1 Basic Functions and Numerical Indexing

1.1 Mathematics

sum, cumsum

sum sums elements in an array. By default, it will sum all elements in the array, and so the second argument is normally used to provide the axis to use – 0 tosumdowncolumns, 1 tosumacross rows. cumsum produces the cumulativesumof the values in the array, and is also usually used with the second argument to indicate the axis to use.

```
>>> x = randn(3,4)
>>> x
array([[0.08542071,
2.05598312,
2.1114733 , 0.7986635 ],
[0.17576066,
0.83327885, 0.64064119,
0.25631728],
[0.38226593,
1.09519101,
0.29416551, 0.03059909]])
>>> sum(x) # all elements
0.62339964288008698
>>> sum(x, 0) # Down rows, 4 elements
array([0.6434473
, 2.31789529,
1.76499762, 0.57294532])
>>> sum(x, 1) # Across columns, 3 elements
array([ 0.76873297, 0.23944028,
1.15269233])
>>> cumsum(x,0) # Down rows
array([[0.08542071,
2.05598312,
2.1114733 , 0.7986635 ],
[0.26118137,
1.22270427,
1.47083211, 0.54234622],
[0.6434473
, 2.31789529,
1.76499762, 0.57294532]])
```

sum and cumsum can both be used as function or as methods. When used as methods, the first input is the axis so that sum(x,0) is the same as x.sum(0).

prod, cumprod

prod and cumprod behave similarly to sum and cumsum except that the product and cumulative product are returned. prod and cumprod can be called as function or methods.

diff

diff computes the finite difference of a vector (also array) and returnsn-1 an element vectorwhenused on an n element vector. diff operates on the last axis by default, and so diff(x) operates across columns and returns x[:,1:size(x,1)]x[:,: size(x,1)1] for a 2-dimensional array. diff takes an optional keyword 75 argument axis so that diff(x, axis=0) will operate across rows. diff can also be used to produce higher order differences (e.g. double difference).

```
>>> x= randn(3,4)
>>> x
array([[0.08542071,
2.05598312,
2.1114733 , 0.7986635 ],
[0.17576066,
0.83327885, 0.64064119,
0.25631728],
[0.38226593,
1.09519101,
0.29416551, 0.03059909]])
>>> diff(x) # Same as diff(x,1)
0.62339964288008698
>>> diff(x, axis=0)
array([[0.09033996,
2.88926197, 2.75211449,
1.05498078],
[0.20650526,
1.92846986,
0.9348067 , 0.28691637]])
>>> diff(x, 2, axis=0) # Double difference, columnbycolumn
array([[0.11616531,
4.81773183,
3.68692119, 1.34189715]])
```

exp

exp returns the element-by-element exponential (e^x) for an array.

log

log returns the element-by-element natural logarithm (ln(x)) for an array.

log10

log10 returns the element-by-element base-10 logarithm (log10 (x)) for an array.

1.2 6.2 Rounding

around, round

around rounds to the nearest integer, or to a particular decimal place when called with two arguments.

```
%----------------%
\begin{framed}
\begin{verbatim}
>>> x = randn(3)
array([ 0.60675173, 0.3361189
, 0.56688485])
>>> around(x)
array([ 1., 0., 1.])
>>> around(x, 2)
array([ 0.61, 0.34,
0.57])
```

around can also be used as a method on an ndarray – except that the method is named round. For example, x.round(2) is identical to around(x, 2). The change of names is needed to avoid conflicting with the Python built-in function round.

floor

floor rounds to the next smallest integer.

```
>>> x = randn(3)
array([ 0.60675173, 0.3361189
```

```
, 0.56688485])
>>> floor(x)
array([ 0., 1.,
1.])
```

ceil

ceil rounds to the next largest integer.

```
>>> x = randn(3)
array([ 0.60675173, 0.3361189
, 0.56688485])
>>> ceil(x)
array([ 1., 0.,
0.])
```

Note that the values returned are still floating points and so 0. is the same as 0..

1.3 Generating Arrays and Matrices

1.3.1 linspace

linspace(l,u,n) generates a set of n points uniformly spaced between l, a lower bound (inclusive) and u, an upper bound (inclusive).

```
>>> x = linspace(0, 10, 11)
>>> x
array([ 0., 1., 2., 3., 4., 5., 6., 7., 8., 9., 10.])
```

1.3.2 logspace

logspace(l,u,n) produces a set of logarithmically spaced points between 10l and 10u . It is identical to 10**linspace(l,u,n).

1.3.3 arange

arange(l,u,s) produces a set of points spaced by s between l, a lower bound (inclusive) and u, an upper bound (exclusive). arange can be used with a single parameter, so that arange(n) is equivalent to arange(0,n,1). Note that arange will return integer data type if all inputs are integer.

```
>>> x = arange(11)
array([ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10])
>>> x = arange(11.0)
array([ 0., 1., 2., 3., 4., 5., 6., 7., 8., 9., 10.])
>>> x = arange(4, 10, 1.25)
array([ 4. , 5.25, 6.5 , 7.75, 9. ])
```

1.3.4 meshgrid

meshgrid broadcasts two vectors to produce two 2-dimensional arrays, and is a useful function when plotting 3-dimensional functions.

```
>>> x = arange(5)
>>> y = arange(3)
>>> X,Y = meshgrid(x,y)
>>> X
array([[0, 1, 2, 3, 4],
[0, 1, 2, 3, 4],
[0, 1, 2, 3, 4]])
>>> Y
array([[0, 0, 0, 0, 0],
[1, 1, 1, 1, 1],
[2, 2, 2, 2, 2]])
```

1.3.5 r_

r_ is a convenience function which generates 1-dimensional arrays from slice notation. While r_ is highly flexible, the most common use it r_[start : end : stepOrCount] where start and end are the start and end points, and stepOrCount can be either a step size, if a real value, or a count, if complex.

```
>>> r_[0:10:1] # arange equiv
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

```
>>> r_[0:10:.5] # arange equiv
array([ 0. , 0.5, 1. , 1.5, 2. , 2.5, 3. , 3.5, 4. , 4.5, 5. ,
5.5, 6. , 6.5, 7. , 7.5, 8. , 8.5, 9. , 9.5])
>>> r_[0:10:5j] # linspace equiv, includes end point
array([ 0. , 2.5, 5. , 7.5, 10. ])
```

r_ can also be used to concatenate slices using commas to separate slice notation blocks.

```
>>> r_[0:2, 7:11, 1:4]
array([ 0, 1, 7, 8, 9, 10, 1, 2, 3])
```

Note that r_ is not a function and that is used with [].

1.3.6 c_

c_ is virtually identical to r_ except that column arrays are generates, which are 2-dimensional (second dimension has size 1)

```
>>> c_[0:5:2]
array([[0],
[2],
[4]])
>>> c_[1:5:4j]
array([[ 1. ],
[ 2.33333333],
[ 3.66666667],
[ 5. ]])
```

c_, like r_, is not a function and is used with [].

1.3.7 ix_

ix_(a,b) constructs an n-dimensional open mesh from n 1-dimensional lists or arrays. The output of ix_ is an n-element tuple containing 1-dimensional arrays. The primary use of ix_ is to simplify selecting slabs inside a matrix. Slicing can also be used to select elements froman array as long as the slice pattern is regular. ix_ is particularly useful for selecting elements froman array using indices which are not regularly spaced, as in the final example.

```
>>> x = reshape(arange(25.0),(5,5))
>>> x
array([[ 0., 1., 2., 3., 4.],
[ 5., 6., 7., 8., 9.],
[ 10., 11., 12., 13., 14.],
[ 15., 16., 17., 18., 19.],
[ 20., 21., 22., 23., 24.]])
>>> x[ix_([2,3],[0,1,2])] # Rows 2 & 3, cols 0, 1 and 2
array([[ 10., 11., 12.],
[ 15., 16., 17.]])
>>> x[2:4,:3] # Same, standard slice
array([[ 10., 11., 12.],
[ 15., 16., 17.]])
>>> x[ix_([0,3],[0,1,4])] # No slice equiv
```

1.3.8 mgrid

mgrid is very similar to meshgrid but behaves like r_ and c_ in that it takes slices as input, and uses a real valued variable to denote step size and complex to denote number of values. The output is an n + 1 dimensional vector where the first index of the output indexes the meshes.

```
>>> mgrid[0:3,0:2:.5]
array([[[ 0. , 0. , 0. , 0. ],
[ 1. , 1. , 1. , 1. ],
[ 2. , 2. , 2. , 2. ]],
[[ 0. , 0.5, 1. , 1.5],
[ 0. , 0.5, 1. , 1.5],
[ 0. , 0.5, 1. , 1.5]]])
>>> mgrid[0:3:3j,0:2:5j]
array([[[ 0. , 0. , 0. , 0. , 0. ],
[ 1.5, 1.5, 1.5, 1.5, 1.5],
[ 3. , 3. , 3. , 3. , 3. ]],
[[ 0. , 0.5, 1. , 1.5, 2. ],
[ 0. , 0.5, 1. , 1.5, 2. ],
[ 0. , 0.5, 1. , 1.5, 2. ]]])
```

1.3.9 ogrid

ogrid is identical to mgrid except that the arrays returned are always 1-dimensional. ogrid output is generally more appropriate for looping code, while mgrid is usually more appropriate for vectorized code. When the size of the arrays is large, then ogrid uses much less memory.

```
>>> ogrid[0:3,0:2:.5]
[array([[ 0.],
[ 1.],
[ 2.]]), array([[ 0. , 0.5, 1. , 1.5]])]
>>> ogrid[0:3:3j,0:2:5j]
[array([[ 0. ],
[ 1.5],
[ 3. ]]),
array([[ 0. , 0.5, 1. , 1.5, 2. ]])]
```