Simple Network Analysis with MatLab

Gergana Bounova

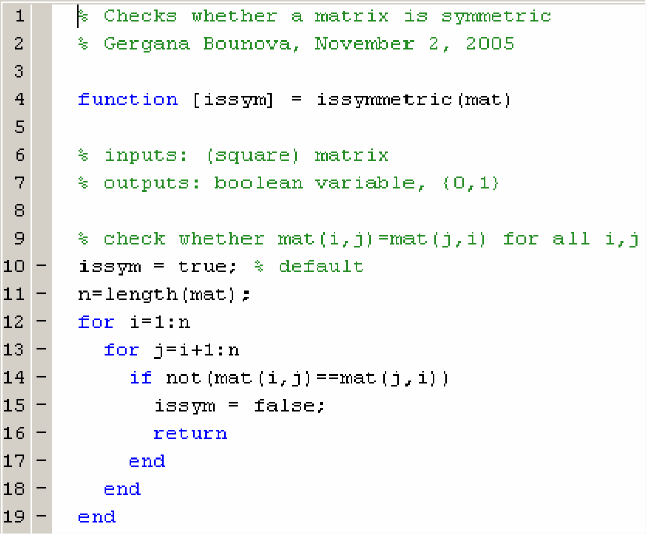
ESD.342

February 23, 2006

MatLab Basics

- Official MathWorks tutorial:
  http://www.mathworks.com/academia/student_center/tutorials/launchpad.html
- List of all MatLab functions
  http://www.mathworks.com/support/functions/alpha_list.html
  - Search by name, topic, description
- MatLab prompt:

  ```
  >> date
  >> help 'what'
  >> lookfor 'something'
  >> help lookfor
   LOOKFOR Search all M-files for keyword.
   See also dir, help, who, what, which.
  >> diary (filename,on,off)
  >> load mydata.mat
  >> type filename.m (.txt)
  ```
- Loading data: ExcelLink, etc



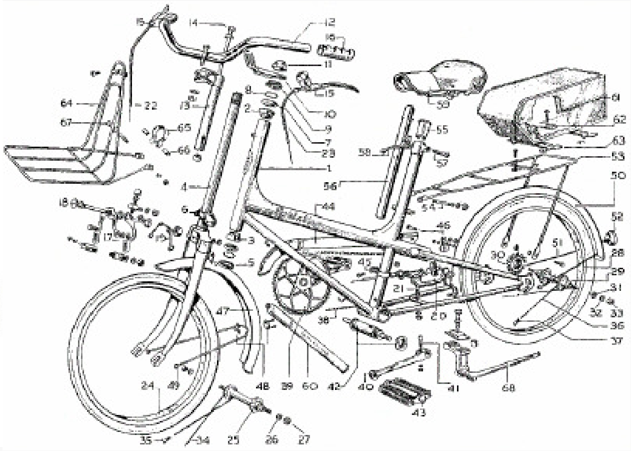
```
% Checks whether a matrix is symmetric
% Gergana Bounova, November 2, 2005

function [issym] = issymmetric(mat)

% inputs: (square) matrix
% outputs: boolean variable, {0,1}

% check whether mat(i,j)=mat(j,i) for all i,j
issym = true; % default
n=length(mat);
for i=1:n
  for j=i+1:n
    if not(mat(i,j)==mat(j,i))
      issym = false;
      return
    end
  end
end
```

Working Example: Bike



- References: Daniel Whitney, "Degree Correlations and Motifs in Technological Networks", Source: http://esd.mit.edu/WPS/esd-wp-2005-10.pdf

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Graph Representation in MatLab

- Depends on what you are going to do! Computation, extracting data/properties, visualization…
- Adjacency matrix A
  - node by node (nxn), if i and j are connected A(i,j)=1, otherwise A(i,j)=0; for multiple edges A(i,j)=2,3,…
  - sum(A) = graph degree sequence (self-loops give an exception)
- Incidence matrix C
  - node by edge (nxm), if node i is an endpoint for edge j, then C(i,j)=1, otherwise C(i,j)=0
  - sum(C) = [2 2 2 …2] – every edge has 2 endpoints
  - Cool formula: $A = C\text{x}C^T - 2I$
- List: every node points to the nodes it's connected to
- Text: for other programs input (Pajek)

```
01110000000000000000000000001010000000000100100100000000000000000000000000000000000000000000000001000000001110000110111111010000110011
10010010000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
10010000100000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
11101111111110100000000010100000000100110000000000000000000000000000000000000000000000000000000000000000000000101100000000000000000000
00010100010000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00011000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
01010001000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00010010001000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00110000010000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00011000100000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00010001000100000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00010000001010000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00010000000100000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000100000111100000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00010000000001011011000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000101100000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
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00010000000000000000000000000000000101000000000000000000000000000000000000000000000000000000000000000000000000010000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000111111111100000000000000000000000000000000000000000
10000000000000000000000000000000000000000011111110000000000000000000001111111110000000000000000000000000000000001000000000000000000
00000000000000000000000000000000000000000101000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000110000000000000000000000000000000000000000000000001000000000000000000000000000000000000000
10000000000000000000000000000000000000000100010000000000000000000000000000000000000000000000000000000000000000001000000000000000000
```

MatLab Code I

```
>> clear all

>> % Load bike data
>> load bike_data
>> who

>> size(adj_bike)
>> size(deg_bike)
>> deg_bike – sum(adj_bike)

>> % Graph Representations **************************************************
>> inc = adj2inc(adj_bike);
>> size(inc)
>> sum(inc)   % should give a vector of 2s

>> % num_edges = sum(sum(adj_bike))/2 for an undirected graph
>> % should be same as second dimension of incidence matrix
>> numedges = num_edges(adj_bike)

>> % Lists
>> str = adj2str(adj_bike);
>> % number of children and number of degrees should be the same
>> str(1).child
>> degrees(1)
```

Graph Diagnostics

- issymmetric.m: $A=A^T$?
- issimple.m: are there self-loops or double edges?
- isdirected: $A=A^T$?
- isconnected.m: is there a path from every node to every other node?
- issparse.m: k << n$_x$m, k – # of non-zero entries
- All of the above return Boolean variables

MatLab Code II

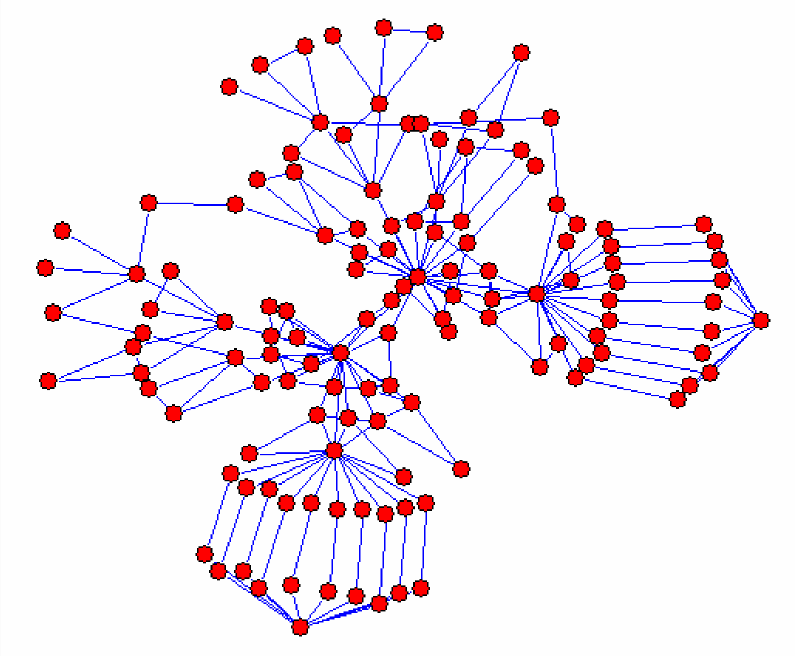
```
>> issymmetric(adj_bike)
ans =

    1
>> issimple(adj_bike)
ans =

    1
>> isdirected(adj_bike)
ans =

    0
>> isconnected(adj_bike)
ans =

    1
```



bikenet (Pajek)

Gergana Bounova
ESD.342
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Graph Properties

LOCAL

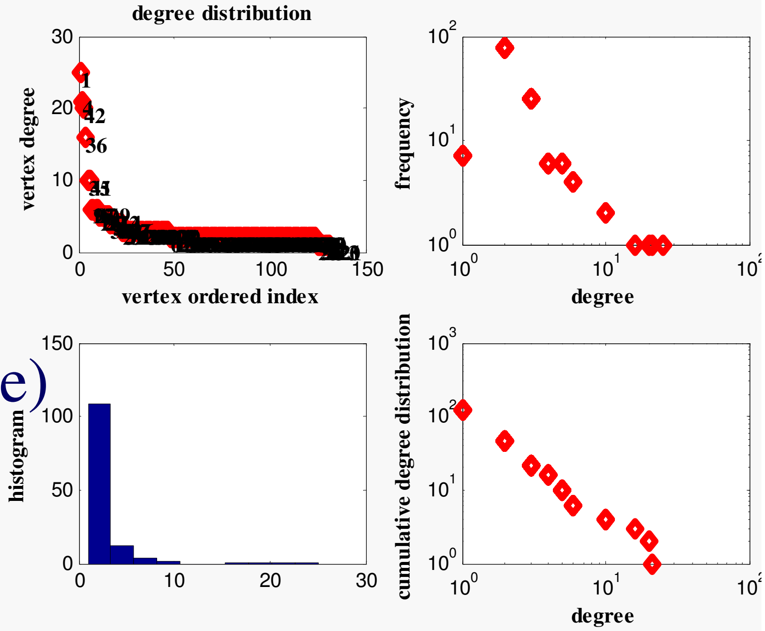
- shortest path (i-j)
- betweenness (i)
- degree (ave, max, in-out)
- clustering coefficient (i)
- harmonic path length (i-j)
- number of k-neighbors (i)

GLOBAL

- mean path length
- betweenness distribution
- degree distributions
- mean clustering coeff.
- mean harmonic path
- k-neighbors distribution
- diameter

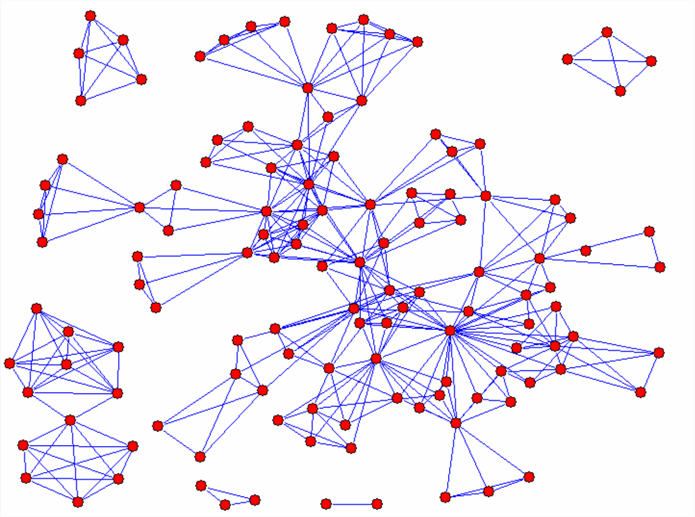
MatLab Code III

```
>> degree_dist(adj_bike)
>> clust_coeff(adj_bike)
ans = 0.3933
>> diagnose_powerlaw?
>>ave_path_length(adj_bike)
ans = 0.9973
>> diameter(adj_bike)
ans = 9
```



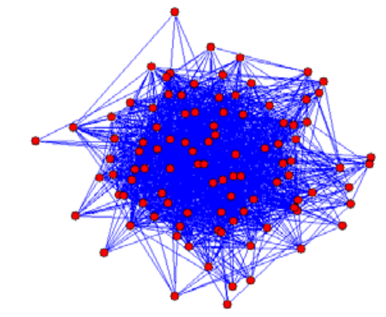
degree_dist.m

Graph Construction/Structure



- min spanning tree
- connected components
- dual graphs (dual.m)
- subgraph and motifs
- growth models
  - Random, preferential, min-cost, max-span
  - k-regular graphs
  - random_graph.m

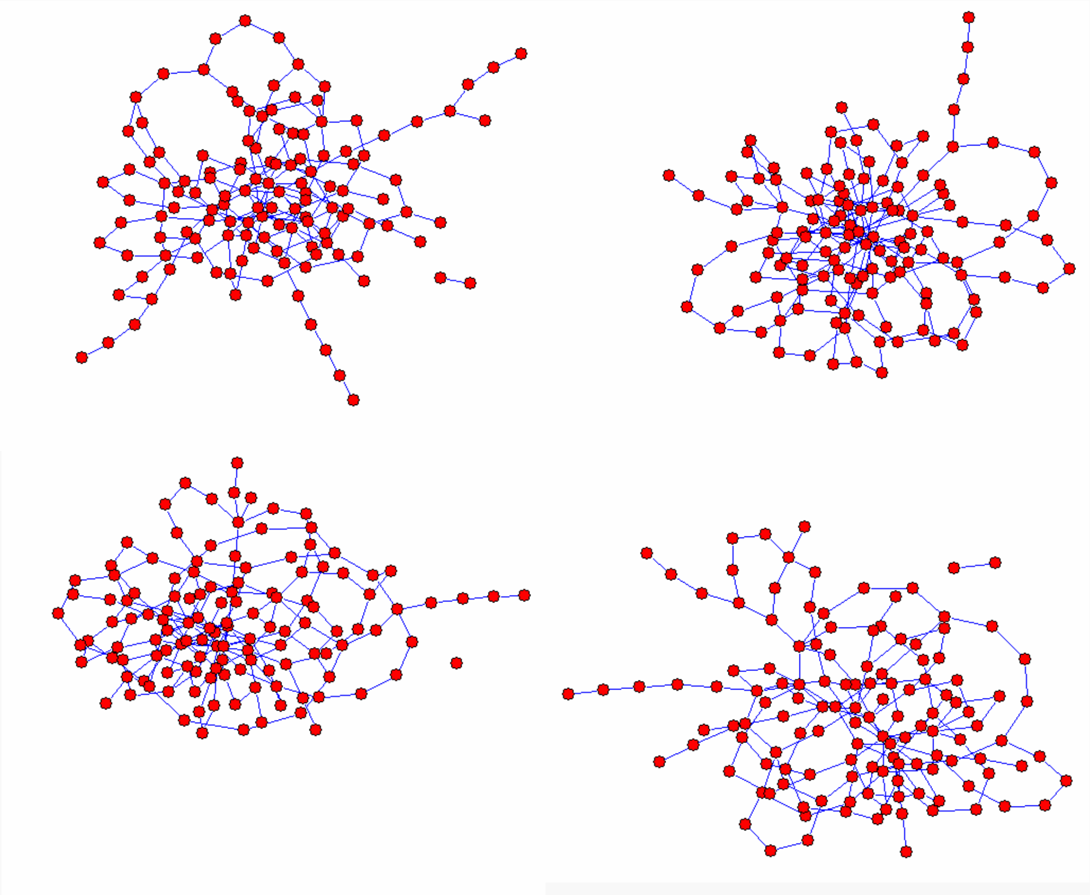
MatLab Code IV: Random Graphs



```
>> adj = random_graph(10)
>> adj = random_graph(10,0.1)
>> adj = random_graph(10,0.1,20)
>> adj = random_graph(10,0.1,20,'normal')
>> adj  = random_graph(10,0.1,20,'custom',@mypdf)
>> degrees = [3 1 1 1];
>> adj = graph_from_degrees(degrees)
```

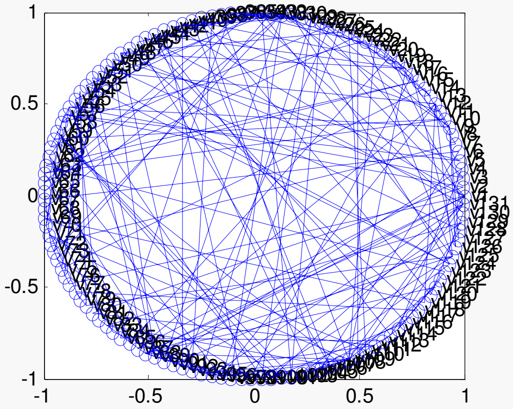
- 2 versions
- ~ 50% success rate (in producing simple graphs)

Bike Distribution Random Graphs



Network Visualization - Pajek

- http://vlado.fmf.uni-lj.si/pub/networks/pajek/
- draw_circ_graph.m



- MatLab-Pajek:

```
>> adj2pajek(adj,'graph.net')
```

- Open graph.net in Pajek
- Gtrl + G

Specialized (Engineering) Metrics

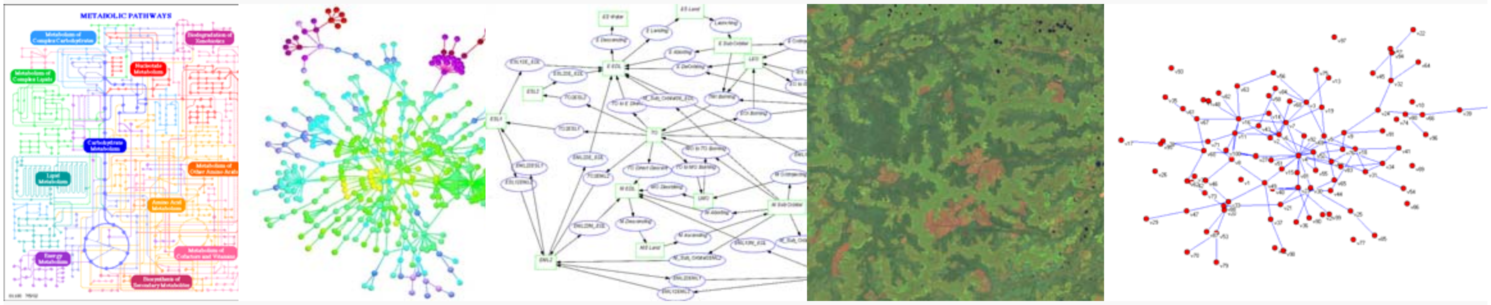
- Robustness:
  - Topological: if you knock out x% of nodes/edges, how many % survive
  - Functional: by how much (%-wise) function degrades
- Span, coverage, geometry considerations
- Cost, performance
  - total launch mass (space), network throughput, comm link costs, number of cities served

Off the Shelf (MatLab Functions)

- dist, pdist, linkage, dendrogram, cluster, kmeans
- Simulink (circuits), neural net toolbox, comp bio toolbox
- Statistics toolbox: distributions
- List of all MatLab functions http://www.mathworks.com/support/functions/alpha_list.html

Your Own Toolbox

- Write functions
- Save them in the same directory
- Set workpath (accessible from anywhere)
- Have Fun!



Appendix: tutorial.m

```
% MatLab tutorial script
% Gergana Bounova, February 22, 2006

clear all

% Load bike data
load bike_data
who

size(adj_bike)
size(deg_bike)

% Graph Representations ********************************
inc = adj2inc(adj_bike);
size(inc)
sum(inc)   % should give a vector of 2s

% num_edges = sum(sum(adj_bike))/2 for an undirected graph
% should be same as second dimension of incidence matrix
numedges = num_edges(adj_bike)

% Lists
str = adj2str(adj_bike);
% number of children and number of degrees should be the same
str(1).child
degrees(1)
```

```
% Graph Diagnostics ***********************************
issymmetric(adj_bike)
issimple(adj_bike)
isdirected(adj_bike)
isconnected(adj_bike)

% Global metrics
degree_dist(adj_bike)
clust_coeff(adj_bike)
diameter(adj_bike)
ave_path_length(adj_bike)
betweenness(adj_bike)
harmonic_path_length(adj_bike)


% Graph construction ***********************************
random_graph(10)
random_graph(10,0.1,20)
random_graph(10,0,0,'normal')
random_graph(10,0,0,'custom',@mypdf)
degs = [3 1 1 1];
random_graph(10,0,0,'custom',@mypdf,degs)
adj_bike1 = graph_from_degrees(degs);


% Graph visualization ***********************************
adj2pajek(adj_bike,'bike.net');
```