

RcppCNPY: Reading and writing NumPy binary files

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Abstract

This document introduces the **RcppCNPY** package for reading and writing files created by or for the **NumPy** module for Python.

RcppCNPY is based on **cnpy**, a C++ library written by Carl Rogers.

1 Motivation

Python¹ is a widely-used programming language. It is deployed for use cases ranging from simple scripting to larger-scale application development. Python is also popular for quantitative and scientific application due to the existence of extension modules such as **NumPy**² (which is shorthand for Numeric Python).

NumPy can be used for N -dimensional arrays, and provides an efficient binary storage model for these files. In practice, N is often equal to two, and matrices processed or generated in Python can be stored in this form.

R has (as of mid-2012) no dedicated reading or writing functionality for these files. However, Carl Rogers has provided a small C++ library called **cnpy**³ which is released under the MIT license. Using the ‘Rcpp modules’ feature in **Rcpp**^{4,5}, we provide (some) features of this library to R.

2 Examples

2.1 Data creation in Python

The first code example simply creates two files in Python: a two-dimensional rectangular array as well as a vector.

```
>>> import numpy as np
>>>
>>> mat = np.arange(12).reshape(3,4) * 1.1
>>> mat
array([[ 0. ,  1.1,  2.2,  3.3],
```

```
      [ 4.4,  5.5,  6.6,  7.7],
      [ 8.8,  9.9, 11. , 12.1]])
>>> np.save("fmat.npy", mat)
>>>
>>> vec = np.arange(5) * 1.1
>>> vec
array([ 0. ,  1.1,  2.2,  3.3,  4.4])
>>> np.save("fvec.npy", vec)
>>>
```

As illustrated, Python uses the Fortran convention for storing matrices and higher-dimensional arrays: a matrix constructed from a single sequence has its first consecutive elements in its first row—whereas R, following the C convention, has these first few values in its first column. This shows that to go back and forth we need to transpose these matrices (which represented internally as two-dimensional arrays).

2.2 Data reading in R

We can read the same data in R using the `npLoad()` function provided by the **RcppCNPY** package:

```
R> library(RcppCNPY)
Loading required package: Rcpp
R>
R> mat <- npLoad("fmat.npy")
R> mat
      [,1] [,2] [,3] [,4]
[1,]  0.0  1.1  2.2  3.3
[2,]  4.4  5.5  6.6  7.7
[3,]  8.8  9.9 11.0 12.1
R>
R> vec <- npLoad("fvec.npy")
R> vec
[1] 0.0 1.1 2.2 3.3 4.4
R>
```

The Fortran-order of the matrix is preserved; we obtain the exact same data as we stored.

¹<http://www.python.org>

²<http://numpy.scipy.org/>

³<https://github.com/rogersce/cnpy>

⁴Eddelbuettel and François, 2011, JSS, 40(8), <http://www.jstatsoft.org/v40/i08/>

⁵<http://CRAN.R-Project.org/package=Rcpp>

2.3 Reading compressed data in R

A useful extension to the **cnpy** is the support of **gzip**-compressed data.

```
R> mat2 <- npyLoad("fmat.npy.gz")
R> mat2
      [,1] [,2] [,3] [,4]
[1,]  0.0  1.1  2.2  3.3
[2,]  4.4  5.5  6.6  7.7
[3,]  8.8  9.9 11.0 12.1
```

Support for compressed file is currently limited to reading, but could be implemented for writing as well.

2.4 Data writing in R

Matrices and vectors can be written to files using the `npysave()` function.

```
R> set.seed(42)
R> m <- matrix(sort(rnorm(6)), 3, 2)
R> m
      [,1] [,2]
[1,] -0.564698 0.404268
[2,] -0.106125 0.632863
[3,]  0.363128 1.370958
R> npysave("randmat.npy", m)
R>
R> v <- seq(10, 12)
R> v
[1] 10 11 12
R> npysave("simplevec.npy", v)
```

2.5 Data reading in Python

Reading the data back in Python is straightforward too:

```
>>> m = np.load("randmat.npy")
>>> m
array([[ -0.56469817,  0.40426832],
       [ -0.10612452,  0.6328626 ],
       [ 0.36312841,  1.37095845]])
>>>
>>> v = np.load("simplevec.npy")
>>> v
array([ 10.,  11.,  12.])
```

3 Performance

The R script `timing` in the `demo/` directory of package **RcppCNPy** provides a simple benchmark. Given two values n and k , a matrix of size $n \times k$ is created with n

Access method	Time in sec.	Relative to best
<code>npysave(pyfile)</code>	1.95	1.00
<code>npysave(pygzfile)</code>	4.92	2.53
<code>read.table(txtfile)</code>	128.85	66.24

Table 1: Performance comparison of data reads using a matrix of size $10^5 \times 50$. File size are 39.7mb for `ascii`, 40.0mb for `npz` and 10.8mb for `npz.gz`. Ten replications were performed, and total times are shown.

rows and k columns. It is written to temporary files in i) `ascii` format using `write.table()`; ii) **NumPy** format using `npysave()`; and iii) **NumPy** format using `npysave()` followed by a call to `gzip`.

Table 1 shows some timing comparisons for a matrix with five million elements. Reading the `npz` is clearly fastest as it required only parsing of the header, followed by a single large binary read (and the transpose required to translate the representation used by R). The compressed file requires only one-fourth of the disk space, but takes approximately 2.5 times as long to read as the binary stream has been transformed. Lastly, the default `ascii` reading mode is clearly by far the slowest.

4 Limitations

4.1 Integer support

Support for integer data types is conditional on use of the `-std=c++11` compiler extension. Only the newer standard supports the `long long int` type needed to represent `int64` data on a 32-bit OS. So until R switches to allowing `-std=c++11` on CRAN packages, users will need to rebuild both **Rcpp** and **RcppCNPy** with the switch enabled. As shown in the previous examples, integers also transparently convert to float types.

4.2 Higher-dimensional arrays

Rcpp supports three-dimensional arrays, this could be supported in **RcppCNPy** as well.

4.3 npz files

The **cnpy** library supports reading and writing of sets of arrays; this feature could also be exported.

5 Summary

The **RcppCNPy** package provides simple reading and writing of **NumPy** files, using the **cnpy** library.

Reading of compressed files is also supported as an extension. This offers users a balance between more compact storage at the prices of slightly longer read times.