APPLICATION OF INTENSIONAL LOGIC TO KNOWLEDGE REPRESENTATION

Tomáš Chrz

FSO Prague, Czechoslovakia

The system of transparent intensional logic (TIL) intro-
duced by Pavel Tichý is used as a framework for a description
of knowledge representation in man - machine communication.
A detailed exposition of TIL can be found in /1/.

A language expression denotes an object by expressing
its construction. The syntactic structure of the expression
reflects the structure of the corresponding construction (thus
obeying Frege's principle of compositionality). To analyze an
expression semantically means to determine the construction it
expresses. Ordinary language expressions have often more than
one analysis.

The analyses of language expressions (i.e. construct-
ions) can be represented by λ-expressions. This representat-
ional language has the same expressive power (within the frame-
work of TIL) as the natural language, but has no ambiguities.
The inference rules of TIL serve as a theoretical foundation
for the inference necessary in knowledge representation.

The infinite hierarchy of types in TIL makes it possible
to work with properties of properties or with relations between
an individual and a proposition in the same way as the first
order theories work with relations between individuals. Thus,
TIL can be considered to be a limit case of the theories of
order n.

A system for knowledge representation, based on TIL, is presently under development. Its knowledge base contains a special atom representing the system itself, and certain procedures allow the system to determine the truth-value of propositions concerning its knowledge (this can be considered as a rudimentary form of self-reflection). This feature allows the system to infer correct answers e.g. in the following conversation, where x,y are variables for individuals and p is a variable for properties; replies from the system are marked by >>>:

(1) John is a boy and Paul is a boy.   >>> Hm.
(2) Is Tom a boy? >>> I don't know.
(3) If x is a boy then you know that x is a boy.   >>> Hm.
(4) Is Tom a boy?   >>> No.
(5) x is omniscient with respect to p iff
     (if y instantiates p then x knows that y instantiates p).
     >>> Hm.
(6) With respect to which property are you omniscent?
     >>> Boyhood.

Note: Before the start of the conversation, the system is in the initial state, where basic inference rules have been programmed and grammar and a dictionary have been introduced, but no factual knowledge. The dictionary entries contain in most cases only a word, its class and the type of the object it denotes.

The self-referential capacity is one of the strong features of natural language (thus allowing the linguist to describe the object of his study). This capacity leads to the possibility of paradoxical assertions (the Liars paradox - as far as a modification for artificial intelligence is concerned, see Cherniavsky /2/, Havel /3/). In the following example, the system is ordered to believe a proposition (8), which is easily performed (9). Nevertheless, if the attempt to believe a proposition (12), although it is "known" to be true (11).

(7) Tom says that the Earth is round. >>> Hm.

(8) Believe the proposition which Tom says! >>> OK.

(9) Which property does the Earth have? >>> Roundness.

(10) Paul says that you do not believe the proposition which Paul says. >>> Hm.

(11) Is the proposition which Paul says true? >>> Yes.

(12) Believe the proposition which Paul says!
        >>> Sorry I cannot.

Note: In this example, to "believe" is interpreted in such a way that the system "believes" a proposition by actual storing its representation. Thus, the positive answer to question (11) does not imply that the system "believes" the proposition. Diverse interpretations of "believe" are possible.

The "the" in (8), (10) - (12) is interpreted locally, i.e. in the context of the knowledge base of the system. Thus, if the system knows only one of the propositions which Tom says, then this proposition is the proposition which Tom says.

The problem of analysis of language expressions (i.e. of determining the constructions expressed by them) is not the main goal of our research. Nevertheless, a restricted subset of scientific English (see sentence (5) above) has been described by a grammar, which is "almost SLR(0)". (The stack automaton accepting the language has some states with shift-reduce and/or reduce-reduce conflicts.) The analyzer gives all possible analyses of the input sentence, taking into account both the ambiguities of the syntactic structure of the sentence and the ambiguities of the individual words. The second case is illustrated by the following example:

(13) John has a ball.

(14) John has every good property which Paul has.

(15) John has a brother.

The sentences can be rephrased as

(13') John owns a ball.

(14´) John instantiates every good property which Paul
    instantiates.

(15´) There is x such that x is a brother of John.

    The word "have" in (13) and (14) denotes the objects
(i.e. relations) denoted by "own" and "instantiate" in (13´)
and (14´), respectively. (The relation in (15´) is difficult
to denote by a single word.) Thus, the analyses of sentences
(13) - (15) are:

(13*) λ w.Some λx.And [[Ball w] x] .[Own w] John x
(14*) λw.Every λp.Cond
        [And [Property p] . And [[Good w] p] . .
        [Instantiate w] Paul p].[Instantiate w] John p
(15*) λw.Some λx.[Brother w] x John

Note: The information of the different analyses of "have" has
to be stored in the dictionary. Here, to own is a relation
between individuals, to instantiate is a relation between an
individual and a property, and in (15) and (15´), a relation
between an individual and a relation is mentioned (since
brotherhood is a relation between individuals). Thus, ambigui-
ties of this sort may be resolved by examining, whether the
type of the denoted object "fits" into the types of objects
denoted by other words in the sentence.

    The system is being programmed in LISP and the current
version has some 2500 lines of source code. The quoted examp-
les (including the inference of answers (1) - (12))have been
processed by the system.

    The aim of the present paper is to demonstrate that TIL
forms a suitable framework for a description of natural lan-
guage semantics, since

1) the language of λ - expressions is sufficiently rich but
   disambiguated
2) the translation of natural language expressions into these
   "semantic representations" is relatively straightforward

3) the inference necessary in language understanding can be
   performed using the inference rules of TIL

References:

/1/ Tichý, P.: Foundations of partial type theory. Reports
    on Mathematical Logic 14
/2/ Cherniavsky, V.S.: On limitations of artificial intelli-
    gence. Information Systems, 6, 1980
/3/ Havel, I. M.: Truth-reaction paradox and limitations of
    artificial intelligence. (manuscript in preparation)