Mining Unstructured Data
Outline

1. Machine Learning NERC
2. Sequence tagging: the B-I-O approach
3. General Structure
4. Detailed Structure
   - Feature Extractor
   - Learner
   - Classifier
5. Core task
6. Goals & Deliverables
Assignment

Write a python program that parses all XML files in the folder given as argument and recognizes and classifies drug names. The program must use a sequence tagging machine learning algorithm.

```
$ python3 ./ml-NER.py data/Devel/ result.out
$ more result.out
DDI-DrugBank.d278.s0|0-9|Enoxaparin|drug
DDI-DrugBank.d278.s0|93-108|pharmacokinetics|group
DDI-DrugBank.d278.s0|113-124|eptifibatide|drug
DDI-MedLine.d88.s0|15-30|chlordiazepoxide|drug
DDI-MedLine.d88.s0|33-43|amphetamine|drug
DDI-MedLine.d88.s0|49-55|cocaine|drug
DDI-MedLine.d88.s1|82-95|benzodiazepine|drug
...
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Sequence tagging: the B-I-O approach

- We want to detect *subsequences* in a sentence (e.g. drug names).

- To approach this as a ML classification problem, we will classify each token.

- The classes predicted by the classifier must allow the later reconstruction of the target subsequences.

- **B-I-O schema**: mark each token as B-e gin of a subsequence, I-nside a subsequence, or O-outside any subsequence.

- If we not only want to recognize the subsequences, but also classify them, we use more informative B-I-O classes:

  - *Ascorbic acid*, *aspirin*, and the *common cold*.

  - B-drug I-drug 0 B-brand 0 0 0 0 0 0

- Different variations of this schema exist: BIO, BIOS, BIOES (aka BILOU)
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Extracting features is a costly operation, which we do not want to repeat for every possible experiment or algorithm parametrization.
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Feature extraction process is performed once, out of learning or predicting processes.
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Feature Extractor

The feature extractor:

- Independent program, separated from learner and classifier
- Receives as argument the directory with the XML files to encode.
- Prints the feature vectors to stdout

```
$ python3 ./feature-extractor.py data/devel > devel.feat
$ more devel.feat
```

DDI-DrugBank.d658.s0 When 0 3 0 form=When formlower=when suf3=hen suf4=When isTitle BoS formNext=administered formlowerNext=administered suf3Next=red suf4Next=ered

DDI-DrugBank.d658.s0 administered 5 16 0 form=administered formlower=administered suf3=red suf4=ered formPrev=When formlowerPrev=when suf3Prev=hen suf4Prev=When isTitlePrev formNext=concurrently formlowerNext=concurrently suf3Next=tly suf4Next=ntly

...
Feature Extractor

```python
# process each file in directory
for f in.listdir(datadir):
    # parse XML file, obtaining a DOM tree
tree = parse(datadir + "\" + f)
# process each sentence in the file
sentences = tree.getElementsByTagName("sentence")
for s in sentences:
    sid = s.attributes["id"].value  # get sentence id
    stext = s.attributes["text"].value  # get sentence text
    # load ground truth entities.
gold = []
    entities = s.getElementsByTagName("entity")
    for e in entities:
        # for discontinuous entities, we only get the first span
        offset = e.attributes["charOffset"].value
        (start, end) = offset.split(";")[0].split("-")
        gold.append((int(start), int(end), e.attributes["type"].value))

    # tokenize text
tokens = tokenize(stext)
# extract features for each word in the sentence
features = extract_features(tokens)
# print features in format suitable for the learner/classifier
for i in range(0, len(tokens)):
    # see if the token is part of an entity, and which part (B/I)
tag = get_tag(tokens[i], gold)
    print (sid, tokens[i][0], tokens[i][1], tokens[i][2],
           tag, "\t".join(features[i]), sep='\t')

# blank line to separate sentences
print()
```
def tokenize(s):
    '''
    Task:
    Given a sentence, calls nltk.tokenize to split it in tokens, and adds to each token its start/end offset in the original sentence.

    Input:
    s: string containing the text for one sentence

    Output:
    Returns a list of tuples (word, offsetFrom, offsetTo)
    '''
Feature extraction for NLP

- In most ML applications, the feature space is finite and known (e.g. credit scoring, medical diagnose prediction, churn prevention, fraud detection, etc).

- Also, most of the used features are numerical or categorical (income, age, sex, colesterol level, number of receipts returned, etc.)

- Thus, in these ML applications, feature vectors are usually exhaustive lists of pairs feature-value.
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**BUT...**
Feature extraction for NLP

- In most ML applications, the feature space is finite and known (e.g. credit scoring, medical diagnose prediction, churn prevention, fraud detection, etc).
- Also, most of the used features are numerical or categorical (income, age, sex, cholesterol level, number of receipts returned, etc.)
- Thus, in these ML applications, feature vectors are usually exhaustive lists of pairs feature-value.

**BUT...**

- In most NLP applications, features are related to appearing words, suffixes, prefixes, lemmas, etc. Thus, the feature space is huge.
- Moreover, features are usually binary-valued (a word appears or not, a suffix appears or not, etc).
- Thus, in NLP applications, feature vectors are usually intensive lists of strings (i.e. listing the names for features with value true, and omitting all the rest), and are stored as sparse vectors.
def extract_features(s):
    
    Task:
    Given a tokenized sentence, return a feature vector for each token

    Input:
    s: A tokenized sentence (list of triples (word, offsetFrom, offsetTo))

    Output:
    A list of feature vectors, one per token.
    Features are binary and vectors are in sparse representation (i.e. only
    active features are listed)

    Example:
    >>> extract_features([("Ascorbic",0,7), ("acid",9,12), (",",13,13),
                        ("aspirin",15,21), (",",22,22), ("and",24,26), ("the",28,30),
                        ("common",32,37), ("cold",39,42), (".",43,43)])
    [ [ "form=Ascorbic", "suf4=rbic", "next=acid", "prev=_BoS_", "capitalized" ]],
    [ "form=acid", "suf4=acid", "next=", "prev=Ascorbic" ],
    [ "form=", "suf4=", "next=aspirin", "prev=acid", "punct" ],
    [ "form=aspirin", "suf4=irin", "next=", "prev=", "" ],
    ...
    ]
def get_tag(token, gold):
    '''
    Task:
    Given a token and a list of ground truth entities in a sentence, decide which is the B-I-O tag for the token

    Input:
    token: A token, i.e. one triple (word, offsetFrom, offsetTo)
gold: A list of ground truth entities, i.e. a list of triples (offsetFrom, offsetTo, type)

    Output:
    The B-I-O ground truth tag for the given token ("B-drug", "I-drug", "B-group", "I-group", "O", ...)

    Example:
    >>> get_tag(("Ascorbic",0,7), [(0, 12, "drug"), (15, 21, "brand")])
    B-drug
    >>> get_tag(("acid",9,12), [(0, 12, "drug"), (15, 21, "brand")])
    I-drug
    >>> get_tag(("common",32,37), [(0, 12, "drug"), (15, 21, "brand")])
    O
    >>> get_tag(("aspirin",15,21), [(0, 12, "drug"), (15, 21, "brand")])
    B-brand
    '''
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Learner - Option 1: CRF

- Install and import pycrfsuite
  
  ```
  $ pip install python-crfsuite
  ```

- Use provided train-crf.py to learn a model.
  
  ```
  $ python3 train-crf.py model.crf < train.feat
  ```

You may modify learner parameters (loss function, thresholds, learning rates, etc).
Learner - Option 2: Maximum Entropy

Use **megam** to train a ME model:

- **megam** does not expect the extra information in the features file, so you need to remove the first 4 fields (*sent_id*, *token*, *span_start*, *span_end*) and the blank lines between sentences:

  $ python3 extract-features.py data/train > train.feat$
  $ cat train.feat | cut -f5- | grep -v ^$ > train.mem.feat$

- Then you can use the fixed feature-encoded dataset to train a MEM model:

  $ ./megam-64.opt -quiet -nc -nobias multiclass train.mem.feat > model.mem$
Learner - Option 3: Your choice

- Select a ML algorithm of your choice (DT, SVM, RF, ...) and a python library implementing it.
- Adapt the feature file format to the needs of the selected algorithm.
- Train a classification model for the task of predicting B-I-O tags for each token.
- Create a module `XXX.py` with a constructor and a `predict` method, following the structure of `CRF.py` and `MEM.py`. Add your new classifier to the constructor in `ML_model.py`.
- **DO NOT** use neural network approaches, we’ll do that later in the course.
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Classifier - All options

You can apply the learned models to new data:

```
$ python3 extract-features.py data/devel > devel.feat
$ python3 predict.py model.mem <devel.feat >devel.out
$ python3 util/evaluator.py data/devel devel.devel.out

$ python3 extract-features.py data/test > test.feat
$ python3 predict.py model.mem <test.feat >test.out
$ python3 util/evaluator.py data/test test.out
```
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Build a good ML-based drug NERC

Strategy to follow:

- Training data (XML)
- Parse XML
- Extract features
- Feature extractor
- Devel/Test data (XML)
- Devel/Test vectors
- Learner
  - Learn
  - Save ML model
- Learner
- Load ML model
- Classify
- Output results
- Classifier
- Results
Build a good ML-based drug NERC

Strategy to follow:

1. **Training data (XML)**
2. **Parse XML**
3. **Extract features**
   - Feature extractor
4. **Devel/Test data (XML)**
5. **Training vectors**
6. **Learner**
   - Learn
   - Save ML model
7. **ML Model**
8. **Load ML model**
9. **Classify**
10. **Output results**
11. **Classifier**
12. **Results**
13. **Modify parameters**
14. **Improve features**

Repeat training – evaluation cycle on devel dataset to find out which is the best parameterization for the used algorithm.

Repeat feature extraction – training – evaluation cycle on devel dataset to find out which features are useful.
Build a good ML-based drug NERC

Strategy to follow:

- Repeat training – evaluation cycle on `devel` dataset to find out which is the best parameterization for the used algorithm.
Build a good ML-based drug NERC

Strategy to follow:

- Repeat training – evaluation cycle on **devel** dataset to find out which is the best parameterization for the used algorithm.
- Repeat feature extraction – training – evaluation cycle on **devel** dataset to find out which features are useful.
Choosing useful features

- Used models are token classifiers, so there is a feature vector per token.

- Features about a token should allow its classification, so they should encode information about both the token itself and its context (i.e. nearby words).

- Feature names must be unambiguous. E.g., a feature named suf\(\text{f}x=\text{azole}\) may not be enough if one wants to encode also context word suffixes. In that case, different feature names are needed (e.g.: suf\(\text{f}x=\text{azole}\) for the focus word, plus e.g. suf\(\text{f}x-2=\text{azole}\), suf\(\text{f}x-2=\text{azole}\), suf\(\text{f}x+1=\text{azole}\), suf\(\text{f}x+2=\text{azole}\) for nearby words).

- As in the rule-based approach, including features encoding information from external dictionaries will largely improve results.
Choosing useful features

- **REMEMBER:** Feature names such as `sufx=azole` are not key-value pairs (i.e. not a `sufx` feature with value `azole`), but just a string naming a binary (true/false) feature. The feature name could be any (`sufxisazole, wordendsinazole, ...`) as long as it is active (i.e. present in the sparse vector) only when that property holds.
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Exercise Goals

What you should do:

- Work on your feature extractor. It is the component of the process where you have most control.
- Experiment with different parameterizations of the chosen learner. You may try different learning algorithms if you feel up to. Note that the same feature vectors can be fed to different learners (maybe with some format adaptation).
- Keep track of tried features and parameter combinations, and results produced by each.

What you should **NOT** do:

- Use neural network learners. We’ll do that later on the course.
- Alter the provided code structure.
Exercise Goals

Orientative results:

- Provided initial version achieves 55%(CRF)/30%(MEM) macro average F1 on devel with 2 simple feature templates.
- A set of 10 feature templates is enough to get a macroaverage F1 about 63%(CRF)/50%(MEM). Used information includes (for current, previous, and next tokens)
  - word forms, original and lowercase
  - suffixes (of different lengths)
  - capitalization pattern (all upper, title, camelcase,...)
  - presence of numbers, dashes, etc
  - ...
- Adding features to look up in external resources (provided in the lab project zipfile) rises macroaverage F1 to about 75% (CRF) or 55% (MEM).
Deliverables

Write a report describing the work carried out on NERC tasks. The report must be a single self-contained PDF document, under 10 pages, containing:

- Introduction: What is this report about. What is the goal of the presented work.
Deliverables (continued)

- **Machine learning NERC**
  - **Selected algorithm**: Which classifier/s did you select or try. Reasons of the choice. Comparison if you tried more than one.
  - **Feature extraction**: Tried/discarded/used features. Impact of different feature combinations.
  - **Code**: Include your `extract_features` function (and any other function it may call), properly formatted and commented. **Do not include any other code.**
  - **Experiments and results**: Results obtained on the `devel` and `test` datasets, for different algorithms, feature combinations, parameterizations you deem relevant.

- **Conclusions**: Final remarks and insights gained in this task.

*Keep result tables in your report in the format produced by the evaluator module. Do not reorganize/summarize/reformat the tables or their content.*