

# Knowledge Representation and Reasoning

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# Knowledge Representation

- Encoding real world knowledge in a formalism that allows us to access it and reason with it

# Some distinct types of individuals

- Discrete objects
  - Cut them up and you get something different
  - Cars, people
- Substances
  - Cut them up and you get more of the same
  - Water, sand
- Mobs
  - Like substance, but worth individuating particular elements
  - Mountains in a range, feathers on a bird
- Events
  - Something happening over time with substructure
- Processes
  - Something happening over time that is internally uniform

# Entities

- are physical objects, substances, places... things that *are*
- are things we usually express with nouns
- can have other Entities as parts, material, content
- can participate in Events

*Container, Barrier, Connector, Water, Air, Place, ...*

*Airplane, Human, Society, Viral Nucleic Acid, ...*

# Entities: Objects and Substances

- *Objects* are tangible entities which might have parts, such as desks, cars, and people.
- *Substances* are tangible entities which might have portions, such as water, wood, tissue.
- Commonly used relationships
  - Car *has-parts* (Engine, Transmission, Chassis)
  - Car *material* (Steel, Plastic, Paint)

# Collections (classes, sets)

- Collections approximate categories
  - Dog is the collection of all dogs
  - The following are equivalent
    - (Dog Dog32)
    - (member Dog32 Dog)
    - (isa Dog32 Dog)
- Comparison with psychological notion of category
  - Typically no compact definition
  - Organized via taxonomic relationships
  - But no similarity effects, recognition criteria, exemplar-driven effects

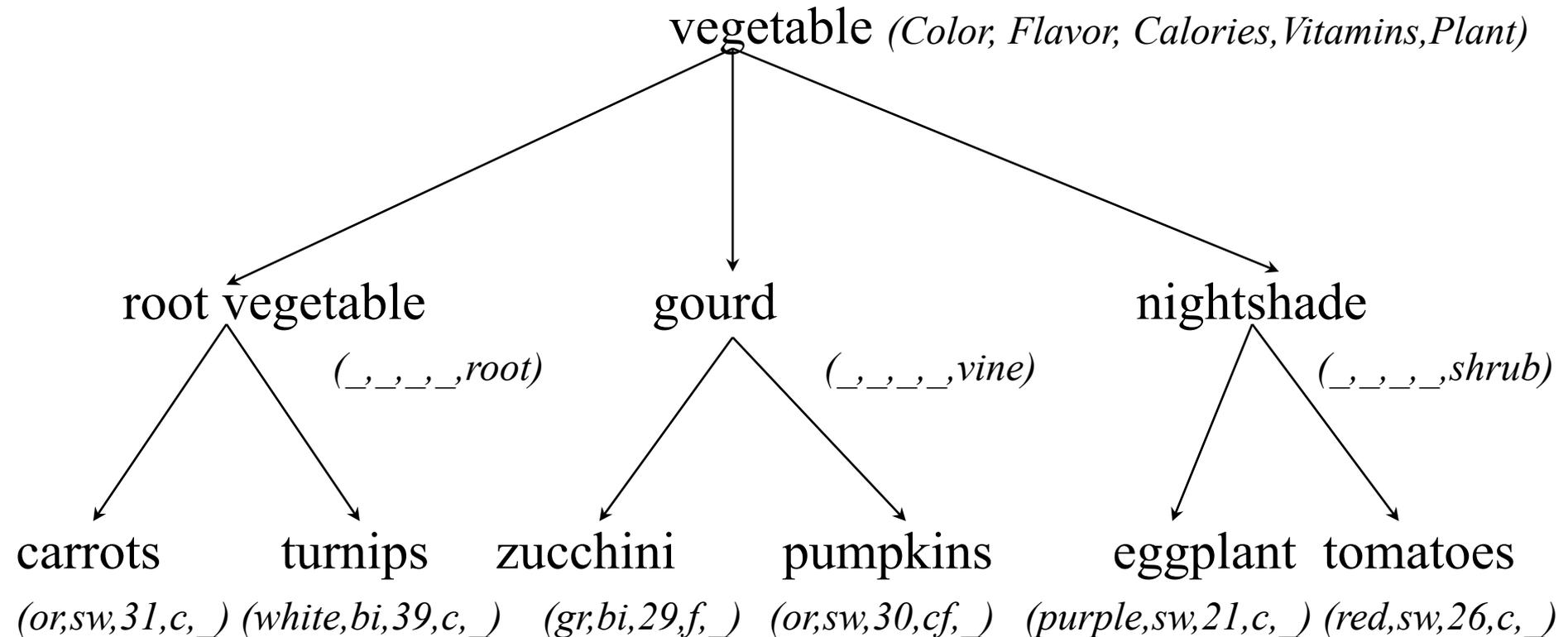
# Inheritance from collections better implementation

- Collection membership supports inference  
color(gray,elephant).  
part\_of(trunk,elephant).

isa(Entity, Type)  $\wedge$  color(Color, Type)  
→ color(Color,Entity)

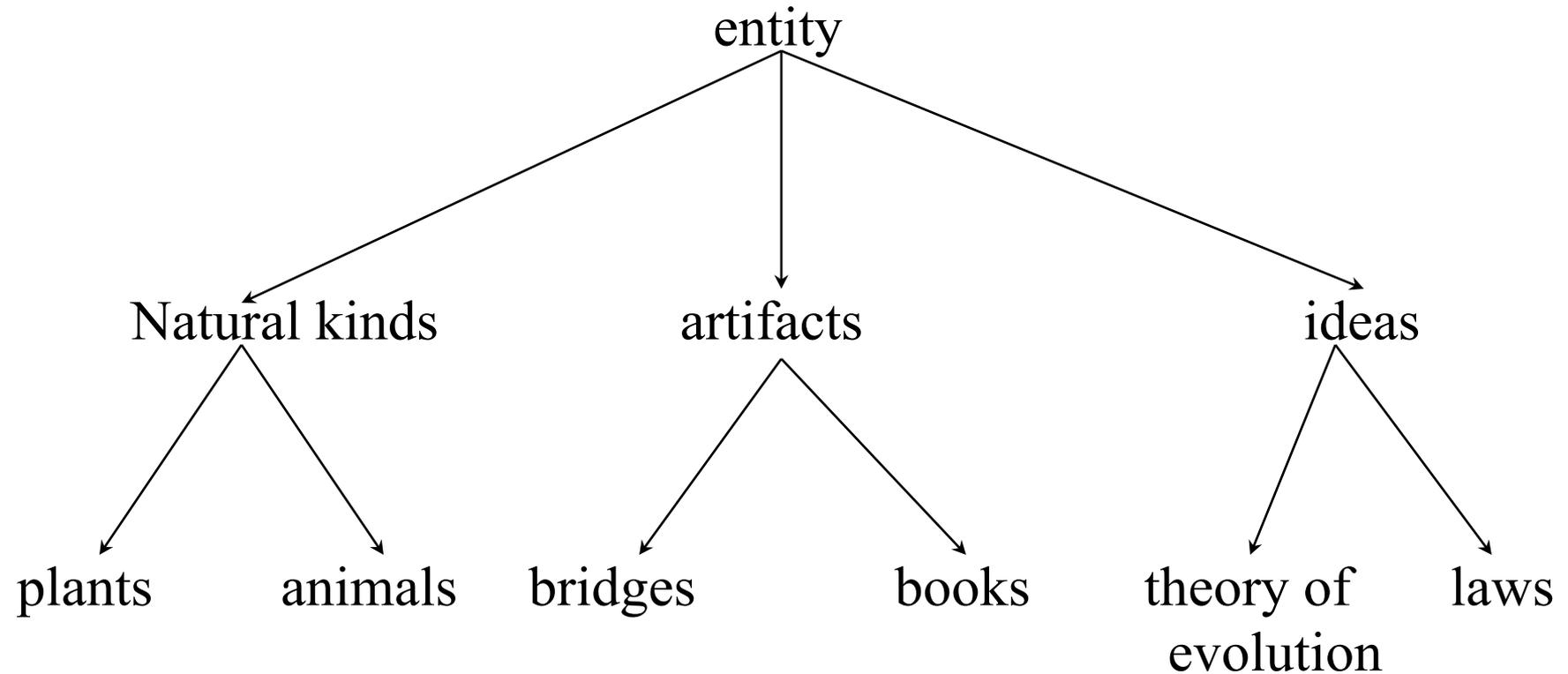
- Inheritance generally treated as  
monotonic – what about exceptions?  
color(pink,clyde).

# A Vegetable Ontology –



Abbreviations: or – orange, gr-green, sw-sweet, bi-bitter, f-folate

# Possible Top-level Ontology



# Type constraints on arguments

- Restrictions on types of arguments in a predicate are extremely common
  - $\text{fluid-path}(X) \wedge \text{container}(Y) \wedge \text{container}(Z)$   
 $\rightarrow \text{fluid-connection}(X, Y, Z)$
- Can express compactly by statements about reified collections that make intent clearer
  - $\text{isa}(X, \text{fluid-path})$   
 $\text{isa}(Y, \text{container})$   
 $\text{isa}(Z, \text{container})$

# Entity: Aggregates

- An *Aggregate* is a collection of entities that can be treated as one item.
  - Ex. *a group of people, a DNA sequence.*
- An aggregate is described with 3 relationships:
  - The group of Larry, Moe and Curly has
    - *element-type* (Person)
    - *members* (Moe, Larry, Curly)
    - *size* (3 Person)

# Practice with Aggregates

- *A DNA sequence* carries genetic information.
- *The set of natural numbers* is infinite.
- *The ribosomes in the cytoplasm* synthesize proteins.
- *The sheriff's posse* was on the move.

# Entities: Purpose

- *Purpose* is a relationship between an entity and an event.
- Many entities have a particular purpose, such as:
  - An enzyme is a catalyst in enzyme catalysis
  - A chemical bond is a connector in an attachment between 2 molecules
  - A protein sliding clamp is a restrainer in DNA-Polymerase

# Events

- Actions, processes... things that *happen*
- Things we usually express with verbs
- Can consist of several steps (called *subevents*)
- Can affect entities, their properties and states

*Move, Create, Attach, Copy, Destroy, Collide, ...*  
*Interpret, Transcribe, Photosynthesize, Advertise,*  
*...*

# Relationships between Two Entities

- Entities are related to each other independently of Events
  - has-part
  - content
  - material
  - is-at, is-near, has-region, and other spatial relationships

# Relationships between Two Events

- How one Event is related to or affects another Event
- Possible relationships
  - causes, enables, entails
  - by-means-of
  - inhibits, prevents

# Relationships between an Event and an Entity

- The roles Entities play when they participate in Events
  - *Who, what, with*
    - Agent, object, instrument, raw-material, result
  - *Where*
    - Location, origin, destination
    - away-from, toward, path

# Classification Languages - Classic

- Basic idea: **cluster information** with object it's about; associate properties with classes.
- **Collect** all information about an object **in one place**; allow for viewing from different perspectives.
- Make **reasoning about classes**/subclasses and **properties**/property inheritance efficient
- Also, in many cases systems need to handle **default** as well as necessary **properties**.
- *less expressive than logic, also very slow*

# WordNet – Princeton

*(Miller 1985, Fellbaum 1998)*

## On-line lexical reference (dictionary)

- Nouns, verbs, adjectives, and adverbs grouped into synonym sets
- Other relations include hypernyms (ISA), antonyms, meronyms
- Typical top nodes - 5 out of 25
  - *(act, action, activity)*
  - *(animal, fauna)*
  - *(artifact)*
  - *(attribute, property)*
  - *(body, corpus)*

# WordNet – call, 28 senses

1. **name, call** -- (assign a specified, proper name to;  
*"They named their son David"; ...*)  
-> LABEL
2. **call, telephone, call up, phone, ring** -- (get or try to get into  
communication (with someone) by telephone;  
*"I tried to call you all night"; ...*)  
-> TELECOMMUNICATE
3. **call** -- (ascribe a quality to or give a name of a common noun  
that reflects a quality;  
*"He called me a bastard"; ...*)  
-> LABEL
4. **call, send for** -- (order, request, or command to come;  
*"She was called into the director's office"; "Call the police!"*)  
-> ORDER

# WordNet

- <http://www.cogsci.princeton.edu/~wn/>
- Call, rush

# Suggested Upper Merged Ontology (SUMO)

- SUMO is a large, open source, formal ontology stated in first-order logic
- Mapped to a large multi-lingual lexicon
  - WordNet
- With open source tools for ontology development and application
- <http://www.ontologyportal.org>

# Definitions

- An ontology is a shared conceptualization of a domain
- An ontology is a set of definitions in a formal language for terms describing the world

# Upper Ontology

- An attempt to capture the most general and reusable terms and definitions
- Provokes thought on clarifying the meaning of more specific terms
- Provides for large-scale reuse

# Ontology vs Language and Knowledge

## Ontology

- Expandable
- Machine understandable
- Language independent
- *Hand crafted*

## Language

- Expandable
- Understood by humans
- Ambiguous
- *Naturally occurring*

## Knowledge

- Changes rapidly
- May be local to an entity

# Suggested Upper Merged Ontology

- 1000 terms, 4000 axioms, 750 rules
- Mapped by hand to all of WordNet 1.6
  - then ported to 3.0
- Development begun in 2000
  - US Government small business grant
- Associated domain ontologies totalling 20,000 terms and 70,000 axioms
- Free
  - SUMO is owned by IEEE but basically public domain
  - Domain ontologies are released under GNU
  - [www.ontologyportal.org](http://www.ontologyportal.org)

# SUMO (continued)

- Formally defined, not dependent on a particular implementation
- Open source toolset for browsing and inference
  - <http://sigmakee.sourceforge.net>
- Many uses of SUMO (independent of the SUMO authors and funders)
  - <http://www.ontologyportal.org/Pubs.html>

# SUMO Validation

- Mapping to all of WordNet lexicon
  - A check on coverage and completeness (at a given level of generality)
- Peer review
  - Open source since its inception
- Formal validation with a theorem prover
  - Free of contradictions (within a generous time bound for search)
- Application to dozens of domain ontologies

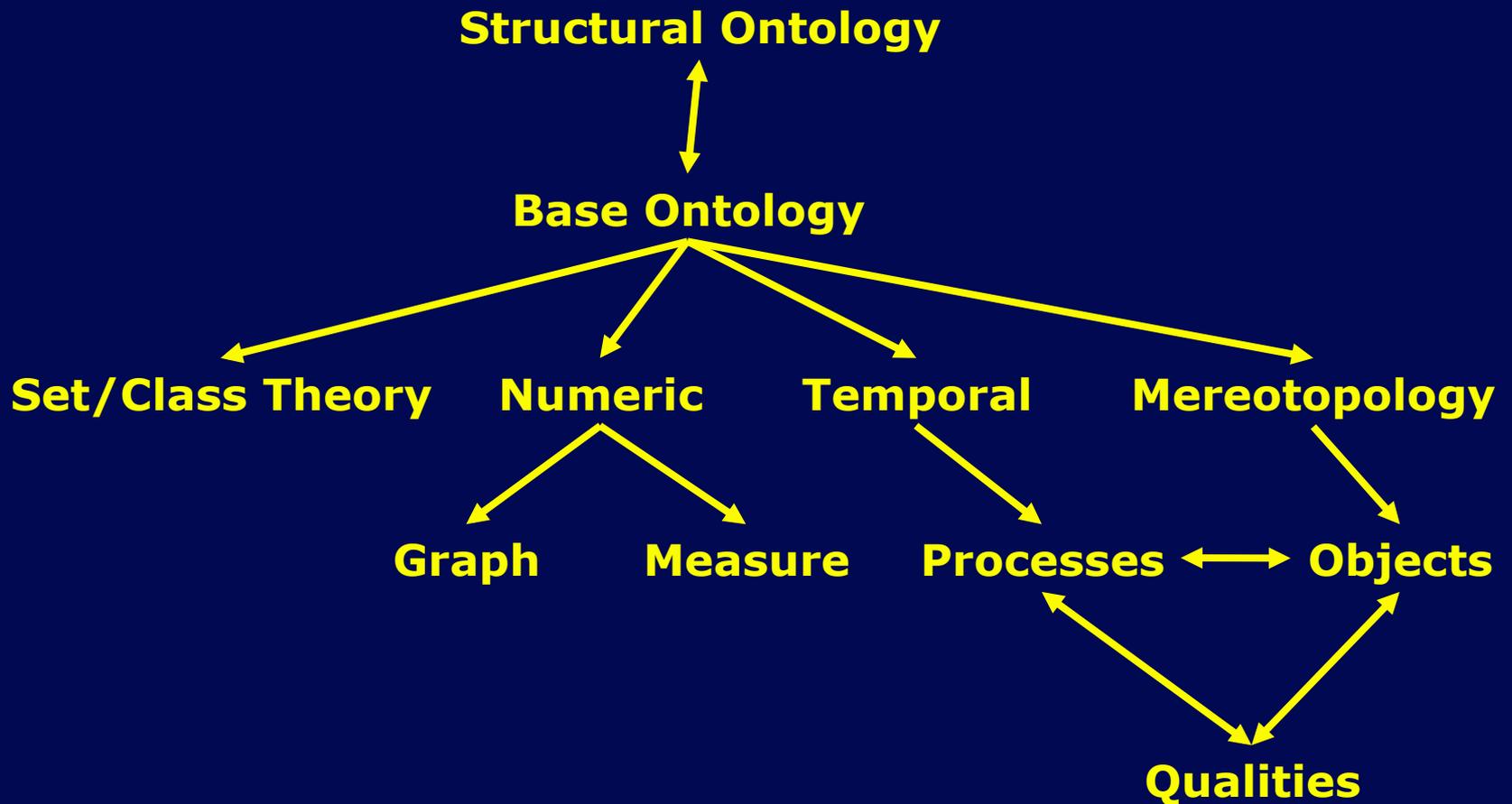
# WordNet to SUMO Mapping

- WordNet synset “plant, flora, plant\_life” is equivalent to the formal SUMO term 'Plant'
  - 00008864 03 n 03 plant 0 flora 0 plant\_life 0 027@ . . . | a living organism lacking the power of locomotion &%Plant=
  - SUMO has axioms that explain formally what a plant is

(=>

```
(and
  (instance ?SUBSTANCE
    PlantSubstance) ↵
  (instance ?PLANT Organism) ↵
  (part ?SUBSTANCE ?PLANT)) ↵
(instance ?PLANT Plant) ↵
```

# SUMO Structure



# CYCorp

<http://www.cyc.com/cycdoc/vocab/vocab-toc.html>

<http://www.cyc.com/>

“The Cyc Knowledge Server is a very large, multi-contextual knowledge base and inference engine.”

“a foundation of basic "common sense" knowledge--a semantic substratum of terms, rules, and relations”

## Review the Proposed Concept Match for the Verb Synonym Set ([rush](#))

[\[more terms\]](#)

### **AssailingSomething**

**Comment:** A collection of events; a subcollection of [ViolentAction](#). In each instance of [AssailingSomething](#), an [IntelligentAgent](#) attacks someone physically.



**([rush](#))**

**Definition:** attack suddenly

#### **Create a new term**

### **PhysicallyAttackingAnAgent**

A specialization of [AttackOnTangible](#) and [ViolentAction](#). Each instance of this collection is an event in which one [Agent-Generic](#) (or a small group of [Agent-Generics](#)) physically attacks another [Agent-Generic](#) (or small group of [Agent-Generics](#)). Such attacks often (but not always) result in [HarmingAnAgent](#). Notable specializations of this collection include [Charging-Rushing](#), [HittingAnOpponent](#), and [SexualAssault](#). [PhysicallyAttackingAnAgent](#) events are also sub-events of each instance of [Fight-Physical](#) and [Battle](#).



### **Charging-Rushing**

The type of action in which an animal aroused by rage, fear, or mating instincts aggressively runs at another animal in a physical attack.

**Lexicon for "rush" indicates this event term**

### **Movement-TranslationEvent**

A specialization of [Translocation](#). Each instance of [Movement-TranslationEvent](#) is an event in which an object (an instance of [Something](#)) moves a certain distance (so that at some point in the event, the object's center of mass changes location with respect to the relevant frame of reference). The object need not move completely out of its original spatial extent; for example, a building moving one foot to the left undergoes a [Movement-TranslationEvent](#). Instances of [Movement-TranslationEvent](#) include events in which the movement ends in the same place it started from (e.g. one lap of a race track, or a trip to the grocery store and back). In such cases (all of which are instances of the specialization [Translation-NoLocationChange](#)), the to and from locations of the movement (see the predicates [toLocation](#) and [fromLocation](#)) are identical. In other instances of [Movement-TranslationEvent](#) (e.g. the movement of the baseball during a home run hit by Roger Maris), the to and from locations are different.

## Position the Verb Synonym Set ([rush](#) | [hurry](#)) in the Concept Hierarchy

[\[more terms\]](#)

### [ExchangeOfOpinion](#)

**Comment:** An instance of [TemporalObjectType](#) and a specialization of [Conversation](#). Each instance of [ExchangeOfOpinion](#) is a [Conversation](#) in which more people deliberately make known to each other some of their [beliefs](#) in a serious discussion.



### [Advising](#)

**Comment:** A collection of events, in which an [IntelligentAgent](#) A tells another [IntelligentAgent](#) B what A thinks B should do, especially when A knows more about something.



### [UrgingSomeone](#)

**Comment:** A collection of events; a subcollection of [Advising](#). In each instance of [UrgingSomeone](#), an [IntelligentAgent](#) forces or impels something in a direction.



### ([rush](#) | [hurry](#))

**Definition:** urge to an unnatural speed; "Don't rush me, please!"

- More Gens
- Wrong Gens

Skip

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This is the first WordNet synset importation page for a verb

## Review the Proposed Concept Name for the Verb Synonym Set ([rush](#) | [hurry](#))

[\[more terms\]](#)

### [UrgingSomeone](#)

**Comment:** The collection of events in which an intelligent agent forces or impels someone in an indicated direction.



([rush](#) | [hurry](#))

**Definition:** urge to an unnatural speed; "Don't rush me, please!"

Verify This Name :

 [\[Edit Preferences\]](#)

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This is the second WordNet synset importation page for a verb in which its concept name is proposed.

The naming heuristics for verbs use the progressive tense of the first synset word, augmented by the type of the sentence object (e.g. Something or Someone). The latter type is determined by the intersection of the arg type constraints on the :OBJECT subcategorization keyword in the verbSemTrans assertions of the immediate gens event type.

## Review the Proposed Comment for the New Term [RushingSomeone](#)

[\[show more terms\]](#)

### [UrgingSomeone](#)

**Comment:** The collection of events in which an intelligent agent forces or impels something in an indicated direction.



([rush](#) | [hurry](#)) represented as [RushingSomeone](#)

**Definition:** urge to an unnatural speed, "Don't rush me, please!"

Verify This Comment :

```
A
collection of events; a subcollection of #UrgingSomeone. In each
instance of #RushingSomeone, an intelligent agent urges someone to do
something at
an
unnatural speed.
```

 [\[Edit Preferences\]](#)

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This is the third WordNet verb synset importation page in which its comment assertion is proposed.

The comment formation heuristics for verbs use the phrase "A collection of events; a subcollection of <gens event type>. In each instance of <this event type>, " followed by an adaptation of the WordNet gloss with the :SUBJECT and :OBJECT types

## Review the Proposed Lexicon for the New Term [RushingSomeone](#)

[\[show more terms\]](#)

### [UrgingSomeone](#)

**Comment:** The collection of events in which an intelligent agent forces or impels something in an indicated direction.



### [RushingSomeone](#)

**Comment:** A collection of events; a subcollection of #UrgingSomeone. In each instance of #RushingSomeone, an intelligent agent urges someone something at an unnatural speed.

#### **rush**

**part of speech:** verb

**sentence pattern:**

Something rushes something	▲
Somebody rushes something	■
Somebody rushes somebody	▼

**infinitive:**

#### **hurry**

**part of speech:** verb

**infinitive:**

## Review the Semantic Translations for the New Term [RushingSomeone](#)

[\[show more terms\]](#)

### [UrgingSomeone](#)

**Comment:** The collection of events in which an intelligent agent forces or impels something in an indicated direction.



### [RushingSomeone](#)

**Comment:** A collection of events; a subcollection of #UrgingSomeone. In each instance of #RushingSomeone, an intelligent agent urges something at an unnatural speed.

SUBJECT rushes OBJECT

- The *information sender* rushes the *perceiver*.

role	sentence constituent
<a href="#">senderOfInfo</a>	SUBJECT
<a href="#">perceiver</a>	OBJECT

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