```
1
2  // ***  時頻數值計算(Time Frequency Numerical Computations)  ***
3  // 微分方程式 : M(t) * yh''(t) + C(t) * yh'(t) + K(t) * yh(t) = dh
4  // 稱此法為 : 實數與複數矩陣轉換( Real And Complex Matrix Transform )
5  // 本求解法可對應於 Laplace、 Fourier、 Z Transform 或是 捲積積分法等等。
6
7  using System;
8  using Matrix_0;
9
10 namespace ConsoleApp48
11 {
12     internal class Program
13     {
14         static void Main(string[] args)
15         {
16
17 // 建構初始矩陣 M、K、C。
18 double[,] M0 = { { 19, -1.5, -2 }, { -1, 15, 0 }, { 0, -3, 27 } };
19 double[,] K0 = { {60, -8, -2}, {-16, 180, -120 }, {-20, -100, 300} };
20 double[,] C0 = { {35, -1, -0.5}, {-1.5, 40, -1.5}, {-1.2, -1.5, 75} };
21
22 // 轉爲SMS型態之矩陣。
23 ReMatrix M = new ReMatrix(M0);
24 ReMatrix K = new ReMatrix(K0);
25 ReMatrix C = new ReMatrix(C0);
26
27 // 狀態響應。速度，變位，加速度。(t = 20秒)
28 double step = 1.0;
29 int iRow = (int)(20 / step + 1);
30
31 int m = M.Row;
32 int r = 2;
33 int iColD = m * r + 1;
34
35 CxMatrix CxVal = new CxMatrix(iRow, iColD);
36 ReMatrix ReVal = new ReMatrix(iRow, iColD);
37
38 for (int i = 0; i != iRow; i++)
39 {
40     double t = step * i;
41
42     // 建構 M、k、C 變數矩陣。
43     M.Matrix[0, 2] = 13.3 * Math.Sin(0.85 * t);
```

```
44      M.Matrix[2, 0] = -2.7 * Math.Cos(1.3 * t);
45      C.Matrix[0, 1] = -13.2 * Math.Sin(0.35 * t);
46      C.Matrix[2, 0] = 22.5 * Math.Cos(1.95 * t);
47      K.Matrix[0, 2] = -332 * Math.Sin(1.37 * t);
48      K.Matrix[2, 1] = 579 * Math.Cos(0.24 * t);
49
50      // 隨時間變化的系統(狀態)矩陣 A。
51      MKCMatrix mkc = new MKCMatrix(M, K, C);
52      ReMatrix A = mkc.Matrix;
53
54      // 隨時間變化的系統特徵值矩陣 D
55      EIG eig = new EIG(A);
56      CxMatrix D = eig.CxMatrixD;
57
58      // 將時間轉爲複數值。
59      CxScalar cxScalar = new CxScalar(t, 0);
60
61      // 隨時間變化的特徵值矩陣。
62      CxVal[i, 0] =  new CxMatrix(cxScalar);
63      CxVal[i, 1] = D[0, 0];
64      CxVal[i, 2] = D[1, 1];
65      CxVal[i, 3] = D[2, 2];
66      CxVal[i, 4] = D[3, 3];
67      CxVal[i, 5] = D[4, 4];
68      CxVal[i, 6] = D[5, 5];
69
70      // 隨時間變化的角矩陣。
71      ReVal.Matrix[i, 0] = i;
72      ReVal.Matrix[i, 1] = D[0, 0].Im[0, 0];
73      ReVal.Matrix[i, 2] = D[1, 1].Im[0, 0];
74      ReVal.Matrix[i, 3] = D[2, 2].Im[0, 0];
75      ReVal.Matrix[i, 4] = D[3, 3].Im[0, 0];
76      ReVal.Matrix[i, 5] = D[4, 4].Im[0, 0];
77      ReVal.Matrix[i, 6] = D[5, 5].Im[0, 0];
78  }
79
80  Console.WriteLine("            時間(由實數值改為複數值)                ➲
        特徵值(Lambda0 ... Lambda5)        ");
81  Console.WriteLine("\n{0}", new PR(CxVal));
82  Console.WriteLine("\n                                                ➲
    ************************************************************\n");
83  Console.WriteLine("\n*** 以下是時間與特徵值的模數(Modulus)[即複數的 ➲
    絕對值]大小排序的角頻率，共計有六組，可作為Excel繪圖 ***\n");
84  Console.WriteLine("        時間(sec)          角頻率(rad/sec)   ( w0 ➲
    ...  w5  )\n");
85  Console.WriteLine("\n{0} \n", new PR(ReVal));
86  Console.WriteLine("\n                                                ➲
```

```
    **********************************************************\n");
Console.WriteLine("\n時間序列\n{0}\n", new PR4(ReVal, 0));
Console.WriteLine("\n*** 以下是依據特定時間點，對應特徵值的模數(Modulus)[即複數的絕對值]大小排序，共計有六組，可作為Python 繪圖***\n");
Console.WriteLine("\n角頻率序列w0\n{0}\n", new PR4(ReVal, 1));
Console.WriteLine("\n角頻率序列w1\n{0}\n", new PR4(ReVal, 2));
Console.WriteLine("\n角頻率序列w2\n{0}\n", new PR4(ReVal, 3));
Console.WriteLine("\n角頻率序列w3\n{0}\n", new PR4(ReVal, 4));
Console.WriteLine("\n角頻率序列w4\n{0}\n", new PR4(ReVal, 5));
Console.WriteLine("\n角頻率序列w5\n{0}\n", new PR4(ReVal, 6));

        }
    }
}

/*輸出結果如下 :
   時間(由實數值改為複數值)       特徵值(Lambda0 ... Lambda5)

    0.00000 +   0.00000i,   -3.21000 +   3.46438i,   -3.21000 -   3.46438i,
    0.49822 +   3.65337i,    0.49822 -   3.65337i,   -0.93205 +   1.51597i,
   -0.93205 -   1.51597i

    1.00000 +   0.00000i,   -3.35013 +   3.36847i,   -3.35013 -   3.36847i,
    0.46206 +   3.42929i,    0.46206 -   3.42929i,   -0.78699 +   1.91013i,
   -0.78699 -   1.91013i

    2.00000 +   0.00000i,   -3.43423 +   3.40458i,   -3.43423 -   3.40458i,
    0.24294 +   3.46203i,    0.24294 -   3.46203i,   -0.79501 +   1.74283i,
   -0.79501 -   1.74283i

    3.00000 +   0.00000i,   -3.05886 +   3.56061i,   -3.05886 -   3.56061i,
    0.29194 +   3.44327i,    0.29194 -   3.44327i,   -0.76658 +   1.47033i,
   -0.76658 -   1.47033i

    4.00000 +   0.00000i,   -2.87664 +   3.44383i,   -2.87664 -   3.44383i,
    0.12903 +   3.50644i,    0.12903 -   3.50644i,   -0.90128 +   1.39138i,
```

```
121    -0.90128 -   1.39138i
122
123     5.00000 +   0.00000i,   -2.70100 +   3.38700i,   -2.70100 -
          3.38700i,
124    -0.15010 +   3.28790i,   -0.15010 -   3.28790i,   -0.66735 +
          1.65960i,
125    -0.66735 -   1.65960i
126
127     6.00000 +   0.00000i,   -1.97070 +   2.80379i,   -1.97070 -
          2.80379i,
128    -1.45147 +   0.86352i,   -1.45147 -   0.86352i,   -0.40136 +
          3.40230i,
129    -0.40136 -   3.40230i
130
131     7.00000 +   0.00000i,   -1.20212 +   3.54723i,   -1.20212 -
          3.54723i,
132    -1.73600 +   2.24270i,   -1.73600 -   2.24270i,   -0.69346 +
          1.70329i,
133    -0.69346 -   1.70329i
134
135     8.00000 +   0.00000i,   -1.16884 +   3.94202i,   -1.16884 -
          3.94202i,
136    -2.32082 +   0.72742i,   -2.32082 -   0.72742i,   -0.33440 +
          2.28179i,
137    -0.33440 -   2.28179i
138
139     9.00000 +   0.00000i,   -1.29592 +   4.34861i,   -1.29592 -
          4.34861i,
140    -1.66918 +   1.61944i,   -1.66918 -   1.61944i,   -0.49513 +
          1.21756i,
141    -0.49513 -   1.21756i
142
143    10.00000 +   0.00000i,   -1.06490 +   4.52265i,   -1.06490 -
          4.52265i,
144    -3.66246 +   0.00000i,   -0.83032 +   2.37958i,   -0.83032 -
          2.37958i,
145     0.74678 +   0.00000i
146
147    11.00000 +   0.00000i,   -1.48404 +   4.61283i,   -1.48404 -
          4.61283i,
148    -3.09567 +   0.00000i,   -1.14919 +   1.92198i,   -1.14919 -
          1.92198i,
149     1.00071 +   0.00000i
150
151    12.00000 +   0.00000i,   -1.24361 +   4.49676i,   -1.24361 -
          4.49676i,
152    -2.84470 +   0.00000i,   -2.02020 +   0.00000i,    0.14019 +
```

```
        1.38514i,
153      0.14019 -    1.38514i
154
155     13.00000 +    0.00000i,    -1.51911 +    4.45419i,    -1.51911 -
          4.45419i,
156     -2.88462 +    1.07089i,    -2.88462 -    1.07089i,     0.50034 +
          1.18121i,
157      0.50034 -    1.18121i
158
159     14.00000 +    0.00000i,    -1.34740 +    4.68863i,    -1.34740 -
          4.68863i,
160     -3.64215 +    0.00000i,    -0.92822 +    1.76636i,    -0.92822 -
          1.76636i,
161      0.88499 +    0.00000i
162
163     15.00000 +    0.00000i,    -1.44180 +    4.56956i,    -1.44180 -
          4.56956i,
164     -3.62775 +    0.00000i,    -1.05291 +    2.07580i,    -1.05291 -
          2.07580i,
165      1.28160 +    0.00000i
166
167     16.00000 +    0.00000i,    -1.28497 +    4.69115i,    -1.28497 -
          4.69115i,
168     -2.46354 +    0.00000i,    -1.00425 +    1.81506i,    -1.00425 -
          1.81506i,
169      0.13938 +    0.00000i
170
171     17.00000 +    0.00000i,    -1.39381 +    4.24885i,    -1.39381 -
          4.24885i,
172     -2.49370 +    1.45714i,    -2.49370 -    1.45714i,     0.03368 +
          1.73808i,
173      0.03368 -    1.73808i
174
175     18.00000 +    0.00000i,    -1.29256 +    4.05128i,    -1.29256 -
          4.05128i,
176     -1.94035 +    1.18769i,    -1.94035 -    1.18769i,    -0.51735 +
          1.86161i,
177     -0.51735 -    1.86161i
178
179     19.00000 +    0.00000i,    -1.08775 +    3.62943i,    -1.08775 -
          3.62943i,
180     -3.10894 +    0.00000i,    -0.93659 +    2.70142i,    -0.93659 -
          2.70142i,
181     -0.46138 +    0.00000i
182
183     20.00000 +    0.00000i,    -2.00354 +    2.76644i,    -2.00354 -
          2.76644i,
```

```
184    -0.55421 +    3.27489i,    -0.55421 -    3.27489i,    -1.26990 +
         1.18921i,
185    -1.26990 -    1.18921i
186
187   ************************************************************
188
189  *** 以下是時間與特徵值的模數(Modulus)[即複數的絕對值]大小排序的角頻
       率，共計有六組，可作為Excel繪圖 ***
190    時間(sec)     角頻率(rad/sec)   ( w0   ...   w5  )
191    0.00000      3.46438   -3.46438    3.65337   -3.65337    1.51597
         -1.51597
192    1.00000      3.36847   -3.36847    3.42929   -3.42929    1.91013
         -1.91013
193    2.00000      3.40458   -3.40458    3.46203   -3.46203    1.74283
         -1.74283
194    3.00000      3.56061   -3.56061    3.44327   -3.44327    1.47033
         -1.47033
195    4.00000      3.44383   -3.44383    3.50644   -3.50644    1.39138
         -1.39138
196    5.00000      3.38700   -3.38700    3.28790   -3.28790    1.65960
         -1.65960
197    6.00000      2.80379   -2.80379    0.86352   -0.86352    3.40230
         -3.40230
198    7.00000      3.54723   -3.54723    2.24270   -2.24270    1.70329
         -1.70329
199    8.00000      3.94202   -3.94202    0.72742   -0.72742    2.28179
         -2.28179
200    9.00000      4.34861   -4.34861    1.61944   -1.61944    1.21756
         -1.21756
201   10.00000      4.52265   -4.52265    0.00000    2.37958   -2.37958
          0.00000
202   11.00000      4.61283   -4.61283    0.00000    1.92198   -1.92198
          0.00000
203   12.00000      4.49676   -4.49676    0.00000    0.00000    1.38514
         -1.38514
204   13.00000      4.45419   -4.45419    1.07089   -1.07089    1.18121
         -1.18121
205   14.00000      4.68863   -4.68863    0.00000    1.76636   -1.76636
          0.00000
206   15.00000      4.56956   -4.56956    0.00000    2.07580   -2.07580
          0.00000
207   16.00000      4.69115   -4.69115    0.00000    1.81506   -1.81506
          0.00000
208   17.00000      4.24885   -4.24885    1.45714   -1.45714    1.73808
         -1.73808
209   18.00000      4.05128   -4.05128    1.18769   -1.18769    1.86161
         -1.86161
```

```
 19.00000      3.62943   -3.62943    0.00000    2.70142   -2.70142
   0.00000
 20.00000      2.76644   -2.76644    3.27489   -3.27489    1.18921
  -1.18921

 ************************************************************

時間序列
   0.0000,    1.0000,    2.0000,    3.0000,    4.0000,
   5.0000,    6.0000,    7.0000,    8.0000,    9.0000,
  10.0000,   11.0000,   12.0000,   13.0000,   14.0000,
  15.0000,   16.0000,   17.0000,   18.0000,   19.0000,
  20.0000,

*** 以下是依據特定時間點，對應特徵值的模數(Modulus)[即複數的絕對值]大小排序，共計有六組，可作為Python 繪圖 ***

角頻率序列w0
   3.4644,    3.3685,    3.4046,    3.5606,    3.4438,
   3.3870,    2.8038,    3.5472,    3.9420,    4.3486,
   4.5226,    4.6128,    4.4968,    4.4542,    4.6886,
   4.5696,    4.6911,    4.2488,    4.0513,    3.6294,
   2.7664,

角頻率序列w1
  -3.4644,   -3.3685,   -3.4046,   -3.5606,   -3.4438,
  -3.3870,   -2.8038,   -3.5472,   -3.9420,   -4.3486,
  -4.5226,   -4.6128,   -4.4968,   -4.4542,   -4.6886,
  -4.5696,   -4.6911,   -4.2488,   -4.0513,   -3.6294,
  -2.7664,

角頻率序列w2
   3.6534,    3.4293,    3.4620,    3.4433,    3.5064,
   3.2879,    0.8635,    2.2427,    0.7274,    1.6194,
   0.0000,    0.0000,    0.0000,    1.0709,    0.0000,
   0.0000,    0.0000,    1.4571,    1.1877,    0.0000,
   3.2749,

角頻率序列w3
  -3.6534,   -3.4293,   -3.4620,   -3.4433,   -3.5064,
  -3.2879,   -0.8635,   -2.2427,   -0.7274,   -1.6194,
   2.3796,    1.9220,    0.0000,   -1.0709,    1.7664,
   2.0758,    1.8151,   -1.4571,   -1.1877,    2.7014,
  -3.2749,

角頻率序列w4
   1.5160,    1.9101,    1.7428,    1.4703,    1.3914,
```

```
254     1.6596,    3.4023,    1.7033,    2.2818,    1.2176,
255    -2.3796,   -1.9220,    1.3851,    1.1812,   -1.7664,
256    -2.0758,   -1.8151,    1.7381,    1.8616,   -2.7014,
257     1.1892,
258
259  角頻率序列w5
260    -1.5160,   -1.9101,   -1.7428,   -1.4703,   -1.3914,
261    -1.6596,   -3.4023,   -1.7033,   -2.2818,   -1.2176,
262     0.0000,    0.0000,   -1.3851,   -1.1812,    0.0000,
263     0.0000,    0.0000,   -1.7381,   -1.8616,    0.0000,
264    -1.1892,
265
266  請按任意鍵繼續 . . .
267  */
```