ntent

New orewor

n ctober , 200 xiom was withdrawn from the market and ended life as a commercial roduct. 2 e tem 06.92 3

h ter 1

Axi e t re

. ntro u tion to xiom

elcome to the world of xiom. e call xiom a

which would g

literall do ens of kinds of numbers to com ute with. These range from various kinds of in

```
nverse(%)
```

$$\begin{bmatrix} \frac{1}{x\ i} & 0 \\ \frac{1}{2\ x\ \ 2\ i} & -\frac{1}{2} \end{bmatrix}$$

```
e    n n(Matr x Fract n P  n  a  C  ex  nte er,...)
```

1 1 4 H erDo

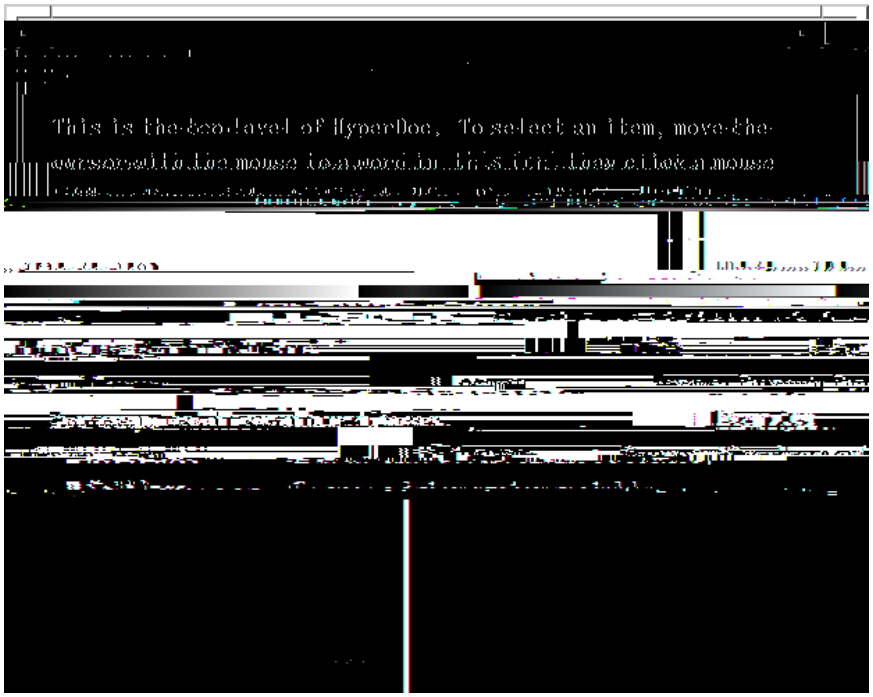


Figure . H erdoc o ening menu

H erDoc resents ou windows o

k

```
draw(5 besse J(0,s rt(x  2    2)), x -20..20,   -20..20)
```

Figure .2 J_0

$$\left[, 3\ x, \quad 5 \right.$$

`e Ex ress n nte er`

Note the use of %" here. This means the value of the last ex ression we com uted. In this case it is the long ex ression above.

1 1 8 P ttern M t h-8 0 0 1 0 12 R 7 s 80Td o 4 3 2 0 8 T 9 6 4 0 T d 1 0 080TdtheT eT 15 720Td oT

Using **in ut** files and the **r ad** command, ou can create our o n librar

h ter 2

en n ent l I e

an

■ e Matr x P■ n■ a Fract ■n nte er

the inter reter

xiom's use of abstract datat es clearl se arates the ex orts of a domain what o erations are defined fro

h ter

t rting Axi

elcome to the xiom environment for interactiv and roblem solving. onsider this cha ter a ief, whirlwind introduce ou xiom's gra hics and th xiom l

If you are running axiom under the Window system, there may be two windows the console window as just described and the HyperDoc main menu. HyperDoc is a multiple-window hypertext system that lets you view axiom documentation and examples on-line, execute axiom expressions, and generate graphics. If you are in a gra

```
2 - 3 / 4   3    2 -
```

$$-\frac{9}{4}$$

```
■ e   Fract ■n  nte er
```

The above ex ression is equivalent to this.

```
((    2) - ((3 / 4)   (3    2))) -
```

$$-\frac{9}{4}$$

```
■ e   Fract ■n  nte er
```

If an ex ression contains subex ressions enclosed in arentheses, the

9999999999

■ e P■s t ve nte er

This is the last result.

%%(-)

9999999999

■ e P■s t ve nte er

This is the result from ste number .

%%( )

0000000000

■ e P■s t ve nte er

3 2 3 So■e T es

ver thing in xiom has a t e. The t e determines what o erations ou can erform on an object and how the

x 8

x^8

The Power Operator

Here a negative integer exponent produces a fraction

x (-8)

$\overline{x^8}$

The Fraction Power Operator

3.2.4 Symbols Variable

This gives the value $z \quad 3/5$ a

3.

T
RTIN XI M

t e declara
tion can

The Format

Use

3 2 6 C ll n Fun t ons

s we saw earlier, when ou want to add or subtract two values, ou lace the arithmetic o erator ”

n o erations that returns a B■■ ean value that is, true or a se

r

3.3.2 The Conversion

To obtain the floating point

3 3 3 Use ul Fun t ons

To obtain the absolute value of a n

e P s t ve nte er

Tests on values can be done using various functions which are generall more efficient than using relational o erators such as articularl if the value is a matrix. xam les of

e B ean

e

3 4 2 Com lex Numbers

For man scientific calculations real numbers aren't sufficient and su ort for com lex numbers is also required. om lex numbers are handled in an intuitive manner. xiom uses the %i macro to re resent the squar

The Computer Vision Pipeline

actuator(%)

i

3. . IN XI M MB LI L L T R

```
rad x(3/2 ,5)
```

$$0.\overline{0324\ 2}$$

■ e R

```
c■  actFract ■n(%)
```

$$6 - {}^{3}$$

$$-3$$

The first example should be read as

```
Let x be a term of Prefield() and assign to it the value 5
```

Note that it is only possible to invert non-zero values if the arithmetic is performed modulo a prime number. Thus arithmetic modulo a non-prime integer is possible but the reciprocal operation is undefinedand will generate an error. Attempting to use the `Prefield` constructor with a non-prime argument will generate an error. An example of non-prime modulo arithmetic is given in sample/field.0440, etc

3.5.4 Comments

file. To get Axiom to read this file, you use the system command `)read mybitmap.input`. If you need to make changes to your approach or definitions, go into your favorite editor, change **mybitmap.input**, then `)read mybitmap.input` again.

Other system commands include `)clear properties`, to display previous input and/or output lines `)display algebra`, to display properties and values of workspace variables and `)what`.

Issue `)what algebra` to get a list of Axiom objects that have a given substring in their name.

```
)w
```

e P s t ve nte er

rst(,5,6,2,3],2)

[,5

e L st P s t ve nte er

rest(,5,6,2,3])

[5, 6, 2, 3

e L st P s t ve nte er

rest(,5,6,2,3],2)

[6, 2, 3

e L st P s t ve nte er

ther functions are

```
reverse(  ,2,- ,2])
```

$$[2, - \ , 2,$$

■ e L st nte er

```
s■rt(  ,2,- ,2])
```

$$[- \ , 2, 2,$$

■ e L st nte er

```
re ■veDu  cates(  ,5,3,5, , ,2])
```

$$[\ , 5, 3, 2$$

■ e L st P■s t ve nte er

```
#  ,2,- ,2]
```

4

■ e P■s t ve nte er

Lists in xiom are mutable and so their contents the elemen

$[9, 2, 4, \ , \ , 5, 42$

■ e L st P■s t ve nte er

```
endO u    rest(u,4)
```

$[\ , 5, 42$

■ e L st P■s t ve nte er

```
 artO u    rest(u,2)
```

$[4, \ , \ , 5, 42$

■ e L st P■s t ve nte er

```
setrest!(endO u, artO u)  u
```

$[9, 2,$

$[9, 99, 20,$

■ e L st P■s t ve nte er

In the revious exam le a new

3 6 2 Se mented L sts

segmented list is one in which some of the elements are ranges of values. The **x and** function converts lists of this t e into ordinar lists

```
.. 0]
```

[.. 0

```
e   L st
```

To create the series the window is laced at the star

x6.8828.32Td [Tj/R240. 2Tf .680Td Tj/R8 0. 2Tf4.440Td 2 Tj/R240. 2Tf5.040Td Tj/R8 0. 2Tf4.440

```
swa !(b,2,3)  b
```

[2, 4, 3, 5, 6

```
■ e  OneD ens ■na Arra P■s t ve nte er
```

```
c■  nt■!(a,b,3)
```

[4, 4, 2, 4, 3, , 4 4, 4,6

T e neDimensio nal rra Posit iv eIn te ger

3 6 5 Flex ble Arr s

Flexible arra s are designed to rovide the efficienc of one-dimensional arra s while re

■ e F ex b eArra nte er

de ete!(,5)

$[4, 3, 42, 8, 2, 28$

■ e F ex b eArra nte er

(3..5)

$[42, 8, 2$

■ e F ex b eArra nte er

.2

$[4, 3, 42, 8, 2, 28$

■ e F ex b eArra nte er

n(er)■ -3 d0■d /R8L8 ■d(rr)■ 0.440■d(r4.440■d(te)■ . d( )■ /R8 0. 2■ 4.440■d(28)■

```
        c  a   b
        c
    )
```

2.82842 24 46 9009 6

e F at

Note that indentation is **xtr l** im ortant. If the exam le abov5 had the

```
Error  A  M ss n   ate.
L ne   2           a  3.0
L ne   3           b   .0
L ne   4           c  a   b
L ne   5           c
L ne   6           )
          .........A
Error  A  ( r  A u  t  A)   n red.
Error  A     r  er s ntax.
Error  A  s ntax error at t   eve
Error  A  P ss b     ss n  a )
 5 error(s)  ars n
```

a similar error will be raised. Finall , the ” m

3.0

e F at

b .0

.0

e F at

c a b

4.0

e F at

s rt(4.0 c)

2.82842 24 46 9009 6

e F at

which achieves the same result and is easier to understa

with some invocations of these functions

()

C■ n unct ■n w t t e () - L st nte er

[

■ e L st nte er

(4)

C■ n unct ■n w t t e nte er - L st nte er

[4

■ e L st nte er

(2,9)

C■ n unct ■n w t t e (

nte er - nte er

■ e V■ d

x (a

```
re eat
         4 t en break
  ut ut( )
```

the **r ad** ields

e P s t ve nte er

```
re eat
         4 t en break
  ut ut( )
```

2
3
4

e V d

It was mentio

0

e NnNe at ve nte er

re eat

6 t en break

4

■ e P■s t ve nte er

r

■ e P■s t ve nte er

```
w   e r <   astr■w re eat
  c      --  ndex ■    rst c■ u n
  w   e c <   astc■  re eat
       e t( ,r,c) < 0 t en
      ■ut ut  r,c,e t( ,r,c)]
      r     astr■w
      break -- D■e
```

■ e V■

the r ad ields

```
 r a  n  ..4  r b  n 8..5 b  -  re eat
  ut ut  a,b]

    ,8]
   2, ]
   3,6]
   4,5]
```

e V d

Note that without the b - " the segment 8..5 em t so there is nothing to iterate over and the loo exits immediatel .

3.8 Numbers

xiom distinguishes ver carefull between different kinds of numbers, how the are re resented and what their ro erties are. Here are a sam ling of some of these kinds of numbers and some things ou can do with them.

Integer arithmetic is alwa s exact.

```
3    3            - 9  5   23  3

            2538  5   25389 859466622448423 298
```

e P s t ve nte er

Integers ca re resented in factored form.

```
act r 6432380 0 48569023 205944 255  04344 455 0 63243
```

$$^{13}\ 3^{11}\ ^{7}\ 9^5\ 23^3\ 29^2$$

e Fact red nte er

Results sta factored when ou do arithmetic. Note that the 2 is automaticall fa

■ e Fact■red nte er

Integers can also be dis la ed to bases other than 0. This is an integer in base .

```
rad x(2593 42460 ,  )
```

0000000000

■ e Rad xEx ans ■n

Roman numerals ar5 also availabl5 for thos5 s ecial occasions.

```
r■ an( 992)
```

M M II

■ e R■ anNu era

Rational number arithmetic is also exact.

```
r     0   9/2   8/3    /4   6/5   5/6   4/    3/8   2/9
```

$$\frac{55\ 39}{2520}$$

■ e Fract ■n nte er

To factor fractions, ou have to ma **fact■r** onto the numerator and denominator.

```
a ( act■r,r)
```

$$\frac{39\ 40}{2^3\ 3^2\ 5}$$

■ e Fract ■n Fact■red nte er

S n e nte er refers to machine word-length integers. In nglish, this ex ression means as a small integer".

```
@S n  e nte er
```

■ e S n e nte er

Machine double- recision floating- oint numbers are also available for numeric and gra hical a lications.

23.2 @D■ub eF ■at

23.2 00000000000

■ e D■ub eF ■at

The normal floating- oint t e in xiom, F ■at, is a software im lementation of floating- oint numbers in which the ex onent and the mantissa ma have an

umber of digits. The t es C■ ex(F ■at) C■ ex(D■ub eF ■at) are the corres onding software im lementations of com lex floating- oint numbers.

This is a floating- oint a roximation to aboutloa

```
d   ts(40)  ex (%     s rt  63.0)
```

26253 4 2640 68 43.9999999999 992500 259 6

```
■ e F ■at
```

Here are com lex numbers with rational numbers um

$u \quad v\, i$

■ e C■ ex P■ n■ a nte er

f course, ou can do com lex arithmetic with these also.

% 2

$$-v^2 \quad u^2 \quad 2\, u\, v\, i$$

■ e C■ ex P■ n■ a nte er

ver rational number hao an exact re resentatio6606Ni

Since 5 is prime, you can invert non-zero values.

```
1/5
```

$$\frac{1}{5}$$

```
PrimeQ[5]
```

True

You can also compute modulo an integer that is not a prime.

```
PowerMod[2, 5, 6]
```

5

```
PowerMod[2, 1/5, 6]
```

PowerMod[2, 1/5, 6]

All of the usual arithmetic operations are available.

```
3 + 2
```

5

```
PowerMod[2, 1/5, 6]
```

PowerMod[2, 1/5, 6]

Inversion is not defined for integers that are not prime.

This defines to be an algebraic number, that is, a root0Td3o,.60Tf5.aa

a

2/%

$$\frac{\left(\begin{array}{l} {}^{4}\_{}^{3}\,2\,{}^{2}\_ \;)\,b^{3}\quad {}^{4}\_{}^{3}\,2\,{}^{2}\_ \;)\,b^{2} \\ {}^{4}\_{}^{3}\,2\,{}^{2}\_ \;)\,b\quad {}^{4}\_{}^{3}\,2\,{}^{2}\_ \;3 \end{array}\right)}{\left(\begin{array}{l} {}^{4}\_{}^{3}\,2\,{}^{2}\_ \;)\,b^{3}\quad {}^{4}\_{}^{3}\,2\,{}^{2}\_ \;)\,b^{2} \\ {}^{4}\_{}^{3}\,2\,{}^{2}\_ \;)\,b\quad {}^{4}\_{}^{3}\,2\,{}^{2}\_ \end{array}\right)}$$

■ e Ex ress ■n nte er

But we need to rational6 e the denominator again.

ratDen■ (%)

$$b$$

■ e Ex ress ■n nte er

T es uatern ■n a

norni on

u ,- ,]

[, – ,

■ e L st nte er

This is the value at the third node. lternativel , ou can sa *u*.3.

rst rest rest u

■ e P■s t ve nte er

Man o era

[, – , ,9

■ e L st nte er

str m is a structure that otentiall has an infinite number of distinct elements. Think of a stream as an infinite list" where elements are com uted successivel .

reate an infinite stream of factored integers. nl a certain numbnct
elemen e s TJ20Td re Tj .880Td co ea
3j4.920Tdnd .64d uccessof l

ne-dimensional arra s are also mutable ou can change their constituent elements in lace."

```
a.3        a
```

$$\left[,- , \quad , \frac{3}{2} \right]$$

```
 e   OneD  ens na Arra  Fract n  nte er
```

However, one-dimensional arra s are not flexible structures. You cannot destructivel **concat!** them together.

```
ncat!(a,neD  ens na Arra     ,-2])
```

```
 ere are 5 ex sed and 0 unex sed   brar  erat ns na ed ncat!
    av n
```

3.9. *T* *TR* *T* *RE* 0

■*b* *t* *Ddim* *nsio*

■ e Mu t set nte er

t bl is conce tuall a set of ke value" airs and is a generali ation of a multiset. For exam les of tables, s

dan e Rec■rd(a e nte er, sa ar F9■at)

■ e V■ d

ive *d niel* a value, using square brackets to enclose the values

3.10 Expanding to Higher Dimensions

To get higher dimensional aggregates,

numbers as coefficients. Moreover, the librar rovides a w lth of o erations that allow ou to create and mani ulate these objects.

This function is less

■ e P■s t ve nte er

The librar version uses an algorithm that is differen

reate an exam le matrix to ermute.

```
atr x    4        r    n  ..4]  r    n 0..3]
```

$$\begin{bmatrix} & 2 & 3 & 4 \\ 5 & 6 & & 8 \\ 9 & 0 & & 2 \\ 3 & 4 & 5 & 6 \end{bmatrix}$$

e Matr x nte er

Interchange the second and20Td85In

.0

■ e F ■at

Here we define our own user-defined function.

```
c■s nv( )    c■s( / )
```

■ e V■ d

Pass this function as an argument to **t**.

```
t(c■s nv, 5.2058)
```

.439223 24 8005 64925 4 4 684 2 932520 85

■ e F ■at

xiom also has attern

MPOLY(x,], N■) (x 2-x 3 3) 2

$$x^4 - 2\ y^3\ x^3 \quad y^6 \quad 6\ y)\ x^2 - 6\ y^4\ x \quad 9\ y^2$$

■ e Mu t var ateP■ n■ a

```
t(s rt(   2)/ ,    0)

          [le tH ndLimit   – ,ri htH ndLimit

   e    n n(Rec rd( e tHandL   t    n n(OrderedC   et n
                Ex ress n  nte er,  a  ed ),r   tHandL   t
     n n(OrderedC   et n Ex ress n  nte er,  a  ed )),...)
```

s

x a roaches 0 along the real axis, `ex (- /x 2)`

tends to 0.

```
t(ex (- /x  2),x   0)
```

0

```
   e    n n(OrderedC   et n Ex ress n  nte er,...)
```

However, if
x
is allowed to a roach 0 along
an ath in the com lex

lane,
the limiting value of `ex (- /x 2)` de ends on the ath taken
because the
function has an essentia
l singularit at x 0. This is reflected in the error
message r eturned
b the function.

```
exL   t(ex (- /x  2),x   0)

      a  ed

          e    n n(  a  ed ,...)
```

4 Series

om also rovides ower
series. B default, xiom tries
to com ute and
he first ten elemen

ts of
a
s eries. Use `)set strea s ca cu ate` to
ult value to something else. F or the ur oses of this document,

■ e n var atePu seuxSer es

2

$$2\,r \quad 3\,r^2 \quad 4\,r^3 \quad 5\,r^4 \quad 6\,r^5 \quad r^6 \quad 8\,r^7 \quad 9\,r^8 \quad 0\,r^9 \quad r^{10} \quad r^{11})$$

e n var atePu seuxSer es(Ex ress n nte er,x,0)

The usual elementar functio

valuate the series at the v 3.f3. ff3. I M

You can also com ute artial derivatives b s ecif ing the order of differentiation.

```
s n(x  2
```

You can use F, x, and y in expressions.

```
a    F(x  ,    ,    2)   x  (   )
```

$$x\ y\ z \qquad F\ x\ z$$

$$\left(2z^2 \quad 2z \right)$$

```
c■   ex nte rate( /(x  2   a),x)
```

$$\frac{\log\left(\frac{x\ \overline{a}\ a}{\overline{a}}\right) - \log\left(\frac{x\ \overline{a}\ a}{\overline{a}}\right)}{2\ \overline{-}}$$

```
■  e   Ex ress ■n  nte er
```

The following two example illustrate the limitations of table-based algorithms. The two integrands are very similar, but the answer to one of them requires the addition of two new algebraic numbers.

This one is the easy one. The next one looks very similar but the answer is much more complicated.

```
nte rate(x  3 / (a b x)  ( /3),x)
```

$$20\ b^3\ x^3 - \ 35\ \ b^2\ x^2 \quad 62\ \ ^2\ b$$

conclusivel roves that an integral cannot be ex ressed in terms of elementar functions.

hen xiom returns an integral sign, it has roved that no answer exists as an elementar function.

```
nte rate( ( s rt(a x b)) / x,x)
```

$$\int^{x} \frac{\log \overline{b \quad \%}}{\%}\, d\%$$

```
e n n(Ex ress n nte er,...)
```

xiom can handle com licated mixed functions much be ond what ou can find in

. If x tan t and tan $t/3$ then the following algebraic relation is tr

■ erat■r

$$y$$

■ e Bas c0 erat■r

Here we solve a third order equation with ol nomial coefficients.

```
de     x  3   D(  x, x, 3)   x  2   D(  x, x, 2) - 2   x   D(  x,
x)   2     x   2   x  4
```

$$x^3\ y'''\ x \quad x^2\ y''\ x - 2\ x\ y'\ x \quad 2\ y\ x \quad 2\ x^4$$

■ e E uat ■n Ex ress ■n nte er

```
s■ ve(de ,  , x)
```

$$\left[\ rticul\ r \quad \frac{x \quad 10\ x^3 \quad 20\ x \quad 4}{15\ x},\right.$$

$$b \quad i \quad \left[2\ x^3 - 3\ x^2\right.$$

3.18. LIN E TIsic N q0R81 0.12Tf 99.62 .956Td 12 q9.9560Td q0R83 0.12Tf 99.62 .956Td N T10.

■ e V■ d

Find the real roots of 9 with rational arithmetic, correct to within

```
e ns    x  2 -      ,x  2     x  4 - b  ,    2    - a - b x]
```

$$\left[-y \quad x^2, x^2 \quad T\ TdT \quad T\ TdbT\ TdyT \quad T\ TdT \quad T\ TdxT \quad T\ TdT \quad T\ Td{,}yTJ\ T\ TdT \quad T\ Td \quad T \right.$$

h ter

Gr p ic

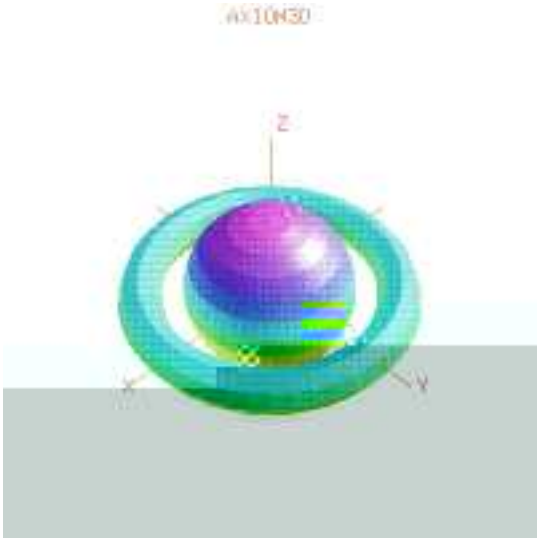


Figure 4.

Plottin 2D ra h of 1 variabl

The general format for drawing a function defined b a formula x is

`draw( (x), x  a..b,` *options*`)`

where $..b$ defines the range of x, and where *oo oo.. n*

Plottin 2D ara

Plottin 2D al braic curv

The general format for drawing a non-singular solution curve given b a ol nomial of the form x, y 0 is

`draw( (x, )  0, x,  , ran e  a..b, c..d], options)`

where the second and third arguments name the first and second inde endent variables of . `ran e` o tion is alwa s given to designate a bounding rectangular region of the lane x b, c y d. Zero or more additional o tions as described in 4.0. on age 36 ma be given.

third kind of two-dimensional gra

come to a oint cus . lgebraicall

ada tive The `ada t ve` o tion turns ada tive lotting on or off. da tive lotting uses an

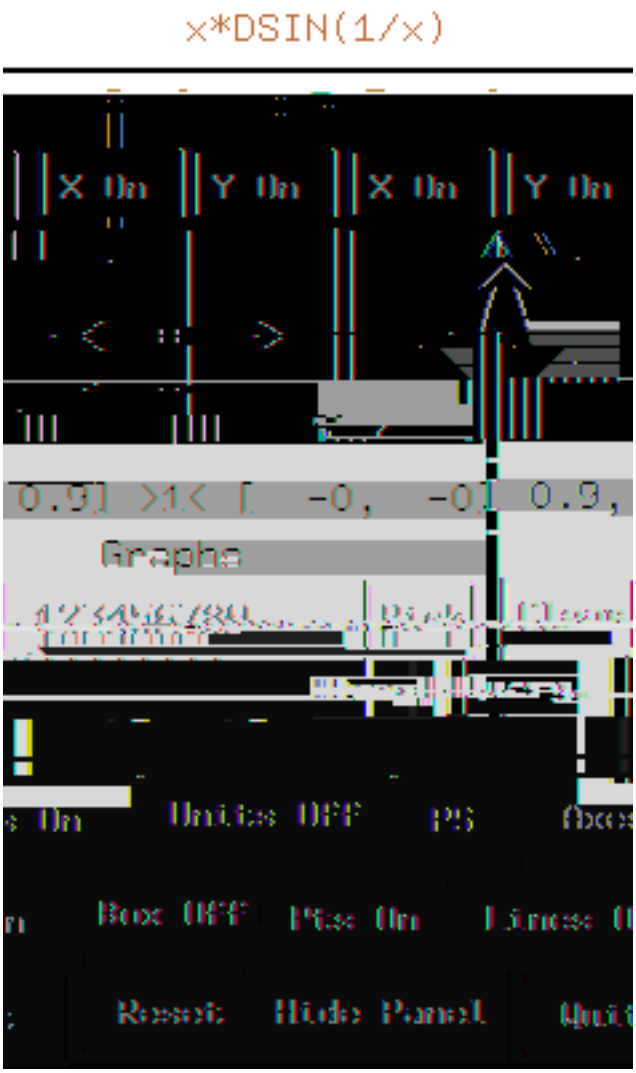


Figure 4.6 Two-dimensional control- anel.

Pick: The **Pick** button is used to select a gra h to be laced or

ax ColorDefault (*color* `default rk blue`)))
sets or indicates the default color of the axes in a two-dimensional graph view ort.

cli Point

r ion (*v ew ort nte er* 1) *str n* " "))
declares whether gra h *int r* is or is not to be dis la ed with a bounding rectangle.

r t (*v ew*

[redacted] e P[redacted] nt9 40

```
8       nt  .5, ]$(P nt DFLOA )  T
```

```
c3     aste   e  w()
```

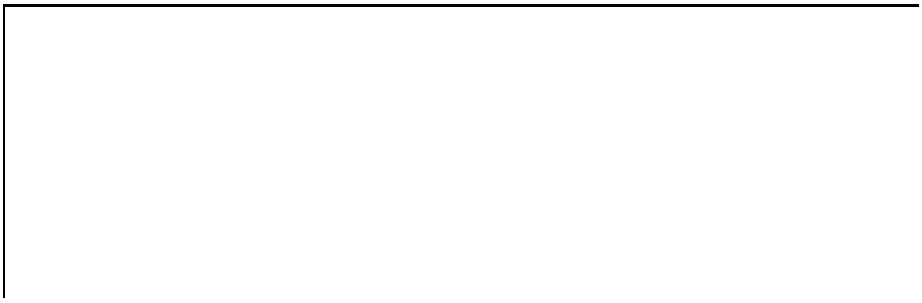
[Hue eight .0 from

```
■r    n    re eat
 c■  ■nent( , , ■ ntC■ ■rDe au t(),  neC■ ■rDe au t(),
    ■ ntS  eDen2■■d(r)■ 5. 60sCd()
De ■e ■etSntSStSS tS tSeC■tS
       De ntS 5. 60sCd() ntS  a,
```

Plottin 3D functio of 2 variabl

The general format for drawing a surface defined

Plottin 3D arame tric urfac



4 0 9 Three-D mens on l Control-P nel

nce o have created a view ort, move our mouse to the view ort and click with or left mouse button. This dis la s a control- anel on the s

ab ct: The **ab ct** button indicates that the rotation is to occur with res ect to the center of volume of the object, inde endent of the axes' origin osition.

cal : scaling transformation occurs b clicking the mouse

BW converts a color view ort to black and white, or vice-versa. hen this button is selected the control- anel and view ort switch to an immutable colorma com osed of a range of gre scale atterns or tiles that are used wherev

i w olum

The **i w olum** button changes the con

colorDiff (*view port* *color*$_1$ 1) *color*$_2$ 27))
sets the colormap range to be from *color*$_1$ to *color*$_2$.

con

tAda tiv 3D (*booleo*

vi w cal D fault (*float*

`Ax ■ .2D. essa eF■nt, Ax ■ .3D. essa eF■nt` *ont*
These indicate the font t e to be used for the text in the control- anel message window. **Rom14**

`Ax ■ ■n■c r■ e`

U i

```
-3
```

$$-3$$

```
■ e    nte er
```

Here we create a rational number but it looks like the last result.

n domain can be refined to a *subdom in* b a membershi `red cate`.
`red cate` is a function that, when a

Polynomial SquareMatrix, Complex Integer

Field Domain

another common category is `Field`, the class of

. a name for exam le, `R n` , used to

[redacted]hen might

If the t e itself has arentheses around it and we are not in the case of the first exam le above, then the arentheses can usuall be omitted.

```
(2/3)@Fract n(P  n  a  nte er)
```

$$\frac{2}{3}$$

```
  e  Fract n P  n  a  nte er
```

If the t e is used in a declaration and the argument is a single-word t e, integer or s mbol, then the arentheses can usuall be omitted.

```
(d, , )  C  ex P  n  a  nte er

  e  V  -
```

5 2 3 T es w th More Th n One Ar u

`?(integer)`, `Matrix(? (Pname a))`, `SquareMatrix(?, integer)` it requires a numeric argument and `SquareMatrix(?, ?)` are all invalid.

You can always combine a declaration with an assignment. When you do, it is equivalent to first giving a declaration statement, then giving an T.960Td al TJf-nmen T-335.8R8 .Td

(, ,r) Matr x P■ n■ a ?

■ e V■ d

$$\begin{bmatrix} -i\ x & y & 4\ i \end{bmatrix}$$

e Matr x P n a C ex nte er

Note the difference between this and the next exam le. This is a com lex object with ol nomial real and imaginar arts.

```
COMPLEX POLY ?    (x
```

r
4
t

Tx . notye Pl

e Rec rd(a nte er,b Str n)

To access a com onen

Records ma be nested and the selector names can be shared at different levels.

```
r    Rec rd(a    Rec rd(b    nte er, c    nte er), b    nte er)

                                                    e   V d
```

The record differs from the Tj20.4aTd reco Tj . 68-338.428b/R2403ren

It is ossible to create unions like n ■n(nte er, P■s t ve nte er) but the
are difficult to work with because of the overla in the branch t

. xiom normall converts a result to the target value before assing it to the function. If we left the declaration information out of this function definition then the **a Branch** c0 would have been attem ted with an `nte er` rather

3

■ e n ■n(nt5 er,...)

and a ed if the quotient is not exact.

ex u■(5,2)

a ed

■ e n ■n(a ed ,...)

union with a a ed is frequentl used to indicate the failure or lack of
a licabilit of an object. s another exam le, assign an in t. at undica T j2. 20dTail 6j9. 20Tn U Tj26.2

3

""fe■bUUmge"5Tj■■

5 5 2 Un ons W th Sele tors

Like records, ou can write

$$\left[\quad , \quad .2, \frac{3}{2}, x^2, \quad \texttt{wa} \qquad \right]$$

e L st An

hen we ask for the elements, xiom dis la s these t es.

u.

e P s t ve nte er

ctuall , these objects belong to An but xiom automaticall

B default, 3 has the t e `Pmst ve nte er`.

```
3
```

$$\begin{bmatrix} x - \frac{3\ i}{4} & y^2\ z & \frac{1}{2} \\ \frac{3\ i}{7}\ y^4 - x & \frac{60\ \ 9\ i}{5} & \end{bmatrix}$$

e S uareMatr x(2,P n a Fract n C ex nte er)

Interchange the P n a and the Fract n levels.

2 S uareMatr x(2,FRAC POLY COMPLEX N)

$$\begin{bmatrix} \frac{4\ x\ \ 3\ i}{4} & \frac{2\ \ z\ \ 1}{2} \\ \frac{3\ i\ \ 7\ x}{7} & \frac{60\ \ 9\ i}{5} \end{bmatrix}$$

e S uareMatr x(2,Fract n P n a C ex nte er)

Interchange the P n a and the C ex levels.

3 2 S uareMatr x(2,FRAC COMPLEX POLY N)

$$\begin{bmatrix} \frac{4\ x\ \ 3\ i}{4} & \frac{2\ \ z\ \ 1}{2} \end{bmatrix}$$

categor

e Fract n nte er

It makes sense then that this is a list of is a list of is a list

■ e F ■at

Perha s we a

ometimes it makes sense, as in this ex ression, to sa choose the o erations in this ex ression so that the final result is Float.

```
(2/3)@F at
```

0.6666666666666666666

```
e F at
```

Here we used @

This sa s that the o erations should be chosen so that the result is a P■ n■ a object.

((x %) 2)@(P■ n■ a C■ ex nte

$$\begin{bmatrix} \frac{1}{8} & \frac{1}{6} \\ -\frac{1}{4} & \frac{1}{9} \end{bmatrix}$$

[illegible]

```
cate r es
        Abe  anGr u                                  ABELGRP
        Abe  anM n  d                                ABELMON
        Abe  anM n  dR n                             AMR
        Abe  anSe  Gr u                              ABELSG
        A  re ate                                    AGG
        A  ebra                                      ALGEBRA
        A  ebra ca   C  sedF e d                     ACF
        A  ebra ca   C  sedFunct  nS ace             ACFS
        ArcH  erb  cFunct  nCate  r                  AHYP
        ...
```

For each constructor in a grou , the full name and the abbreviation is given. There are other grou s in **x d l** but initiall onl the constructors in ex osure grou s basic" categories" naglink" and anna" are ex osed.

s an interactive user of xiom, ou do

This is a ol nomial.

```
x   x
```

$$2\ x$$

```
                                                  e   P   n   a   nte er
```

x ose Out utF r .

```
)set ex se add c nstruct r Out utF r
```

```
   Out utF r   s n w ex   c t   ex sed  n  ra e G82322
```

This is what we get when Out utF r is automaticall available.

```
x   x
```

$$x \quad x$$

```
                                                  e   Out utF r
```

Hide Out utF r so we don't run into roblems with an later exam les

```
)set ex se dr   c nstruct r Out utF r
```

```
   Out utF r   s n w ex   c t     dden  n  ra e G82322
```

Finall , ex osure is done on a frame-b -frame basis. *r m* is one of os [illegible] rs [illegible]

o erations. The most o

```
 RMA■CA■- Rectan u arMatr xCate ■r &
 RMA■R X  Rectan u arMatr x
 SMA■CA■- S uareMatr xCate ■r &
 S MA■R X S uareMatr x
```

imilarl , if ou wish to see all ackages whose names contain `auss`", enter this.

```
)w at  acka e  auss


---------------------- Packa es ----------------------

Packa es w t  na es  atc  n   atterns
      auss

 GA SSFAC Gauss anFact■r  at ■nPacka e
```

This comm[illegible]2a co

)d s a erat n c ex

ere s ne ex s

h ter

U ing yper c

Figure 6. The H erDoc root window age

H erDoc is the gatewa to xiom. It's both an on-line tutorial and an on-line reference manual. It also enables ou to use xiom sim l b using the mouse and filling in

Dɒwn Arrɒw croll down one line.

Pa U croll u one age.

Pa dɒ T 10 20Td wn T

The in ut area g
Back ac ke
the right-arrow →

The glossar has an in ut area at its bottom. e review the various kinds of search strings ou can

its text hen ou do, the exam le line is co ied into a new interactive xiom buffer for this H erDoc age.

ometimes one exam le line cannot be run before ou run an earlier one. Don't wo

h ter 7

Inp t ile n O tp t tyle

In this cha ter

Turn T out ut on again.

```
)set ■ut ut tex ■n
```

The characters used for the matrix brackets above are rather ugl . You get this character set when ou issue `)set ■ut ut c aracters a n`. This character set should be used when ou are running on a machine that does not su ort the IBM extended II character set. If ou are running on an IBM workstation, for exam le, issue `)set ■ut ut c aracters de au t` to get

```
\def \csc {\ at ■ {\r  csc }\n■    ts}

\def \er {\ at ■ {\r  er }\n■    ts}

\def \ a # #2{
  {{\      \ e t. {# } \r   t }
   \■ver
   {\ e t  {#2} \r   t. \     }
  }
}
```

7.6 BMP Script Formula Format

AXIOM can produce IBM Script Formula Format output Tj 0.4485 0.6412 Td [(2.5623)] TJ

ince some versions of F RTR N have restrictions on the number of lines er statement, xiom breaks long ex ressions into segments with a maximum of 320 characters 20 lines of 66 characters er segment. If ou want t8 change this, sa , to 660 characters, issue the s stem command `)set`

■ e P■ n■ a nte er

This c

```
R8 S N(EXPP( )■  0.440■d(P))
```

sin e

■ e Ex ress ■n nte er

x ressions that look like lists, streams, sets or matrices cause arra code to be generated.

```
x  ,  ,  ]
```

```
■ (  x
■ (
■ (
R9 ■
```

$[x \quad , y \quad , z$

■ e L st P■ n■ a nte er

tem orar va

h ter 8

Axi y te n

This cha ter describes s stem commands, the command-line facilities used to con

8.2)abbre iation

U r L v l R quir d: com iler

)c e , saved histo environment files for) st r)rest re , com iled xiom librar files for) brar , and files to edit for)ed t . It is also used for writing s ool files via)s , writing histo in ut files via) st r)wr te and histor environment files via) st r)save ,and com iled xiom librar files via)c e .

If issued with no argument, this command sets the xiom current director to our home director . If an argument is used, it must be a valid director name. xce t for the)" at the beginning of the command, this has the same s nta as the o erating s i

8.6) lear

U r L v l R quir d: inter reter

Co and ntax:

```
)c ear a

)c ear c ete

)c ear r ert es a
```

d Lev4r3TJ0.560TmTd in40[l - 0 is in90.560Tdused in Tj 0.440t al T

wd a6er Tj2 . r 2.24 28Td[s c

```
)c ear va ue a
)c ear v a
```

This retains whatever declarations the objects had. To remove definitions and values for the s ecific objects `x,` and , issue

```
)c ear va ue x
)c ear v x
```

To remove the declav x fl ear vac er eanringel hat- 92.3623.64Td2 .6 2

)cc -el N m -a

)cc -e dir

first looks in the standard s stem directories for files with extension . *s*, . *o* and . *l* and then files with extension

`-O -Fas -Fa■ -F s - ax ■ -Mn■-AXL_ _ Obs■ ete -DAx ■`

These o tions mean

`-O` erform all o timi ations,

`-Fas` generate a `.as` file,

`-Fa■` generate a `.a■` file,

`-F s` generate a .

domains and categories should not be ex osed. For exam le, a domain ma just be used rivatel b another domain and ma not be meant for to -level use. The) brar command shouldstill be used, though, so that thecode will be loaded on demand. In this case, ou should use the)n brar o tion on)c e and the)nex se o tion in the) brar command. For exam le,

```
)c     e    cde.as )n   brar
)  brar     cde )nex se
```

nce ou ha
e

```
)c■    e  atr x.s ad
)ed t
)c■    e
```

will call the com iler, edit, and then call the com iler again on the file **■■a-trix ad** If ou do not s ecif a *dir ct*

8.8) ispla

U r L v l R quir d: inter reter

Co■■■and ntax:

```
)d s  a  a

)d s  a  r■ ert es

)d s  a  r■ ert es a

)d s  a  r■ ert es
```

To just show the value and the t e of `d`, issue

```
)d s  a  va ue d
```

To just show the declared mode of `d`, issue

```
)d s  a  ■de d
```

ll modema s for a given o eration ma be dis la ed

```
)s ste  e acs /etc/rc.tc
```

calls `e acs`

ome frames are created b the H erDoc rogramb these can have rett strange names, since the are generated automaticall . To find out the names of all frames, issue

```
) ra e na
```

```
) e   c ear
```

will dis la

has been issued. Issuing either

```
)set   st■r  ■
)  st■r  )■
```

will discontinue the recording of information.

■hether the facilit is disabled or

`)reset` will flush the internal list of the most recent works ace calculations so that the data structures ma be garbage collected b the underl ing ommon Lis s stem. Like `) st■r )c an e`, this o tion onl has real effect when histor data is being saved in a file.

`)rest■re` *s v dHistor N m* com letel clears the environment and restores it to a saved session, if ossible. The `)save` o tion

) brar)nex se

Command Description:

This command replaces the) ad system command that was available in xiom releases

ince this command is onl useful for evaluating single ex ressions, the) n command ma

8. 9) uit

U r L v l R quir d: inter reter

Co and ntax:

```
) u t
```

```
)set u t r tected un r tected
```

Co and D cri tion:

This comma is used t terminate xiom and return to the o ting s s-
tem. ther tha 5 b redoing all our com utat ns or b ing the) st r
)rest re command to tr to restore our working environment, ou cannot
retur 5 to xiom in the same state.

) u t differs from the) u t in that it asks for confir ation onl if the com-
mand

```
)set u t r tected
```

ha

will read the contents of the file **matrix in ut** into xiom. The .in ut" file extension is o tional.

This command remembers the revious file ou edited, read or com iled. If ou do not s ecif a file name, the revious file will be read.

The `) t ere` o tion checks to see whether the

8.22

```
)s ■w POLY  N■ )■ erat ■ns
)s ■w P■  n■  a   nte er
)s ■w P■  n■  a   nte er )■ erat ■ns
```

are among the com

This command is used to create short s non

We do not r

8.26.

)a r s p tt rn1 [p tt rn2 ...

Co and D cri tion:

This command is used t8 dis la lists of things in the s stem. The atterns are all strings and, if resent, restrict the contents of the lists. nl those items that contain one or more of the strings as substrings are dis la ed. For exam le,

```
)w at s n n
```

dis la s all command s n8n ms,

```
)w at s n n   ver
```

dis la s all command s n8n ms containing the substring ver",

```
)w at s n n   ver  r
```

dis la s all command s n8n ms containing the substring ver" or the substring r". ut ut similar t8 the following will be dis la ed

```
---------------- S ste  C  and S n n  s -----------------

user-de  n d( ) /88s@tds   n   atterns
    ver  r

)a r ............................ )w at t  n s
)a r s ........................ )w at t  n s
) r  t ........................ )set  essa e  r  t
)vers n ....................... )  s    earweek
```

everal other things can be listed with the)w at command

cate r es dis la s a list of categor constructors.

c ands dis la s a list of s stem commands available at our user-level. Your user-level is set via the)s d( ) e/88 command. To get a descri tion of a

`acka es` dis la s a

i li gr p y

[Jenks, R.J. and utor, R. . xiom The

In ex