Image Schema Decompositions of the Conceptual Dependency INGEST Primitive: A Study of Paraphrases

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Abstract
One of the hallmarks of the Schank-Minsky Conceptual Dependency Trans-Frames meaning representation system is that it attempts to express complex meanings by building large and complex conceptual structures using a relatively small number of primitives. Recently comparisons of image schemas with Conceptual Dependency primitives revealed ways of possibly reducing the number of primitives while maintaining the expressiveness of the set—an important research goal because it increases the flexibility and richness of the primitive-decomposed structures in a way that better approximates human cognition. Inspired by this prior work, we employ a paraphrase generation system to explore the replacement of the Conceptual Dependency INGEST primitive by PTRANS and CONTAIN, which are the analogs of SOURCE_PATH_GOAL and CONTAINMENT image schemas. The results of the study bring us a step closer to a possible unification of image schemas with Conceptual Dependency.

Keywords
Image Schemas, Conceptual Dependency, Natural Language Generation

1. Introduction

One of the hallmarks of the Schank-Minsky Conceptual Dependency Trans-Frames meaning representation system is that it attempts to express complex meanings by building large and complex conceptual structures using a relatively small number of primitives [1]. Recently comparisons of image schemas (IS) with Conceptual Dependency (CD) primitives [2] revealed ways of possibly reducing the number of primitives while maintaining the expressiveness of the set—an important research goal because it increases the flexibility and richness of the primitive-decomposed structures in a way that better approximates human cognition. Inspired by this prior work, we employ a paraphrase generation system to explore the replacement of the Conceptual Dependency INGEST primitive by PTRANS and CONTAIN, which are the analogs of SOURCE_PATH_GOAL and CONTAINMENT image schemas. The results of the study bring us a step

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closer to a possible unification of image schemas with Conceptual Dependency, grounding CD in cognitive linguistics and experimental psychology, and providing working cognitive artificial intelligence systems as a tool in the study of image schemas.

We first provide background on Conceptual Dependency and the Babel system that forms the basis of our paraphrase studies. This is followed by presentations of novel CD structures and paraphrases, a discussion of the results, related work, and a conclusion with ideas for the future.

2. Background and Motivation

Prior work has shown the deep connections between image schemas [3, 4] and Schank-Minsky Conceptual Dependency Trans-Frames [5, 6, 1, 7], which are theoretical structures from the symbolic artificial intelligence community which evolved through the development of AI systems for in-depth understanding of narratives presented in natural language. Work by Macbeth, Gromann and Hedblom [2] compares image schemas and Conceptual Dependency, and seeks out mappings between the schemas and primitives of the two systems. The purpose of the study herein is to explore whether, based on juxtapositions with image schemas, the INGEST conceptual primitive could be removed from the set of CD primitives, making the set more compact and increasing the richness of the mappings between the primitive decomposition structures.

2.1. Conceptual Dependency

Conceptual Dependency is a method of representing meaning that aims to reveal the conceptual structures that form the core of natural language sentences [5, 6]. It focuses on primitive actions (ACTs). It is composed of concepts and the relationships between them. The CD framework decomposes complicated language into a set of fundamental primitive elements. Optimally, primitive ACTs should have universal applicability regardless of language. In a Conceptual Dependency structure, a conceptualization contains an actor, an action, and a specific set of conceptual cases. Alternatively, it can also contain an object and a description of a state that it is in, or a state change that it has undergone.

2.1.1. Primitive ACTs

Conceptual Dependency uses 11 primitive ACTs for meaning representation. There are five primitive ACTs for physical actions. One is PROPEL, which is to "apply a force to". This ACT needs a physical object that the force applies to and a direction of the force being exerted. The second one is MOVE, which is to "move a body part". This ACT is for moving body parts only, and it requires a directive conceptual case to point the path of the body part that is moving. The third one is INGEST, which is to "take something to the inside of an animate object". This ACT is paired with a fixed directive case that is from the old position of the object to the opening of the body. The fourth one is EXPEL, which is to "take something from inside an animate object and force it out". This ACT has a direction that is the reverse of the previous one, as it is from the opening of the body to the new location of the object. The final one is GRASP, which is to "physically grasp an object".

Besides these, there are two more primitive ACTs that are aligned with the human tendency of focusing on the result of actions. One is called PTRANS, and it is to "change the location of something". Another is called ATRANS, and it is to "change some abstract relationship with respect to an object". There are also two primitive ACTs that are heavily instrumental: SPEAK and ATTEND. SPEAK is to "produce a sound" and ATTEND is to "direct a sense organ or focus organ towards a particular stimulus". Both of them are used as the instruments of other ACTs. Finally, there are two mental primitive ACTs. One is called MTRANS, which is to "transfer information". Another is called MBUILD, which is to "create or combine thoughts".

2.1.2. Conceptual Cases and States

As stated before, there are conceptual cases added to actions in Conceptual Dependency. Specifically, the conceptual cases of one action are a set of additional modifications of the action. One is OBJECTIVE, which describes the object that is acted upon. Another is DIRECTIVE, which describes the direction or location that the action is directed. RECIPIENT is the receiver of the object, also the result of the action. Lastly, the INSTRUMENTAL case is the means or tools to achieve the action. In Conceptual Dependency, we also have ways to show the "states" of objects. One state is called CONTAIN, which simply describes containment relationships between objects.

2.2. Juxtaposition of CD INGEST with Image Schemas

The definition of the INGEST primitive in CD is the action of an object or substance entering an animate object. Considering the close relationship between CD and motion, the act of going into an object (or region) can also be a SOURCE_PATH_GOAL of crossing the boundary and entering a CONTAINER, given the image schema CONTAINMENT incorporating the idea of inside, an outside, and a border that separates the two. In addition, INGEST indicates that FORCE is applied to the motion of an OBJECT, whether it is active or passive. Therefore, CD INGEST can be the mapping of three image schemas: CONTAINMENT, FORCE, and SOURCE_PATH_GOAL. Inspired by this mapping with image schemas, the study in this paper focuses on CD structures and the possibility of replacing INGEST ACTs with combinations of the CD PTRANS ACT primitive, corresponding to the SOURCE_PATH_GOAL image schema, and the CD CONTAIN primitive, corresponding to the CONTAINMENT image schema (for this paper, we will leave out the connection to FORCE).

3. The BABEL Natural Language Generator

For our study of replacing CD INGEST with PTRANS and CONTAIN, we use an automated paraphrase generation system, BABEL [8]. BABEL is a component of a natural language generation model based on Conceptual Dependency called MARGIE [MARGIE, 9]. BABEL's role within the system is generative: it receives as input a conceptualization, a language-free meaning structure, and generates a natural language sentence that expresses the conceptualization. BABEL's process can be broken down into three major subtasks. The first is to select the individual words that

AMY $\Longleftrightarrow$ INGEST $\xleftarrow{o}$ AIR	Amy breathed. Amy took a breath. Amy inhaled air.

Figure 1: Left: a CD representation of Amy taking a breath. Right: paraphrases generated by the BABEL "Paraphrase Generation from a Conceptual Base" system.

best convey the meaning of the conceptualization. The second is to connect the word selection together with English syntax relations. The final step is to then linearize the words and relations into an English sentence.

Word selection in BABEL is guided by the use of discrimination nets, or binary tree data structures that analyze a conceptualization for information units that inform the CD structure's verb sense. When a discrimination net is applied to the conceptualization, it checks if the conceptual structure contains field specifications which match the predicate given by a nonterminal node. If the conceptualization satisfies the set of defining characteristics associated with a particular verb sense, the respective verb is selected. A terminal node in the net indexes the system's conceptual lexicon for the appropriate entry, which provides the word sense as well as syntactic information that then guides BABEL's production of a syntax network.

A syntax network determines how the word selection is connected together. It is a set of nodes representing syntax relations and their values within the given conceptualization, where different relations affect different potential word orders. As with the word selection process, syntax net production centers on the verb; once a verb is chosen, the remainder of the syntactic framework becomes known. A completed syntax net is then passed to the grammar control algorithm, which applies an augmented finite state transition network (AFSTN) to the net and creates the output English sentence.

The depth and breadth of BABEL's data structures are evidence of the system's sophistication despite its age. The discrimination networks are one such data structure. The INGEST tree has a total of 15 nodes, among which there are 7 predicates, contained in nonterminal nodes, and 8 word senses, contained in terminal nodes. On the other hand, the PTRANS discrimination net tree, in which some nodes contain multiple predicates or word senses, has 40 predicates and 20 word senses among its total of 43 nodes. BABEL's AFSTN English grammar has 104 nodes.

4. Novel Decompositions and Paraphrases

For our study we chose a CD conceptualization with an INGEST ACT for someone INGESTing air or taking a breath which has been used in prior studies [10, 11]. We ran BABEL in its AND-OR paraphrasing mode, which generates every possible English realization of a CD structure that it is capable of. With significant modifications and additions to the original BABEL conceptual lexicon and AFSTN grammar, we generated sets of paraphrase sentences to evaluate the replacement of INGEST.

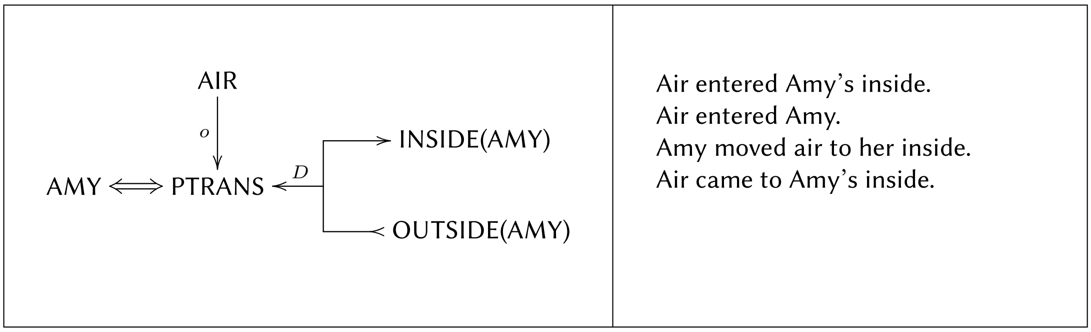


Figure 2: Left: CD representation of Amy taking a breath with the INGEST further decomposed into a PTRANS with a direction case (single arrow labeled D) indicating the start and destination of the movement. The CD PTRANS primitive corresponds to the Source_Path_Goal image schema. Right: paraphrases generated from the representation by the Babel "Sentence Paraphrasing from a Conceptual Base" system.

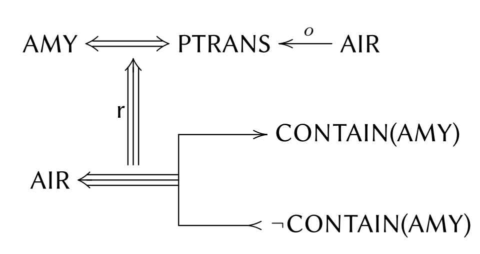
4.1. An Example of INGEST

Figure 1 is an example of a typical "original" INGEST CD conceptualization structure, an INGEST with a single object case to represent the act of breathing. The discrimination net tree structures and word senses in Babel for INGEST assume that its conceptual primitive sense has embedded within it that an object is entering the body of the animate actor. The figure also shows the paraphrases that are generated by the unmodified Babel code when given this structure.

4.2. INGEST as PTRANS with Direction Case

In our first attempt at decomposing INGEST and representing INGEST ACTs using PTRANS, we created a PTRANS ACT in which the direction case is used to indicate a change in containment relationship. Because INGEST represents an object entering or being taken into the body of the actor, the actor is treated as a container. To represent containment, we added an INSIDE predicate. We used INSIDE and OUTSIDE as destinations in the "to" and "from" conceptual case of a PTRANS ACT to indicate that the PTRANS of an object results in a change of containment relationship. Although it is not shown in the figure, in the corresponding Babel code, the INSIDE and OUTSIDE destinations also include PART designations to indicate the containing object (e.g. `TO (*INSIDE* PART(AMY1))`) which facilitated the generation of phrases such as "Amy's inside". Figure 2 shows an example of this, expressing the same concept as in the previous figure, with the "from" case for the PTRANS being the outside of the actor Amy's body, and the "to" case being Amy's inside.

We modified Babel's conceptual and linguistic knowledge structures to enable it to generate surface realizations of a conceptual structure based on this novel CD/IS representation. The use of INSIDE and OUTSIDE as "inalienable" PARTs of an animate object or of any object did not exist in the original Babel's structures, and introducing them into the CD representations required the introduction of new predicates to the list of existing predicates that are used in discrimination nets to interrogate the CD structure and determine appropriate word senses. This also required additions to the discrimination net for PTRANS to introduce new word senses.



Amy contained air by moving it to her inside.
Air became contained because it came to Amy's inside.
Entering Amy's inside caused air to become contained.
The containment of air is resulting from air entering Amy.
Coming to Amy's inside made air become contained.

Figure 3: Left: CD representation of Amy taking a breath with the INGEST further decomposed into a PTRANS with a "result" causal link (the triple arrow labeled "r") to a containment state change event. The containment state change event is the triple arrow pointing at AIR with "to" and "from" arrows indicating the begin and end CONTAIN states. The CD PTRANS primitive corresponds to the SOURCE_PATH_GOAL image schema. Right: paraphrases generated from the representation by the BABEL "Sentence Paraphrasing from a Conceptual Base" system.

For example, the word senses of "enter" and "move" that appear in the paraphrases shown in the figure were not in the original lexicon. Figure 2 also shows the paraphrases generated by BABEL with this conceptual structure.

4.3. INGEST as PTRANS with State Change

In our second attempt at decomposing and representing INGEST ACTs using PTRANS, we created a PTRANS primitive ACT which is linked to a second "state change" primitive ACT representing the creation of a containment relationship between two objects. The two ACTs are linked using a "result" causation link, which is used to indicate that the physical movement of the object resulted in the object being contained in another object. Here the PTRANS of air caused the air to be contained in Amy's body. Figure 3 shows an example of this, expressing the same concept as in the previous figures with a PTRANS act of air moving causing a state change consisting of a new containment relationship of the air within Amy's body.

We further modified BABEL's conceptual and linguistic knowledge structures to enable it to generate surface realizations of the conceptual structure in the figure. Although the early literature on Conceptual Dependency (e.g. [6]) does mention a CONTAIN predicate, it did not exist in the original BABEL structures, so we added new predicates to the list of existing predicates for the discrimination nets. This also required additions to the discrimination net for state change events to introduce new word senses for containment, for example, the verb and noun word senses of "contain" that appear in the paraphrases that were not in the original BABEL lexicon. Figure 3 also shows the paraphrases generated by BABEL with this conceptual structure.

5. Discussion

The paraphrases are meant to explore whether the decomposition of the concept in the representation is a match or is similar to the non-linguistic imagery representations and schemas that humans create. Examining the paraphrases shown in Figures 2 and 3 we find that, although these realizations are not the typical English expressions that fluent speakers would use, they generally convey the "Amy breathed" concept of the structures.

The representation of the change of a containment relationship as a separate state change ACT comes with a number of consequences. One issue is that a structure which decouples INGEST into two separate acts connected causally enables a larger number of paraphrases through the many syntactic combinations that it makes available. BABEL takes advantage of the linguistic constructions conveying causality (e.g. "... caused ...", "... because ...", "... made ...") combining every expression it can generate for each of the separate ACTs that are causally connected. Consequently, the sentences generated from this structure also tended to be larger.

One questionable aspect to the paraphrases is the exact identity of the container; the direction case structure identifies the destination of the movement as Amy's "inside", and the state change structure identifies the container as simply "Amy". Human participants in a prior study [11] reliably identified the more specific "lungs" as part of the CD representation of "Amy took a breath", and we must consider whether this more specific container should have been used here.

6. Related Work

Other important work on image schemas with Conceptual Dependency has endeavored to compare, combine, formalize, and crowdsource the two [12, 13, 11, 2, 10, 14]. The BABEL system [BABEL, 8] is part of MARGIE: the Memory, Analysis, Response Generation, and Inference in English system [MARGIE, 9] a classic demonstration of meaning representation featuring non-linguistic structures. BABEL generates natural language surface realizations of Conceptual Dependency language-free conceptual base structures [CD, 5] using an augmented transition network [15, 16]. Recently BABEL has been used to test the in-depth language understanding capabilities of deep learning [17].

7. Conclusion

This paper documents our attempts to replace the Conceptual Dependency INGEST primitive with PTRANS based on constructions inspired by SOURCE_PATH_GOAL and CONTAINMENT image schemas. We find that BABEL is a useful tool for exploring image schemas through language generation. The generated paraphrases teach us about combining and contrasting image schemas and CD primitives, and they operationalize a theoretical proposition that contrasting image schemas with CD taught us about how to improve CD or how to make it correspond more with human cognition. The paraphrase generation process provides strong evidence in favor of replacing INGEST with PTRANS.

We intend to perform similar studies on replacing CD's EXPEL primitive, which represents an dual opposite of INGEST. In future work we plan to fully embed BABEL's original INGEST and

EXPEL discrimination nets into the PTRANS net fully replacing them with PTRANS, making it into what is effectively a single discrimination net for Source_Path_Goal. Studies with human subjects similar to those in [17] will provide even stronger evidence to guide the development of these primitive decomposition systems. These are important steps toward the possible merging of image schemas and Conceptual Dependency, which could have a great many benefits both for cognitive linguistics and for cognitive artificial intelligence research.

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