#### Parallel Computing in R using NetWorkSpaces

N Carriero, J Lai, M Schultz, S Weston and G Warnes

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Scientific Computing Associates, Inc.

Pfizer

### **Shared Workspaces**

- Variation on the theme of a workspace.
- The NetWorkSpace object encapsulation uses an Internet-based server to hold the workspace.
- A given NetWorkSpace can be accessed by multiple processes: Any process capable of instantiating an appropriate NetWorkSpace object may retrieve the value of a variable. (Or store (name, value) pairs for that matter.)

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'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
> library(nws)
> ws = netWorkSpace('outer space')
> nwsVariable(ws, 'input'); nwsVariable(ws, 'output'); nwsVariable(ws, 'param',
mode = 'single')
>
```

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	mode = 'single') > input = 123 > ∎	> input [1] 123 > [

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> input = 123 > []	> input

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> Input - 1005	> [

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Type 'contributors()' for more information and	Type 'q()' to quit R.
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Type 'demo()' for some demos, 'help()' for on-line help, or	> ws = netWorkSpace('outer space')
help.start()' for an HTML browser interface to help.	> nwsVariable(ws, 'input'); nwsVariable(ws, 'output'); nwsVariable(ws, 'param',
Type 'q()' to quit R.	mode = 'single')
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> library(nws)	[1] 123
<pre>&gt; ws = netWorkSpace('outer space') &gt; nwsVariable(ws, 'input'); nwsVariable(ws, 'output'); nwsVariable(ws, 'param',</pre>	> input [1] 456
<pre>mosvariable(ws, input ); nwsvariable(ws, output ); nwsvariable(ws, param , mode = 'single')</pre>	
$\rightarrow$ input = 123	> input [1] 1001
input = 456	> input
input = 1001	[1] 1002
input = 1002	> input
> input = 1003	[1] 1003

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<pre>&gt; library(nws) &gt; ws = netWorkSpace('outer space') &gt; nwsVariable(ws, 'input'); nwsVariable(ws, 'output'); nwsVariable(ws, 'param', '')</pre>	<pre>mode = 'single') &gt; input [1] 123</pre>
mode = 'single') > input = 123 > input = 456	> input [1] 456 > input
> input = 1001 > input = 1002 > input = 1003	[1] 1001 > input [1] 1002
> input = 111 > output	> input [1] 1003 > [

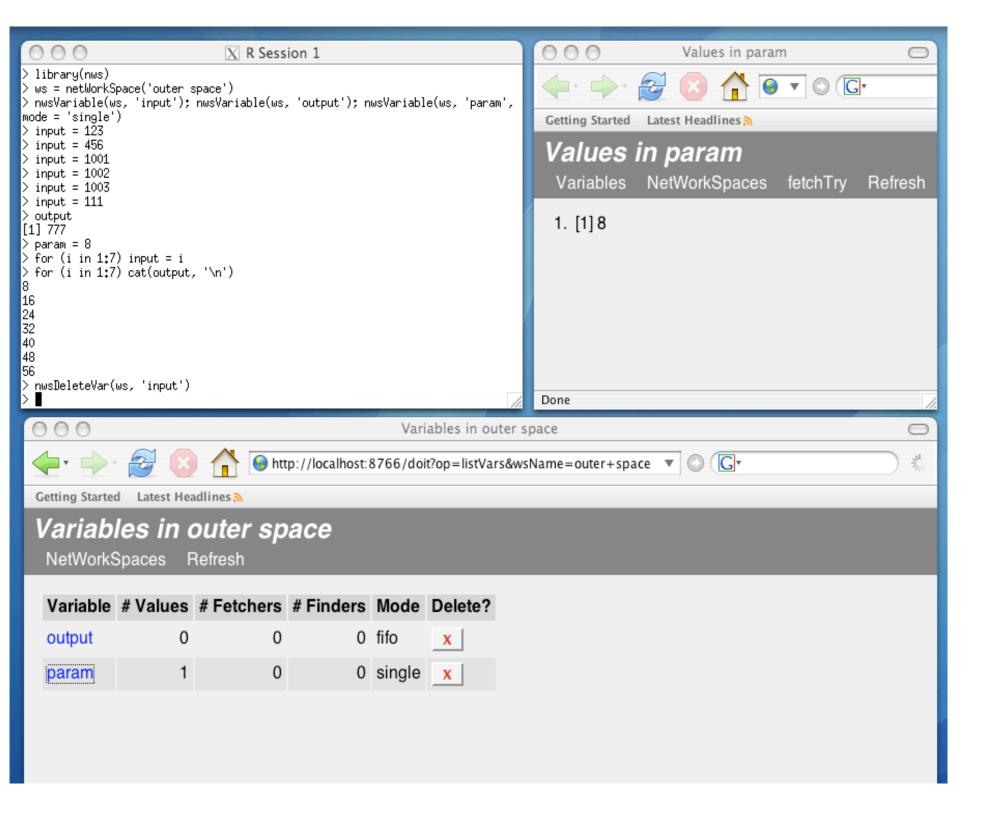
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[1] 777 > []	> output = input * 7 > ■

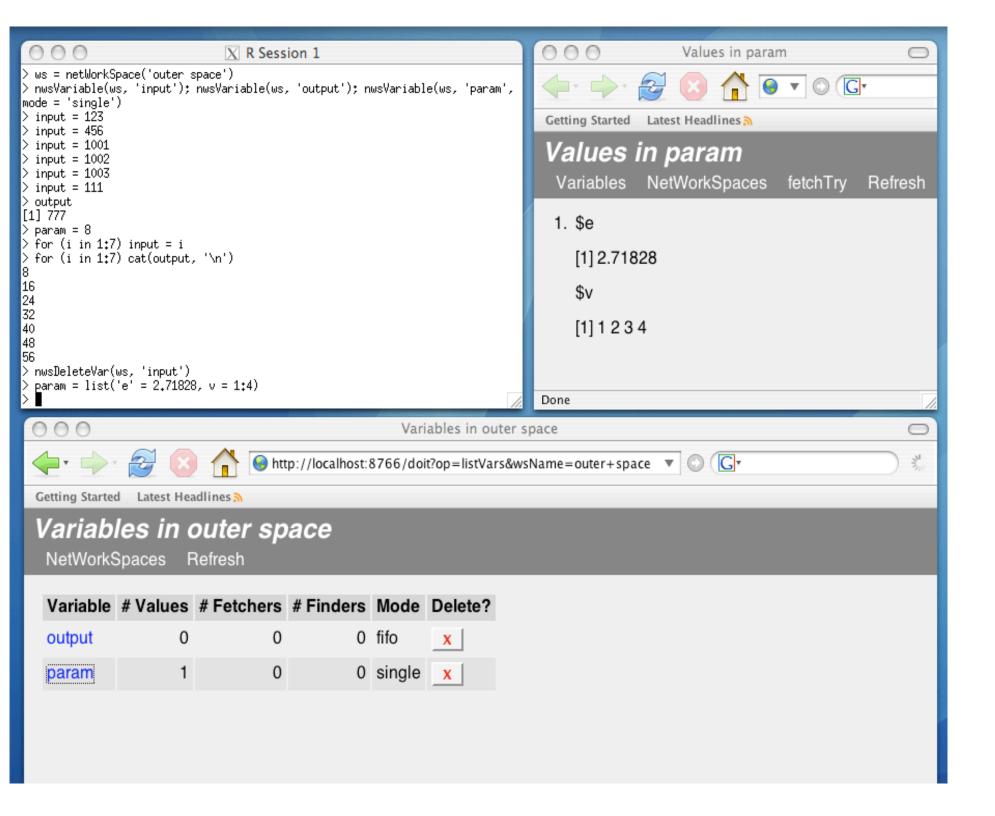
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R is a collaborative project with many contributors. Type 'contributors()' for more information and 'citation()' on how to cite R or R packages in publications.	<pre>&gt; library(nws) &gt; ws = netWorkSpace('outer space') &gt; nwsVariable(ws, 'input'); nwsVariable(ws, 'output'); nwsVariable(ws, 'param', mode = 'single')</pre>
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> input = 456 > input = 1001 > input = 1002 > input = 1003	[1] 1003 > output = input * 7 > param [1] 8
> input = 111 > output [1] 777 > param = 8	> param [1] 8 > param [1 <u>]</u> 8

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[1] 777 > param = 8 > []	<pre>[1] 8 &gt; while (1) { x = input; cat(x, '\n'); output = x * param } </pre>
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56 > nwsDeleteVar(ws, 'input') > ■	Error in nwsRetrieve(s, ws, xName, "fetch") : retrieval failed > []
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	retrieval failed





## Coordination via NetWorkSpaces

- Shared Access: Communication.
- Blocking References: Synchronization.
- Coordination provided within the context of the existing, familiar concept of a "workspace".
- Coordination data has independent existence

### **Benefits**

- Simplifies development:
  - Familiar conceptual foundation
  - Uncoupling in space and time
  - Anonymity
- Promotes flexibility:
  - Dynamic processing ensembles
  - Cross platform
  - Cross environment

# Sleigh

- Inspired by snow (Tierney, Rossini, Li, Sevcikova), but snow and sleigh differ in many ways.
- Supports "parallel" apply.
- Implemented on top of NetWorkSpaces.
- Vehicle for launching codes that explicitly use NetWorkSpaces for coordination.

000 X R Ses	sion 1		000 \	/ariables in	sleigh_ride_0	003nwssni	2t719	C
> nwsVariable(ws, 'input');    nwsVariable(ws mode = 'single')	;, 'output'); nws	Variable(ws, 'param',	🔶 - 🄶 - 🄁 🌘	3	😔 http://lc 🔻	© ( <b>G</b> •		- The second sec
> input = 123 > input = 456 > input = 1001			Getting Started Latest	Headlines 🔊				
> input = 1001 > input = 1002 > input = 1003			Variables in	sleig	h_ride_	0003	nwssn	2t7l9
<pre>&gt; input = 111 &gt; output [1] 777 &gt; param = 8 &gt; for (i in 1:7) input = i &gt; for (i in 1:7) cat(output, '\n') 8 16 24 32</pre>		NetWorkSpaces	Refresh					
		Variable #	# Values	# Fetchers	# Finders	Mode	Delete?	
		Sleigh ride over	0	0	3	unknown	x	
		localhost@0	1	0	0	single	X	
40 48 56			localhost@1	1	0	0	single	x
> nwsDeleteVar(ws, 'input') > param = list('e' = 2.71828, v = 1:4)			localhost@2	1	0	0	single	x
>s=sleigh() >∎		1	nodeList	1	0	0	single	x
000		NetWorkSpaces	rankCount	1	0	0	single	X
+ + 2 (2) Attp://localhost:8766/doit?op=listWss		task	0	3	0	unknown	x	
Getting Started Latest Headlines 🔊		totalTasks	1	0	0	single	x	
NetWorkSpaces			worker info	3	0	0	fifo	x
Clients Refresh			workerCount	1	0	0	single	x
Name	Monitor	Owner	Done	Persiste	Variable	s Delete	۲	
Python babelfish	[none]	IPv4Address(TCP, (4654)	'127.0.0.1', 51321)	False	1	X		- Andrew
R babelfish	[none]	IPv4Address(TCP, (4693)	'127.0.0.1', 51328)	False	2	x		
default	[none]	[system]		False	0	x		- And -
outer space	[none]	IPv4Address(TCP, (4668)	'127.0.0.1', 51322)	False	2	x		
sleigh_ride_0003nwssn2t7l9	Sleigh Monitor	IPv4Address(TCP, (4668)	'192.168.2.1', 51329)	False	10	X		

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> s = sleigh() > eachElem(s, function(x) { x*x*x }, list( [[1]] Kilonoz	13:19))		🔶 - 🍌 - 🌌 🌘			//lc   C Values in localhost@0
[1] 2197 [[2]] [1] 2744			Getting Started Latest H	sleigl		OOO Values in localhost@0 ← → ∂ ② Ô ↑ ⊙ ▼ €
[[3]] [1] 3375			NetWorkSpaces	Refresh		Getting Started Latest Headlines 🔊
[[4]] [1] 4096				Values	# Fet	Values in localhost@0 Variables NetWorkSpaces fetch
[[5]] [1] 4913			Sleigh ride over	0	÷Ē	1. 3
[[6]] [1] 5832		/	localhost@1	1		D
[[7]] [1] 6859			localhost@2	1	0	Values in localhost@1
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000		NetWorkSpaces	rankCount	1		tting Started Latest Headlines
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Getting Started Latest Headlines 🔊	_		totalTasks	1		
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Name	Monitor	Owner	Done	Persiste	nt Va	
Python babelfish	[none]	IPv4Address(TCP, (4654)	'127.0.0.1', 51321)	False	1	Getting Started Latest Headlines Values in localhost@2
R babelfish	[none]	IPv4Address(TCP, (4693)	'127.0.0.1', 51328)	False	2	Variables NetWorkSpaces fetc
default	[none]	[system]		False	0	1. 2
outer space	[none]	IPv4Address(TCP, (4668)	'127.0.0.1', 51322)	False	2	Done
sleigh_ride_0003nwssn2t7l9	Sleigh Monitor	IPv4Address(TCP, (4668)	'192.168.2.1', 51329)	False	10	x

OOO X R Session 1	OOO X Python Session 1
[1] 2197	Python 2.3.5 (#1, Jan 13 2006, 20:13:11)
[[2]] [1] 2744	[GCC 4.0.1 (Apple Computer, Inc. build 5250)] on darwin Type "help", "copyright", "credits" or "license" for more information. >>> from client import NetWorkSpace
[[3]] [1] 3375	ws = NetWorkSpace('outer space') sv = ws.variables('input', 'output', ['param','single']) >>> >>> sv.param 'greetings from R!'
[[4]] [1] 4096	Sreetings from K! >>> sv.param = 'hssssss' >>> ∎
[[5]] [1] 4913	
[[6]] [1] 5832	
[[7]] [1] 6859	
> param = 'greetings from R!' > param [1] "hsssssss" > []	

- MATLAB, octave, python, perl, ruby,
- Software available from: <u>http://nws-r.sourceforge.net</u> (open source for open source systems; commercial for commercial systems: <u>www.lindaspaces.com</u>)
- API used in this talk is a "teaser".
   More serious projects use a richer, but more verbose, API.