Course Goals

- Look at event structure from a unifying perspective, enabled by a new synthesis from different disciplines;
- Examine the structure of events at every level impacted by communication;
- Survey formal semantic models of events;
- Examine AI approaches to defining and manipulating events;
- Review CL techniques for finding events and reasoning with them;
- Answer: When is a model of events computational?
A General Computational Theory of Event Structure: A common vocabulary and model for events at all levels

Atomic Event Structures: Compositional at the level of the sentence

Graphical Event Structures: Modal Model of Change at the subatomic level

Linking sub-atomic and atomic events: temporal ordering of events

Linking atomic events: discourse structuring of events

Linking events with actors: Narrative structures
Course Outline

- **Monday**: The Role of Events in Language and Computation
- **Tuesday**: Atomic Theories of Events
- **Wednesday**: Sub-atomic and Dynamic Models of Events
- **Thursday**: Situational Grounding of Events
- **Friday**: Event Structure above the Sentence
Monday Lecture Outline

- Definitions of event from different fields: linguistics, logic, AI, robotics, computational linguistics
- Constituents of events: frame structure, participants, inter-participant relations
- Temporal Characterization of Events measurement, quantity, order
- Event Localization and Situating Events spatial anchoring, locus, aspect
- Events in Discourse and Narrative
- Objects and Latent Event Structure qualia structure, affordances, habitats
“Computational modeling is the use of computers to simulate and study the behavior of complex systems using mathematics, physics and computer science. A computational model contains numerous variables that characterize the system being studied.”

“Computational models are mathematical models that are simulated using computation to study complex systems. ... The parameters of the mathematical model are adjusted using computer simulation to study different possible outcomes.”

“A computational model takes the form of an algorithm, that is, a precise description of the steps that are carried out.”
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- Objects and Latent Event Structure: qualia structure, affordances, habitats
- Events in Discourse and Narrative
Events in Different Disciplines

- **Philosophy**: kinds of occurrences
- **Linguistics**: grammatically and compositionally relevant object types
- **Artificial Intelligence**: states for goals, and events for moving through plans
- **Computational Linguistics**: Reasoning and explanation
Events in Philosophy

- Events vs.: objects, facts, propositions, properties
- Types of Events: states, activities, achievements, accomplishments
- Negative Events: non-events, prevented events
Events in Philosophy - Distinctions

- Mode of being (Hacker 1982a; Cresswell 1986):
  - material objects such as stones and chairs are said to exist;
  - events are said to occur or happen or take place

- Relation to space and time.
  - objects are supposed to have relatively crisp spatial boundaries and vague temporal boundaries;
  - events have relatively vague spatial boundaries and crisp temporal boundaries.
  - objects are said to be located in space
  - events can be co-located (Quinton 1979)
  - objects can move;
  - events cannot (Dretske 1967)

- Type
  - objects are construed as continuants: they are in time and persist through time by being wholly present at every time at which they exist;
  - events are occurrents: they take up time and persist by having different parts (or stages) at different times (Mellor 1980; Simons 2000)
Events in Linguistics

- Aspectual Properties
  - durativity, boundedness, dynamicity, telicity, iteration
- Aktionsarten
  - states, activities, achievements, accomplishments
- Quantification
  - cumulativity, distributivity
Aktionsarten – conceptual categories of event types

- Stative vs. Non-stative

  - (1) a. John is tall.
     b. Mary knows the answer.
     c. It is 8:00 p.m.
     d. John is being tall.

  - (2) a. The statue stands in the square.
     b. The statue is standing in the square.

Structural vs. Phenomenal distinction – Goldsmith and Woisetschlager (1979)
Aktionsarten – conceptual categories of event types

- **Stative vs. Non-stative**
- **States** - Conceived of as not changing over time, as well as extended in time and permanent.

(a) John is tall.
(b) Mary knows the answer.
(c) It is 8:00 p.m.
(d) ! John is being tall.

(4) a. The statue stands in the square.
   b. The statue is standing in the square.

Structural vs. Phenomenal distinction – Goldsmith and Woisetschlager (1979)
Aktionsarten – conceptual categories of event types

- Stative vs. Non-stative
- States - Conceived of as not changing over time, as well as extended in time and permanent.

(5) a. John is tall.
   b. Mary knows the answer.
   c. It is 8:00 p.m.
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Aktionsarten – conceptual categories of event types

- Stative vs. Non-stative
- States - Conceived of as not changing over time, as well as extended in time and permanent.

(7) a. John is tall.
    b. Mary knows the answer.
    c. It is 8:00 p.m.
    d. John is being tall.

Generally only compatible with simple present, but notice extended use of progressive and subtle meaning differences:
Aktionsarten – conceptual categories of event types

- **Stative vs. Non-stative**
- **States** - Conceived of as not changing over time, as well as extended in time and permanent.

  (9) a. John is tall.
  b. Mary knows the answer.
  c. It is 8:00 p.m.
  d. ! John is being tall.

Generally only compatible with simple present, but notice extended use of progressive and subtle meaning differences:

(10) a. The statue stands in the square.
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**Structural vs. Phenomenal distinction** – Goldsmith and Woisetschlager (1979)
As seen with the English progressive marking before, states are not always permanent. Other languages also mark these differences (but not always for the same concepts).
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- Spanish – *ser* vs. *estar*

  (12) a. Soy enfermo (I am a sickly person)
  b. Estoy enfermo (if I have a cold)
Processes

- Involve change and are extended in time. In present tense they need to be used in the progressive (unless habitual)

  a. John ran a mile in under four minutes.
  b. Sheila wrote three letters in an hour.
  c. John ran a mile for six minutes.
  d. Sheila ate an apple for ten minutes.

  a. John ran for twenty minutes.
  b. Sheila ate apples for two days straight.
  c. John ran in twenty minutes.
  d. Sheila ate apples in two days.
Processes

- Involve change and are extended in time. In present tense they need to be used in the progressive (unless habitual)

(15) a. John ran a mile in under four minutes.
   b. Sheila wrote three letters in an hour.
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Processes

- Involve change and are extended in time. In present tense they need to be used in the progressive (unless habitual)

(17)  a. John ran a mile in under four minutes.  
b. Sheila wrote three letters in an hour.  
c. !John ran a mile for six minutes.  
d. !Sheila ate an apple for ten minutes.

(18) a. John ran for twenty minutes.  
b. Sheila ate apples for two days straight.  
c. !John ran in twenty minutes.  
d. !Sheila ate apples in two days.
Activities: Atelic i.e. have no natural endpoint or goal (e.g. *I’m running in the park*) Compatible with a durative adverbial (e.g. *for*) that profiles the amount of time the activity takes.

Accomplishments: Telic i.e. have a natural endpoint of goal (e.g. *I'm running a mile*) Compatible with a container adverbial (e.g. *in*) that profiles the amount of time taken to reach the desired goal.
Distinguishing Processes from Transitions

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- **Accomplishments:** Telic i.e. have a natural endpoint of goal (e.g. *I’m running a mile*) Compatible with a container adverbial (e.g. *in*) that profiles the amount of time taken to reach the desired goal.
Some languages are more systematic than English in distinguishing indicators of actual and potential terminal points. Thus Swedish use different prepositions:

(19) Jeg reser till Frankrike på två månader.
I am going to France for two months.

(20) Jeg reste i Frankrike i två månader.
I traveled in France for two months.
Some languages are more systematic than English in distinguishing indicators of actual and potential terminal points. Thus Swedish use different prepositions:

(21) Jeg reser till Frankrike på två månader.
    I(’m) going to France for two months.

(22) Jeg reste i Frankrike i två månader.
    I traveled in France for two months.
Achievements and points

Achievements: Events that are conceived of as instantaneous. Often, however, there is an underlying activity that causes a change of state. Their point-like nature tends to require them to be described in the past tense or narrative present.
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(24) a. John shattered the window.
    b. ! John shatters/is shattering the window.
    c. The canals froze.
    d. Mary found her keys.
    e. *Mary is finding her keys.
    f. John reached the top.
Points: Similar to achievements in being conceived as instantaneous, but without the underlying run-up activity that characterizes gradual achievements.

(a) Bill coughed.
(b) The light flashed.
(c) Bill is coughing.
(d) The light is flashing.

(c) and (d) have an iterative interpretation. Compare with the gradual achievements

John is reaching the top
or
The canals are freezing.
Points: Similar to achievements in being conceived as instantaneous, but without the underlying run-up activity that characterizes gradual achievements.

(26) a. Bill coughed.
b. The light flashed.
c. Bill is coughing.
d. The light is flashing.
Achievements and points

Points: Similar to achievements in being conceived as instantaneous, but without the underlying run-up activity that characterizes gradual achievements

(27) a. Bill coughed.
   b. The light flashed.
   c. Bill is coughing.
   d. The light is flashing.

(c) and (d) have an iterative interpretation. Compare with the gradual achievements *John is reaching the top* or *The canals are freezing.*
Events in AI

- events as states for goals in planning
- actions that move from one state to the next state
- models of agent beliefs and intentions
Events in AI - Data

- Causation/enablement

*Bill flicked the switch.*

*The room was flooded with light.*

Bill moved the switch to the “on” position, which caused a light to come on, which lit up the room Bill was in.

*Betty opened the blinds.*

*The courtyard was flooded with light.*

Betty adjusted the blinds so that she could see through the window they were in front of, after which she could see that the courtyard on the other side of the window was bright.
Events in AI - Planning

\[ S_1 = \text{result}(\text{go}(\text{store}), S_0) \]

\[ \neg \text{holds}(\text{at}(\text{home}), S_1) \]
\[ \text{holds}(\text{at}(\text{store}), S_1) \]

\[ \text{holds}(\text{at}(\text{home}), S_0) \]
\[ \text{holds}(\text{color}(\text{door}, \text{red}), S_0) \]
I go from home to the store, creating a new situation $S'$. In $S'$:
- My friend is still at home
- The store still sells chips
- My age is still the same
- Los Angeles is still the largest city in California…

How can we efficiently represent everything that hasn’t changed?
Events in Computational Linguistics

- Textual and semantic named entities in text
- Units that need to be normalized, anchored, and ordered relative to a fixed time
- Task is to identify, reference, and co-reference recurring mentions of events
Textual and semantic named entities in text

Units that need to be normalized, anchored, and ordered relative to a fixed time

Task is to identify, reference, and co-reference recurring mentions of events
The bridge **collapsed during the storm** but **after** traffic was **rerouted** to the Bay Bridge.

President Roosevelt **died** in **April 1945 before**
- the war **ended**. *(event happened)*
- he **dropped** the bomb. *(event did not happen)*

The CEO **plans** to **retire next month**.

**Last week** Bill was **running** the marathon **when** he **twisted** his ankle. Someone had **tripped** him. He **fell** and didn’t **finish** the race.
Influences on Modeling Events

- **Model-Theoretic Semantics:**

- **Decompositional Semantics:**

- **Lexical-semantic approaches:**

- **Modern Syntheses:**
Cognitive and Computational Models of Events

- **Simulation Semantics**

- **Simulation Theory**

- **Computational Modal Logic**
The Role of Events

- **Planning as Temporal Reasoning:**

- **Textual Entailment:**

- **Syntactically-governed entailments:**
  Davidson (1967)

- **Event-class based entailments:**
  Dowty (1979), Bach (1986)
Levels of Analysis for Events

- **Atomic** event structure: the clausal (sentential) event
- **Molecular** event structure: events connected by discourse relations
- **Sub-atomic** event structure: internal structure of atomic event
- **Macro-event** structure: event sequencing and grouping beyond linguistic provenance.
Definitions of event from different fields:
linguistics, logic, AI, robotics, computational linguistics

Constituents of events:
frame structure, participants, inter-participant relations

Temporal Characterization of Events
measurement, quantity, order

Event Localization and Situating Events
spatial anchoring, locus, aspect

Objects and Latent Event Structure
qualia structure, affordances, habitats

Events in Discourse and Narrative
Constituents of Events

- **Aspectual Type**: state, process, achievement, accomplishment
- **Semantic Type**: action, motion, contact, change_of_state ...
- **Participants**: Agent, Patient, Theme, Goal, Source, Location, ...
- **Temporal Anchoring or Ordering**: before, equal, after, overlap, ...
- **Modality and Evidentiality**: future, necessary, possible, heard-of, seen, ...
- **Embedding Space (medium)**
STATE: John loves his mother.
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- **ACTIVITY**: Mary played in the park for an hour.
Vendler Event Classes + Semelfactive

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- **ACTIVITY**: Mary played in the park for an hour.
- **ACCOMPLISHMENT**: Mary wrote a novel.
Vendler Event Classes + Semelfactive

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- **ACTIVITY**: Mary played in the park for an hour.
- **ACCOMPLISHMENT**: Mary wrote a novel.
- **ACHIEVEMENT**: John found a Euro on the floor.
\begin{itemize}
\item \textbf{STATE}: John loves his mother.
\item \textbf{ACTIVITY}: Mary played in the park for an hour.
\item \textbf{ACCOMPLISHMENT}: Mary wrote a novel.
\item \textbf{ACHIEVEMENT}: John found a Euro on the floor.
\item \textbf{POINT}: John knocked on the door (for 2 minutes).
\end{itemize}
Bach Eventuality Typology (Bach, 1986)

eventualities

states
  - dynamic (a)
  - static (b)

non-states
  - processes (c)
  - events
    - protracted (d)
    - momentaneous
      - happenings (e)
      - culminations (f)
Event Transition Graph (Moens and Steedman 1988)