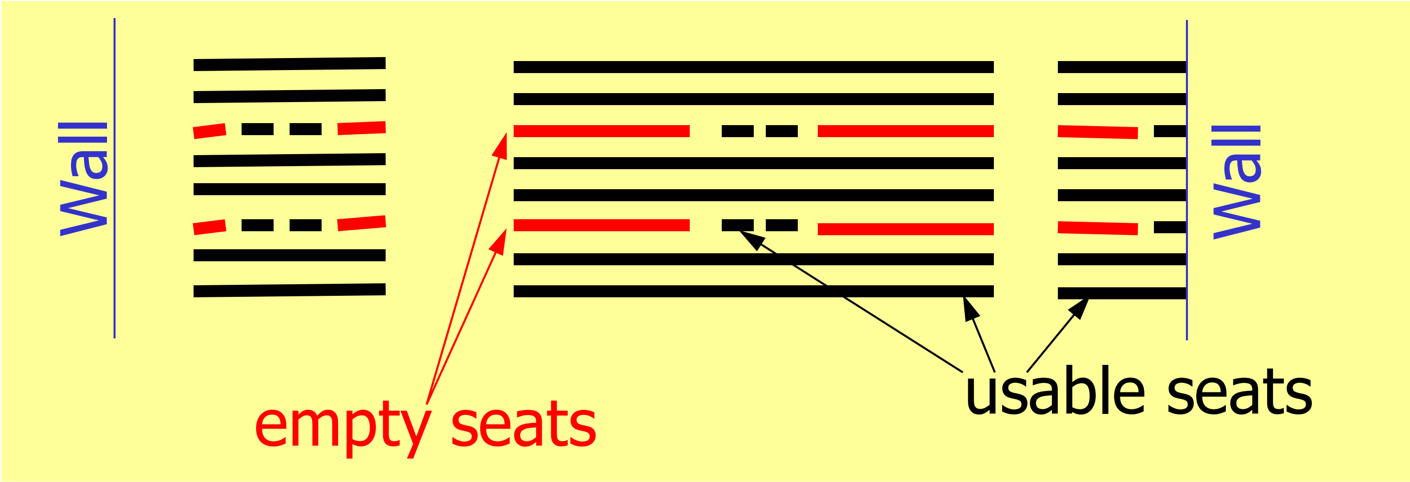
Try to leave every 3rd row (mostly) empty



- Prelim 1 tonight 7:30 PM
  - NetID ends in 0-6: Olin Hall 155
  - NetID ends in 7-9: Olin Hall 165

```
if rem(row, 3)==0
    % skip row
end
```

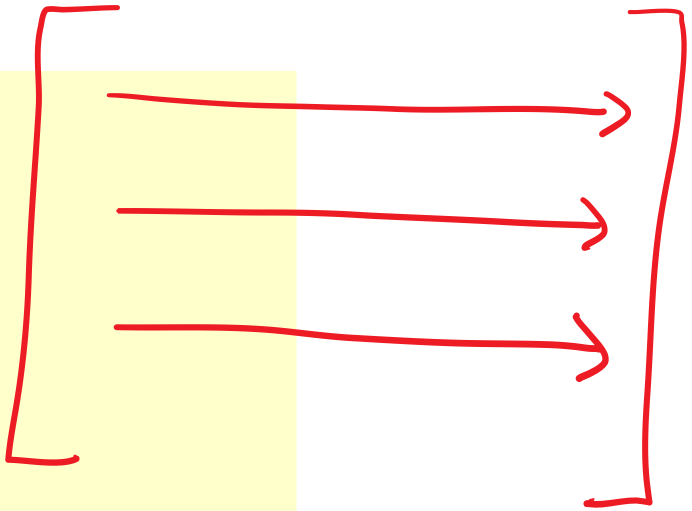
- Previous Lecture:
  - Introduction to 2-d array—*matrix*

- Today, Lecture 14:
  - Examples on computing with matrices
  - Optional reading: contour plot (7.2, 7.3 in *Insight*)

- Announcements:
  - Prelim 1 tonight at 7:30pm
    - Olin Hall 155 & 165
  - Discussion section in Upson 225 computer lab this week

Pattern for traversing a matrix M

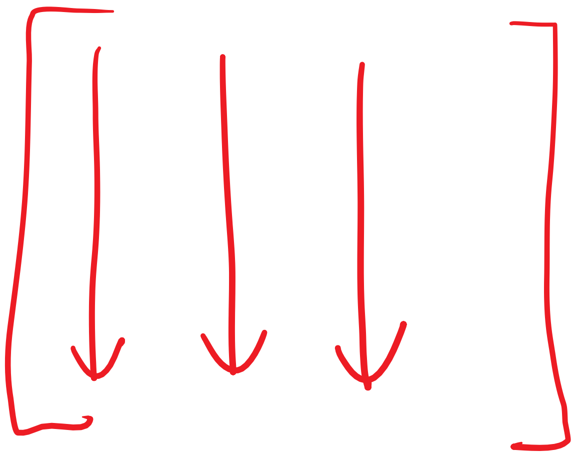
```
[nr, nc] = size(M)
for  r= 1:nr
      % At row r
      for  c= 1:nc
            % At column c (in row r)
            %
            % Do something with M(r,c) …
      end
end
```



Exercise: what's different about this version?

```
function val = minInMatrix(M)

val= M(1,1);
[nr, nc] = size(M);
for c = 1:nc
    for r = 1:nr
        if M(r,c) < val
            val= M(r,c);
        end
    end
end
```

- A: Nothing (identical to previous version)
- B: Searches elements in a different order
- C: Index-out-of-bounds if M is not square
- D: Doesn't correctly return minimum

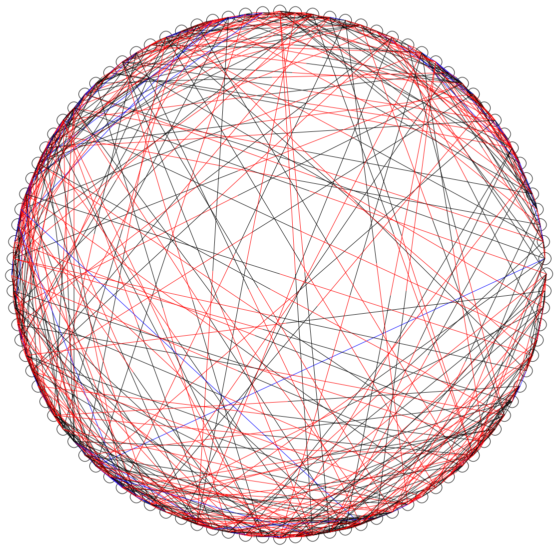


Storing and using data in *tables*

A merchant has 3 suppliers that stock 5 products with these costs:

10	36	22	15	62
12	35	20	12	66
13	37	21	16	59

What is the best way to fill a given purchase order?



Connections between webpages

0	0	1	0	1	0	0
1	0	0	1	1	1	0
0	1	0	1	1	1	1
1	0	1	1	0	1	0
0	0	1	1	0	1	1
0	0	1	0	1	0	1
0	1	1	0	1	1	0

A Cost/Inventory Problem

- A merchant has 3 supplier warehouses that stock 5 different products
- The cost of a product varies from warehouse to warehouse
- The inventory varies from warehouse to warehouse

Problems

A customer submits a purchase order that is to be shipped from a single warehouse.

1. How much would it cost a warehouse to fill the order?
2. Does a warehouse have enough inventory to fill the order?
3. Among the warehouses that can fill the order, who can do it most cheaply?

Available data

`C(i,j)` is what it costs warehouse i to supply product j

C

10	36	22	15	62
12	35	20	12	66
13	37	21	16	59

`Inv(i,j)` is the inventory in warehouse i of product j

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

`PO(j)` is the number of product j's that the client wants

PO

1	0	12	29	5

C	10	36	22	15	62
	12	35	20	12	66
	13	37	21	16	59

PO	1	0	12	29	5

Cost for warehouse 1:

1*10 + 0*36 + 12*22 + 29* 15 + 5*62

C

10	36	22	15	62
12	35	20	12	66
13	37	21	16	59

PO

1	0	12	29	5

Cost for warehouse 1:

```
s = 0;   %Sum of cost
for j=1:5
   s = s + C(1,j)*PO(j)
end
```

C	10	36	22	15	62
	12	35	20	12	66
	13	37	21	16	59

PO	1	0	12	29	5

Cost for warehouse 2:

```
s = 0;   %Sum of cost
for j=1:5
   s = s + C(2,j)*PO(j)
end
```

C

10	36	22	15	62
12	35	20	12	66
13	37	21	16	59

PO

1	0	12	29	5

Cost for warehouse i:

```
s = 0;   %Sum of cost
for j=1:5
   s = s + C(i,j)*PO(j)
end
```

Encapsulate…

```
function  theBill = iCost(i,C,PO)
% The cost when warehouse i fills the
% purchase order

nProd= length(PO);  or size(c,2)
theBill= 0;
for j = 1:nProd
   theBill= theBill + C(i,j)*PO(j);
end
```

Finding the Cheapest

Both which warehouse and how cheap

```
iBest= 0;  minBill= inf;
for i = 1:nSuppliers
    iBill= iCost(i,C,PO);
    if iBill < minBill
        % Found an Improvement
        iBest= i; minBill= iBill;
    end
end
```

Aside: floating-point “bonus numbers”

- `inf`: Represents “infinity”
  - Both positive and negative versions
  - Larger (or smaller) than any other number
  - Generated on overflow or when dividing by zero
- `nan`: Not-a-number
  - Not equal to anything (even itself)
  - Not greater-than or less-than anything (even `inf`)
  - Generated from `0/0`, `inf*0`, …
  - If involved in mathematical operation, result will be nan

Inventory/Capacity Considerations

What if a warehouse lacks the inventory to fill the purchase order?

Such a warehouse should be excluded from the find-the-cheapest computation.

Who Can Fill the Order?

Inv	38	5	99	34	42	Yes
	82	19	83	12	42	No
	51	29	21	56	87	Yes

PO	1	0	12	29	5

Wanted: A True/False Function

DO is "true" if warehouse i can fill the order.

DO is "false" if warehouse i cannot fill the order.

Example: Check inventory of warehouse 2

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

PO

1	0	12	29	5

Method 1: check the inventory for every product

Initialization

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

DO 1

PO

1	0	12	29	5

Still True…

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

DO 1

PO

1	0	12	29	5

```
DO = DO && ( Inv(2,1) >= PO(1) )
```

Still True…

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

DO 1

PO

1	0	12	29	5

`DO = DO && ( Inv(2,2) >= PO(2) )`

Still True…

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

DO 1

PO

1	0	12	29	5

```
DO = DO && ( Inv(2,3) >= PO(3) )
```

No Longer True…

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

DO 0

PO

1	0	12	29	5

```
DO = DO && ( Inv(2,4) >= PO(4) )
```

Stay False…

Inv

38	5	99	34	42
82	19	83	12	42
51	29	21	56	87

DO 0

PO

1	0	12	29	5

```
DO = DO && ( Inv(2,5) >= PO(5) )
```

Encapsulate…

```
function  DO = iCanDo(i,Inv,PO)
% DO is true if warehouse i can fill
% the purchase order. Otherwise, false

nProd= length(PO);
DO= 1;
for j = 1:nProd
     DO= DO && ( Inv(i,j) >= PO(j) );
end
```

Encapsulate…

```
function  DO = iCanDo(i,Inv,PO)
% DO is true if warehouse i can fill
% the purchase order. Otherwise, false
nProd= length(PO);
j= 1;
while j<=nProd && Inv(i,j)>=PO(j)
   j= j + 1;
end
DO= __________;
```

Method 2: stop as soon as you find one product for which there isn't enough inventory

Encapsulate…


```
function  DO = iCanDo(i,Inv,PO)
% DO is true if warehouse i can fill
% the purchase order. Otherwise, false
nProd= length(PO);
j= 1;
while j<=nProd && Inv(i,j)>=PO(j)
   j= j + 1;
end
DO= _________;
```

DO should be true when…

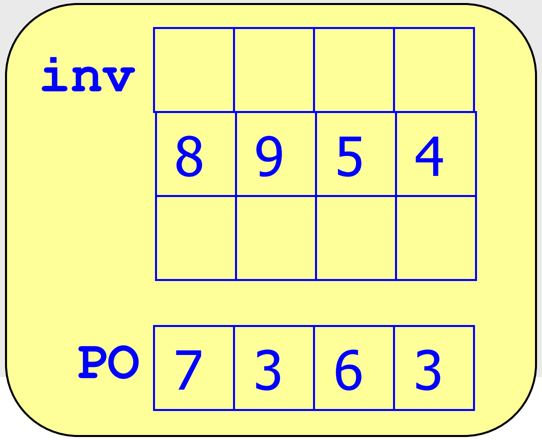
A `j < nProd`

B `j == nProd`

C `j > nProd`

Encapsulate…

```
function  DO = iCanDo(i,Inv,PO)
% DO is true if warehouse i can fill
% the purchase order. Otherwise, false
nProd= length(PO);
j= 1;
while j<=nProd && Inv(i,j)>=PO(j)
   j= j + 1;
end
DO= (j>nProd);
```



Back To Finding the Cheapest

```
iBest= 0; minBill= inf;
for i = 1:nSuppliers
    iBill= iCost(i,C,PO);
    if iBill < minBill
        % Found an Improvement
        iBest= i; minBill= iBill;
    end
end
```

Don't bother with this unless there is sufficient inventory.

Back To Finding the Cheapest

```
iBest= 0; minBill= inf;
for i = 1:nSuppliers
    if iCanDo(i,Inv,PO)
      iBill= iCost(i,C,PO);
      if iBill < minBill
      % Found an Improvement
         iBest= i; minBill= iBill;
      end
    end
end
```

See `Cheapest.m`
for alternative implementation

Finding the Cheapest

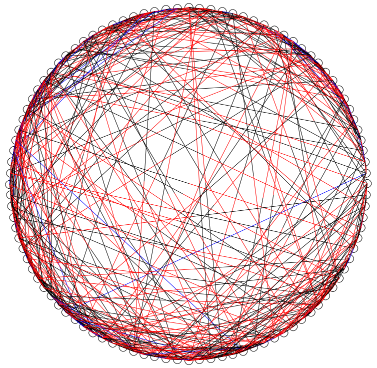
	10	36	22	15	62	1019	Yes
C	12	35	20	12	66	930	No
	13	37	21	16	59	1040	Yes

PO	1	0	12	29	5

As computed by `iCost`

As computed by `iCanDo`

Matrix example: Random Web



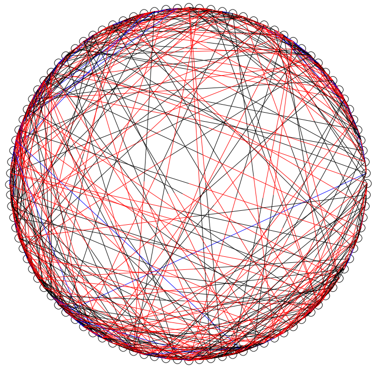
- N web pages can be represented by an N-by-N Link Array A.
- A(i,j) is 1 if there is a link on webpage j to webpage i

Page 4 links to Page 2

0	0	1	0	1	0	0
1	0	0	1	1	1	0
0	1	0	1	1	1	1
1	0	1	1	0	1	0
0	0	1	1	0	1	1
0	0	1	0	1	0	1
0	1	1	0	1	1	0

But Page 2 does not link back to Page 4

Matrix example: Random Web



- N web pages can be represented by an N-by-N Link Array A.
- A(i,j) is 1 if there is a link on webpage j to webpage i
- **Generate a random link array** and display the connectivity:
  - There is no link from a page to itself
  - If i≠j then A(i,j) = 1 with probability $\frac{1}{1+|i-j|}$

$$\begin{array}{c|cccc} & & & j & \\ \hline & 0 & & & \\ i & & 0 & & \\ & & & 0 & \\ & & & & 0 \end{array}$$

There is more likely to be a link if i is close to j

```
function A = RandomLinks(n)
% A is n-by-n matrix of 1s and 0s
% representing n webpages

A= zeros(n,n);  % initialize to 0s
for i = 1:n
  for j = 1:n
    % if A(i,j) not on diagonal,
    % assign 1 with some probability




  end
end
```

An event happens with probability p, 0<p<1

```
% Flip a fair coin
r= rand();
if r < .5
   disp('heads')
else
   disp('tails')
end
```

p

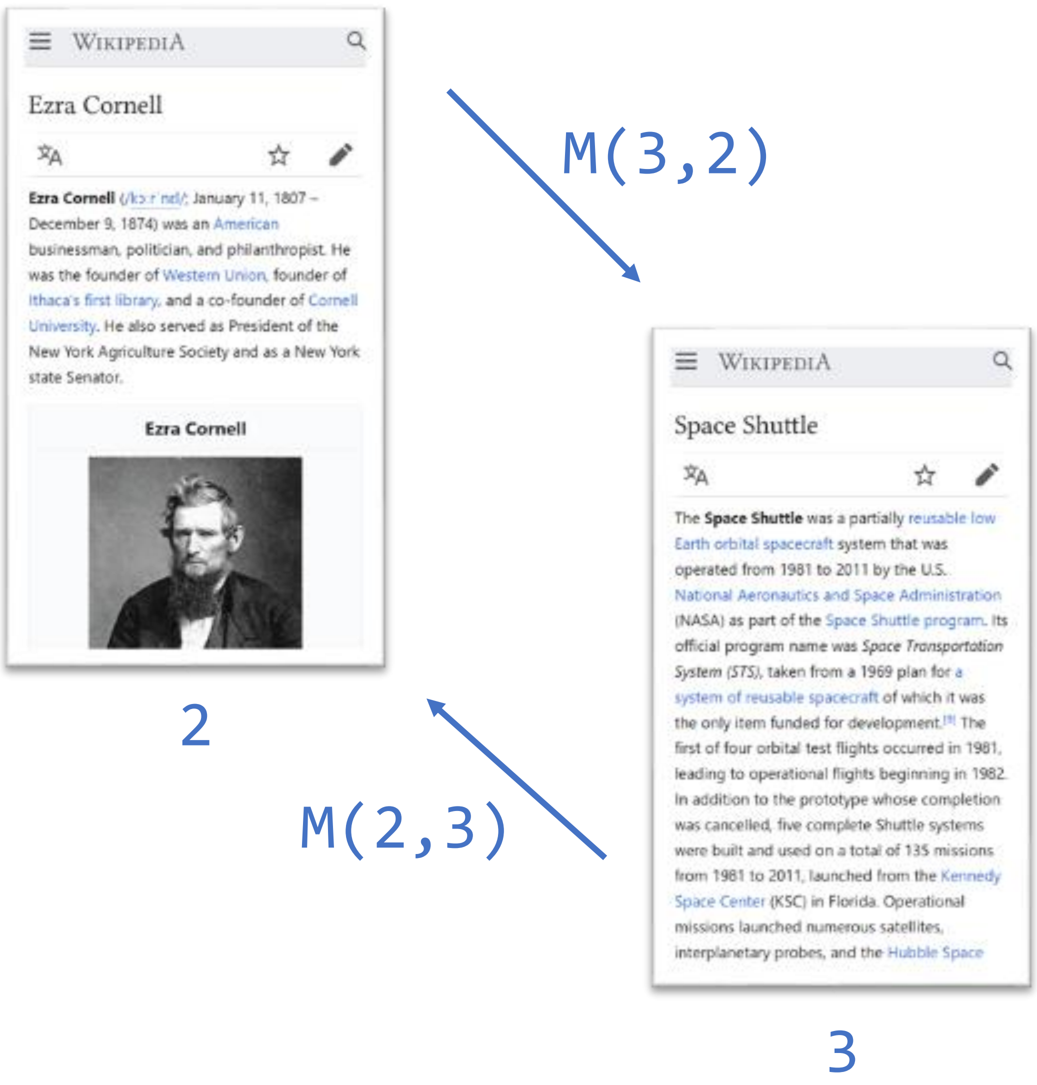
```
% Unfair coin: shows heads
% twice as often as tails
r= rand();
if r < 2/3
   disp('heads')
else
   disp('tails')
end
```

p

```
% Event X happens with probability p
r= rand();
if r < p
   % Code for event X
end
```

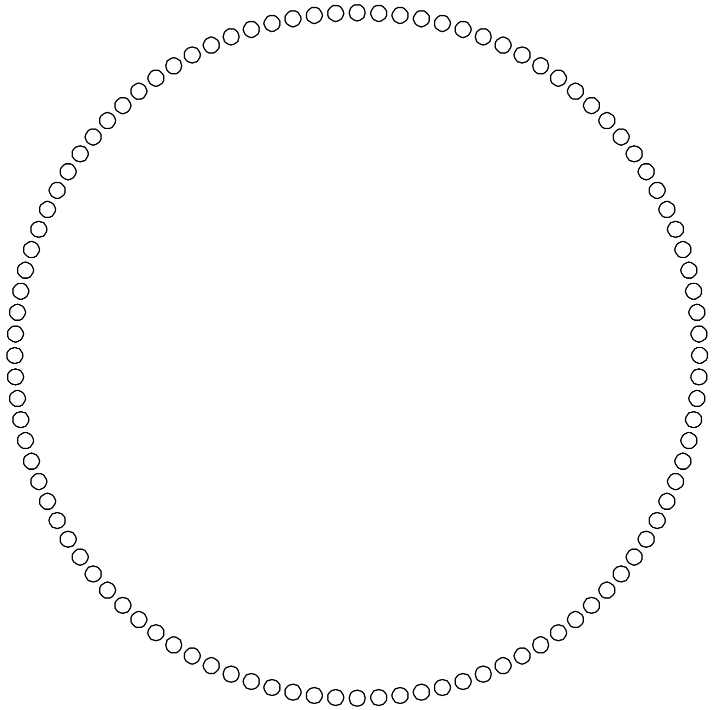
```
function A = RandomLinks(n)
% A is n-by-n matrix of 1s and 0s
% representing n webpages

A= zeros(n,n);
for i = 1:n
  for j = 1:n
    r= rand();
    if i~=j && r < 1/(1 + abs(i-j));
        A(i,j)= 1;
    end
  end
end
```

Random web: N=20



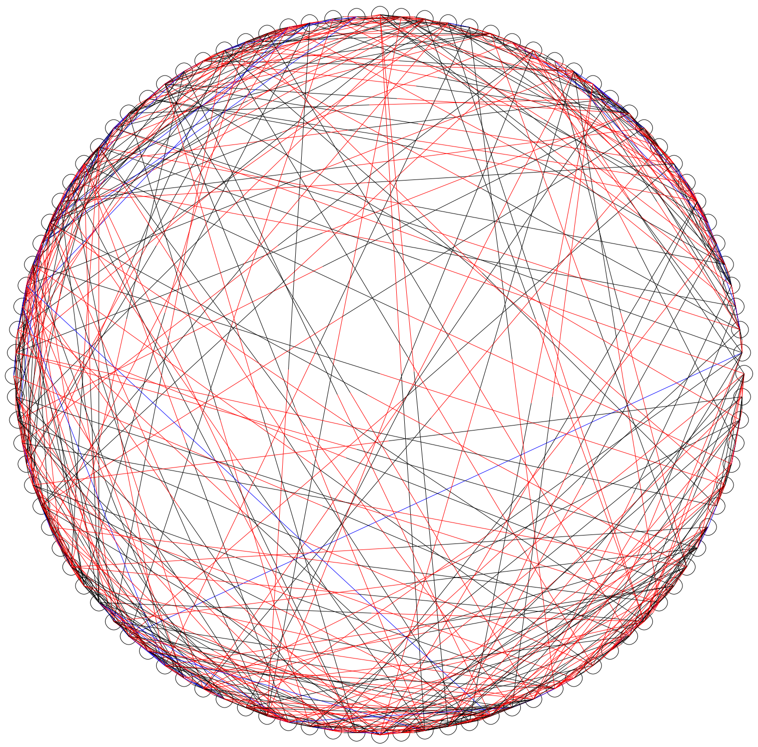
0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0
0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
0	1	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0
0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1
0	0	0	1	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0
0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	0	0	0	1
0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0

Represent the web pages graphically…



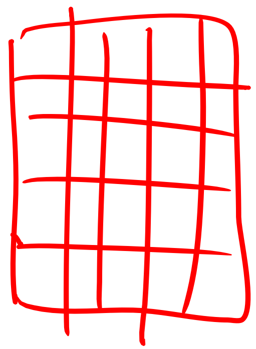
100 Web pages arranged in a circle.
Next display the links….

Represent the web pages graphically…



100 Web pages arranged in a circle. Bidirectional links are blue. Unidirectional link is black as it leaves page j, red when it arrives at page i.

A



```
for i = 1:n
    for j = 1:n
        if A(i,j) == 1 && A(j,i) == 1
            % Blue

        elseif A(i,j) == 1
            % Black - Red
            j -> mid    mid -> i

        end
    end
end
```

Somewhat inefficient: each blue line gets drawn twice.
See **ShowRandomLinks.m**

A(1,3)

	0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0
A(3,1)	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
	0	1	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0
	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0
	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1 A(10,12)
	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
A(12,10)	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1
	0	0	0	1	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0
	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0
	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	0	0	0	1
	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0

Transpose—like switching row and column indices