pyTLEX: A Python Library for TimeLine EXtraction
User's Guide
Version 1.0

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1 Purpose of the Software

pyTLEX is a Python library for implementing the TLEX (TimeLine EXtraction) algorithm which is a formally correct method for extracting a set of exact timelines using all the information available in a TimeML graph. pyTLEX accepts three types of input: a '.tml' file, a JSON-TimeML output, and a text of TimeML annotations. pyTLEX contains classes that can parse TimeML annotated files into TimeML objects and build TimeML graphs where nodes are events and times, and edges are TimeML links. It also contains classes to perform temporal analysis on TimeML annotated texts: (1) partitioning TimeML graphs into temporally connected graphs, (2) transforming the TimeML graphs into Temporal Constraint Satiscfaction Problems (TCSPs), (3) checking consistency of TCSPs and extracting a set of exact timelines of TCSPs, (4) detecting inconsistent subgraphs in the graph that cause temporal inconsistency, and (5)identifying time points that lack uniquely specify the full ordering (temporal indeterminacy). Furthermore, pyTLEX can return any event attribute values (polarity, aspect, POS, tense, etc.), any time expression values (type, temporalFunction, freq, etc.), and any link values (nodes, types, signalIDs, etc.). Finally, using pyTLEX, users can strip the TimeML annotation from the file and obtain the raw text.

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2 Getting Started

pyTLEX is currently set to run on files inside the TimeBank Corpus, or those which follow the same structure. These files can be found at: https://catalog.ldc.upenn.edu/LDC2006T08. In the future, adapters will be built to handle more corpora.

2.1 pyTLEX Input

In this section we'll cover the accepted input types and give a few use cases.

pyTLEX accepts four types of arguments:

- a Python str object representing the filepath of a TimeML annotated file
- a Python str object representing the body of a TimeML annotated file
- a set of Node objects and a set of Link objects
- no parameters

If constructed using valid TimeML annotated data, the library will automatically partition the graph on subordinate links, calculate the smallest timeline for each partition, and find the indeterminant time pairs. If constructed with the empty constructor, nodes and links must be added manually.

Each of these arguments must be equated to the TimeBank Corpus TimeML binary string input, shown as follows:

2.1.1 Building a Graph from a '.tml' File

Users can generate a TimeML graph from a '.tml' file as follows:

```
#filepath input
graph1 = new Graph(filepath="path/to/timeML/file.tml")

#str input
str_data = "TimeML annotated body text"
graph2 = new Graph(time_ml_string=str_data)
```

Listing 1: File input with pyTLEX1.0

2.1.2 Bulding Custom Graphs

Next, we'll look at how to build a custom graph, using the built in data types.

```

if __name__ == '__main__':

    event1 = Event(1, "REPORTING", "Test Stem")
    node2 = Instance(2, event1, "PAST", "NONE", "NOUN", "POS")
    node3 = TimeX(3, "Test Value", True, "Test Phrase")

    Link1 = Link(1, "ALINK", "INITIATES", node2, node3)

    node_set = {node2, node3}
    link_set = {link1}

    graph = Graph(nodes=node_set, links=link_set)
```

Listing 2: Building of custom pyTLEX1.0 graph

In this case, we create two "nodes", an event (Event -> Instance) and a Time expression (Timex) and tie them to a temporal link of type A-Link INITIATES. We then add both nodes and the link into the graph.

3 Usage and Output

Here, we will cover the many functions that are available to the end user.

3.1 Iterating

It is possible to iterate through the set of main partitions, subordination partitions, or all partitions, as follows:

```
graph = graph(filepath=timeMLFilePath);
for partition in graph.main_graphs:
    print(partition)

for partition in graph.subordination_graphs:
    print(partition)

for partition in graph.main_graphs + graph.subordination_graphs:
    print(partition)
```

Listing 3: Iterating Through Partitions

3.2 Timelines

If given a valid TimeML annotated file, pyTLEX will attempt to generate timelines for all consistent partitions these are held as str:list[str] dictionaries; e.g. {'1':['eiid52_minus', 't5_minus'], '2':['eiid52_plus'], '3':['t5_plus']}

To access these timelines we can use the following syntax. We will use wsj_0006.tml as an example:

```

if __name__ == '__main__':
    graph = Graph(filepath=CORPUS_DIRECTORY + '/wsj_0006.tml')

    main_timeline = graph.timeline
    subordination_timelines = graph.subordination_timelines()

    print("Main Timeline: {}".format(main_timeline))
    print("Subordinate Timelines: ")
    for timeline in subordination_timelines:
        print(timeline)
```

Listing 4: Accessing Timelines

When pointing pyTLEX towards wsj_0006.tml in TimeBank Corpus 2.0, this is the expected result:

```
Main Timeline: {'1': ['eiid75_minus'], '2': ['eiid75_plus'], '3': ['eiid74_minus'], '4': ['eiid74_plus'], '5': ['eiid73_minus', 'eiid76_minus'], '6': ['eiid73_plus', 'eiid76_plus'], '7': ['t9_minus'], '8': ['t9_plus']}

Subordinate Timelines:
{'1': ['eiid81_minus'], '2': ['eiid80_minus'], '3': ['eiid81_plus', 'eiid80_plus'], '4': ['t10_minus'], '5': ['t10_plus']}
{'1': ['eiid79_minus'], '2': ['eiid79_plus']}
{'1': ['eiid77_minus'], '2': ['eiid77_plus']}
{'1': ['eiid78_minus'], '2': ['eiid78_plus']}
```

Listing 5: Output of Listing 4

3.3 Graph Methods

3.3.1 Check Consistency

To check consistency, '.getConsistency()' method has to be called. This method returns 'true' if the graph is consistent, otherwise, it returns 'false'. This may be run on the overall graph, or any of the partitions, as follows:

```
Graph graph = new Graph(dataInput);

if (graph.consistency)
    print("The overall graph is consistent.")
else {
    print("The overall graph is inconsistent. The inconsistent partitions are:");

    for partition in graph.main_graphs + graph.subordination_graphs {
        if (!partition.consistency)
            print(partition);
    }
```

```
}
```

Listing 6: Checking Consistency

3.3.2 Generate Inconsistent Subgraphs

The TLEX consistency detection algorithm is capable of sending back the sets of nodes and links that yield an inconsistency. Using 'getInconsistentSubgraphs()' method, inconsisten subgraphs of the TimeML graph can be generated like so:

```
Graph graph = new Graph(dataInput);

Set<IGraph> inconsistentSubgraphs = graph.getInconsistentSubgraphs();
```

Listing 7: Generate Inconsistent Subgraphs

3.3.3 Check Indeterminacy

The user may check the indeterminacy of the entire graph, retreive a set of indeterminant time pairs, or retrieve the set of indeterminant timeline sections using the following methods:

```
Graph graph = new Graph(filepath=TimeML_file_path);

score = graph.indeterminacy_score;
print("The indeterminancy score of the graph is: {}".format(score))

indeterminant_points = graph.indeterminant_time_points
for time_point in indeterminant_points:
    print(time_point)

indeterminant_sections = graph.indeterminant_sections
for section in indeterminant_sections:
    print(section)
```

Listing 8: Checking Indeterminacy

3.3.4 Access Graph Components

The user may use the following functions to access the TimeML unannotated text, the temporal links, and the set of Timex and Instance nodes.

```
Graph graph = new Graph(filepath=timeML_file_path);

# Raw Text
rawText = graph.raw_text

# Links
links = graph.links

# Nodes
nodes = graph.nodes
```

Listing 9: Accessing Graph Components

3.3.5 Check Suggested Links

The user may check for any suggested links for the graph. These links connect the Document Creation Time (DCT) acting as a temporal anchor with other time expressions in the graph, in order to increase the connectivity of the partitions. Users can retrieve a list of these suggested links by directly accessing the links as a graph component or via a method:

```
Graph graph = new Graph(filepath=TimeML_file_path);

sug_links = graph.get_suggested_links()
print("The suggested links for this graph are:")
for sug_link in sug_links:
    print(sug_link)

sug_links = graph.suggested_links
print("The suggested links for this graph are:")
for sug_link in sug_links:
    print(sug_link)
```

Listing 10: Checking Suggested Links

3.4 JSON Output

Given any valid input, the user may call the '.toJSON()' function on the Graph object, which yields the JSON output of a graph analysis. This output is meant to be used by a web server and is an untabulated, "Ugly", JSON format, which can be interpreted for human reading with many tools which can be found online, but is much easier for web servers to parse. Listing 12 shows a "prettified", human-readable template for how the structures are built.

```
graph = Graph(inputData);
print(graph.toJSON())
```

Listing 11: Basic use of pyTLEX1.0

```
{
   "nodes":[
      {
         "id":<node_id>,
         "type":<node_type>,
         "value":<node_value>,
         "temporalFunction":<temporalFunction>,
         "anchorID":<anchorID>,
         "beginPoint":<beginPointID>,
         "endPoint":<endPointID>,
         "quantity":<quantity_or_null>,
         "frequency":<frequency_or_null,
         "signal":<signal_or_null>,
         "event":{
            "id":<event_id>,
            "eventClass":<event_class>,
            "stem":<event_stem>
         }
         "partOfSpeech":<partOfSpeech>,
         "polarity":<polarity>
      },
      ...
```

```
    ],
    "links":[
       {
          "id":<link_id>,
          "linkTag":{"TLINK", "ALINK", "SLINK"},
          "syntax":<link_syntax>,
          "temporalRelation":<temporalRelation>,
          "signal":<signal_or_{}>,
          "relatedToNode":<node_id>,
          "eventInstance":<node_id>
       },
       ...
    ],
    "partitions":[
       {
          "nodeIDs":[
            <node_id1>,
            <node_id2>,
            ...
          ],
          "linkIDs":[
             <link_id1>,
             <link_id2>,
             ...
             ],
          "Timeline":[
             {
                "id":<node_id>
                "eventBoundary":{"-", "+"},
                "position":"1.."
             },
             ...
          ],
          "isConsistent":{"true", "false"},
          "indeterminantTimePairs":[
             <node_id1>,
             <node_id2>,
             ...
          ]
       },
       {
         <parition_2>
       },
       ...
     }
    ],
    "inconsistentSubgraphs":[
         {
         nodes: {<nodes>},
         links: {<links>}
         },
         ...
    ]
}
```

Listing 12: Template output of the `Graph.toJSON()` method in Listing 11 (for pyTLEX1.0)

3.5 Sanity Check

The user has access to a set of sanity check algorithms, meant to check for possible faults and broken rules that may compromise the accuracy of the graph. These include checking for certain missing links, checking that specific links contain the correct elements, checking that no node pairs exceed the 2 in-between links limit, check for orphaned nodes, and check for repeating links. Each of these algorithms may be accessed by calling specific methods from the sanity check file, and providing a TimeML filepath as a parameter:

```
filepath = TimeML_file_path;

Sanity_Check.sco_identity_rule(filepath)
Sanity_Check.orphaned_node_rule(filepath)
Sanity_Check.node_to_node(filepath)
Sanity_Check.perception_rule(filepath)
Sanity_Check.repeating_links(filepath)
Sanity_Check.conditional_slink_rule(filepath)
Sanity_Check.ALINK_rule(filepath)
```

Listing 13: Calling the Sanity Check Methods

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