from numpy import random as nprand seed = hash("Network Science in Python") % 2\*\*32 nprand.seed(seed) In []: import networkx as nx Affiliation Networks in NetworkX In [ ]: # Import bipartite module from networkx.algorithms import bipartite from networkx import NetworkXError # Load Zachary karate network G = nx.karate\_club\_graph() try: # Find and print node sets left, right = bipartite.sets(G) print("Left nodes\n", left) print("\nRight nodes\n", right) except NetworkXError as e: # Not an affiliation network print(e) Graph is not bipartite. In []: B = nx.Graph()B.add\_edges\_from([(v, (v, w)) for v, w in G.edges]) B.add\_edges\_from([(w, (v, w)) for v, w in G.edges]) try: # Find and print node sets left, right = bipartite.sets(B) print("Left nodes\n", left) print("\nRight nodes\n", right) except NetworkXError as e: # Not an affiliation network print(e) Left nodes  $\{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33\}$ Right nodes  $\{(13, 33), (29, 32), (3, 13), (5, 10), (23, 25), (0, 5), (15, 32), (2, 32), (23, 27), (0, 7), (14, 33), (1, 17), (8, 32), (31, 33), (20, 33), (23, 29), (1, 19), (2, 27), (2, 27), (3, 27), (3, 27), (3, 27), (3, 27), (3, 27), (4$ ), (0, 2), (5, 16), (22, 32), (1, 3), (1, 21), (1, 30), (25, 31), (3, 12), (23, 33), (27, 33), (2, 13), (24, 25), (29, 33), (14, 32), (1, 7), (3, 7), (4, 6), (31, 32), (18, 32), (20, 32), (0, 11), (2, 8), (30, 33), (8, 33), (19, 33), (26, 29), (5, 6), (1, 2), (0, 4), (0, 13), (0, 31), (2, 28), (4, 10), (0, 6), (2, 3), (1, 13), (28, 31) ), (24, 27), (15, 33), (26, 33), (0, 8), (0, 17), (28, 33), (8, 30), (32, 33), (0, 1), (0, 10), (2, 7), (0, 19), (30, 32), (6, 16), (24, 31), (18, 33), (0, 3), (22, 33) , (23, 32), (0, 12), (2, 9), (0, 21), (9, 33)} In [ ]: bipartite.is bipartite(B) Out[]: In [ ]: # Create data directory path from pathlib import Path data dir = Path('.') / 'data' B = nx.Graph()with open(data\_dir / 'bartomeus2008' / 'Bartomeus\_Ntw\_nceas.txt') as f: # Skip header row next(f) for row in f: # Break row into cells cells = row.strip().split('\t') # Get plant species and pollinator species plant = cells[4].replace('\_', '\n')

pollinator = cells[8].replace('\_', '\n')

bipunctata

Anthidium

Trichodes apiarius Nomada

gemmeus Aetheorrina

Sedum sediforme

Opuntia

Daucus

Andrena tomentosa

B.nodes[pollinator]["bipartite"] = 0

B.add\_edge(pollinator, plant)

B.nodes[plant]["bipartite"] = 1

# Set node types

# Only consider connected species

Scolia

D30

Halyctus

Linum

Helianthemum guttatum

Cerceris

In [ ]: # Configure plotting in Jupyter

%matplotlib inline plt.rcParams.update({

from matplotlib import pyplot as plt

'figure.figsize': (7.5, 7.5), 'axes.spines.right': False, 'axes.spines.left': False, 'axes.spines.top': False,

'axes.spines.bottom': False})

# Seed random number generator

B = B.subgraph(list(nx.connected\_components(B))[0]) In [ ]: # Get node sets pollinators = [v for v in B.nodes if B.nodes[v]["bipartite"] == 0] plants = [v for v in B.nodes if B.nodes[v]["bipartite"] == 1] In [ ]: # Create figure plt.figure(figsize=(30,30)) # Calculate layout pos = nx.spring\_layout(B, k=0.9) # Draw using different shapes and colors for plant/pollinators nx.draw\_networkx\_edges(B, pos, width=3, alpha=0.2) nx.draw\_networkx\_nodes(B, pos, nodelist=plants, node\_color="#bfbf7f", node\_shape="h", node\_size=3000) nx.draw networkx nodes(B, pos, nodelist=pollinators, node color="#9f9fff", node size=3000) nx.draw\_networkx\_labels(B, pos) plt.savefig('output-4.1.png', dpi=150) Brassica Vicea Hypericum fruticulosa perfolatum H91 Sphaerophoeria D33 atlantica Hylaeus H83 variegatus Eucera Helorus coruscus H82 H92 D32 Zygaena Criptocephalus D22 Sphecodes Pyronia Hylaeus Pieris tithonus nigritus rapae Lassiopogon Papilion Alyssum maritimum C53 Bombus terrestris Mordella

Apis melifera

Colletes

RosmarinusCistus officinangnspeliensis

picrioides

chalepensis

Carpobrotus

spp. acinaciformis

Galactites

tomentosa

Alyssum

maritimum

Thymelaea

hirusta

monspeliensis

stricta

Lavandula stoechas

Convolvulus althaeoides

Sedum

sediforme

Scabiosa

stellata

Psoralea

bituminosa

Equium

sabulicola

Carpobrotus

acinaciformis

Cist Kngium albid Hspestre

stellata

Lavandula stoechas

Ruta

carota chalepensis

Oedemera

nobilis

C7

Euphorbea

segatalis

Megachil

Ceratina

curcubitin

C57

H241

D26

L2

H93 Convolvulus Lasioglossum Anthidium althaeoides Oedemera sticticum flavipes Mordellistena Equium Oxythyrea Hylaeus sabulicola funesta pumila Halictus H94 C59 Callophrys Psilothrix Psoralea pigmaea Conophorus<sub>bituminos</sub>a Myrabilis D24 virescens quadripunctata Halictus Helichrisum pyrenaicus stoechas Amegilla femorata? Oedemera barbara H81 Dianthus Megaquile Dorichnium H27 D21 D28 Anthophora Lathirus Stenopterus
Polistenfus dymenum gallicum **Projections** In [ ]: # Create co-affiliation network G = bipartite.projected\_graph(B, plants) # Create figure plt.figure(figsize=(24,24)) # Calculate layout pos = nx.spring\_layout(G, k=0.5) # Draw edges, nodes, and labels nx.draw\_networkx\_edges(G, pos, width=3, alpha=0.2) nx.draw\_networkx\_nodes(G, pos, node\_color="#bfbf7f", node\_shape="h", node\_size=10000) nx.draw\_networkx\_labels(G, pos) plt.savefig('output-4.2.png', dpi=150) Dorichnium pentaphylum Brassica fruticulosa Helichrisum stoechas Helianthemum Vicea Linum lutea sp. Dianthus caryophillus Urospermum picrioides Eryngium Daucus Cistus Cistus carota salvifolius albidus carota Aetheorrina bulbosa Sonchus Rosmarinus officinalis tenerrinus Ruta

Lathirus dymenum Euphorbea segatalis Hypericum perfolatum In [ ]: # Create co-affiliation network G = bipartite.projected\_graph(B, pollinators) # Create figure plt.figure(figsize=(30,30)) # Calculate layout pos = nx.spring\_layout(G, k=0.5) # Draw edges, nodes, and labels nx.draw\_networkx\_edges(G, pos, width=3, alpha=0.2) nx.draw\_networkx\_nodes(G, pos, node\_color="#9f9fff", node\_size=6000) nx.draw\_networkx\_labels(G, pos) plt.savefig('output-4.3.png', dpi=150) D25 Hylaeus variegatus D26 D9 Callophrys Polistes gallicum H81 D21 Megaquile Lassiopogon H82 Halyctus Plagiolepsis Xylocopa Anthophora Oxythyrea funesta Oedemera nobilis Megachile Osmia H94 Hylaeus nigritus Cerceris Conophorus virescens asioglossum Halictus pyrenaicus C56 Oedemera flavines Vanesa Bombus Apis Andrena terrestrismelifera flavipes atlantica Eucera Nordellistena pumila Halictus Psilothrix Helorus Hylaeus Halictus Trichodes apiarius Scolia H241 Ceratina Zygaena Oedemera curcubitina barbara D29 H83 Pyronia tithonus Papilion machaon D33 Pieris C53 rapae H27

H92

In [ ]: # Create co-affiliation network G = bipartite.overlap\_weighted\_projected\_graph(B, pollinators) # Get weights weight = [G.edges[e]['weight'] for e in G.edges] # Create figure plt.figure(figsize=(30,30)) # Calculate layout pos = nx.spring\_layout(G, weight='weight', k=0.5) # Draw edges, nodes, and labels

In [ ]: G = bipartite.weighted\_projected\_graph(B, plants)

list(G.edges(data=True))[0]

nx.draw\_networkx\_labels(G, pos)

Out[]:

D28

('Urospermum\npicrioides', 'Opuntia\nstricta', {'weight': 7})

nx.draw\_networkx\_nodes(G, pos, node\_color="#9f9fff", node\_size=6000)

D35

plt.savefig('output-4.4.png', dpi=150)

nx.draw\_networkx\_edges(G, pos, edge\_color=weight, edge\_cmap=plt.cm.Blues, width=6, alpha=0.5)

Megachile H241 Hylaeus variegatus Eucera D21 H94 Callophrys Plagiolepsis rubi Halyctus pigmaea Helorus C56 coruscus C57 L2 Amegilla femorata? Criptocephalus Sphaerophoeria D26 H91 D9 Colletes Oedemera Sphecodes C7 Anthidium Megaquile sticticum Osmia D25 H81 Psilothrix D29 Oedemera Nomada Oxythyrea funesta Halictus H93 pyrenaicus C59 Anthophora Oedemera flavipes C4 Hylaeus melifera D32 Mordella Mordellistena D22 bipunctata pumila D24 Polistes Bombus Andrena H92 gallicum D30 Lasioglossum terrestris Halictus H82 Scolia Halictus Myrabilis gemmeus quadripunctata Conophorus D33 virescens Oedemera Anthidium barbara H83 Trichodes Pyronia Camponotus apiarius tithonus aetiops H27 Stenopterus Zygaena Hylaeus Cerceris nigritus C58 Xylocopa Pieris rapae D28 Lassiopogon D35 Vanesa Papilion atlantica Ceratina machaon curcubitina