

Master in Artificial Intelligence

Advanced Human Language Technologies

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables



UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Facultat d'Informàtica de Barcelona



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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

Session 2 - NERC using machine learning

Assignment

The main program parses all XML files in the folder given as argument and recognizes and classifies drug names, calling 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
```

```
...
```

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

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**egin of a subsequence, **I**nside a subsequence, or **O**utside 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	O	B-brand	O	O	O	O	O	O
- Different variations of this schema exist: BIO, BIOS, BIOES (aka BILOU)

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

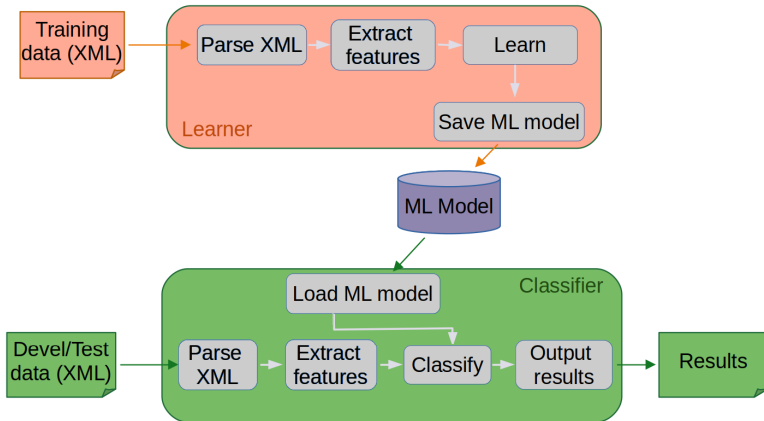
General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

General Structure



Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

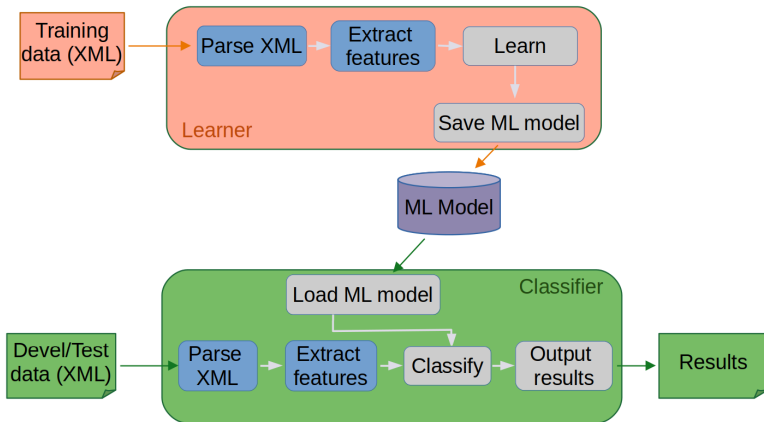
General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

General Structure



Extracting features is a costly operation, which we do not want to repeat for every possible experiment or algorithm parametrization.

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

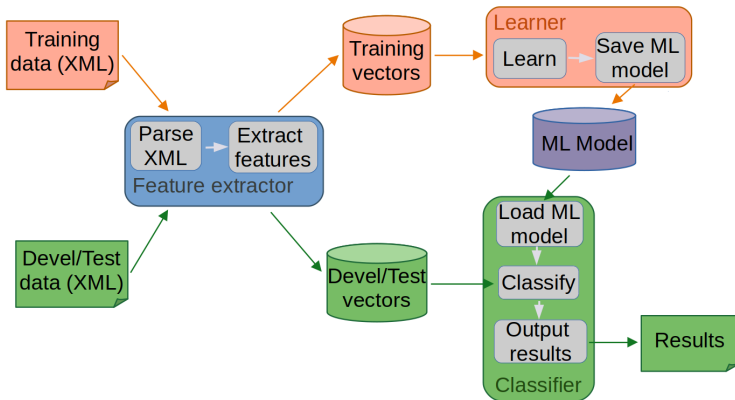
General
Structure

Detailed
Structure

Core task

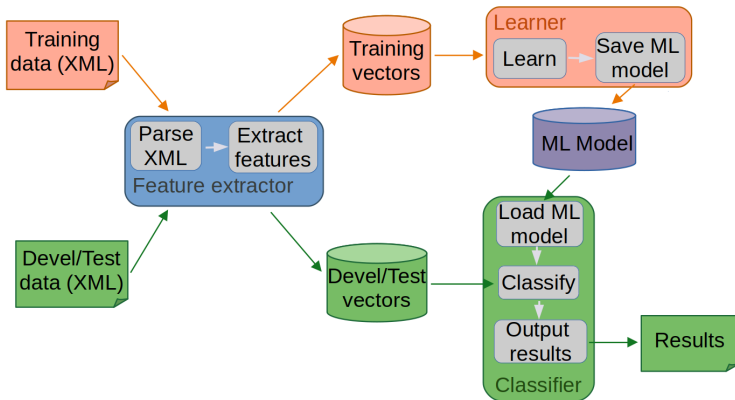
Goals &
Deliverables

General Structure



Feature extraction process is performed once, out of learning or predicting processes.

General Structure



Feature extraction process is performed once, out of learning or predicting processes.

Thus, we need to write not a single program, but three different components: feature extractor, learner, and classifier.

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Feature Extractor

Core task

Goals &
Deliverables

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.feats
```

```
$ more devel.feats
```

```
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

```
# 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()
```

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Feature Extractor

Core task

Goals &
Deliverables

Feature Extractor Functions - Tokenize text

```
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)
'''

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Feature Extractor

Core task

Goals &
Deliverables

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 categorial (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.

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Feature Extractor

Core task

Goals &
Deliverables

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 categorial (income, age, sex, colestherol level, number of receipts returned, etc.)
- Thus, in these ML applications, feature vectors are usually *exhaustive* lists of pairs feature-value.

BUT...

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Feature Extractor

Core task

Goals &
Deliverables

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.

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 ommiting all the rest), and are stored as *sparse vectors*.

Feature Extractor Functions - Extract features

```
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=", ],  
          ...  
        ]  
    ,,,
```

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Feature Extractor

Core task

Goals &
Deliverables

Feature Extractor Functions - Ground truth tag

```
def get_tag(token, gold) :
```

```
    """
```

```
    Task:
        Given a token and a list of ground truth entites 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
```

```
    """
```

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Feature Extractor

Core task

Goals &
Deliverables

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Learner

Core task

Goals &
Deliverables

Learner - Option 1: CRF

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Learner

Core task

Goals &
Deliverables

- Install and import pycrfsuite
`$ pip install python-crfsuite`
- Use provided train-crf.py to learn a model.
`$ python3 train-crf.py model.crf < train.feats`
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.feats
$ cat train.feats | cut -f5- | grep -v ^$ > train.mem.feats
```

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

```
$ ./megam-64.opt -quiet -nc -nobias multiclass train.mem.feats >
model.mem
```

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Learner

Core task

Goals &
Deliverables

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.

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Classifier

Core task

Goals &
Deliverables

Classifier - All options

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Classifier

Core task

Goals &
Deliverables

You can apply the learned models to new data:

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

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

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

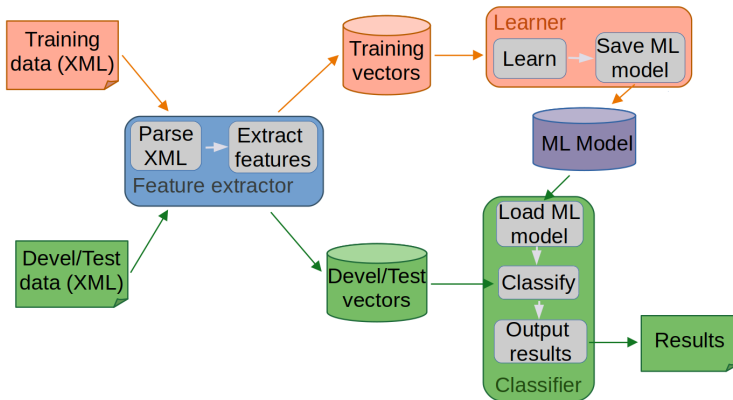
Detailed
Structure

Core task

Goals &
Deliverables

Build a good ML-based drug NERC

Strategy to follow:



Machine Learning NERC

Sequence tagging: the B-I-O approach

General Structure

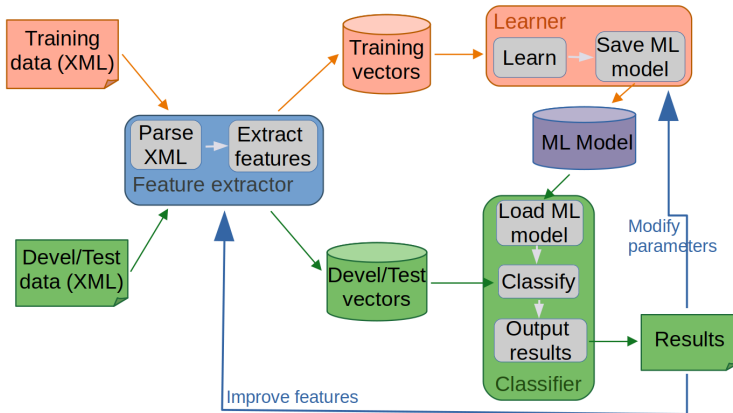
Detailed Structure

Core task

Goals & Deliverables

Build a good ML-based drug NERC

Strategy to follow:



Machine Learning NERC

Sequence tagging: the B-I-O approach

General Structure

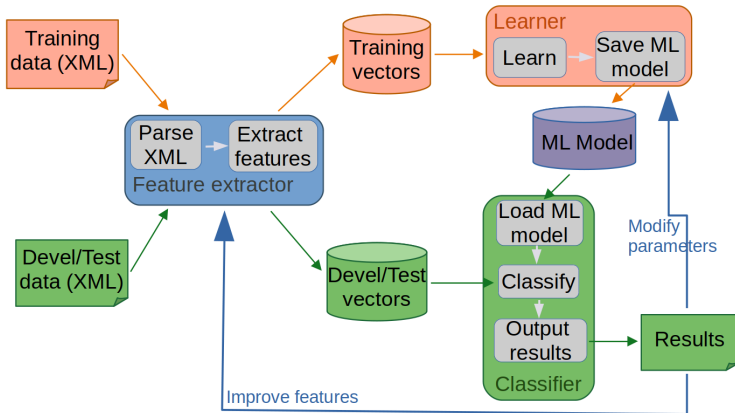
Detailed Structure

Core task

Goals & Deliverables

Build a good ML-based drug NERC

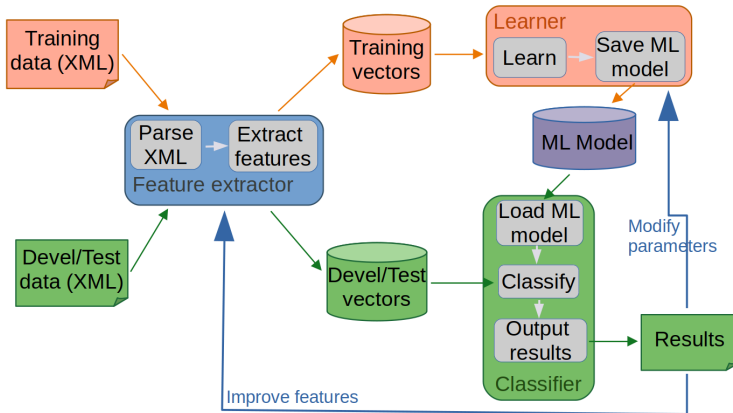
Strategy to follow:



- 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 `sufx=azole` may not be enough if one wants to encode also context word suffixes. In that case, different feature names are needed (e.g.: `sufx=azole` for the focus word, plus e.g. `sufx-2=azole`, `sufx-1=azole`, `sufx+1=azole`, `sufx+2=azole` for nearby words).
- As in the rule-based approach, including features encoding information from external dictionaries will largely improve results.

Choosing useful features

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

- **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.

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

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

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)/47%(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 74%(CRF)/66%(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
 - existence of the token in external lists
 - ...

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

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.
- *Rule-based baseline*
 - *Ruleset construction*: What did you observe in the data exploration. Which rules did you write according to those observations.
 - *Code*: Include your `extract_entities` 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 rule combinations you deem relevant.

Machine
Learning
NERC

Sequence
tagging: the
B-I-O
approach

General
Structure

Detailed
Structure

Core task

Goals &
Deliverables

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.