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Solving complicated advanced mathematical problems based on matlab software

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Abstract
By solving a series of complicated problems using the function and the loop statement provided by Matlab software, we found that the Matlab software is a powerful and convenient software. It not only requires fewer commands but also gives results in a short time. It is suitable to help researchers to solve any problems in higher mathematics, both simple problems, and complicated problems. However, it has some shortcomings also.

Keywords: Matlab, mathematics, software, derivative, integral

1. Introduction

Matlab software is a useful mathematical software, which can solve many problems in mathematics, especially in advance mathematics, such as solving the problems of equations, limits, polynomials, integrals, matrices, etc. Regarding the application of Matlab software in advanced mathematics, numerous books and articles have introduced it [1-14]. However, most of them are only about the simple application, such as using Matlab software to find simple limit value [1, 7, 9, 14], to find the value of the third-order determinant [3, 8], to find the single definite integral [11], etc. Furthermore, it is only limited to finding the Taylor expansion of a function at a certain point, solving linear equations and simple ordinary differential equations [2, 4, 5, 6, 10, 12, 13]. Actually, except for this, Matlab software can also be used to solve more complicated problems in advanced mathematics with the effective use of various functions and loop statements provided by Matlab software. We will elaborate on this issue below.

2. The solution of complicated problems

2.1 The Solution of higher derivative problem

Example 1. Find the 1st to 10th derivative of the function $y = \sin(e^x) + \cos(\frac{1}{x})$

To solve this problem, we call the derivative function of Matlab software and input the following commands in combination with loop statements.

```
Syms x
y=sin (exp (x)) + cos (1/x)
For n=1:10
Diff (y, x, n)
End
```

The results obtained are as follows:

cos (exp (x))*exp (x) + sin (1/x)/x^2

cos (exp (x))*exp (x) - cos (1/x)/x^4 - (2*sin (1/x))/x^3 - sin (exp (x))*exp (2*x)

(6*cos (1/x))/x^5 + cos (exp (x))*exp (x) + (6*sin (1/x))/x^4 - sin (1/x)/x^6-cos (exp (x))*exp (3*x) - 3*sin (exp (x))*exp (2*x)

cos (1/x)/x^8 - (36*cos (1/x))/x^6 + cos (exp (x))* exp (x) - (24*sin (1/x))/x^5 + (12*sin (1/x))/x^7 - 6*cos (exp (x))*exp (3*x) - 7*sin (exp (x))*exp (2*x) + sin (exp (x))*exp (4*x)

(240* cos (1/x))/x^7 - (20* cos (1/x))/x^9 + cos (exp (x))* exp (x) + (120* sin (1/x))/x^6 - (120 * sin (1/x))/x^8 + sin (1/x)/x^10 - 25* cos (exp (x))* exp (3*x) + cos (exp (x))* exp (5*x) - 15* sin (exp (x))* exp (2*x) + 10* sin (exp (x))* exp (4*x)

(300* cos (1/x))/x^10 - (1800* cos (1/x))/x^8-cos (1/x)/x^12 + cos (exp (x))* exp (x) - (720* sin (1/x))/x^7 + (1200* sin (1/x))/x^9 - (30* sin (1/x))/x^11 - 90* cos (exp (x))*exp (3*x) + 15*cos (exp (x))*exp (5*x) - 31*sin (exp (x))* exp (2*x) + 65*sin (exp (x))*exp (4*x) – sin (exp (x))* exp (6*x)

(15120* cos (1/x))/x^9 - (4200* cos (1/x))/x^11 + (42* cos (1/x))/x^13 + cos (exp (x))* exp (x) + (5040* sin (1/x))/x^8 - (12600* sin (1/x))/x^10 + (630* sin (1/x))/x^12 – sin (1/x)/x^14 - 301* cos (exp (x))* exp (3*x) + 140* cos (exp (x))* exp (5*x) – cos (exp (x))* exp (7*x) - 63* sin (exp (x))* exp (2*x) + 350* sin (exp (x))* exp (4*x) - 21* sin (exp (x))* exp (6*x)

(58800* cos (1/x))/x^12 - (141120* cos (1/x))/x^10 - (1176* cos (1/x))/x^14 + cos (1/x)/x^16 + cos (exp (x))* exp (x) - (40320* sin (1/x))/x^9 + (141120* sin (1/x))/x^11 - (11760* sin (1/x))/x^13 + (56* sin (1/x))/x^15 - 966* cos (exp (x))* exp (3*x) + 1050* cos (exp (x))* exp (5*x) - 28* cos (exp (x))* exp (7*x) - 127* sin (exp(x))* exp (2*x) + 1701* sin (exp (x))* exp (4*x) - 266* sin (exp (x))* exp (6*x) + sin (exp (x))* exp (8*x)

(1451520* cos (1/x))/x^11 - (846720* cos (1/x))/x^13 + (28224* cos (1/x))/x^15 - (72* cos (1/x))/x^17 + cos (exp(x))* exp (x) + (362880* sin (1/x))/x^10 - (1693440* sin (1/x))/x^12 + (211680* sin (1/x))/x^14 - (2016* sin (1/x))/x^16 + sin (1/x)/x^18 3025* cos (exp (x))* exp (3*x) + 6951* cos (exp (x))* exp (5*x) - 462* cos (exp (x))* exp (7*x) + cos (exp (x))* exp (9*x) 255* sin (exp (x))* exp (2*x) + 7770* sin (exp (x))* exp (4*x) - 2646* sin (exp (x))* exp (6*x) + 36* sin (exp (x))* exp (8*x)

(12700800* cos (1/x))/x^14 - (16329600* cos (1/x))/x^12 - (635040* cos (1/x))/x^16 + (3240* cos (1/x))/x^18 cos (1/x)/x^20 + cos (exp (x))* exp (x) - (3628800* sin (1/x))/x^11 + (21772800* sin (1/x))/x^13 (3810240* sin (1/x))/x^15 + (60480* sin (1/x))/x^17 - (90* sin (1/x))/x^19 - 9330* cos (exp (x))* exp (3*x) + 42525* cos (exp (x))* exp (5*x) - 5880* cos (exp (x))* exp (7*x) + 45* cos (exp (x))* exp (9*x) - 511* sin (exp (x))* exp (2*x) + 34105* sin (exp (x))* exp (4*x) - 22827* sin (exp (x))* exp (6*x) + 750* sin (exp (x))* exp (8*x) - sin (exp (x))* exp (10*x)

These results have been verified to be correct, except it is too difficult to read.

2.2 The solution of high dimensional integral problem

Example 2. Find the 10 fold integral of the function $f(x) = 5x^2 + \frac{\sin x}{x}$.

To solve this problem, we call the integral function of Matlab software, and input the following commands in combination with the loop statement.

```
syms x
y=5*x^2+sin(x)/x
For i=1:10
int_y=int(y)
y=int_y
End
int_y
int_y =
```

The result obtained is as follows:

(x^9*sinint(x))/362880 - (115*cos(x))/21 + (cos(x)*(5*x^4 - 60*x^2 + 120))/420 + (67*x^2*cos(x))/24-(7*x^4*cos(x))/144 + (x^6*cos(x))/2880 + (cos(x)*(x^8 - 56*x^6 + 1680*x^4-20160*x^2 + 40320))/362880 + (61*x^3*sin(x))/144 - (13*x^5*sin(x)) /2880 + (x^7*sin(x))/40320 + (sin(x)*(-8*x^7 + 336*x^5-6720*x^3 + 40320*x))/362880 - (32*cos(x)*(x^2 - 2))/21 + (sin(x)* (x^5 - 20*x^3 + 120*x))/420 + (11*cos(x)*(x^4-12*x^2 + 24))/420 + (8*sin(x)*(- x^3 + 6*x))/35 + (11*sin(x)*(- 4*x^3 + 24*x)) /420 - (143*x*sin(x))/56 - (8*cos(x)*(3*x^2-6))/35 + x^12/47900160 - (cos(x)*(x^6 - 30*x^4 + 360*x^2 - 720))/5040 + (sin(x)* (6*x^5 - 120*x^3 + 720*x))/5040

This result has been verified to be correct. The same, it is very difficult to read too.

2.3 Determination of the properties of solutions of complicated differential equation

Example 3. For the following ordinary differential equation: $\begin{cases} \frac{dx}{dt} = y \\ \frac{dy}{dt} = -x - y - x^2 - y^2 \end{cases}$ it is easy to know that point $(-1,0)$ and point $(0,0)$ are its two singularities. But what the properties of these two points have?

This is a difficult problem to solve by traditional methods. To solve this problem, we will use the plotting function of Matlab software. That is to input the following commands and make the phase diagram of the above differential equation.

```
Clear; clc
x0 =-1.3:0.01:0.3
y0 =-1:0.01:1
[x, y] = Meshgrid (x0, y0)
dx = y
dy = -x-y-x.^2-y.^2
d = sqrt (x. ^2+y. ^2)
u = dx./d
v = dy./d
Figure; streamslice (x, y, u, v)
```

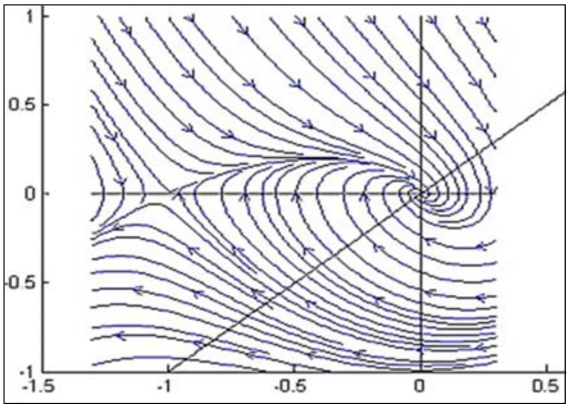

Fig 1: Phase diagram

Hold on; plot ([-1.3, 0.3], [0, 0],'k', 'line width', 0.50)
Hold on; plot ([0, 0], [-1, 1], 'k', 'line width', 0.50)
Hold on; plot ([-1, 1], [-1, 1], 'k', 'line width', 0.50)

After executing these commands, the phase diagram is shown in Figure 1. As can be seen from Figure 1, point $(-1,0)$ and point $(0,0)$ are saddle point and stable focus of the above differential equation respectively. This is hard to know without the assist of Matlab software.

2.4 Drawing the images of gamma and beta function

Example 4. The gamma function $\Gamma((x) = \int_0^{+\infty} t^{x-1}e^{-t}dt$ is also known as Euler second integral. Because of its complexity and particularity, it is difficult to draw its image by using traditional methods. Next, we will call the relevant functions of Matlab software to draw its image by entering the following commands.

```
x=-5:0.01:5;
Plot (x, gamma (x),'line Width', 2, 'color', 'r')
    Axis ([-5, 5,-10, 10])
    Title ('gamma function')
    Xlabel ('x')
    Ylabel ('gamma(x)')
    Set (gca, 'xtick', [-5:1:5])
    Grid on
```

The image obtained is shown in figure 2

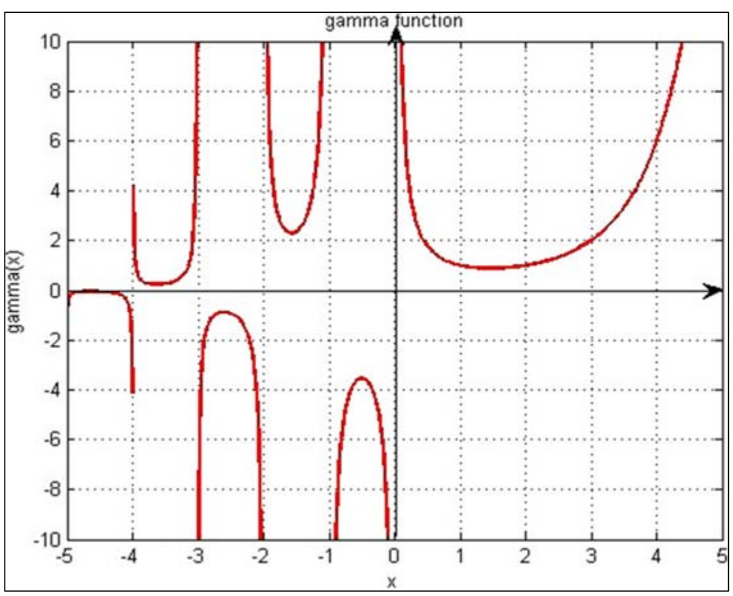

Fig 2: Image of gamma function

After checking with the function image in related books, the function image in Figure 2 is exactly the image of gamma function. Additionally, we can see that the function also exists on the interval less than 0, and the image is more complex. When x is greater than 0, the function decreases first and then increases.

Example 5. Beta function $B(a,b)=\int_0^1 x^{a-1}(1-x)^{b-1}dx$ is known as Euler first integral. Because of its complexity and particularity, it is difficult to draw its image by traditional methods. Next, we will call the relevant functions of Matlab software to draw its image by entering the following commands.

```
Clc; clear all
x=0:0.1:5
Ylabel ('$beta (m, n) $','interpreter', 'latex', 'Font Size', 18)
Xlabel ('x')
Plot (x, beta (x, 0.05), x, beta (x, 0.1), x, beta (x, 0.2), x, beta (x, 0.5), x, beta (x, 0.8))
Legend ('n=0.05', 'n=0.1', 'n=0.2', 'n=0.5', 'n=0.8')
Grid on
```

The image obtained is shown in figure 3.

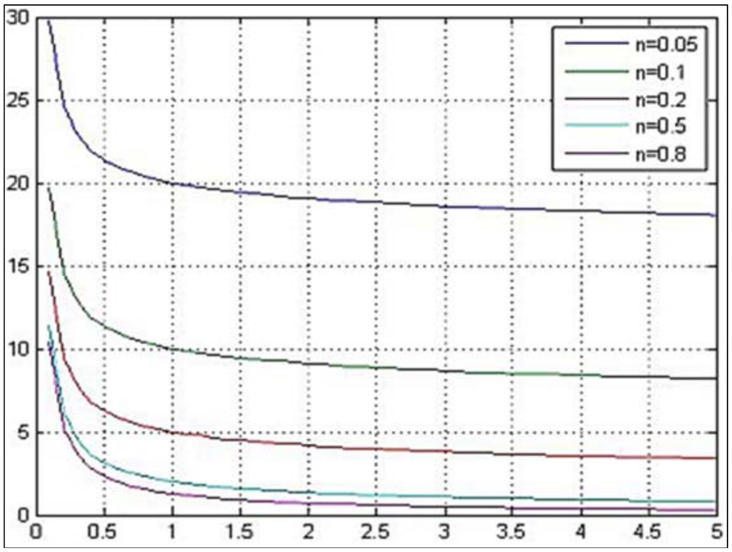

Fig 3: The image of beta function

After checking with the function image in related books, the function image in Figure 3 is exactly the image of beta function. As can be seen from Figure 3, when one of the parameters is fixed and the other parameter increases, the function value decreases, but the speed of reduction tends to be slow.

2.5 Drawing the images of common probability density function

Example 6. The normal distribution of two-dimensional random variables, when $\rho = 0$ the formula is $N((\ (\mu,,\sigma_1,\sigma_2)=\frac{1}{2\pi\sigma_1\sigma_2}e^{-\frac{(x-\mu)^2}{2\sigma_1^2}-\frac{(x-\mu)^2}{2\sigma_2^2}}$. Fixing its parameters, and inputting the following commands, then the density function image of its two-dimensional joint normal distribution could be drawn.

```
Mu = [1 -1]; Sigma = [.9 .4, .4 .3]
[X1, X2] = meshgrid (linspace (-1, 3, 100)', linspace (-3, 3, 100)')
X = [X1(:) X2(:)]
p = mvnpdf (X, mu, Sigma)
Surf (X1, X2, reshape (p, 100, 100))
```

The result is shown in Figure 4.

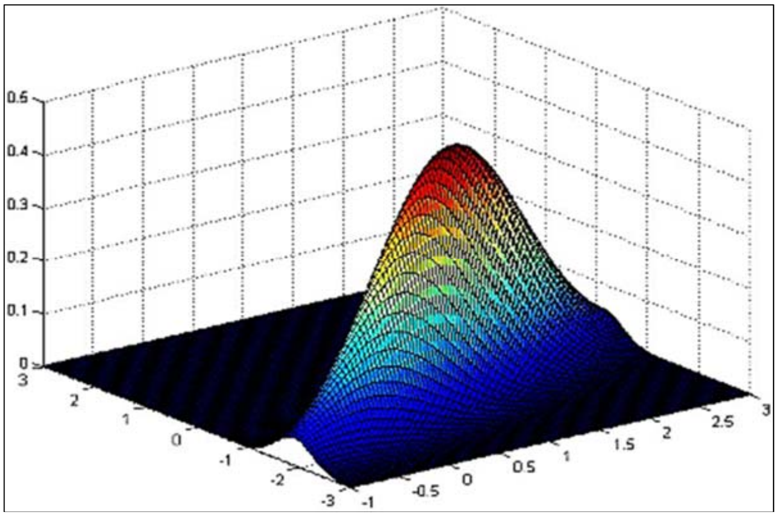

Fig 4: The image of density function

2.6 Drawing the image of complex density function

Example 7. The probability density function formula of gamma distribution is $\Gamma(x,a,b)=\frac{\beta^{\alpha}}{\Gamma(\alpha)}x^{\alpha-1}e^{-\beta x}, x>0$. To draw the function image when two parameters change, enter the following commands.

```
Clear all; clc;
outgifflag = true;
x=0:0.1:5;
n=linspace (1, 5, 20);
Axis ([0 5 0 0.5]);
ylabel ('$ Γ ( α ,   β )$', 'interpreter', 'latex', 'Font Size', 18);
xlabel ('x')
For i=1:10
    Fig = figure ('color', 'w')
    A (i, :) = gampdf (x, n (i), 0.5)
    Axis ([0 5 0 0.5])
    Plot (x, A)
    Pause (0.1)
    If outgifflag
        Pics (i) = getframe (fig);
    End
End
If outgifflag
    gifname = 'outgif3.gif'
    dt = 1/20
    num = size(pics, 2)
    For i = 1: num
        [I, map] = rgb2ind (frame2im (pics (i)), 256)
        If i == 1
            imwrite (I, map, gifname, 'gif', 'LoopCount', Inf, 'DelayTime', dt);
        Else
            Imwrite (I, map, gifname, 'gif', 'WriteMode', 'append', 'DelayTime', dt);
        End
    End
End
```

The resulting image-a dynamic image too, as shown in Figure 5. It can be seen that the density function of gamma distribution becomes flat when the second parameter is fixed to 0.5 and the first parameter is increased from 1 to 5.

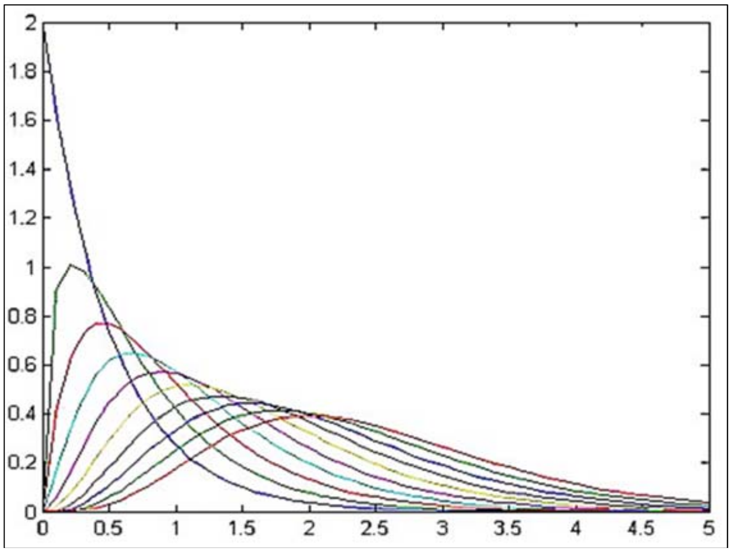

Fig 5: The image of gamma distribution

Example 8. The formula of the rate density function of F distribution is $f(x)=\begin{cases}\dfrac{\Gamma[(m+n)/2](m/n)^{n/2}x^{n/2-1}}{\Gamma(m/2)\Gamma(n/2)[1+mx/n]^{(m+n)/2}}, x>0\\ 0, others\end{cases}$, when its parameters change, we can enter the following commands to draw its image.

```
x=0:0.1:5;
ylabel ('$F(m, n)$', 'interpreter', 'latex', 'FontSize', 18)
xlabel ('x')
Plot (x, fpdf (x, 1, 1), x, fpdf (x, 5, 10), x, fpdf (x, 10, 50))
Legend ('F (1, 1)', 'F (5, 10)', 'F (10, 50)')
```

The resulting image is shown in Figure 6.

3. Conclusion

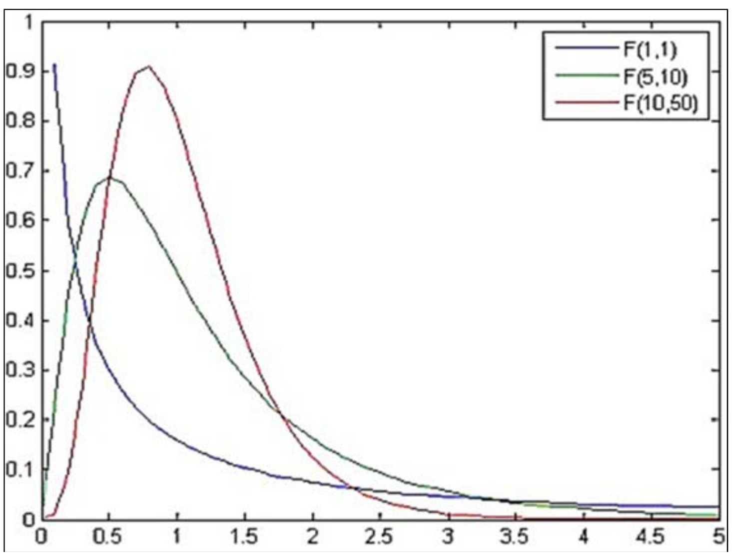

Fig 6: The image of F distribution

It can be seen from the above:

1) It is very easy to solve the high-dimensional calculus problem by using the built-in function of Matlab software.
2) By using the plotting function of Matlab software, it is very convenient to solve some difficult problems of ordinary differential equation.
3) For the very complicate functions in advanced mathematics, with Matlab software we can draw its image easily and accurately.
4) In advanced mathematics, the probability distribution functions which are very difficult to draw can be plotted. And when their parameters range, the graph produced can be dynamic, making them more visualized.

Therefore, Matlab software is a very powerful mathematical software, and also a very convenient one. It not only requires less commands, but also gives results in a short time. It is suitable to help researchers solve the problems in advanced mathematics, both simple problems and difficult problems.

However, through the above work, we also found that when we do numerical calculation, the results calculated are all in decimal form, and we do not find the fraction form as we usually see, for example $\frac{2}{3}$. So we are not able to verify whether the results are correct or not. There is even no constant form, such as $\frac{\sqrt{\pi}}{2}$ and e^2. When Matlab software give the symbolic results, the form is also different from the requently-used form, which makes it very difficult for us to read. If Matlab software can also give such numerical calculation, it will be more convenient.

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