V Q) (U V * Z)) < (ADPAIR (R X) Q 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, *MEMPR*, *DEPAIR*, *ADDPK*, 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 VI. (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 RIIME. 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 SNTRL SUB) TNS 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 SNTRL SUB) TNS PAST LOC (DESERT PREP IN DET A LOC (NEWMEXICO) NBR SING)) U)
IX) NBR PL)) NBR SING SNTRL SUB) TNS PAST LOC (DESER T PREP IN DET A LOC (NEW MEXICO) NBR SING)) (TATSU AE (ROCKET POSTP WA SIZE (OHKII FORM ORG) COLOR (KUROI FORM CONT *AND (KIIROI FORM ORG)) TYPE (V=2) LGTH (NAGASA POSTP NO MSR (FEET POSTP NO QU (#46 FORM ORG)))) LOC (NAKA POSTP NI LOC (SABA KU POSTP NO LOC (NEW MEXICO))) AUX (IRU TNS PAST) TNS PAST)))

<< 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

(LONG MSR

(FOOT QU (FORTY-SIX) NBR PL))

NBR

SING

SNTRL

SUB)

TNS

PAST

LOC

(DESER T PREP IN

DET

A

LOC

(NEW MEXICO)

NBR

SING))

(TATSU AE

(ROCKET POSTP WA

SIZE

(OHKII FORM ORG)

COLOR
NIL

*rtime

(0.055000000 SECS)

<< It took real CPU time 0.055 secs, >>

*st3

(TRANSLATE (CARRY PU (FUEL PREP FOR NBR SING) AE (IT NBR SING G 3NTRL SUB) TNS PAST AE (ALCOHOL MSR (TON PREP OF QU (EIGHT ) NBR PL) NBR SING *AND (OXYGEN ST (LIQUID) NBR SING) 3NTRL OBJ)) V)

*(sprint (car (try st3)))

CONTINUE? *Y

<< Sentence 3 demonstrates the features following;
Preposition handling (purpose)--> POSTP NI.
SNTRL ORJ (AE) --> POSTP O. >>

(TRANSLATE (CARRY PU

(FUEL PREP FOR NBR SING)

AE

(IT NBR SING 3NTRL SUB)

TNS
PAST
AE
(ALKOHOL MSR
(TON PREP OF QU (EIGHT) NBR PL)
NBR
SING
*AND
(OXYGEN ST (LIQUID) NBR SING)
SNTRL
OBJ))

(TSUHU PU
(MENRYO POSTP NI)
AE
(SORE POSTP WA)
AE
(ALKOHOL POSTP
0
MSR
(TUM POSTP NO QU (*8 FORM ORG))
*AND
(SANSO ST (EKITAI)))

AUX
(IRU TNS PAST)
TNS
PAST))

NIL

*rtme
(0.37600000 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 ($S_{11}, S_{12}, \ldots$) 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 #1 V1, Z1) R)
 <
 (PHR X V1 R1)
 (VP R1 (Z, Z1) R)
 (SEMF Z V1 w1)))

(((S12 X (Z #1 V1 #2 V2, Z1) R)
 <
 (PHR X V1 R1)
 (PHR R1 V2 R2)
 (VP R2 (Z, Z1) R))
(SEMF Z V1 w1)
(SEMF Z V2 w2))

(((S13 X (Z w1 V1 w2 V2 w3 V3 w4 V4 * Z1) R)
<
(PHR X V1 w1)
(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 * 2) R)
<
(NP1 X (V1 * 2) (R1 * R2))
(CONJ R1)
(NP1 R2 V2 R3)
(PP R3 w R)))

(((NP1 (X Y * R) (Y w (X)) R)
<
(NOUN X)
(NOUN Y)
(PEAT X w))
((NP1 (X * R) (X) R) < (NOUN X))
((NP1 X w R) < (MDNP X w R))
((NP1 X (V2 w V1 * 0) R)
\[
<
(\text{ADJP X V1 R1})
(\text{NP1 R1 (V2 . Q) R})
(\text{FEAT V1 w}))

(((\text{NP2 (X Y . R) (Y w (X)) R})
<
(\text{NOUN X})
(\text{NOUN Y})
(\text{FEAT X w}))
((\text{NP2 (X . R) (X) R}) < (\text{NOUN X}))
((\text{NP2 X (V2 w V1 . Q) R})
<
(\text{ADJP X V1 R1})
(\text{NP2 R1 (V2 . Q) R})
(\text{FEAT V1 w}))

(((\text{MDNP X (V3 w2})
\text{(V2 POSTP R3 w1 (V1 POSTP R1 . Q1) . Q2) . Q3})
R)
<
(\text{NP2 X (V1 . Q1) (R1 . R2)})
(\text{MODARC V1 w1})
(\text{POSTPP R1})
(\text{NP2 R2 (V2 . Q2) (R3 . R4)})
(\text{MODARC V2 w2})
(\text{POSTPP R3})
(\text{NP2 R4 (V3 . Q3) R}))
((\text{MDNP X (V2 w1 (V1 POSTP R1 . Q1) . Q2) R})
<
(\text{NP2 X (V1 . Q1) (R1 . R2)})
(\text{MODARC V1 w1})
(\text{POSTPP R1})
(\text{NP2 R2 (V2 . Q2) R}))

(((\text{ADVP (X Y . Z) (X AND V1) R})
<
(\text{ADV X})
(\text{CONJ Y})
(\text{ADVP Z V1 R}))
((\text{ADVP (X . Y) (V1 w (X) . Q) R})
<
(\text{ADV X})
(\text{ADVP Y (V1 . Q) R})
(\text{FEAT X w}))
\]
(((ADV P (X,Y) (X) Y) < (ADV X))
((ADV P (X,Y) (V1 = (X2) Q) Y)
 <
(ADV X X1 X2)
(ADJP X1 (V1 =Q))
(FEAT X2 =V))

(((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) < (ADJ X X1))
((ADJP (X,Y) (V1 = (X) Q) R)
 <
(ADV X)
(ADJP Y (V1 = Q) R)
(FEAT X W)))

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

(((PP TEST X (Y POSTP W1 =Q) =V)
 <
(FEAT X X1)
(FEAT Y Y1)
(ARCVAL X1 Y1 W1 W)))

(((VP (X,Y,Z) (V2 = 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)
 <
(VBP X X1 X2)
(VV X1 (V = Q))
(VBE X2 V1)))

(((VBP TATTEITA TATTA ITA))
(((VBP TSUNDEITA TSUNDA ITA))
(((VBP UCHIAGERARETE UCHIAGERU HARETE))
(((VBP MIENAKUNARU MIENAI HAREI)))

(((SEM F X (Y = Y1 =V) W) < (ADV Y) (FEAT Y W))
(((SEM F X (Y = Y1 =V) W) < (ADJP Y V1) (FEAT Y W))

}}
((SEMFT X Y W) < (PPTEST X Y W)))

(2) **Lexical Assertions**

(((NOUN NAGASA))
((NOUN W-2))
((NOUN ROCKET))
((NOUN NEW-MEXICO))
((NOUN SABAKU))
((NOUN KARA))
((NOUN TON))
((NOUN HOSA))
((NOUN NERIO))
((NOUN ALCOHOL))
((NOUN EKITAI))
((NOUN SASU))
((NOUN JUBAI))
((NOUN KAGAKUSHI))
((NOUN SHOGUN))
((NOUN OGE))
((NOUN USHIRO))
((NOUN NAKA))
((NOUN HONOH))
((NOUN SHINGO))
((NOUN AIRO))
((NOUN UTO))
((NOUN FEET))
((NOUN HOSHI))
((NOUN RARAY))
((NOUN MPH))
((NOUN HAYASA))
((NOUN TEISATSUKI))
((NOUN PILOT))
((NOUN HASSHA))
((NOUN CHIEN))
((NOUN TOKORO))
((NOUN SORI))
((NOUN SUBETE))
((NOUN HON))
((NOUN MILE))
((NOUN BYOH))
((NOUN NOCHI))
((NOUN HUN)))

(((ADJ OHXII (OHXII FORM ORG))))
((((ADJ KIIROI (KIIROI FORM ORG))))
((ADJ AKAI (AKAI FORM ORG))))
((ADJ KURUKU (KIIROI FORM CONT))))
((ADJ *46 (*46 FORM ORG))))
((ADJ *5 (*5 FORM ORG))))
((ADJ *3 (*3 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 WADE))))

(((POSTNP NO)) ((POSTNP KARA))))

(((VV OCHITA (OCHIRU TNS PAST))))
(((VV MITA (MIRU TNS PAST))))
(((VV OTTA (OTU TNS PAST))))
(((VV METERA (MIERU TNS PAST))))
(((VV HIITA (HIKU TNS PAST))))
(((VV AGATTA (AGARU TNS PAST))))
(((VV SUMATTA (SUMARU TNS PAST))))
(((VV MATTA (MARU TNS PAST))))
(((VV ATTA (ARU TNS PAST))))
(((VV DEKITA (DEKIRU TNS PAST))))
(((VV UCHIAGERU (UCHIAGERU TNS PRES))))
(((VV TASSURU (TASSURU TNS PRES))))
(((VV MODORU (MODORU TNS PRES))))
(((VV IATTA (TATSU TNS PAST))))
(((VV TSMUDA (TSUMU TNS PAST))))
(((VV HANAGERU (HANAGERU TNS PRES))))
(((VV TOMONAU (TOMONAU TNS PRES))))
(((VV NIENGAKU (MIERU FORM CONT MOD WEG TNS PRES)))
(((VV OIKAKETA (OIKAKERU TNS PAST)))
(((VV HANARETE (HANARERU FORM CONT TNS PAST)))
(((VV TOMONATTE (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) (ARCNAME Y1 W)))

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

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

(((FEAT OKI II SIZE))
((FEAT KIROI COLOR))
((FEAT AKAI COLOR))
((FEAT KUROI COLOR))
((FEAT SUGITE INTENS))
((FEAT TAKAI HI))
((FEAT SUKOSHI DGR))
((FEAT SUGUNI TIME))
((FEAT YUKKURI RATE))
((FEAT DANDAN DGR))
((FEAT HAYAKU RATE))
((FEAT MAGASA LGTH))
((FEAT V=2 TYPE))
((FEAT ROCKET POBJ))
((FEAT NEWMEXICO LOC))
((FEAT SARAKU LOC))
((FEAT KARA ST))
((FEAT TOP MSR))
((FEAT DOROSA LGTH))
((FEAT NENRYO POBJ))
((FEAT ALCOHOL POBJ))
((FEAT EKITAI ST))
((FEAT SAMSO POBJ))
((FEAT JUMBI POBJ))
((FEAT KAGAKUSHI HUMAN))
((FEAT SHOGUN HUMAN))
((FEAT DOTE LOC))
((FEAT USHIRO LOC))
((FEAT NAKA LOC))
((FEAT HONOH POBJ))
((FEAT SHINGO POBJ))
((FEAT AIZU POBJ))
((FEAT OTO SOUND))
((FEAT FERT MSR))
((FEAT HOSHI POBJ))
((FEAT RADAR DEV))
((FEAT MPH RATE))
((FEAT HAYASA SP))
((FEAT TEISATSUKI POBJ))
((FEAT PILOT HUMAN))
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 NI LOC (w, y1))))
 <
 (MEMPR (PREP X) Y)
 (DEPAIR (PREP X) Y Y2)
 (ADDPR (POSTP NO) Y2 Y1)))

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

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

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

(MPM (SNTRL SUB) Y)
(DEPAIR (SNTRL SUB) Y Y2)
(ADDP (SNTRL SUB) Y2 Y1))

(((AE JP AE (W . Y) (W . Y1))
  (MEMPR (SNTRL OBJ) Y)
  (DEPAIR (SNTRL OBJ) Y Y2)
  (ADDP (SNTRL OBJ) Y2 Y1))
((AE JP AE (W . Y) (W . Y1))
  (MEMPR (SNTRL SUB) Y)
  (DEPAIR (SNTRL SUB) Y Y2)
  (ADDP (SNTRL SUB) Y2 Y1)))

(((AP JP AP (W . Y) (W . Y1))
  (MEMPR (PREP X) Y)
  (DEPAIR (PREP X) Y Y2)
  (ADDP (POSTP NI) Y2 Y1)))

(((SUBST JP SUBST (W . Y) (W . Y1))
  (MEMPR (SNTRL OBJ) Y)
  (DEPAIR (SNTRL OBJ) Y Y2)
  (ADDP (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 SORI Y Y1) < (DEPAIR (NBR X) Y Y1)))
(((SOON JP SUGUNI Y Y1)))

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

(((GREAT JP OMKII Y Y1))
<
(MEMPR (*AND X) Y)
(ADDRPR (FORM CONT) Y Y1))
(((GREAT JP OOKII Y Y1) < (ADDRPR (FORM ORG) Y Y1)))

(((YELLOW JP KIROI Y Y1)
 <
(MEMPR (*AND X) Y)
(ADDRPR (FORM CONT) Y Y1))
(((YELLOW JP KIROI Y Y1) < (ADDRPR (FORM ORG) Y Y1)))

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

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

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

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

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

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

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

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

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

(((TON JP TON Y Y1)
(DEPAIR (QU (X)) Y3 Y4)
(ADDPR (M5R (W1 POSTP NO QU (X))) Y4 Y1))
((FLARE JP HONOY Y Y1)
 <
 (DEPAIR (NBR X) Y Y2)
 (DEPAIR (DET X1) Y2 Y1)))

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

(((LONG JP NAGASA Y Y1)
 <
 (MEMPR (M5R 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)))

(((WITHDRAW 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 MIKU 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)))

(((CMTFEAT ROCKET CNT1)) ((CMTFEAT FLARE CNT2)))

(((CMT1 X DAI)))

(((CMT2 ONE PON)) ((CMT2 TWO HON)) ((CMT2 THREE HON))))
Appendix C. Japanese Sentence Analysis

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

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

*(sprint (car (try st8)))

CONTINUE? *y

(S13 (SORE WA USHIRO MI *60 FEET NO KIIROI HONOH O HIITA)
     (HIKU INSTR
     (SORE POSTP WA)
     LOC
     (USHIRO POSTP MI)
     AE
     (HONOH POSTP
      0
      *SR
      (FEET POSTP NO QU (*60 FORM ORG))
      COLOR
      (KIIROI FORM ORG))
     TNS
     PAST)
NIL
NIL

#rt ime
(0.87200000 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 WA) LOC (USHIRO POSTP NI) AE
(HONOH POSTP O HSR (FEET POSTP NO QU (*60 FORM ORG)) COLOR
(KIROI FORM ORG)) TNS PAST) NIL).

*(try j)
((S13 (SORE WA USHIRO NI *60 FEET NO KIROI HONOH O HIITA) (HIKU INSTR (SORE POSTP WA) LOC (USHIRO POSTP NI) AE (HONOH POSTP O HSR (FEET POSTP NO QU (*60 FORM ORG)) COLOR (KIROI FORM ORG)) TNS PAST) NIL))

*rtime
(0.57300000 SECS)

*(sprint st9)
(S13 (SUGUNI HONOH WA KIROI HOSHI NI MIETA) X X1)
NIL
<< WE TRY TO PARSE SENTENCE 9. >>

*(sprint (car (try st9)))

CONTINUE? *Y

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

*rtime
(0.94800000 SECS)

*(setq j (car (subst x (cadar val) val)))
(S13 =X (MIERU TIME (SUGUNI) AE (HONOH POSTP WA) 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))

*runtime
(0.18300000 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)

*runtime
(0.68300000 SECS)

*(setq j (car (subst x (cadar val) val)))
(S12 -X (OCHIRU INSTR (SORE POSTP WA) LOC (TOKORO POSTP NI M
SR (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 MILE NO TOKORO NI OCHI
TA) (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))
```

*rtimetime*

```
(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 (ROUND PREP BEHIND TYPE (EAR TH NBR SING) NBR PL))) V)

*(sprint (car (try st5)))*

CONTINUE? *y

<< We can see the following features from this example. Preposition (LOC) is different here, because of TO. NOUN (noun) is a composite form in Japanese. It consists of ROUND 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)
LOC
(MOUND PREP
BEHIND
TYPE
(EARTH NBR SING)
NBR
PL))

(HANARERU AGT
(KAGAKUSA POSTP WA *AND (SHOGUN))
LOC
(TOKKUNI)
*AND
(SUWARU LOC
(USHIRO POSTP
NI
LOC
(DOTE POSTP NO))
TNS
PAST)
FORM
CONT
TNS
PAST))

*all

*runtime
(0.57100000 SECS)

*st6
(TRANSLATE (RISE AE (FLARE QU (IWO) COLOR (RED) NBR PL SNTRL
SUR) 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 + NBR ( QU ) as described
in section 3.>>
<< Preposition in Purpose is changed into POSTP NI.>>

(TRANSLATE (RISE AE
(FLARE QU
(IWO)
COLOR
(RED)
NBR
PU
SNTRL
SUB)
TNS
PASI
PU
(SIGNAL PREP
AS
DET
A
PU
(FIRE INF
TJ
TNS
PRES
AE
(ROCKET DET
THE
NBR
SING
SNTRL
OBJ))

NBR
SING))

(AGARU AE
(HONOHR "SR
(HON POSTP NO GU (TWO))
POSTP
"A
COLOR
(AKAI FORM ORG))
PU
(AIZU POSTP
NI
PU
(UCHIAGERU POSTP
TAKE
POSTP
NO
AE
(ROCKET POSTP 0))
TNS
PRES))

TNS
PAST))
NIL

astime
(0.40100000 SECS)

astb
(TRANSLATE (TRAIL LOC BEHIND INSTR (IT NBR SING SNTRL SUB) T
NS PAST SUBST (FLAME MSR (FOOT PREP OF QU (SIXTY) NBR PL) CO
LOR (YELLOW) NBR SING SNTRL OBJ)) V)

*(print (car (try astb)))

CONTINUE? *y

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

(HIKO) LOC
(USHIRO POSTP NI)
INSTR
(SORE POSTP WA)
SUBST
(HONOH POSTP

MSR
(FEET POSTP NO QU (*60 FORM ORG))
COLOR
(KIIRDI FORM ORG))
NS
PAST))

NIL
*rtime
(0.54300000 SECS)

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

*(sprint (car (try st9)))

CONTINUE? *v

(TRANSLATE (LOOK TIME
SOON
AE
(FLAME DET THE NBR SING SHTRL 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 (KIROI FORM ORG))
TNS
PAST))

WIL

*rtime
(0.22300000 SECS)

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


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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This report was typed by Diablo, using Scribe formatter.