Space, Metaphor and Schematization in Sign:

Sign Language Translation in the ZARDOZ System

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Abstract: The sign languages used by deaf communities around the world represent a linguistic challenge that natural language researchers in A.I. have only recently begun to take up. ZARDOZ is a system which tackles the cross-modal machine-translation problem, translating speech and text into fluid sign language. This paper presents an architectural overview of Zardoz, describing its central blackboard organization and the nature of its Interlingual representation, while discussing the deep conceptual issues raised by such a system, in particular, the role of schematization or *concept chunking* in translation, the coherent allocation of spatial indices in the communication of explicitly-realised spatial descriptions, and the creative contributions to the translation process that can be made by an underlying theory of metaphor.

1. Introduction

Recent years have seen the acceptance of sign-language by the linguistics community as a fully-featured, *first-class* natural language, one that exhibits the full range of traditional linguistic phenomena, as well as a host of expressive powers unique to gestural communication. This paper describes the architecture and methodology of the ZARDOZ multilingual sign translation system, designed to translate spoken language (ostensibly English) into a variety of sign-language variants, in particular ASL (American), ISL (Irish) and JSL (Japanese). This goal of fluid articulation of sign language gestures from English language input embodies the unique linguistic challenge of *cross-modal* translation, possessing significant social, commercial and theoretical implications. For there exists a sizeable body of sign language users world-wide, for which such technology will provide valuable educational tools: the technology will not *replace,* but *empower* and educate new sign interpreters. Indeed, contrary to the perceived A.I. goal of humanizing machinery, sign translation systems are tailor-made for social situations where an obviously *non-human* translator is required, for a machine will not violate the doctor/patient and lawyer/client confidentiality expected by a signer. From a linguistic and cognitive perspective, the pursuit of cross-modal translation further challenges our preconceptions about what constitute language universals. And from a pragmatic A.I. perspective, sign-language translation is a unifying goal which provides an ideal opportunity for the synthesis of existing A.I. theories and techniques into a workable and socially-relevant application in the short term. As there exists an ever-growing body of research concerning the structural properties of sign-languages, for instance the treatment of ASL due to Liddell (1980), this paper complements this work in discussing the purely AI considerations of sign communication.

Given these pragmatic and theoretical goals, the rest of this paper assumes the following structure: section two introduces the sign language medium, which serves to place the contents of the paper in some focus. Section three then presents an overview of the system architecture of ZARDOZ, which is conceived and implemented around the blackboard control metaphor. Section four discusses the issue of *schematization* in sign-languages, that is, the mechanism by which concepts are *chunked* into manageable units, and the manner in which these chunks are manifest at the lexical/gestural level. It is surely an untendentious claim that different languages conceptualise the world in different ways (i.e., the weak Sapir-Whorf hypothesis); sign-languages tend to schematise experiential situations in ways which stress the spatial dimensions of the actions involved, and thus a sign translation system requires a deep conceptual chunking mechanism to yield natural sign generation. The issue of schematization is therefore a major point of consideration in any interlingua-based translation system. A related phenomenon is that of spatial metaphor in sign language; much of spoken language, such as English, is *localist* in nature (see Lyons 1977), structured as it is around a host of core spatial metaphors (such as the orientation metaphors of Lakoff & Johnson 1980). It should not be surprising then that sign language, which uses space not only as a conceptual medium but as an expressive canvass, should be rich in spatial metaphor. Section five presents various examples of such metaphor in Japanese Sign Language (JSL), and shows how an existing model of metaphor analysis—the *Conceptual Scaffolding* model of Veale & Keane (1992a,b)—is directly applicable to the phenomenon. Spatial metaphor is shown to be a highly regular and productive facet of sign language which proves useful in the generation of new signs, a form *of gestural catachresis,* to remedy gaps in the system's sign repertoire. Space, and it's cognitive role in sign thought, would thus seem to be the unifying theme of this paper. Section six then discusses more pressing issues of spatial awareness in sign, such as the systematic allocation of spatial indices in multi-entity situations.

2. Sign Language as a Communication Medium

There is a strong tendency among the speaking community to trivialise the capacity of sign as a full communication medium. It is not an uncommon assumption that sign language, being iconic in nature, is a universal language shared by the deaf communities of the world. It therefore comes as no small shock to holders of this view that variants of sign language differ widely from country to country, and that nations which ostensibly share the same language (e.g., English in the cases of Britain, Ireland and America) do not necessarily employ the same form of sign (e.g., BSL, ISL and ASL respectively). These assumptions derive from two common misconceptions: firstly, that sign language is primarily iconic in nature, and secondly, that sign language is a gesturally-coded form of spoken language. Certainly iconicity plays a stronger role in sign language than sound symbolism does in spoken language, but as with any full language there exists a strong tendency to move from iconicity to arbitrariness (see Klima & Bellugi 1979). And while sign language can often be employed as mere gestural *coding* of a spoken language, *native* sign language possesses a syntax which is independent of any spoken language.

However, the difficulty in specifying and storing sign gestures, as opposed to lexemes, severely limits the range of lexical resources available within the medium. It follows that the consensus core of a sign language (the body of signs known to most users) is considerably smaller than that of a language such as English (as defined by the O.E.D., say), and thus sign language is often seen to be lexically (though not expressively) *impoverished.* It is thus necessary for a sign generator to exhibit some degree of creativity in assigning concept-to-sign correspondences. Metaphor-based measures for assigning such correspondences *on-the-fly* are discussed in Section five.

Notational Conventions: At this juncture it is perhaps useful to introduce the notation employed throughout this paper to distinguish words, concepts and signs. A lexeme is always used in quotation marks, while the underlying, language-independent concept is fully capitalised. Thus, "Headache" denotes the English word "headache" while HEADACHE denotes the interlingual token corresponding to the lexeme. Signs, being symbolic frame names for the purposes of the system, are also capitalised, but are additionally qualified by a particular sign variant identifier. The token ASL-HEADACHE thus denotes the sign token for "Headache" in ASL. In addition, the notation Part::Sign indicates that Sign is made at, or with (if Part is a hand) a particular body

Part.Thus Left-Hand::ASL-MAN directs that the sign for "Man" in ASL is to be made *with* the left hand, while Elbow::ASL-HURT directs that the ASL sign for"Pain" (as "Hurt" and "Pain" are synonymous in ASL) be made *at* the elbow. And finally, because the letters of the English alphabet "A"..."Z" are represented in a sign language like ASL by distinct hand-position signs, are denoted here as ASL-A...ASL-Z for the purposes of finger-spelling.

3. System Architecture: An Overview of the ZARDOZ system

In this section we present an overview of the system architecture of ZARDOZ, a modular system organized around a central blackboard control structure (see Cunningham & Veale 1991, Veale & Cunningham 1992). This blackboard is built upon the frame-based KR-language KRELL (see Veale & Smyth 1992), which supports a generic frame format and rich demonology also suited to the representation of the concept network, the Interlingua, and language-specific lexicons. The primary knowledge agencies of the system are thus cut from the same cloth, facilitating the free flow of information and application of inference across the blackboard.

A process-oriented view of the system is illustrated in Figure 1, which presents the blackboard as compartmentalised into distinct *panels.* Task-specific knowledge agencies (composed of autonomous, write-activated demons) communicate by both reading from and writing to these panels.

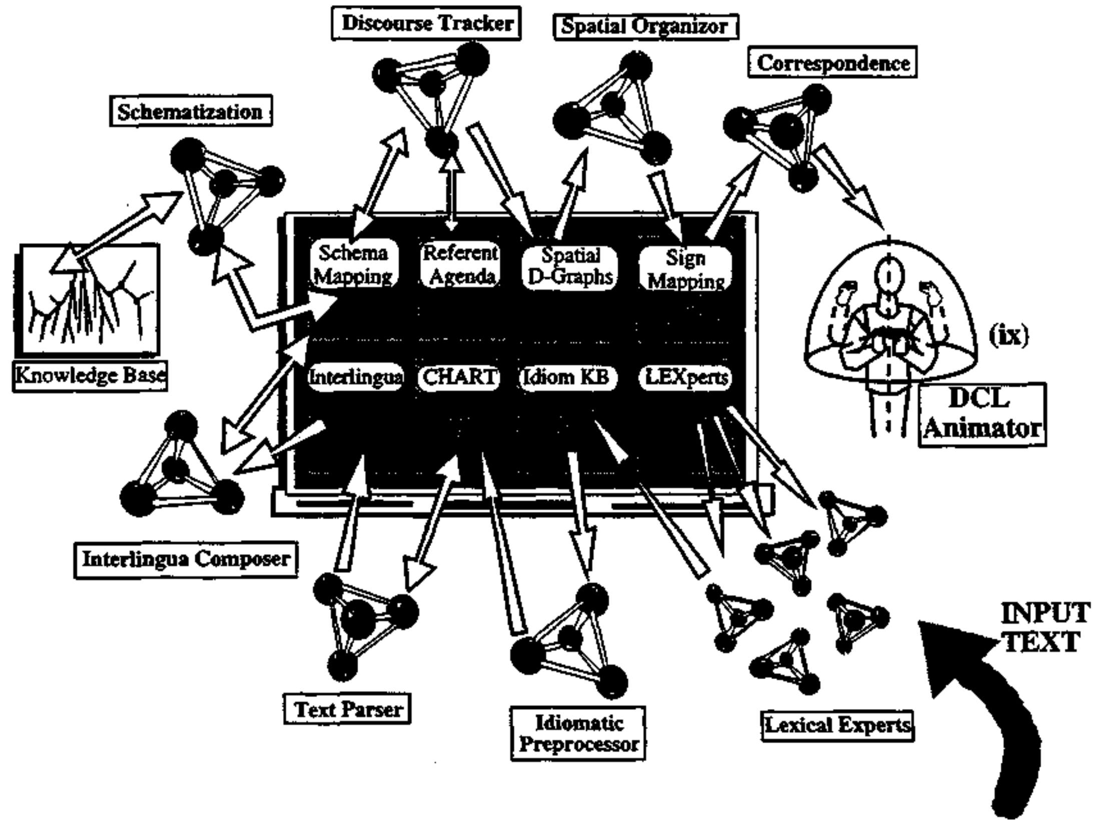

Figure 1: The ZARDOZ Blackboard Architecture: A communication medium for diverse knowledge agencies.

Taking a clockwise tour around Figure 1, system operation proceeds as follows: (i) the incoming text stream is processed by a swarm of *Lexperts*—lexical experts specified as autonomous demons—which individually implement both morphological rules and heuristic measures for recognising and representing compound word constructs (e.g., "Laptop" can be decomposed into Lap + Computer and signed accordingly, by comparison with the word "Desktop", which is known to the system as a form of computer). The digested text then undergoes (ii) *idiomatic reduction,* before it is subsequently (iii) *parsed* (the parse agency employs a unification grammar) to produce a deep syntactic/semantic representation. From the resultant unification structure a first-cut Interlingua representation is (iv) composed into an *interlingual frame* format; however, before this representation can be considered truly language-independent, metaphoric and metonymic structures specific to the source language are removed by a process of (v) *schematization* (described in the next section). The interlingua representation proper provides grist for the (vi) *discourse tracking* agency (anaphoric resolution is an issue even in translation—see sections (ix)), before being passed to the generation panels of the system, (vii) the *sign syntax* agency, which employs a robust scheme of spatial dependency graphs (see Veale & Conway 1994), and (viii) the *sign mapping* agency, which employs direct lookup or a variety of heuristic measures to assign concept-to-sign correspondences to the tokens that comprise the interlingua structure. The syntax and mapping agencies are responsible for transducing the interlingua structure into a flat output stream of sign tokens, which eventually forms the compilation basis for a Doll Control Language (DCL) program. A DCL program, when executed, manipulates an on-screen animated doll, causing the correct gesture sequence to be articulated graphically to the user by (ix) a *DCL animator* (see Conway & Veale 1994).

4. Schematization and Interlingual Representation

To ensure maximal decoupling of the input languages (e.g., English, Japanese) from the output sign variants (ISL, ASL, or JSL), ZARDOZ eschews the *Transfer* approach (originated in Yngve (1957) and more recently advocated by Lee & Kunii 1992) in favour of the *Interlingua* methodology (originated in Weaver (1955), and more recently employed by Mitamura et al 1991), which places a language-independent interface between source and target. An interlingua may capture the generic fact-stating capacity of language, broadly speaking, using two different strategies: the first attempts to construct a *universal grammar* which generalises over the syntactic forms of many languages; the second side-steps form and attempts to model the world directly. This second strategy is knowledge intensive, but allows for the natural incorporation of heterogeneous common-sense inference processes into the translation process.

The English-to-ASL translation system of Patten & Hartigan (1993) employs an interlingua closer in spirit to the first strategy above, but as ZARDOZ is built upon the foundations of the TWIG knowledge-acquisition system (see Veale & Cunningham 1992), the knowledge-based approach is our methodology of choice. The present approach therefore emphasises the representation of content over form, albeit with some concessions to surface style. In theory an ideal representation of meaning will implicitly preserve any surface style that affects the semantics of interpretation. In practice however, it is nigh impossible to separate form from content, for the expressive style of an utterance often contributes nuances of meaning which are not captured by a strictly compositional representation.

The first-cut representation of an utterance is derived compositionally from stored lexeme-to-concept correspondences. However, as different languages employ a multitude of conventional metonymies and metaphors, these are subsequently *spirited away* to achieve a truly interlingual representation. This situation is illustrated in Figure 2, which demonstrates the use of the core English metaphor POSSESSION-AS-ABSTRACT-STATE (see also Veale & Keane 1992 for a discussion of the computational treatment of metaphor). The logical form of the utterance "I have a terrible headache" suggests that the interlingua frame instantiation HAVE-0 be created, with the concepts *SPEAKER* and HEADACHE-0 filling the POSSESSOR and POSSESSION slots respectively. With a first-cut representation in hand, the system can then proceed to locate the most suitable schema set that describes the current situation. Thus, upon finding the schema SUFFER-FROM-

AILMENT, the concepts *SPEAKER* and HEADACHE-0 are subsequently remapped into the more appropriate slots SUFFERER and AILMENT.

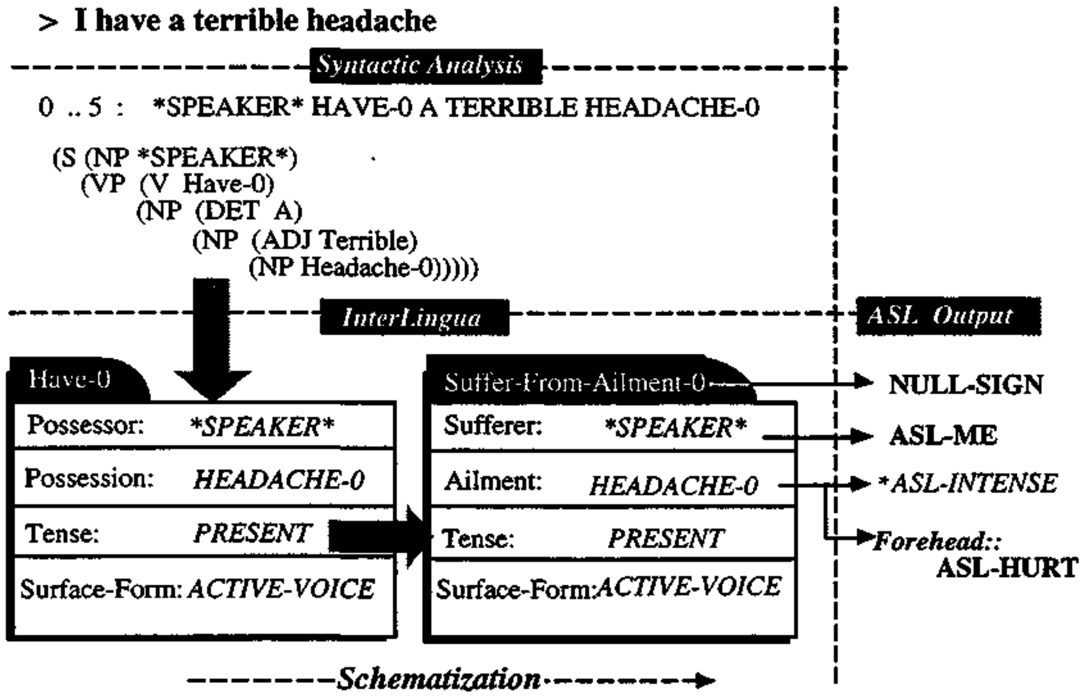

*Figure 2: Sample Syntactic and Interlingual Analysis with ASL output. ASL tokens prefixed with * are sign modifiers, rather than first-class sign gestures.*

Schematization is a *search-and-match* task which employs spreading activation to locate the most apt schema (in this case, activation is spread from the matriarch nodes HAVE, *SPEAKER* and HEADACHE). A *preference-based* case representation of each schema is then used (in the fashion of Wilks 1975) as the basis of a *frame subsumption* test to determine which marked schema most suits the situation concerned.The importance of the schematization phase is recognized when one considers that ASL supports a sign for HAVE (possession), but dictates that the sign for SUFFER-FROM be elided (thus Figure 2 shows NULL-SIGN as a translation): the metaphor simply does not travel to ASL, and must be side-stepped to produce a natural translation. Other common scenarios requiring schematization concern *polymorphic verbs* such as "Paint"; this verb is articulated in ISL as a backward and forward sweeping motion, the wrist swivelling to indicate a brushing motion but remaining fixed to suggest the use of a roller-pad, while the articulation plane of the sign reflects whether it is a wall, ceiling, floor or canvass being painted.

5. Spatial Metaphor in Sign

Spatial metaphor is frequently argued to provide a descriptive framework expressive enough to describe many of the conceptual structures underlying everyday language (see Lakoff & Johnson 1980; Veale & Keane 1992a, 1992b). Naturally, this argument is applicable not only to spoken/written language, but also to other modalities of expression, such as sign language. It should not be surprising, then, to find that sign languages, which employ space hot only as a conceptualization framework but also as an expressive medium, is steeped in highly productive and coherent spatial metaphor.

The Conceptual Scaffolding model of metaphor, proposed by Veale & Keane, is a skeletal meaning representation itself built upon spatial metaphor; the rationale for such an approach is provided by the work of Lakoff & Johnson, whic argue that conceptual structures must be experientially grounded in physical reality. This in turn follows the empiricist tradition which claims that our linguistic/conceptual map of the world is acquired via sensory experience, and is thus structured in those terms (see Lyons 1977). This would suggest that spatial metaphor, combining a physical origin with an abstract descriptive power, provides both the physical experience, and the conceptual framework, upon which to base a general model of meaning.

The Scaffolding model specifies a spatial calculus defined upon the metaphor constructors Up, Down, Connect and Disconnect, posited as cognitively-real *building blocks* of meaning, from which the semantics of many everyday concepts, both concrete and abstract, may be composed. The Up & Down constructors model the fundamental orientation metaphor, as exhibited in such conventional metaphors as "Food prices *soared",* "IBM *fell* into a *slump"* and 'The market *rose* out of a *depression",* while the Connect & Disconnect constructors similarly model the fundamental connection metaphor. The association of two ideas/concepts is seen as conceptual *connection,* while the disassociation of ideas is seen as conceptual *disconnection.* In our previous work we have demonstrated that the connection/disconnection metaphor underlies social concepts as Friendship, Marriage, Divorce, and other abstract state changes, and at a more abstract level, corporate relations such as company mergers and rivalries; we now argue that this metaphor, in conjunction with the orientation metaphor, can be highly productive in the creation of new signs.

Empirical evidence for the cognitive reality of these spatial constructors is found in Japanese Sign Language (JSL), which seems to exploit the scaffolding philosophy in a regular and coherent manner. Consider for example Figure 3, which presents a representative montage of spatial metaphor in JSL. Employing the classifier handshapes of 3(a), which are essentially a type of *semantic anaphor* or *class restriction,* the scaffolding constructors Up, Down, Connect & Disconnect are used to construct the meanings of signs 3(b)...3(n). Given a sign language which supports a rich class of classifier handshapes (and most sign languages do, such as ASL and ISL), and a system knowledge-base specified around the spatial semantics of the scaffolding model (such as that of Cunningham & Veale 1991), then signs (b)...(k) represent simple applications of this spatial knowledge, allowing ZARDOZ to dynamically create such signs on the fly if a gestural correspondence does not already exist in the target sign-language. It is a major thesis of the scaffolding philosophy that these metaphor constructors, derived as they are from shared world experience, are cognitively realised (in some form) in most cultures, and thus any dynamic creation should be readily interpretable by the end-user. We should expect then that dynamic metaphor signs should differ only in classifier handshapes between sign languages sharing a similar cultural basis, such as ISL, BSL, FSL and ASL.

For example, a sign language that provides a classifier for Company or Institution will thus support a metaphoric definition of Employee as the connection of Company and Person, effectively one who is married to the company, in the fashion of 3(b). Likewise, a corporate merger might be metaphorically articulated as the connection of two companies, whilst corporate rivalry is signed as a disconnection of companies—a corporate divorce (one is reminded of IBM and Microsoft)—in the fashion of 3(c).

More complex examples of localist meaning are depicted in 3(1)..(n), which illustrate how composite, or *aspectually inflected,* forms of the scaffolding constructors can be used to represent even more abstract concepts. As further evidence of the claim argued in Veale & Keane(1992a,b) —that the ABSTRACT STATE-CHANGE AS MOVEMENT metaphor schema can be exploited to structure a wealth of diverse verbs—Figure 3(1)..(n) demonstrate that if organized around the necessary spatial underpinnings, abstract concepts such as Tradition can be communicated as the successive concatenation of other, less abstract concepts, here the Father/Daughter metaphors of 3(f)/(g).

6. Spatial Dimensions

Space is exploited in sign language in two distinct fashions. The first, and most obvious usage of space is as an expressive medium in which to articulate different concepts — just as sound is

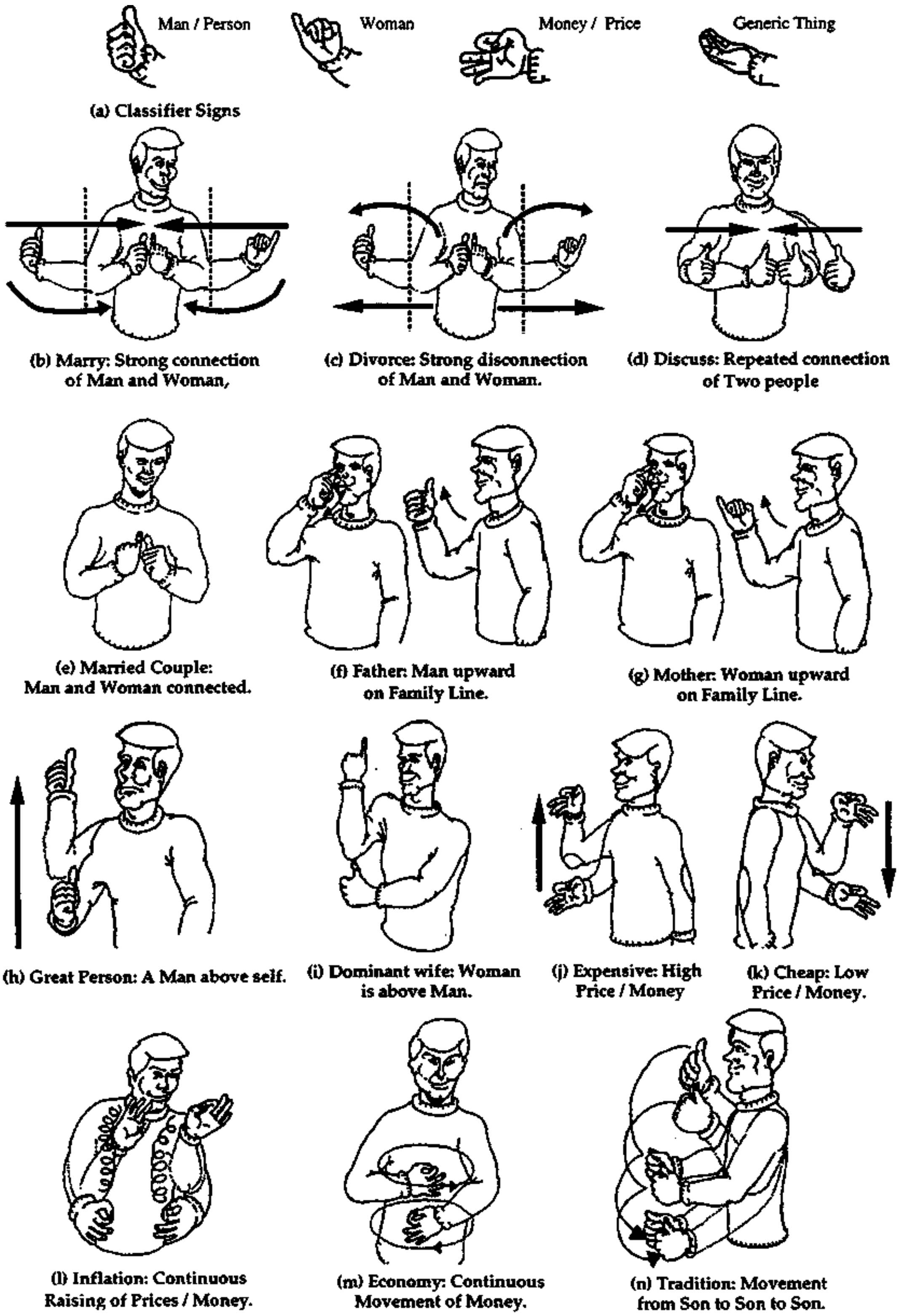

Figure 3: A montage of spatial metaphors in JSL. Part (a) presents the classifier handshapes that are coherently exploited in signs (b) ...(n).

exploited by spoken language to shape and combine phonetic structures, space lies at the phonological heart of sign language. The conventional metaphor of the time-line, for example, is often employed to convey temporal concepts such as past and future tense in spatial terms (see Klima and Bellugi 1979). Spatial nuances are also applied during articulation to express different sign inflections and aspectual modifiers (such as Continuous, Resultative, etc.), and to conflate adjectival descriptors into their associated noun gestures (for instance, a "wide road" is not articulated as two successive signs, but as one sign, "road", where the spatial interactions of the hands are *widened* to convey broadness). The second usage of space follows from the iconic or analogue qualities of sign language, in which descriptions of spatial scenarios are mirrored in a *re-constructive* fashion by the signer. Language is forever used to describe spatial relations between entities (such as "The car park is to the left of the dept. store"), but verbal languages such as English often leave much of the spatial reasoning inherent in a statement implicitly coded, placing the onus on the hearer to mentally reconstruct the spatial situation under description. Sign language, however, in its capacity to exploit the three spatial dimensions, is used to convey such spatial reasoning explicitly (for example, the signer will literally articulate CAR-PARK to the left of DEPT-STORE). From a machine translation perspective, then, natural generation of sign can be a much more complex task than that for verbal output, as a translation system must actually apply some spatial common-sense to *understand* the situation being conveyed.

Both manifestations of space are modelled in ZARDOZ using the same representational strategy, wherein sign concepts are organized around an object-oriented inheritance hierarchy which supports method attachment at different levels of sign specification. Additionally, ZARDOZ employs a representational isomorphism between frames, objects & blackboard-panels, and between demons, methods & knowledge-sources, that is, each is simply a different perspective upon the same underlying representation. The knowledge-base thus becomes its own control architecture, as the blackboard and concept hierarchy are cut from the same cloth. This allows for maximal integration of knowledge in the system, and allows for a uniform treatment of space in sign generation.

Associated with each frame in this sign-concept hierarchy are one or more DCL (Doll Control Language) code-segments, which when collectively assembled under inheritance, provide the articulatory basis for each sign gesture. These DCL segments (containing doll commands such as *HS R FLAT*—direct the right hand to assume a flat shape) may also make reference to local slot variables defined in (or inherited by) the sign-concept in question. Sign inflections are in turn modelled as method-activating messages which are passed to the sign concept under inflection, with the expectation that a local or inherited method is capable of adapting either its DCL segments, or the slot variables over which these are defined, to induce the correct articulatory behaviour. For example, the message ASL-INTENSE is mirrored at the highest point of the sign hierarchy, SIGN-CONCEPT, by a demon which telescopes the local values of the slot variables ?IN, ?OUT, ?LEFT and ?RIGHT. Provided then that a hyponymic sign, such as ASL-ACHE, makes reference to these variables in its DCL specification, this message will induce the correct gestural behaviour, i.e., the sign will be articulated with broader, more urgent, motions. Similarly, body locales may be employed in sign language as inflectional messages—when the message HEAD-LOCALE is passed to ASL-ACHE, a corresponding demon (again inherited from SIGN-CONCEPT) modifies the local value of the slot-variable ?LOCALE, thus ensuring that the sign is articulated at the forehead rather than its default stomach location. Also, the KBMS maintains a slot audit to allow these local modifications to be undone by particular demons, for example, whenever the message NORMAL is passed to a sign-concept. Until such a message is passed (for instance, if the user should explicitly state "I have just an everyday headache") the knowledge-base retains the imprint of earlier inflections (such as ASL-INTENSE), thereby acting as a form of contextual memory. Such a sign hierarchy is illustrated in Figure 4.

The second form of spatial usage in sign language—the explicit modelling of spatial assumptions—is also supported by this sign hierarchy organization. Inherited slot variables, under the auspices of dedicated spatial demons, provide a default assignment of spatial indices to the participants of a communicated scenario, say the act of looking over a wall.

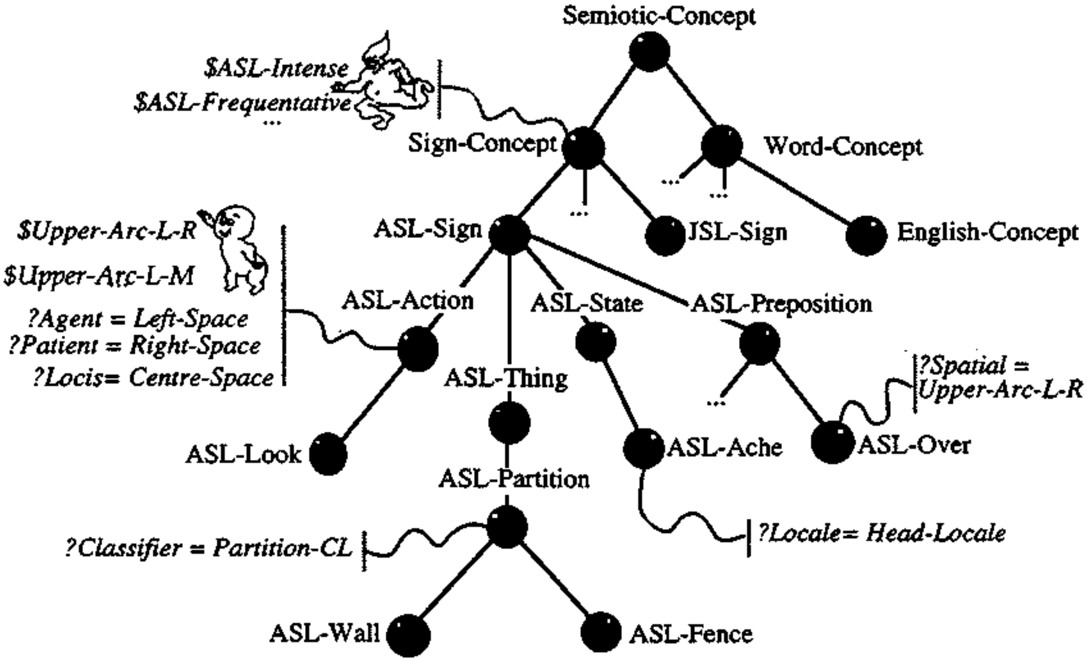

Figure 4: The ZARDOZ Concept Network and Object Hierarchy. Statements prefixed with "?" indicate local slot assignments, while tokens prefixed "$" indicate demon attachments for given message types.

Such a scenario, wherein an agent Bill uses binoculars to look over a wall and spy upon a patient, Mary, on the other side, is the basis of the Zardoz trace illustrated in Figure 5. The first form of pragmatic reasoning demanded in this context requires Zardoz to recognize that the act of looking frequently leads to the act of seeing, and thus, if Mary is the patient/observation of the latter (See-0), she is most likely the observation of the former (Look-0) also. With both participants thus bound within the same frame, they are allocated, by inheritance, the coherent spatial bindings Left-Space (for Bill, the agent) and Right-Space (for Mary, the patient) respectively. Because the concept Wall is recognized to serve the role of Locus point for the action Look-0 (and by the previous pragmatic inference, See-0 also), it receives the default spatial index Centre-Space. Thus the entities Bill, Mary and Wall are assigned spatial indices which explicitly convey the implicit spatial organization of the original English input—that Bill and Mary are on opposite sides of the wall.

It should of course be mentioned that particular reference to the central preposition of the action, Over, must also be made in deriving this assignment of indices. In this case, however, the actions of the demon $Upper-Arc-L-R, inherited by the concept ASL-LOOK and mirrored as a message specifier in the concept ASL-OVER, do nothing to alter the default assignment of indices inherited from ASL-ACTION. In contrast, however, were the sentence under analysis "Bill looked *onto* the wall and saw a squirrel with binoculars", the demon $Upper-Arc-L-M would be invoked accordingly, causing the local value of ?Patient at ASL-LOOK to become temporally set to the value Upper-Middle-Space (or more precisely, a spatial index suited to the local assignment of ?Locus). Thus, the sweeping arc of the Look gesture would terminate above the locusposition—the hand classifier for Wall, ASL-PARTITION-CL, held in Centre-Space—while the hand classifier for Squirrel, ASL-ANIMATE, is signed accordingly above this sign place-holder for Wall.

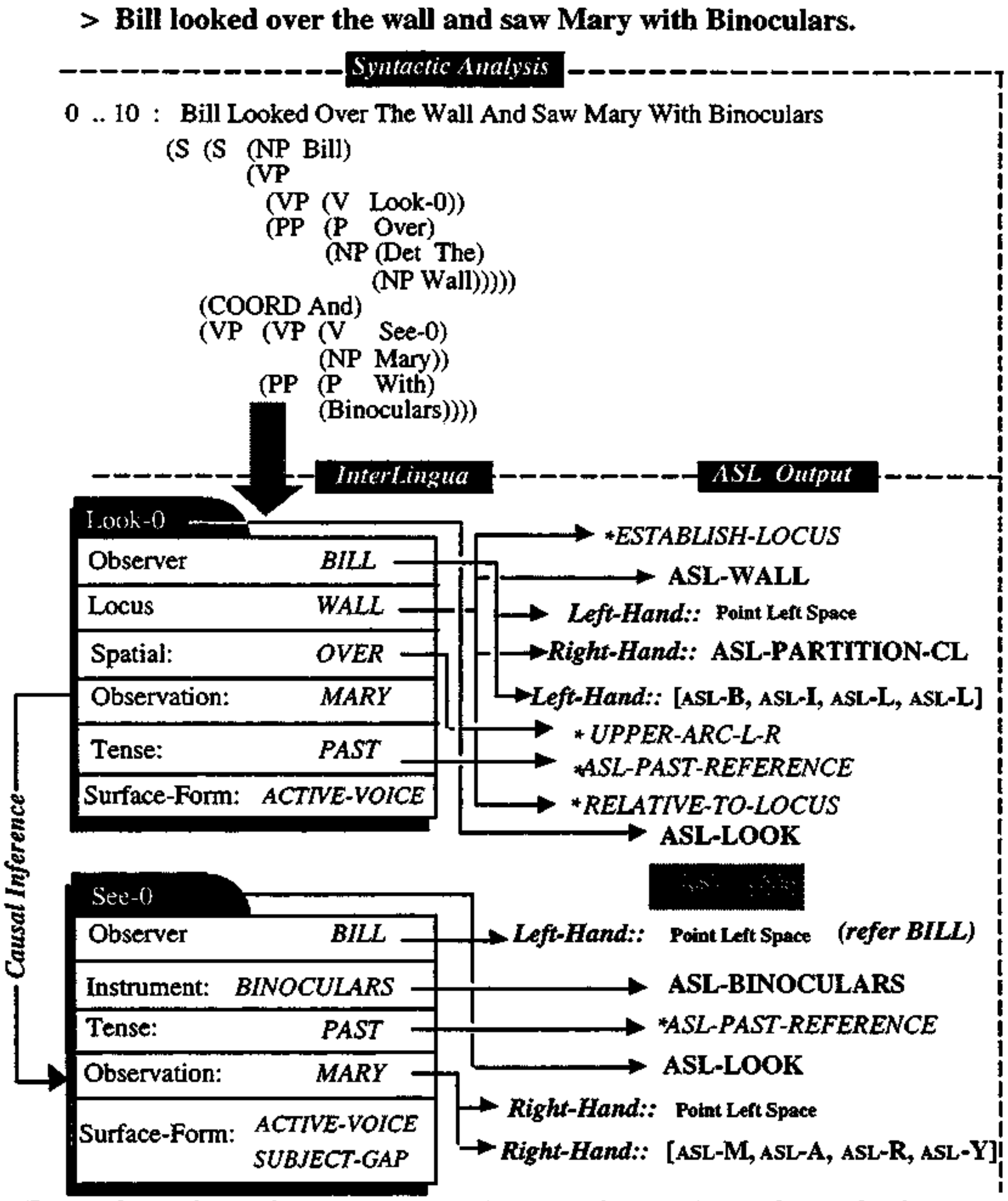

Figure 5: Analysis of a sentence requiring spatial reasoning and causal inference.

7. Summary and Conclusions

It has been a goal of this paper not only to describe the challenges of cross-modal translation, and outline how such issues may be computationally addressed, but also to convey the expressive elegance of sign language as a communication medium. The issues of translation from one language medium to another hold not only theoretical interest, but we also believe that the A.I./linguistic *technology* is mature enough to build a practical system, of considerable value to sign users, in the short term.

In general, sign language usage can take two forms: *native signing,* which employs a unique syntax of its own, and *sign coding,* which borrows the syntax of an existing language such as English. Many sign language users are comfortable with both manifestations of sign, and can freely switch from one to another. This capacity thus provides a system such as ZARDOZ with a base-line performance ability. ZARDOZ strives for full analysis of the source text, syntactically and semantically, but when such analyses are unattainable, given the working limits of the system, ZARDOZ is always in a position to produce a *coded* translation (even if this output is completely finger-spelled!).

The Interlingua methodology has been pursued for two main reasons: (a) to ensure maximal decoupling of source and target languages, as ZARDOZ is intended to possess competence is several different sign languages, and possibly even multiple input languages (Japanese is a current possibility); and (b), an interlingual stage of representation allows the system to bring common-sense inference to bear upon the translation process. This latter advantage is necessary as sign generation requires a level of understanding and spatial reasoning that is clearly outside the realm of traditional linguistic analysis, instead demanding an AI knowledge-based comprehension system. As the ZARDOZ blackboard shell, object hierarchy and demonology are all woven from the KRELL frame system, message-passing between heterogeneous agencies is supported, thereby ensuring the optimum integration of linguistic, conceptual and pragmatic knowledge.

In concluding, one should not lose sight of the multimedia potential of this cross-modal technology. A language-configurable sign translation system with gesture articulation on a graphical doll display (as described in Conway & Veale 1994) overcomes the many limitations of using spliced video footage for sign generation, and will support native sign interfaces in applications as diverse as automated information-points, tutorial systems, sign-email, sign-teletext, and any interface where gestural communication is advantageous.

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