IM-UH 1511 **Introduction to Digital Humanities**

HOMEWORK 9

Network of synonyms from NLTK WordNet

50 points totally

In [1]:

```
import math, random, pickle, collections, operator, string, community #!pip
import itertools as it
import pandas as pd
import numpy as np
import networkx as nx
from networkx import NetworkXNoPath
from networkx.drawing.nx_agraph import graphviz_layout
import pygraphviz
import matplotlib.pyplot as plt
import matplotlib as mpl
from nltk.corpus import wordnet as wn
import warnings
warnings.filterwarnings('ignore')
warnings.filterwarnings("ignore", category=RuntimeWarning)
```

In [2]:

```
def g_diagnostics(G,st):

    print("The %s has %i nodes and %i edges \n" %(st,len(G.nodes()), len(G.

    if G.is_directed()==True:
        print("The %s is a directed graph" %st)
    else:
        print("The %s is an undirected graph" %st)
    if nx.is_weighted(G)==True:
        print("The %s graph is a weighted graph" %st)
    else:
        print("The %s graph is an unweighted graph" %st)
    if G.is_directed()==False:
        if nx.is_connected(G)==True:
            print("The %s is a connected graph" %st)
        else:
            print("The %s graph is a disconnected graph and it has %i conne
            giant = max(nx.connected_components(G), key=len)
            Glcc=G.subgraph(giant)
            print("The largest connected component of this graph has %i nod
    else:
        if nx.is_strongly_connected(G)==True:
            print("The %s is a strongly connected graph" %st)
        else:
            print("The %s graph is not strongly connected and it has %i str
            giant = max(nx.strongly_connected_components(G), key=len)
            Glcc=G.subgraph(giant)
            print("The largest strongly connected component of this graph h
        if nx.is_weakly_connected(G)==True:
            print("The %s is a weakly connected graph" %st)
        else:
            print("The %s graph is not weakly connected and it has %i weakl
            giantw = max(nx.weakly_connected_components(G), key=len)
            Glwcc=G.subgraph(giantw)
            print("The largest weakly connected component of this graph has
    print("The density of the %s is %.3f" %(st,nx.density(G)))
    print("The transitivity of the %s is %.3f" %(st,nx.transitivity(G)))
    if G.is_directed()==True:
        print("The reciprocity of the %s is %.3f" %(st,nx.reciprocity(G)))

def g_diameter(G,st):
    try:
        diameter=nx.diameter(G)
        print("The diameter of the largest strongly connected component of
    except Exception as e:
        print(e)
```

In [3]:
```
def syn_ant(word):
    synonyms = []
    isynonyms=[]
    antonyms = []
    for syn in wn.synsets(word):
        for l in syn.lemmas():
            synonyms.append(l.name())
            if l.antonyms():
                antonyms.append(l.antonyms()[0].name())
    synonyms = sorted(set([w for w in synonyms if w!=word and w.lower()!=wo
    synonyms = sorted(set([w for w in synonyms if "ise" not in w and "isati
    antonyms = sorted(set([w for w in antonyms if w!=word and w.lower()!=wo
    return (synonyms,antonyms) #isynonyms,
```

The WordNet is lexical database in NLTK

There exist 117659 words in the WordNet database. However, some of them have empty sets of synonyms or antonyms.

In [4]:
```
word = "good"
sa=syn_ant(word)
print("The synonyms of '%s' are: \n %s \n" %(word,sa[0]))
print("The antonyms of '%s' are: \n %s" %(word,sa[1]))
```

```
The synonyms of 'good' are:
 ['adept', 'beneficial', 'commodity', 'dear', 'dependable', 'effective',
'estimable', 'expert', 'full', 'honest', 'honorable', 'in_effect', 'in_fo
rce', 'just', 'near', 'practiced', 'proficient', 'respectable', 'right',
'ripe', 'safe', 'salutary', 'secure', 'serious', 'skilful', 'skillful',
'sound', 'soundly', 'thoroughly', 'undecomposed', 'unspoiled', 'unspoil
t', 'upright', 'well']

The antonyms of 'good' are:
 ['bad', 'badness', 'evil', 'evilness', 'ill']
```

In [5]:
```
word = "coronavirus"
sa=syn_ant(word)
print("The synonyms of '%s' are: \n %s \n" %(word,sa[0]))
print("The antonyms of '%s' are: \n %s" %(word,sa[1]))
```

```
The synonyms of 'coronavirus' are:
 []

The antonyms of 'coronavirus' are:
 []
```

In [6]:

```python
word = "virus"
sa=syn_ant(word)
print("The synonyms of '%s' are: \n %s \n" %(word,sa[0]))
print("The antonyms of '%s' are: \n %s" %(word,sa[1]))
```

```
The synonyms of 'virus' are:
 []

The antonyms of 'virus' are:
 []
```

In [7]:

```python
word = 'ammoniac'
sa=syn_ant(word)
print("The synonyms of '%s' are: \n %s \n" %(word,sa[0]))
print("The antonyms of '%s' are: \n %s" %(word,sa[1]))
```

```
The synonyms of 'ammoniac' are:
 []

The antonyms of 'ammoniac' are:
 []
```

In [8]:

```python
word = 'conventionalization'
sa=syn_ant(word)
print("The synonyms of '%s' are: \n %s \n" %(word,sa[0]))
print("The antonyms of '%s' are: \n %s" %(word,sa[1]))
```

```
The synonyms of 'conventionalization' are:
 []

The antonyms of 'conventionalization' are:
 []
```

In [9]:

```
word1 = "marriage"
sa1=syn_ant(word1)
word2 = "education"
sa2=syn_ant(word2)
word3 = "success"
sa3=syn_ant(word3)
print("The synonyms of '%s' are: \n %s" %(word1,sa1[0]))
print("The antonyms of '%s' are: \n %s \n" %(word1,sa1[1]))
print("The synonyms of '%s' are: \n %s" %(word2,sa2[0]))
print("The antonyms of '%s' are: \n %s \n" %(word2,sa2[1]))
print("The synonyms of '%s' are: \n %s" %(word3,sa3[0]))
print("The antonyms of '%s' are: \n %s \n" %(word3,sa3[1]))
```

```
The synonyms of 'marriage' are:
 ['man_and_wife', 'married_couple', 'matrimony', 'spousal_relationship',
'union', 'wedding', 'wedlock']
The antonyms of 'marriage' are:
 []

The synonyms of 'education' are:
 ['Department_of_Education', 'Education_Department', 'breeding', 'didacti
cs', 'instruction', 'pedagogy', 'teaching', 'training']
The antonyms of 'education' are:
 []

The synonyms of 'success' are:
 ['achiever', 'succeeder', 'winner']
The antonyms of 'success' are:
 ['failure', 'loser']
```

In [10]:

```
# https://www.nltk.org/howto/wordnet.html

# synset1.path_similarity(synset2):
# Return a score denoting how similar two word senses are, based on the sho
# connects the senses in the is-a (hypernym/hypnoym) taxonomy.
# The score is in the range 0 to 1.

# synset1.lch_similarity(synset2):
# Leacock-Chodorow Similarity: Return a score denoting how similar two word
# based on the shortest path that connects the senses (as above)
# and the maximum depth of the taxonomy in which the senses occur. The rela
# as -log(p/2d) where p is the shortest path length and d the taxonomy dept

# synset1.wup_similarity(synset2):
# Wu-Palmer Similarity: Return a score denoting how
# similar two word senses are, based on the depth of the two senses in the
# that of their Least Common Subsumer (most specific ancestor node).

w1='good'
w2='dear'
w3='bad'
w1s=wn.synsets(w1)[0]
w2s=wn.synsets(w2)[0]
w3s=wn.synsets(w3)[0]
print("The path similarity between %s and %s is %s" %(w1,w2,w1s.path_simila
print("The path similarity between %s and %s is %s \n" %(w1,w3,w1s.path_sim
print("The lch similarity between %s and %s is %s" %(w1,w2,w1s.lch_similari
print("The lch similarity between %s and %s is %s \n" %(w1,w3,w1s.lch_simil
print("The wup similarity between %s and %s is %s" %(w1,w2,w1s.wup_similari
print("The wup similarity between %s and %s is %s" %(w1,w3,w1s.wup_similari
```

```
The path similarity between good and dear is 0.08333333333333333
The path similarity between good and bad is 0.2

The lch similarity between good and dear is 1.1526795099383855
The lch similarity between good and bad is 2.0281482472922856

The wup similarity between good and dear is 0.15384615384615385
The wup similarity between good and bad is 0.6666666666666666
```

Graph of References of Words to Synonyms

In [11]:

```
# nos=10  #number of words

# wns=list(wn.all_synsets()) #117659
# syn_d={}
# for w in random.sample(wns,nos): #wns: #
#     w=w.lemmas()[0].name()
#     sl=syn_ant(w)
#     sl=syn_ant(w)[0]
#     sl=list(set(sl))
#     if len(sl)>0:
#         syn_d[w]=sl

# for k,v in syn_d.items():
#     print("The synonyms of '%s' are %s \n" %(k,v))
```

In [12]:

```
nos=1500  #25000 #number of words

wns=list(wn.all_synsets())
syn_d={}
for w in random.sample(wns,nos): #wns: #
    w=w.lemmas()[0].name()
    sl=syn_ant(w)
    sl=syn_ant(w)[0]
    sl=list(set(sl))
    if len(sl)>0:
        syn_d[w]=sl

# for k,v in syn_d.items():
#     print("The synonyms of '%s' are %s \n" %(k,v))
```

In [13]:
```
eds=[]
for k,v in syn_d.items():
    for vv in v:
        if vv in syn_d.keys():
            ks=wn.synsets(k)[0]
            vvs=wn.synsets(vv)[0]
            simi=ks.path_similarity(vvs)
            if simi==None:
                asimi=0
            else:
                asimi=1-ks.path_similarity(vvs)
            eds.append((k,vv,asimi))
print(len(eds),len(set(eds)))
eds
```

```
173 173
```

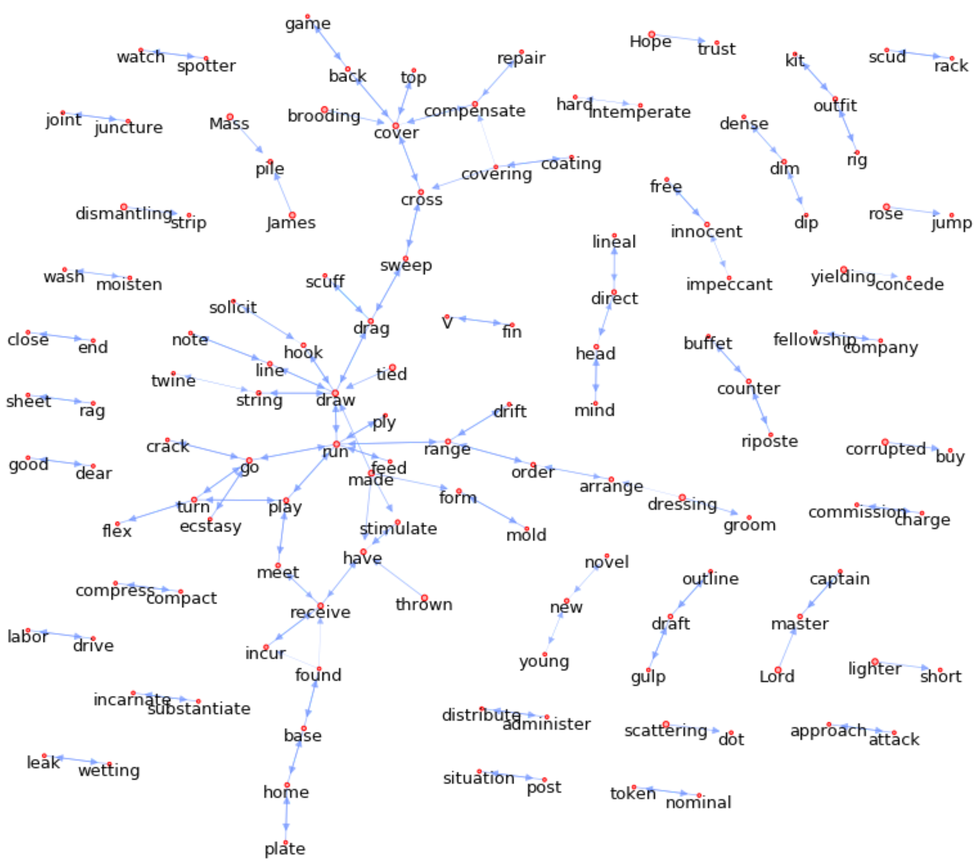
In [14]:
```
G=nx.DiGraph()
G.add_weighted_edges_from(eds)

st="graph among %i words and their synonyms" %len(G)
g_diagnostics(G,st)
```

```
The graph among 129 words and their synonyms has 129 nodes and 173 edges

The graph among 129 words and their synonyms is a directed graph
The graph among 129 words and their synonyms graph is a weighted graph
The graph among 129 words and their synonyms graph is not strongly connec
ted and it has 55 strongly connected components
The largest strongly connected component of this graph has 35 nodes and 7
0 edges
The graph among 129 words and their synonyms graph is not weakly connecte
d and it has 36 weakly connected components
The largest weakly connected component of this graph has 49 nodes and 93
edges
The density of the graph among 129 words and their synonyms is 0.010
The transitivity of the graph among 129 words and their synonyms is 0.024
The reciprocity of the graph among 129 words and their synonyms is 0.867
```

In [15]:

```
edge_width=[G[u][v]['weight'] for u,v in G.edges()]
edge_width=[w if type(w)==float else 0 for w in edge_width]
edge_width=[1*math.log(1.3+w) for w in edge_width]

nsi=[]
for n in G.nodes():
    if G.in_degree(n)>0:
        nsi.append(10*math.log(1+G.in_degree(n)))
    else:
        nsi.append(20)
figsize=(17,13)
pos=graphviz_layout(G)

labels={}
for n in G.nodes():
    labels[n]=""

node_color="#ffb3b3"
node_border_color="r"
edge_color="#668cff"
plt.figure(figsize=figsize);
nodes = nx.draw_networkx_nodes(G, pos, node_color=node_color,node_size=nsi)
nodes.set_edgecolor(node_border_color)
nx.draw_networkx_edges(G, pos,arrowsize=12, width=edge_width,edge_color=edg
# nx.draw_networkx_labels(G,pos,labels=labels)
# nx.draw_networkx_edge_labels(G,pos,edge_labels=elabels);
plt.axis('off');
yoffset = {}
y_off = -10 # offset on the y axis
for k, v in pos.items():
    yoffset[k] = (v[0], v[1]+y_off)
nx.draw_networkx_labels(G, yoffset,font_size=13);
# st1="graph of %i words \n in a random sample of %i words and their synony
sst="The directed %s" %st
plt.title(sst,fontsize=20);
plt.margins(x=0.1, y=0)
```

The directed graph among 129 words and their synonyms



In [16]:

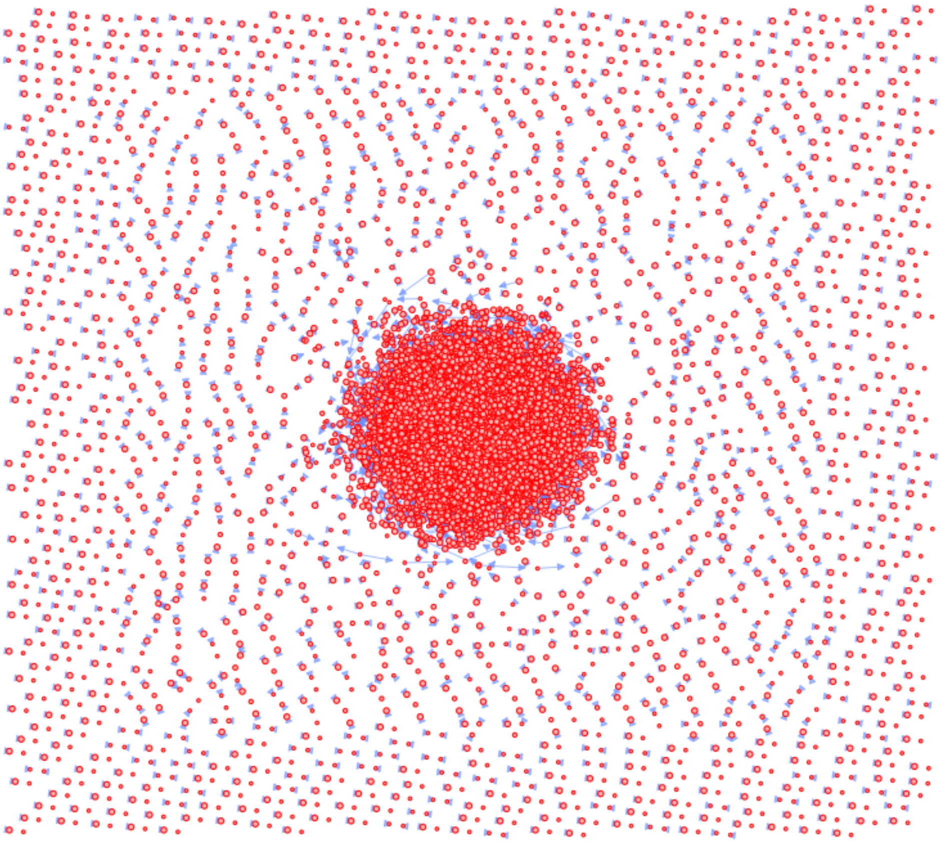
```
# nsi=[]
# for n in G.nodes():
#     if G.in_degree(n)>0:
#         nsi.append(10*math.log(1+G.in_degree(n)))
#     else:
#         nsi.append(20)
# figsize=(17,13)
# pos=graphviz_layout(G)

# labels={}
# for n in G.nodes():
#     labels[n]=""

# node_color="#ffb3b3"
# node_border_color="r"
# edge_color="#668cff"
# plt.figure(figsize=figsize);
# nodes = nx.draw_networkx_nodes(G, pos, node_color=node_color,node_size=ns
# nodes.set_edgecolor(node_border_color)
# nx.draw_networkx_edges(G, pos,arrowsize=12, edge_color=edge_color,alpha=0
# nx.draw_networkx_labels(G,pos,labels=labels)
# # nx.draw_networkx_edge_labels(G,pos,edge_labels=elabels);
# plt.axis('off');
# yoffset = {}
# y_off = -20 # offset on the y axis
# for k, v in pos.items():
#     yoffset[k] = (v[0], v[1]+y_off)
# # nx.draw_networkx_labels(G, yoffset,font_size=13);
# # st1="graph of %i words \n in a random sample of %i words and their syno
# sst="The directed %s" %st
# plt.title(sst,fontsize=20);
# plt.margins(x=0.1, y=0)
```

In [17]:

```
from IPython.display import Image
Image(filename='allDirected.png',width=800, height=400)
```

Out[17]:

The directed graph among 10741 words and their synonyms



In [18]:

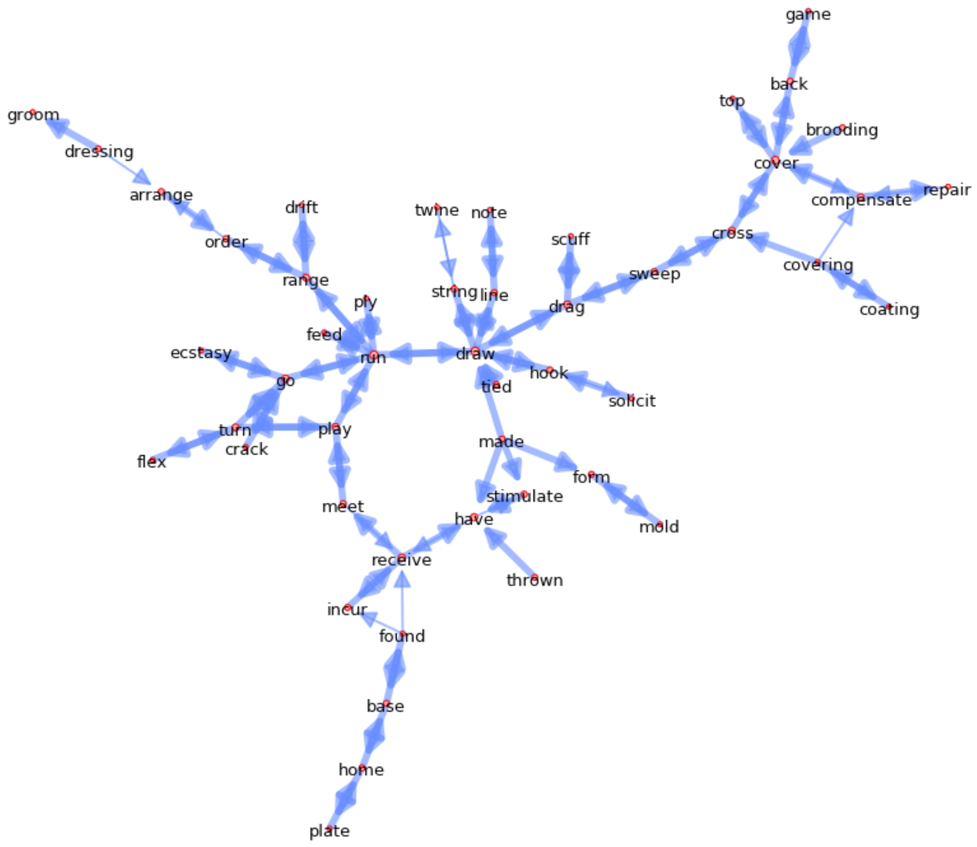
```
giant = max(nx.weakly_connected_components(G), key=len)
Glwcc=G.subgraph(giant)

st1="weakly connected component of the directed %s" %st
# graph of %i words \n in a random sample of %i words and their synonyms" %
g_diagnostics(Glwcc,st1)
```

```
The weakly connected component of the directed graph among 129 words and
their synonyms has 49 nodes and 93 edges

The weakly connected component of the directed graph among 129 words and
their synonyms is a directed graph
The weakly connected component of the directed graph among 129 words and
their synonyms graph is a weighted graph
The weakly connected component of the directed graph among 129 words and
their synonyms graph is not strongly connected and it has 10 strongly con
nected components
The largest strongly connected component of this graph has 35 nodes and 7
0 edges
The weakly connected component of the directed graph among 129 words and
their synonyms is a weakly connected graph
The density of the weakly connected component of the directed graph among
129 words and their synonyms is 0.040
The transitivity of the weakly connected component of the directed graph
among 129 words and their synonyms is 0.026
The reciprocity of the weakly connected component of the directed graph a
mong 129 words and their synonyms is 0.860
```

In [19]:

```
edge_width=[Glwcc[u][v]['weight'] for u,v in Glwcc.edges()]
edge_width=[w if type(w)==float else 0 for w in edge_width]
edge_width=[7*math.log(1.3+w) for w in edge_width]

nsi=[]
for n in Glwcc.nodes():
    if Glwcc.in_degree(n)>0:
        nsi.append(20*math.log(1+Glwcc.in_degree(n)))
    else:
        nsi.append(20)
figsize=(17,13)
pos=graphviz_layout(Glwcc)

labels={}
for n in Glwcc.nodes():
    labels[n]=""

node_color="#ffb3b3"
node_border_color="r"
edge_color="#668cff"
plt.figure(figsize=figsize);
nodes = nx.draw_networkx_nodes(Glwcc, pos, node_color=node_color,node_size=
nodes.set_edgecolor(node_border_color)
nx.draw_networkx_edges(Glwcc, pos,arrowsize=30,width=edge_width, edge_color
# nx.draw_networkx_labels(Glscc,pos,labels=labels)
# nx.draw_networkx_edge_labels(G,pos,edge_labels=elabels);
plt.axis('off');
yoffset = {}
y_off = -4 # offset on the y axis
for k, v in pos.items():
    yoffset[k] = (v[0], v[1]+y_off)
nx.draw_networkx_labels(Glwcc, yoffset,font_size=13);
st1="The weakly connected component of the directed %s" %st
# graph of %i words \n in a random sample of %i words and their synonyms" %
sst=st1
plt.title(sst,fontsize=20);
plt.margins(x=0.1, y=0)
```

The weakly connected component of the directed graph among 129 words and their synonyms

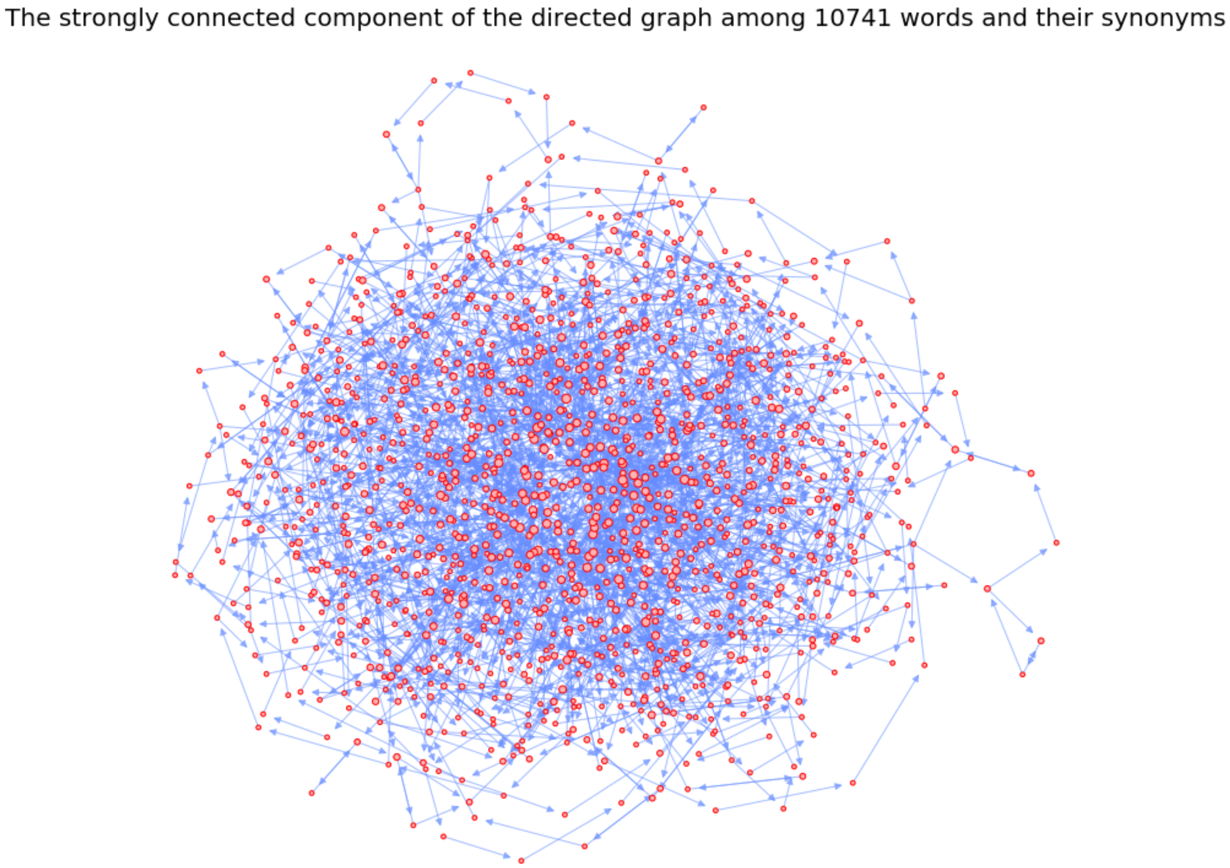


In [20]:

```
# nsi=[]
# for n in Glscc.nodes():
#     if Glscc.in_degree(n)>0:
#         nsi.append(20*math.log(1+Glscc.in_degree(n)))
#     else:
#         nsi.append(20)
# figsize=(17,13)
# pos=graphviz_layout(Glscc)

# labels={}
# for n in Glscc.nodes():
#     labels[n]=""

# node_color="#ffb3b3"
# node_border_color="r"
# edge_color="#668cff"
# plt.figure(figsize=figsize);
# nodes = nx.draw_networkx_nodes(Glscc, pos, node_color=node_color,node_siz
# nodes.set_edgecolor(node_border_color)
# nx.draw_networkx_edges(Glscc, pos,arrowsize=12, edge_color=edge_color,alp
# nx.draw_networkx_labels(Glscc,pos,labels=labels)
# # nx.draw_networkx_edge_labels(G,pos,edge_labels=elabels);
# plt.axis('off');
# yoffset = {}
# y_off = -10 # offset on the y axis
# for k, v in pos.items():
#     yoffset[k] = (v[0], v[1]+y_off)
# # nx.draw_networkx_labels(Glscc, yoffset,font_size=13);
# st1="The strongly connected component of the directed %s" %st
# # graph of %i words \n in a random sample of %i words and their synonyms"
# sst=st1
# plt.title(sst,fontsize=20);
# plt.margins(x=0.1, y=0)
```

In [21]:
```
Image(filename='allDirectedLSCC.png',width=800, height=400)
```

Out[21]:



The strongly connected component of the directed graph among 10741 words and their synonyms

In [22]:
```
# for e in G.edges(data=True):
#     print(e)
```

In [23]:
```
reds=[]
for e in G.edges(data=True):
    if (e[1],e[0]) in G.edges():
        reds.append(e)
print(len(reds)) #,len(set(reds)))
# for e in reds:
#     if (e[1],e[0]) in reds:
#         reds.remove(e)
# print(len(reds)) #,len(set(reds)))
```

```
150
```

In [24]:
```
# for e in reds:
#     print(e)
```

In [25]:
```
Gr=nx.Graph()
Gr.add_weighted_edges_from(reds)

st1="subgraph of reciprocating references among %i words and their synonyms
g_diagnostics(Gr,st1)
```

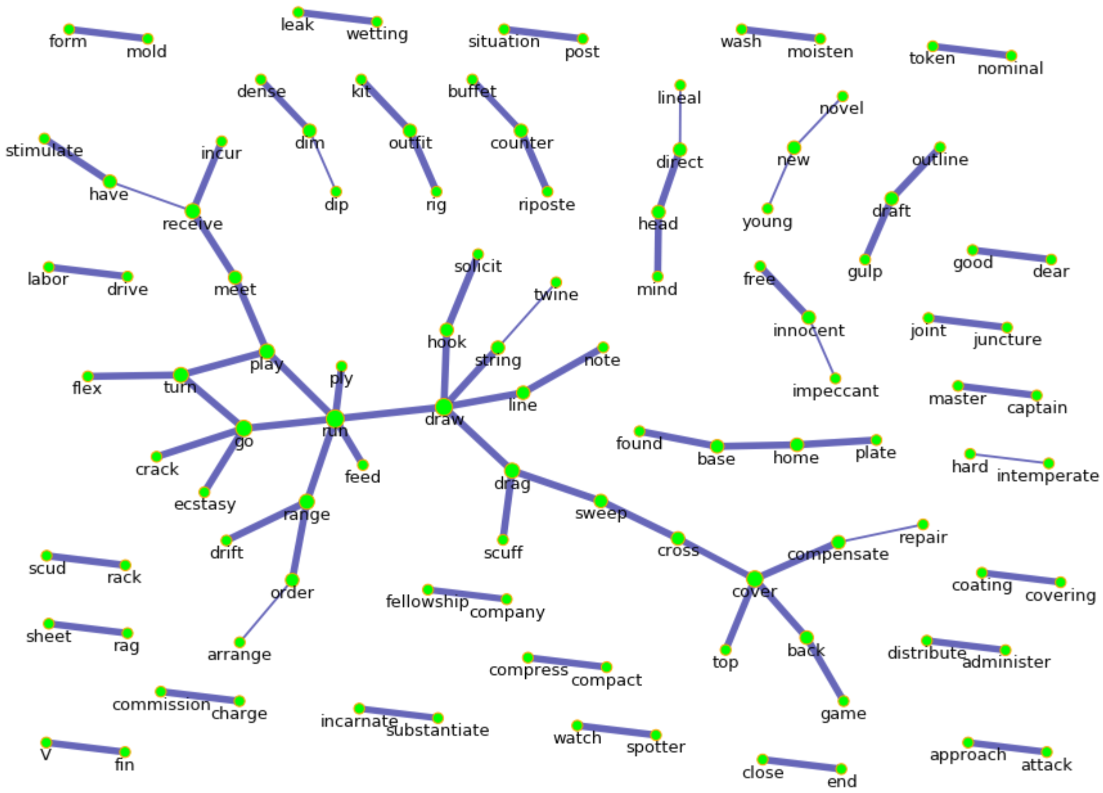
```
The subgraph of reciprocating references among 105 words and their synony
ms has 105 nodes and 75 edges

The subgraph of reciprocating references among 105 words and their synony
ms is an undirected graph
The subgraph of reciprocating references among 105 words and their synony
ms graph is a weighted graph
The subgraph of reciprocating references among 105 words and their synony
ms graph is a disconnected graph and it has 31 connected components
The largest connected component of this graph has 35 nodes and 35 edges
The density of the subgraph of reciprocating references among 105 words a
nd their synonyms is 0.014
The transitivity of the subgraph of reciprocating references among 105 wo
rds and their synonyms is 0.000
```

In [26]:
```
# for e in Gr.edges(data=True):
#     print(e)
```

In [27]:

```
edge_width=[Gr[u][v]['weight']['weight'] for u,v in Gr.edges()]
edge_width=[w if type(w)==float else 0 for w in edge_width]
edge_width=[7*math.log(1.3+w) for w in edge_width]

nsi=[]
for n in Gr.nodes():
    if Gr.degree(n)>0:
        nsi.append(100*math.log(1+Gr.degree(n)))
    else:
        nsi.append(20)
figsize=(17,13)
pos=graphviz_layout(Gr)

labels={}
for n in Gr.nodes():
    labels[n]=""

node_color="lime"
node_border_color="orange"
edge_color="darkblue"
plt.figure(figsize=figsize);
nodes = nx.draw_networkx_nodes(Gr, pos, node_color=node_color,node_size=nsi
nodes.set_edgecolor(node_border_color)
nx.draw_networkx_edges(Gr, pos,width=edge_width,edge_color=edge_color,alpha
# nx.draw_networkx_labels(G, pos)
# nx.draw_networkx_edge_labels(G,pos,edge_labels=elabels);
plt.axis('off');
yoffset = {}
y_off = -15 # offset on the y axis
for k, v in pos.items():
    yoffset[k] = (v[0], v[1]+y_off)
nx.draw_networkx_labels(Gr, yoffset,font_size=13);
# st1="subgraph of %i reciprocating references to synonyms \n in the %s" %(
sst="The undirected %s" %st1
plt.title(sst,fontsize=20);
plt.margins(x=0.1, y=0.1)
```

The undirected subgraph of reciprocating references among 105 words and their synonyms

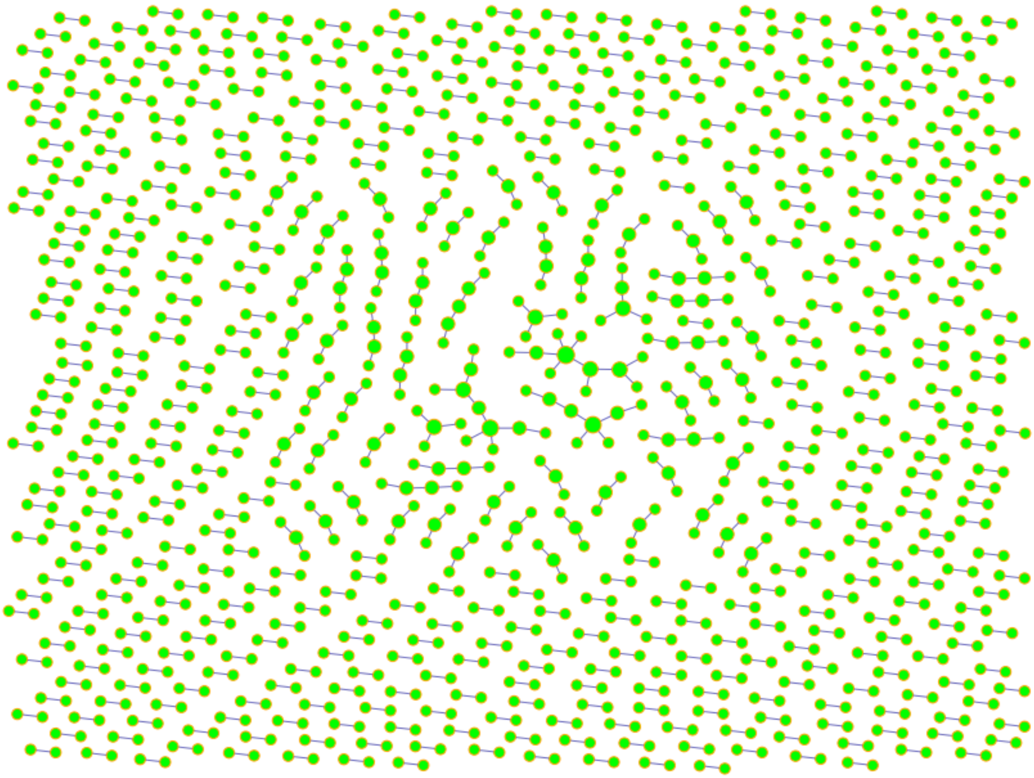


In [28]:

```
# nsi=[]
# for n in Gr.nodes():
#     if Gr.degree(n)>0:
#         nsi.append(100*math.log(1+Gr.degree(n)))
#     else:
#         nsi.append(20)
# figsize=(17,13)
# pos=graphviz_layout(Gr)

# labels={}
# for n in Glscc.nodes():
#     labels[n]=""

# node_color="lime"
# node_border_color="orange"
# edge_color="darkblue"
# plt.figure(figsize=figsize);
# nodes = nx.draw_networkx_nodes(Gr, pos, node_color=node_color,node_size=n
# nodes.set_edgecolor(node_border_color)
# nx.draw_networkx_edges(Gr, pos,edge_color=edge_color,alpha=0.6)
# # nx.draw_networkx_labels(G, pos)
# # nx.draw_networkx_edge_labels(G,pos,edge_labels=elabels);
# plt.axis('off');
# yoffset = {}
# y_off = -15 # offset on the y axis
# for k, v in pos.items():
#     yoffset[k] = (v[0], v[1]+y_off)
# # nx.draw_networkx_labels(Gr, yoffset,font_size=13);
# # st1="subgraph of %i reciprocating references to synonyms \n in the %s"
# sst="The undirected %s" %st1
# plt.title(sst,fontsize=20);
# plt.margins(x=0.1, y=0.1)
```

```
In [29]: Image(filename='allReci.png',width=800, height=400)
```

Out[29]: The undirected subgraph of reciprocating references among 1186 words and their synonyms



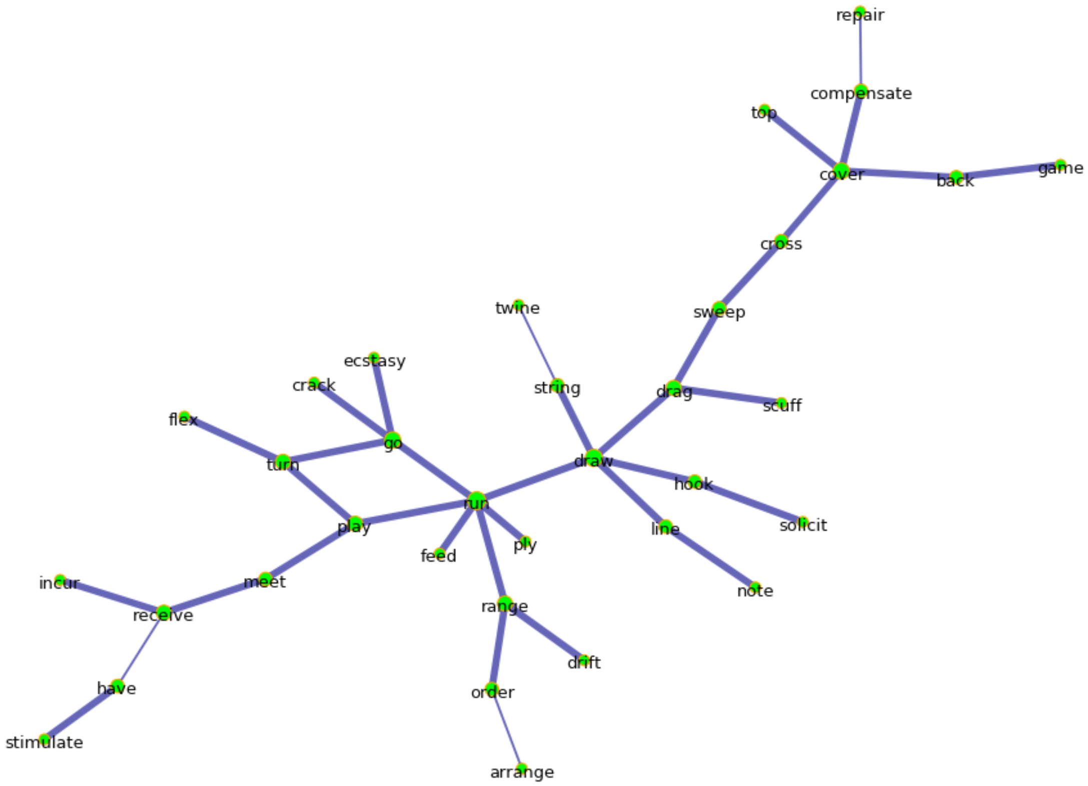
In [30]:
```
giant = max(nx.connected_components(Gr), key=len)
Grlscc=Gr.subgraph(giant)

st2="largest connected component of the undirected %s" %st1
# graph of reciprocating synonyms of %i words \n in a random sample of %i w
g_diagnostics(Grlscc,st2)
```

```
The largest connected component of the undirected subgraph of reciprocati
ng references among 105 words and their synonyms has 35 nodes and 35 edge
s

The largest connected component of the undirected subgraph of reciprocati
ng references among 105 words and their synonyms is an undirected graph
The largest connected component of the undirected subgraph of reciprocati
ng references among 105 words and their synonyms graph is a weighted grap
h
The largest connected component of the undirected subgraph of reciprocati
ng references among 105 words and their synonyms is a connected graph
The density of the largest connected component of the undirected subgraph
of reciprocating references among 105 words and their synonyms is 0.059
The transitivity of the largest connected component of the undirected sub
graph of reciprocating references among 105 words and their synonyms is
0.000
```

In [31]:

```
edge_width=[Grlscc[u][v]['weight']['weight'] for u,v in Grlscc.edges()]
edge_width=[w if type(w)==float else 0 for w in edge_width]
edge_width=[7*math.log(1.3+w) for w in edge_width]

nsi=[]
for n in Grlscc.nodes():
    if Grlscc.degree(n)>0:
        nsi.append(100*math.log(1+Grlscc.degree(n)))
    else:
        nsi.append(20)
figsize=(17,13)
pos=graphviz_layout(Grlscc)

node_color="lime"
node_border_color="orange"
edge_color="darkblue"
plt.figure(figsize=figsize);
nodes = nx.draw_networkx_nodes(Grlscc, pos, node_color=node_color,node_size
nodes.set_edgecolor(node_border_color)
nx.draw_networkx_edges(Grlscc, pos,width=edge_width,edge_color=edge_color,a
# nx.draw_networkx_labels(G, pos)
# nx.draw_networkx_edge_labels(G,pos,edge_labels=elabels);
plt.axis('off');
yoffset = {}
y_off = -4 # offset on the y axis
for k, v in pos.items():
    yoffset[k] = (v[0], v[1]+y_off)
nx.draw_networkx_labels(Grlscc, yoffset,font_size=13);
# st3="The largest connected component of the undirected %s" %st1
st3="The largest connected component of the \n undirected subgraph of recip
# subgraph of \n %i reciprocating references to synonyms \n in the %s" %(le
sst=st3
plt.title(sst,fontsize=20);
plt.margins(x=0.1, y=0.1)
```

The largest connected component of the
undirected subgraph of reciprocating references among 105 words



```
In [ ]:
```