NLTK:
The Natural Language Toolkit

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Natural Language Processing

- Use computational methods to process human language.
- Examples:
  - Machine translation
  - Text classification
  - Text summarization
  - Question answering
  - Natural language interfaces

Teaching NLP

- **How do you create a strong practical component for an introductory NLP course?**
  - **Students come from diverse backgrounds (CS, linguistics, cognitive science, etc.)**
    - **Many students are learning to program for the first time.**
    - **We want to teach NLP, not programming.**
  - **Processing natural language can involve lots of low-level "house-keeping" tasks**
    - **Not enough time left to learn the subject matter itself.**
  - **Diverse subject matter**

NLTK: Python-Based NLP Courseware

- NLTK: Natural Language Toolkit
  - A suite of Python packages, tutorials, problem sets, and reference documentation.
  - Provides standard data types and interfaces for NLP tasks.
- Development:
  - Created during a graduate NLP course at U. Penn (2001)
  - Extended & redesigned during subsequent semesters.
  - Many additions from student projects & outside contributors.
- Deployment:
  - Released under GPL (code) and creative commons (docs).
  - Used for teaching intro NLP at 8 universities
  - Used by students & researchers for independent study
- http://nltk.sourceforge.net

NLTK Uses

- **Course Assignments:**
  - Use an existing module to explore an algorithm or perform an experiment.
  - Combine modules to form a complete system.
- **Class demonstrations:**
  - Tedious algorithms come to life with online demonstrations.
  - Interactive demos allow live topic exploration.
- **Advanced Projects:**
  - Implement new algorithms.
  - Add new functionality.

Design Goals

Requirements

- Ease of use
- Consistency
- Extensibility
- Documentation
- Simplicity
- Modularity

Non-requirements

- Comprehensiveness
- Efficiency
- Cleverness

Why Use Python?

- Shallow learning curve
- Python code is exceptionally readable
  - "Executable pseudocode"
- Interpreted language
  - Interactive exploration
  - Immediate feedback
- Extensive standard library
- Light-weight object oriented system
  - Useful when it's needed
  - But doesn't get in the way when it's not
- Generators make it easy to demonstrate algorithms
  - More on this later.

Design Overview

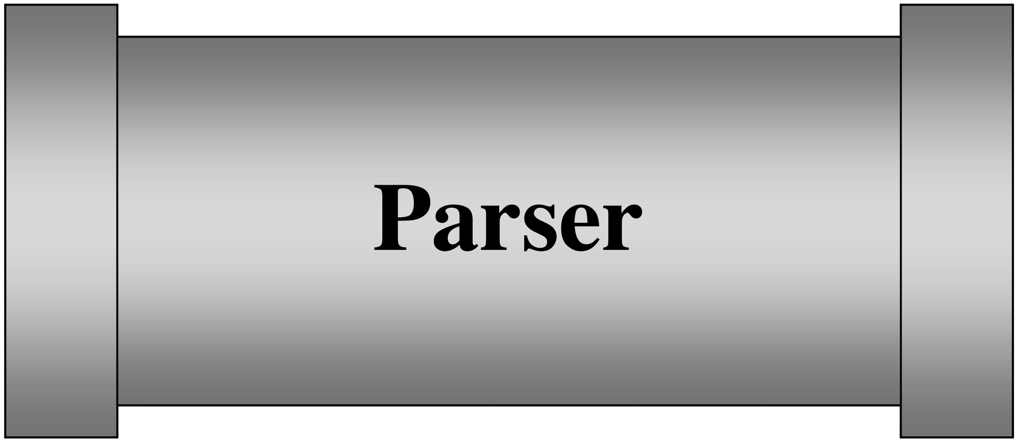
- **Flow control is organized around NLP *tasks*.**
  - **Examples: tokenizing, tagging, parsing**
- **Each task is defined by an *interface*.**
  - **Implemented as a stub base class with docstrings**
- **Multiple *implementations* of each task.**
  - **Different techniques and algorithms**
  - **Different algorithms**
- **Tasks communicate using a standard data type:**
  - **The `Token` class.**

Pipelines and Blackboards

- **Traditionally, NLP processing is described using a transformational model: *"The pipeline"***
  - **A series of pipeline stages transforms information.**

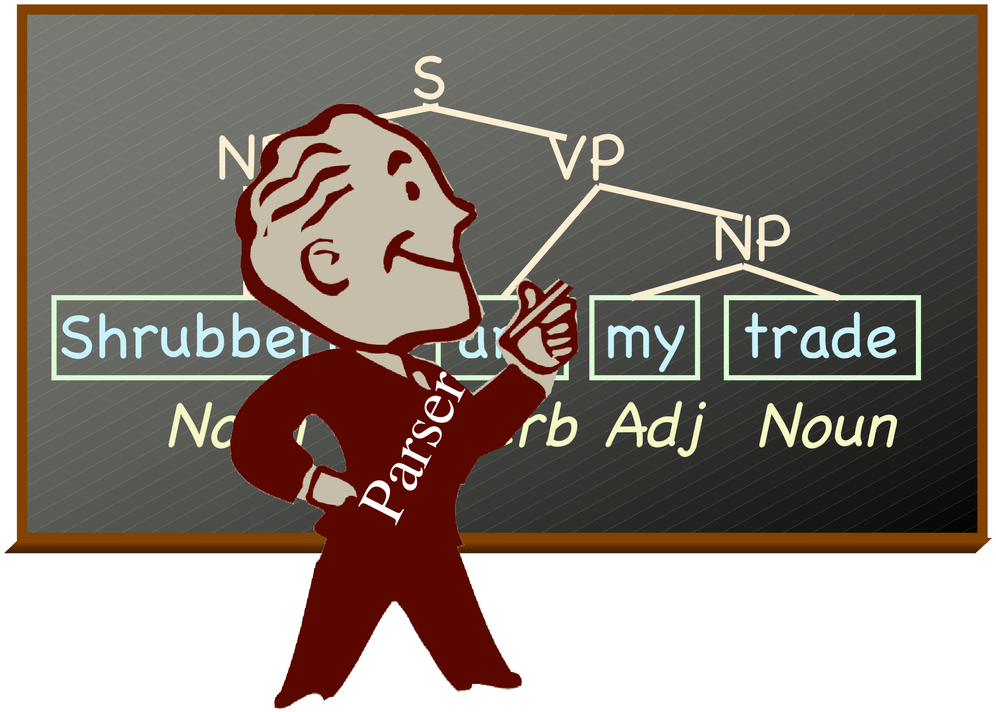
- **For an educational toolkit, we prefer to use an annotation-based model: "The blackboard"**
  - **A series of annotators add information.**

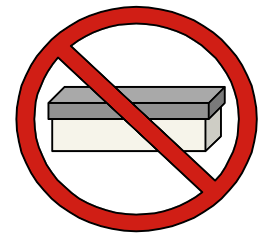
The Pipeline Model



- A series of sequential transformations.
- Input format ≠ Output format.
- Only preserve the information you need.

The Blackboard Model





- Task process a single shared data structure
- Each task adds new information

Advantages of the Blackboard

- Easier to experiment
  - Tasks can be easily rearranged.
  - Students can swap in new implementations that have different requirements.
  - No need to worry about "threading" info through the system.
- Easier to debug
  - We don't throw anything away.
- Easier to understand
  - We build a single unified picture.

Tokens

- **Represent individual pieces of language.**
  - **E.g., documents, sentences, and words.**
- **Each token consists of a set of properties:**
  - **Each property maps a name to a value.**
- **Some typical properties:**

TEXT	**Text content**	*WAVE*	**Audio content**
POS	**Part of speech**	*SENSE*	**Word sense**
TREE	**Parse tree**	*WORDS*	**Contained words**
STEM	**Word stem**		

Properties

- **Properties are not fixed or predefined.**
  - **Consenting adults.**
  - **Dynamic polymorphism.**
- **Properties are mutable.**
  - **But typically mutated *monotonically*. I.e., only add properties; don't delete or modify them.**
- **Properties can contain/point to other tokens.**
  - **A sentence token's** *WORDS* **property**
  - **A tree token's** *PARENT* **property.**

Locations:
Unique Identifiers for Tokens

- **How many words in this phrase?**

  An African swallow or a European swallow.

  a) 5 b) 6 c) 7 d) 8

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  1 2 3 4 5 6 7
  An African swallow or a European swallow

  a) 5 **b) 6** **c) 7** **d) 8**

1. **An**
2. **African**
3. **swallow**
4. **or**
5. **a**
6. **European**
7. **swallow**

Locations: Unique Identifiers for Tokens

- **How many words in this phrase?**

  1 2 3 4 5 6 3

  An African swallow or a European swallow

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1. **An**
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6. **European**

Locations: Unique Identifiers for Tokens

- **How many words in this phrase?**

An African swallow or a European swallow

- **Need to distinguish between an abstract piece of language and an occurrence.**
- **Create unique identifiers for Tokens**
  - **Based on their locations in the containing text.**
  - **Stored in the *LOC* property**

Specialized Tokens

- **Use subclasses of Token to add specialized behavior.**
- **E.g.,** `ParentedTreeToken` **adds…**
  - **Standard tree operations.**
    - `height()`**,** `leaves()`**, etc.**
  - **Automatically maintained parent pointers.**
- **All data is stored in properties.**

Task Interfaces

- **Each task is defined by an *interface*.**
  - **Implemented as a stub base class with docstrings.**
  - **Conventionally named with a trailing "I"**
  - **Used only for documentation purposes.**
- **All interfaces have the same basic form:**
  - **An "action" method monotonically mutates a token.**

```
class ParserI:
   def parse(token):
       """
       A processing class for deriving trees that …
       """
```

Variations on a Theme

- Where appropriate, interfaces can define a set of extended action methods:
  - `action()` The basic action method.
  - `action_n()` A variant that outputs the *n* best solutions.
  - `action_dist()` A variant that outputs a probability distribution over solutions.
  - `xaction()` A variant that consumes and generates iterators.
  - `raw_action()` A transformational (pipeline) variant.

Building Algorithm Demos

- **An example algorithm: CKY**

```
for w in range(2, N):
    for i in range(N-w):
        for  k in range(1, w-1):
            if A→BC and B→α∈chart[i][i+k] and C→β∈chart[i+k][i+w]:
                chart[i][i+w].append(A→BC)
```

- **How do we build an interactive GUI demo?**
  - **Students should be able to see each step.**
  - **Students should be able to tweak the algorithm**

Building Algorithm Demos: Generators to the Rescue!

- **A generator is a resumable function.**
- **Add a `yield` to stop the algorithm after each step.**

```
for w in range(2, N):
    for i in range(N-w):
        for  k in range(1, w-1):
            if A→BC and B→α∈chart[i][i+k] and C→β∈chart[i+k][i+w]:
                chart[i][i+w].append(A→BC)
                yield A →BC
```

- **Accessing algorithm state:**
  - **Yield a value describing the state or the change**
  - **Use member variables to store state (`self.chart`)**

Example: Parsing

- What is it like to teach a course using NLTK?
- Demonstration:
  - Two kinds of parsing
  - Two ways to use NLTK

A) Assignments: chunk parsing

B) Demonstrations: chart parsing

Chunk Parsing

- Basic task:
  - Find the noun phrases in a sentence.
- Students were given…
  - A regular-expression based chunk parser
  - A large corpus of tagged text
- Students were asked to…
  - Create a cascade of chunk rules
  - Use those rules to build a chunk parser
  - Evaluate their system’s performance

Competition Scoring

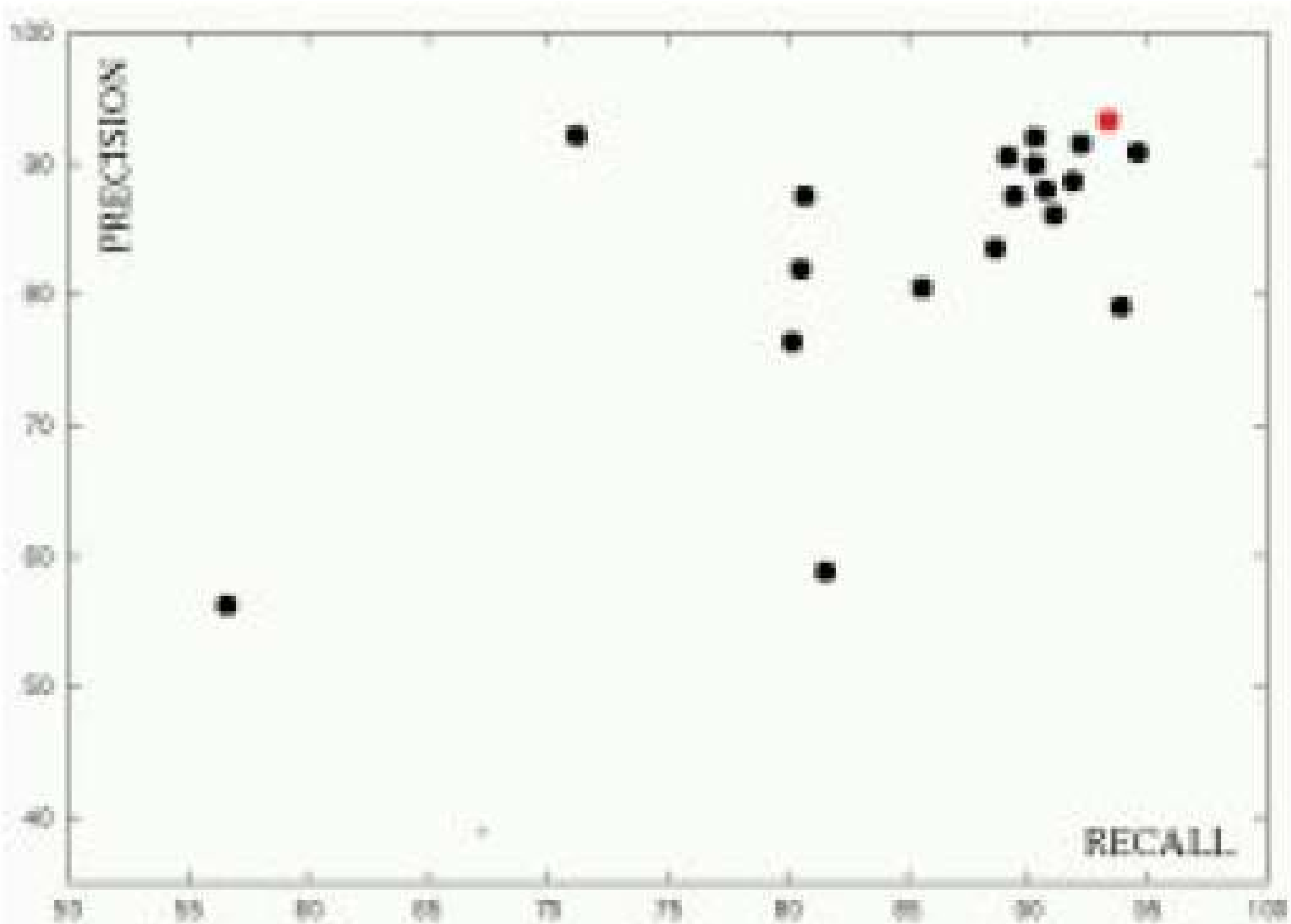

Chart Parsing

- **Basic task:**
  - **Find the structure of a sentence.**
- **Chart parsing:**
  - **An efficient parsing algorithm.**
  - **Based on dynamic programming.**
    - **Store partial results, so we don't have to recalculate them.**
- **Chart parsing demo:**
  - **Used for live in-class demonstrations.**
  - **Used for at-home exploration of the algorithm.**

Conclusions

- Some lessons learned:
  - Use simple & flexible inter-task communication
    - A general polymorphic data type
    - Simple standard interfaces
  - Use blackboards, not pipelines.
  - Don't throw anything away unless you have to.
  - Generators are a great way to demonstrate algorithms.

Natural Language Toolkit

- If you're interested in learning more about NLP, we encourage you to try out the toolkit.
- If you are interested in contributing to NLTK, or have ideas for improvement, please contact us.
- Open session: today at 2:15 (Room 307)

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