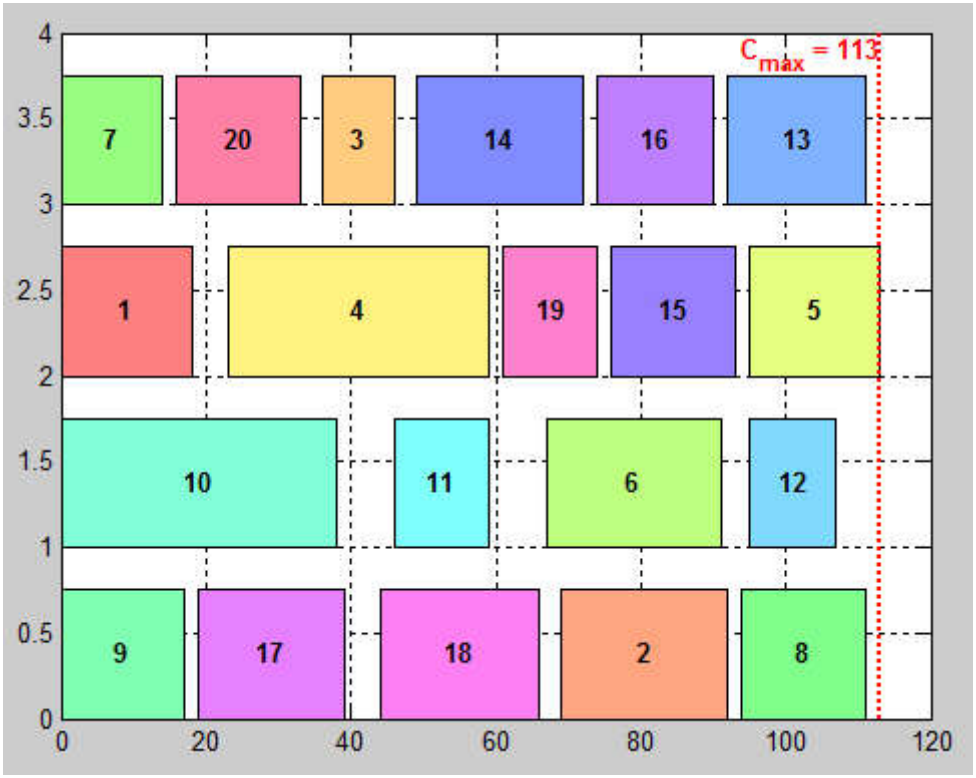
حل مسئله زمانبندی ماشین ها موازی Parallel Machine Scheduling با تبرید SA در متلب

J ماشین و I کار داریم. هر ماشین می تواند تعدادی کار انجام دهد. فرض می کنیم هر کار تنها توسط یک ماشین قابل انجام است. هر دو کار i و j سه وضعیت متفاوت نسبت به هم می توانند داشته باشند: - i پیش نیاز j است. به عبارت دیگر، j وقتی قابل اجرا است که i اجرا شده باشد. - j پیش نیاز i است. - دو کار با هم ارتباطی ندارند. همچنین اجرای کار i، به زمان ti احتیاج دارد. هر ماشین در هر لحظه تنها می تواند یک کار را انجام دهد. هدف این است که کارها با توالی در ماشین ها اجرا شوند که C_{max} (حداکثر زمانی که طول می کشد تا همه کارها در ماشین ها اجرا شوند) حداقل شود.



صورت مسئله:

۲۰ تا کار و ۴ تا ماشین به شرح زیر داریم می خواهیم این کارها در این ماشین ها طوری اجرا شود که حداکثر زمانی که طول می کشد تا همه کارها در ماشین ها اجرا شوندC_{max}، حداقل شود.

۲۰ کار و ۴ ماشین: 20x4

```
p=[ 48     27     18     15
    23     52     50     59
```

```
35    39    25    10
45    38    36    49
55    56    18    51
58    24    40    54
37    48    23    14
17    48    43    30
17    29    45    23
23    38    48    50
52    13    32    32
22    12    14    56
51    37    21    19
22    49    56    23
57    57    17    17
27    16    52    16
20    39    37    54
22    33    60    39
41    10    13    38
34    27    32    17]
```

وابستگی زمانبندی کارها در هر ماشین این صورت است:
یک ماتریس 20x20 برای ۴ ماشین:

```
s(:,:,1)=[4  7  5  7  7  5  2  7  5  3  8  6  6  6  7  2  6  2  8  6
          3  5  8  5  6  6  5  2  7  4  2  2  5  2  4  7  5  2  3  4
          6  8  6  8  3  2  7  8  4  2  3  2  4  7  3  4  5  3  3  4
          3  4  3  6  6  6  8  8  5  5  2  7  2  2  2  6  6  3  4  5
          2  7  3  6  2  4  3  8  2  4  5  8  7  2  7  8  2  4  2  4
          7  4  4  7  6  2  3  8  3  3  2  5  4  6  3  5  4  4  6  4
          3  7  7  8  6  5  5  7  6  3  8  2  6  4  4  6  7  3  4  5
          5  7  7  8  7  3  6  5  4  8  3  7  7  6  5  7  6  3  8  7
          6  4  7  2  8  2  4  3  8  6  2  4  2  7  3  5  2  8  4  4
          4  3  4  8  8  3  3  4  2  5  4  4  2  6  6  6  2  6  6  5
          7  7  5  6  7  3  8  2  8  8  5  7  5  7  5  2  2  5  3  2
          4  8  2  8  6  3  2  2  5  2  2  2  5  3  3  8  2  3  4  2
          6  4  2  5  8  2  2  8  6  7  8  2  8  7  7  3  4  3  3  4
          6  6  2  5  6  6  2  4  8  7  4  6  7  8  2  3  6  2  7  4
          5  5  6  7  2  3  3  4  4  5  4  6  7  8  4  7  7  8  8  6
          2  7  5  3  2  5  6  4  4  3  2  5  2  2  3  5  5  6  4  8
          4  7  3  5  8  6  6  5  5  6  4  7  2  4  5  7  2  5  6  8
          4  3  5  8  5  5  2  6  7  4  2  6  2  4  2  4  6  4  4  5
          3  8  3  6  7  5  8  2  7  2  5  7  7  6  4  3  2  3  5  3
          3  8  2  7  3  5  7  7  2  3  7  4  8  6  2  2  2  6  7  7]

s(:,:,2)=[7  7  7  6  3  3  2  4  7  2  5  7  3  5  4  4  5  8  4  5
```

```
                7 7 3 4 4 3 3 6 6 3 5 4 3 5 2 2 6 5 6 3
                7 2 2 8 2 5 3 7 2 2 8 5 6 8 3 3 4 7 8 8
                2 5 7 3 6 3 2 6 7 5 7 8 6 4 3 7 2 6 7 7
                6 4 6 6 3 7 2 5 8 3 5 5 6 5 4 7 5 2 5 8
                5 5 7 6 2 8 6 6 7 8 8 4 6 8 3 8 4 5 7 3
                3 4 6 4 7 2 8 5 2 2 2 6 2 2 4 6 7 6 4 6
                2 4 4 2 4 5 4 2 4 2 4 4 4 8 2 2 7 5 8 6
                7 3 4 2 6 2 4 7 6 5 8 7 5 3 8 8 6 4 8 2
                3 3 7 4 4 7 8 8 7 7 8 4 3 6 2 7 2 8 8 4
                3 2 4 3 6 8 8 4 3 4 6 5 7 6 8 4 2 7 4 3
                6 8 7 7 2 2 6 8 3 3 6 6 7 6 4 5 5 7 5 7
                8 6 7 4 8 8 8 4 6 4 4 8 3 4 2 8 4 4 3 3
                5 8 7 7 7 2 7 8 5 3 8 4 7 6 4 7 8 6 7 8
                6 3 5 7 7 6 4 5 6 5 2 7 2 7 7 7 8 8 8 7
                3 8 6 5 7 7 6 4 3 8 7 7 7 2 7 5 4 8 8 4
                8 7 8 3 4 5 3 3 3 6 6 8 2 2 5 5 7 6 5 5
                5 6 5 8 6 8 4 2 7 2 7 2 6 8 6 5 8 3 6 6
                6 5 2 3 6 8 6 4 7 4 4 4 4 6 8 3 6 6 3 7
                2 3 8 8 5 6 5 7 8 2 7 6 7 3 2 7 8 2 8 6]

s(:,:,3)=[6 5 8 5 4 6 3 8 2 3 6 5 3 6 7 2 6 5 7 8
                4 6 5 6 5 5 5 6 3 2 6 7 2 5 4 6 6 7 6 5
                5 8 5 7 4 3 2 5 2 6 5 3 4 6 6 2 3 8 8 2
                6 7 4 5 7 6 7 7 5 8 3 4 6 3 2 6 2 7 2 2
                8 4 5 3 7 2 7 5 3 8 7 3 6 2 2 7 3 4 6 7
                7 7 5 5 5 6 8 5 4 3 3 4 5 5 8 3 8 5 3 5
                2 2 2 4 6 6 8 6 4 5 4 4 5 3 3 5 8 7 7 4
                6 2 8 8 8 2 5 4 2 4 8 5 4 8 6 5 6 2 3 7
                5 2 2 6 7 2 3 3 5 5 7 2 5 8 8 2 7 2 5 4
                5 3 5 6 6 3 2 6 6 3 4 5 7 4 3 5 3 3 4 5
                2 4 7 7 2 2 5 8 3 2 4 3 7 2 3 6 6 5 7 6
                7 4 4 4 4 5 6 4 7 5 6 3 6 6 4 3 7 8 6 8
                4 2 6 5 6 7 7 2 2 3 8 3 7 7 8 7 4 6 3 4
                3 5 7 5 5 6 2 5 4 2 8 3 6 8 4 8 8 4 4 6
                4 2 8 3 2 5 6 4 2 8 6 8 2 2 3 7 2 4 2 8
                4 3 8 5 3 8 5 4 3 5 4 8 5 5 3 5 4 7 6 2
                5 6 3 6 7 2 3 7 2 8 7 7 4 6 4 3 5 8 5 6
                5 8 3 4 2 8 8 4 3 7 5 7 2 6 4 7 2 6 3 4
                4 8 8 7 8 2 6 4 2 2 8 3 3 7 2 3 7 3 3 4
                4 5 6 7 2 5 5 4 3 6 2 4 3 6 5 8 5 2 5 3]

s(:,:,4)=[7 7 8 3 8 2 5 2 3 8 2 5 7 7 3 4 7 6 8 7
                8 5 2 3 6 7 6 4 7 6 4 8 5 8 8 4 7 3 5 6
                3 3 2 4 4 4 8 8 4 6 7 7 4 3 6 8 4 5 8 5
```

```
7 5 4 8 7 7 3 5 4 7 3 8 7 2 8 6 5 7 7 3
3 5 6 5 8 5 7 4 3 2 7 3 5 3 5 8 8 3 5 8
8 8 5 4 5 5 6 3 7 8 6 5 8 4 8 3 6 4 6 5
7 7 8 3 5 2 5 5 6 4 7 2 8 4 2 7 7 5 8 2
4 8 5 8 4 2 8 8 7 2 7 7 4 8 6 6 3 4 3 6
7 6 5 4 2 2 4 2 7 7 4 6 5 2 7 3 6 7 4 5
5 4 5 7 3 6 3 5 2 3 4 8 4 6 3 5 6 8 8 2
7 8 6 6 2 3 6 7 8 3 5 8 6 3 8 4 8 3 4 8
4 5 2 4 5 7 6 2 5 6 4 8 7 7 7 6 2 3 6 4
2 3 7 8 2 8 4 6 7 3 7 4 7 3 7 7 5 6 8 3
6 4 2 7 8 8 7 8 7 4 7 2 2 5 6 2 5 4 8 2
8 6 5 5 6 5 8 3 7 4 5 5 7 8 7 7 2 8 6 4
3 5 3 7 2 3 8 2 3 4 3 3 2 4 4 7 8 8 2 3
5 7 4 8 2 3 2 6 5 4 6 3 4 2 3 4 8 6 2 6
7 8 6 5 3 5 3 8 6 6 3 4 7 3 4 5 5 8 6 2
2 8 3 4 5 7 2 6 8 3 5 2 7 4 6 6 7 4 5 3
8 5 3 6 2 4 6 8 7 3 4 7 4 4 7 6 3 6 8 3]
```

شرح کد:

این سورس کد شامل ۷ فایل می باشد که عبارتند از:

CreateModel.m: برای ایجاد مدل،کارها و ماشین ها و وابستگی های زمانی و کارها و مقدار دهی اولیه پارامتر های مدل مسیله از آن استفاده می شود.

```
function model=CreateModel()

    p=[ 48     27     18     15
        23     52     50     59
        35     39     25     10
        45     38     36     49
        55     56     18     51
        58     24     40     54
        37     48     23     14
        17     48     43     30
        17     29     45     23
        23     38     48     50
        52     13     32     32
        22     12     14     56
```

```
    51    37    21    19
    22    49    56    23
    57    57    17    17
    27    16    52    16
    20    39    37    54
    22    33    60    39
    41    10    13    38
    34    27    32    17];

I=size(p,1);

J=size(p,2);

s(:,:,1)=[4 7 5 7 7 5 2 7 5 3 8 6 6 6 7 2 6 2 8 6
          3 5 8 5 6 6 5 2 7 4 2 2 5 2 4 7 5 2 3 4
          6 8 6 8 3 2 7 8 4 2 3 2 4 7 3 4 5 3 3 4
          3 4 3 6 6 6 8 8 5 5 2 7 2 2 2 6 6 3 4 5
          2 7 3 6 2 4 3 8 2 4 5 8 7 2 7 8 2 4 2 4
          7 4 4 7 6 2 3 8 3 3 2 5 4 6 3 5 4 4 6 4
          3 7 7 8 6 5 5 7 6 3 8 2 6 4 4 6 7 3 4 5
          5 7 7 8 7 3 6 5 4 8 3 7 7 6 5 7 6 3 8 7
          6 4 7 2 8 2 4 3 8 6 2 4 2 7 3 5 2 8 4 4
          4 3 4 8 8 3 3 4 2 5 4 4 2 6 6 6 2 6 6 5
          7 7 5 6 7 3 8 2 8 8 5 7 5 7 5 2 2 5 3 2
          4 8 2 8 6 3 2 2 5 2 2 2 5 3 3 8 2 3 4 2
          6 4 2 5 8 2 2 8 6 7 8 2 8 7 7 3 4 3 3 4
          6 6 2 5 6 6 2 4 8 7 4 6 7 8 2 3 6 2 7 4
          5 5 6 7 2 3 3 4 4 5 4 6 7 8 4 7 7 8 8 6
          2 7 5 3 2 5 6 4 4 3 2 5 2 2 3 5 5 6 4 8
          4 7 3 5 8 6 6 5 5 6 4 7 2 4 5 7 2 5 6 8
          4 3 5 8 5 5 2 6 7 4 2 6 2 4 2 4 6 4 4 5
          3 8 3 6 7 5 8 2 7 2 5 7 7 6 4 3 2 3 5 3
          3 8 2 7 3 5 7 7 2 3 7 4 8 6 2 2 2 6 7 7];

s(:,:,2)=[7 7 7 6 3 3 2 4 7 2 5 7 3 5 4 4 5 8 4 5
          7 7 3 4 4 3 3 6 6 3 5 4 3 5 2 2 6 5 6 3
          7 2 2 8 2 5 3 7 2 2 8 5 6 8 3 3 4 7 8 8
          2 5 7 3 6 3 2 6 7 5 7 8 6 4 3 7 2 6 7 7
          6 4 6 6 3 7 2 5 8 3 5 5 6 5 4 7 5 2 5 8
          5 5 7 6 2 8 6 6 7 8 8 4 6 8 3 8 4 5 7 3
          3 4 6 4 7 2 8 5 2 2 2 6 2 2 4 6 7 6 4 6
          2 4 4 2 4 5 4 2 4 2 4 4 4 8 2 2 7 5 8 6
          7 3 4 2 6 2 4 7 6 5 8 7 5 3 8 8 6 4 8 2
          3 3 7 4 4 7 8 8 7 7 8 4 3 6 2 7 2 8 8 4
```

```
              3 2 4 3 6 8 8 4 3 4 6 5 7 6 8 4 2 7 4 3
              6 8 7 7 2 2 6 8 3 3 6 6 7 6 4 5 5 7 5 7
              8 6 7 4 8 8 8 4 6 4 4 8 3 4 2 8 4 4 3 3
              5 8 7 7 7 2 7 8 5 3 8 4 7 6 4 7 8 6 7 8
              6 3 5 7 7 6 4 5 6 5 2 7 2 7 7 7 8 8 8 7
              3 8 6 5 7 7 6 4 3 8 7 7 7 2 7 5 4 8 8 4
              8 7 8 3 4 5 3 3 3 6 6 8 2 2 5 5 7 6 5 5
              5 6 5 8 6 8 4 2 7 2 7 2 6 8 6 5 8 3 6 6
              6 5 2 3 6 8 6 4 7 4 4 4 4 6 8 3 6 6 3 7
              2 3 8 8 5 6 5 7 8 2 7 6 7 3 2 7 8 2 8 6];

s(:,:,3)=[6 5 8 5 4 6 3 8 2 3 6 5 3 6 7 2 6 5 7 8
              4 6 5 6 5 5 5 6 3 2 6 7 2 5 4 6 6 7 6 5
              5 8 5 7 4 3 2 5 2 6 5 3 4 6 6 2 3 8 8 2
              6 7 4 5 7 6 7 7 5 8 3 4 6 3 2 6 2 7 2 2
              8 4 5 3 7 2 7 5 3 8 7 3 6 2 2 7 3 4 6 7
              7 7 5 5 5 6 8 5 4 3 3 4 5 5 8 3 8 5 3 5
              2 2 2 4 6 6 8 6 4 5 4 4 5 3 3 5 8 7 7 4
              6 2 8 8 8 2 5 4 2 4 8 5 4 8 6 5 6 2 3 7
              5 2 2 6 7 2 3 3 5 5 7 2 5 8 8 2 7 2 5 4
              5 3 5 6 6 3 2 6 6 3 4 5 7 4 3 5 3 3 4 5
              2 4 7 7 2 2 5 8 3 2 4 3 7 2 3 6 6 5 7 6
              7 4 4 4 4 5 6 4 7 5 6 3 6 6 4 3 7 8 6 8
              4 2 6 5 6 7 7 2 2 3 8 3 7 7 8 7 4 6 3 4
              3 5 7 5 5 6 2 5 4 2 8 3 6 8 4 8 8 4 4 6
              4 2 8 3 2 5 6 4 2 8 6 8 2 2 3 7 2 4 2 8
              4 3 8 5 3 8 5 4 3 5 4 8 5 5 3 5 4 7 6 2
              5 6 3 6 7 2 3 7 2 8 7 7 4 6 4 3 5 8 5 6
              5 8 3 4 2 8 8 4 3 7 5 7 2 6 4 7 2 6 3 4
              4 8 8 7 8 2 6 4 2 2 8 3 3 7 2 3 7 3 3 4
              4 5 6 7 2 5 5 4 3 6 2 4 3 6 5 8 5 2 5 3];

s(:,:,4)=[7 7 8 3 8 2 5 2 3 8 2 5 7 7 3 4 7 6 8 7
              8 5 2 3 6 7 6 4 7 6 4 8 5 8 8 4 7 3 5 6
              3 3 2 4 4 4 8 8 4 6 7 7 4 3 6 8 4 5 8 5
              7 5 4 8 7 7 3 5 4 7 3 8 7 2 8 6 5 7 7 3
              3 5 6 5 8 5 7 4 3 2 7 3 5 3 5 8 8 3 5 8
              8 8 5 4 5 5 6 3 7 8 6 5 8 4 8 3 6 4 6 5
              7 7 8 3 5 2 5 5 6 4 7 2 8 4 2 7 7 5 8 2
              4 8 5 8 4 2 8 8 7 2 7 7 4 8 6 6 3 4 3 6
              7 6 5 4 2 2 4 2 7 7 4 6 5 2 7 3 6 7 4 5
              5 4 5 7 3 6 3 5 2 3 4 8 4 6 3 5 6 8 8 2
              7 8 6 6 2 3 6 7 8 3 5 8 6 3 8 4 8 3 4 8
              4 5 2 4 5 7 6 2 5 6 4 8 7 7 7 6 2 3 6 4
```

```
                2 3 7 8 2 8 4 6 7 3 7 4 7 3 7 7 5 6 8 3
                6 4 2 7 8 8 7 8 7 4 7 2 2 5 6 2 5 4 8 2
                8 6 5 5 6 5 8 3 7 4 5 5 7 8 7 7 2 8 6 4
                3 5 3 7 2 3 8 2 3 4 3 3 2 4 4 7 8 8 2 3
                5 7 4 8 2 3 2 6 5 4 6 3 4 2 3 4 8 6 2 6
                7 8 6 5 3 5 3 8 6 6 3 4 7 3 4 5 5 8 6 2
                2 8 3 4 5 7 2 6 8 3 5 2 7 4 6 6 7 4 5 3
                8 5 3 6 2 4 6 8 7 3 4 7 4 4 7 6 3 6 8 3];

    model.I=I;
                                                        کار
    model.J=J;
                                                        ماشین
    model.p=p;
                                                ماتریس شامل کار و ماشین
    model.s=s;
                                                زمانبندی هر ماشین
    model.nVar=I+J-1;
                تعداد متغیرها  21 ,22 ,23 جدا کننده هستند بین ماشین ها

end
```

MyCost.m:این تابع برای مشخص کردن میزان هزینه راه حل می باشد. چون تبرید min یاب است هزینه برای ما مهم است.

```
 function [z, sol]=MyCost(q,model)

        اجرای تابع ParseSolution با مدل و q (جدا کننده کارها)
    sol=ParseSolution(q,model);

 زمانی که طول می کشد تا همه کارها در همه ماشین ها اجرا شوند.
    z=sol.Cmax;

end
```

ParseSolution.m:راه حل را برای ما ایجاد می کند.

```
function sol=ParseSolution(q,model)
```

```
I=model.I;
J=model.J;
p=model.p;
s=model.s;

                                                    موقعیت جداکننده ها
DelPos=find(q>I);

                ترتیب و شوع و پایان کارها را تعیین می کند.
From=[0 DelPos]+1;
To=[DelPos I+J]-1;

                                                    ایجاد لیست کارها
L=cell(J,1);
for j=1:J
    L{j}=q(From(j):To(j));
end

                                                شبیه سازی مبتنی بر زمان
ST=zeros(I,1);
PT=zeros(I,1);
FT=zeros(I,1);
MCT=zeros(J,1);
for j=1:J
    for i=L{j}
        k=find(L{j}==i);
        if k==1
            ST(i)=0;
        else
            PreviousJob=L{j}(k-1);
            ST(i)=FT(PreviousJob)+s(PreviousJob,i,j);
        end

        PT(i)=p(i,j);

        FT(i)=ST(i)+PT(i);
    end

    if ~isempty(L{j})
        MCT(j)=FT(L{j}(end));
    end

end
```

```
    Cmax=max(MCT);

    sol.L=L;
    sol.ST=ST;
    sol.PT=PT;
    sol.FT=FT;
    sol.MCT=MCT;
    sol.Cmax=Cmax;

end
```

CreateRandomSolution.m:ایجاد راه حل به صورت تصادفی

```
function q=CreateRandomSolution(model)

                                                تعداد متغیرها
    nVar=model.nVar;

    یک جایگشت تصادفی از اعداد ۱ تا nVar را بر می گرداند.
    q=randperm(nVar);

end
```

CreateNeighbor.m: ایجاد همسایه

```
function qnew=CreateNeighbor(q)
                        یک عدد تصادفی بین ۱ تا۳ تولید می کند.

    m=randi([1 3]);

    switch m
                                اگر عدد تولید شده ۱ بود جابه جایی
        case 1
            جابه جایی
            qnew=Swap(q);
                                اگر عدد تولید شده ۲ بود معکوس



        case 2
            معکوس
            qnew=Reversion(q);
```

```
                                    اگر عدد تولید شده ۳ بود اضافه کن

            case 3
                اضافه کن
                qnew=Insertion(q);
        end

    end

    function qnew=Swap(q)

        n=numel(q);

        i=randsample(n,2);
        i1=i(1);
        i2=i(2);

        qnew=q;
        qnew([i1 i2])=q([i2 i1]);

    end

    function qnew=Reversion(q)

        n=numel(q);

        i=randsample(n,2);
        i1=min(i(1),i(2));
        i2=max(i(1),i(2));

        qnew=q;
        qnew(i1:i2)=q(i2:-1:i1);

    end

    function qnew=Insertion(q)

        n=numel(q);

        i=randsample(n,2);
        i1=i(1);
        i2=i(2);
```

```
    if i1<i2
        qnew=[q(1:i1-1) q(i1+1:i2) q(i1) q(i2+1:end)];
    else
        qnew=[q(1:i2) q(i1) q(i2+1:i1-1) q(i1+1:end)];
    end

end
```

sa.m: این فایل شامل کد الگوریتم تبرید به همراه توابع بالا برای پیاده سازی مسئله ست.

```
clc;
clear;
close all;

تعریف مسیله

model=CreateModel();          ایجاد مدل مسیله

CostFunction=@(q) MyCost(q,model);        تابع هزینه

nVar=model.nVar;
تعداد متغیرهای تصمیم(کارها به همراه جداکننده برای هر ماشین)

VarSize=[1 nVar];        اندازه ماتریس متغیرها


پارامترهای تبرید

MaxIt=500;       ماکزیمم تعداد تکرار

MaxIt2=25;       ماکزیمم تعداد تکرار داخلی

T0=10;           دمای اولیه

alpha=0.97;      نرخ میرایی دما


مقداردهی اولیه

ایجاد راه حل اولیه
x.Position=CreateRandomSolution(model);
```

```
[x.Cost, x.Sol]=CostFunction(x.Position);

بروزرسانی بهترین راه حل که تاکنون پیدا شده است
BestSol=x;

آرایه برای نگه داشتن بهترین مقادیر هزینه
BestCost=zeros(MaxIt,1);

تنظیم دمای اولیه
T=T0;


حلقه اصلی تبرید

for it=1:MaxIt
    for it2=1:MaxIt2

        ایجاد همسایه
        xnew.Position=CreateNeighbor(x.Position);
        [xnew.Cost, xnew.Sol]=CostFunction(xnew.Position);

        if xnew.Cost<=x.Cost
            % xnew بهتر است ، بنابراین پذیرفته می شود
            x=xnew;

        else
            % xnew  بهتر نیست ، بنابراین به طور مشروط
پذیرفته می شود            delta=xnew.Cost-x.Cost;
            p=exp(-delta/T);

            if rand<=p
                x=xnew;
            end

        end

          آپدیت بهترن راه حل
        if x.Cost<=BestSol.Cost
            BestSol=x;
        end

    end

بهترین هزینه را ذخیره کنید
    BestCost(it)=BestSol.Cost;
```

```
    نمایش اطلاعات تکرار
     disp(['Iteration ' num2str(it) ': Best Cost = '
num2str(BestCost(it))]);

     کاهش دما
     T=alpha*T;

     کشیدن راه حل
     figure(1);
     PlotSolution(BestSol.Sol,model);
     pause(0.01);

end

نتایج

figure;
plot(BestCost,'LineWidth',2);
xlabel('Iteration');
ylabel('Best Cost');
grid on;
```

نتایج:

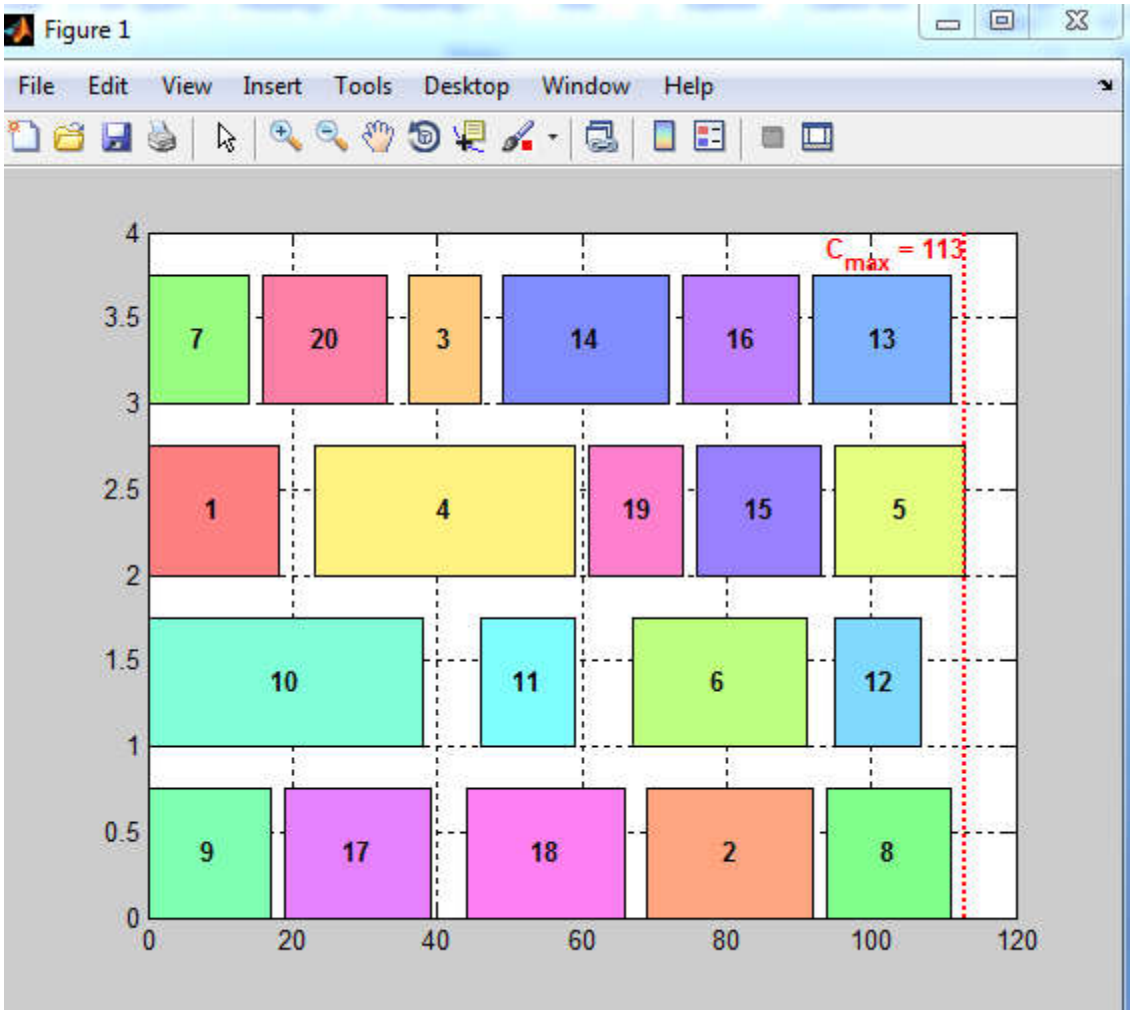
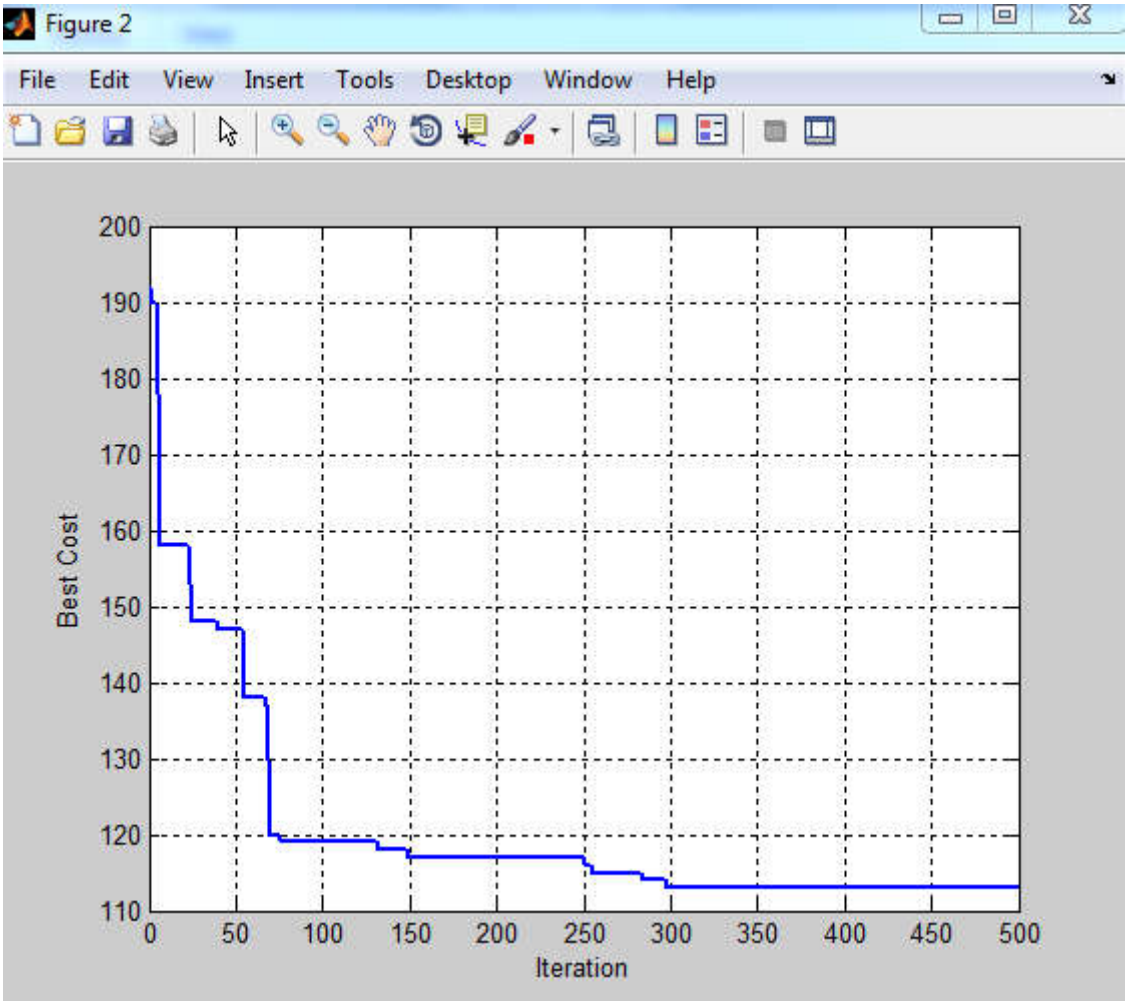


Figure 1
File Edit View Insert Tools Desktop Window Help
C_{max} = 113
7
20
3
14
16
13
1
4
19
15
5
10
11
6
12
9
17
18
2
8
0
0.5
1
1.5
2
2.5
3
3.5
4
0
20
40
60
80
100
120

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Iteration 1: Best Cost = 192
Iteration 2: Best Cost = 190
Iteration 3: Best Cost = 190
Iteration 4: Best Cost = 190
Iteration 5: Best Cost = 178
Iteration 6: Best Cost = 158
Iteration 7: Best Cost = 158
Iteration 8: Best Cost = 158
Iteration 9: Best Cost = 158
Iteration 10: Best Cost = 158
Iteration 11: Best Cost = 158
Iteration 12: Best Cost = 158
Iteration 13: Best Cost = 158
Iteration 14: Best Cost = 158
Iteration 15: Best Cost = 158
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Iteration 16: Best Cost = 158
Iteration 17: Best Cost = 158
Iteration 18: Best Cost = 158
Iteration 19: Best Cost = 158
Iteration 20: Best Cost = 158
Iteration 21: Best Cost = 158
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Iteration 23: Best Cost = 158
Iteration 24: Best Cost = 153
Iteration 25: Best Cost = 148
Iteration 26: Best Cost = 148
Iteration 27: Best Cost = 148
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Iteration 31: Best Cost = 148
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Iteration 49: Best Cost = 147
Iteration 50: Best Cost = 147
Iteration 51: Best Cost = 147
Iteration 52: Best Cost = 147
Iteration 53: Best Cost = 147
Iteration 54: Best Cost = 147
Iteration 55: Best Cost = 138
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Iteration 56: Best Cost = 138
Iteration 57: Best Cost = 138
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Iteration 63: Best Cost = 138
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Iteration 65: Best Cost = 138
Iteration 66: Best Cost = 138
Iteration 67: Best Cost = 137
Iteration 68: Best Cost = 137
Iteration 69: Best Cost = 130
Iteration 70: Best Cost = 120
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Iteration 73: Best Cost = 120
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Iteration 490: Best Cost = 113
Iteration 491: Best Cost = 113
Iteration 492: Best Cost = 113
Iteration 493: Best Cost = 113
Iteration 494: Best Cost = 113
Iteration 495: Best Cost = 113
```

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Iteration 496: Best Cost = 113
Iteration 497: Best Cost = 113
Iteration 498: Best Cost = 113
Iteration 499: Best Cost = 113
Iteration 500: Best Cost = 113

>> BestSol.Sol

ans =

       L: {4x1 cell}
      ST: [20x1 double]
      PT: [20x1 double]
      FT: [20x1 double]
     MCT: [4x1 double]
    Cmax: 113

>> BestSol.Position
```

21,22,23 جدا کننده هستند بین ماشین ها

```
ans =

  Columns 1 through 18

     9    17    18     2     8    21    10    11
     6    12    23     1     4    19    15
     5    22     7

  Columns 19 through 23

    20     3    14    16    13
```

ماشین اول

ماشین دوم

ماشین سوم

ماشین چهارم

```
>>
```