

# A Universal Identifier for Computational Results

## AAAS 2011

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# Credibility Crisis in Scientific Communication

Jon Claerbout, 1990 (paraphrase Donoho and Buckheit, 1995)

*An article about computational science in a scientific publication is not the scholarship itself, it is merely advertising of the scholarship. The actual scholarship is the complete software development environment and the complete set of instructions which generated the figures.*

- “Most published scientific research is false”.  
(John Ioannidis, with apologies)
- “Most published scientific research is not reproducible”.  
(John Ioannidis et al., Keith Baggerly et al.)

# Stages of Reproducibility

## Stages of Reproducibility

- Write scientific paper [1660?]
- Publish a pidgin algorithm and describe simulation datasets [1950?]
- Sell magtape of code and data [1970?]
- Place idiosyncratic software at website.  
Place idiosyncratic dataset at Website [1991?]
- Write R Package, of software, place at CRAN.  
Publish datasets and scripts at Website [2000?]
- Use Sweave to integrate code and data [??]

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# Reflections 1...

## Encouraging signs –

- *Biostatistics* has a reproducibility editor (*Roger Peng*), standard process for certification (using R)
- Growing literature on reproducibility (Special issues, workshops like this one, ...).

## The truth is –

- Very few researchers follow even minimal reproducibility standards.
- No-one expects or requires reproducibility [Even my own students!]
- No uniform standards of reproducibility, so no established user base.

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## Reflections 2...

### Psychological Obstacles to Reproducibility

- Publication is the real goal
- Publication is *informal* description of work we do in *private*
- We use files and personal coding idioms *no-one else will ever see*
- Reproducibility involves cleaning up post-facto.  
It's a *pretentious waste of time*.

### Working reproducibility requires a discipline

- *The endgame*. Release of code and results to the internet.
- Commit to the endgame *before you start your project*
- Work consistently to a discipline *shaped by the endgame*



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## Publication and Computation are one and the same

- Every computation for a scientific project, at instant of creation, is *publicly registered* (+timestamped, documented) at *external server*.
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- Scientific Publication is post-facto creation of humanly-readable hypertext document explaining *pre-existing, already 'public' results*.
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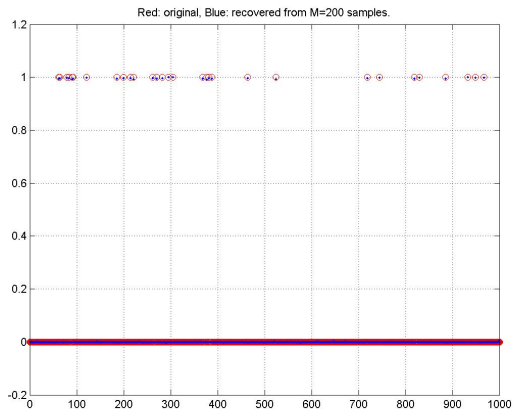
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# Problem we've encountered

1. How exactly did I create this nice figure two years ago?

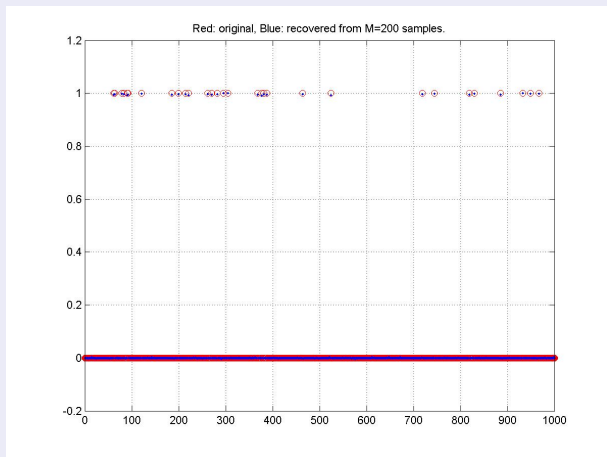
## My own paper



## Problem we've encountered

2. My student Bob graduated. My new student Alice can't reproduce his thesis results.

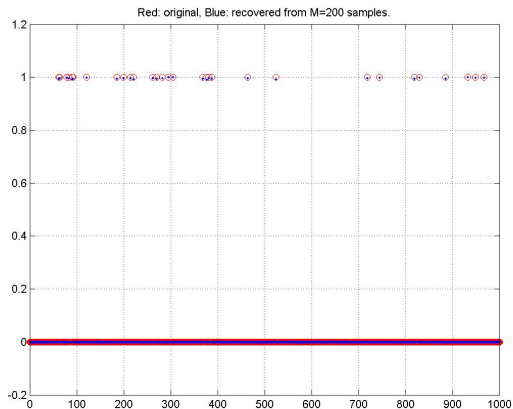
### Bob's thesis



## Problem we've encountered

3. I don't believe the figure in this published paper.

### A published paper

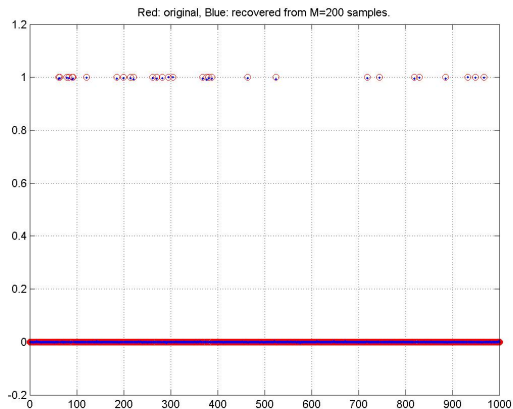




# Problem we've encountered

4. I don't believe the figure in your lecture slide.

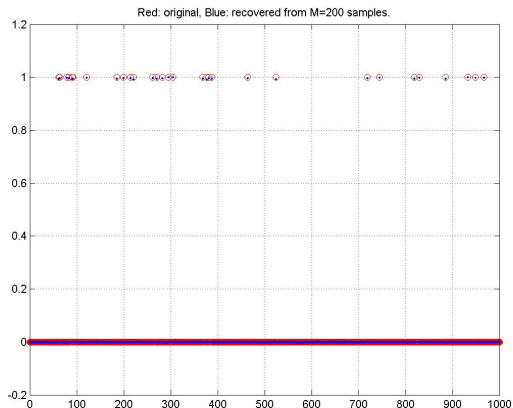
## Lecture slides



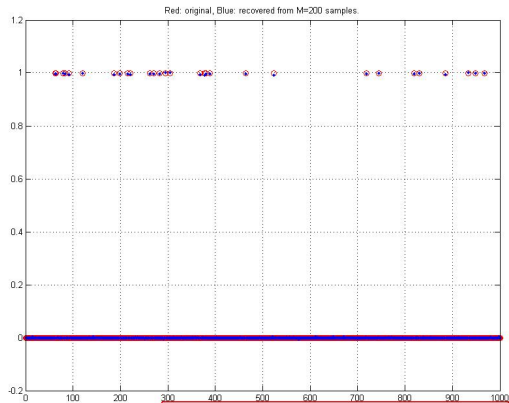
## Problem we've encountered

5. I cannot honestly referee this paper without the computation details.

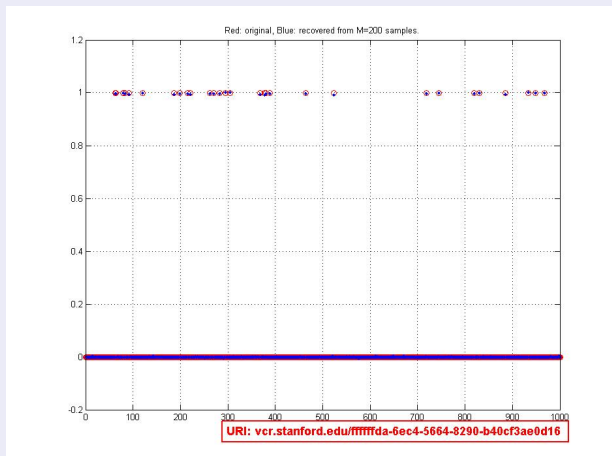
### A Submitted paper



# Utopia



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(Try clicking on the figure...)

[vcr.stanford.edu/ffffffda-6ec4-5664-8290-b40cf3ae0d16](http://vcr.stanford.edu/ffffffda-6ec4-5664-8290-b40cf3ae0d16)  
is a URI: Universal Result Identifier

URI is a *universal* and *permanent* connection to a computational result  
(and its generating environment)

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# The computational science workflow

## Program Code

```
x = read_data('C:/result_of_previous_computation.txt')  
figure1 = plot(x)  
save(figure1, 'figure1.eps')
```

## Document processor

```
\includegraphics{C:/figure1}
```

## Publication: Paper or slides



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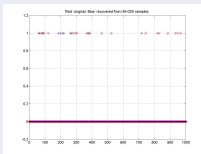
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## Publication: Paper or slides



# How computational science used to work

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function experiment
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```
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> experiment  
> "C:/figure1.eps saved"
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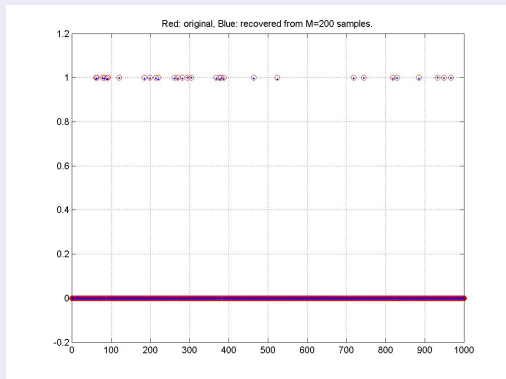
...Our results are summarized in Figure 1.

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Publication: Paper or slides

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# How computational science *should* work

## Program Code

```
function experiment
```

```
    repository('vcr.science.com')  
    x = read_data('vcr.science.com/cd6e83d7-3929')  
    verifiable figure1 = plot(x)
```

# How computational science *should* work

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    verifiable figure1 = plot(x)
```

```
> experiment  
> "vcr.science.com replied:"  
> "URI of figure1 is ffaaffb1-48d7"  
> "Receipt sent to gavish@stanford.edu"
```

# How computational science *should* work

## Document processor

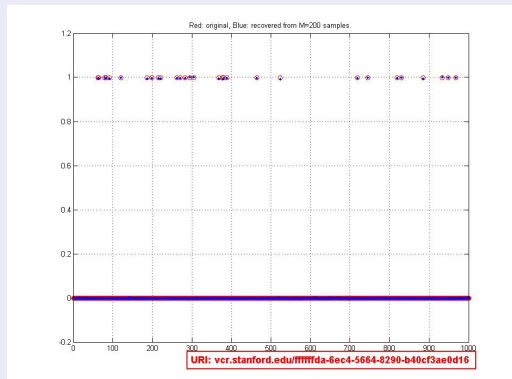
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```
\include_result{vcr.science.com/ffaaffb1-48d7}
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# How computational science *should* work

Publication: Paper or slides

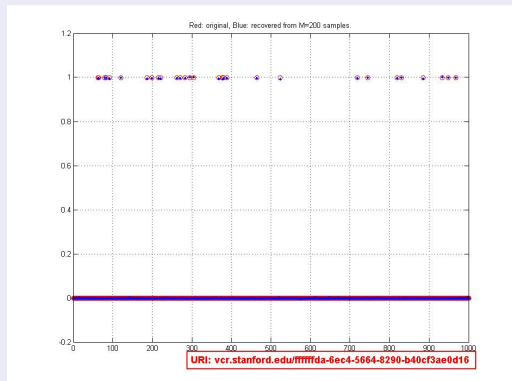
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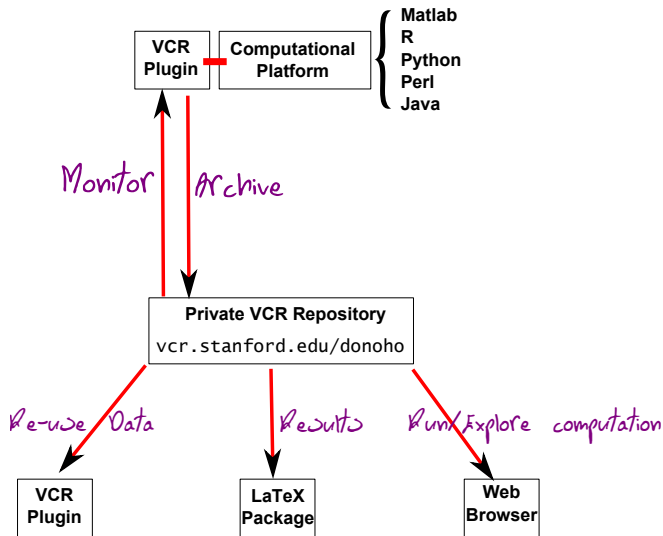
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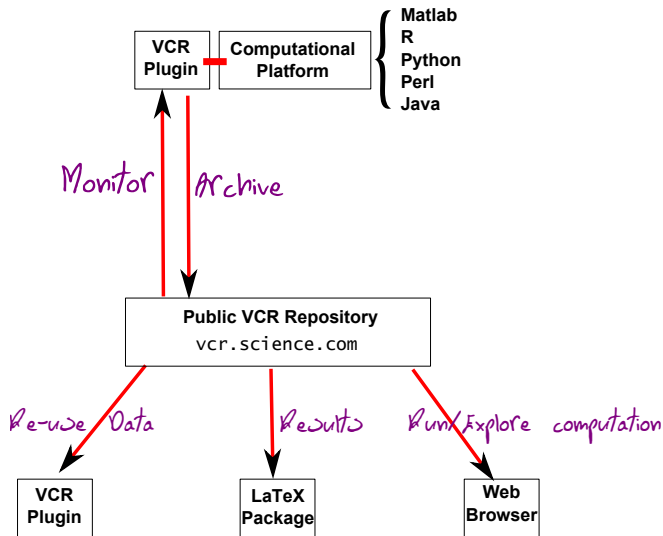


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# Eventual system components



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# The bottom line

## Using our system requires -

- Publishers to make subtle changes in article appearance
- Authors to make simple changes in a few lines of programs and word processors

## Using our system allows/implies -

- Universal, permanent and secure identifier for each citable computational result
  - A single, citable copy of each published result
  - A single, citable and reusable copy of each published dataset
- Immediate publication \* of result upon issuance of URI
- VCR server protocol serves up not only result, but various *views and metadata* about result
  - Code
  - Dataset values, summaries
- Potentially, operators on result (eg. bootstrap)

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# Larger Picture – Computational Results are Web Services

## Web Services Standards

- URI – Universal Resource Identifier
- RESTful web service (eg Amazon S3)

## Implications

- Instead of files, objects in the cloud.
- Server responds to object/method pairs
- URI: <http://www.stanford.edu/gavish/vcr/371aee2f-0d1f-405b-f1dd-7d4446363324>
- URI+method:

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## Existing implementation

Beta version in use in the Stanford Statistics Department.

<http://vcr.stanford.edu>

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