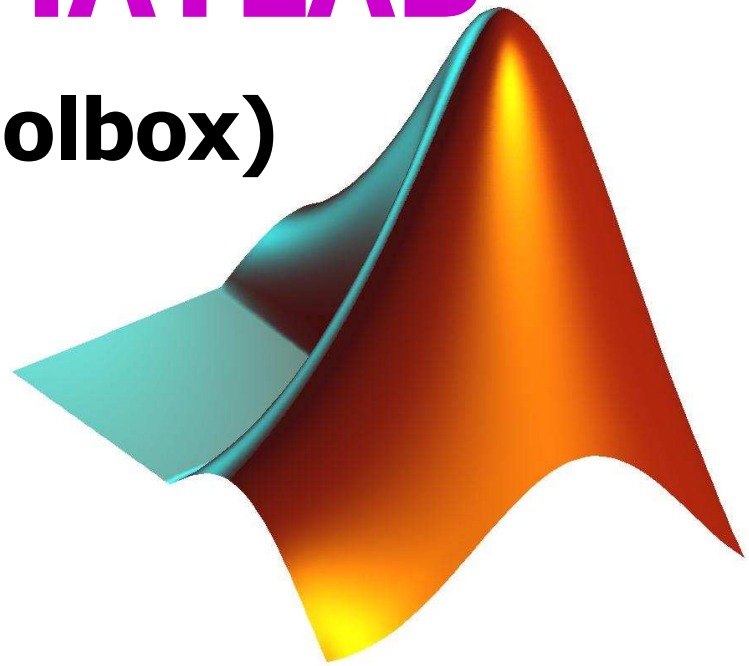
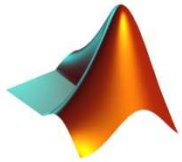
Introduzione al calcolo simbolico in MATLAB

(Symbolic math toolbox)



Analisi Numerica - A.A. 2010/11

Calcolo Simbolico in MATLAB



Fino ad ora si è utilizzato MATLAB per eseguire solo operazioni numeriche. In realtà spesso è utile manipolare espressioni matematiche con l'ausilio del calcolatore per ottenere risultati in forma analitica.

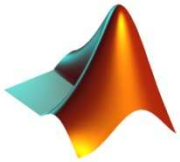
Es: Consideriamo l'equazione $$y = \frac{2(x+3)^2}{x^2+6x+9}$$

Sfruttando il calcolo simbolico, essa è equivalente a

$$y = \frac{2(x+3)^2}{x^2+6x+9} = \frac{2*(x^2+6x+9)}{(x^2+6x+9)} = 2$$

In Matlab variabili ed espressioni di tipo simbolico possono essere definite e trattate sfruttando le potenzialità del **Symbolic math toolbox**

Help e Demos



Il **Symbolic Math Toolbox** utilizza molti dei nomi delle funzioni numeriche di MATLAB e per ottenere le informazioni relative alla versione simbolica di una particolare funzione occorre digitare nella Command Window

>>help sym/*nomefunzione*

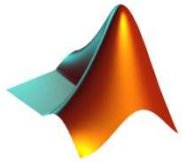
Può essere utile anche consultare le dimostrazioni e gli esempi contenuti nel MATLAB Demos. Digitare quindi

>>demos

e cliccare su

Toolboxes ⟶ **Symbolic Math**

Le variabili simboliche



Il **Symbolic Math Toolbox** definisce un nuovo tipo di variabile, chiamato **oggetto simbolico**. E' una struttura dati che memorizza una rappresentazione stringa del simbolo. Per creare oggetti simbolici in MATLAB si utilizza la funzione **sym**.

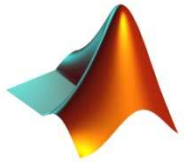
Esempio:

```
>> x=sym('x')
( >> syms  x )
x =
x

>> class(x)
ans =
sym
```

```
>> t=6;
>> g=sym(t)
g =
6
```

```
>> class(g)
ans =
sym

>> class(t)
ans =
double
```

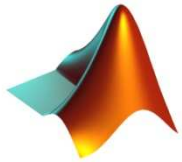
Rappresentazione simbolica di un valore numerico



>>t=0.1;

sym(t,'r')	rappresentazione razionale (default)	1/10
sym(t,'f')	rappresentazione floating-point	(2^-4+2702159776422298 *2^-56)
sym(t,'d')	espansione decimale con 32 cifre significative	.10000000000000055511 1512312578
digits(7) **sym(t,'d')**	espansione decimale con *7* cifre significative	.1000000

Creare funzioni matematiche simboliche



```
>>syms x y z real
```

VARIABILI SIMBOLICHE REALI

```
>>r = sqrt(x^2 + y^2 + z^2)
r =
(x^2+y^2+z^2)^(1/2)
```

ESEMPI DI ESPRESSIONI SIMBOLICHE

```
>>t = atan(y/x)
t =
atan(y/x)
```

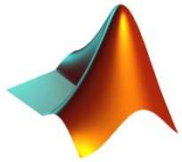
```
>> f=r+t
f =
(x^2+y^2+z^2)^(1/2)+atan(y/x)
```

OPERAZIONI TRA ESPRESSIONI SIMBOLICHE

Funzioni per manipolare espressioni simboliche

collect(E)	raccoglie i coefficienti con la stessa potenza di x
expand(E)	applica regole algebriche per espandere l'espressione E
factor(E)	esprime E come prodotto di polinomi con coefficienti razionali
poly2sym(p)	converte i coefficienti del vettore p in un polinomio simbolico
sym2poly(E)	converte l'espressione E nel vettore di coefficienti
pretty(E)	visualizza l'espressione E in forma matematica
simple(E)	ricerca la forma dell'espressione E più corta in termini di numero di caratteri, utilizzando differenti semplificazioni algebriche
simplify(E)	semplifica l'espressione E
subs(E,old,new)	sostituisce *new* al posto di *old* nell'espressione E

Esempi



1)
```
>> x=sym('x');
>> E=(x-1)*(x-2)*(x-3);
>> collect(E)
ans =
x^3-6*x^2+11*x-6
```

2)
```
>> E=(x-5)^2+(y-3)^2;
>> collect(E,y)
ans =
y^2-6*y+9+ (x-5)^2
```

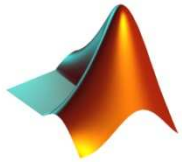
3)
```
>> E=cos(x+y);
>> expand(E)
ans =
cos(x)*cos(y)-sin(x)*sin(y)
```

4)
```
>> E= x^3-6*x^2+11*x-6;
>> factor(E)
ans =
(x-1)*(x-2)*(x-3)
```

5)
```
>> p=[2 6 4];
>> poly2sym(p)
ans =
2*x^2+6*x+4
```

6)
```
>> E=5*y^2-3*y+7
>> sym2poly(E)
ans =
[5 -3 7]
```

Esempi



1)
```
>> x=sym('x');
>> E=(x-1)*(x-2)*(x-3);
>> collect(E)
ans =
x^3-6*x^2+11*x-6
```

2)
```
>> E=(x-5)^2+(y-3)^2;
>> collect(E,y)
ans =
y^2-6*y+9+ (x-5)^2
```

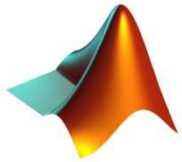
3)
```
>> E=cos(x+y);
>> expand(E)
ans =
cos(x)*cos(y)-sin(x)*sin(y)
```

4)
```
>> E= x^3-6*x^2+11*x-6;
>> factor(E)
ans =
(x-1)*(x-2)*(x-3)
```

5)
```
>> p=[2 6 4];
>> poly2sym(p)
ans =
2*x^2+6*x+4
```

6)
```
>> E=5*y^2-3*y+7
>> sym2poly(E)
ans =
[5 -3 7]
```

Esempi



1)
```
>> x=sym('x');
>> E=(x-1)*(x-2)*(x-3);
>> collect(E)
ans =
x^3-6*x^2+11*x-6
```

2)
```
>> E=(x-5)^2+(y-3)^2;
>> collect(E,y)
ans =
y^2-6*y+9+ (x-5)^2
```

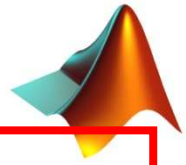
3)
```
>> E=cos(x+y);
>> expand(E)
ans =
cos(x)*cos(y)-sin(x)*sin(y)
```

4)
```
>> E= x^3-6*x^2+11*x-6;
>> factor(E)
ans =
(x-1)*(x-2)*(x-3)
```

5)
```
>> p=[2 6 4];
>> poly2sym(p)
ans =
2*x^2+6*x+4
```

6)
```
>> E=5*y^2-3*y+7
>> sym2poly(E)
ans =
[5 -3 7]
```

Esempi



1)
```
>> x=sym('x');
>> E=(x-1)*(x-2)*(x-3);
>> collect(E)
ans =
x^3-6*x^2+11*x-6
```

2)
```
>> E=(x-5)^2+(y-3)^2;
>> collect(E,y)
ans =
y^2-6*y+9+ (x-5)^2
```

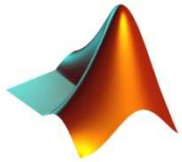
3)
```
>> E=cos(x+y);
>> expand(E)
ans =
cos(x)*cos(y)-sin(x)*sin(y)
```

4)
```
>> E= x^3-6*x^2+11*x-6;
>> factor(E)
ans =
(x-1)*(x-2)*(x-3)
```

5)
```
>> p=[2 6 4];
>> poly2sym(p)
ans =
2*x^2+6*x+4
```

6)
```
>> E=5*y^2-3*y+7
>> sym2poly(E)
ans =
[5 -3 7]
```

Esempi



1)
```
>> x=sym('x');
>> E=(x-1)*(x-2)*(x-3);
>> collect(E)
ans =
x^3-6*x^2+11*x-6
```

2)
```
>> E=(x-5)^2+(y-3)^2;
>> collect(E,y)
ans =
y^2-6*y+9+ (x-5)^2
```

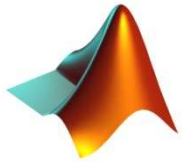
3)
```
>> E=cos(x+y);
>> expand(E)
ans =
cos(x)*cos(y)-sin(x)*sin(y)
```

4)
```
>> E= x^3-6*x^2+11*x-6;
>> factor(E)
ans =
(x-1)*(x-2)*(x-3)
```

5)
```
>> p=[2 6 4];
>> poly2sym(p)
ans =
2*x^2+6*x+4
```

6)
```
>> E=5*y^2-3*y+7
>> sym2poly(E)
ans =
[5 -3 7]
```

Esempi



1)
```
>> x=sym('x');
>> E=(x-1)*(x-2)*(x-3);
>> collect(E)
ans =
x^3-6*x^2+11*x-6
```

2)
```
>> E=(x-5)^2+(y-3)^2;
>> collect(E,y)
ans =
y^2-6*y+9+ (x-5)^2
```

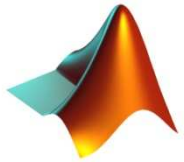
3)
```
>> E=cos(x+y);
>> expand(E)
ans =
cos(x)*cos(y)-sin(x)*sin(y)
```

4)
```
>> E= x^3-6*x^2+11*x-6;
>> factor(E)
ans =
(x-1)*(x-2)*(x-3)
```

5)
```
>> p=[2 6 4];
>> poly2sym(p)
ans =
2*x^2+6*x+4
```

6)
```
>> E=5*y^2-3*y+7
>> sym2poly(E)
ans =
[5 -3 7]
```

Esempi



1) **>> syms x**
>> E=x^3-6*x^2+11*x-6
>>pretty(E)
ans=
$x^3 - 6\,x^2 + 11\,x - 6$

2) **>> E=(1-x^2)/(1-x)**
>>simplify(E)
ans=
x+1

3) **>> E =cos(x)^2 + sin(x)^2**
>>simplify(E)
ans=
1

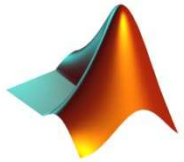
4) **>> E = x^2+6*x+7**
>> subs(E,x,2)
ans=
23

5) **>> E = a*sin(b)**
>> subs(E, {a,b}, {x,2})
ans=
x*sin(2)

6) **>> E = 3*cos(x)^2+sin(x)^2**
>>simplify(E)
ans=
2*cos(x)^2+1

7) **>> E = 3*cos(x)^2+sin(x)^2**
>>simple(E)
ans=
cos(2*x)+2

Esempi



1) **>> syms x**
>> E=x^3-6*x^2+11*x-6
>>pretty(E)
ans=
$x^3 - 6\,x^2 + 11\,x - 6$

2) **>> E=(1-x^2)/(1-x)**
>>simplify(E)
ans=
x+1

3) **>> E =cos(x)^2 + sin(x)^2**
>>simplify(E)
ans=
1

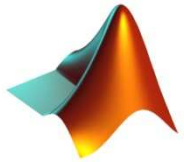
4) **>> E = x^2+6*x+7**
>> subs(E,x,2)
ans=
23

5) **>> E = a*sin(b)**
>> subs(E, {a,b}, {x,2})
ans=
x*sin(2)

6) **>> E = 3*cos(x)^2+sin(x)^2**
>>simplify(E)
ans=
2*cos(x)^2+1

7) **>> E = 3*cos(x)^2+sin(x)^2**
>>simple(E)
ans=
cos(2*x)+2

Esempi



1) **>> syms x**
>> E=x^3-6*x^2+11*x-6
>>pretty(E)
ans=
$x^3 - 6\,x^2 + 11\,x - 6$

2) **>> E=(1-x^2)/(1-x)**
>>simplify(E)
ans=
x+1

3) **>> E =cos(x)^2 + sin(x)^2**
>>simplify(E)
ans=
1

4) **>> E = x^2+6*x+7**
>> subs(E,x,2)
ans=
23

5) **>> E = a*sin(b)**
>> subs(E, {a,b}, {x,2})
ans=
x*sin(2)

6) **>> E = 3*cos(x)^2+sin(x)^2**
>>simplify(E)
ans=
2*cos(x)^2+1

7) **>> E = 3*cos(x)^2+sin(x)^2**
>>simple(E)
ans=
cos(2*x)+2

Esempi

1) **>> syms x**
>> E=x^3-6*x^2+11*x-6
>>pretty(E)
ans=
$x^3 - 6\,x^2 + 11\,x - 6$

2) **>> E=(1-x^2)/(1-x)**
>>simplify(E)
ans=
x+1

3) **>> E =cos(x)^2 + sin(x)^2**
>>simplify(E)
ans=
1

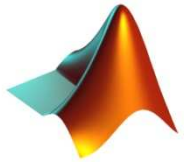
4) **>> E = x^2+6*x+7**
>> subs(E,x,2)
ans=
23

5) **>> E = a*sin(b)**
>> subs(E, {a,b}, {x,2})
ans=
x*sin(2)

6) **>> E = 3*cos(x)^2+sin(x)^2**
>>simplify(E)
ans=
2*cos(x)^2+1

7) **>> E = 3*cos(x)^2+sin(x)^2**
>>simple(E)
ans=
cos(2*x)+2

Esempi



1) **>> syms x**
>> E=x^3-6*x^2+11*x-6
>>pretty(E)
ans=
$x^3 - 6\,x^2 + 11\,x - 6$

2) **>> E=(1-x^2)/(1-x)**
>>simplify(E)
ans=
x+1

3) **>> E =cos(x)^2 + sin(x)^2**
>>simplify(E)
ans=
1

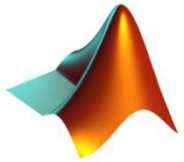
4) **>> E = x^2+6*x+7**
>> subs(E,x,2)
ans=
23

5) **>> E = a*sin(b)**
>> subs(E, {a,b}, {x,2})
ans=
x*sin(2)

6) **>> E = 3*cos(x)^2+sin(x)^2**
>>simplify(E)
ans=
2*cos(x)^2+1

7) **>> E = 3*cos(x)^2+sin(x)^2**
>>simple(E)
ans=
cos(2*x)+2

Esempi



1) **>> syms x**
>> E=x^3-6*x^2+11*x-6
>>pretty(E)
ans=
$x^3 - 6\,x^2 + 11\,x - 6$

2) **>> E=(1-x^2)/(1-x)**
>>simplify(E)
ans=
x+1

3) **>> E =cos(x)^2 + sin(x)^2**
>>simplify(E)
ans=
1

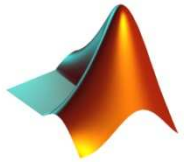
4) **>> E = x^2+6*x+7**
>> subs(E,x,2)
ans=
23

5) **>> E = a*sin(b)**
>> subs(E, {a,b}, {x,2})
ans=
x*sin(2)

6) **>> E = 3*cos(x)^2+sin(x)^2**
>>simplify(E)
ans=
2*cos(x)^2+1

7) **>> E = 3*cos(x)^2+sin(x)^2**
>>simple(E)
ans=
cos(2*x)+2

Esempi



1) **>> syms x**
>> E=x^3-6*x^2+11*x-6
>>pretty(E)
ans=
$x^3 - 6\,x^2 + 11\,x - 6$

2) **>> E=(1-x^2)/(1-x)**
>>simplify(E)
ans=
x+1

3) **>> E =cos(x)^2 + sin(x)^2**
>>simplify(E)
ans=
1

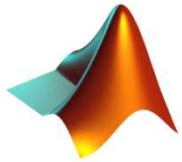
4) **>> E = x^2+6*x+7**
>> subs(E,x,2)
ans=
23

5) **>> E = a*sin(b)**
>> subs(E, {a,b}, {x,2})
ans=
x*sin(2)

6) **>> E = 3*cos(x)^2+sin(x)^2**
>>simplify(E)
ans=
2*cos(x)^2+1

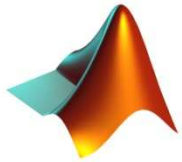
7) **>> E = 3*cos(x)^2+sin(x)^2**
>>simple(E)
ans=
cos(2*x)+2

Funzioni per creare e valutare espressioni simboliche



class(E)	restituisce la classe dell'espressione E
double(E)	converte l'espressione E in forma numerica
findsym(E)	restituisce il nome delle variabili contenute in E
[num,den]=numden(E)	restituisce due espressioni simboliche che rappresentano il numeratore e il denominatore della rappresentazione razionale di E
vpa(E,d)	usa l'aritmetica a precisione variabile per calcolare gli elementi di E con d cifre decimali

Esempi



1) **>>syms x**
>>E=(x-1)*(x-2)*(x-3)
>>class(E)
ans=
sym

2) **>>E=sym('(1+sqrt(5))/2')**
>>double(E)
ans=
1.6180

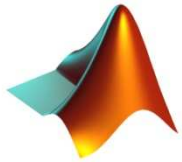
3) **>>digits(25)**
>>vpa(pi)
ans=
3.1415926535897932384626433

4) **>>E= x/y + y/x**
>> [num den]=numden(E)
num=x^2+y^2
den=y*x

5) **>>E=x+i*y-j*z**
>> findsym(E)
ans=
x, y, z

6) **>>E= x^2-6*x+7**
>>ezplot(E,[-2 6])

Esempi



1) **>>syms x**
>>E=(x-1)*(x-2)*(x-3)
>>class(E)
ans=
sym

2) **>>E=sym('(1+sqrt(5))/2')**
>>double(E)
ans=
1.6180

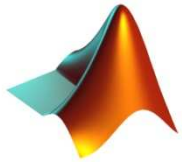
3) **>>digits(25)**
>>vpa(pi)
ans=
3.1415926535897932384626433

4) **>>E= x/y + y/x**
>> [num den]=numden(E)
num=x^2+y^2
den=y*x

5) **>>E=x+i*y-j*z**
>> findsym(E)
ans=
x, y, z

6) **>>E= x^2-6*x+7**
>>ezplot(E,[-2 6])

Esempi



1) **>>syms x**
>>E=(x-1)*(x-2)*(x-3)
>>class(E)
ans=
sym

2) **>>E=sym('(1+sqrt(5))/2')**
>>double(E)
ans=
1.6180

3) **>>digits(25)**
>>vpa(pi)
ans=
3.141592653589793238462643

4) **>>E= x/y + y/x**
>> [num den]=numden(E)
num=x^2+y^2
den=y*x

5) **>>E=x+i*y-j*z**
>> findsym(E)
ans=
x, y, z

6) **>>E= x^2-6*x+7**
>>ezplot(E,[-2 6])

Esempi

1) **>>syms x**
>>E=(x-1)*(x-2)*(x-3)
>>class(E)
ans=
sym

2) **>>E=sym('(1+sqrt(5))/2')**
>>double(E)
ans=
1.6180

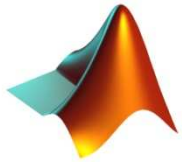
3) **>>digits(25)**
>>vpa(pi)
ans=
3.1415926535897932384626433

4) **>>E= x/y + y/x**
>> [num den]=numden(E)
num=x^2+y^2
den=y*x

5) **>>E=x+i*y-j*z**
>> findsym(E)
ans=
x, y, z

6) **>>E= x^2-6*x+7**
>>ezplot(E,[-2 6])

Esempi



1) **>>syms x**
>>E=(x-1)*(x-2)*(x-3)
>>class(E)
ans=
sym

2) **>>E=sym('(1+sqrt(5))/2')**
>>double(E)
ans=
1.6180

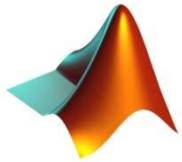
3) **>>digits(25)**
>>vpa(pi)
ans=
3.1415926535897932384626433

4) **>>E= x/y + y/x**
>> [num den]=numden(E)
num=x^2+y^2
den=y*x

5) **>>E=x+i*y-j*z**
>> findsym(E)
ans=
x, y, z

6) **>>E= x^2-6*x+7**
>>ezplot(E,[-2 6])

Esempi



1)
```
>>syms x
>>E=(x-1)*(x-2)*(x-3)
>>class(E)
ans=
sym
```

2)
```
>>E=sym('(1+sqrt(5))/2')
>>double(E)
ans=
1.6180
```

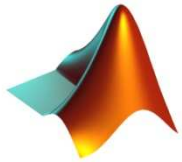
3)
```
>>digits(25)
>>vpa(pi)
ans=
3.1415926535897932384626433
```

4)
```
>>E= x/y + y/x
>> [num den]=numden(E)
num=x^2+y^2
den=y*x
```

5)
```
>>E=x+i*y-j*z
>> findsym(E)
ans=
x, y, z
```

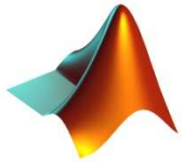
6)
```
>>E= x^2-6*x+7
>>ezplot(E,[-2 6])
```

Funzioni per risolvere equazioni algebriche e trascendenti



solve(E)	Risolve una equazione oppure una espressione (E=0) simbolica. *Non è necessario dichiarare le variabili con sym o syms*
solve(E1, …, En)	Risolve un sistema di equazioni o espressioni simboliche
S=solve(E)	Memorizza la soluzione in una struttura

Esempi



1) **>>solve('x+5')**

ans =

-5

2) **>>eq='exp(2*x)+3*exp(x)=54';**

>>solve(eq)

ans =

[log(-9)]

[log(6)]

3) **>>eq1= '6*x+2*y=14';**

>>eq2= '3*x+7*y=31';

>>S=solve(eq1,eq2)

S =

x: [1x1 sym]

y: [1x1 sym]

>>S.x

ans =

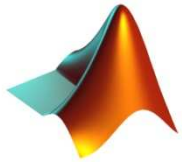
1

>>S.y

ans =

4

Esempi



1) **>>solve('x+5')**

ans =

-5

2) **>>eq='exp(2*x)+3*exp(x)=54';**

>>solve(eq)

ans =

[log(-9)]

[log(6)]

3) **>>eq1= '6*x+2*y=14';**

>>eq2= '3*x+7*y=31';

>>S=solve(eq1,eq2)

S =

x: [1x1 sym]

y: [1x1 sym]

>>S.x

ans =

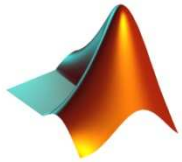
1

>>S.y

ans =

4

Esempi

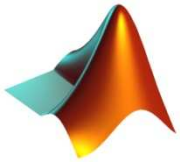


1)
```
>>solve('x+5')
ans =
     -5
```

2)
```
>>eq='exp(2*x)+3*exp(x)=54';
>>solve(eq)
ans =
    [ log(-9)]
    [  log(6)]
```

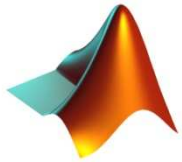
3)
```
>>eq1= '6*x+2*y=14';
>>eq2= '3*x+7*y=31';
>>S=solve(eq1,eq2)
S =
    x: [1x1 sym]
    y: [1x1 sym]

>>S.x
ans =
     1
>>S.y
ans =
     4
```

Esempi



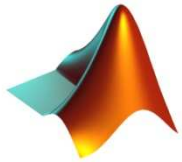
```
4) >> syms a u v
   >> f1=a*u^2+v^2;
   >> f2=u-v-1;
   >> f3=a^2-5*a+6;
   >> A=solve(f1,f2,f3)
A =
   a: [4x1 sym]
   u: [4x1 sym]
   v: [4x1 sym]
```

Funzioni per il calcolo simbolico



diff(E)	Restituisce la derivata dell'espressione E rispetto alla variabile indipendente di default (x)
int(E)	Restituisce l'integrale dell'espressione E
limit(E)	Restituisce il valore del limite di E per x che tende a 0 (default)
symsum(E)	Restituisce la somma dell'espressione E rispetto alla sua variabile k da 0 a k-1
taylor(f,n,a)	Restituisce il polinomio di Maclaurin di f di ordine n-1, valutato nel punto x=a

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

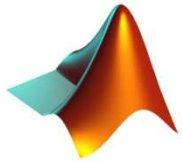
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

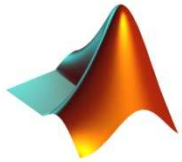
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

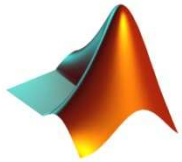
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

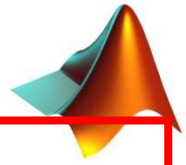
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

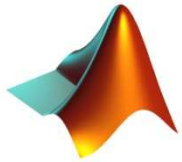
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

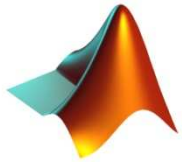
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

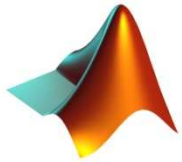
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1) **>>E= '(sin(x))^2 ';**
>>diff(E) [>>diff('(sin(x))^2 ')]
ans =
2*sin(x)*cos(x)

2) **>> syms x y**
>> diff(x*sin(x*y),y)
ans =
x^2*cos(x*y)

3) **>> syms x**
>> diff(x^3,2)
ans =
6*x

4) **>> syms x y**
>>diff(x*sin(x*y),y,2)
ans =
-x^3*sin(x*y)

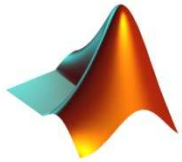
5) **>> syms n x**
>> int(x^n)
ans =
x^(n+1)/(n+1)

6) **>> syms x**
>> int(x^2,2,5)
ans =
39

7) **>> syms x y**
>> int(x*y^2,y,0,5)
ans =
125/3*x

8) **>> syms t x**
>> int(sin(x),t,exp(t))
ans =
-cos(exp(t))+cos(t)

Esempi



1)
```
>>syms a x
>>limit(sin(a*x)/x)
ans =
a
```

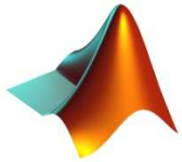
2)
```
>> syms h x
>> limit((sin(x+h)-sin(x))/h,h,0)
ans =
cos(x)
```

3)
```
>> syms x
>>limit(1/x,x,0, 'right')
ans =
-inf
```

4)
```
>> syms k x
>>symsum(k^2,1,4)
ans =
30
```

5)
```
>> syms x
>> f=exp(x);
>>taylor(f,4)
ans =
1+x+1/2*x^2+1/6*x^3
```

Esempi



1) **>>syms a x**
>>limit(sin(a*x)/x)
ans =
a

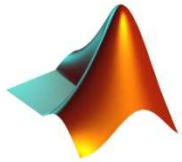
2) **>> syms h x**
>> limit((sin(x+h)-sin(x))/h,h,0)
ans =
cos(x)

3) **>> syms x**
>>limit(1/x,x,0, 'right')
ans =
-inf

4) **>> syms k x**
>>symsum(k^2,1,4)
ans =
30

5) **>> syms x**
>> f=exp(x);
>>taylor(f,4)
ans =
1+x+1/2*x^2+1/6*x^3

Esempi



1) **>>syms a x**
>>limit(sin(a*x)/x)
ans =
a

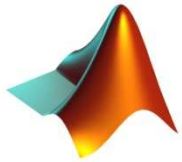
2) **>> syms h x**
>> limit((sin(x+h)-sin(x))/h,h,0)
ans =
cos(x)

3) **>> syms x**
>>limit(1/x,x,0, 'right')
ans =
-inf

4) **>> syms k x**
>>symsum(k^2,1,4)
ans =
30

5) **>> syms x**
>> f=exp(x);
>>taylor(f,4)
ans =
1+x+1/2*x^2+1/6*x^3

Esempi



1)
```
>>syms a x
>>limit(sin(a*x)/x)
ans =
a
```

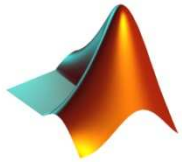
2)
```
>> syms h x
>> limit((sin(x+h)-sin(x))/h,h,0)
ans =
cos(x)
```

3)
```
>> syms x
>>limit(1/x,x,0, 'right')
ans =
-inf
```

4)
```
>> syms k x
>>symsum(k^2,1,4)
ans =
30
```

5)
```
>> syms x
>> f=exp(x);
>>taylor(f,4)
ans =
1+x+1/2*x^2+1/6*x^3
```

Esempi



1)
```
>>syms a x
>>limit(sin(a*x)/x)
ans =
a
```

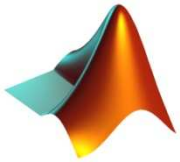
2)
```
>> syms h x
>> limit((sin(x+h)-sin(x))/h,h,0)
ans =
cos(x)
```

3)
```
>> syms x
>>limit(1/x,x,0, 'right')
ans =
-inf
```

4)
```
>> syms k x
>>symsum(k^2,1,4)
ans =
30
```

5)
```
>> syms x
>> f=exp(x);
>>taylor(f,4)
ans =
1+x+1/2*x^2+1/6*x^3
```

ESERCIZIO



Supponete che dell'acqua venga pompata in un serbatoio inizialmente vuoto. E' noto che la velocità del flusso dell'acqua nel serbatoio al tempo t sia uguale a 50-t l/sec. Si può dimostrare che la quantità Q di acqua che fluisce nel serbatoio durante i primi x secondi è

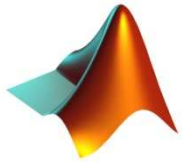
$$\int_0^x 50 - t \; dt$$

(a) determinare l'equazione simbolica che rappresenta la quantità di acqua nel serbatoio dopo x sec;

(b) determinare la quantità di acqua nel serbatoio dopo 30 sec;

(c) determinare la quantità di acqua che è fluita nel serbatoio tra 10 e 15 sec dopo l'inizio del flusso.

ESERCIZIO



Supponete che il seguente polinomio rappresenti l'altitudine in metri durante le prime 48 ore dopo il lancio di un pallone meteorologico:

$$h(t)=-0.12t^4+12t^3-380t^2+4100t+220$$

Le unità di t sono le ore.

(a) Utilizzare Matlab per determinare l'equazione per la velocità di salita oppure discesa del pallone.

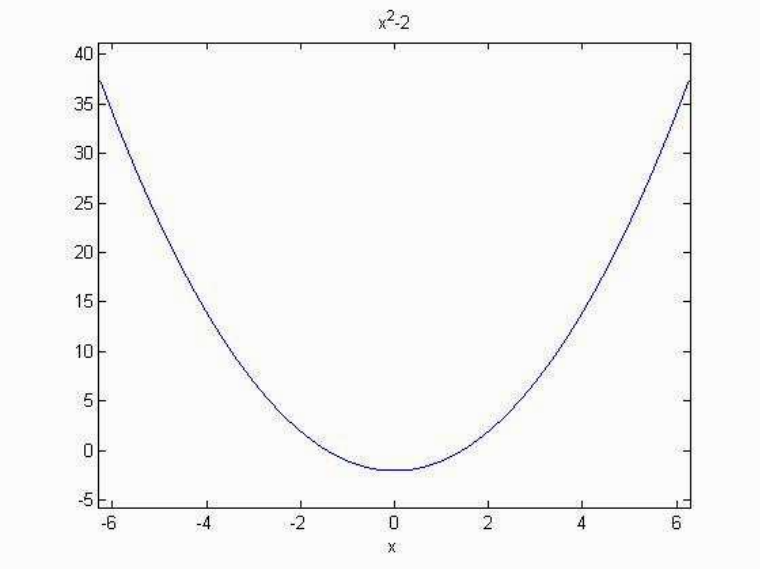
(b) Determinare l'equazione per l'accelerazione del pallone.

(c) Disegnare i grafici della quota, della velocità e dell'accelerazione nell'intervallo [0,48].

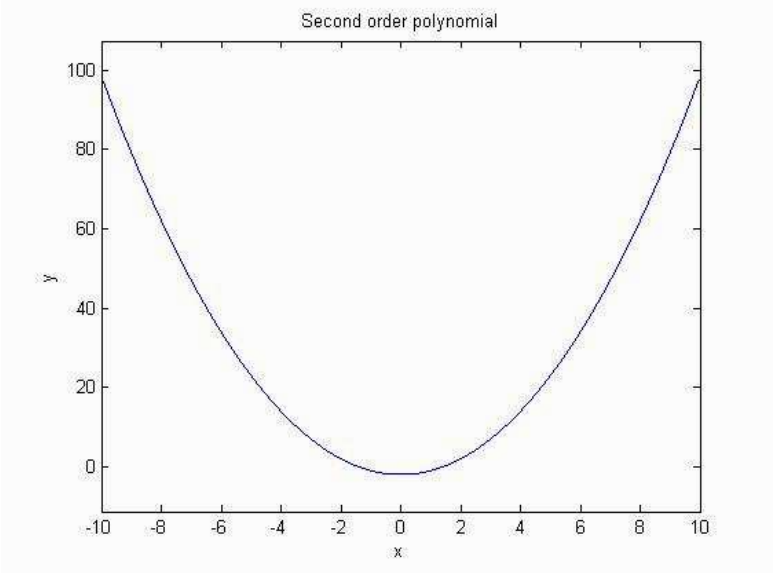
Plot di variabili ed espressioni simboliche

1) >>y=sym('x^2-2');
   >>ezplot(y);

La funzione è valutata in [-2pi, 2pi]



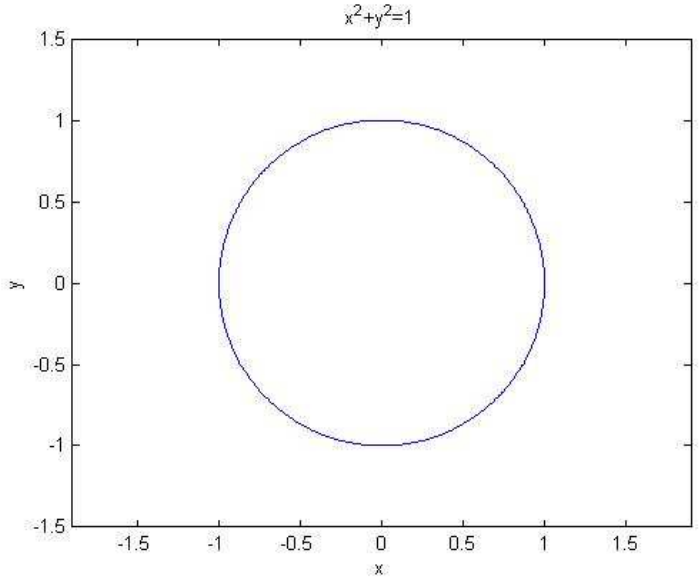
2) >>ezplot(y,[-10,10]);
   title('Second order polynomial')
   xlabel('x');
   ylabel('y');

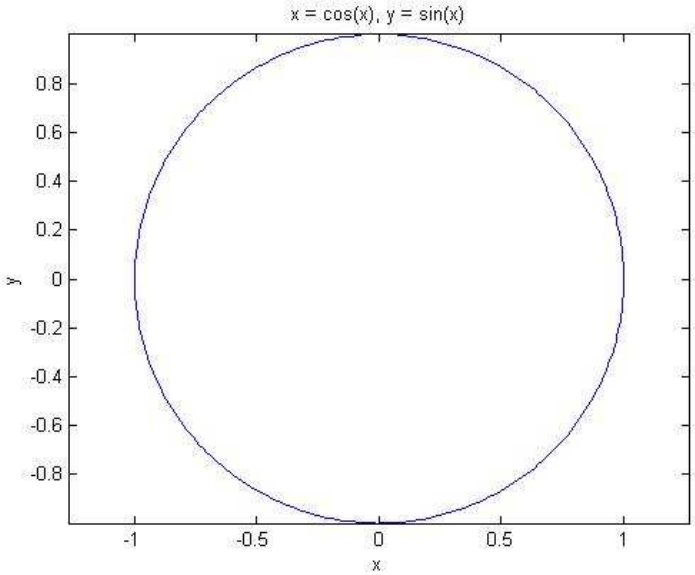


Grafici di funzioni implicite e parametriche

1) >>ezplot('x^2+y^2=1',[-1.5,1.5])
>>ezplot('x^2+y^2-1',[-1.5,1.5])
>>z=sym('x^2+y^2-1')
>>ezplot(z, [-1.5,1.5])

2) >>ezplot('sin(x)','cos(x)');





Grafici 3d

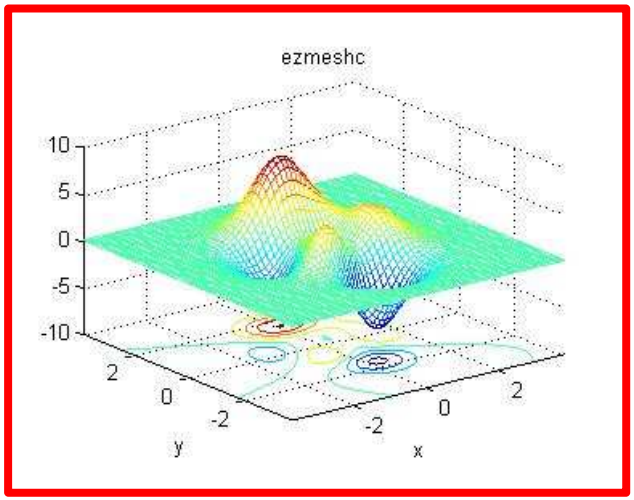
```
>>z1=sym('3*(1-x)^2*exp(-(x^2)-(y+1)^2)');
>>z2=sym('-10*(x/5-x^3-y^5)*exp(-x^2-y^2)');
>>z3=sym('-1/3*exp(-(x+1)^2-y^2)');
>>z=z1+z2+z3;
```

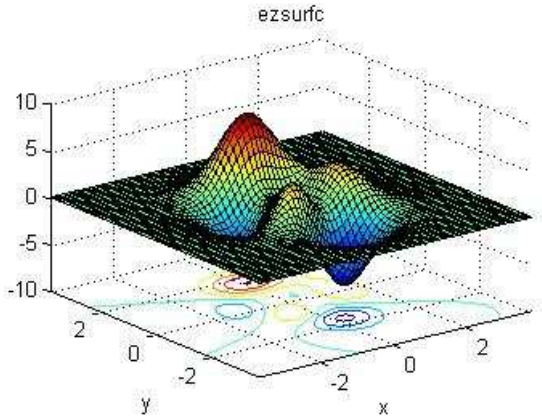
```
>>subplot(2,2,1);
>>ezmeshc(z);
>>title('ezmeshc');
```

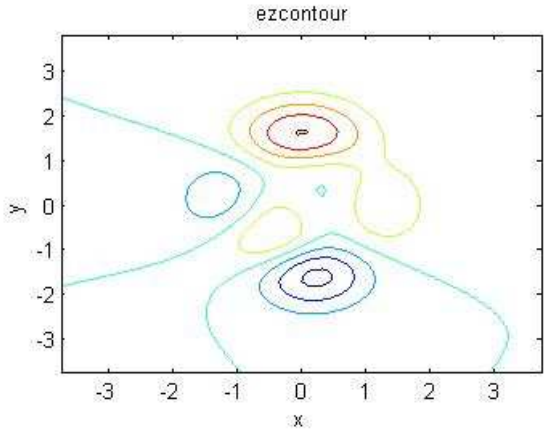
```
>>subplot(2,2,2);
>>ezsurfc(z);
>>title('ezsurfc');
```

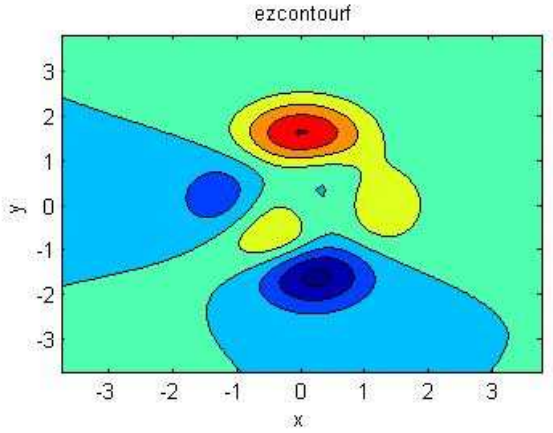
```
>>subplot(2,2,3);
>>ezcontour(z);
>>title('ezcontour');
```

```
>>subplot(2,2,4);
>>ezcountourf(z);
>>title('ezcontourf');
```



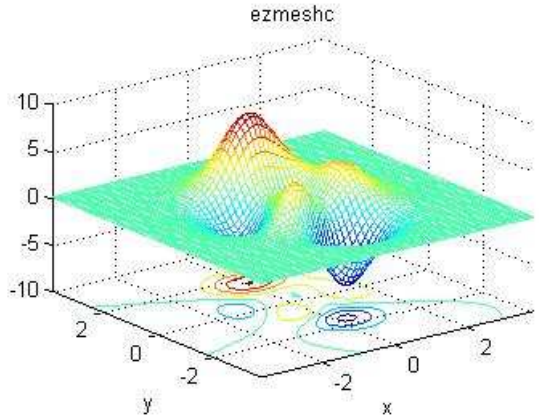


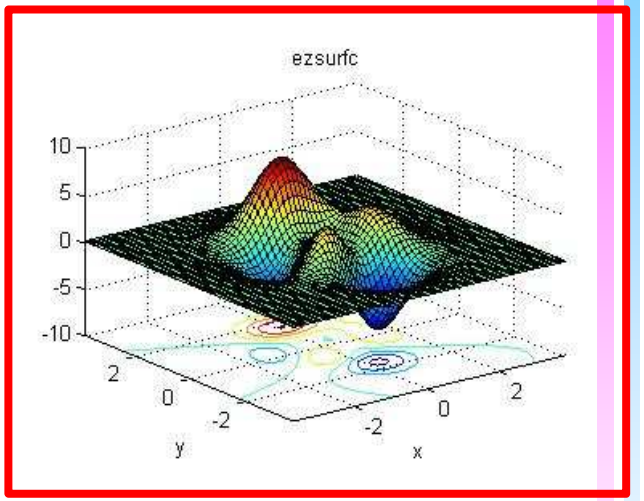


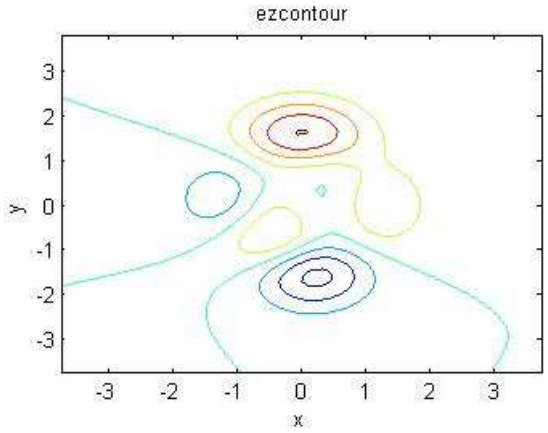


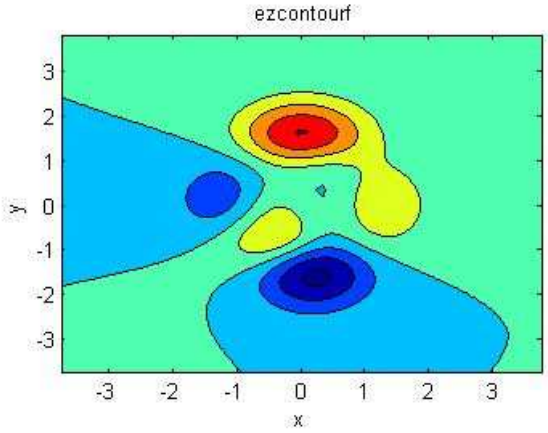
Grafici 3d

```
>>z1=sym('3*(1-x)^2*exp(-(x^2)-(y+1)^2)');
>>z2=sym('-10*(x/5-x^3-y^5)*exp(-x^2-y^2)');
>>z3=sym('-1/3*exp(-(x+1)^2-y^2)');
>>z=z1+z2+z3;

>>subplot(2,2,1);
>>ezmeshc(z);
>>title('ezmeshc');

>>subplot(2,2,2);
>>ezsurfc(z);
>>title('ezsurfc');

>>subplot(2,2,3);
>>ezcontour(z);
>>title('ezcontour');

>>subplot(2,2,4);
>>ezcountourf(z);
>>title('ezcontourf');
```



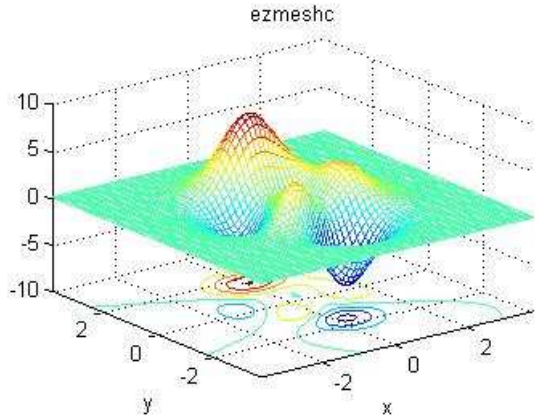


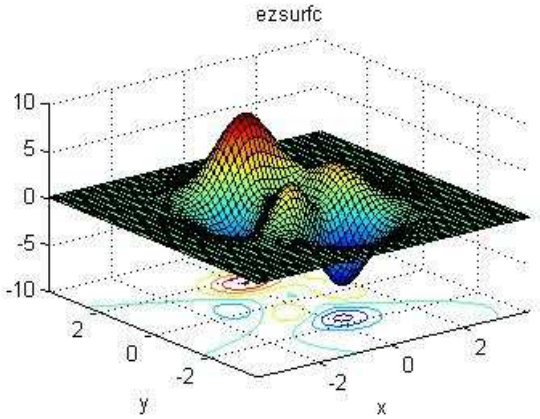


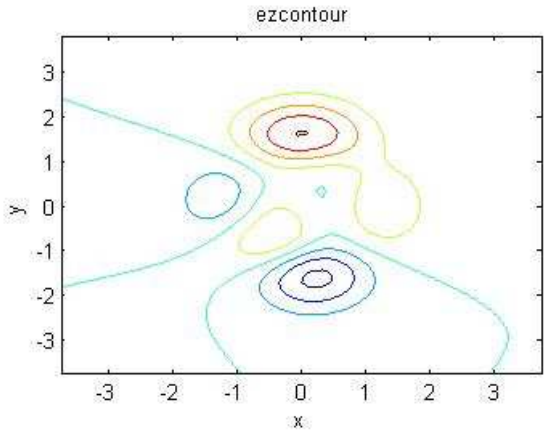


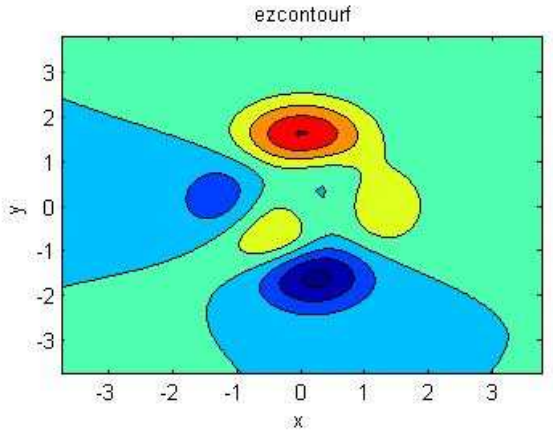
Grafici 3d

```
>>z1=sym('3*(1-x)^2*exp(-(x^2)-(y+1)^2)');
>>z2=sym('-10*(x/5-x^3-y^5)*exp(-x^2-y^2)');
>>z3=sym('-1/3*exp(-(x+1)^2-y^2)');
>>z=z1+z2+z3;

>>subplot(2,2,1);
>>ezmeshc(z);
>>title('ezmeshc');

>>subplot(2,2,2);
>>ezsurfc(z);
>>title('ezsurfc');

>>subplot(2,2,3);
>>ezcontour(z);
>>title('ezcontour');

>>subplot(2,2,4);
>>ezcountourf(z);
>>title('ezcontourf');
```



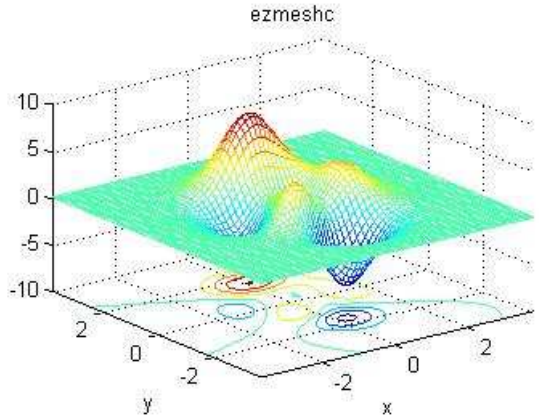


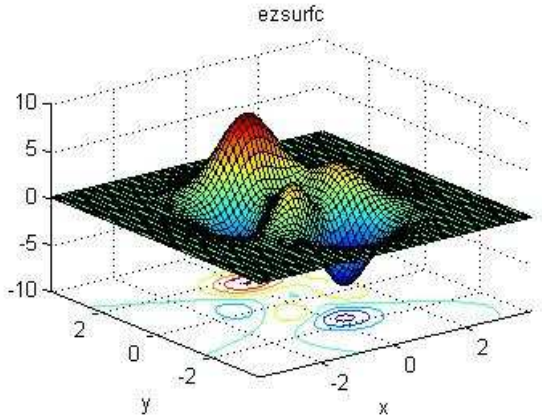


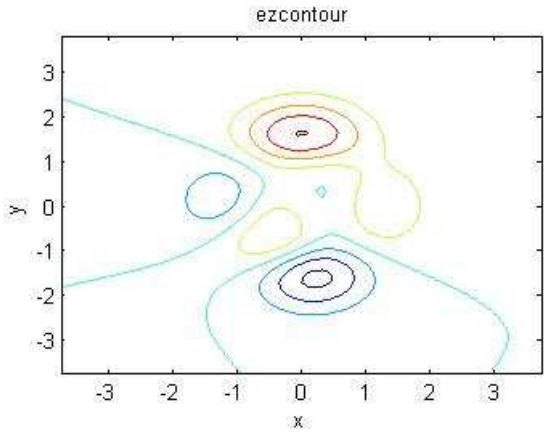


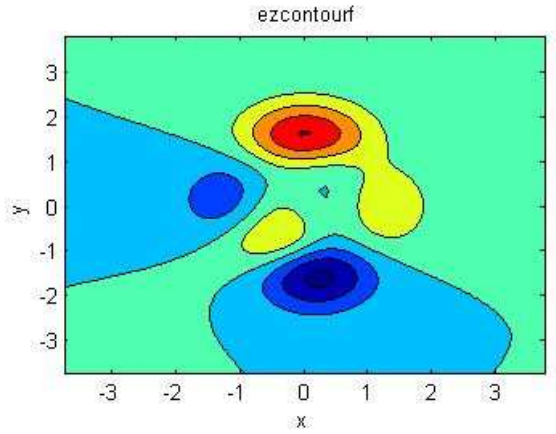
Grafici 3d

```
>>z1=sym('3*(1-x)^2*exp(-(x^2)-(y+1)^2)');
>>z2=sym('-10*(x/5-x^3-y^5)*exp(-x^2-y^2)');
>>z3=sym('-1/3*exp(-(x+1)^2-y^2)');
>>z=z1+z2+z3;

>>subplot(2,2,1);
>>ezmeshc(z);
>>title('ezmeshc');

>>subplot(2,2,2);
>>ezsurfc(z);
>>title('ezsurfc');

>>subplot(2,2,3);
>>ezcontour(z);
>>title('ezcontour');

>>subplot(2,2,4);
>>ezcountourf(z);
>>title('ezcontourf');
```









Calcolatrice grafica interattiva

Il comando funtool fornisce una interfaccia grafica interattiva per manipolare simbolicamente delle funzioni e studiarne le principali caratteristiche

>>funtool