## Assignment 3

1. Using your favorite software for finding eigenvectors of matrices, construct the Laplacian and the modularity matrix for this small network:
a. Find the eigenvector of the Laplacian corresponding to the second smallest eigenvalue and perform a spectral bisection of the network into two equally sized parts.
b. Find the eigenvector of the modularity matrix corresponding to the largest eigenvalue and divide the network into two communities.
2. Generate random networks using random.graph.game, measure their metrics (such as clustering coefficient, degree distribution, ...), and discuss the disagreements between random networks and real networks. Please use the table in the next page for the discussion.

- Deadline: Feb. 6, 2012(Mon) 13:20


# metrics in real networks <br> s : the size of the largest component as a fraction of total network size 

|  | network | type | $n$ | $m$ | $z$ | $\ell$ | $\alpha$ | $C^{(1)}$ | $C^{(2)}$ | $r$ | Ref(s). | S |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | film actors | undirected | 449913 | 25516482 | 113.43 | 3.48 | 2.3 | 0.20 | 0.78 | 0.208 | 20, 416 | 0.980 |
| $\begin{aligned} & \text { तु } \\ & \text { 융 } \end{aligned}$ | company directors | undirected | 7673 | 55392 | 14.44 | 4.60 | - | 0.59 | 0.88 | 0.276 | 105, 323 | 0.876 |
|  | math coauthorship | undirected | 253339 | 496489 | 3.92 | 7.57 | - | 0.15 | 0.34 | 0.120 | 107, 182 | 0.822 |
|  | physics coauthorship | undirected | 52909 | 245300 | 9.27 | 6.19 | - | 0.45 | 0.56 | 0.363 | 311, 313 | 0.838 |
|  | biology coauthorship | undirected | 1520251 | 11803064 | 15.53 | 4.92 | - | 0.088 | 0.60 | 0.127 | 311, 313 | 0.918 |
|  | telephone call graph | undirected | 47000000 | 80000000 | 3.16 |  | 2.1 |  |  |  | 8, 9 | - |
|  | email messages | directed | 59912 | 86300 | 1.44 | 4.95 | 1.5/2.0 |  | 0.16 |  | 136 | 0.952 |
|  | email address books | directed | 16881 | 57029 | 3.38 | 5.22 | - | 0.17 | 0.13 | 0.092 | 321 | 0.590 |
|  | student relationships | undirected | 573 | 477 | 1.66 | 16.01 | - | 0.005 | 0.001 | -0.029 | 45 | 0.503 |
|  | sexual contacts | undirected | 2810 |  |  |  | 3.2 |  |  |  | 265, 266 | - |
|  | WWW nd.edu | directed | 269504 | 1497135 | 5.55 | 11.27 | 2.1/2.4 | 0.11 | 0.29 | -0.067 | 14, 34 | 1.000 |
|  | WWW Altavista | directed | 203549046 | 2130000000 | 10.46 | 16.18 | 2.1/2.7 |  |  |  | 74 | 0.914 |
|  | citation network | directed | 783339 | 6716198 | 8.57 |  | 3.0/- |  |  |  | 351 | - |
|  | Roget's Thesaurus | directed | 1022 | 5103 | 4.99 | 4.87 | - | 0.13 | 0.15 | 0.157 | 244 | 0.977 |
|  | word co-occurrence | undirected | 460902 | 17000000 | 70.13 |  | 2.7 |  | 0.44 |  | 119, 157 | 1.000 |
|  | Internet | undirected | 10697 | 31992 | 5.98 | 3.31 | 2.5 | 0.035 | 0.39 | -0.189 | 86, 148 | 1.000 |
|  | power grid | undirected | 4941 | 6594 | 2.67 | 18.99 | - | 0.10 | 0.080 | -0.003 | 416 | 1.000 |
| $8$ | train routes | undirected | 587 | 19603 | 66.79 | 2.16 | - |  | 0.69 | -0.033 | 366 | 1.000 |
| $\stackrel{\circ}{0}$ | software packages | directed | 1439 | 1723 | 1.20 | 2.42 | 1.6/1.4 | 0.070 | 0.082 | -0.016 | 318 | 0.998 |
| चु | software classes | directed | 1377 | 2213 | 1.61 | 1.51 | - | 0.033 | 0.012 | -0.119 | 395 | 1.000 |
|  | electronic circuits | undirected | 24097 | 53248 | 4.34 | 11.05 | 3.0 | 0.010 | 0.030 | -0.154 | 155 | 1.000 |
|  | peer-to-peer network | undirected | 880 | 1296 | 1.47 | 4.28 | 2.1 | 0.012 | 0.011 | -0.366 | 6,354 | 0.805 |
| . | metabolic network | undirected | 765 | 3686 | 9.64 | 2.56 | 2.2 | 0.090 | 0.67 | $-0.240$ | 214 | 0.996 |
|  | protein interactions | undirected | 2115 | 2240 | 2.12 | 6.80 | 2.4 | 0.072 | 0.071 | -0.156 | 212 | 0.689 |
|  | marine food web | directed | 135 | 598 | 4.43 | 2.05 | - | 0.16 | 0.23 | -0.263 | 204 | 1.000 |
|  | freshwater food web | directed | 92 | 997 | 10.84 | 1.90 | - | 0.20 | 0.087 | -0.326 | 272 | 1.000 |
|  | neural network | directed | 307 | 2359 | 7.68 | 3.97 | - | 0.18 | 0.28 | -0.226 | 416, 421 | 0.967 |

TABLE II Basic statistics for a number of published networks. The properties measured are: type of graph, directed or undirected; total number of vertices $n$; total number of edges $m$; mean degree $z$; mean vertex-vertex distance $\ell$; exponent $\alpha$ of degree distribution if the distribution follows a power law (or "-" if not; in/out-degree exponents are given for directed graphs); clustering coefficient $C^{(1)}$ from Eq. (3); clustering coefficient $C^{(2)}$ from Eq. (6); and degree correlation coefficient $r$, Sec. III.F.

M. Newman "The structure and function of complex networks" http://arxiv.org/abs/cond-mat/0303516

## Instructions for submission (1)

- Submit your assignment to 5-8 report box at the passage on the third floor between $\quad$ A4 size
- Use A4 size papers
- Please staple in the upper left corner
- Write your name and student ID number
- Electronic submission (sending by email) is allowed for the students from Suzukakedai.


## Submit to the right box



## Instructions for submission (2)

- Students from Suzukakedai campus are allowed to submit this assignment by email. Attach PDF or MS Word file and sent it to cn@ai.cs.titech.ac.jp. Size of the attached file should be less than 2MB. Subject of the email should be "[cn]".

