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第4章 函数与数值积分

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1. 单变量非线性函数求解

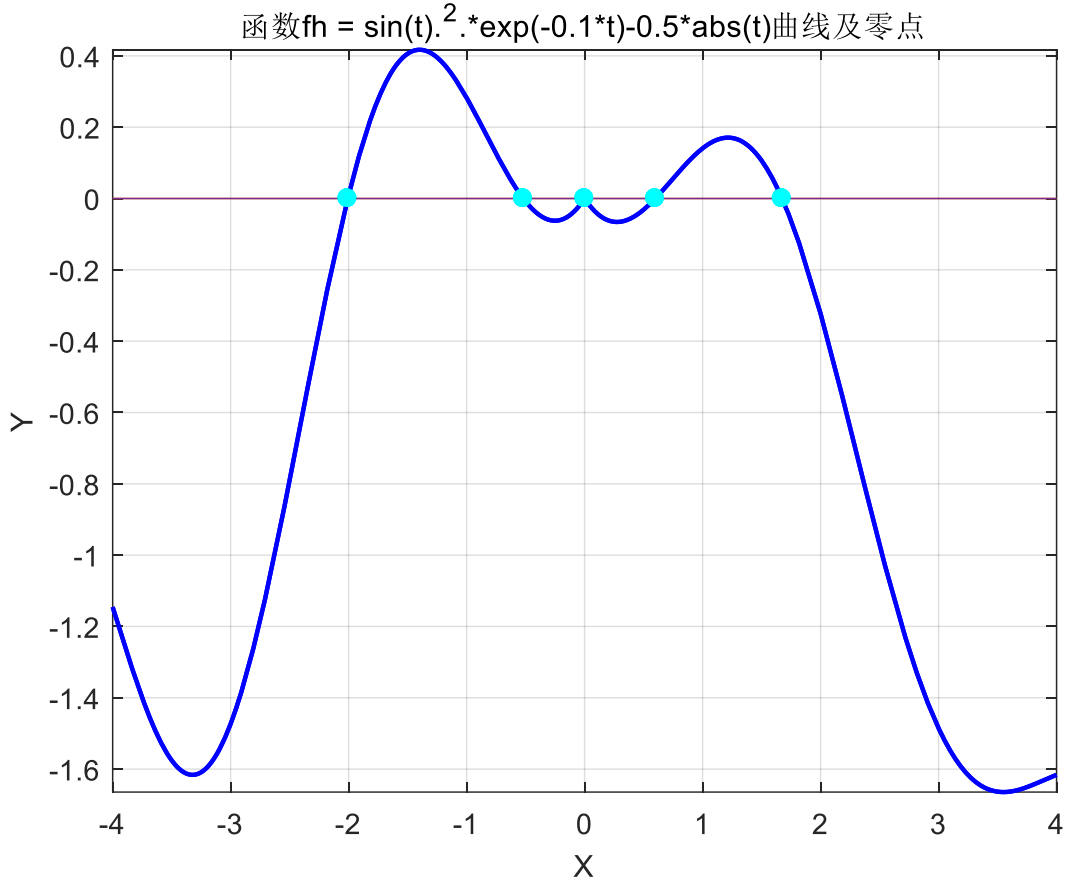
函数 fzero() 用来求一元函数的零点，调用格式如下：

- x = fzero(fun,x0)，x = fzero(fun,[x1,x2])：寻找 x0 附近或者区间 [x1,x2] 内 fun 的零点，返回该点的 x 坐标；
- [x,fval] = fzero(fun,x0,options)：给定参数options，返回零点的同时返回该点的函数值；
- [x, fval, exitflag, output] = fzero(fun,x0,options)：返回零点、该点的函数值、程序退出的标志及选定的输出结果。
- x = fzero(problem)： 对 problem 指定的求根问题求解。

1. 单变量非线性函数求解

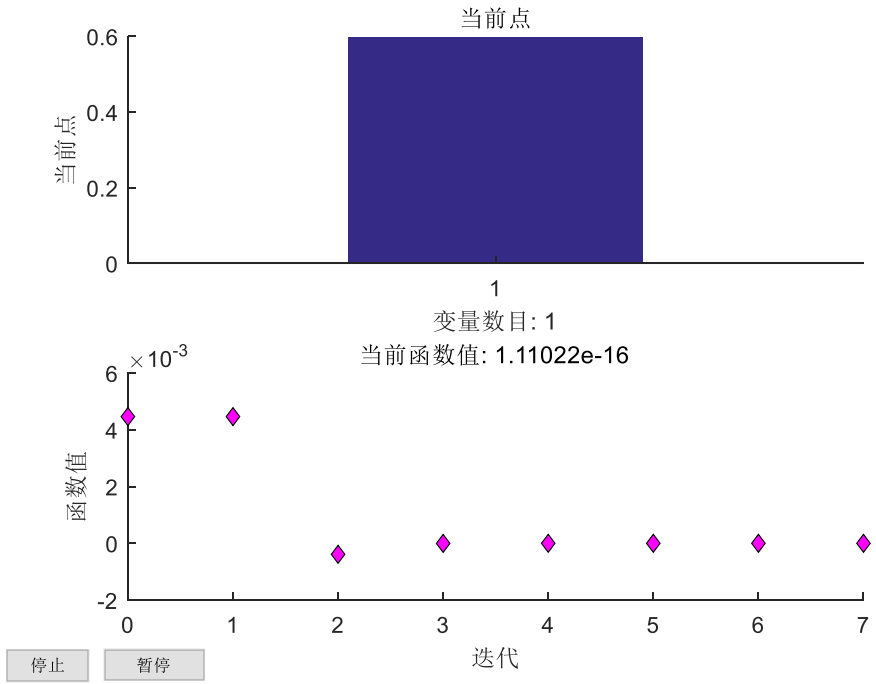
- 例：求函数 $f(t)=(\sin^2 t)e^{-0.1t}-0.5|t|$ 的零点。

```
>> fh = @(t)sin(t).^2.*exp(-0.1*t)-0.5*abs(t);
>> fplot(fh,[-4,4],'b-','LineWidth',1.5)
>> grid on; hold on
>> fplot(@(t)0*t,[-4,4])
>> %分别求各点附近的根
>> [t1,y1] = fzero(fh,-2)
t1 =
   -2.0074
y1 =
   2.2204e-16
>> [t2,y2] = fzero(fh,-0.5)
t2 =
   -0.5198
y2 =
     0
>> [t3,y3] = fzero(fh,0.1);
>> [t4,y4] = fzero(fh,0);
>> [t5,y5] = fzero(fh,2);
>> plot([t1,t2,t3,t4,t5],[y1,y2,y3,y4,y5],'co','MarkerFaceColor','c')
```



1. 单变量非线性函数求解

```
>> fh = @(t)sin(t).^2.*exp(-0.1*t)-0.5*abs(t);
>> options = optimset('PlotFcns',{@optimplotx,@optimplotfval});
>> [t,y] = fzero(fh,0.1,options)
t =
    0.5993
y =
   1.1102e-16
```




```
>> problem.objective = @(t)sin(t).^2.*exp(-0.1*t)-0.5*abs(t);
>> problem.x0 = 0.1;
>> problem.solver = 'fzero'; % a required part of the structure
>> problem.options = optimset('Display','iter','PlotFcns',{@optimplotx,@optimplotfval});
>> [t,y] = fzero(problem)

围绕 0.1 搜索包含符号变换的区间:
 Func-count     a           f(a)             b           f(b)        Procedure
     1              0.1    -0.0401325           0.1    -0.0401325    initial interval
     3        0.0971716    -0.0392642      0.102828    -0.0409855    search
                                                                     3344    search
在区间 [-0.412,  0.612] 中搜索零:                                    8234    search
 Func-count     x           f(x)             Procedure               5061    search
    33            0.612     0.00446291       initial                 4538    search
    34            0.612     0.00446291       interpolation           7587    search
    35         0.598152  -0.000387467        interpolation           5338    search
    36         0.599258  -3.51262e-06        interpolation
    37         0.599268   1.39217e-10        interpolation
    38         0.599268   -9.4369e-16        interpolation
    39         0.599268  -1.11022e-16        interpolation
    40         0.599268   1.11022e-16        interpolation

在区间 [-0.412,  0.612] 中发现零
t =
    0.5993
y =
   1.1102e-16
```

2. 多元非线性函数求解

- [x,fval,exitflag,output,jacobian] = fsolve(fun,x0,options)
- 例：求解非线性方程组

$$\begin{cases} \sin x + y + z^2 e^x - 4 = 0 \\ x + yz = 0 \\ xyz = 0 \end{cases}$$

① 定义函数文件

② 命令行窗口获取函数句柄

③ 设置options参数

④ 调用函数求解

nlineqsfun.m

```
1   %建立M文件：
2   function f = nlineqsfun(v)
3       x = v(1);
4       y = v(2);
5       z = v(3);
6       f(1) = sin(x)+y+z^2.*exp(x)-4;
7       f(2) = x+y*z;
8       f(3) = x*y*z;
9   end
```

```
>> fh = @nlineqsfun;
>> options = optimoptions('fsolve','Display','none','PlotFcn',@optimplotfirstorderopt);
>> [x,fval] = fsolve(fh,[1,1,1],options)
x =
    0.0005   -0.0002    1.9995
fval =
   1.0e-06 *
   -0.2636    0.1200   -0.2131
```

2. 多元非线性函数求解

- 例：在给定的初值$(1,1,1)$下，求方程组的数值解。

$$\begin{cases} \sin x + y^2 + \ln z - 7 = 0 \\ 3x + 2^y - z^3 + 1 = 0 \\ x + y + z - 5 = 0 \end{cases}$$

```
x =
    0.5991    2.3959    2.0050
fval =
   1.0e-10 *
    0.2213    0.3803   -0.0004
exitflag =
     1
output =
  包含以下字段的 struct:

       iterations: 7
        funcCount: 29
        algorithm: 'trust-region-dogleg'
    firstorderopt: 4.4767e-10
          message: 'Equation solved.…'
```

```
>> fh = @(x)[sin(x(1))+x(2)^2+log(x(3))-7, 3*x(1)+2^x(2)-x(3)^3+1, x(1)+x(2)+x(3)-5];
>> options = optimoptions('fsolve','Display','iter','PlotFcn',@optimplotfirstorderopt);
>> [x,fval,exitflag,output] = fsolve(fh,[1,1,1],options)
```

Iteration	Func-count	f(x)	Norm of step	First-order optimality	Trust-region radius
0	4	55.6104		22.2	1
1	8	23.0855	1	14.4	1
2	9	23.0855	2.13102	14.4	2.5
3	13	9.93091	0.532754	9.5	0.533
4	17	0.582066	0.875905	4.9	1.33
5	21	0.00159514	0.219095	0.403	2.19
6	25	5.02061e-10	0.00610298	0.000124	2.19
7	29	1.93608e-21	7.63728e-06	4.48e-10	2.19

```
Equation solved.

fsolve completed because the vector of function values is near zero
as measured by the default value of the function tolerance, and
the problem appears regular as measured by the gradient.
```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