Analysis: Network of Comorbidity in US Veterans

for the course:
Complessità nei sistemi e nelle reti

The Paper

997 138 individuals
US Military Veterans, on average 41 years old, 86% male

95 conditions
17 psychiatric, 78 medical, earliest diagnosis 7 August 2010

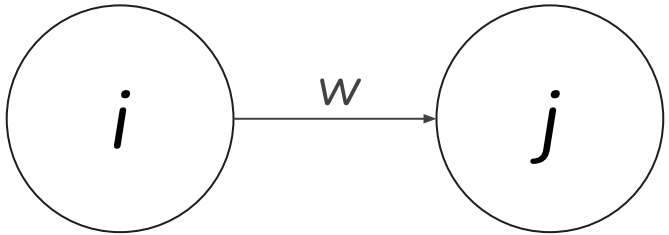
4 main contributions:
relationship between psychiatric and medical conditions
model the temporal aspect of comorbidity
clinical vulnerability score
association between the degree of comorbidity and mortality

The Data

95x95 matrix
increased log odds of co-morbidity of condition *i* given condition *j*

95x95 matrix
p-values from logistic regression

A curious notation



an arc from *i* to *j* represents
the influence of currently having condition *j* on the future development of condition *i*

if I have condition *j* my odds of developing condition *i* increase by *w*

strong predictors have high in-degree

Data Preparation

start from 8930 (= 95x94) nonzero values

remove 2236 values that are NOT statistically significant ($p > 0.05$)

remove 2915 negative values
they correspond to odds increase between 0 and 1 (negative correlation)

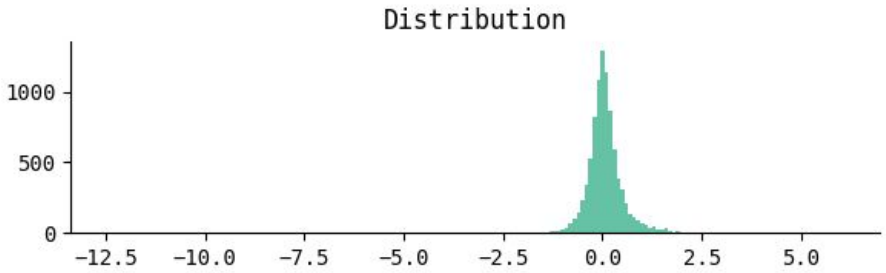
3779 nonzero values left
42.32%

```
# remove values that are not statistically significative
mask = pmat <= 0.05
vmat = vmat[mask].fillna(0)

# remove negative values
vmat = vmat[vmat > 0].fillna(0)
```

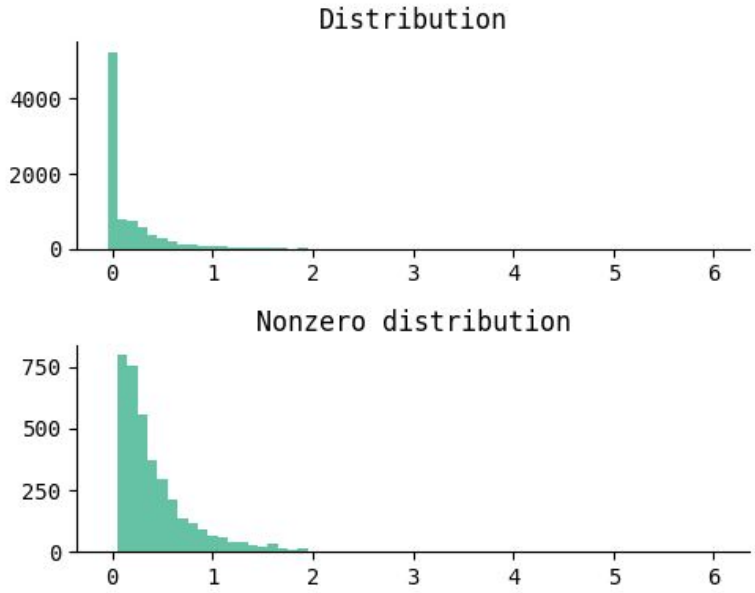
Before

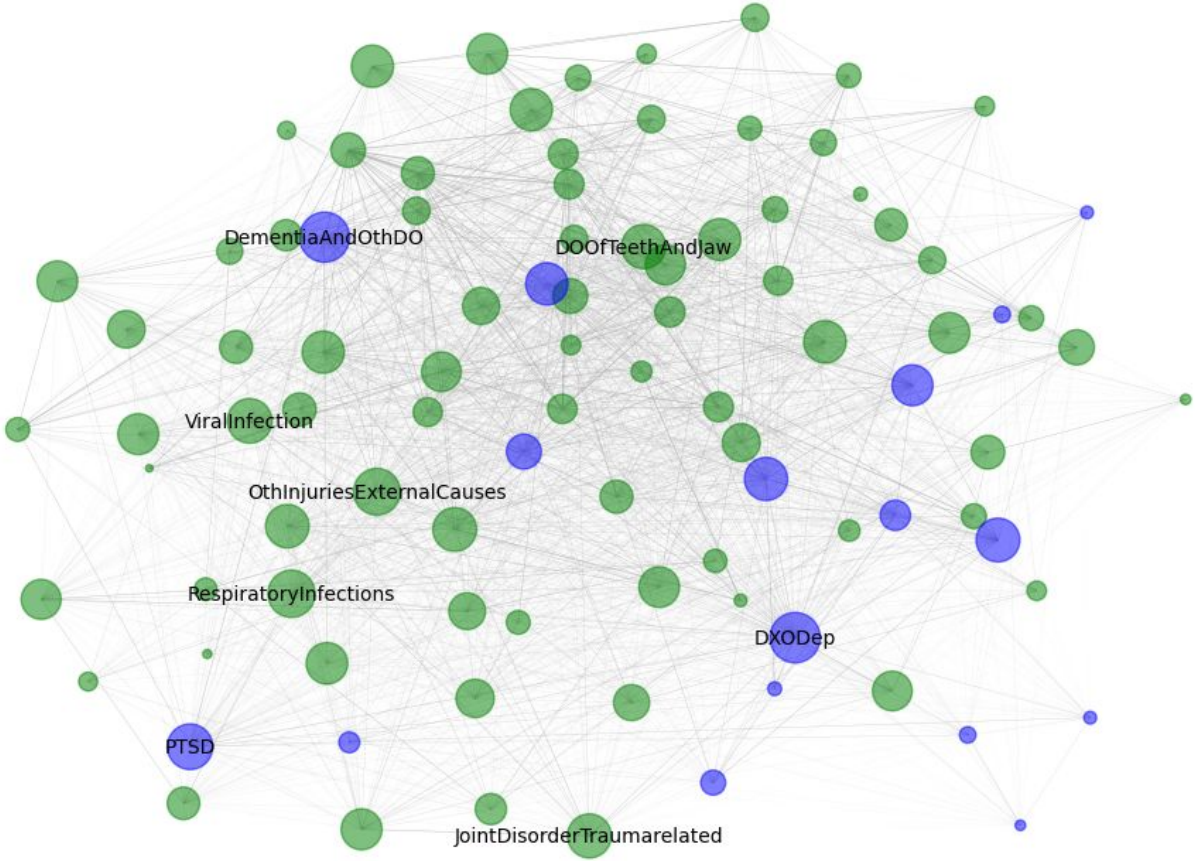
min = -12.36
max = 6.03
nonzero = 8930 (= 95x94)



After

min = 0.00
max = 6.03
nonzero = 3779




DementiaAndOthDO
DOOfTeethAndJaw
ViralInfection
OthInjuriesExternalCauses
RespiratoryInfections
DXODep
PTSD
JointDisorderTraumarelated

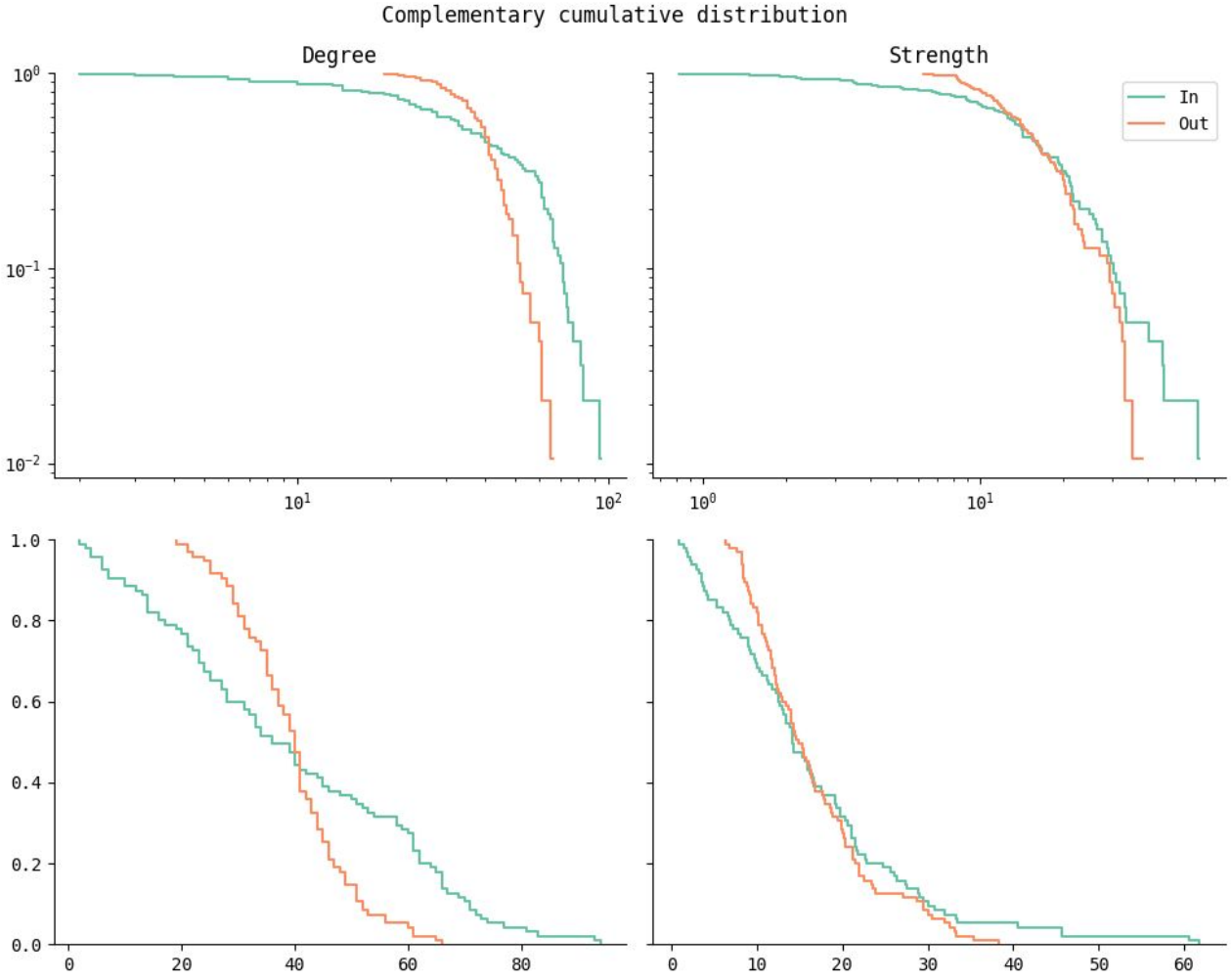
Network Properties

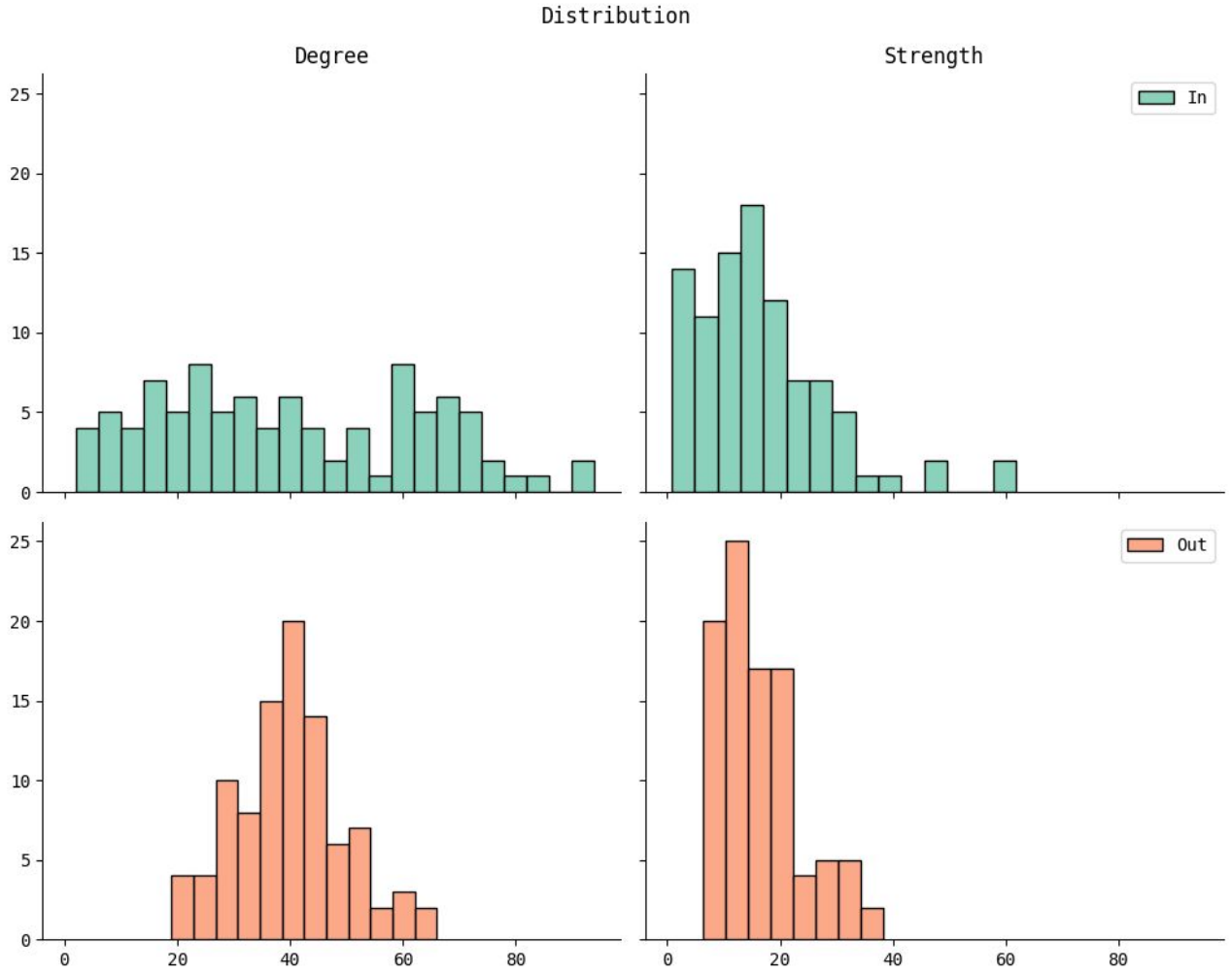
directed = True
weighted = True
nodes = 95
edges = 3779

selfloops = 0
WCCs = 1
SCCs = 1
density = 0.42 (= $3779/95^2$)

clustering = 0.59
diameter = 3
average shortest path = 1.61
assortativity = -0.09

property	min	max	mean
weight	0.02	6.03	0.42
in-degree	2	94	39.78
out-degree	19	66	39.78
in-strength	0.82	61.85	16.60
out-strength	6.26	38.37	16.60

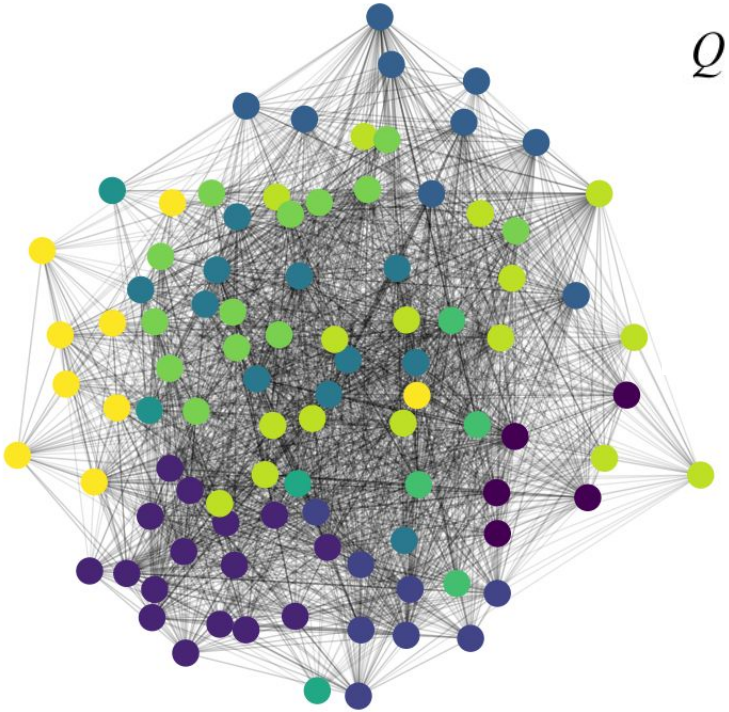

Complementary cumulative distribution
Degree
Strength
In
Out
10^0
10^{-1}
10^{-2}
10^1
10^2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
10
30
50


Distribution
Degree
Strength
In
Out
0
5
10
15
20
25
0
20
40
60
80

centrality	min	max	mean	top-3
in-degree	0.02	1.00	0.42	'DXODep' 'DementiaAndOthDO' 'RespiratoryInfections'
out-degree	0.20	0.70	0.42	'DisOfTheUrinarySystem' 'DisOfArteries' 'DisOfTheHeart'
eigenvector	0.00	0.19	0.09	'DXODep' 'DementiaAndOthDO' 'OthInjuriesExternalCauses'
katz	-0.16	0.31	0.01	'PancreaticDO' 'FluidAndElectrolyteDO' 'NoninfectiousGastroenterit0'
in-closeness	0.36	1.00	0.64	'DXODep' 'DementiaAndOthDO' 'RespiratoryInfections'
out-closeness	0.53	0.76	0.62	'DisOfTheUrinarySystem' 'DisOfArteries' 'DisOfTheHeart'
betweenness	0.00	0.02	0.01	'DXDRG' 'OthInjuriesExternalCauses' 'PersonalityDO'

Mesoscale Analysis

Louvain Community Detection Algorithm: 11 communities found.



Q = *(fraction of links internal to communities) -*
(expected fraction of such links)

$$= \frac{1}{2L} \sum_{C_h} \sum_{i,j \in C_h} \left[a_{ij} - \frac{k_i k_j}{2L} \right]$$

Modularity: 0.24

Community 1 (5 nodes):
{'COPDAndBronchiectasis_DT',
'OthLowerRespiratoryDs_DT',
`OthUpperRespiratoryDs_DT',
'RespiratoryInfections_DT',
'Asthma_DT'}

Community 2 (16 nodes):
{'Anemia_DT',
`BiliaryTractDs_DT',
'OthHematologicConditions_DT',
'DisOfTheHeart_DT',
'SystemicLupus_DT',
'IntestinalInfection_DT',
'LiverDs_DT', 'DisOfArteries_DT',
'DisOfWhiteBloodCells_DT',
'PancreaticDO_DT',
'CoagulationDO_DT',
'Pleurisy_DT',
'RespiratoryFailure_DT',
'BacterialInfection_DT',
'FluidAndElectrolyteDO_DT',
'DisOfTheUrinarySystem_DT'}

Community 3 (8 nodes):
{'OthGIDO_DT', `cancerdxDT',
'AbdominalHernia_DT',
'UpperGIDO_DT', 'GIHemorrhage_DT',
'LowerGIDO_DT', 'DisOfVeins_DT',
'NoninfectiousGastroenterit0'}

Community 4 (9 nodes):
{'SprainsAndStrains_DT',
'OthBoneDs_DT','EarConditions_DT',
'OthConnectiveTissueDs_DT',
'JointDisorderTraumarelated_DT',
'anomdxDT','AcquiredDeformities_DT',
'Spondylosis_DT',
'NontraumaticJointDO_DT'}

Community 5 (11 nodes):
{`SuperficialInjury_DT',
'CrushingInjuryOrInternalIn0',
'DOOfTeethAndJaw_DT',
'Fractures_DT', 'DisOfMouth_DT',
'OthInjuriesExternalCauses'',
'Burns_DT', 'OpenWounds_DT',
'SkinInfections_DT',
'EyeDO_DT', 'InfectiveArthritis_DT'}

Community 6 (2 nodes):
{'PathologicalFracture_D',
'Osteoporosis'}

Community 7 (2 nodes):
{'OthInfections', 'ImmunityDO'}

Community 8 (4 nodes):
{'Mycoses_DT', 'OthSkinDO_DT',
'ViralInfection_DT',
'OthInflamCondOfSkin'}

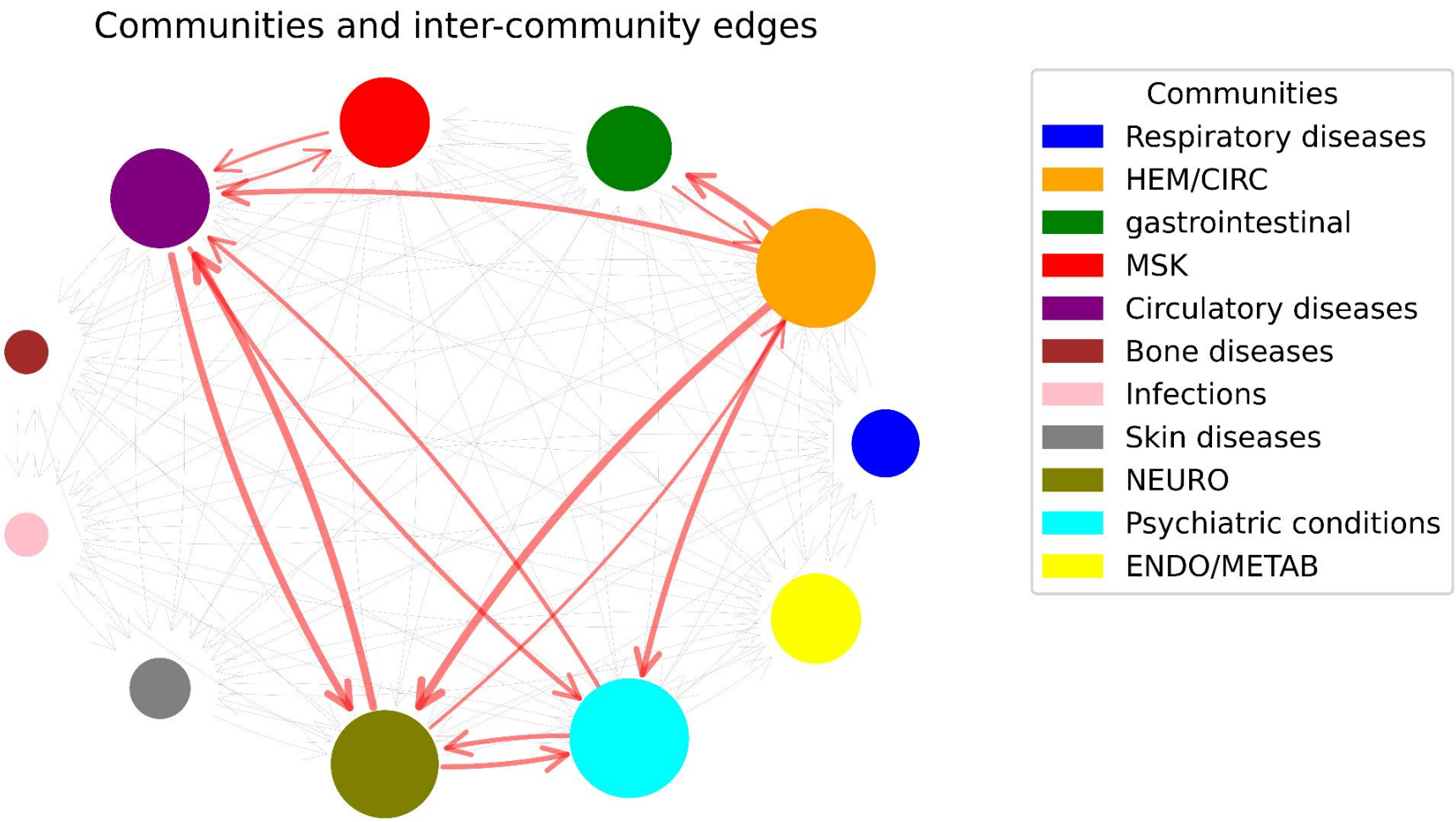
Community 9 (13 nodes):
{'IntracranialInjury_DT',
'Paralysis_DT',
'ComaBrainDamage_DT',
'OthNervousSystemDO_DT',
'Headache_DT',
'NSConditions_DT',
'EpilepsyConvulsions_DT',
'CerebrovascularDs_DT',
'DevelopmentalDO_DT',
'CNSInfection_DT',
'SpinalCordInjury_DT',
'ChronicUlcerOfSkin_DT',
'DementiaAndOthDO_DT'}

Community 10 (16 nodes):
{'ANXunsp_DT', 'MDD_DT',
'ImpulseControlDONEC_DT',
'SCHZ_DT',
'AdjustmentDO_DT',
'AFBPDX_DT', 'DXDRG_DT',
'PersonalityDO_DT',
'PTSD_DT', 'DXODep_DT',
'DXALC_DT', 'ANXgen_DT',
'AttentionDeficitDO_DT',
'DOInChildhood_DT',
'SuicideAndSelfInjury_DT',
'Poisoning_DT'}

Community 11 (9 nodes):
{'GoutAndOth_DT',
'OthNutritionalEndocrineDO_D',
'DOOfLipidMetabolism_DT',
'ThyroidDO_DT', 'genitaldxDT',
'OthEndocrineDO_DT',
'dmdxDT', 'Hypertension_DT',
'NutritionalDeficiencies_DT'}

What do communities represent?

Community_1 : Respiratory diseases
Community_2 : HEM/CIRC
Community_3 : gastrointestinal
Community_4 : MSK
Community_5 : Mixed Injury and Disorders
Community_6 : Bone diseases
Community_7 : Infections
Community_8 : Skin diseases
Community_9 : NEURO
Community_10 : Psychiatric conditions
Community_11 : ENDO/METAB


Communities and inter-community edges
Communities
Respiratory diseases
HEM/CIRC
gastrointestinal
MSK
Circulatory diseases
Bone diseases
Infections
Skin diseases
NEURO
Psychiatric conditions
ENDO/METAB

Who are the predictors?

Weighted edges entering Community_10:

Community_6: 2.21
Community_7: 3.94
Community_8: 8.56
Community_1: 8.83
Community_4: 9.67
Community_3: 12.10
Community_11: 16.29
Community_5: 32.72
Community_9: 34.86
Community_2: 41.86

In-strengths for Community_10: 171.03

Weighted edges entering Community_5:

Community_11: 3.05
Community_7: 5.95
Community_1: 7.18
Community_3: 7.86
Community_6: 8.50
Community_8: 10.01
Community_4: 23.06
Community_10: 28.87
Community_2: 35.76
Community_9: 54.14

In-strengths for Community_5: 184.37

Weighted edges entering Community_9:

Community_7: 2.76
Community_8: 3.24
Community_1: 3.64
Community_11: 7.66
Community_3: 9.72
Community_4: 12.28
Community_6: 13.60
Community_10: 32.01
Community_5: 49.64
Community_2: 55.58

In-strengths for Community_9: 190.12

Reference and possible improvements

the paper
http://dx.doi.org/10.1098/rspa.2019.0790

the data
https://github.com/aaronab/comorbidity_networks/

our code
https://github.com/CristinaLiccia/co-morbidity-network-analysis