

Introduction

Go is the future for doing data science. In this cheatsheet, we look at 2 libraries that will allow you to do that.

Note on panic and error behaviour:

1. Most tensor operations return error.
2. gonum has a [good policy](#) of when errors are returned and when panics happen.

What To Use

I ever only want a float64 matrix or vector

use gonum/mat

I want to focus on doing statistical/scientific work

use gonum/mat

I want to focus on doing machine learning work

use gonum/mat or gorgonia/tensor.

I want to focus on deep learning work

use gorgonia/tensor

I want multidimensional arrays

use gorgonia/tensor, or []mat.Matrix

I want to work with different data types

use gorgonia/tensor

I want to wrangle data like in Pandas or R - with data frames

use kniren/gota

Default Values

Numpy

```
a = np.Zeros((2,3))
```

gonum/mat

```
a := mat.NewDense(2, 3, nil)
```

tensor

```
a := ts.New(ts.Of(Float32), ts.WithShape(2,3))
```

A Range...

Numpy

```
a = np.arange(0, 9).reshape(3,3)
```

gonum

```
a := mat.NewDense(3, 3,
floats.Span(make([]float64, 9), 0, 8))
```

tensor

```
a := ts.New(ts.WithBacking(ts.Range(ts.Int, 0, 9),
ts.WithShape(3,3))
```

Identity Matrices

Numpy

```
a = np.eye(3,3)
```

gonum/mat

```
a := mat.NewDiagonal(3, []float64{1, 1, 1})
```

tensor

```
a := ts.I(3, 3, 0)
```

Elementwise Arithmetic Operations

Addition

Numpy

```
c = a + b
c = np.add(a, b)
a += b # in-place
np.add(a, b, out=c) # reuse array
```

gonum/mat

```
c.Add(a, b)
a.Add(a, b) // in-place
```



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Elementwise Arithmetic Operations (cont)

tensor

```
var c *ts.Dense; c, err = a.Add(b)
var c ts.Tensor; c, err = ts.Add(a, b)
a.Add(b, ts.UseUnsafe()) // in-place
a.Add(b, ts.WithReuse(c)) // reuse tensor
ts.Add(a, b, ts.UseUnsafe()) // in-place
ts.Add(a, b, ts.WithReuse(c)) // reuse
```

Note: The operations all returns a result and an error, omitted for brevity here. It's good habit to check for errors.

Subtraction

Numpy

```
c = a - b
c = np.subtract(a, b)
```

gonum/mat

```
c.Sub(a, b)
```

tensor

```
c, err := a.Sub(b)
c, err = ts.Sub(a, b)
```

Multiplication

Numpy

```
c = a * b
c = np.multiply(a, b)
```

gonum/mat

```
c.MulElem(a, b)
```

tensor

```
c, err := a.Mul(b)
c, err := ts.Mul(a, b)
```

Division

Numpy

```
c = a / b
c = np.divide(a, b)
```

gonum/mat

```
c.DivElem(a, b)
```

Elementwise Arithmetic Operations (cont)

tensor

```
c, err := a.Div(b)
c, err := ts.Div(a, b)
```

Note: When encountering division by 0 for non-floats, an error will be returned, and the value at which the offending value will be 0 in the result.

Note: All variations of arithmetic operations follow the patterns available in *Addition* for all examples.

Note on Shapes

In all of these functions, `a` and `b` has to be of the same shape. In Numpy operations with dissimilar shapes will throw an exception. With `gonum/mat` it'd panic. With `tensor`, it will be returned as an error.

Aggregation

Sum

Numpy

```
s = a.sum()
s = np.sum(a)
```

gonum/mat

```
var s float64 = mat.Sum(a)
```

tensor

```
var s *ts.Dense = a.Sum()
var s ts.Tensor = ts.Sum(a)
```

Note: The result, which is a scalar value in this case, can be retrieved by calling `s.ScalarValue()`

Sum Along An Axis

Numpy

```
s = a.sum(axis=0)
s = np.sum(a, axis=0)
```

gonum/mat

Write a loop, with manual aid from `mat.Col` and `mat.Row`

Note: There's no performance loss by writing a loop. In fact there arguably may be a cognitive gain in being aware of what one is doing.



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Aggregation (cont)

tensor

```
var s *ts.Dense = a.Sum(0)
var s ts.Tensor = ts.Sum(a, 0)
```

Argmax/Argmin

Numpy

```
am = a.argmax()
am = np.argmax(a)
```

gonum

Write a loop, using `mat.Col` and `mat.Row`

tensor

```
var am *ts.Dense; am, err = a.Argmax(ts.AllAxes)
var am ts.Tensor; am, err = ts.Argmax(a, ts.AllAxes)
```

Argmax/Argmin Along An Axis

Numpy

```
am = a.argmax(axis=0)
am = np.argmax(a, axis=0)
```

gonum

Write a loop, using `mat.Col` and `mat.Row`

tensor

```
var am *ts.Dense; am, err = a.Argmax(0)
var am ts.Tensor; am, err = ts.Argmax(a, 0)
```

Data Structure Creation

Numpy

```
a = np.array([1, 2, 3])
```

gonum/mat

```
a := mat.NewDense(1, 3, []float64{1, 2, 3})
```

tensor

```
a := ts.New(ts.WithBacking([]int{1, 2, 3}))
```

Creating a float64 matrix

Numpy

```
a = np.array([[0, 1, 2], [3, 4, 5]], dtype='float-64')
```

gonum/mat

```
a := mat.NewDense(2, 3, []float64{0, 1, 2, 3, 4, 5})
```

tensor

```
a := ts.New(ts.WithBacking([]float64{0, 1, 2, 3, 4, 5}, ts.WithShape(2, 3)))
```

Creating a float32 3-D array

Data Structure Creation (cont)

Numpy

```
a = np.array([[[0, 1, 2], [3, 4, 5]], [[100, 101, 102], [103, 104, 105]]], dtype='float32')
```

tensor

```
a := ts.New(ts.WithShape(2, 2, 3),
ts.WithBacking([]float32{0, 1, 2, 3, 4, 5, 100, 101, 102, 103, 104, 105}))
```

Note: The `tensor` package is imported as `ts`

Additionally, `gonum/mat` actually offers many different data structures, each being useful to a particular subset of computations. The examples given in this document mainly assumes a dense matrix.

gonum Types

<code>mat.Matrix</code>	Abstract data type representing any <code>float64</code> matrix
<code>*mat.Dense</code>	Data type representing a dense <code>float64</code> matrix

tensor Types

<code>tensor.Tensor</code>	An abstract data type representing any kind of tensors. Package functions work on these types.
<code>*tensor.Dense</code>	A representation of a densely packed multidimensional array. Methods return <code>*tensor.Dense</code> instead of <code>tensor.Tensor</code>



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tensor Types (cont)

<code>*tensor.CS</code>	A representation of compressed sparse row/column matrices.
<code>*tensor.MA</code>	<i>Coming soon</i> - representation of masked multidimensional array. Methods return <code>*tensor.MA</code> instead of <code>tensor.Tensor</code>
<code>tensor.DenseTensor</code>	Utility type that represents densely packed multidimensional arrays
<code>tensor.MaskedTensor</code>	Utility type that represents densely packed multidimensional arrays that are masked by a slice of <code>bool</code>
<code>tensor.Sparse</code>	Utility type that represents any sparsely packed multi-dim arrays (for now: only <code>*CS</code>)

Metadata

Metadata	Numpy	gonum	tensor
Shape	<code>a.shape</code>	<code>a.Dims()</code>	<code>a.Shape()</code>
Strides	<code>a.strides</code>		<code>a.Strides()</code>
Dims	<code>a.ndim</code>		<code>a.Dims()</code>

Tensor Manipulation

Zero-op Transpose

Numpy

`aT = a.T`

gonum/mat

`aT := a.T()`

tensor

`a.T()`

Transpose With Data Movement

Numpy

`aT = np.transpose(a)`

gonum/mat

`b := a.T(); aT := mat.DenseCopyOf(b)`

tensor

`aT, err := ts.Transpose(a)`

or

`a.T(); err := a.Transpose()`

Reshape

Numpy

`b = a.reshape(2,3)`

gonum/mat

`b := NewDense(2, 3, a.RawMatrix().Data)`

tensor

`err := a.Reshape(2,3)`

Note on reshaping when using gonum: the matrix `a` mustn't be a view.

Linear Algebra

Inner Product of Vectors

Numpy

`c = np.inner(a, b)`

gonum

`var c float64 = mat.Dot(a, b)`

tensor

`var c interface{} = ts.Inner(a, b)`

or

`var c interface{} = a.Inner(b)`

Note: The `tensor` package comes with specialized execution engines for `float64` and `float32` which will return `float64` or `float32` without returning an `interface{}`

Matrix-Vector Multiplication



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Linear Algebra (cont)

Numpy

```
mv = np.dot(m, v)
or
mv = np.matmul(m, v)
or
mv = m @ v
or
mv = m.dot(v)
```

gonum

```
mv.Mul(m, v)
```

tensor

```
var mv ts.Tensor; mv, _ = ts.MatVecMul(m, v)
or
var mv *ts.Dense; mv, _ = m.MatVecMul(v)
```

Matrix-Matrix Multiplication

Numpy

```
mm = np.dot(m1, m2)
or
mm = np.matmul(m1, m2)
or
mm = m1 @ m2
or
mm = m1.dot(m2)
```

gonum

```
mm.Mul(m1, m2)
```

tensor

```
var mm Tensor; mm, _ = ts.MatMul(m1, m2)
or
var mm *ts.Dense; mm, _ = m1.MatMul(m2)
```

Magic

Numpy

```
c = np.dot(a, b)
c = a.dot(b)
```

tensor

```
var c ts.Tensor; c, _ = ts.Dot(a, b)
var c *ts.Dense; c, _ = a.Dot(b)
```

Note: The `Dot` function and method in package `tensor` works similarly to `dot` in Numpy - depending on the number of dimensions of the inputs, different functions will be called. You should treat it as a "magic" function that does products of two multi-dimensional arrays.

`gonum` has a whole suite of linear-algebra functions and structures that are too many to enumerate here. You should check it out too.

Combinations

Concatenation

Numpy

```
c = np.concatenate((a, b), axis=0)
```

gonum/mat

```
c.Stack(a,b)
```

tensor

```
var c ts.Tensor; c, err = ts.Concat(0, a, b)
var c *ts.Dense; c, err = a.Concat(0, b)
```

Vstack

Numpy

```
c = np.vstack((a, b))
```

gonum/mat

```
c.Stack(a,b)
```

tensor

```
var c *ts.Dense; c, err = a.Vstack(0, b)
```

Hstack

Numpy

```
c = np.hstack((a, b))
```

gonum/mat

```
c.Augment(a,b)
```

tensor

```
var c *ts.Dense; c, err = a.Hstack(0, b)
```

Stack onto a New Axis

Numpy

```
c = np.stack((a, b))
```

gonum/mat

```
var stacked []mat.Matrix; stacked = append(stacked, a, b)
```

tensor

```
var c ts.Tensor; c, _ = ts.Stack(0, a, b)
var c *ts.Dense; c, _ = a.Stack(0,b)
```

Note: Unlike in Numpy, `Stack` in `tensor` is a little more strict on the axis. It has to be specified.

Repeats



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Combinations (cont)

Numpy

```
c = np.repeat(a, 2) # returns a flat array
c = np.repeat(a, 2, axis=0) # repeats along axis 0
c = np.repeat(a, 2, axis=1) # repeats along axis 1
```

gonum/mat

Unsupported for now

tensor

```
var c ts.Tensor; c, _ = ts.Repeat(a, ts.AllAxes,
2) // returns a flat array
c = ts.Repeat(a, 0, 2) // repeats along axis 0
c = ts.Repeat(a, 1, 2) // repeats along axis 1
```

Data Access

Value At (Assuming Matrices)

Numpy

```
val = a[0, 0]
```

gonum/mat

```
var va float64 := a.At(0, 0)
```

tensor

```
var val interface{}; val, _ = a.At(0,0)
```

Slice Row or Column (Assuming Matrices)

Numpy

```
row = a[0]
col = a[:, 0]
```

gonum/mat

```
var row mat.Vector = a.RowView(0)
var col mat.Vector = a.ColView(0)
```

tensor

```
var row ts.View = a.Slice(s(0))
var col ts.View = a.Slice(nil, s(0))
```

Advanced Slicing (Assuming 9x9 Matrices)

Numpy

```
b = a[1:4, 3:6]
```

gonum/mat

```
var b mat.Matrix = a.Slice(1,4, 3,6)
```

tensor

```
var b ts.View = a.Slice(rs(1,4), rs(3,6))
```

Advanced Slicing With Steps

Data Access (cont)

Numpy

```
b = a[1:4:1, 3:6:2]
```

gonum/mat

Unsupported

tensor

```
var b ts.View = a.Slice(rs(1,4,1), rs(3,6,2))
```

Getting Underlying Data

Numpy

```
b = a.ravel()
```

gonum/mat

```
var b []float64 = a.RawMatrix().Data
```

tensor

```
var b interface{} = a.Data()
```

Setting One Value (Assuming Matrices)

Numpy

```
a[r, c] = 100
```

gonum/mat

```
a.Set(r, c, 100)
```

tensor

```
a.SetAt(100, r, c)
```

Setting Row/Col (Assuming 3x3 Matrix)

Numpy

```
a[r] = [1, 2, 3]
a[:, c] = [1, 2, 3]
```

gonum/mat

```
a.SetRow(r, []float64{1, 2, 3})
a.SetCol(c, []float64{1, 2, 3})
```

tensor

No simple method - requires Iterators and multiple lines of code.

Note: in the tensor examples, the `a.Slice` method take a list of `tensor.Slice` which is an interface defined [here](#). `s`, and `rs` in the examples simply represent types that implement the `tensor.Slice` type. A `nil` is treated as `a :` in Python. There are no default `tensor.Slice` types provided, and it is up to the user to define their own.



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