YAGL: Yet Another Graph Language

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1 Introduction

We seek to make a language, YAGL (Yet Another Graph Language), which allows users to interact with graphs in a manner similar to the language of mathematical proofs. This should allow a person with a theoretical understanding of graphs to engage with them in an intuitive practical way.

With YAGL, users will be able to easily create graphs and add vertices and edges, and associate arbitrary attributes with them (for example, colors with vertices and weights with edges). Common graph algorithms will be able to be written cleanly and concisely, as if they came out of the classic Algorithms textbook by CLRS.

2 Language Design and Syntax

This section provides a rough idea of the design of YAGL, and is subject to change. Final language design and syntax will be provided in the language reference manual.

2.1 Comments

YAGL will use Python-style comments for single line, and will not have a special syntax for multi-line comments. Example:

# This line is a comment.

2.2 Data Types

Basic types:

<table>
<thead>
<tr>
<th>Type</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>int</td>
<td>integer</td>
</tr>
<tr>
<td>float</td>
<td>floating point number</td>
</tr>
<tr>
<td>string</td>
<td>sequence of characters</td>
</tr>
</tbody>
</table>

YAGL also implements a notion of infinity and negative infinity using the keywords INF and -INF respectively. INF is greater than every int or float and is equal to INF. -INF is less than every int or float and is equal to -INF.

YAGL implements constants True and False which evaluate to 1 and 0 respectively. These constants add syntactic sugar to algorithms though they are directly replaceable with ints.

Additionally we implement a Null which can take the place of int, float, or string. Null comparisons are always false. To detect nulls YAGL implements an isNull built in function.

Collection types:

<table>
<thead>
<tr>
<th>Type</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>list</td>
<td>a list of values, all of the same type</td>
</tr>
<tr>
<td>map</td>
<td>a map of from keys (alphanumeric strings) to values of arbitrary types</td>
</tr>
<tr>
<td>set</td>
<td>a set of values, all of the same type</td>
</tr>
</tbody>
</table>
Graph types:

<table>
<thead>
<tr>
<th>Type</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graph</td>
<td>an undirected graph</td>
</tr>
<tr>
<td>Digraph</td>
<td>a directed graph</td>
</tr>
</tbody>
</table>

2.2.1 Elaboration on Graphs

A graph has vertices and edges. Fundamentally, the edges in a graph are either all undirected or all directed, so we have the graph types Graph and Digraph. Vertices will be accessed by labels, and edges will be accessed via two vertex labels.

One will be able to associate any vertex or any edge with any number of attributes. These attributes will be keyed by alphanumeric, and have a value of arbitrary type. In particular, note that edge weights are not a fundamental attribute within the language, but one will be able to easily define an edge weight via, say, an attribute with name ‘w’ and either a float or int value.

Vertices will have the immutable attribute ‘label’, and edges will have the immutable attributes ‘orig’ and ‘dest’, representing the origin and destination vertices. These attributes will be defined when the vertex or edge is created.

2.3 Operators

2.3.1 Basic Operators

<table>
<thead>
<tr>
<th>Category</th>
<th>Data Type</th>
<th>Operator</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison</td>
<td>int, float, string</td>
<td>==, !=, &gt;, &lt;, &lt;=, &gt;=</td>
<td>Act the same as C++ operators.</td>
</tr>
<tr>
<td>Computation</td>
<td>int, float</td>
<td>+, -, *, /, %</td>
<td>Act the same as C++ operators.</td>
</tr>
<tr>
<td>Computation &amp; Assignment</td>
<td>int, float</td>
<td>+=, -=, *=, /=</td>
<td>Act the same as C++ operators.</td>
</tr>
<tr>
<td>Concatenation</td>
<td>string</td>
<td>+</td>
<td>Concatenates two strings.</td>
</tr>
<tr>
<td>Concatenation &amp; Assignment</td>
<td>string</td>
<td>+=</td>
<td>Concatenates right hand side string to original and assigns.</td>
</tr>
<tr>
<td>Boolean</td>
<td>int, float</td>
<td>!</td>
<td>0 maps to 1, and all other values map to 0.</td>
</tr>
<tr>
<td>Boolean</td>
<td>int, float</td>
<td>AND</td>
<td>1 if both values are nonzero, and 0 otherwise.</td>
</tr>
<tr>
<td>Boolean</td>
<td>int, float</td>
<td>OR</td>
<td>0 if both values are zero, and 1 otherwise.</td>
</tr>
</tbody>
</table>
### 2.3.2 Collection Operators

<table>
<thead>
<tr>
<th>Category</th>
<th>Data Type</th>
<th>Operator</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison</td>
<td>list, map, set</td>
<td>==, !=</td>
<td>If all values in all indices/keys are equal then == returns True else != returns False.</td>
</tr>
<tr>
<td>Contains</td>
<td>list, map, set</td>
<td>in</td>
<td>Returns if an item exists in the list, map, or set.</td>
</tr>
<tr>
<td>Concatenation</td>
<td>list, set</td>
<td>+</td>
<td>Concatenates two lists or sets. On sets removes duplicates.</td>
</tr>
<tr>
<td>Concatenation, Assignment</td>
<td>list, set</td>
<td>+=</td>
<td>Concatenates right hand side list to original and assigns.</td>
</tr>
<tr>
<td>Removal</td>
<td>set, map</td>
<td>-</td>
<td>Removes all items in the right hand set, or map (by key), from the left hand set if they exist.</td>
</tr>
<tr>
<td>Removal, Assignment</td>
<td>set, map</td>
<td>-=</td>
<td>Removes all items from in the right hand set, or map (by key), from the left hand set if they exist and assigns back to left hand side set.</td>
</tr>
<tr>
<td>Access</td>
<td>list</td>
<td>[i]</td>
<td>Access the ith element of a list (zero-indexed).</td>
</tr>
<tr>
<td>Access</td>
<td>map</td>
<td>myMap.literal or myMap[“literal”] or myMap[variable]</td>
<td>YAGL supports multiple map access methods for ease of use. myMap.literal is identically equivalent to myMap[“literal”]. The bracket notation must be used if accessing using a variable.</td>
</tr>
</tbody>
</table>

### 2.3.3 Graph Operators

<table>
<thead>
<tr>
<th>Category</th>
<th>Data Type</th>
<th>Operator</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison</td>
<td>Graph, Digraph</td>
<td>==, !=</td>
<td>If all attributes in all vertices and edges are equal then == returns True else != returns False.</td>
</tr>
<tr>
<td>Concatenation</td>
<td>Graph, Digraph</td>
<td>+</td>
<td>Concatenates two graphs together into a single graph. Note, names of vertices in both graphs must be distinct to concatenate them.</td>
</tr>
<tr>
<td>Concatenation &amp; Assignment</td>
<td>Graph, Digraph</td>
<td>+=</td>
<td>Concatenates two graphs together into a single graph. Note, names of vertices in both graphs must be distinct to concatenate them.</td>
</tr>
</tbody>
</table>
### 2.4 Built-in Functions

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>print(arg1,arg2,...)</td>
<td>print out a comma separated list of variables and a new line character</td>
</tr>
<tr>
<td>size(iterable)</td>
<td>return the size of iterable</td>
</tr>
<tr>
<td>isEmpty(iterable)</td>
<td>return size(iterable) &gt; 0</td>
</tr>
<tr>
<td>isNull(arg)</td>
<td>returns 1 if the arg is Null 0 otherwise</td>
</tr>
<tr>
<td>enqueue(list, elem)</td>
<td>add an element to the end of a list</td>
</tr>
<tr>
<td>dequeue(list)</td>
<td>remove the first element of a list and return it</td>
</tr>
<tr>
<td>push(list, elem)</td>
<td>add an element to the end of a list</td>
</tr>
<tr>
<td>pop(list)</td>
<td>remove the last element of a list and return it</td>
</tr>
<tr>
<td>adj(graph, v)</td>
<td>return the set of vertices in a graph adjacent to v</td>
</tr>
</tbody>
</table>

### 2.5 Control Flow

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>if( condition )</td>
<td>if-else block</td>
</tr>
<tr>
<td># If condition code</td>
<td></td>
</tr>
<tr>
<td>else</td>
<td></td>
</tr>
<tr>
<td># Else condition code</td>
<td></td>
</tr>
<tr>
<td>while( condition )</td>
<td>while loop</td>
</tr>
<tr>
<td># While condition code</td>
<td></td>
</tr>
<tr>
<td>forEach( item, iterable )</td>
<td>simple for loop</td>
</tr>
<tr>
<td># code operating on each item of iterable</td>
<td></td>
</tr>
<tr>
<td>forComponentValue( key, value, iterable )</td>
<td>enumerating for loop</td>
</tr>
<tr>
<td># code operating on each key-value pair</td>
<td></td>
</tr>
</tbody>
</table>

### 2.6 Function Definition

Functions will be defined using the keyword `def` and the syntax below and the return keyword will return any output of the function.

```python
def myFunction( Arg1, Arg2 )
    # The code of my function
    return( 'This is the return value of myFunction()' )
```
## Sample Code

```python
# Simple collection manipulation

# Define a List
a = []
push( a, 1 )
push( a, 2 )
a == [1,2]
>> 1
pop( a )
>> 2
a
>> [1]
enqueue( a, 3 )
a
>> [1,3]
dequeue(a)
>> 1

# Define a map
c = {}
c.key1 = 'Value1'
c.key2 = [ 0, 1, 3 ]
c.key3 = 10
print( size( c ) )
>> 3

# Define a set
d = {}
forEach( elem, c.key2 )
   d += elem
print( d )
>> {0,1,3}
d += 3
print( d )
>> {0,1,3}
d -= { 0, 1, 3, 4 }
print( isEmpty( d ) )
>> 1

# Build and examine a basic Graph
G = Graph()
G.V += 'a'
G.V += {'b','c'}
forEach( v, G.V )
   G.E += [v,v]
   G.E[v,v].weight = 1
G.E += [ 'b','c' ]
print( G.E[ 'b', 'c' ].weight )
```
# Create a copy of G as a digraph
D = Digraph()
forComponentValue( label, attributes, G.V )
    D.V += label
    forComponentValue( key, value, attributes )
        D.V[key] = value
forEach( edge, G.E )
    D.E += [ edge.orig.label, edge.dest.label ]
    D.E += [ edge.dest.label, edge.orig.label ]
    forComponentValue( key, value, edge )
        D.E[ edge.orig.label, edge.dest.label ][ key ] = value
        D.E[ edge.dest.label, edge.orig.label ][ key ] = value

# BFS takes as arguments a graph or digraph G #
# and s is a string representing the label of #
# the desired root vertex
#
def BFS( G, s )
    # Takes a graph G and a label for a start node s
    forEach( v, G.V )
        if( v.label == s )
            v.color = 'gray'
            v.d = 0
            v.parent = NULL
        else
            v.color = 'white'
            v.d = INF
            v.parent = NULL
    queue = []
    enqueue( queue, G.V[s] )
    while( !isEmpty( queue ) )
        u = dequeue( queue )
        forEach( v, adj( G, u ) )
            if v.color == 'white'
                v.color = 'gray'
                v.d = u.d + 1
                v.parent = u
                enqueue( queue, u )
        u.color = 'black'
    return( G )

# Relax is a helper function for BellmanFord #
# it takes as arguments a graph or digraph G #
# and an edge e in that graph #
#
def Relax( G, e )
# If the distance of is more than the weight of the edge u->v and the distance on u
v = e.dest
u = e.orig
if( v.d > u.d + e.weight )
  v.d = u.d + e.weight
  v.parent = u
return()

# The BellmanFord algorithm takes a graph or digraph G and a label for a source s and
# returns True if there is a negative weight cycle that is reachable from s
# returns False if there is not a negative weight cycle that is reachable from s
def BellmanFord( G, s )
  ret = True
  forEach( v, G.V )
    v.d = INF
    v.parent = NULL
  G.V[s].d = 0
  forEach( i, range( 0, size( G.V ) ) )
    forEach( edge, G.E )
      Relax( G, edge )
    forEach( edge, G.E )
      if( edge.dest.d > edge.orig.d + edge.w )
        ret = False
  return( ret )