Knowledge Representation and Reasoning
Logics for Artificial Intelligence

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7 A Potpourri of Subdomains

Taxonomies: Categories as Intensional Sets

In mathematics, a set is defined by its members.

This is an **extensional set**.

Plato: *Man is a featherless biped.*

An **intensional** set is defined by properties.

Aristotle: *Man is a rational animal.*

A category (type, class) is an intensional set.

Taxonomies: Need for Two Relations

With sets, there's a difference between

set membership, $\in$
$5 \in \{1, 3, 5, 7, 9\}$

and subset, $\subset, \subseteq$
$\{1, 3, 5, 7, 9\} \subset \{1, 2, 3, 4, 5, 6, 7, 8, 9\}$

One difference is that subset is transitive, membership isn't.

Similarly, we need both the instance relation and the subcategory relation.

Taxonomies:
Categories as Unary Predicates

One way to represent taxonomies:

$Canary(Tweety)$

$\forall x[(Canary(x) \Rightarrow Bird(x)]$
$\forall x[(Bird(x) \Rightarrow Vertebrate(x)]$
$\forall x[(Vertebrate(x) \Rightarrow Chordate(x)]$
$\forall x[(Chordate(x) \Rightarrow Animal(x)]$

Taxonomies: Reifying

To reify: to make a thing of.
Allows discussion of "predicates" in FOL.

Membership: *Member* or *Instance* or *Isa*
$Isa(Tweety, Canary)$

Subcategory: *Subclass* or *Ako* (sometimes, even, *Isa*)
$Ako(Canary, Bird)$
$Ako(Bird, Vertebrate)$
$Ako(Vertebrate, Chordate)$
$Ako(Chordate, Animal)$

Axioms:
$\forall x \forall c_1 \forall c_2 [Isa(x, c_1) \wedge Ako(c_1, c_2) \Rightarrow Isa(x, c_2)]$
$\forall c_1 \forall c_2 \forall c_3 [Ako(c_1, c_2) \wedge Ako(c_2, c_3) \Rightarrow Ako(c_1, c_3)]$

Discussing Categories

$$Isa(Canary, Species)$$

$$Isa(Bird, Class)$$

$$Isa(Chordate, Phylum)$$

$$Isa(Animal, Kingdom)$$

$$Extinct(Dinosaur)$$

Note: That's *Isa*, not *Ako*.

If categories are predicates, requires second-order logic.

Other relationships: exhaustive subcategories, disjoint categories, partitions.

DAG (directed acyclic graph), rather than just a tree.
E.g., human: man vs. woman; child vs. adult vs. senior.

Transitive Closure

It's sometimes useful (especially in Prolog)
to have a second relation, R_2
be the transitive closure of a relation, R_1.

E.g. *ancestor* is the transitive closure of *parent*:

$\forall x, y[parent(x, y) \Rightarrow ancestor(x, y)]$

$\forall x, y, z[parent(x, y) \wedge ancestor(y, z) \Rightarrow ancestor(x, z)]$

7.2 Time

How would you represent time?

Discuss

Subjective *vs.* Objective: Subjective

Make now an individual in the domain.

Include other times relative to now.

OK if time doesn't move.

Subjective *vs.* Objective: Objective

Make `now` a meta-logical variable with some time-denoting term as value.

Relate times to each other, *e.g.* $Before(t1, t2)$.

Now can move by giving `now` a new value.

Points *vs.* Intervals: Points

Use numbers: integers, rationals, reals?

Computer reals aren't really dense.

How to assign numbers to times?

Granularity: How big, numerically, is a day, or any other interval of time?

If an interval is defined as a pair of points, which interval is the midpoint in, if one interval immediately follows another?

Points *vs.* Intervals: Intervals

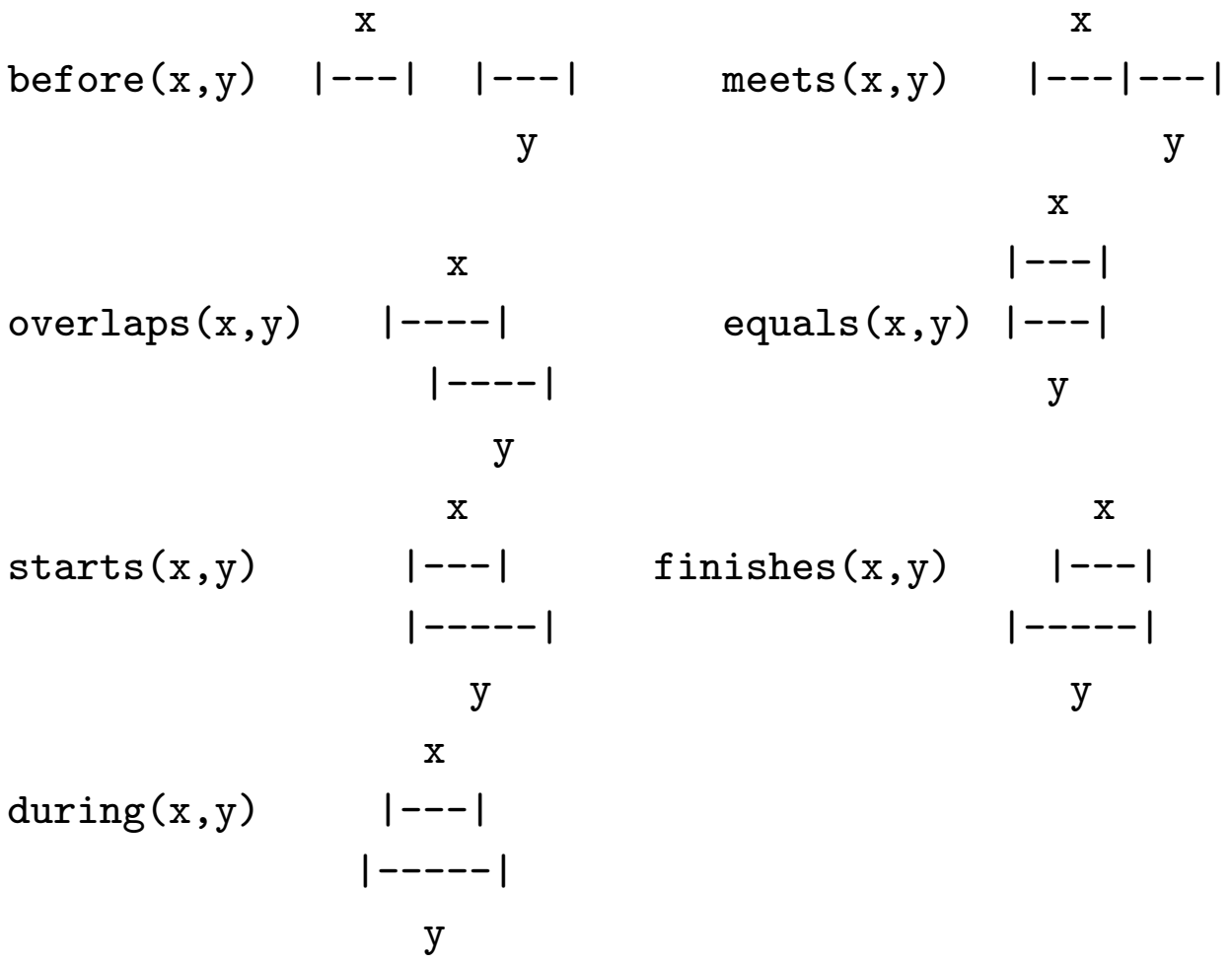
Use intervals only: no points at all.

More cognitively accurate.

Granularity is not fixed.

A "point" is just an interval with nothing inside it.

James Allen's Interval Relations



A Smaller Set of Temporal Relations

If fewer distinctions are needed, one may use

$before(x, y)$ for Allen's $before(x, y) \vee meets(x, y)$

$during(x, y)$ for Allen's $starts(x, y) \vee during(x, y) \vee finishes(x, y)$

$overlaps(x, y)$ and $equals(x, y)$

and appropriate converses.

7.3 Things *vs.* Substances
Count Nouns *vs.* Mass Nouns

A count noun denotes a thing.
Count nouns can be singular or plural.
Things can be counted.
One dog. Two dogs.

A mass noun denotes a substance.
Mass nouns can only be singular.
One can have a quantity of a substance.
A glass of water. A pint of ice cream.

A Quantity of a Substance is a Thing

water a substance

a lake = a body of water a thing

lakes a plurality of things

40 acres of lakes a quantity of a substance

Nouns with mass and count senses

A noun might have both senses.

a piece of pie vs. *A piece of a pie*

two pieces of steak vs. *two steaks*

Any count noun can be "massified".
Any thing can be put through "the universal grinder".
I can't get up; I've got cat on my lap.