1. Introduction

Interlingual MT has typically come to include a syntactic analysis of source language (ST) text followed by its semantic interpretation and representation in terms of a text meaning representation (TMR) scheme, an interlingua. Recently two distinct views of the nature of the interlingua have become current— one based on a world model (e.g., Nirenburg et al., 1992) and another one based on the notion of lexical conceptual structure (LCS) (e.g., Dorr, 1992). In this paper we analyze the role of LCS in the extraction of text meaning and argue that, though it cannot be considered an interlingua when used by itself, it contributes significantly to the specification of an actual interlingua. The task of an interlingual MT system builder is, then, to find a way to integrate the information provided in LCS into an ontology-motivated text meaning representation serving as interlingua. In this paper, we propose a model for this integration and illustrate the processes and static knowledge sources involved, centrally including the lexicon.

In Section 2 we propose a model of MT that involves both an LCS-based lexical semantic structure and a TMR that is not based on LCS. Because our lexicon formalism does not represent LCSs, but semantic role names that serve as labels for LCS variables, we will use the abbreviation SDLs (for syntax-driven lexical semantics, Nirenburg and Levin, 1992) in reference to our system instead of LCS. We argue that TMR and SDLs are both necessary and that they are distinct. This model forms the basis of lexical-semantic treatment of texts in the multilingual MT project Mikrokosmos. In Section 3 we present specific examples as analyzed in Mikrokosmos. We illustrate the static knowledge sources (primarily the lexicon) and the representations that are produced (syntax, lexical semantics, and TMR). The Mikrokosmos model is based on a theory of form-to-meaning correspondence which relies on the concept of a society of microtheories integrated in a non-stratificational manner. We briefly sketch the main points of this theory in the final section of this paper.

2. The model

Traditionally, interlingual MT systems which employ a full-blown syntactic module (e.g., KBMT-89 (Goodman and Nirenburg, 1992) or KANT (Carbonell et al., 1992)) use a single mapping between syntactic structure and interlingua. In Mikrokosmos, we propose a different model, as illustrated in Figure 1. Lexical-conceptual structures (LCSs) have been suggested as meaning representations for natural language sentences produced in accordance with the semantic theory developed by Hale and Jackendoff (e.g., Jackendoff, 1983) and used in MT-related experiments by Dorr (Dorr, 1993). The interlinguist text (or text meaning representation, TMR) is a structure which represents meaning of texts in accordance with the ontology-oriented approach to computational semantics (see Nirenburg and Levin, 1992).

It is convenient to structure our argument for this model around the questions below (referoring to labels in Figure 1), which we will discuss one-by-one in the following sub-sections.

2.1. Are Lexical-Conceptual Structures Language-Universal?

Attempts have been made to use LCSs as interlinguas for MT (notably, Dorr, 1993). The impetus for such work is provided by observations that in many cases LCSs for translation equivalents are, in fact, identical. The many cases in which LCSs are not identical across languages pose problems for this approach. Methodologically, therefore, the type of work in LCS-as-interlingua projects is finding ways of resolving each such case, based on observing cross-linguistic divergences in realizing meanings. There is a danger that some of the divergences will prove untreatable at the LCS level and, alternatively, that solutions for some problems will necessitate changes to the nature of the representation which will make the resulting structure resemble the original LCS in progressively smaller ways. The problematic cases will be those in which translation equivalents can
have different lexical semantics. We will mention two
such cases here.

The first problem arises in the context of a complex
event, such as a merger of two companies, which can
be described by mentioning any of its parts (bids, nego-
tiations, etc.). This is particularly problematic when
different languages, by convention or for ease of expres-
sion, refer to different parts of the complex event. In fact,
such divergences exist even within one language. For ex-
ample, you can go to a meeting (directed motion), attend
a meeting (activity), or be at a meeting (state). Similarly,
while in English one takes a taxi, using a transitive verb,
the corresponding Japanese for the same event is takaisi
ni noru (get on, board, ride in a taxi), using an intransi-
tive verb with a goal argument. Even seemingly atomic
events and states can be broken down into their respectu-
also components to consist of events leading up to changes
of state that result in new states. For example, the situa-
tion of knowing something can be expressed in English
using the stative verb know or in Japanese using a non-
transitive verb suru (come to know). In its resultative form
site iru (Lit: have come to know). In examples such as
these, there will be no direct correspondence at the level
of lexical semantics in individual languages.

The second circumstance in which translation equiva-
ente have different lexical semantics is that an element of
meaning that is expressed as an argument-taking predicate
in one language might not be expressed as an argument-
taking predicate in another language. Well-known ex-
amples from MT literature include like vs. seem, venir
de vs. just, etc. However, this phenomenon is much more
widespread than normally acknowledged in the MT
literature. Things that are expressed as main or auxili-
ary verbs in English, but are not verbs at all in Japanese
include many high-frequency meaning elements such as
phase (begin, continue, finish), modality (must/should,
plan, expect, try), and evidentiality (see, appear, look
like). In fact, the syntactic means for encoding these types
of meaning vary wildly among languages, going far be-
Yond the well-known verb-adverb divergences. This is
why in the Mikrokosmos interlingua we represent such
elements of meaning as features or operators that scope
over clauses and propositions.

2.2. How is an Interlingua Different from an SDS
Output?
In the cases described above in which a single event is
described with different lexical semantics the meaning
shared by each member in the set of paraphrases makes
a better candidate for the interlingual semantic represen-
tation than does the lexical semantics; and it is this type
of meaning that we are striving to extract and represent
in the interlingua text in Mikrokosmos. Additionally, while
SDLS concentrates on the "who-did-what-to-whom" as-
ppect of text meaning, TMRs contain additional meaning
facts, such as aspect, modality, evidentiality, speech act,
reference, etc. Finally, as TMRs are not based on the
lexical semantics of one particular language, there is no
special benefit to be accrued from the imposition of the
requirement to preserve predicate-argument structures.

2.3. Universals of Semantic Role Assignment
It is very enticing to be able to apply principles of lexi-
cal mapping theory cross-linguistically. Similarities that
have been observed across languages involve linkings of
semantic roles to syntactic positions or grammatical func-
tions, transitivity alternations, and verb classes. The latter
have been described in some detail for English by B. Levin
(1993) and others. Thus, to the extent that the hypothesis
of cross-linguistic equivalence holds, the description of
similar phenomena in other languages, for the purposes
of MT, becomes much simpler, if not utterly trivial.

However, languages, as a rule, have different transi-
tivity alternations (Mitamura 1989) and even when they
have a similar transitivity alternation, the classes of verbs
to which they apply may be different. See Mahmoud
1989 for a discussion of the differences in the verbs that
undergo the causative-inchoative alternation in English
and Arabic.3 It is, of course, desirable to take advantage
of universals, but it is also necessary to have a system
that is flexible enough to accommodate cross-linguistic
variation.

2.4. Integration of SDLs into Interlingual MT
Taking a position on the necessity of both SDLs and TMRs
has to be based on a general approach to unraveling the
form-meaning correspondence. For example, to make a
TMR for John began to read we need to identify a num-
ber of meaning elements, primarily that something took
place before the time of speech, which was the begin-
ing phase of a reading event carried out by John. How
do we find these pieces of information? Time before the
time of speech is indicated by the morphology of "began".
The beginning phase is typically indicated lexically by the
verb begin in English. We know that it is the beginning
phase of reading because the syntax module tells us that
to read is the complement of begin. We know that John is
reading because John is the subject of begin (once again,
the syntactic module produced this element of informa-
tion), whose lexical properties tell us that John is also
understood as the subject of the complement clause. In
other words, it is the predicate argument structure of be-

1Incidentally, therefore verb classes are not suitable as se-
mantic hierarchies for ontology (Mitamura 1989).

2It could also be the beginning phase of a habit of reading in-
stead just one instance of reading — there is no way to determine
which in the absence of context.
cally in the TMR. The examples also illustrate the use of constructions (Fillmore et al. 1988, Fillmore and Kay 1992) as a unit of analysis alongside words, and show that treatment of MT divergences in this approach simply falls out of the general model. The languages used for illustration are English, Russian, and Japanese. Since the system is symmetrical, we do not identify which is the source language and which is the target language for all of the languages, as well as synchronic structures, semantic role assignments (SDLS), and lexical entries for each language. It should be apparent that the TMR is not necessarily isomorphic to the SDLS of any of the languages, and that sentences from different languages can correspond to the same TMR even if their syntactic and SDLS representations are not isomorphic. The Mikrokosmos TMR structure consists of clauses which roughly correspond to the "who did what to whom" component of meaning but also includes such components as speech acts, speaker attitudes, indices of the speech situation, stylistic factors as well as relations (e.g., temporal ones) among any of the above, and other elements.

The lexical entries include three zones—syntax, semantic role assignment, and mapping to TMR. (The first and third zones are discussed by Meyer et al. 1991.) The first zone specifies an LFG-style (Bresnan 1982) syntactic subcategorization frame of a predicate, including which grammatical functions (subject, object, complement, etc.) the predicate must appear with and any requirements the predicate has of those functions (case, syntactic category, specific lexical items, etc.). The second zone, also in the spirit of LFG, specifies a mapping between the syntactic functions governed by a predicate and the semantic roles it assigns. Semantic role assignment is indicated by coindexing of a syntactic slot and a semantic role slot. The semantic role names used in the examples are simply labels for argument positions in lexical conceptual structures, which are not shown here. The syntax and semantic role assignment zones serve the purpose of locating the important participants in the sentence. For example, they might tell us that the experiencer argument is in the subject slot with dative case, or that the phrase functioning as the theme argument is found in the object position. They are also important in capturing both language-specific generalizations about verb clauses and universals of semantic role assignment. For these reasons, the syntax and semantic role zones are crucial, and therefore must be included even in cases in which they differ drastically from the TMR.

The third zone of the lexical entry specifies portion of TMR that is associated with a lexical item and how the components of the TMR correspond to the components of the syntactic and semantic role zones. We have chosen examples in which the TMR is not isomorphic to the syntactic and lexical semantic zones. In most of the examples, a lexical item specifies that one of its complements leads the associated TMR. In these cases, the syntactic head of the sentence corresponds to some kind of scope-taking operator or a simple feature-value pair in TMR.

The examples, incidentally illustrate our treatment of MT divergences—situations in which a source language sentence and its target language translation differ significantly in syntactic structure, syntactic category, or predicate-argument structure. No special mechanisms need to treat MT divergences in our model. All that is needed in order to translate a sentence involving a divergence are source and target language lexical entries of the sort illustrated here that map different syntactic structures onto the same TMR. The representations and mechanisms shown in the lexical entries are motivated for non-divergent examples and do not have to be modified to deal with divergent examples. This is because source and target language sentences are not normally expected to be isomorphic to the TMR or to each other.

Another important feature of our model is that it considers constructions to be basic lexical units along with words. Following Fillmore et al., 1988, we define constructions as (possibly, discontinuous) syntactic structure or productive syntactic pattern whose meaning it is often impossible to derive solely based on the meanings of its components. In other words, a construction is a combination of a syntactic structure and the associated semantic and pragmatic representations which, once detected, do not have to be compositionally produced by a TMR extractor. Constructions are typically ways of expressing a meaning that are conventional in the sense that they are frozen, and not synchronically derivable from general principles, even if they once were. Note that a formalism such as the HPSG-like sign or the dictionary structure of the ACQUILEX project can be made to support such an idea, as Fillmore and Kay (1992) show.

4. Lexical Semantics in an Overall Theory of Form-Meaning Correspondence

The Mikrokosmos project is based on a theory of form-meaning correspondence, whose underlying assumptions can be stated as follows:

- Meanings are extracted from texts on the basis of all and any available clues (e.g., syntactic, morphological, and lexical properties of an utterance). The extraction of meaning consists of constructing the most plausible, though usually defeasible, hypothesis that is compatible with the evidence, making it an abductive process (Hobbs, 1991).
- The processing of clues in Mikrokosmos is grouped into microtheories for elements of meaning such as predicate-argument relations, aspect, temporal relations, modality, evidentiality, etc. Each microtheory specifies the ways to construct TMRs for some aspect of meaning by identifying the various syntactic, morphological, and lexical clues for that element of meaning in individual languages.
- In integrating the microtheories, Mikrokosmos rejects the pure stratificational approach shared by such otherwise diverse models as AI NLP semantics (e.g., Hirst, 1987) or Mel'čuk's MTM (e.g., Mel'čuk, 1981). Knowledge from all kinds of areas coexists in the same roles for the determination of meaning units.
- The clues (pieces of evidence) for an element of meaning can interact in complex ways. Clues can reinforce or contradict each other. Coercion is possible in situations in which the clues conflict. Interpretation of a clue can be dependent on which other clues are present.
Figure 3. Speech Act

English | Japanese
--- | ---
*Can you buy me a book?* | *morau (receive)*
*Hon o katte moraen asen ka?* | *monaus (receive)*

**TMR**

| Clause | Subject | Complement | Predicate | Mood | Tense | Subject | Object |
| --- | --- | --- | --- | --- | --- | --- | --- |
| buy-1 | you | book-1 | buy | potential | non-past | speaker | book (book) |

**Semantic Role Assignment**

| Can | Buy | morau | recei | speak | hea |
| --- | --- | --- | --- | --- | --- |
| buy | buy | buy | buy | buy | buy |
| you | subject | object | subject | subject | subject |
| book | object | object | object | object | object |

**Lexicon: Syntactic Structure**

| Can | Buy | morau |
| --- | --- | --- |
| can | buy | buy |
| subject | subject | subject |
| complement | complement | complement |

**Lexicon: Semantic Role Assignment**

| CAN | Buy | morau |
| --- | --- | --- |
| proposition | agent | source |
| buy | beneficiary | favor |
| book | theme | favor |

**Lexicon: Mapping to TMR**

| CAN | Buy | morau |
| --- | --- | --- |
| clause | clause | clause |
| [3] | [4] | [5] |
| head: meaning-of (2) | head: BUY agent: meaning-of (11) | head: [G] head: meaning-of (14) |
| type: request-action | type: request-action | type: request-action |
| scope: [3] | scope: [3] | scope: [3] |
| speaker: speaker* | speaker: speaker* | speaker: speaker* |
| hearer: hearer* | hearer: hearer* | hearer: hearer* |
| relation | relation | relation |
| [5] | [6] | [7] |
| type: temporal-before from: time-of-speech to: time-of (5) | type: temporal-before from: time-of-speech to: time-of (5) |

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1. When a reference is made to an entire event, the phase is none of begin, end or continue.
2. This lexical entry is for the construction "Can you X", which we take to be a conventional way of making a request. There are other lexical entries for other senses of can.
3. Note that this relation (that the beneficiary will possess the book) is not explicit in the SDLS, but is part of the default meaning of the sentence. The Mikrokosmos architecture allows for this default to be overridden in contexts that contain conflicting information.
4. The constituent structure of this sentence would be mono-clausal, but the functional structure as shown here is bi-clausal. It is possible that it should even be tri-clausal depending on the analysis of the potential morpheme. See Masunoto (1992) for a discussion of these issues.
5. This entry, like the English entry for can describes a construction that is conventionally used for making requests. The verb morau (receive) has other entries as well. The potential and negative morphemes are optional in the request construction. It is important, though, that they simply soften the construction and do not take on their literal meanings (Horiguchi 1993).
**Figure 2. Phasal Verbs**

| English | Russian |
|---------|---------|
| **English:** John started to speak. | **Russian:** Dzhon zagovoril. |

| Syntactic Structure | English | Russian |
|---------------------|---------|---------|
| **PREDICATE** | start | zagovorit' |
| **SUBJECT** | John | Dzhon |
| **COMPLEMENT** | speak | |
| **SUBJECT** | John | |

| Semantic Role Assignment | START | ZAGOVORIT' |
|--------------------------|-------|------------|
| **theme:** | John | agent: Dzhon² |
| **goal:** | SPEAK | |
| **agent:** | John | |

| Lexicon: Syntactic Structure | START | SPEAK | ZAGOVORIT' |
|------------------------------|-------|-------|------------|
| **predicate:** | [0] | [0] | [0] |
| **start:** | | | |
| **subject:** | [1] | | |
| **complement:** | [2] | | |
| **phase:** | begin | | |
| **inflection:** | infinitive | | |

| Lexicon: Semantic Role Assignment | theme: | SPEAK | ZAGOVORIT' |
|-----------------------------------|--------|-------|------------|
| **[1]** | | | |
| **goal:** | | | |
| **agent:** | | | [1] |

| Lexicon: Mapping to TMR | clause | SPEAK | ZAGOVORIT' |
|-------------------------|--------|-------|------------|
| **[3]** | | | |
| **head:** | meaning-of | | |
| **aspect:** | [2] | | |
| | phase: begin | | |

| clause | SPEAK | ZAGOVORIT' |
|--------|-------|------------|
| **[2]** | | |
| **head:** | *SPEAK | |
| **agent:** | meaning-of | |
| **aspect:** | [1] | |
| | phase: begin³ |

¹ OR iteration: multiple (in e.g., "John started to speak at union meetings").

² We are treating the sentence as mono-clausal, even at the level of argument structure, because the sentence "Dzhon zagovoril kazhdyj den" (John started to speak every day) does not exhibit the same ambiguity (Every day John started to speak/John started a habit of speaking every day) as the bi-clausal English sentence. If this reasoning is wrong, we can easily have a bi-clausal lexical semantic structure associated with the mono-clausal syntactic structure.

³ To the extent that morphology is productive, this entry can be derived automatically from the entry for the base form "govorit'".
### Figure 4. Modality

| Syntactic Structure | Syntactic Structure | Syntactic Structure |
|---------------------|---------------------|---------------------|
| **English**         | **Japanese**        | **Russian**         |
| **Predicate:**      | **Predicate:**      | **Predicate:**      |
| bad better          | ilt (good)          | ilt (cost)          |
| **Subject:**        | **Subject:**        | **Subject:**        |
| you                 | hoo (alternative)   | tebe (you-dative)   |
| **Complement:**     | **Rel-Clause:**     | **Complement:**     |
| you                 | ilt (go-past)       | ilt (go)            |
| **Predicate:**      | **Predicate:**      | **Predicate:**      |
| go                  | ilt (go-past)       | ilt (go)            |
| **Subject:**        | **Subject:**        | **Subject:**        |
| you                 | pronoun             | tebe                |

| Semantic Role Assignment | Semantic Role Assignment | Semantic Role Assignment |
|--------------------------|--------------------------|--------------------------|
| **English**              | **Japanese**             | **Russian**              |
| **Predicates:**          | **Predicates:**          | **Predicates:**          |
| HAD-BETTER               | HOO                      | STOTT                    |
| **Proposition:**         | **Proposition:**         | **Proposition:**         |
| Go                       | Hoo                      | POFI                     |

| Lexicon: Mapping to TMR | Lexicon: Mapping to TMR | Lexicon: Mapping to TMR |
|-------------------------|-------------------------|-------------------------|
| **English**             | **Japanese**            | **Russian**             |
| **Clause:**             | **Clause:**             | **Clause:**             |
| [3]                     | [3]                     | [3]                     |
| **Head:**               | **Head:**               | **Head:**               |
| meaning-of (12)         | meaning-of (12)         | meaning-of (12)         |
| **Attribute:**          | **Attribute:**          | **Attribute:**          |
| [4]                     | [4]                     | [4]                     |
| **Type:**               | **Type:**               | **Type:**               |
| deictic                 | deictic                 | deictic                 |
| **Value:**              | **Value:**              | **Value:**              |
| 0.8-1.0                 | 0.8-1.0                 | 0.8-1.0                 |
| **Scope:**              | **Scope:**              | **Scope:**              |
| [3]                     | [3]                     | [3]                     |
| **Attribute-to:**       | **Attribute-to:**       | **Attribute-to:**       |
| *speaker*               | *speaker*               | *speaker*               |
| **Time:**               | **Time:**               | **Time:**               |
| time-of-speech          | time-of-speech          | time-of-speech          |

1. fairly high
2. This is an entry for a specific construction involving the noun hoo. There are other entries for other uses of hoo. The constructional illustrated here is a convention expression of modality.
3. We are taking tebe to be a non-nominative subject, and the verb root to show impersonal agreement typical with non-nominative subjects. Other analyses are possible.

There are a number of paraphrases of the Russian sentence which seem to be equally conventional. For instance,

*Tebe xoresho by poji (You-Dat well counterfactual go=Inf)*

*Tebe nado by poji (You-Dat necessary counterfactual go=Inf)*

In fact, when we talk about conventionality we might have to operate with sets similar to the above instead of trying to find differences among each and every conventional way of realizing a certain meaning. This approach probably has its roots in the pioneering work of Apresjan (e.g., Apresjan, 1974).
• Mikrokosmos is amenable to working with incomplete information. If not all of the input conditions of the rules are present, some findings will still be possible. This property is important because we intend to deal with real texts, and we cannot hope that complete knowledge will be available. In the absence of specific knowledge, Mikrokosmos falls back on probabilistic and statistical devices.

• An important factor in the design of the microtheories is the identification of forms (above the lexical level) that are associated with some aspect of meaning by convention, rather than through compositional or productive rules. We follow Fillmore et al., 1988 in adopting the construction as a basic unit of analysis.

In conclusion, note how the examples in Figures 2, 3 and 4 relate to the above background assumptions of Mikrokosmos. The examples illustrate how SDLS is used as a source of clues for various microtheories, including that of lexical-semantic dependency, aspect, modality, speech acts, etc. The major finding of this paper is that TMRs are not identical to SDLS output structures, but that the latter are still necessary in that they are essential for the extraction of meaning from a text. The examples also illustrate the complex interaction of the various clues (Hornguchi 1993). For instance, the Japanese verb norma can signal a request-action speech act but only if it appears in a specific morpho-syntactic environment (nonpast, question, speaker is subject, hearer is second object). In this environment, other clues take on special meanings. For example negation and potentiality serve only to soften the assertiveness of the request. Conventionality is also illustrated in the above examples. Many of the examples illustrate constructions that are associated with semantic and pragmatic meanings by convention. We leave the issues of non-stratificationality and working with incomplete information for future papers which deal primarily with the control structure of Mikrokosmos.

Another important contribution of this paper is to suggest a framework in which MT divergences are handled using only the mechanisms that are needed for non-divergent sentences. Our theory predicts that divergences will arise because the same element of meaning in different languages will not necessarily be expressed with isomorphic syntax, morphology, and lexical items. The Mikrokosmos TMR and the set of microtheories for all the relevant languages naturally handle the so-called divergences without any additional mechanisms.

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