送货路线设计问题

摘要

本题是关于送货路线的设计问题，可以转化为图论中的问题进行求解。将送货点抽象为图中的点，将送货线路抽象为图中的边。参考 TSP 问题和中国邮递员问题，利用图论中汉密尔顿圈等知识建立模型，并通过 MATLAB 编程实现模型的求解。

针对问题 1，先用 Floyd 算法求出 21 个送货点和 0 点任意两点之间的最短路的权值，将问题转化为 TSP 问题。用改良圈算法求出最优汉密尔顿回路，即 51->18->13->19->24->31->27->39->27->31->34->40->45->42->49->42->43->38->36->38->35->32->23->16->14->17->21->26->51
送货员的总路程S_1=54708m。

针对问题 2，通过 MATLAB 检验发现问题 1 所得路线不符合时间约束条件，需要求解新的送货路线。在问题 1 模型的基础上加入时间限制，筛选出符合时间约束条件且路程最短的汉密尔顿回路如下：
51->18->13->19->24->31->34->40->45->42->49->42->43->38->35->32->23->16->14->17->21->36->27->39->27->31->26->51
送货员的总路程是S_2 =54994m。

针对问题 3，先利用 Dijkstra 算法求出从 0 点到 50 个送货点的最短路，通过作图观察最短路的分布以确定合理的分组原则，将送货点分成 3 组。在每个分组内利用问题 1 的模型求出分组内的最佳汉密尔顿圈，即为分组内的送货路线。并通过合理分配货物使各分组均满足重量和体积的约束条件。最终求得三组送货路线如下：

第 1 组：51-18-13-11-12-15-5-2-4-3-8-1-6-1-7-10-9-14-16-23-17-21-51
第 2 组：51-21-17-23-32-35-38-43-42-49-50-45-36-27-39-27-31-26-51
第 3 组：51-26-31-34-40-47-40-37-41-44-48-46-33-28-30-22-20-22-29-25-19-24-31-26-51

送货员的总路程为S_3 =130351m，总时间$T_3 = 10.43$h。

关键词：最优汉密尔顿圈　改良圈算法 Dijkstra 算法 Floyd 算法 TSP 模型

目录

一、问题背景和重述

1.1 问题背景

现今社会网络越来越普及，网购已成为一种常见的消费方式，随之物流行业也渐渐兴盛，每个送货员需要以最快的速度及时将货物送达，而且他们往往一人送多个地方，请设计方案使其耗时最少。

1.2 问题重述

现有一快递公司，库房在图 1 中的 0 点，一送货员需将货物送至城市内多处，请设计送货方案，使所用时间最少。该地形图的示意图见图 1，各点连通信息见表 3，假定送货员只能沿这些连通线路行走，而不能走其它任何路线。各件货物的相关信息见表 1，50 个位置点的坐标见表 2。

假定送货员最大载重 50 公斤，所带货物最大体积 1 立方米。送货员的平均速度为 24 公里/小时。假定每件货物交接花费 3 分钟，为简化起见，同一地点有多件货物也简单按照每件 3 分钟交接计算。

现在送货员要将 100 件货物送到 50 个地点。请完成以下问题。

1. 若将 1~30 号货物送到指定地点并返回。设计最快完成路线与方式。给出结果。要求标出送货线路。
2. 假定该送货员从早上 8 点上班开始送货，要将 1~30 号货物的送达时间不能超过指定时间，请设计最快完成路线与方式。要求标出送货线路。
3. 若不需要考虑所有货物送达时间限制(包括前 30 件货物)，现在要将 100 件货物全部送到指定地点并返回。设计最快完成路线与方式。要求标出送货线路，给出送完所有快件的时间。由于受重量和体积限制，送货员可中途返回取货。可不考虑中午休息时间。

以上各问尽可能给出模型与算法。

二、模型假设

1. 假设任意两个地点之间的道路都是双向的；
2. 假设送货员的平均速度为 24 公里/小时，且送货员不休息；
3. 假定每件货物交接花费 3 分钟，同一地点有多件货物也简单按照每件 3 分钟交接计算。
4. 将 0 点编号为 51。

三、 符号说明

符号	说明
t_0	每件货物交接花费的时间(min)
d_{i-j}	送货点 i，j 之间的距离(m)
$M_i(i=1,2,3)$	问题 3 中第 i 组货物的质量(kg)
$V_i(i=1,2,3)$	问题 3 中第 i 组货物的体积(m^3)
$S_i(i=1,2,3)$	问题 i 中送货员的总路程(m)
$T_i(i=1,2,3)$	问题 i 中送货员花费的总时间(min)
$m_i(i=1,2,\dots,100)$	第 i 件货物的质量(kg)
$v_i(i=1,2,\dots,100)$	第 i 件货物的体积(kg)

四、分析与求解

4.1 问题 1

4.1.1 问题分析

1~30 号货物的总重量是 48.5 公斤（<50 公斤），总体积是 0.88 立方米（<1 立方米），均没有达到送货员携带货物重量和体积的上限，因此可以忽略重量和体积的限制。

1~30 号货物的目的地是[13，14，16，17，18，21，23，24，26，27，31，32，34，36，38，39，40，42，43，45，49]，共 21 个地点，如图 4-1 所示。

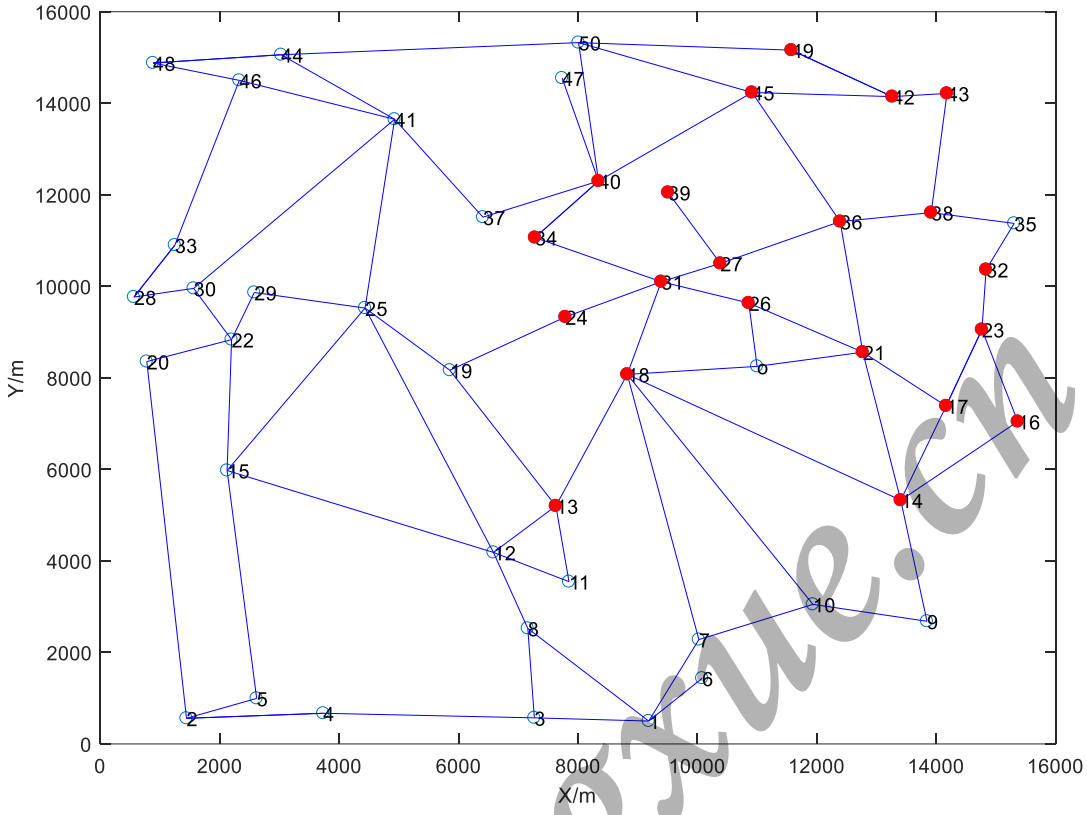


图 4-1

为了便于分析和建模，我们不仅保留上述 21 个地点，同时保留 19，35 两点。因为送货途中可能会出现 13->19->24 和 38->35->32 这两条路线。

送货员将货物送到指定地点并返回，设计最快完成路线与方式。把地点看作结点，地点之间的线路看作边，线路的长度看作相应边的权值，于是问题简化为在无向带权图中寻找一条经过每个顶点至少一次的最短闭通路问题，即最佳推销员问题。

在加权图中寻求最佳推销员回路的问题可以转化为在一个完备加权图中寻求最佳汉密尔顿圈的问题，即 TSP 问题。

所以，对 TSP 问题进行求解即可。

4.1.2 模型建立

首先，使用 MATLAB 编程求得图中可直达的两点之间的距离，并构造带权邻接矩阵 W。

将 W 作为 Floyd 算法中距离矩阵的初值，即$D^{(0)} = (D_{ij}^{(0)})_{v\times v} = W$，通过 Floyd 算法求出任意两点之间的最短距离。

Floyd 算法的基本思想及原理：

Floyd 算法的基本思想是直接在图的带权邻接矩阵中用插入顶点的方法依

次构造出 v 个矩阵$D^{(1)}, D^{(2)}, \ldots D^{(v)}$, 使得最后得到的矩阵$D^{(v)}$成为图的距离矩阵，同时也求出插入点矩阵以便得到两点之间的最短路径。距离矩阵$D^{(v)}$中的元素即为相应的两点之间的最短路的长度。

在得到任意两点之间的最短路的长度后，就可以把加权图中的最佳推销员回路问题转化为在完备加权图中寻求最佳汉密尔顿圈的问题。

转化方法如下：

由给定的图$\mathrm{G} = (V, E)$构造一个以V为顶点集的完备图$G' = (V, E')$，E'的每条边(x, y)的权等于顶点x与y在图中最短路的权，即：

$$\forall \mathrm{x}, \mathrm{y} \in E', w(x, y) = mind_G(x, y)$$

采用改良圈算法求解 TSP 问题。

改良圈算法的基本思想与原理：

设初始圈 C=$v_1 v_2 \ldots . v_n v_1$

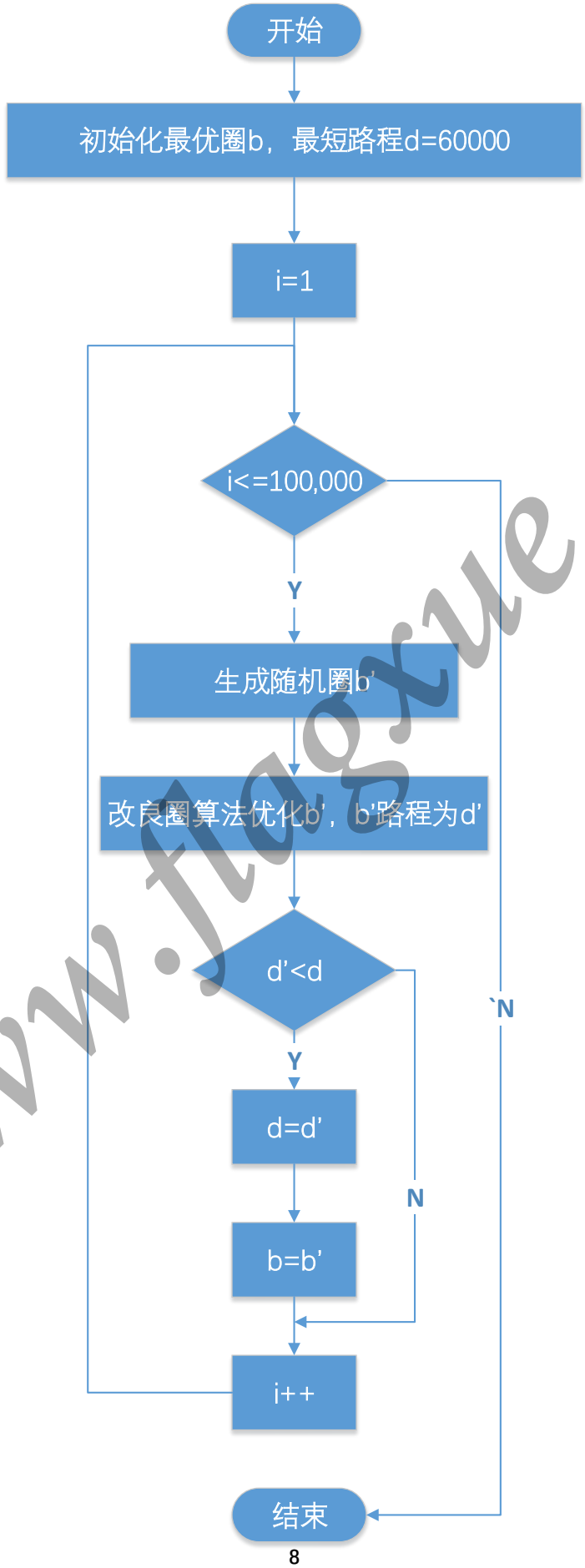
（1）对于 1≤i<i+1<j≤ n,构造新的哈密尔顿圈

C_{ij}=$v_1 v_2 \ldots . v_i v_j v_{j-1} v_{j-2} \ldots . . v_{i+1} v_{j+1} v_{j+2} \ldots . . v_n v_1$，它是由 C 中删去边$v_i v_{i+1}$和$v_j v_{j+1}$，添加$v_i v_j$和$v_{i+1} v_{j+1}$而得到的。若 w（$v_i v_j$）+w（$v_{i+1} v_{j+1}$）<w（$v_i v_{i+1}$）+w（$v_j v_{j+1}$），则以$C_{ij}$代替 C，$C_{ij}$称为 C 的改良圈。

（2）转（1），直至无法改进，停止。

用改良圈算法得到的结果几乎可以肯定不是最优的。为了得到更高的精确度，可以选择不同的初始圈，重复进行几次，以求得较精确的结果。

问题 1 模型流程图如下：



4.1.3 模型求解

首先求得图中可直达的两点之间的距离，详见附表 1-1。
构造 21 个送货点和 0 点的带权邻接矩阵 W，其中

$$d_{13-14} = d_{13-19} + d_{19-24}$$
$$d_{32-38} = d_{32-35} + d_{35-38}$$

详见附表 1-2。

使用 Floyd 算法求得距离矩阵$D^{(v)}$,详见附表 1-3。

问题可以转化为 TSP 问题，如图 4-2 所示。

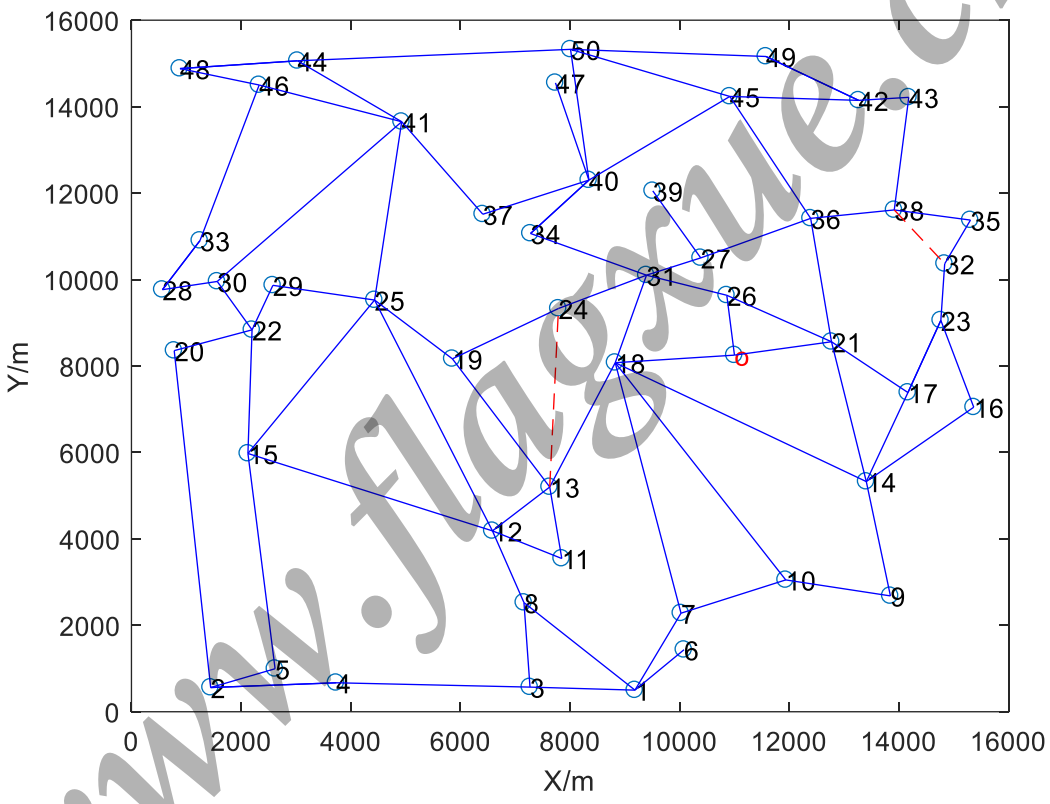


图 4-2

我们通过 MATLAB 生成几十万个初始圈，并通过改良圈优化，最终筛选出一条权最小的汉密尔顿回路如下（MATLAB 代码见附录 1）：
51->18->13->24->31->27->39->34->40->45->42->49->43->38->36->32->23->16->14->17->21->26->51

上述回路对应的遍历结点的顺序如下：
51->18->13->19->24->31->27->39->27->31->34->40->45->42->49->42->43->38->36->38->35->32->23->16->14->17->21->26->51

送货员的总路程为S_1=54708m，总时间

$$T_1 = \frac{S_1}{400} + 30 * t_0 = 226.77\text{min}$$

送货路线如图 4-3 所示。

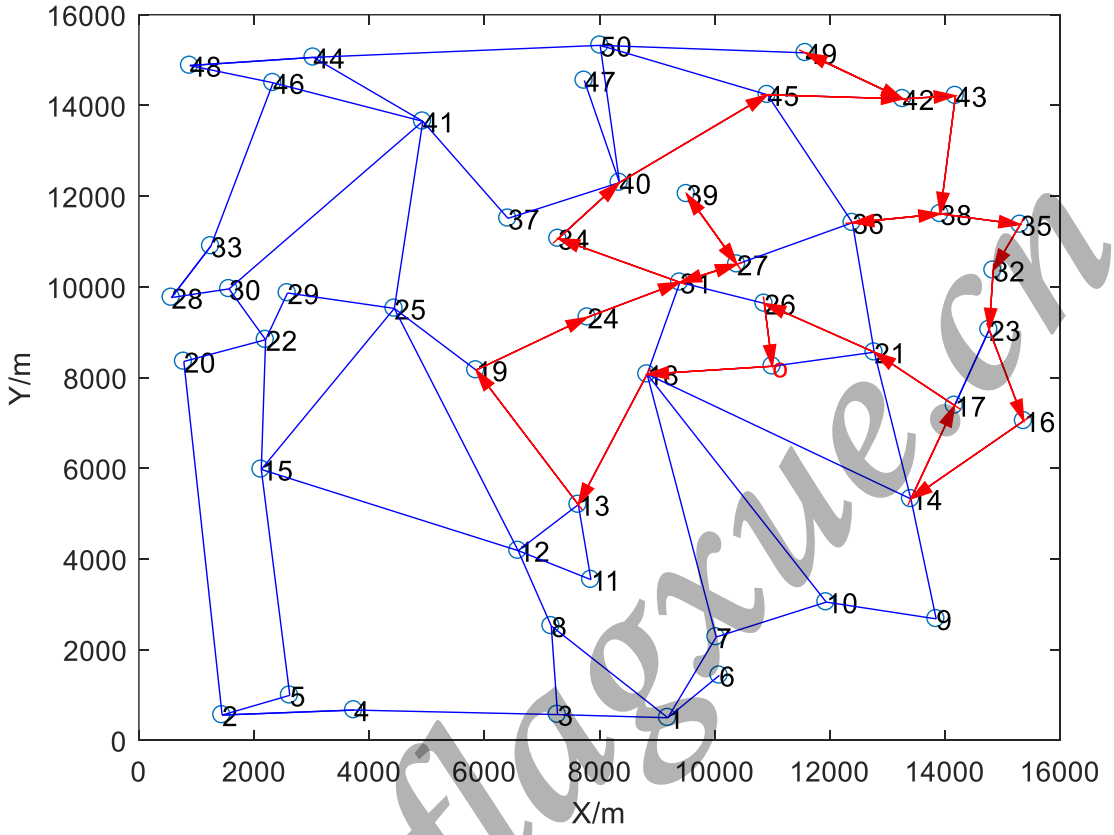


图 4-3

4.2 问题 2

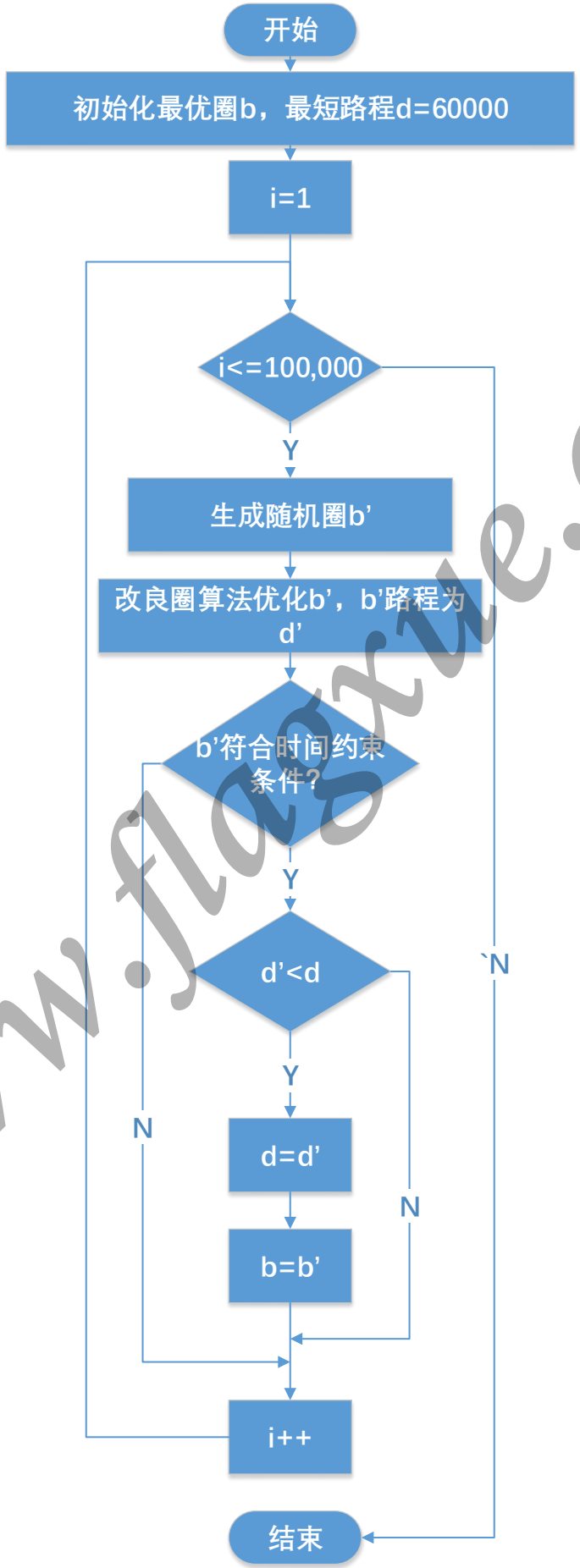
4.2.1 问题分析

问题 2 要求货物的送达时间不能超过指定时间，只需在问题 1 的基础上加入时间限制，筛选出符合约束条件的 Hamilton 圈。要求设计最快完成路线与方式，需要找到耗时最短的 Hamilton 圈，即为最优路线。

4.2.2 模型建立

在问题 1 模型的基础上，通过 MATLAB 编程在改良圈算法求得的送货路线中筛选出一条符合时间约束条件且耗时最短的最优汉密尔顿圈，即为所求结果。

问题 2 模型流程图如下：



4.2.3 模型求解

将 1~30 号货物按照时间限制重新排序，得表 4-1 如下。

表 4-1

货物号	送货地点	不超过时间	送货员已用时间/h	送货员已用时间/min
1	13	9:00	1	60
2	18	9:00	1	60
20	24	9:00	1	60
3	31	9:30	1.5	90
11	45	9:30	1.5	90
14	45	9:30	1.5	90
21	31	9:30	1.5	90
24	34	9:30	1.5	90
25	40	9:30	1.5	90
26	45	9:30	1.5	90
10	38	10:15	2.25	135
12	43	10:15	2.25	135
15	42	10:15	2.25	135
16	43	10:15	2.25	135
27	49	10:15	2.25	135
4	26	12:00	4	240
5	21	12:00	4	240
6	14	12:00	4	240
7	17	12:00	4	240
8	23	12:00	4	240
9	32	12:00	4	240
13	39	12:00	4	240
17	32	12:00	4	240
18	36	12:00	4	240
19	27	12:00	4	240
22	27	12:00	4	240
23	26	12:00	4	240
28	32	12:00	4	240
29	23	12:00	4	240
30	16	12:00	4	240

首先检验问题 1 所得路线是否符合时间约束条件。若符合，则该路线即问题 2 所求路线；若不符合，需要寻找新的送货路线。

由于$T_1 = 226.77\text{min}$小于 4 小时，所以我们只需检验表 4-1 中前 15 件货物是否超出时间限制即可。

通过 MATLAB 编程检验问题 1 求得的路线是否符合时间约束条件（MATLAB 代码见附录 2-1）。

检验发现 11、14、26 号货物不能按时送达，且这三个货物均是送至 45 号地点。因此问题 1 求得的路线不满足问题 2 的约束条件，需要寻找新的汉密尔顿圈。

于是通过 MATLAB 编程生成几十万个随机初始圈，经改良圈算法优化后找到符合时间约束条件且路程最短的路线如下（MATLAB 代码见附录 2-2）：

51->18->13->24->31->34->40->45->42->49->43->38->32->23->16->14->17->21->36->39->27->26->51

上述回路对应的遍历结点的顺序如下：

51->18->13->19->24->31->34->40->45->42->49->42->43->38->35->32->23->16->14->17->21->36->27->39->27->31->26->51

送货员的总路程是S_2 =54994m。

$$T_2 = \frac{S_2}{400} + 30 * t_0 = 227.49\text{min}$$

送货路线如图 4-4 所示。

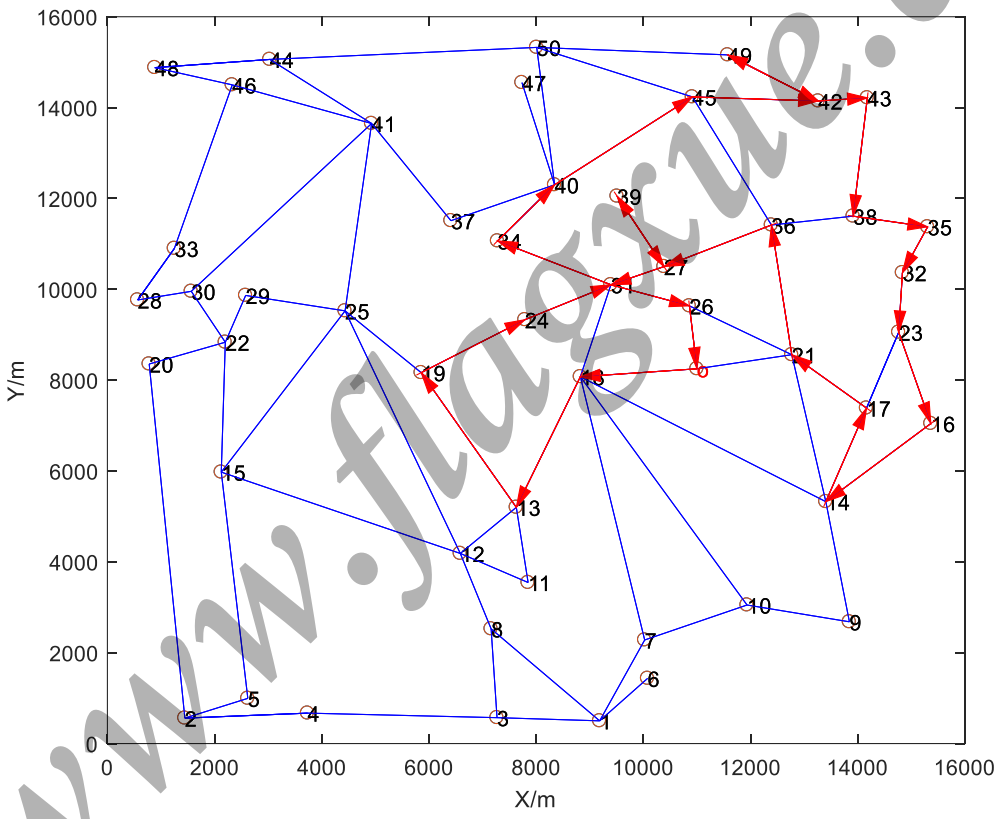


图 4-4

表 4-2 给出了 1~30 号货物送达的时间。

表 4-2

货物号	送货地点	不超过时间/min	送达所用时间/min
1	13	60	19.23872894
2	18	60	8.45507218
20	24	60	36.52457185
3	31	90	43.97494051
11	45	90	73.9062778
14	45	90	76.9062778
21	31	90	46.97494051
24	34	90	55.78680876
25	40	90	62.86376381
26	45	90	79.9062778
10	38	135	119.4827616
12	43	135	106.9366511
15	42	135	88.78558473
16	43	135	109.9366511
27	49	135	96.71402579
4	26	240	221.0059453
5	21	240	177.8841418
6	14	240	161.8350574
7	17	240	170.3243652
8	23	240	141.0717512
9	32	240	128.7920789
13	39	240	201.0441859
17	32	240	131.7920789
18	36	240	188.0845866
19	27	240	208.4939928
22	27	240	211.4939928
23	26	240	224.0059453
28	32	240	134.7920789
29	23	240	144.0717512
30	16	240	152.315855

4.3 问题 3

4.3.1 问题分析

100 件货物的总重量是 148 公斤，总体积是 2.8 立方米。而送货员最大载重 50 公斤，所带货物最大体积 1 立方米。所以送货员至少需要 3 次才能把货物送完。

此问题是多个推销员的最佳推销员回路问题。即在加权图 G 中求顶点集 V 的划分V_1，V_2，…，V_n，将 G 分成 n 个生成子图 G[V_1]，G[V_2]，…，G[V_n]，使得

（1）顶点 0∈V_i，i=1,2,3,…,n.

（2）$\bigcup_{i=1}^{n} V_i = V(G)$.

求解此问题，需要考虑两个方面：一是对送货点进行合理分组，二是在每个分组内求最佳推销员回路。

由于单个推销员的最佳推销员回路问题不存在多项式时间内的精确算法，故多个推销员的问题也不存在多项式时间内的精确算法。而图中节点数较多，为 50 个，我们只能去寻求一种较合理的划分准则，对送货点进行初步划分后，求出各部分的近似最佳推销员回路，再进一步进行调整，使得各部分满足题中所给条件。

4.3.2 模型建立

首先我们要得到一个合理的划分标准。

从 0 点出发去其他点，要使路程较小应尽量走 0 点到该点的最短路。故用 Dijkstra 算法求出 0 点到其余顶点的最短路，这些最短路构成一棵以 0 为树根的树，将从 0 点出发的树枝称为干枝。

Dijkstra 算法基本思想及原理：

Dijkstra 算法采用树生长的过程来指定顶点到其余顶点的最短路。最短路是一条路径，且最短路的任一段也是最短路。假设在u_0-v_0的最短路只有一条，则从u_0到其余顶点的最短路将构成一棵以u_0为根的树。

设 G 为赋权图有向图或无向图，G 边上的权均非负。

S：具有永久标号的顶点集

对每个顶点，定义两个标记(l(v),z(v))，其中：

l(v)：表示从顶点u_0到 v 的一条路的权

z(v)：v 的父亲点，用以确定最短的路线。

每一步改进这两个标记，使最终 l(v)为从顶点u_0到 v 的最短路的权，输入为带权邻接矩阵 W

(1)赋初值：令$\mathrm{S}=\{u_0\},\mathrm{l}(u_0)=0.\forall \mathrm{v}\in \bar{S}=V\backslash S$，令$\mathrm{L(v)}=\mathrm{W}(u_0,\mathrm{v}),\mathrm{z(v)}=u_0,u\leftarrow u_0.$

(2) 更新 l(v),z(v)：$\forall \mathrm{v}\in \bar{S}=V\backslash S$，若 l(v)>l(u)+W(u,v)，则令 l(v)=l(u)+W(u,v),z(v)=u.

(3)设v^*是使 l(v)取得最小值$\bar{S}$的中的顶点，则令 S=S∪{v^*},u← v^*.

(4)若$\bar{S}\neq\Phi$，转(2)；否则，停止。

用上述算法求出的 l(v)就是到 v 的最短路的权，从 v 的父亲点标记 z(v)追溯到，就得到 v 到的最短路的路线。

根据生活经验及上述分析，在分组时应遵从以下准则：

准则一：尽量使同一干枝上及其分枝上的点分在同一组；

准则二：应将相邻的干枝上的点分在同一组；

在得到合理的分组后，用改良圈算法求出近似最优解及相应的送货路线。

4.3.3 模型求解

首先，用 Dijkstra 算法求 0 点至其余各点最短路径，并画出这些最短路径（MATLAB 代码见附录 3-1），如图 4-5 所示，并作图 4-6 以便合理分组。

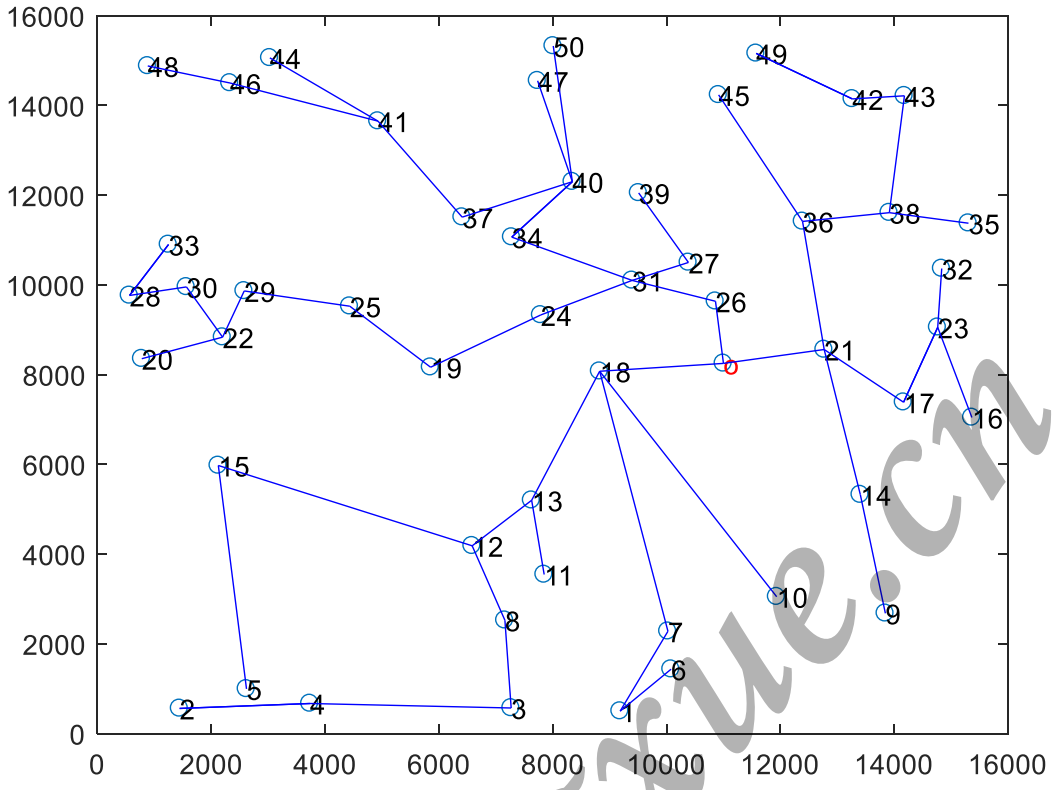


图 4-5

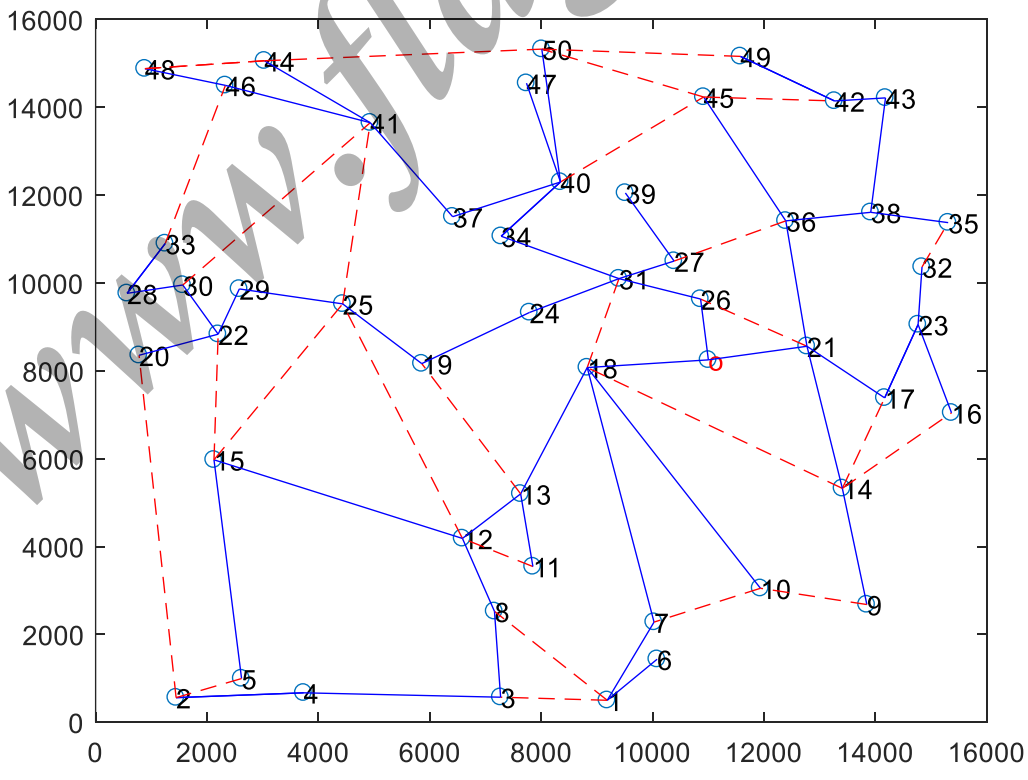


图 4-6

由图 4-5，得到 51-18, 51-21, 51-26 三个干枝。根据上述两个分组准则和对一些临界送货点（出现在不只一个分组中）的合理分配，得到三个分组，如表 4-3 所示。

表 4-3

分组	送货点	对应图示
1	51 18 13 11 12 15 5 2 4 3 8 1 6 7 10 9 14 16 23 17 21	图4-7(1)
2	51 21 17 23 32 35 38 43 42 49 50 45 36 27 39 31 26	图4-7(2)
3	51 26 31 34 40 47 37 41 44 48 46 33 28 30 22 20 29 25 19 24	图4-7(3)

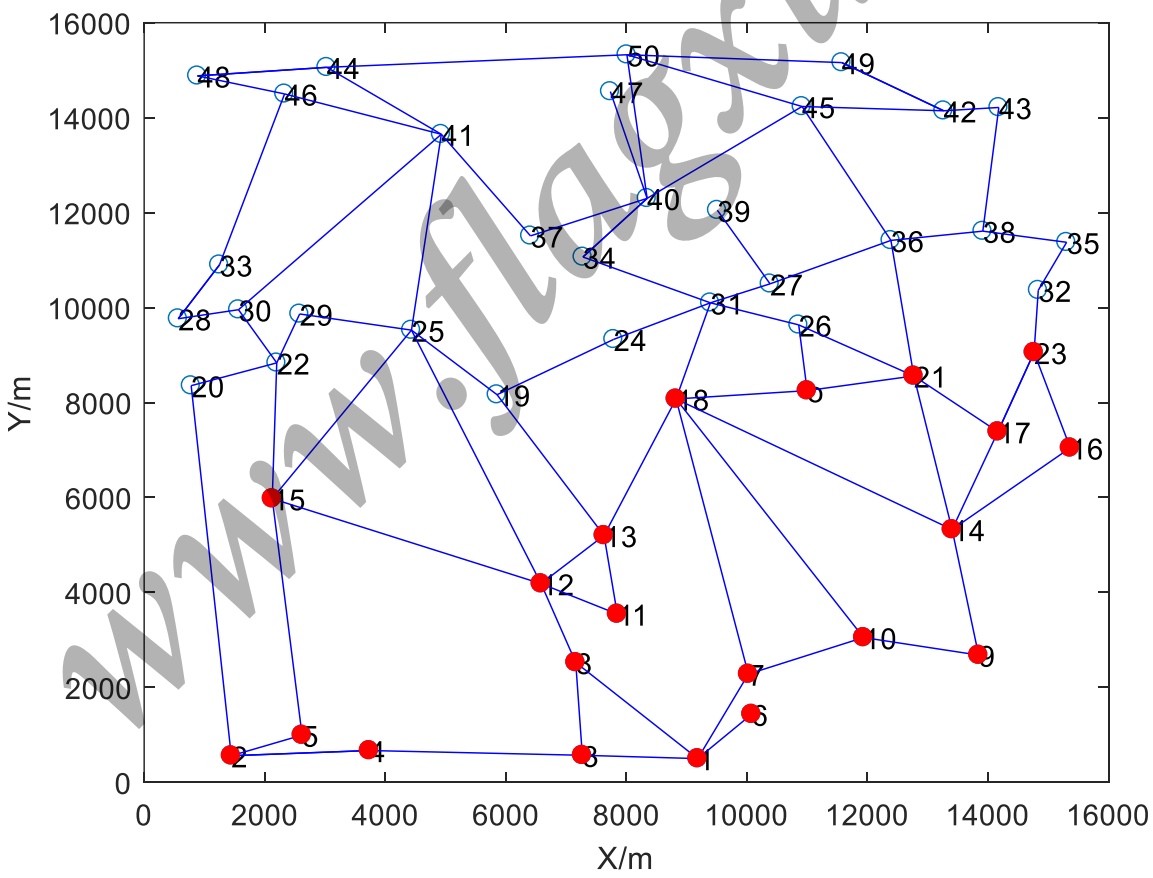


图 4-7 (1)

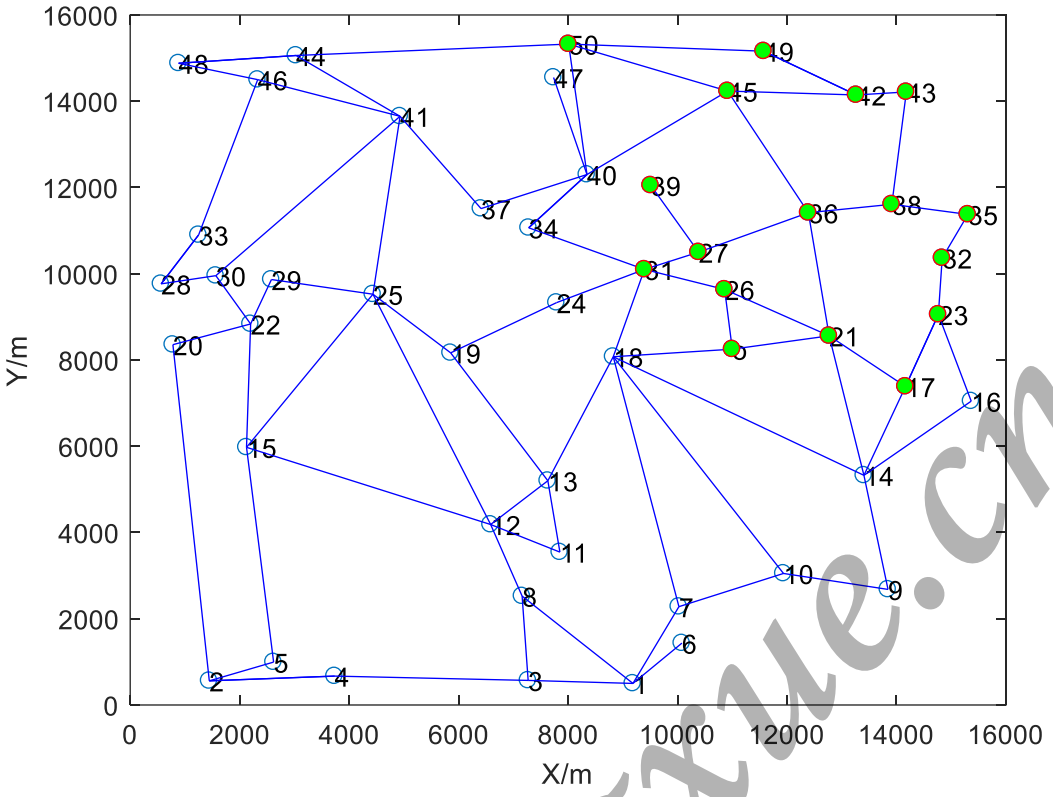


图 4-7 (2)

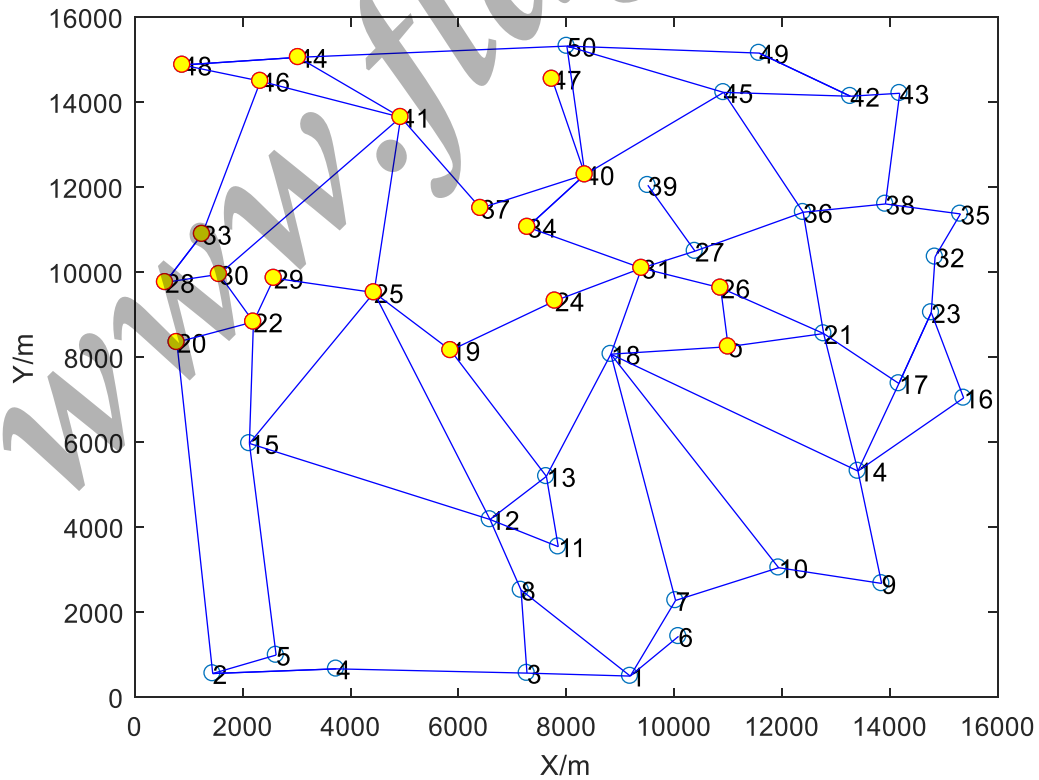


图 4-7 (3)

在各个分组内，应用改良圈算法求得最优汉密尔顿回路，并求得相应的路程，如表 4-4 所示（MATLAB 代码见附录 3-2）。

表 4-4

分组	送货路线	对应图示	路程/m
1	51-18-13-11-12-15-5-2-4-3-8-1-6-1-7-10-9-14-16-23-17-21-51	图4-8(1)	51441
2	51-21-17-23-32-35-38-43-42-49-50-45-36-27-39-27-31-26-51	图4-8(2)	34353
3	51-26-31-34-40-47-40-37-41-44-48-46-33-28-30-22-20-22-29-25-19-24-31-26-51	图4-8(3)	44557

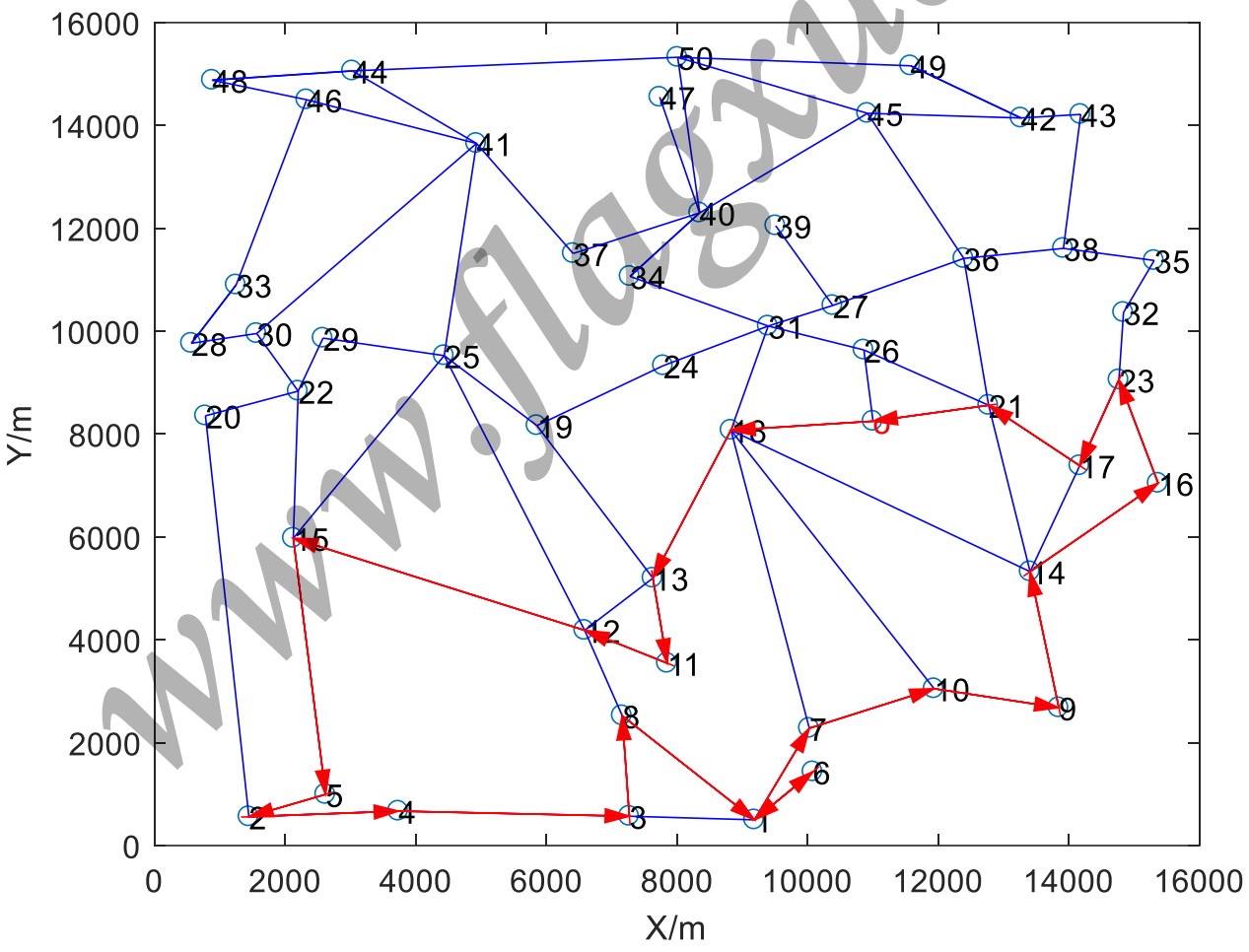


图 4-8(1)

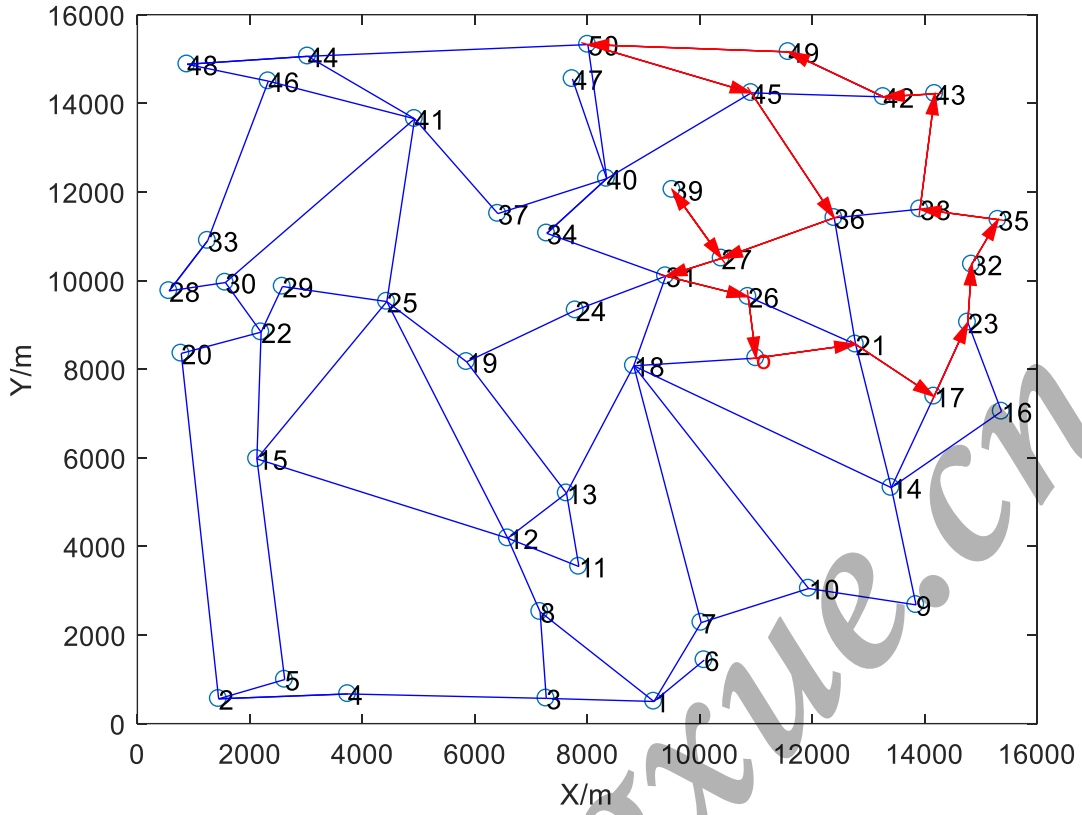


图 4-8(2)

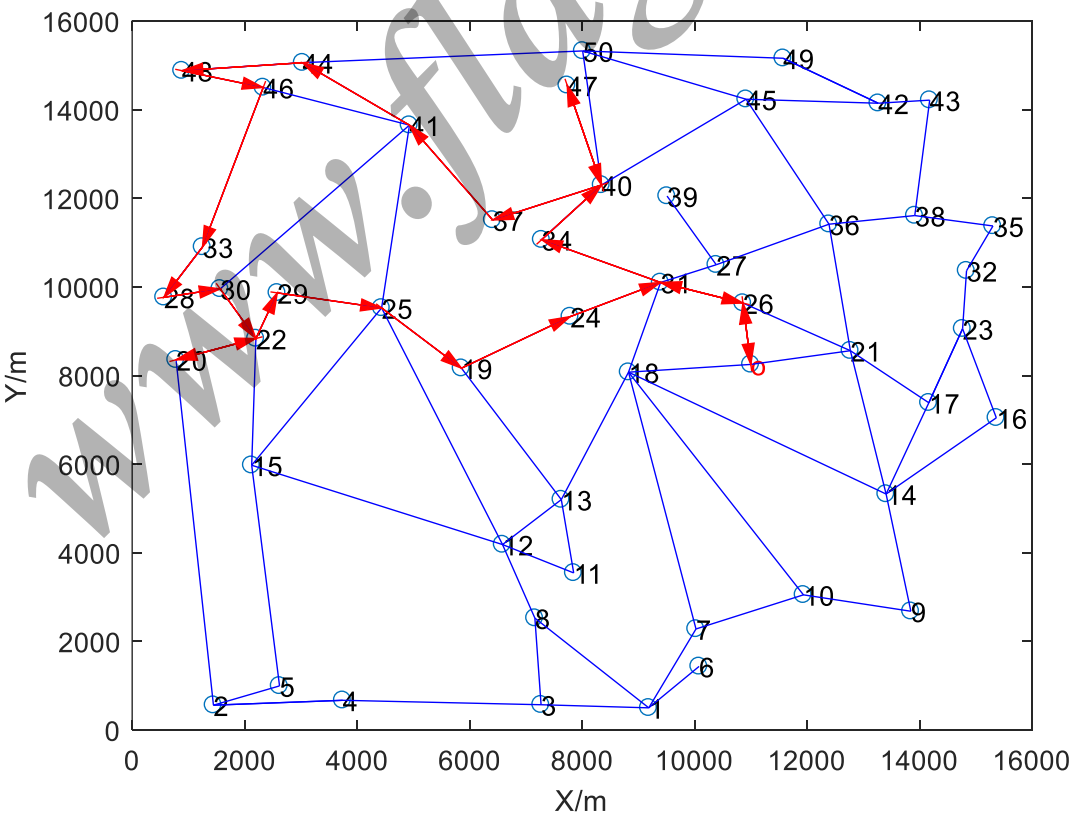


图 4-8(3)

考虑到一些送货点出现在不只一个分组中，给出如下计算各组货物重量和体积的方法，设 i 为组号：

1.依次求得 1，2，3 组货物的重量和体积；

2.当 i=1 时，若送货点出现在第 1 组中，则该送货点货物的重量和体积计入到该分组内；

3.当 i≥1 时，若送货点出现在第 i 组中且未出现在第 1，2,…i-1 组中，则该送货点货物的重量和体积计入到该分组内；

通过 MATLAB 实现上述方法，求得M_1=52.61kg，M_2= 50.26，M_3=45.13kg V_1= 1.032，V_2= 0.9939，V_3= 0.7741，发现M_1，M_2，V_1均不符合约束条件，而M_3和V_3远小于约束条件。

这是由上面的计算方法导致的，可以对货物的分配做适当调整以满足约束条件。

路线 2 和路线 3 都经过 26 号、31 号送货点，将 3 号货物（送至 31 号地点）、4 号货物（送至 26 号地点）、23 号货物（送至 26 号地点）从 2 组转向 3 组，则有

$$M_2 = M_2 - m_3 - m_4 - m_{23}$$
$$M_3 = M_3 + m_3 + m_4 + m_{23}$$
$$V_2 = V_2 - v_3 - v_4 - v_{23}$$
$$V_3 = V_3 + v_3 + v_4 + v_{23}$$

调整后，$M_2 = 45.95kg, M_3 = 49.44kg, V_2 = 0.9139m^3, V_3 = 0.8541m^3$ ，均符合约束条件。

路线 1 和路线 2 都经过 21 号地点，将 5 号货物（送至 21 号地点）、51 号货物（送至 21 号地点）从 1 组转向 2 组,则有

$$M_1 = M_1 - m_5 - m_{51}$$
$$M_2 = M_2 + m_5 + m_{51}$$
$$V_1 = V_1 - v_5 - v_{51}$$
$$V_2 = V_2 + v_5 + v_{51}$$

调整后，$M_1 = 49.08kg, M_2 = 49.48kg, V_1 = 0.9596m^3, V_2 = 0.9863m^3$ 。

三组货物的重量和体积都符合约束条件。上述求解过程见附录 3-3。

送货员的总路程为S_3 =130351m，送完所有快件所用的时间为

$$T_3 = \frac{S_3}{400} + 100 * t_0 = 625.88\text{min} = 10.43\text{h}$$

五、模型评价与改进

1.问题 1 和问题 2 中采用完全随机的方式生成初始圈，没有使用构造型算法，因而效率不高。构造型算法是按一定规则一次性地构造出一个解。常见的两种构造型算法是最小权匹配算法和对角线完全算法。

2.在求解问题时，未能使用遗传算法、蚁群算法等启发式算法。

3. 问题 3 中送货点的分组和货物的分配具有主观性。

4.问题 1 和问题 2 的路线是通过 MATLAB 进行数十万次模拟求得的结果，虽然不能保证是最优解，但是所求路线都十分接近最优解。

六、参考文献

[1]赵静、但琦，数学建模与数学实验(第 4 版)，高等教育出版社，2014
[2]司守奎、孙兆亮，数学建模算法与应用，国防工业出版社，2015
[3]刘超，MATLAB 基础与实践教程，机械工业出版社，2016

七、附录

附录 1

```
%问题 1 求解
D=[0    10389.16665    12788.49961    8916.344056    3113.462703
    7092.433422    10690.85807    5714.337164    6687.549404
    6284.910537    5217.155884    12002.72697    7541.903182
    8488.827505    10026.24417    8064.833288    9172.685203
    13562.36205    12644.68836    11671.28332    15533.73848
    5295.491575
10389.16665    0    2607.680962    2195.723116    7275.703951
    3296.733232    3970.237134    8805.647224    5488.473408
    8093.254411    7025.499758    5282.10603 9350.247056    6176.911178
    7714.327842    9873.177162    10981.02908    11250.44573
    10332.77204    9359.366991    13221.82215    5093.675079
12788.49961    2607.680962    0    3872.155551    9675.036904
    5696.066185    2097.641533    11204.98018    7887.806361
    9674.571007    9424.832711    3409.510429    11749.58001
    7470.654039    5933.237375    11454.49376    13380.36203
    9469.355259    8551.68157 10653.10985    11440.73168    7493.008032
8916.344056    2195.723116    3872.155551    0    5802.881353
    1823.910634    1774.514018    7332.824626    4015.65081 6620.431813
    5552.67716 3086.382914    7877.424458    4704.08858 5610.10986
    8400.354564    9508.206479    9146.227744    8228.554055
    7886.544393    11117.60417    3620.852481
3113.462703    7275.703951    9675.036904    5802.881353    0
    3978.970719    7577.395371    3883.840647    3574.086701
    3171.447834    2103.693181    8889.264267    4428.440479
    5375.364802    6912.781466    4951.370585    6059.2225    10448.89935
    9531.225661    8557.820615    12420.27577    2182.028872
7092.433422    3296.733232    5696.066185    1823.910634    3978.970719
    0    3598.424652    5508.913992    2191.740176    4796.521179
    3728.766526    4910.293548    6053.513824    2880.177946
    4417.59461 6576.44393 7684.295845    7953.712494    7036.038805
    6062.633759    9925.088917    1796.941847
10690.85807    3970.237134    2097.641533    1774.514018    7577.395371
```

3598.424652 0 9107.338644 5790.164828 7576.929474
7327.191178 1311.868896 9651.938476 5373.012506
3835.595842 9356.852225 11282.7205 7371.713726 6454.040037
8555.468319 9343.090149 5395.366499
5714.337164 8805.647224 11204.98018 7332.824626 3883.840647
5508.913992 9107.338644 0 3317.173816 2847.902119
1780.147466 9112.962697 4104.894764 5051.819087
6589.235751 4627.82487 5735.676785 10125.35364 9207.679946
8234.2749 12096.73006 4709.231645
6687.549404 5488.473408 7887.806361 4015.65081 3574.086701
2191.740176 5790.164828 3317.173816 0 2604.781003
1537.02635 7102.033724 3861.773648 4808.697971 6346.114635
4384.703754 5492.555669 9882.232519 8964.55883 7991.153784
11853.60894 1392.057829
6284.910537 8093.254411 9674.571007 6620.431813 3171.447834
4796.521179 7576.929474 2847.902119 2604.781003 0
1067.754653 6265.060578 3392.501951 2203.916968
3741.333632 1779.922751 5023.283972 7277.451516
6359.777827 5386.372781 9248.827939 3996.838832
5217.155884 7025.499758 9424.832711 5552.67716 2103.693181
3728.766526 7327.191178 1780.147466 1537.02635 1067.754653
0 7332.815231 2324.747298 3271.671621 4809.088285
2847.677404 3955.529319 8345.206169 7427.53248 6454.127434
10316.58259 2929.084179
12002.72697 5282.10603 3409.510429 3086.382914 8889.264267
4910.293548 1311.868896 9112.962697 7102.033724
6265.060578 7332.815231 0 9657.562529 4061.14361
2523.726946 8044.983329 10460.60502 6059.84483 5142.171141
7243.599423 8031.221253 6707.235395
7541.903182 9350.247056 11749.58001 7877.424458 4428.440479
6053.513824 9651.938476 4104.894764 3861.773648
3392.501951 2324.747298 9657.562529 0 5596.418919
7133.835583 5172.424702 1630.782021 7199.510389
8117.184078 4847.787616 9170.886812 5253.831477
8488.827505 6176.911178 7470.654039 4704.08858 5375.364802
2880.177946 5373.012506 5051.819087 4808.697971
2203.916968 3271.671621 4061.14361 5596.418919 0
1537.416664 3983.839719 6399.461408 5073.534548
4155.860859 3182.455813 7044.910971 4677.119793
10026.24417 7714.327842 5933.237375 5610.10986 6912.781466
4417.59461 3835.595842 6589.235751 6346.114635 3741.333632
4809.088285 2523.726946 7133.835583 1537.416664 0
5521.256383 7936.878072 3536.117884 2618.444195
4719.872477 5507.494307 6214.536457

```
8064.833288    9873.177162    11454.49376    8400.354564    4951.370585
    6576.44393 9356.852225    4627.82487 4384.703754    1779.922751
    2847.677404    8044.983329    5172.424702    3983.839719
    5521.256383    0    6803.206723    9057.374267    8139.700578
    7166.295532    11028.75069    5776.761583
9172.685203    10981.02908    13380.36203    9508.206479    6059.2225
    7684.295845    11282.7205 5735.676785    5492.555669    5023.283972
    3955.529319    10460.60502    1630.782021    6399.461408
    7936.878072    6803.206723    0    5568.728368    6486.402057
    3217.005595    7540.104791    6884.613498
13562.36205    11250.44573    9469.355259    9146.227744    10448.89935
    7953.712494    7371.713726    10125.35364    9882.232519
    7277.451516    8345.206169    6059.84483 7199.510389    5073.534548
    3536.117884    9057.374267    5568.728368    0    917.6736893
    2351.722773    1971.376423    9750.654341
12644.68836    10332.77204    8551.68157 8228.554055    9531.225661
    7036.038805    6454.040037    9207.679946    8964.55883 6359.777827
    7427.53248 5142.171141    8117.184078    4155.860859    2618.444195
    8139.700578    6486.402057    917.6736893    0    3269.396462
    2889.050112    8832.980652
11671.28332    9359.366991    10653.10985    7886.544393    8557.820615
    6062.633759    8555.468319    8234.2749  7991.153784    5386.372781
    6454.127434    7243.599423    4847.787616    3182.455813
    4719.872477    7166.295532    3217.005595    2351.722773
    3269.396462    0    4323.099196    7859.575606
15533.73848    13221.82215    11440.73168    11117.60417    12420.27577
    9925.088917    9343.090149    12096.73006    11853.60894
    9248.827939    10316.58259    8031.221253    9170.886812
    7044.910971    5507.494307    11028.75069    7540.104791
    1971.376423    2889.050112    4323.099196    0    11722.03076
5295.491575    5093.675079    7493.008032    3620.852481    2182.028872
    1796.941847    5395.366499    4709.231645    1392.057829
    3996.838832    2929.084179    6707.235395    5253.831477
    4677.119793    6214.536457    5776.761583    6884.613498
    9750.654341    8832.980652    7859.575606    11722.03076    0
];
L=size(D,1);
distance=60000;
 b=zeros(1,23);
for u=1:100000
    i=2;
    a=zeros(1,23);
    a(1)=22;
while(i<=22)
```

```
        z=unidrnd(21);
        flag=0;
        for j=1:i-1
            if (a(j)==z)
            flag=1;
            end
        end
        if(flag==0)
            a(i)=z;
            i=i+1;
        end
end
a(i)=22;
a;
[cirlce,long]=sm4(D,L,a);
if(long<distance)
    distance=long;
    b=cirlce;
end
end
m=[13
14
16
17
18
21
23
24
26
27
31
32
34
36
38
39
40
42
43
45
49
51
];
for i=1:23
```

```
    b(i)=m(b(i));
end
distance
b

% 改良圈算法
function [circle,long]=sm4(a,L,c)
for k=1:L
    flag=0;
    for m=1:L-2
        for n=m+2:L
            if
(a(c(m),c(n))+a(c(m+1),c(n+1))<a(c(m),c(m+1))+a(c(n),c(n+1)))
                c(m+1:n)=c(n:-1:m+1);
                flag=flag+1;
            end
        end
    end
    if(flag==0)
        long=0;
        for i=1:L
            long=long+a(c(i),c(i+1));
        end
        circle=c;
        return
    end
end
```

附录 2-1

```
%检验问题 1 求得的路线是否符合时间约束条件
way=[51,18,13,24,31,27,39,27,31,34,40,45,42,49,42,43,38,36,38,32,23,1
6,14,17,21,26,51];
bag=[13    60
18  60
24  60
31  90
45  90
45  90
31  90
34  90
```

```
40  90
45  90
38  135
43   135
42   135
43  135
49  135
26  240
21  240
14  240
17  240
23  240
32  240
39  240
32  240
36  240
27  240
27  240
26  240
32  240
23  240
16  240
];
distance=[0    Inf Inf Inf 3113.462703    Inf Inf 5714.337164    Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf 0    2607.680962    2195.723116    Inf 3296.733232    Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf 2607.680962    0    Inf Inf Inf 2097.641533    Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf 2195.723116    Inf 0    Inf 1823.910634    1774.514018    Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
3113.462703    Inf Inf Inf 0    Inf Inf Inf Inf Inf 2103.693181    Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf 2182.028872
Inf 3296.733232    Inf 1823.910634    Inf 0    Inf Inf 2191.740176    Inf
    Inf Inf Inf Inf 2880.177946    Inf Inf Inf Inf Inf Inf Inf 1796.941847
Inf Inf 2097.641533    1774.514018    Inf Inf 0    Inf Inf Inf Inf
    1311.868896    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
5714.337164    Inf Inf Inf Inf Inf Inf 0    Inf Inf 1780.147466    Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf 2191.740176    Inf Inf 0    Inf 1537.02635 Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf 1392.057829
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 0    1067.754653    Inf Inf 2203.916968
    Inf 1779.922751    Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf 2103.693181    Inf Inf 1780.147466    1537.02635
```

```
    1067.754653    0    Inf 2324.747298    Inf Inf Inf Inf Inf Inf Inf Inf
    Inf
Inf Inf Inf Inf Inf Inf 1311.868896    Inf Inf Inf Inf 0    Inf Inf
    2523.726946    Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2324.747298    Inf 0    Inf Inf Inf
    1630.782021    Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf 2880.177946    Inf Inf Inf 2203.916968    Inf Inf Inf 0
    1537.416664    Inf Inf Inf Inf 3182.455813    Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2523.726946    Inf 1537.416664
    0    Inf Inf Inf 2618.444195    Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1779.922751    Inf Inf Inf Inf Inf 0
    Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1630.782021    Inf Inf Inf 0
    Inf Inf 3217.005595    Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 0
    917.6736893    2351.722773    1971.376423    Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2618.444195    Inf
    Inf 917.6736893    0    Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3182.455813    Inf Inf
    3217.005595    2351.722773    Inf 0    Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    1971.376423    Inf Inf 0    Inf
Inf Inf Inf Inf 2182.028872    1796.941847    Inf Inf 1392.057829    Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 0
];
bag=bag';
t=0;
lastpos=51;
nowpos=51;
lateflag=zeros(1,15);
for i=2:27
    i
    %到达新的目的地
    nowpos=way(i);
    %计算从上一个地点转移到新地点的时间
    t=t+distance(i12(nowpos),i12(lastpos))/400;
    t
    for j=1:30
        if(bag(1,j)==nowpos)
            t=t+3;
            t
            bag(1,j)=0;
            if(i<=15)
                if(t>bag(2,j))
```

```
                    lateflag(j)=t-bag(2,j);
                end
            end
        end
    end
    %离开此地
    lastpos=way(i);
end
bag
```

附录 2-2

```
%问题 2 求解
D=[0    10389.16665    12788.49961    8916.344056    3113.462703
    7092.433422    10690.85807    5714.337164    6687.549404
    6284.910537    5217.155884    12002.72697    7541.903182
    8488.827505    10026.24417    8064.833288    9172.685203
    13562.36205    12644.68836    11671.28332    15533.73848
    5295.491575
10389.16665    0    2607.680962    2195.723116    7275.703951
    3296.733232    3970.237134    8805.647224    5488.473408
    8093.254411    7025.499758    5282.10603 9350.247056    6176.911178
    7714.327842    9873.177162    10981.02908    11250.44573
    10332.77204    9359.366991    13221.82215    5093.675079
12788.49961    2607.680962    0    3872.155551    9675.036904
    5696.066185    2097.641533    11204.98018    7887.806361
    9674.571007    9424.832711    3409.510429    11749.58001
    7470.654039    5933.237375    11454.49376    13380.36203
    9469.355259    8551.68157 10653.10985    11440.73168    7493.008032
8916.344056    2195.723116    3872.155551    0    5802.881353
    1823.910634    1774.514018    7332.824626    4015.65081 6620.431813
    5552.67716 3086.382914    7877.424458    4704.08858 5610.10986
    8400.354564    9508.206479    9146.227744    8228.554055
    7886.544393    11117.60417    3620.852481
3113.462703    7275.703951    9675.036904    5802.881353    0
    3978.970719    7577.395371    3883.840647    3574.086701
    3171.447834    2103.693181    8889.264267    4428.440479
    5375.364802    6912.781466    4951.370585    6059.2225  10448.89935
    9531.225661    8557.820615    12420.27577    2182.028872
7092.433422    3296.733232    5696.066185    1823.910634    3978.970719
    0    3598.424652    5508.913992    2191.740176    4796.521179
```

3728.766526 4910.293548 6053.513824 2880.177946
4417.59461 6576.44393 7684.295845 7953.712494 7036.038805
6062.633759 9925.088917 1796.941847
10690.85807 3970.237134 2097.641533 1774.514018 7577.395371
3598.424652 0 9107.338644 5790.164828 7576.929474
7327.191178 1311.868896 9651.938476 5373.012506
3835.595842 9356.852225 11282.7205 7371.713726 6454.040037
8555.468319 9343.090149 5395.366499
5714.337164 8805.647224 11204.98018 7332.824626 3883.840647
5508.913992 9107.338644 0 3317.173816 2847.902119
1780.147466 9112.962697 4104.894764 5051.819087
6589.235751 4627.82487 5735.676785 10125.35364 9207.679946
8234.2749 12096.73006 4709.231645
6687.549404 5488.473408 7887.806361 4015.65081 3574.086701
2191.740176 5790.164828 3317.173816 0 2604.781003
1537.02635 7102.033724 3861.773648 4808.697971 6346.114635
4384.703754 5492.555669 9882.232519 8964.55883 7991.153784
11853.60894 1392.057829
6284.910537 8093.254411 9674.571007 6620.431813 3171.447834
4796.521179 7576.929474 2847.902119 2604.781003 0
1067.754653 6265.060578 3392.501951 2203.916968
3741.333632 1779.922751 5023.283972 7277.451516
6359.777827 5386.372781 9248.827939 3996.838832
5217.155884 7025.499758 9424.832711 5552.67716 2103.693181
3728.766526 7327.191178 1780.147466 1537.02635 1067.754653
0 7332.815231 2324.747298 3271.671621 4809.088285
2847.677404 3955.529319 8345.206169 7427.53248 6454.127434
10316.58259 2929.084179
12002.72697 5282.10603 3409.510429 3086.382914 8889.264267
4910.293548 1311.868896 9112.962697 7102.033724
6265.060578 7332.815231 0 9657.562529 4061.14361
2523.726946 8044.983329 10460.60502 6059.84483 5142.171141
7243.599423 8031.221253 6707.235395
7541.903182 9350.247056 11749.58001 7877.424458 4428.440479
6053.513824 9651.938476 4104.894764 3861.773648
3392.501951 2324.747298 9657.562529 0 5596.418919
7133.835583 5172.424702 1630.782021 7199.510389
8117.184078 4847.787616 9170.886812 5253.831477
8488.827505 6176.911178 7470.654039 4704.08858 5375.364802
2880.177946 5373.012506 5051.819087 4808.697971
2203.916968 3271.671621 4061.14361 5596.418919 0
1537.416664 3983.839719 6399.461408 5073.534548
4155.860859 3182.455813 7044.910971 4677.119793
10026.24417 7714.327842 5933.237375 5610.10986 6912.781466

```
    4417.59461 3835.595842    6589.235751    6346.114635    3741.333632
    4809.088285    2523.726946    7133.835583    1537.416664    0
    5521.256383    7936.878072    3536.117884    2618.444195
    4719.872477    5507.494307    6214.536457
8064.833288    9873.177162    11454.49376    8400.354564    4951.370585
    6576.44393 9356.852225    4627.82487 4384.703754    1779.922751
    2847.677404    8044.983329    5172.424702    3983.839719
    5521.256383    0    6803.206723    9057.374267    8139.700578
    7166.295532    11028.75069    5776.761583
9172.685203    10981.02908    13380.36203    9508.206479    6059.2225
    7684.295845    11282.7205 5735.676785    5492.555669    5023.283972
    3955.529319    10460.60502    1630.782021    6399.461408
    7936.878072    6803.206723    0    5568.728368    6486.402057
    3217.005595    7540.104791    6884.613498
13562.36205    11250.44573    9469.355259    9146.227744    10448.89935
    7953.712494    7371.713726    10125.35364    9882.232519
    7277.451516    8345.206169    6059.84483 7199.510389    5073.534548
    3536.117884    9057.374267    5568.728368    0    917.6736893
    2351.722773    1971.376423    9750.654341
12644.68836    10332.77204    8551.68157 8228.554055    9531.225661
    7036.038805    6454.040037    9207.679946    8964.55883 6359.777827
    7427.53248 5142.171141    8117.184078    4155.860859    2618.444195
    8139.700578    6486.402057    917.6736893    0    3269.396462
    2889.050112    8832.980652
11671.28332    9359.366991    10653.10985    7886.544393    8557.820615
    6062.633759    8555.468319    8234.2749  7991.153784    5386.372781
    6454.127434    7243.599423    4847.787616    3182.455813
    4719.872477    7166.295532    3217.005595    2351.722773
    3269.396462    0    4323.099196    7859.575606
15533.73848    13221.82215    11440.73168    11117.60417    12420.27577
    9925.088917    9343.090149    12096.73006    11853.60894
    9248.827939    10316.58259    8031.221253    9170.886812
    7044.910971    5507.494307    11028.75069    7540.104791
    1971.376423    2889.050112    4323.099196    0    11722.03076
5295.491575    5093.675079    7493.008032    3620.852481    2182.028872
    1796.941847    5395.366499    4709.231645    1392.057829
    3996.838832    2929.084179    6707.235395    5253.831477
    4677.119793    6214.536457    5776.761583    6884.613498
    9750.654341    8832.980652    7859.575606    11722.03076    0
];
L=size(D,1);
distance=60000;
b=zeros(1,23);
```

```
for u=1:1000
%%%%%%%%%%%
%找到一条新路
    i=2;
    a=zeros(1,23);
    a(1)=22;
while(i<=22)
        z=unidrnd(21);
        flag=0;
        for j=1:i-1
            if (a(j)==z)
            flag=1;
            end
        end
        if(flag==0)
            a(i)=z;
            i=i+1;
        end
end
a(i)=22;
a;
[circle,long]=sm4(D,L,a);
%%%%%%%%%
%检验时间初始化
t=0;
lastpos=22;
nowpos=22;
lateflag=0;
bag=[13    60
18  60
24  60
31  90
45  90
45  90
31  90
34  90
40  90
45  90
38  135
43   135
42   135
43  135
49  135
26  240
```

```
21  240
14  240
17  240
23  240
32  240
39  240
32  240
36  240
27  240
27  240
26  240
32  240
23  240
16  240
];
bag=bag';
%%%%%%%%%
%检验时间
for i=2:23
    %到达新的目的地
    nowpos=circle(i);
    %计算从上一个地点转移到新地点的时间
    t=t+D(nowpos,lastpos)/400;
    for j=1:30
        if(bag(1,j)~=0&&i12(bag(1,j))==nowpos)
            t=t+3;
            bag(1,j)=0;
            %if(i<=15)
                if(t>bag(2,j))
                    lateflag=1;
                end
            %end
        end
    end
    %离开此地
    lastpos=circle(i);
end
%%%%%%%%%%%%%%%%%
if(lateflag==0)
    if(long<distance)
        distance=long;
        b=circle;
        time=t;
    end
```

```
end
end
m=[13
14
16
17
18
21
23
24
26
27
31
32
34
36
38
39
40
42
43
45
49
51
];
for i=1:23
    b(i)=m(b(i));
end
distance
b
time
```

附录 3-1

```
%迪杰特斯拉求 0 点至其余各点最短路径，并画出这些最短路径
w=[Inf  Inf 1916.278946    Inf Inf 1294.31449 1968.247952    2863.782464
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf 2292.640399    1252.936551    Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf 7823.314515    Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
```

Inf Inf Inf Inf Inf
1916.278946 Inf Inf 3536.414144 Inf Inf Inf 1958.092184 Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf 2292.640399 3536.414144 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf 1252.936551 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
5004.540438 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf
1294.31449 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
1968.247952 Inf Inf Inf Inf Inf Inf Inf Inf 2059.368835 Inf Inf Inf
Inf Inf Inf Inf 5917.940943 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
2863.782464 Inf 1958.092184 Inf Inf Inf Inf Inf Inf Inf Inf
1756.765494 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf 1945.507646 Inf Inf Inf 2681.347609
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf
Inf Inf Inf Inf Inf Inf 2059.368835 Inf 1945.507646 Inf Inf Inf Inf
Inf Inf Inf Inf 5909.545245 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1417.682969 1669.558325
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf 1756.765494 Inf Inf 1417.682969 Inf
1456.794426 Inf 4805.798581 Inf Inf Inf Inf Inf Inf Inf Inf Inf
5756.570159 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1669.558325 1456.794426 Inf
Inf Inf Inf Inf 3113.462703 3455.698193 Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf 2681.347609 Inf Inf Inf Inf Inf Inf
2607.680962 2195.723116 5342.181202 Inf Inf 3296.733232
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf 5004.540438 Inf Inf Inf Inf Inf Inf 4805.798581 Inf
Inf Inf Inf Inf Inf Inf Inf Inf 2860.983223 Inf Inf 4235.398446
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2607.680962 Inf Inf
Inf Inf Inf Inf Inf Inf Inf 2097.641533 Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2195.723116 Inf Inf
Inf Inf Inf Inf 1823.910634 Inf 1774.514018 Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf 5917.940943 Inf Inf 5909.545245 Inf Inf
3113.462703 5342.181202 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf 2103.693181 Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2182.028872
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3455.698193 Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf 2258.638971 1966.214637 Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf 7823.314515 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf 1498.932954 Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3296.733232 Inf Inf
1823.910634 Inf Inf Inf Inf Inf Inf Inf 2191.740176 Inf Inf
Inf Inf Inf Inf Inf Inf 2880.177946 Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf 1796.941847
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2860.983223 Inf
Inf Inf Inf 1498.932954 Inf Inf Inf Inf Inf Inf Inf 1097.861558
1287.487864 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2097.641533
1774.514018 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
1311.868896 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
2258.638971 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1780.147466
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 5756.570159 Inf Inf
4235.398446 Inf Inf Inf 1966.214637 Inf Inf Inf Inf Inf Inf Inf
Inf Inf 1885.901641 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
4154.593843 Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf 2191.740176 Inf Inf Inf Inf Inf Inf Inf Inf 1537.02635 Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
1392.057829
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1067.754653 Inf Inf Inf
Inf 2203.916968 Inf Inf 1779.922751 Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1017.889974 Inf Inf 1325.6885
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf 1097.861558 Inf Inf 1885.901641 Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf 1287.487864 Inf Inf Inf Inf Inf 1017.889974 Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf 4997.624436 Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
2103.693181 Inf Inf Inf Inf Inf 1780.147466 Inf 1537.02635
1067.754653 Inf Inf Inf Inf Inf Inf 2324.747298 Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf 1311.868896 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
1114.001795 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf 1325.6885 Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3758.510343 Inf Inf Inf Inf
Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2324.747298 Inf Inf Inf
Inf Inf Inf Inf Inf 1630.782021 Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1114.001795 Inf Inf
Inf Inf Inf 1409.725151 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf 2880.177946 Inf Inf Inf Inf Inf 2203.916968 Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf 1537.416664 Inf Inf Inf Inf Inf Inf
3182.455813 Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf 2090.053827 2601.922366 Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1409.725151
1537.416664 Inf Inf Inf Inf Inf Inf 2618.444195 Inf Inf Inf Inf
Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf 1779.922751 Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1630.782021
Inf Inf 2090.053827 Inf Inf Inf Inf Inf Inf Inf 3217.005595 Inf
2331.222855 Inf Inf 3043.493059 Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf 4154.593843 Inf Inf Inf Inf 4997.624436 Inf
Inf Inf Inf Inf Inf Inf 2601.922366 Inf Inf Inf Inf Inf Inf 2366.030431
Inf 2735.415873 Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf 917.6736893 Inf 2351.722773 Inf Inf Inf
1971.376423 Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
2618.444195 Inf Inf Inf 917.6736893 Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf 2366.030431 Inf Inf Inf Inf Inf Inf 2152.539198 Inf
4987.045719 Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
3182.455813 Inf Inf Inf 3217.005595 Inf 2351.722773 Inf Inf
Inf Inf Inf Inf Inf 3102.760867 Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3758.510343 Inf
Inf Inf Inf Inf Inf Inf 2735.415873 Inf Inf Inf Inf Inf Inf
1494.130182 Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

```
    Inf Inf 2331.222855    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf 2152.539198    Inf 1494.130182    Inf Inf Inf
    Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf 1971.376423    Inf Inf Inf Inf Inf Inf Inf 3568.81633
    Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf 3043.493059    Inf Inf Inf 4987.045719    3102.760867    Inf
    Inf Inf 3568.81633 Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    2182.028872    Inf Inf 1796.941847    Inf Inf Inf Inf 1392.057829
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf
];
for i=1:51
   w(i,i)=0;
end
n=size(w,1);
w51=w(51,:);
for i=1:n
    l(i)=w51(i);
    z(i)=51;
end
s=[];
s(1)=51;
u=s(1);
k=1;
l
z
while k<n
    for i=1:n
    for j=1:k
        if i~=s(j)
            if(l(i)>l(u)+w(u,i))
                l(i)=l(u)+w(u,i);
                z(i)=u;
            end
        end
    end
end
```

```
l
z
ll=l;
for i=1:n
    for j=1:k
        if i~=s(j)
            ll(i)=ll(i);
        else
            ll(i)=inf;
        end
    end
end

lv=inf;
for i=1:n
    if(ll(i)<lv)
        lv=ll(i);
        v=i;
    end
end
lv;
v;
s(k+1)=v;
k=k+1;
u=s(k);

end
l
z
way=[0 1   3
0   1   8
0   2   20
0   2   4
0   3   8
0   3   4
0   4   2
0   5   15
0   5   2
0   6   1
0   7   18
0   7   1
0   8   12
0   9   14
0   9   10
```

0 10 18
0 10 7
0 11 12
0 12 13
0 12 25
0 12 15
0 13 18
0 13 19
0 13 11
0 14 18
0 14 16
0 14 17
0 14 21
0 15 22
0 15 25
0 16 23
0 17 23
0 18 31
0 19 24
0 20 22
0 21 26
0 21 36
0 21 17
0 22 30
0 23 17
0 24 31
0 25 41
0 25 19
0 25 29
0 27 31
0 28 33
0 29 22
0 30 28
0 30 41
0 31 26
0 31 34
0 32 35
0 32 23
0 33 46
0 33 28
0 34 40
0 35 38
0 36 45
0 36 27

```
0   37  40
0   38  36
0   39  27
0   40  34
0   40  45
0   41  44
0   41  37
0   41  46
0   42  43
0   42  49
0   43  38
0   44  48
0   44  50
0   45  50
0   45  42
0   46  48
0   47  40
0   48  44
0   49  50
0   49  42
0   50  40
0   51  18
0   51  21
0   51  26
];
for i=1:51
    for j=1:83

if( (i==way(j,2)&&z(i)==way(j,3))||(i==way(j,3)&&z(i)==way(j,2)) )
            way(j,1)=1;
        end
    end
end
x=[9185
1445
7270
3735
2620
10080
10025
7160
13845
11935
7850
```

```
6585
7630
13405
2125
15365
14165
8825
5855
780
12770
2200
14765
7790
4435
10860
10385
565
2580
1565
9395
14835
1250
7280
15305
12390
6410
13915
9510
8345
4930
13265
14180
3030
10915
2330
7735
885
11575
8010
11000
];
x=x';
y=[500
560
```

570
670
995
1435
2280
2525
2680
3050
3545
4185
5200
5325
5975
7045
7385
8075
8165
8355
8560
8835
9055
9330
9525
9635
10500
9765
9865
9955
10100
10365
10900
11065
11375
11415
11510
11610
12050
12300
13650
14145
14215
15060
14235
14500

```
14550
14880
15160
15325
8250
];
y=y';
plot(x,y,'o')
hold on
for i=1:50
    text(x(i),y(i),num2str(i),'color','k');
end
text(x(51),y(51),'o','color','r');
m=[1
1
2
2
3
3
4
5
5
6
7
7
8
9
9
10
10
11
12
12
12
13
13
13
14
14
14
14
15
15
16
```

47
48
49
49
50
51
51
51
];
m=m';
n=[3
8
20
4
8
4
2
15
2
1
18
1
12
14
10
18
7
12
13
25
15
18
19
11
18
16
17
21
22
25
23
23
31
24

22
26
36
17
30
17
31
41
19
29
31
33
22
28
41
26
34
35
23
46
28
40
38
45
27
40
36
27
34
45
44
37
46
43
49
38
48
50
50
42
48
40
44
50

```
42
40
18
21
26
];
n=n';
for i=1:83
    if(way(i,1)==1)
    plot([x(m(i)) x(n(i))],[y(m(i)) y(n(i))],'b');
    hold on
    end
end
way
```

附录 3-2

```
%问题 3 输入一个分组，生成最优汉密尔顿回路，并计算路的权值。

%初始化距离矩阵
D=[Inf Inf 1916.278946   Inf Inf 1294.31449 1968.247952   2863.782464
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf 2292.640399   1252.936551   Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf 7823.314515   Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf
1916.278946   Inf Inf 3536.414144   Inf Inf Inf 1958.092184   Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf
Inf 2292.640399   3536.414144   Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf
Inf 1252.936551   Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    5004.540438   Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf
1294.31449 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
    Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
```

1968.247952 Inf Inf Inf Inf Inf Inf Inf Inf 2059.368835 Inf Inf Inf Inf Inf Inf Inf 5917.940943 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

2863.782464 Inf 1958.092184 Inf Inf Inf Inf Inf Inf Inf Inf 1756.765494 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf 1945.507646 Inf Inf Inf 2681.347609 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf 2059.368835 Inf 1945.507646 Inf Inf Inf Inf Inf Inf Inf Inf 5909.545245 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1417.682969 1669.558325 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf 1756.765494 Inf Inf 1417.682969 Inf 1456.794426 Inf 4805.798581 Inf Inf Inf Inf Inf Inf Inf Inf Inf 5756.570159 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1669.558325 1456.794426 Inf Inf Inf Inf Inf 3113.462703 3455.698193 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf 2681.347609 Inf Inf Inf Inf Inf 2607.680962 2195.723116 5342.181202 Inf Inf 3296.733232 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf 5004.540438 Inf Inf Inf Inf Inf Inf 4805.798581 Inf Inf Inf Inf Inf Inf Inf Inf Inf 2860.983223 Inf Inf 4235.398446 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2607.680962 Inf Inf Inf Inf Inf Inf Inf Inf 2097.641533 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2195.723116 Inf Inf Inf Inf Inf Inf 1823.910634 Inf 1774.514018 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf 5917.940943 Inf Inf 5909.545245 Inf Inf 3113.462703 5342.181202 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2103.693181 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2182.028872

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3455.698193 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2258.638971 1966.214637 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf 7823.314515 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1498.932954 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3296.733232 Inf Inf 1823.910634 Inf Inf Inf Inf Inf Inf Inf Inf 2191.740176 Inf Inf Inf Inf Inf Inf Inf Inf Inf 2880.177946 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1796.941847

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2860.983223 Inf Inf Inf Inf 1498.932954 Inf Inf Inf Inf Inf Inf Inf Inf 1097.861558 1287.487864 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2097.641533 1774.514018 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1311.868896 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2258.638971 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1780.147466 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 5756.570159 Inf Inf 4235.398446 Inf Inf Inf 1966.214637 Inf Inf Inf Inf Inf Inf Inf Inf Inf 1885.901641 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 4154.593843 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2191.740176 Inf Inf Inf Inf Inf Inf Inf Inf Inf 1537.02635 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1392.057829

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1067.754653 Inf Inf Inf Inf 2203.916968 Inf Inf 1779.922751 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1017.889974 Inf Inf 1325.6885 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf 1097.861558 Inf Inf 1885.901641 Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf 1287.487864 Inf Inf Inf Inf Inf 1017.889974 Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf 4997.624436 Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
2103.693181 Inf Inf Inf Inf Inf 1780.147466 Inf 1537.02635
1067.754653 Inf Inf Inf Inf Inf Inf 2324.747298 Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf 1311.868896 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
1114.001795 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf 1325.6885 Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3758.510343 Inf Inf Inf Inf
Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2324.747298 Inf Inf Inf
Inf Inf Inf Inf Inf 1630.782021 Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1114.001795 Inf Inf
Inf Inf Inf 1409.725151 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf 2880.177946 Inf Inf Inf Inf 2203.916968 Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf 1537.416664 Inf Inf Inf Inf Inf Inf
3182.455813 Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf 2090.053827 2601.922366 Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1409.725151
1537.416664 Inf Inf Inf Inf Inf Inf 2618.444195 Inf Inf Inf Inf
Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf 1779.922751 Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf
Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1630.782021

Inf Inf 2090.053827 Inf Inf Inf Inf Inf Inf Inf 3217.005595 Inf 2331.222855 Inf Inf 3043.493059 Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 4154.593843 Inf Inf Inf Inf 4997.624436 Inf Inf Inf Inf Inf Inf 2601.922366 Inf Inf Inf Inf Inf Inf 2366.030431 Inf 2735.415873 Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 917.6736893 Inf 2351.722773 Inf Inf Inf 1971.376423 Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2618.444195 Inf Inf Inf 917.6736893 Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2366.030431 Inf Inf Inf Inf Inf Inf 2152.539198 Inf 4987.045719 Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3182.455813 Inf Inf Inf 3217.005595 Inf 2351.722773 Inf Inf Inf Inf Inf Inf Inf 3102.760867 Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3758.510343 Inf Inf Inf Inf Inf Inf Inf 2735.415873 Inf Inf Inf Inf Inf Inf 1494.130182 Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2331.222855 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2152.539198 Inf 1494.130182 Inf Inf Inf Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 1971.376423 Inf Inf Inf Inf Inf Inf Inf 3568.81633 Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 3043.493059 Inf Inf Inf 4987.045719 3102.760867 Inf Inf Inf 3568.81633 Inf Inf

Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf 2182.028872 Inf Inf 1796.941847 Inf Inf Inf Inf 1392.057829 Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf Inf

```
    Inf Inf Inf Inf Inf Inf Inf
];
for i=1:51
   D(i,i)=0;
end

%此处以分组 1 为例
wa=[51 18 13 11 12 15 5 2 4 3 8 1 6 7 10 9 14 16 23 17 21];
n=length(wa);
d=zeros(n,n);
for i=1:n
    for j=1:n
        d(i,j)=D(wa(i),wa(j));
    end
end

%调用弗洛伊德算法,distance 为任意两点最短路长度
[distance,R]=floyd(d);

%求最优汉密尔顿回路
L=size(distance,1);
length=60000;
b=zeros(1,n+1);
for u=1:10
    i=2;
    a=zeros(1,n+1);
    a(1)=1;
while(i<=n)
        z=unidrnd(n-1)+1;
        flag=0;
        for j=1:i-1
            if (a(j)==z)
            flag=1;
            end
        end
        if(flag==0)
            a(i)=z;
            i=i+1;
        end
end
a(i)=1;
a;
[cirlce,long]=sm4(distance,L,a);
if(long<length)
```

```
    length=long;
    b=cirlce;
end
end
length
for i=1:n+1
    b(i)=wa(b(i));
end
b
```

附录 3-3

```
d=[0    0    1916.278946    0    0    1294.31449 1968.247952    2863.782464
    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    0    0    0    0    0    0    0    0    0
    0    0    0    0    0
0    0    0    2292.640399    1252.936551    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    7823.314515    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
    0    0
1916.278946    0    0    3536.414144    0    0    0    1958.092184    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    0    0    0    0    0    0    0    0    0    0    0    0
    0    0
0    2292.640399    3536.414144    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    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    1252.936551    0    0    0    0    0    0    0    0    0    0    0
    5004.540438    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    0    0    0    0    0    0
    0    0
1294.31449 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    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
1968.247952    0    0    0    0    0    0    0    0    2059.368835    0    0    0    0
    0    0    0    5917.940943    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    0    0
    0    0
2863.782464    0    1958.092184    0    0    0    0    0    0    0    0
    1756.765494    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    0    0    0    0    0    0
    0    0    0    0    0
```

0 0 0 0 0 0 0 0 0 1945.507646 0 0 0 2681.347609
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 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 2059.368835 0 1945.507646 0 0 0 0 0
0 0 0 5909.545245 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 0 0 0
0 0
0 0 0 0 0 0 0 0 0 0 0 1417.682969 1669.558325 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 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1756.765494 0 0 1417.682969 0
1456.794426 0 4805.798581 0 0 0 0 0 0 0 0 0 0
5756.570159 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 0 0 0 0 0 0 0 0 1669.558325 1456.794426 0 0
0 0 0 3113.462703 3455.698193 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 0 0 0 0
0 0 0 0 0 0 0 0 2681.347609 0 0 0 0 0 0
2607.680962 2195.723116 5342.181202 0 0 3296.733232 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 0 0 0
0 0 0 0 5004.540438 0 0 0 0 0 0 4805.798581 0 0
0 0 0 0 0 0 0 2860.983223 0 0 4235.398446 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 0 0 0 0 0 0 0 0 0 0 0 0 2607.680962 0 0 0
0 0 0 0 0 2097.641533 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 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 2195.723116 0 0 0
0 0 0 1823.910634 0 1774.514018 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
0 0 0 0 0 0 5917.940943 0 0 5909.545245 0 0
3113.462703 5342.181202 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 2103.693181 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 2182.028872
0 0 0 0 0 0 0 0 0 0 0 0 0 3455.698193 0 0 0 0
0 0 0 0 0 0 0 2258.638971 1966.214637 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 7823.314515 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 1498.932954 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 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 3296.733232 0 0
1823.910634 0 0 0 0 0 0 0 0 2191.740176 0 0 0
0 0 0 0 0 0 2880.177946 0 0 0 0 0 0 0 0 0
0 0 0 0 0 1796.941847
0 0 0 0 0 0 0 0 0 0 0 0 0 0 2860.983223 0 0
0 0 1498.932954 0 0 0 0 0 0 0 0 1097.861558
1287.487864 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 0 0 0 0 0 0 0 2097.641533
1774.514018 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1311.868896 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 0 0 0 0 0 0 0 0 0
2258.638971 0 0 0 0 0 0 0 0 0 0 0 0 1780.147466
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 0 0 5756.570159 0 0
4235.398446 0 0 0 1966.214637 0 0 0 0 0 0 0 0
0 1885.901641 0 0 0 0 0 0 0 0 0 0 0
4154.593843 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 0
2191.740176 0 0 0 0 0 0 0 0 0 1537.02635 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1392.057829
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 0 1067.754653 0 0 0 0
2203.916968 0 0 1779.922751 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 0 0 0
0 0 0 0 0 0 0 0 0 1017.889974 0 0 1325.6885 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 0 0 0 0 0 0 0 0 0
0 1097.861558 0 0 1885.901641 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 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 1287.487864 0 0 0 0 0 1017.889974 0 0 0 0 0
0 0 0 0 0 0 0 4997.624436 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
2103.693181 0 0 0 0 0 1780.147466 0 1537.02635
1067.754653 0 0 0 0 0 0 2324.747298 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 0 0 0 0 0 0 0 0 0
0 0 1311.868896 0 0 0 0 0 0 0 0 0 0 0 0

1114.001795 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 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1325.6885 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 3758.510343 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 0 0 0 0 0 0 0 2324.747298 0 0 0 0 0
0 0 0 1630.782021 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 0 0
0 0 0 0 0 0 0 0 0 0 0 0 1114.001795 0 0 0 0
0 1409.725151 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 0 0 0 0
2880.177946 0 0 0 0 0 2203.916968 0 0 0 0 0 0
0 0 0 0 1537.416664 0 0 0 0 0 0 3182.455813 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 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2090.053827 2601.922366 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 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1409.725151
1537.416664 0 0 0 0 0 0 2618.444195 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 0 0 0 0 0 0 1779.922751 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 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 1630.782021 0 0
2090.053827 0 0 0 0 0 0 0 3217.005595 0
2331.222855 0 0 3043.493059 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 4154.593843 0 0 0 0 4997.624436 0 0 0
0 0 0 2601.922366 0 0 0 0 0 0 2366.030431 0
2735.415873 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 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 917.6736893 0 2351.722773 0 0 0 1971.376423
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 0 0 0 0 0 0 0 0 0 0 0
2618.444195 0 0 0 917.6736893 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
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 2366.030431 0 0 0 0 0 0 2152.539198 0

```
    4987.045719    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   0   0   0   0   0   0   0   3182.455813
    0   0   0   3217.005595    0   2351.722773    0   0   0   0   0   0   0
    3102.760867    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   0   0   0   0   3758.510343    0   0   0
    0   0   0   0   2735.415873    0   0   0   0   0   0   1494.130182    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   0   0   0   0   0   0   0   0   0   0   0   0   0
    2331.222855    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   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   2152.539198    0   1494.130182    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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   1971.376423    0   0   0   0   0   0   0   3568.81633 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   0   0   0   0   0   0   0   0   0   0   0
    3043.493059    0   0   0   4987.045719    3102.760867    0   0   0
    3568.81633 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    2182.028872    0   0   1796.941847    0   0   0   0   1392.057829    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
];
a=[51 18 13 11 12 15 5 2 4 3 8 1 6 1 7 10 9 14 16 23 17 21 51];
b=[51 21 17 23 32 35 38 43 42 49 50 45 36 27 39 27 31 26 51];
c=[51 26 31 34 40 47 40 37 41 44 48 46 33 28 30 22 20 22 29 25 19 24
31 26 51];
al=length(a);
bl=length(b);
cl=length(c);
ad=0;
bd=0;
cd=0;
for i=1:al-1
    ad=ad+d(a(i),a(i+1));
end
for i=1:bl-1
    bd=bd+d(b(i),b(i+1));
end
for i=1:cl-1
```

```
    cd=cd+d(c(i),c(i+1));
end
td=ad+bd+cd;
v=[13   0.0316
18  0.0354
31  0.024
26  0.035
21  0.0305
14  0.01
17  0.0109
23  0.0426
32  0.0481
38  0.0219
45  0.0287
43  0.0228
39  0.0595
45  0.0301
42  0.019
43  0.0782
32  0.0412
36  0.0184
27  0.0445
24  0.042
31  0.0108
27  0.0018
26  0.021
34  0.0103
40  0.0155
45  0.0382
49  0.0144
32  0.002
23  0.0487
16  0.0429
1   0.025
2   0.0501
3   0.0483
4   0.0006
5   0.0387
6   0.0067
7   0.0129
8   0.0346
9   0.0087
10  0.0124
11  0.051
```

12 0.0428
13 0.0048
14 0.0491
15 0.0209
16 0.0098
17 0.0324
18 0.0554
19 0.0262
20 0.0324
21 0.0419
22 0.0001
23 0.0502
24 0.0534
25 0.0012
26 0.0059
27 0.0224
28 0.058
29 0.0372
30 0.0402
31 0.0274
32 0.0503
33 0.0494
34 0.0325
35 0.0055
36 0.0177
37 0.0361
38 0.011
39 0.044
40 0.0329
41 0.0094
42 0.0455
43 0.0121
44 0.0005
45 0.0413
46 0.0241
47 0.023
48 0.0542
49 0.0566
50 0.0284
25 0.0011
46 0.0492
32 0.0034
23 0.0054
20 0.049

```
25  0.0088
19  0.0249
41  0.0038
46  0.0434
37  0.002
32  0.03
33  0.0133
36  0.002
38  0.0308
17  0.0345
11  0.0172
15  0.0536
12  0.0056
10  0.0175
7   0.0493
];
v=v';
m=[13  2.5
18  0.5
31  1.18
26  1.56
21  2.15
14  1.72
17  1.38
23  1.4
32  0.7
38  1.33
45  1.1
43  0.95
39  2.56
45  2.28
42  2.85
43  1.7
32  0.25
36  1.79
27  2.45
24  2.93
31  0.8
27  2.25
26  1.57
34  2.8
40  1.14
45  0.68
49  1.35
```

32 0.52
23 2.91
16 1.2
1 1.26
2 1.15
3 1.63
4 1.23
5 1.41
6 0.54
7 0.7
8 0.76
9 2.14
10 1.07
11 1.37
12 2.39
13 0.99
14 1.66
15 0.45
16 2.04
17 1.95
18 2.12
19 3.87
20 2.01
21 1.38
22 0.39
23 1.66
24 1.24
25 2.41
26 1.26
27 0.42
28 1.72
29 1.34
30 0.06
31 0.6
32 2.19
33 1.89
34 1.81
35 1
36 1.24
37 2.51
38 2.04
39 1.07
40 0.49
41 0.51

```
42  1.38
43  1.31
44  1.26
45  0.98
46  1.35
47  2.12
48  0.54
49  1.01
50  1.12
25  0.79
46  2.12
32  2.77
23  2.29
20  0.21
25  1.29
19  1.12
41  0.9
46  2.38
37  1.42
32  1.01
33  2.51
36  1.17
38  1.82
17  0.33
11  0.3
15  4.43
12  0.24
10  1.38
7   1.98
];
m=m';
am=0;
bm=0;
cm=0;
av=0;
bv=0;
cv=0;
for i=2:a1-1
    for j=1:100
        if(m(1,j)==a(i))
            am=am+m(2,j);
            av=av+v(2,j);
            m(1,j)=0;
        end
```

```
    end
end
for i=2:bl-1
    for j=1:100

            if(m(1,j)==b(i))
                bm=bm+m(2,j);
                bv=bv+v(2,j);
                m(1,j)=0;
            end

    end
end
for i=2:cl-1
    for j=1:100
        if(m(1,j)==c(i))
            cm=cm+m(2,j);
            cv=cv+v(2,j);
            m(1,j)=0;
        end
    end
end

%发现 am bm av 不符合要求
%手动进行调整


%第 4 件货物从 b 组转向 c 组
cm=cm+1.56;
bm=bm-1.56;
cv=cv+0.035;
bv=bv-0.035;

%第 3 件货物从 b 组转向 c 组
cm=cm+1.18;
bm=bm-1.18;
cv=cv+0.024;
bv=bv-0.024;

%第 23 件货物从 b 组转向 c 组
cm=cm+1.57;
bm=bm-1.57;
cv=cv+0.021;
bv=bv-0.021;
```

```
%第 5 件货物从 a 组转向 b 组
bm=bm+2.15;
am=am-2.15;
bv=bv+0.0305;
av=av-0.0305;

%第 51 件货物从 a 组转向 b 组
bm=bm+1.38;
am=am-1.38;
bv=bv+0.0419;
av=av-0.0419;

am
bm
cm
av
bv
cv
td
```