Semantics, Conceptual Spaces and the Meeting of Minds

- M. Warglien & P. Gärdenfors – *Semantics, conceptual spaces and the meeting of minds* (2005)
- P. Gärdenfors – *Conceptual Spaces: The Geometry of Thought* (2000)

Semantics

- Language -> World
    a. Extensional: Tarskian model theory
        i. Proposition -> Truth Value
           $I(P(c))$ = true iff $c \in P = \{x_1,\ldots,x_n\}$
    b. Intensional:
        i. Proposition -> Possible Worlds -> Truth Values
           $V_w(P(c))$ = true iff $c \in P = \{x_1,\ldots,x_n\}$ in world w
    c. Problems:
        i. Does not involve language users
        ii. Does not explain how users “grasp” meanings
        iii. Requires truth function that does not adequately account for properties
            1. How can color of ink, aroma of coffee or shape of your hand be functions in this sense?
            2. Goodman’s riddle of induction (green-blue vs grue-bleen)
            3. Stalnaker’s antiessentialism argument
            4. Putnam’s cat on a mat
- Language -> Mental States
    a. “Cognitive Semantics”
        i. Psychologically motivated
        ii. “Truth” is in the mind
        iii. Examples:
            1. Stalnaker’s information states, update semantics, dynamic epistemic logic, etc.
    b. Problem:
        i. How do we explain communication?
- Language = Use
    a. Late Wittgenstein (*Philosophische Untersuchungen*)
    b. “Socio-Cognitive Semantics”
        i. Provides cognitive semantics with explanation for communication

Socio-Cognitive Semantics

- Meaning emerges from communicative interaction
    a. Communication affects the states of mind of others
    b. Meeting of mind means representations become sufficiently compatible
- Example: declarative pointing (Fig. 1, p. 6)

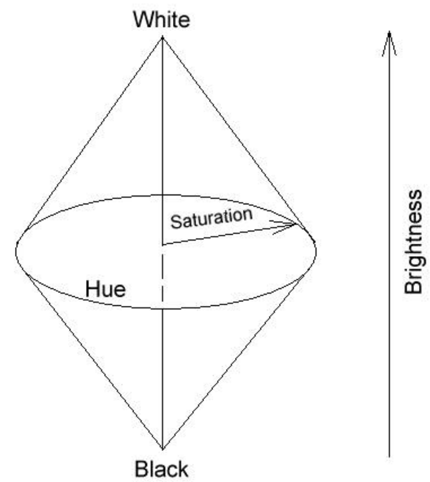
Conceptual Spaces

- Standard dichotomy:
    a. Symbolic level
    b. Sub-symbolic level (connectionism, neurons, transistors?, current, whatever)
- Gärdenfors:
    a. Three levels:
        i. Symbolic
        ii. Conceptual
        iii. Sub-conceptual
    b. Conceptual level "bridges the gap" for cognitive science
- Conceptual level = conceptual spaces

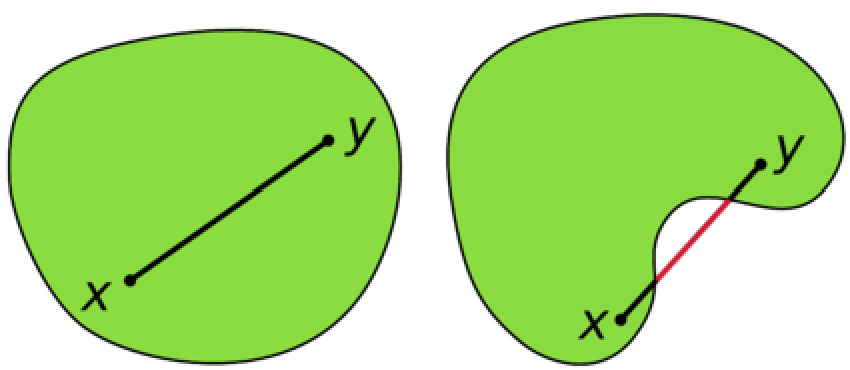
- "Inner world" is modeled with topological and geometrical structure
    a. Conceptual spaces are construed from *primitive quality dimensions*
    b. Metric: similarity
    c. Similarity measure is a continuous function of Euclidean distance in conceptual spaces
        i. (could also be non-Euclidean, but that's beside the point)
- Similarity = distance, really?
    a. Tversky's criticism:
        i. (Psychological experiments show:) Tel Aviv is more similar to New York than New York is similar to Tel Aviv
        ii. Many psychologists do not believe that "distance" in this sense is not the right similarity measure
    b. Gärdenfors' reply:
        i. Context matters:
            1. Dimensions have different salience
            2. Dimensions are weighed differently
        ii. "Perceived similar is the result of psychological processes and it is highly variable. The central process that changes perceptual similarity is attention. The perceived similarity of two objects changes with changes in selective attention to specific perceptual properties" (Smith & Heise, 1992: p. 242)

- Not necessarily <u>all</u> properties represent primitive quality dimensions: primarily *natural properties*
    a. Political-systemhood is not a dimension for democracy
        i. But what is?

- Example
    a. Color has three primitive, integral dimensions:
        i. Hue
        ii. Saturation
        iii. Brightness
- A conceptual space consists of a class $D_1, \ldots, D_n$ of quality dimensions. A point in that space is represented by a vector $v=\langle d_1,\ldots,d_n \rangle$.



- So what is a property?
    a. “We, as cognitive agents, are primarily interested in the *natural* properties—those that are natural for the *purposes* of problem-solving, planning, memorizing, communicating, and so forth.”
    b. CRITERION P: “A *natural property* is a convex region of a domain in a conceptual space” (CS, p. 71)



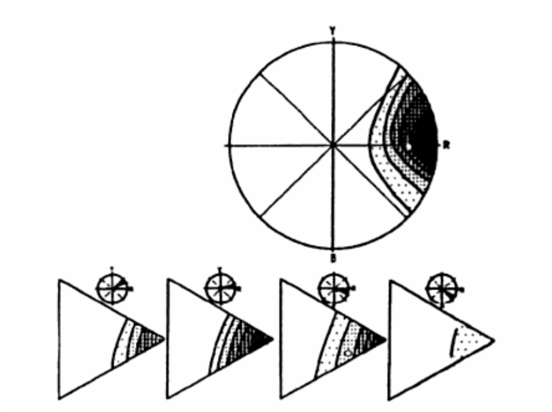


Fig. The color red.

Convexity

- Representations grounded in perception almost always convex
- Main arguments:
    a. Cognitive economy
        i. Hebb: "fire together, wire together'
        ii. Evolution
    b. Learnability
    c. (Effectiveness of) communication

Concepts

- Properties are special case of concepts:
    a. Property is based on <u>one</u> domain
    b. Concept may be based on <u>several</u> (separable) domains
- This difference in logic:
    a. Consider:
        i. The big brown dog
           $\exists x\ [dog(x) \wedge big(x) \wedge brown(x)]$ FOL
           $\exists x\ [big(brown(dog(x)))]$ HOL
    b. Adjectives/properties have one domain
    c. Nouns/concepts have several domains
    d. FOL cannot deal with this
        i. Arguably, higher-order logic could differentiate—but problematic in its own right (and what about adjective-ordering?)

- Example—<u>APPLE</u>
    a.

<u>Domain</u>	<u>Region</u>
Color	red-yellow-green
Shape	roundish (cycloid)
Texture	smooth
Taste	sweet-sour
Fruit	specs of seed structure, flesh and peel type, etc. according to "pomological principles"
Nutrition	specs of sugar content, vitamins, fibers, etc.
Weight	…
Size	…

- Weight of dimensions varies according to context:
    a. "Comparing apples and pears"
    b. "Green apples are more sour than red ones"
- CRITERION C: "A *natural concept* is represented as a set of regions in a number of domains together with an assignment of salience weights to the domains and information about how the regions in different domains are correlated"

Convexity and concepts

- "A basic tenet of cognitive semantics is that language can preserve the spatial structure of concepts"
    a. i.e., language can preserve neighborhood relations among points of conceptual spaces
        i. a neighborhood preserving function is nothing but a continuous function
        ii. So: "assuming that language can preserve neighborhood relations of conceptual spaces implies assuming that language can establish a continuous mapping between mental spaces of different individuals" (p. 12)
- But which points?
    a. Relation between convex sets (properties/concepts) and prototype theory
        (=>) In a convex set you can always calculate the center of gravity
        (<=) Given certain prototypes you can "plot" them in conceptual space and assign convex regions accordingly
    b. Voronoi Tessellations
        i. See Fig. 2 (p. 10)
    c. Delaunay Triangulation
        i. See Fig. 3 (p. 11)
    d. "This mechanism is a very central principle in connecting the continuity of mental spaces and the discreteness of language" (p. 11)

Towards a Semantics

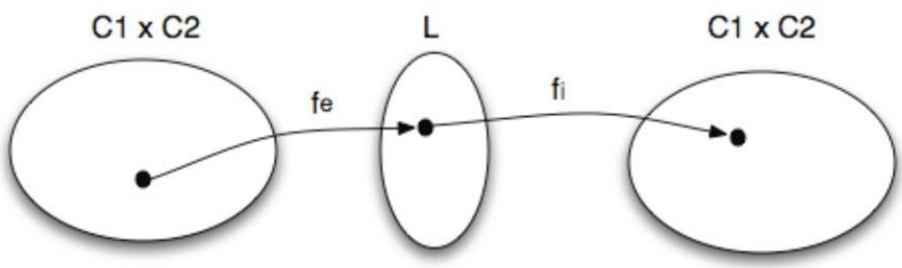
- Conceptual spaces are generally Euclidean
- Concepts are regions in conceptual space
    a. With properties:
        i. Compactness
        ii. Convexity
- Towards semantics:
    a. Language has to preserve neighborhood relations (spatial structure) between concepts
- In conceptual spaces (and topology in general) this accomplished by a continuous mapping function from C1 to C2

Fixed points & Continuity

- Communication can be described with the help of continuous "semantic reaction functions" from (x_1,x_2) to (y_1,y_2) in product space $C=C_1xC_2$
- A fixed point is now a point (x_1^*,x_2^*) where the mental spaces do not change
    a. Example fixpoint:
        i. Suppose $f(x)=x^2 - 3x + 4$, then $f(2)=2$ so 2 is a fixpoint
- Relation fixpoints and convex sets:
    a. Each continuous map of a convex, compact set on itself has at least one fixpoint
- Why continuous? See Fig. 4 (p. 13)

Mapping Mental States

- Provided we have well-shaped representations (convex, compact, with continuous mapping), we can guarantee a "meeting of minds", i.e., a fixpoint.
- But we are not telepathic
  a. Mediator of concept spaces: language
- Semantic reaction function f: C1x C2 → L →C1x C2
  a. (f_e is expression function; f_i is the interpretation function)



- In order to get fixpoints, f should be continuous
  a. But: continuous functions can be approximated
     i. Makes sense, because language (e.g. lexical resources) and other constraints seem to imply discreteness
     ii. All you need is prototypes of Voronoi decompositions
  b. Simplicial Approximation Theorem
     i. Given convex, compact sets X and Y and a continuous mapping function g: X→ Y, there is always a simplicial (discrete) map that approximates g and preserves its fixpoints

- Prototypes generate a basic triangulation of conceptual spaces, providing building blocks for a continuous map between mental spaces
- The correspondence between words and prototypes then explains how language is an effective mediator

Claims

- Well-shapedness
  a. occurs regularly in nature, especially when grounded in perception
  b. is preserved under certain operations, allowing for compositionality
  c. improves learnability and generalization
  d. provides at least one fixpoint in continuous mappings (which we have)
- Claim: concepts in the mind are well-shaped

- Advantages of Socio-Cognitive Semantics
  a. Established connection between discreteness of language and continuity of thought
  b. Takes into account mental states of all communicators
  c. Realism (i.e. world-mappings) is only really needed when something is at stake, i.e. when success depends on outcome of communication game

Compositionality

- Emerges already from conceptual spaces and well-shapedness:
  a. Let A and B be well-shaped, then:
     i. A X B is also well-shaped
     ii. Let f: $A \rightarrow B$ and g: $A \rightarrow B$ be continuous, then:
        1. Product function h = (f,g) is also continuous
        2. Composition $f_o g$ is also continuous
- Non-Fregean: not composition of meaning, but composition of domains and functions

- Issue for composition:
  a. domains of product constructions are not always independent:
     i. tall mouse and tall elephant
     ii. white wine
- Modifier-head composition
  a. achieved through radial projection:
     i. homeomorphism which, again, preserves well-shapedness
     ii. (thus, preserves neighborhood relations)
- Consider:
  a. White skin (Fig. 8, p. 24)
  b. Metaphor: Peak (Fig. 10, p. 27)
  c. Pet fish
  d. Stone lion