Conceptual Dependency

Conceptual Dependency

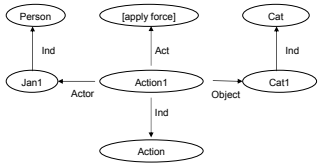
- Developed by Schank, starting in 1968.
- Tried to get as far away from language as possible, embracing canonical form, proposing an interlingua.
- Borrowed
  - from Colby and Abelson, the terminology that sentences reflected *conceptualizations*, which combine *concepts*.
  - from case theory, the idea of cases, but assigned these to underlying *concepts* rather than to linguistic units (e.g., verbs).
  - from the dependency grammar of David Hayes, idea of *dependency*.

Very Rough Idea

- Consider
  Jan hit the cat.
- First, classify the situation as of type *Action*.
- Actions have *conceptual cases*, e.g., all actions require
  Act (the particular type of action)
  Actor (the responsible party)
  Object (the thing acted upon)

Notation

- Might have just represented example as
  Action
  Act: [apply a force]
  Actor: Jan1
  Object: Cat1
- Or using some graphic notation, e.g.:



But Nooo…

- Introduced his own, rather curious notation:

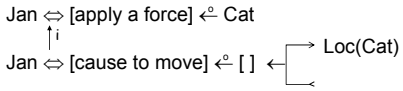
Jan ⇔ [apply a force] ⇐^{o} Cat

Comments

- Conceptual cases for a given concept are *always obligatory*.
- No claim about what gets expressed in a sentence.
- Things like [apply a force] are placeholders for now.
  - Can't use things like "hit", since those are too close to a given language.

In fact

- A more careful analysis might be



I.e., Jan applied a force to the cat by moving some object to come in contact with the cat.

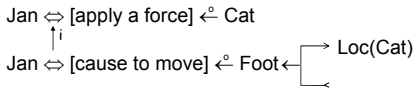
(The new arrow denotes *instrumental case*.)

Hitting, etc.

- Now consider

  Jan kicked the cat.

  A plausible representation is

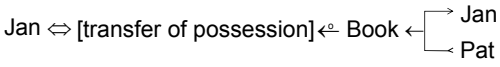


I.e., we have *decomposed* "kick" into "hit with one's foot".

Another Example

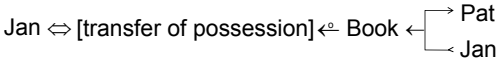
- Consider

  Jan took the book from Pat.



- Now consider

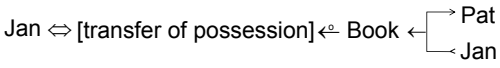
  Jan gave the book to Pat.



Example (con't)

- How about

  Pat received the book from Jan.



- Note that this is *exactly* the same as for

  Jan gave the book to Pat.

Comments

- CD is a *decompositional* approach.
  - The representation analyzes surface forms into an underlying structure, in an attempt to capture common meaning elements.
- The diagrams above are incomplete.
  - Time, modal info, etc., was provided for.
    - » But haphazardly. E.g., a "**p**" over a "⇔" indicates that the time was in the past.

Ontology

- Situations were divided into several types:
  - Actions
  - States
  - State changes
  - Causals
- (There wasn't much of an attempt to classify objects.)

States

- In general
  Object <≡> State-type(state-value)
- Example: The ball is red.
  Ball <≡> Color(Red)
- Example: Jan is 6 feet tall.
  Jan <≡> Height(6 feet)
- Example: Jan's height is 6 feet.
  - Exactly the same.

More Interesting Example

- What about: "Jan is taller than Pat." ?
- In CD:
  Jan <≡> Height(X)
  &
  Pat <≡> Height(Y)
  &
  X > Y

Many States Viewed as Points on Scales

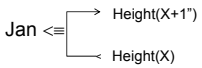
- Jan is angry.
  Jan <≡> Anger(5)
- Jan is furious.
  Jan <≡> Anger(7)
- Jan is livid.
  Jan <≡> Anger(10)
- Jan is irritated.
  Jan <≡> Anger(2)

Scales

- There are supposed to be lots of scales.
  - The numbers themselves weren't meant to be taken seriously.
  - But that lots of different terms differ only in how they refer to scales was.
- Examples:
  Jan is ill.
  Jan <≡> Health(-3)
  Jan is dead.
  Jan <≡> Health(-10)
- An interesting question is what sort of semantic objects are there to describe locations on a scale?
  - E.g., modifiers like "very", "extremely" might have an interpretation as "toward an end of a scale".

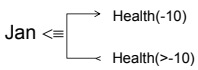
Example

- What is "Jan grew an inch."
- This is supposed to be a *state change*.
  - I.e., somewhat like an action, but with no responsible agent posited.
- Notation:



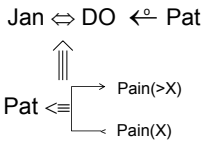
Another State Change Example

- Jan died.



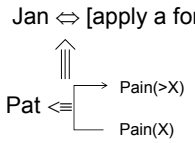
Example

- What about "Jan hurt Pat."
  (assuming the physical interpretation.)
- Intuitively, this is "Jan did something to cause Pat to become hurt."
- So:



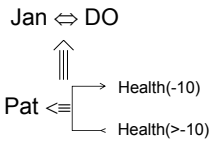
Causals

- Now if we heard
  Jan hurt Pat by hitting her.
  we would have

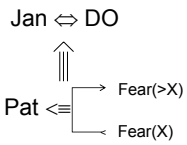


More Examples

- Jan killed Pat.

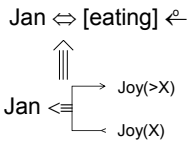


- Jan frightened Pat.



One More

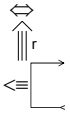
- Consider
  Jan likes ice cream.
- Proposal:



Need to add some element of habitual, tendency….

Types of Causals

- Several types of causals were distinguished, each with different constraints:
  - Actions **result** in state changes:



  - States **enable** (potential) actions:

Types of Causals (con't)

- A mental state can be the **reason** for an action:

- Anything could **initiate** a mental state:

Types of Causals (con't)

- There was a general "catch all" causal.
  - One situation and indirectly lead to another:

- Might be used in something like

  The hurricane caused by depression.

The Promissory Note

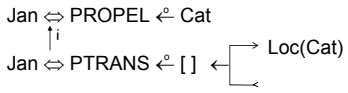
- We have decomposed lexical items into complexes of states, actions, state changes, and causals.
- We postulated some states, and some causals.
  - and state changes use the state vocabulary
- But what is the act vocabulary?
- E.g., "kick" is "hit with foot", and "hit" is "apply a force by moving", but what are "apply a force" and "move"?

Claim: Primitives

- There are some things we can't decompose any further.
- These are *conceptual primitives*.
- Schank claimed
  - we always *decompose complex concepts into primitives*.

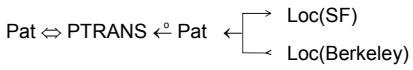
Primitives: Example

- PROPEL: "apply a force".
- PTRANS: "physical transfer"
  - i.e., for moving an object from one location to another.
- We can render "Jan hit the cat" as follows:



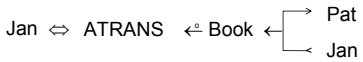
Another PTRANS Example

- Pat went to SF from Berkeley.

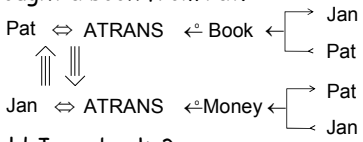


Another Primitive: ATRANS

Jan gave the book to Pat.



Jan bought a book from Pat.



Pat sold Jan a book. ?

Exactly the same.

Action Primitives

- Schank claimed that there were only a handful of primitives for *all* actions.
  - » Something like 11-14, depending on the version.

A Set of CD Primitives

- General Physical acts
  - PTRANS: physical transfer.
    - » E.g., "send" might be PTRANS an object to a location; "go" was PTRANS oneself to a location; "walk", "swim", "fly", etc., added an instrument.
  - PROPEL: apply a force.

CD Primitives (con't)

- Animate physical acts
  - MOVE: Move a body part. Generally occurs as an instrument.
    - » As, e.g., in analysis of verbs "walk" and "run".
  - INGEST: An animal moving something into its body.
    - » E.g., "eat" is INGESTing food through the mouth; "breathing" is INGESTing air into the lungs.
  - EXPEL: An animal moving a substance from its body to outside.
    - » E.g., "spit"
  - GRASP: Hold an object.
  - SPEAK: Make a sound.
    - » E.g., occurs in "talk"

CD Primitives (con't)

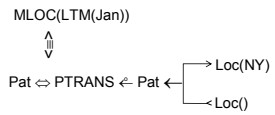
- Mental acts
  - MTRANS: Mental transfer.
    - » E.g., "inform", "communicate," "threaten", "tell", "remember", "forget", and "learn" are analyzed using MTRANS.
  - CD postulates mental states primitives as well.
    - » MLOC: mental locations generally.
    - » CP ("conscious processor"): the place where an idea is when one is thinking about it)
    - » IM ("intermediate memory")
    - » LTM ("long-term memory").
  - E.g.:
    - » (some) rememberings would be MTRANSs of a thought from one's LTM to one's CP;
    - » "tell" is MTRANSing by SPEAKing words

CD Primitives (con't)

- Mental acts (con't)
  - ATTEND: Direct a sense organ toward a percept. Usually occurs as an instrument.
  - E.g.,
    - » "listen" is glossed as MTRANSing by ATTENDing one's ear;
    - » "see" as MTRANSing (from one's eyes to one's CP) by ATTENDing one's eyes;
    - » "read" as MTRANSing by ATTENDing one's eyes to some written language.
- MBUILD: Come to a conclusion.
  - E.g., "decide" and "solve" are analyzed in terms of MBUILD.

Comment

- Recall case semantics postulated an *experiencer* case for (passive) mental events.
- In CD, these would just be objects of mental states.
- E.g., Jan in "Jan believes Pat went to NY" is just the person whose MLOC contains this proposition:



(The arrow is just the normal state arrow turned on its side.)

CD Primitives (con't)

- Social acts:
  - ATRANS: Abstract transfer
  - Others?
    - » The lack of other social actions probably should be construed not as a denial of their existence, but of a lack of clear understanding of how to represent them.

CD Pros

- Daring attempt to get away from words.
  - And so, affords at least the possibility of achieving canonical form and being an interlingua.
- Decomposition address problems in case theory by revealing underlying conceptual structure.
  - E.g., issues of "co-theme" (as in "Jan bought a book *for $5*"), and of the cases for a verb like "frighten";
  - CD resolves by postulating relations between *concepts*, not between linguistic elements.
    - » E.g., "$5" is simply the object of one of the underlying ATRANS components of buying.

CD Pros (con't)

- Paraphrase recognition is now essentially trivial.
  - E.g.:
    "Jan went to SF by BART"
    "Jan took BART to SF"
    both have exactly the same representation.
- Also, some partial paraphrase would be captured.
  - E.g., the representations for "hit" and "kick" overlap.
- This is in contrast to semantic network (and more lexically-based) approaches, in which such commonalities must be addressed by inference rules.
- Lets us account for "false alarm" results.
  - I.e., CD is the thing you remember when you have forgotten the words.

CD Pros (con't)

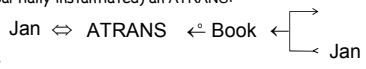
- Prospects for machine translation are improved.
  - Since representation is supposed to be an interlingua, MT is ostensibly just analysis and generation.
  - Recall that interlingua-based MT would require only a single analysis and generation program for each language, not a cross-product of language-to-language programs.
  - Of course, analysis and generation are going to be interesting here!

CD Pros (con't)

- Inference might become more managable.
- Idea was that a lot of inference would be dependent only on knowledge of particular primitives.
  - But there are only a few of these.
- E.g., for any ATRANS, we could infer
  - Prior to the ATRANS,
    - » the **donor** has the **object**
    - » And, at least normatively, the **actor** wanted the **recipient** to have the **object**
  - After the ATRANS, the **recipient** has the **object**.
- These would be in lieu of rules for each transfer-of-possession verb, i.e., buy, sell, give, take, donate.

CD Pros (con't)

- It was hoped that the structure of the conceptual level might aid parsing by generating *predictions*.
- E.g., in understanding
  "Jan gave a book to Pat."
  when the analyzer gets to "book", it can
  - choice among possible conceptual structures based on which afford a place for this sort of thing, and thus choose (and partially instantiated) an ATRANS:



- Now
  - there is a place for an animate entity (the **recipient** slot).
  - So we can put "Pat" in there when we see it.
- So maybe one could conceptually/semantically (rather than syntactically or lexically) drive the parser.

CD Pros (con't)

- Some early systems seemed promising.
  - Conceptual Analysis: I.e., mapping from English to CD.
    - » Riesbeck produced a number of such program, including ELI (English Language Interpreter).
  - Inference and Memory: Chuck Rieger build a system (MEMORY) that stored CD-represents of sentence and made inference from them.
  - Production: Neil Goldman wrote a program (Babel) that mapped CD-formulas into English.
- These systems were combined for demonstration purposed into the MARGIE system.
  - ran "paraphrase" and "inference" modes.

Problems With CD: Incompleteness

- There was no language for dealing with quantification, scoping.
  - E.g., there is no way to say in CD that the actor of every action is animate.
- No specific treatment of objects, others
- No hierarchies
  - Everything is expanded into primitives, but there is no concept per se of "running", or "buying" or "buying at a supermarket"
  - This made it very difficult to deal with sentences like these:
    - Lynn went to the circus [to a restaurant].
    - Pat took the bus to the city.
    - Jan got in touch with Lynn.
    - What happened?
- Some cheating.
  - E.g., "run" was "walk quickly", which isn't exactly right.

Problems With CD: Nature of Primitives

- There was a lot of debate whether there are such things are conceptual primitives.
- Some arguments were that
  - Primitives might be relative.
    - » E.g., MOVE to a physiologist is complex. (So primitives are atomic only in the sense that atoms are.)
  - Primitive could be made out of other primitives. E.g., PTRANS could be broken down into littler PTRANSes.
- Some object to the idea that concepts have definitions, much less that one can decompose them into primitives.

Problems With CD: Justifying the Details

- How do we know we have the right analysis?
- There are some tests that can help.
- E.g., the "but test" helps to distinguish
  - logically necessary components of meaning
  - plausible inferences
  - non-sequiturs
- The test:
  - Negate the candidate support, conjoin it to proposition with "but".
  - If the resulting sentence is
    - » a contradiction, then it is logically necessary
    - » normal, then it is a plausible inference
    - » absurd, then it is a non-sequitur

"But Test" Example

- Suppose the sentence is

  Jan hit Lynn.
- Now consider

  Jan hit Lynn but Lynn wasn't touched by anything.
  - » contradictory, so being touched is part of hitting.

  Jan hit Lynn but Lynn wasn't hurt.
  - » normal, so being hurt is a plausible inference.

  Jan hit Lynn but Lynn didn't go to SF by bus.
  - » silly, so this isn't either.

Entailment and CD

- Note that CD didn't explicitly include the logical entailments as part of the meaning if they were entailments of the primitive act.
- E.g., "hit" entails "being touched", "give" entails "recipient having".
- But these were implicit in our knowledge.

Problems With CD: Justifying the Details (con't)

- Do we have the right set of primitives?
- E.g., an alternative analysis of actions (advocated by Rumelhart, Lindsay and Norman) is "do cause state-change".
  - with no action primitives, but just states, which we have to postulate anyway.
- There were appeals to general principles (canonical form, aiding inference)
  - and CD changed a lot based on such arguments
  - but a convincing methodology never arrived.

Problems With CD: Proliferation of Non-Primitives

- Lots of non-action primitives in any analysis.
- I.e., states, objects, motions, etc. didn't seem to boil down to a very small number of primitives.
- So the reduction achieved in actions, even if you buy it, wouldn't be across the board.

Problems With CD: Need for Higher Level Concepts for Inference

- CD emphasized the importance of action primitives for inference.
- However, knowledge needed is not necessarily organized at this level.
- E.g, consider

"Jan bought a book"
  - » inf: at the store

"Jan kissed Lynn"
  - » inf: Jan likes Lynn

"Jan got a gun"
  - » inf: to threaten or shoot someone

"Bush said social security will run out of money in 2017."
  - » inf: believe based on person, etc.

Problems With CD: Semantic Parsing Didn't Pan Out

- Looking for appropriate slots to fill wasn't generally good enough.
  - E.g., consider "Jan learned Pat left town."
  - "learned" is glossed (at least here) as an MTRANS from an unspecified actor.
    - » When an analyzer sees "Pat", it will be tempted to make it the actor by slot-fitting, which is just wrong.
- As we suggested previously, lots of linguistic details are very lexically-dependent.

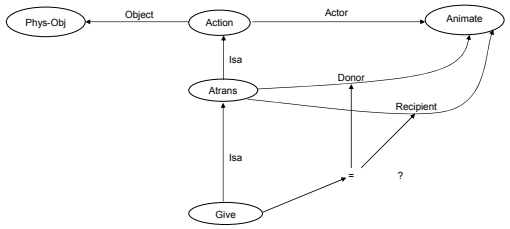
Jan forced Pat to leave.
Jan made Pat leave.
It is likely that Bush will remain in office.
It is probable that Bush will remain in office.
Bush is likely to remain in office.
*Bush is probable to remain in office.

A Possible Resolution

- Propose a hierarchy of action and other event types.
  - Make these as language-neutral as possible.
  - Inheritance captures similarities between concepts.
  - I.e., CD primitives simply become fairly high (but otherwise undistinguished) elements of the hierarchy.
- E.g., have nodes denoting only the possession senses of the English words "Give", Take", etc.
  - These might be subtypes of an ATRANS node.
- Decomposition would be "virtual".
- Is it still an interlingua?
  - Exact concepts in our network would be a function of particular languages.
  - But only to the degree that the languages really have different underlying cognitive structures.
  - Upon generation, a concept that didn't occur in another language would just be generated by a circumlocution. E.g., "He caused a transfer of possession unto himself."

Example: CD In A Semantic Network

- Trying to combine CD and semantic networks:



Example, Logically

$\forall$ e Ind(e,Action) $\rightarrow \exists$ a,o Actor(a,e) $\wedge$ Object(o,e)
$\forall$ e,a Actor(a,e) $\rightarrow$ Animate(a)
$\forall$ e,o Object(o,e) $\rightarrow$ Phys-obj(o)
…
$\forall$ e Ind(e,Atrans) $\rightarrow$ Ind(e,Action) $\wedge$
$\exists$ d,r Donor(d,e) $\wedge$ Recipient(r,e)
$\forall$ e,d Donor(d,e) $\rightarrow$ Animate(d)
$\forall$ e,r Recipient(r,e) $\rightarrow$ Animate(r)
…
$\forall$ e Ind(e,Give) $\rightarrow$ Ind(e,Atrans) $\wedge \exists$ g Giver(g,e)
$\forall$ e,g Giver(g,e) $\rightarrow$ Actor(g,e) $\wedge$ Donor(g,e)

Adding Content

- Some related facts:

$\forall$ s Ind(s,Possession) $\rightarrow$ Ind(s,State)
$\wedge \exists$ p,n,Possessor(p,s) $\wedge$ Possessed(n,s)
$\forall$ s,p Possessor(p,s) $\rightarrow$ Animate(p)
…

- Now use your favorite way to express change:

$\forall$ e Ind(e,Atrans) $\rightarrow$
$\wedge \exists$ d,r,o,p_1,p_2
Donor(d,e) $\wedge$ Recipient(r,e) $\wedge$ Object(o,e) $\wedge$
Ind(p_1,Possession) $\wedge$ Possessor(d,p_1) $\wedge$ Possessed(o,p_1) $\wedge$
Meet(End(p_1),Start(e)) $\wedge$
Ind(p_2,Possession) $\wedge$ Possessor(r,p_2) $\wedge$ Possessed(o,p_2) $\wedge$
Meet(End(e),Start(p_2))

Individual Facts and Inferences

- So "Jan gave Pat a book" becomes

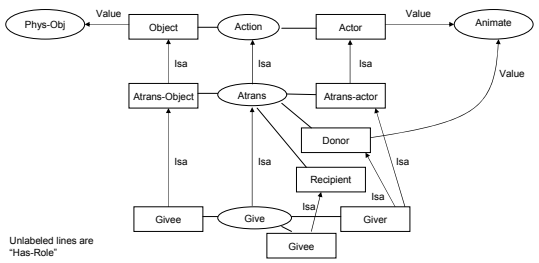
Ind(G1,Give) $\wedge$ Giver(Jan1,G1) $\wedge$ Recipient(Pat1,G1) $\wedge$
Object(Book1,G1)
…

- By (logical) inference

Ind(P1,Possession) $\wedge$ Possessor(Jan1,P1) $\wedge$
Possessed(Book1, P1) $\wedge$ Meet(End(P1),Start(G1)) $\wedge$
Ind(P2,Possession) $\wedge$ Possessor(Pat1,P2) $\wedge$
Possessed(Book1, P2) $\wedge$ Meet(End(G1),Start(P2))

Using More Sophisticated Semantic Networks

- Same example with "reified" roles:



This Has Logical Form, Too

Has-Role(Action,Actor)
Has-Role(Action,Object)
Value(Actor,Animate)
Value(Object,Phys-obj)

Isa(Atrans,Action)
Has-Role(Atrans,Atrans-actor)
Isa(Atrans-actor,Actor)
Has-Role(Atrans,Donor)
Value(Atrans-actor,Animate)
Has-Role(Atrans,Recipient)
Value(Recipient,Animate)
Has-Role(Atrans,Atrans-object)
Isa(Atrans-object,Object)

Isa(Give,Atrans)
Has-Role(Give,Giver)
Isa(Giver,Atrans-actor)
Isa(Giver,Donor)
Has-Role(Give,Givee)
Isa(Givee,Recipient)
Has-Role(Give,Given)
Isa(Given,Atrans-object)

About These Predicates

$\forall$ i,c_1,c_2 Isa(c_1,c_2) $\rightarrow$ (Ind(i,c_1) $\rightarrow$ Ind(i,c_2))
$\forall$ i,r,c Value(r,c) $\rightarrow$ (Filler(r,i) $\rightarrow$ Ind(i,c))
$\forall$ i,r,c Has-Role(c,r) $\rightarrow$
(Ind(i,c) $\rightarrow \exists$ ir Has-IRole(i,ir) $\wedge$ Ind(ir,r))

Individual Facts and Inferences

- So "Jan gave Pat a book" becomes (the somewhat more complicated):

Ind(G1,Give) ∧
Has-IRole(G1,Giver1) ∧ Filler(Giver1, Jan1)
Has-IRole(G1,Givee1) ∧ Filler(Givee1, Pat1)
Has-IRole(G1,Given1) ∧ Filler(Given1, Book1)
…

- Inference similar

Assignment

- Work with a logical-semantic network representation language.