



Department of
Industrial Engineering

IE 454 Combinatorial Analysis

<http://ie454.cankaya.edu.tr>

Fall 2010 Tuesday 9:40-12:30 A201

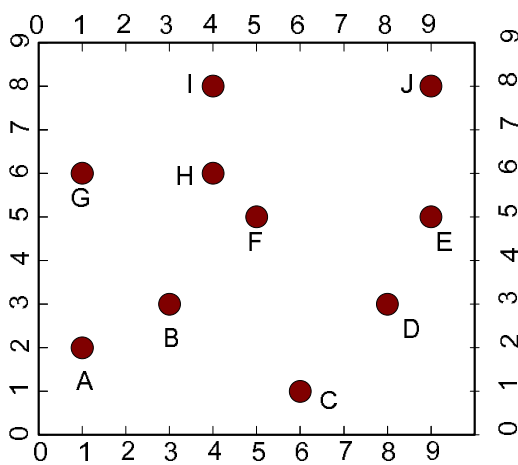
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Solution to HOMEWORK 3

Consider the Printed Circuit Board (PCB) given in the figure having 34 legs separated uniformly along the sides of the wafer. Suppose that a CNC machine with a robot arm makes vias (a kind of drill operation) at points A, B, ..., J. A high volume of PCB's are processed one after another.



$$A = \begin{bmatrix} 1 \\ 2 \end{bmatrix}, B = \begin{bmatrix} 3 \\ 3 \end{bmatrix},$$

$$C = \begin{bmatrix} 6 \\ 1 \end{bmatrix}, D = \begin{bmatrix} 8 \\ 3 \end{bmatrix},$$

$$E = \begin{bmatrix} 9 \\ 5 \end{bmatrix}, F = \begin{bmatrix} 5 \\ 5 \end{bmatrix},$$

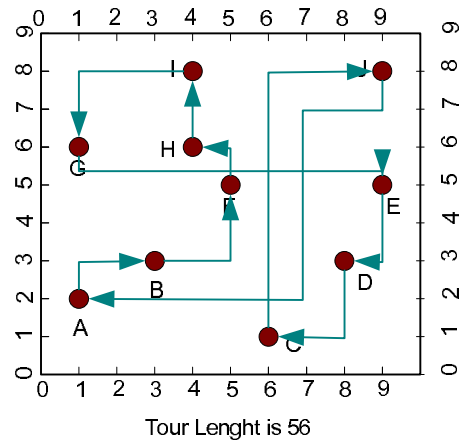
$$G = \begin{bmatrix} 1 \\ 6 \end{bmatrix}, H = \begin{bmatrix} 4 \\ 6 \end{bmatrix},$$

$$I = \begin{bmatrix} 4 \\ 8 \end{bmatrix}, J = \begin{bmatrix} 9 \\ 8 \end{bmatrix}.$$

- Suppose that the robot arm moves in horizontal as well as vertical direction using a single motor. It switches its direction in an infinitesimal time unit. The CNC programmer uses the following logic to find the sequence of vias to be processed: Start from A, go to the closest neighbor if it has not been processed yet. Break the ties in terms of ascending lexicographical order of locations.

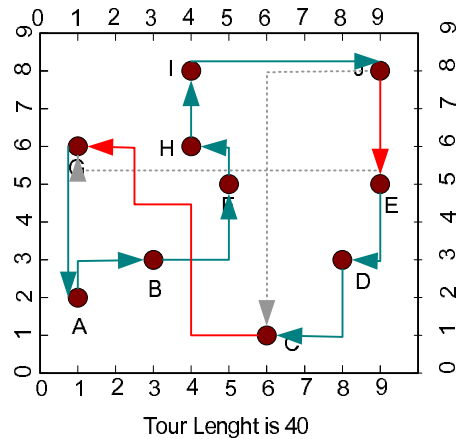
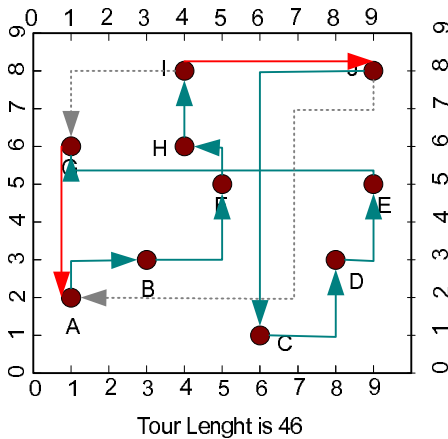
(a) Find the initial tour after deciding on the appropriate metric. **Rectilinear Distance:**

X	Y	Point	A	B	C	D	E	F	G	H	I	J
1	2	A	0	3	6	8	11	7	4	7	9	14
3	3	B	3	0	5	5	8	4	5	4	6	11
6	1	C	6	5	0	4	7	5	10	7	9	10
8	3	D	8	5	4	0	3	5	10	7	9	6
9	5	E	11	8	7	3	0	4	9	6	8	3
5	5	F	7	4	5	5	4	0	5	2	4	7
1	6	G	4	5	10	10	9	5	0	3	5	10
4	6	H	7	4	7	7	6	2	3	0	2	7
4	8	I	9	6	9	9	8	4	5	2	0	5
9	8	J	14	11	10	6	3	7	10	7	5	0



(b) Calculate the gains associated with all possible pairs once. Once all the gains are calculated, all the independent switches is made. This improvement procedure is executed only once.

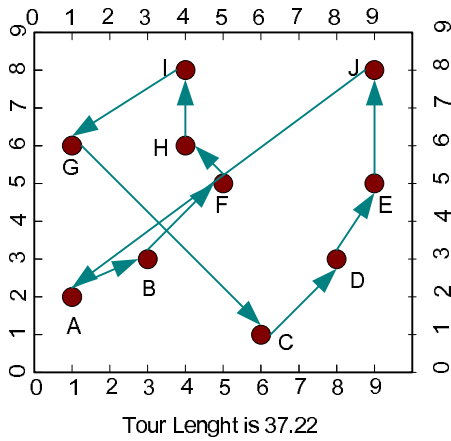
Length	3	4	2	2	5	9	3	4	10	14	
Length	GAIN	AB	BF	FH	HI	IG	GE	ED	DC	CJ	JA
3	AB										
4	BF										
2	FH										
2	HI										
5	IG										
9	GE										
3	ED										
4	DC										
10	CJ										
14	JA										



2. What if the robot arm moves in any direction using its motor?

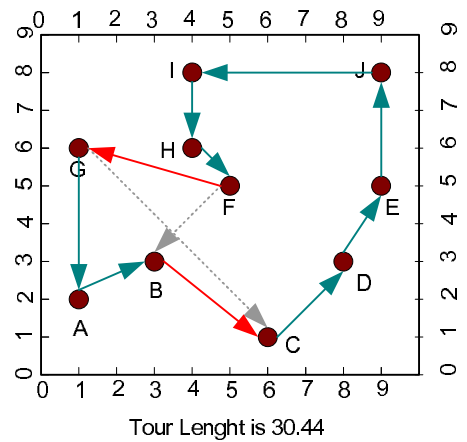
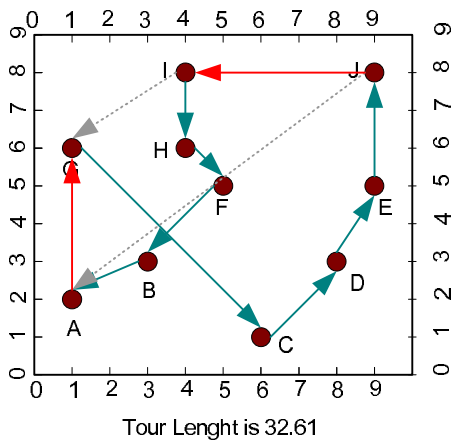
(a) Find the initial tour after deciding on the appropriate metric. **Euclidian Distance:**

X	Y	Point	A	B	C	D	E	F	G	H	I	J
1	2	A	0,000	2,236	5,099	7,071	8,544	5,000	4,000	5,000	6,708	10,000
3	3	B	2,236	0,000	3,606	5,000	6,325	2,828	3,606	3,162	5,099	7,810
6	1	C	5,099	3,606	0,000	2,828	5,000	4,123	7,071	5,385	7,280	7,616
8	3	D	7,071	5,000	2,828	0,000	2,236	3,606	7,616	5,000	6,403	5,099
9	5	E	8,544	6,325	5,000	2,236	0,000	4,000	8,062	5,099	5,831	3,000
5	5	F	5,000	2,828	4,123	3,606	4,000	0,000	4,123	1,414	3,162	5,000
1	6	G	4,000	3,606	7,071	7,616	8,062	4,123	0,000	3,000	3,606	8,246
4	6	H	5,000	3,162	5,385	5,000	5,099	1,414	3,000	0,000	2,000	5,385
4	8	I	6,708	5,099	7,280	6,403	5,831	3,162	3,606	2,000	0,000	5,000
9	8	J	10,000	7,810	7,616	5,099	3,000	5,000	8,246	5,385	5,000	0,000



(b) Calculate the gains associated with all possible pairs once. Once all the gains are calculated, all the independent switches is made. This improvement procedure is executed only once.

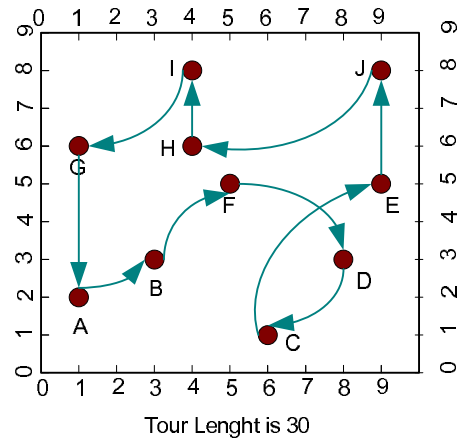
Length	GAIN	AB	BF	FH	HI	IG	GC	CD	DE	EJ	JA
2,236	AB			-4,5120	-5,8630	-4,4721	1,7016	-5,0345	-8,9235	-15,6205	
2,828	BF				-1,4961	-2,7881	2,1708	-1,5542	-3,9355	-5,4961	0,0182
1,414	FH					-1,7481	-1,7948	-7,5456	-7,1807	-5,6848	1,4142
2,000	HI						0,2401	-6,6737	-8,0440	-5,3852	-0,0934
3,606	IG							-8,4619	-8,6238	-7,4716	4,6056
7,071	GC								-3,3086	-5,6070	3,7258
2,828	CD									-4,2706	-1,8584
2,236	DE										-1,4070
3,000	EJ										
10,000	JA										



3. What if the robot arm moves in horizontal as well as vertical direction using two independent but identical motors?

(a) Find the initial tour after deciding on the appropriate metric. Tchebychev's Distance:

X	Y	Point	A	B	C	D	E	F	G	H	I	J
1	2	A	0	2	5	7	8	4	4	4	6	8
3	3	B	2	0	3	5	6	2	3	3	5	6
6	1	C	5	3	0	2	4	4	5	5	7	7
8	3	D	7	5	2	0	2	3	7	4	5	5
9	5	E	8	6	4	2	0	4	8	5	5	3
5	5	F	4	2	4	3	4	0	4	1	3	4
1	6	G	4	3	5	7	8	4	0	3	3	8
4	6	H	4	3	5	4	5	1	3	0	2	5
4	8	I	6	5	7	5	5	3	3	2	0	5
9	8	J	8	6	7	5	3	4	8	5	5	0



(b) Calculate the gains associated with all possible pairs once. Once all the gains are calculated, all the independent switches is made. This improvement procedure is executed only once.

Length	GAIN	AB	BF	FD	DC	CE	EJ	JH	HI	IG	GA
2	AB			-4	-6	-5	-9	-4	-5	-4	
2	BF				-5	-1	-5	0	-2	-4	-1
3	FD					1	-3	0	-1	-4	-4
2	DC						-4	-3	-7	-5	-6
4	CE							-3	-4	-8	-5
3	EJ								-5	-7	-9
5	JH									0	-3
2	HI										-3
3	IG										
4	GA										

