

課題 22

方法

三次元空間(χ^2, v, a)において, ある点($\text{para}_v, \text{para}_{x0}$)=(5,5)を出発点としてその点周りの χ^2 の値を計算し, その値で最も小さい値を示す点を選んでその点に移動する. これらの移動の終了条件は, 仮定した点よりも周りの点がすべて値が大きくなる場合である.

課題 22-0 のコード

```
1  #include<stdio.h>
2
3  #define ndat 20    /**/
4  #define dd 1e-5
5
6
7
8  /*float func(float x, float v, float x0);*/
9  /*float calc_chi2(float t[],float x[],float s[], float a,float b);*/
10
11
12 float func(float t, float v, float x0)
13 {
14     float func = v * t + x0;
15     return func;
16 }
17
18 float calc_chi2(float t[], float x[], float s[], float a,float b)
19 {
20     float chi2 = 0 ;
21     for(int i=0;i<ndat;i++){
22         if(s[i]==0){
23             printf("Error:division by zero\n");
24             continue ;
25         }
26         float diff = x[i]-func(t[i],a,b);
27
28         chi2 += diff * diff/ (s[i]*s[i]);
29
30         if(chi2 > 1e5){
31             printf("Warning: chi2 has become too large\n");
32             break;
33         }
34     }
35     return chi2;
36 }
37
38
39
40 int main(void)
41 {
42     FILE*fp;
43     float t[ndat],x[ndat],s[ndat],y[ndat],exp_y[ndat];
44     float para_v, para_x0;
45     int ih;
46
47     fp = fopen("u1.dat","r");
48
49
50     for(ih=0;ih < ndat; ih++){
```

```

51         fscanf(fp,"%f, %f, %f, %f,
%f",&t[ih],&x[ih],&y[ih],&exp_y[ih],&s[ih]);
52         s[ih] = 0.1;
53     }
54     fclose(fp);
55
56     int try;
57
58
59     float chi2_0,chi2_1, chi2_2, chi2_3, chi2_4, min_chi2;
60     float dv,dx0;
61     int min_num,i;
62
63     /*****set initial parameters*****/
64     para_v = 5;
65     para_x0 = 5;
66     /*****set step size*****/
67     dv = para_v * dd;
68     dx0 = para_x0 *dd;
69
70
71     chi2_0 = calc_chi2(t,x,s,para_v,para_x0);
72     printf("chi2_0 = %f\n",chi2_0);
73     for(try=0;try<1e8;try++){
74         chi2_1 = calc_chi2(t,x,s,para_v+dv,para_x0);
75         chi2_2 = calc_chi2(t,x,s,para_v-dv,para_x0);
76         chi2_3 = calc_chi2(t,x,s,para_v,para_x0+dx0);
77         chi2_4 = calc_chi2(t,x,s,para_v,para_x0-dx0);
78
79         min_chi2 = chi2_1;
80         min_num = 1;
81         if(chi2_2 < min_chi2){
82             min_chi2 = chi2_2;
83             min_num = 2;
84         }
85         if(chi2_3<min_chi2){
86             min_chi2 = chi2_3;
87             min_num = 3;
88         }
89         if(chi2_4<min_chi2){
90             min_chi2 = chi2_4;
91             min_num = 4;
92         }
93         /* printf("%f,%f,%f\n",min_chi2,para_v,para_x0)*/
94
95         if(min_chi2>chi2_0){
96             printf("reach minimum point\n");
97             break;
98         }
99
100         if(min_num == 1){para_v += dv;}
101         if(min_num == 2){para_v -= dv;}
102         if(min_num == 3){para_x0 += dx0;}
103         if(min_num == 4){para_x0 -= dx0;}
104
105         chi2_0 = min_chi2;
106     }
107
108     printf("minimum chi2 = %f\n",min_chi2);
109     printf("at best parameters = %f,%f\n",para_v,para_x0);
110     printf("search precision = %f,%f\n",dv,dx0);
111
112
113

```

```
114     return 0;
115 }
```

課題 22-1 のコード

```
1  /*課題 22-2 のコードです.*/  
2  /*24cb062h 菅原明*/  
3  
4  
5  
6  #include<stdio.h>  
7  
8  #define ndat 20    /**/  
9  #define dd 1e-5  
10 #define g 9.8  
11  
12  
13 /*float func(float x, float v, float x0);*/  
14 /*float calc_chi2(float t[],float x[],float s[], float a,float b);*/  
15  
16  
17 float func_y(float t,float a, float v, float y0)  
18 {  
19     float func = - 0.5*a*t*t + v*t + y0;  
20     return func;  
21 }  
22  
23 float calc_chi2_y(float t[], float y[], float s[], float a, float b, float c)  
24 {  
25     float chi2 = 0 ;  
26     for(int i=0;i<ndat;i++){  
27         if(s[i]==0){  
28             printf("Error:division by zero\n");  
29             continue ;  
30         }  
31         float diff = y[i]-func_y(t[i],a,b,c);  
32  
33         chi2 += diff * diff/ (s[i]*s[i]);  
34  
35         if(chi2 > 1e5){  
36             printf("Warning: chi2 has become too large\n");  
37             break;  
38         }  
39     }  
40     return chi2;  
41 }  
42  
43  
44  
45 int main(void)  
46 {  
47     FILE*fp;  
48     float t[ndat],x[ndat],s[ndat],y[ndat],exp_y[ndat];  
49     float para_ay,para_v, para_y0;  
50     int ih;  
51  
52     fp = fopen("u1.dat","r");  
53  
54  
55     for(ih=0;ih < ndat; ih++){  
56         fscanf(fp,"%f, %f, %f, %f,  
57 %f",&t[ih],&x[ih],&y[ih],&exp_y[ih],&s[ih]);  
58         s[ih] = 0.5;  
59     }  
60 }
```

```

59     fclose(fp);
60
61     int try;
62
63
64     float chi2_0,chi2_1, chi2_2, chi2_3, chi2_4, chi2_5, chi2_6, min_chi2;
65     float da,dv,dy0;
66     int min_num,i;
67
68     /*****set initial parameters*****/
69     para_ay = 5;
70     para_v = 5;
71     para_y0 = 5;
72     /*****set step size*****/
73     da = para_ay * dd;
74     dv = para_v * dd;
75     dy0 = para_y0 *dd;
76
77
78     chi2_0 = calc_chi2_y(t, y, s, para_ay, para_v, para_y0);
79     printf("chi2_0 = %f\n",chi2_0);
80     for(try=0;try<1e8;try++){
81         chi2_3 = calc_chi2_y(t,y,s,para_ay,para_v+dv,para_y0);
82         chi2_4 = calc_chi2_y(t,y,s,para_ay,para_v-dv,para_y0);
83         chi2_5 = calc_chi2_y(t,y,s,para_ay,para_v,para_y0+dy0);
84         chi2_6 = calc_chi2_y(t,y,s,para_ay,para_v,para_y0-dy0);
85         chi2_1 = calc_chi2_y(t,y,s,para_ay+da,para_v,para_y0);
86         chi2_2 = calc_chi2_y(t,y,s,para_ay-da,para_v,para_y0);
87
88         min_chi2 = chi2_1;
89         min_num = 1;
90         if(chi2_2 < min_chi2){
91             min_chi2 = chi2_2;
92             min_num = 2;
93         }
94         if(chi2_3 < min_chi2){
95             min_chi2 = chi2_3;
96             min_num = 3;
97         }
98         if(chi2_4 < min_chi2){
99             min_chi2 = chi2_4;
100             min_num = 4;
101         }
102         if(chi2_5 < min_chi2){
103             min_chi2 = chi2_5;
104             min_num = 5;
105         }
106         if(chi2_6 < min_chi2){
107             min_chi2 = chi2_6;
108             min_num = 6;
109         }
110         /* printf("%f,%f,%f,%f\n",min_chi2,para_ay,para_v,para_y0);*/
111
112         if(min_chi2>chi2_0){
113             printf("reach minimum point\n");
114             break;
115         }
116
117         if(min_num == 3){para_v += dv;}
118         if(min_num == 4){para_v -= dv;}
119         if(min_num == 5){para_y0 += dy0;}
120         if(min_num == 6){para_y0 -= dy0;}
121         if(min_num == 1){para_ay += da;}
122         if(min_num == 2){para_ay -= da;}

```

```

123
124         chi2_0 = min_chi2;
125     }
126
127     printf("minimum chi2 = %f\n",min_chi2);
128     printf("at best parameters (a,v,y0) = %f,%f,%f\n",para_ay,para_v,para_y0);
129     printf("search precision = %f,%f,%f\n",da,dv,dy0);
130
131
132
133     return 0;
134 }

```

結果

課題 22-0 の結果

```

1  chi2_0 = 31869.998047
2  reach minimum point
3  minimum chi2 = 0.000015
4  at best parameters = 4.000144,9.999827
5  search precision = 0.000050,0.000050

```

課題 22-1 の結果

```

1  chi2_0 = 936.103088
2  reach minimum point
3  minimum chi2 = 0.000016
4  at best parameters (a,v,y0) = 9.797545,5.992246,5.001402
5  search precision = 0.000050,0.000050,0.000050

```

考察

課題 16 では、初期条件 $(v_{x0}, x_0) = (5, 10)$, $(v_{y0}, y_0) = (6.0, 5.0)$ としてあり, (v_0, x_0, y_0) , をパラメーターとしたとき, χ^2 が最も小さくなる時の値(at best parameters)が $(v_{x0}, x_0) = (5, 10)$, $(v_{y0}, y_0) = (6, 5)$ に近いのでこの結果は正しい。

課題 23

方法

課題 22 ではなるべく効率的に χ^2 を最低にするパラメーターを探索したが、課題 23 では必ずしも効率は良くないが確実に最適化パラメーターを得られる方法として、乱数生成を用いたモンテカル口法による探索をする。ある範囲に最適値があるはず、という探索範囲を設し、この範囲内で乱数生成させ、この中から χ^2 の最低値を与えるパラメーターの組み合わせを探し出す。例として課題 23-0 では 56, 57 行目で範囲を設定している。

課題 23-0 のコード

```

1  #include<stdio.h>
2  #include<stdlib.h>
3  #include<math.h>
4
5  #define ndat 20
6  #define ntry 1e7

```

```

7  #define RANGE 0.5
8
9  /*****func の定義*****/
10 float func(float t, float v, float x0)
11 {
12     float x = v*t + x0;
13     return x;
14 }
15 /*****calc_chi2 の定義*****/
16 float calc_chi2(float t[], float x[], float s[], float a, float b)
17 {
18     float chi2 = 0;
19     int i;
20
21     for(i=0;i<ndat;i++){
22         float diff = x[i]-func(t[i],a,b);
23         chi2 += diff * diff / (s[i] * s[i]);
24     }
25     return chi2;
26 }
27
28 /*****main()のやつ*****/
29
30
31 int main(void)
32 {
33     FILE*fp;
34     /*変数の型*/
35     float t[ndat],x[ndat],y[ndat],s[ndat],exp_y[ndat];
36     float para_v,para_x0,ini_v,ini_x0;
37     float chi2,min_chi2,best_v,best_x0;
38     int ih,i;
39     int try;
40
41     /*****ファイルの読み込み*****/
42     fp =fopen("ul.dat","r");
43
44     for(ih=0;ih < ndat; ih++){
45         fscanf(fp,"%f, %f, %f, %f,
46 %f",&t[ih],&x[ih],&y[ih],&exp_y[ih],&s[ih]);
47         s[ih] = 0.1;
48     }
49     fclose(fp);
50
51     /*-----set initial parameters-----*/
52     ini_v = 8;
53     ini_x0 = 8;
54
55     min_chi2 = 1e20;
56     for(try=0;try<ntry;try++){
57         para_v = (float)rand() / RAND_MAX * (2*ini_v*RANGE) + ini_v * (1-
58 RANGE);
59         para_x0 = (float)rand() / RAND_MAX * (2*ini_x0*RANGE) + ini_x0*(1-
60 RANGE);
61
62         chi2 = calc_chi2(t,x,s,para_v,para_x0);
63         if(chi2<min_chi2){
64             min_chi2 = chi2;
65             best_v = para_v;
66             best_x0 = para_x0;
67             /* printf("%d,%f,%f,%f\n",try,min_chi2,best_v,best_x0);*/
68         }
69     }
70 }

```

```

67     printf("minimum chi2 = %f\n",min_chi2);
68     printf("at best parameters = %f,%f\n",best_v,best_x0);
69
70     return 0;
71 }

```

課題 23-1 のコード

```

1  #include<stdio.h>
2  #include<stdlib.h>
3  #include<math.h>
4
5  #define ndat 20
6  #define ntry 1e7
7  #define RANGE 0.5
8
9  /*****func の定義*****/
10 float func(float t,float a, float v, float y0)
11 {
12     float y = -0.5*a*t*t+ v*t + y0;
13     return y;
14 }
15 /*****calc_chi2 の定義*****/
16 float calc_chi2(float t[], float x[], float s[], float a, float b, float c)
17 {
18     float chi2 = 0;
19     int i;
20
21     for(i=0;i<ndat;i++){
22         float diff = x[i]-func(t[i],a,b,c);
23         chi2 += diff * diff / (s[i] * s[i]);
24     }
25     return chi2;
26 }
27
28 /*****main()のやつ*****/
29
30
31 int main(void)
32 {
33     FILE*fp;
34     /*変数の型*/
35     float t[ndat],x[ndat],y[ndat],s[ndat],exp_y[ndat];
36     float para_v,para_y0,para_ay,ini_ay,ini_v,ini_y0;
37     float chi2,min_chi2,best_ay,best_v,best_y0;
38     int ih,i;
39     int try;
40
41     /*****ファイルの読み込み*****/
42     fp =fopen("u1.dat","r");
43
44     for(ih=0;ih < ndat; ih++){
45         fscanf(fp,"%f, %f, %f, %f, %f",
46             &t[ih],&x[ih],&y[ih],&exp_y[ih],&s[ih]);
47         s[ih] = 0.5;
48     }
49     fclose(fp);
50
51     /*-----set initial parameters-----*/
52     ini_ay = 8;
53     ini_v = 8;
54     ini_y0 = 8;

```

```

55  min_chi2 = 1e20;
56  for(try=0;try<ntry;try++){
57      para_ay = (float)rand()/ RAND_MAX * (2*ini_ay*RANGE) + ini_ay * (1-
58  RANGE);
59      para_v = (float)rand() / RAND_MAX * (2*ini_v*RANGE) + ini_v * (1-
60  RANGE);
61      para_y0 = (float)rand() / RAND_MAX * (2*ini_y0*RANGE) + ini_y0*(1-
62  RANGE);
63      chi2 = calc_chi2(t,y,s,para_ay,para_v,para_y0);
64      /* printf("chi2 = %f\n",chi2);*/
65      if(chi2<min_chi2){
66          min_chi2 = chi2;
67          best_ay = para_ay;
68          best_v = para_v;
69          best_y0 = para_y0;
70          printf("%d,%f,%f,%f,
71  %f\n",try,min_chi2,best_ay,best_v,best_y0);
72      }
73  }
74  printf("minimum chi2 = %f\n",min_chi2);
75  printf("at best parameters = %f,%f,%f\n",best_ay,best_v,best_y0);
76  return 0;
77  }

```

結果

課題 23-0 の結果

```

1  minimum chi2 = 0.004855
2  at best parameters = 4.001032,9.997477

```

課題 23-1 の結果

```

1  minimum chi2 = 0.006329
2  at best parameters = 9.804707,5.985717,5.016786

```

考察

課題 16 での、初期条件と誤差がほとんどないためこの結果は妥当である。

課題 24

方法

課題 23 では、 χ^2 を最低にするパラメーターを探索したが、今回はそこから 1 だけ χ^2 が増える範囲を、乱数生成させて探索する。この範囲がパラメーター誤差の範囲を表す。 χ^2 の値が最低値よりも 1 大きい値より小さいときにのみ出力するようになっている(76 行目)。課題 24-0 のコード

```

1  #include<stdio.h>
2  #include<stdlib.h>
3  #include<math.h>
4
5  #define ndat 20
6  #define ntry 1e7

```



```

7  #define entry 1e3
8  #define RANGE 0.5
9
10 /*****func の定義*****/
11 float func(float t, float v, float x0)
12 {
13     float x = v*t + x0;
14     return x;
15 }
16
17 /*****calc_chi2 の定義*****/
18 float calc_chi2(float t[], float x[], float s[], float a, float b)
19 {
20     float chi2 = 0;
21     int i;
22     for(i=0; i<ndat; i++){
23         float diff = x[i] - func(t[i], a, b);
24         chi2 += diff * diff / (s[i] * s[i]);
25     }
26     return chi2;
27 }
28
29 /*****main()*****/
30
31 int main(void)
32 {
33     FILE*fp;
34
35     float t[ndat], x[ndat], y[ndat], s[ndat], exp_y[ndat];
36     float para_v, para_x0, ini_v, ini_x0;
37     float best_v, best_x0;
38     float chi2, min_chi2;
39     int i, ih, try;
40
41     fp = fopen("u1.dat", "r");
42
43     for(i=0; i<ndat; i++){
44         fscanf(fp, "%f, %f, %f, %f, %f", &t[i], &x[i], &y[i], &exp_y[i], &s[i]);
45         s[i] = 0.5;
46     }
47     fclose(fp);
48
49     /*-----set initial parameters-----*/
50     ini_v = 5;
51     ini_x0 = 9;
52
53     min_chi2 = 1e20;
54
55     for(try=0; try<ntry; try++){
56         para_v = (float)rand() / RAND_MAX * (2*ini_v * RANGE) + ini_v * (1-
57 RANGE);
58         para_x0 = (float)rand() / RAND_MAX * (2*ini_x0 * RANGE) + ini_x0 * (1-
59 RANGE);
60         chi2 = calc_chi2(t, x, s, para_v, para_x0);
61         if(chi2<min_chi2){
62             min_chi2 = chi2;
63             best_v = para_v;
64             best_x0 = para_x0;
65         }
66     }
67
68     /*****search error region*****/
69     int ncount = 0;
70     float min_v = 1e10, max_v = 1e-10, min_x0=1e10, max_x0=1e-10, err_v, err_x0;

```

```

69
70     for(try=0;ncount<entry;try++){
71         /*      para_v = (float)rand() / RAND_MAX * (2*ini_v*RANGE) + ini_v * (1-
RANGE);*/
72         /*      para_x0 = (float)rand() / RAND_MAX * (2* ini_x0*RANGE) + ini_x0
*(1-RANGE);*/
73         para_v = (float)rand() / RAND_MAX * (2*ini_v * RANGE) + ini_v * (1-
RANGE);
74         para_x0 = (float)rand() / RAND_MAX * (2*ini_x0 * RANGE) + ini_x0
*(1-RANGE);
75         chi2 = calc_chi2(t,x,s,para_v,para_x0);
76         if(chi2<min_chi2+1){
77             printf("%f,%f\n",para_v,para_x0);
78             ncount++;
79             if(para_v<min_v)min_v = para_v;
80             if(para_v>max_v)max_v=para_v;
81             if(para_x0<min_x0)min_x0=para_x0;
82             if(para_x0>max_x0)max_x0=para_x0;
83         }
84
85     }
86     /*      printf("%f,%f",min_v,min_x0) ;*/
87     err_v = (max_v - min_v) / 2;
88     err_x0 = (max_x0 -min_x0) / 2;
89     printf("v= %f +- %f, x0 = %f +- %f \n",best_v,err_v,best_x0,err_x0);
90
91     return 0;
92
93 }

```

課題 24-1 のコード

```

1  #include<stdio.h>
2  #include<stdlib.h>
3  #include<math.h>
4
5  #define ndat 20
6  #define ntry 1e7
7  #define entry 1e3
8  #define RANGE 0.5
9
10 /******func の定義******/
11 float func(float t,float a, float v, float x0)
12 {
13     float y = -0.5*a*t*t +v*t + x0;
14     return y;
15 }
16
17 /******calc_chi2 の定義******/
18 float calc_chi2(float t[], float x[],float s[], float a, float b, float c)
19 {
20     float chi2 = 0;
21     int i;
22     for(i=0;i<ndat;i++){
23         float diff = x[i] - func(t[i], a, b, c);
24         chi2 += diff * diff / (s[i] * s[i]);
25     }
26     return chi2;
27 }
28
29 /******main()******/
30

```

```

31 int main(void)
32 {
33     FILE*fp;
34
35     float t[ndat],x[ndat],y[ndat],s[ndat],exp_y[ndat];
36     float para_a,para_v,para_y0,ini_a,ini_v,ini_y0;
37     float best_a,best_v,best_y0;
38     float chi2,min_chi2;
39     int i,ih,try;
40
41     fp= fopen("u1.dat","r");
42
43     for(i=0;i<ndat;i++){
44         fscanf(fp,"%f, %f, %f, %f, %f",&t[i],&x[i],&y[i],&exp_y[i],&s[i]);
45         s[i] = 0.5;
46     }
47     fclose(fp);
48
49     /*-----set initial parameters-----*/
50     ini_a = 9.8;
51     ini_v = 6;
52     ini_y0 = 5;
53
54     min_chi2 = 1e20;
55
56     for(try=0;try<ntry;try++){
57         para_a = (float)rand()/ RAND_MAX * (2*ini_a * RANGE) + ini_a * (1-
RANGE);
58         para_v = (float)rand() / RAND_MAX * (2*ini_v * RANGE) + ini_v * (1-
RANGE);
59         para_y0 = (float)rand() / RAND_MAX * (2*ini_y0 * RANGE) + ini_y0 *(1-
RANGE);
60         chi2 = calc_chi2(t,y,s,para_a,para_v,para_y0);
61         if(chi2<min_chi2){
62             min_chi2 = chi2;
63             best_a = para_a;
64             best_v = para_v;
65             best_y0 = para_y0;
66         }
67     }
68
69     /******search error region*****/
70     int ncount = 0;
71     float min_a=1e10, max_a=1e-10, min_v=1e10, max_v=1e-10, min_y0=1e10,
max_y0=1e-10, err_a, err_v, err_y0;
72
73     for(try=0;ncount<entry;try++){
74         /* para_v = (float)rand() / RAND_MAX * (2*ini_v*RANGE) + ini_v * (1-
RANGE); */
75         para_a = (float)rand() / RAND_MAX * (2* ini_a * RANGE) + ini_a *(1-
RANGE);
76         para_v = (float)rand() / RAND_MAX * (2*ini_v * RANGE) + ini_v * (1-
RANGE);
77         para_y0 = (float)rand() / RAND_MAX * (2*ini_y0 * RANGE) + ini_y0
*(1-RANGE);
78         chi2 = calc_chi2(t,y,s,para_a,para_v,para_y0);
79         if(chi2<min_chi2+1){
80             ncount++;
81             if(para_a<min_a)min_a = para_a;
82             if(para_a>max_a)max_a = para_a;
83             if(para_v<min_v)min_v = para_v;
84             if(para_v>max_v)max_v=para_v;

```

```

85             if(para_y0<min_y0)min_y0=para_y0;
86             if(para_y0>max_y0)max_y0=para_y0;
87         }
88
89     }
90     /* printf("%f,%f",min_v,min_y0) ;*/
91     err_a = (max_a - min_a) / 2;
92     err_v = (max_v - min_v) / 2;
93     err_y0 = (max_y0 -min_y0) / 2;
94     printf("a = %f +- %f,v= %f +-%f, y0 = %f +- %f
95 \n",best_a,err_a,best_v,err_v,best_y0,err_y0);
96
97     return 0;
98 }

```

結果

課題 24-0 の結果

```

1  v= 4.000438 +-0.191118, x0 = 9.998825 +- 0.230118

```

課題 24-1 の結果

```

1  a = 9.805310 +- 0.733169,v= 6.005863 +-0.802432, y0 = 4.996111 +- 0.352095

```

考察

得られた結果は課題 16 の初期条件との誤差がほとんどない.したがってこの結果は妥当である.