Reproducible Research for OMNeT++ Based on Python and Pweave

Kyeong Soo (Joseph) Kim

Department of Electrical and Electronic Engineering

Xi’an Jiaotong-Liverpool University

07 September 2017

Outline

- Reproducible Research
- Python and Pweave
- Reproducible Research for OMNeT++
- Example: OMNeT++ FIFO Simulation

Reproducible Research

Reproducible Research

- Reproducible research is a key to any scientific method and ensures repeating an experiment and the results of its analysis in any place with any person.

- A study can be truly reproducible when it satisfies at least the following three criteria:
    - All experimental methods are fully reported.
    - All data and files used for the analysis are (publicly) available.
    - The process of analyzing raw data is well reported and preserved.

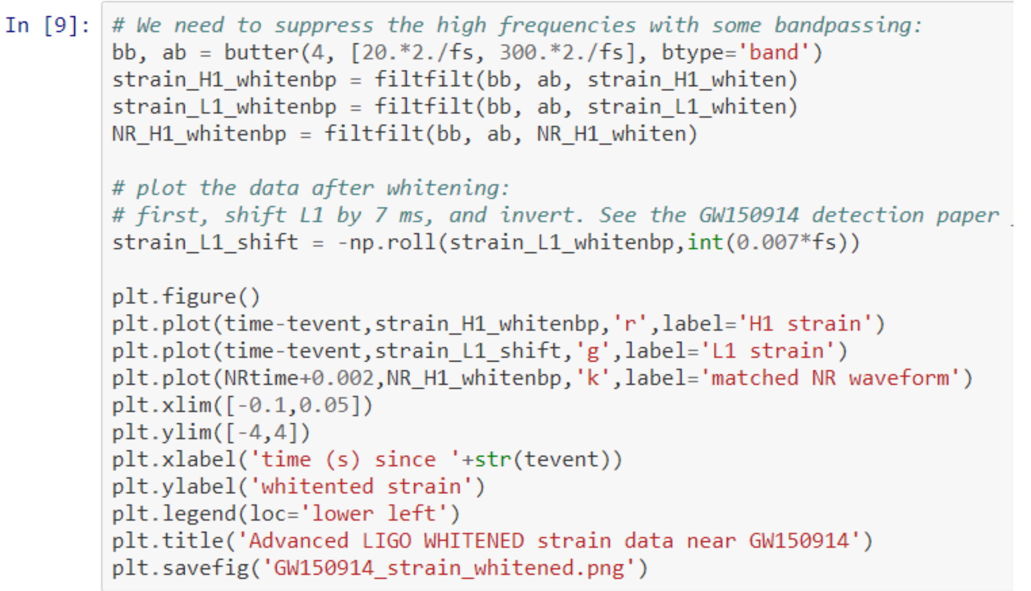
- Reproducible research is to ensure
    - Same data + Same script = Same results

Why Do We Need Reproducible Research: Two Examples

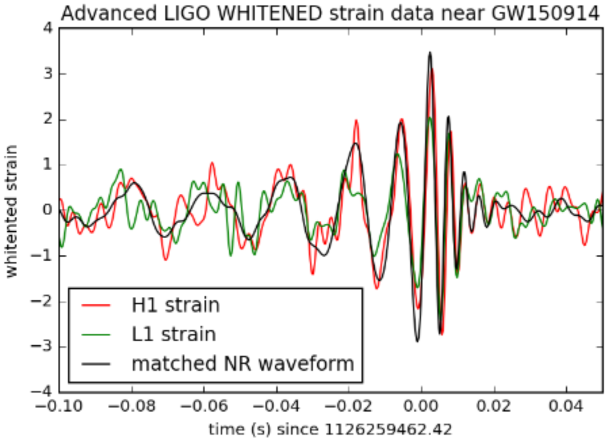
- LIGO - Gravitational Wave Detection
- Schön scandal - Molecular Computing

LIGO - Gravitational Wave Detection

- The *Laser Interferometer Gravitational-Wave Observatory (LIGO)* is a large-scale physics experiment and observatory to detect cosmic gravitational waves.
  - The detection of gravitational wave was reported in *Physical Review Letters* in Feb. 2016, together with ipython notebook with analysis code and data.

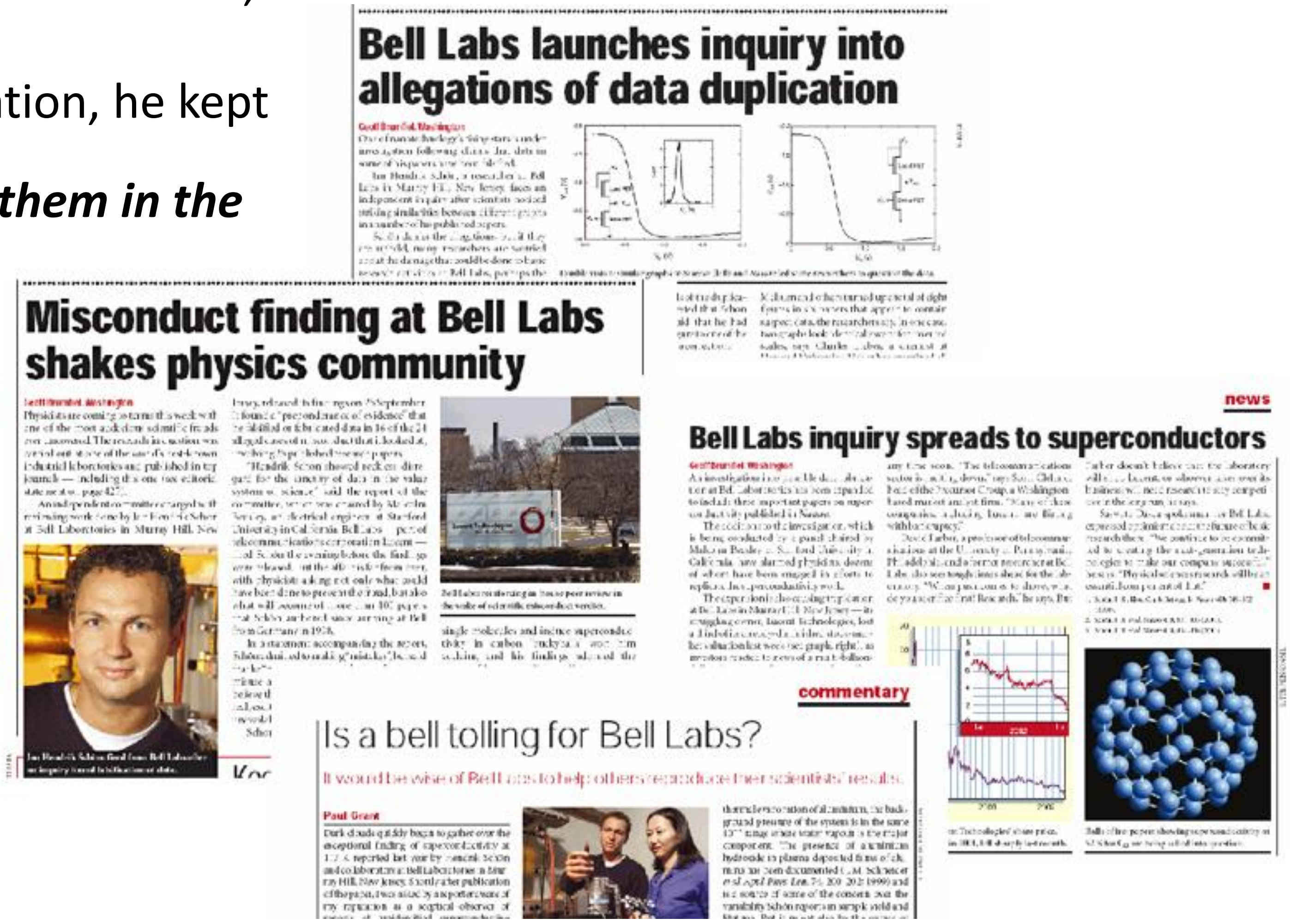


```
In [9]: # We need to suppress the high frequencies with some bandpassing:
        bb, ab = butter(4, [20.*2./fs, 300.*2./fs], btype='band')
        strain_H1_whitenbp = filtfilt(bb, ab, strain_H1_whiten)
        strain_L1_whitenbp = filtfilt(bb, ab, strain_L1_whiten)
        NR_H1_whitenbp = filtfilt(bb, ab, NR_H1_whiten)

        # plot the data after whitening:
        # first, shift L1 by 7 ms, and invert. See the GW150914 detection paper
        strain_L1_shift = -np.roll(strain_L1_whitenbp,int(0.007*fs))

        plt.figure()
        plt.plot(time-tevent,strain_H1_whitenbp,'r',label='H1 strain')
        plt.plot(time-tevent,strain_L1_shift,'g',label='L1 strain')
        plt.plot(NRtime+0.002,NR_H1_whitenbp,'k',label='matched NR waveform')
        plt.xlim([-0.1,0.05])
        plt.ylim([-4,4])
        plt.xlabel('time (s) since '+str(tevent))
        plt.ylabel('whitented strain')
        plt.legend(loc='lower left')
        plt.title('Advanced LIGO WHITENED strain data near GW150914')
        plt.savefig('GW150914_strain_whitened.png')
```



Schön Scandal - Molecular Computing

- No records found for his ground-breaking experimental results, including lab notebook, experimental samples and data, hard disk drives.
- During the investigation, he kept repeating
  “I clearly observed them in the Lab but …”



Bell Labs launches inquiry into allegations of data duplication

Geoff Brumfiel, Washington

[illegible]

Misconduct finding at Bell Labs shakes physics community

Geoff Brumfiel, Washington

[illegible]

news

Bell Labs inquiry spreads to superconductors

Geoff Brumfiel, Washington

[illegible]

commentary

Is a bell tolling for Bell Labs?

It would be wise of Bell Labs to help others reproduce their scientists' results.

Paul Grant

[illegible]

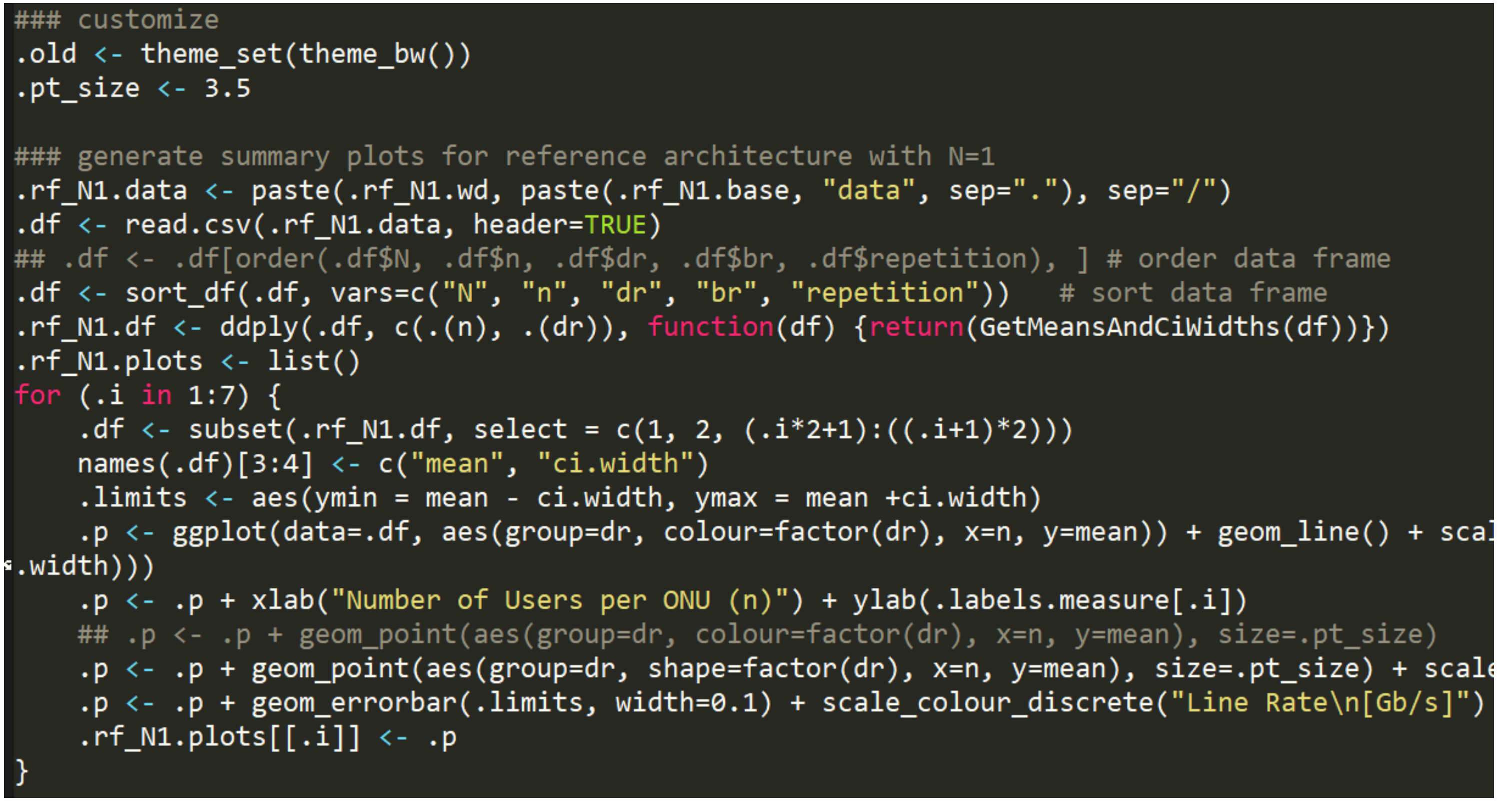
Python and Pweave

R/Sweave to Python/Pweave

- Until recently, R was the language of choice for statistical processing and data analysis.
  - Still, R has the largest code base for a wide variety of statistical and graphical techniques.

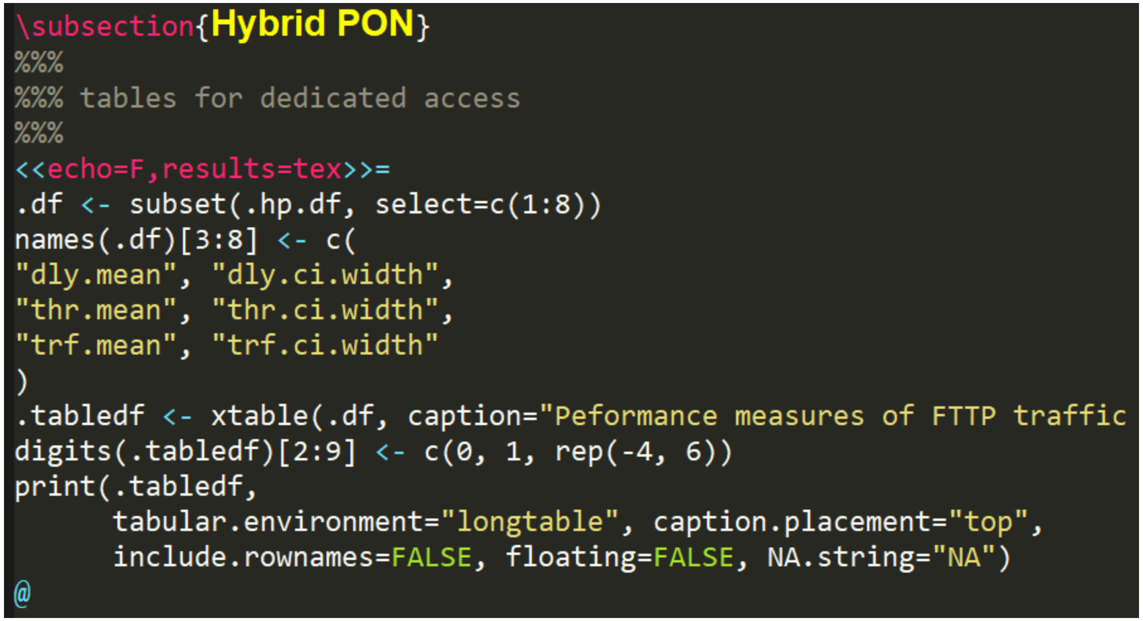
- Like *ipython* (now *jupyter*), R provides a nice tool called *Sweave* (now replaced by *knitr*) to weave documentation and the results of the execution of R code chunks into one source file for integrated documentation.

- Python — one of the most popular languages in scientific computing, including artificial intelligence & machine learning — recently takes over R in statistical processing and data analysis as well.
  - Thanks to *pandas* implementing DataFrame object similar to R and *Pweave*, python can replace R for most statistical and data analysis tasks, while retaining its many advantages over R (i.e., fully-featured programming language with easy syntax and higher speed).

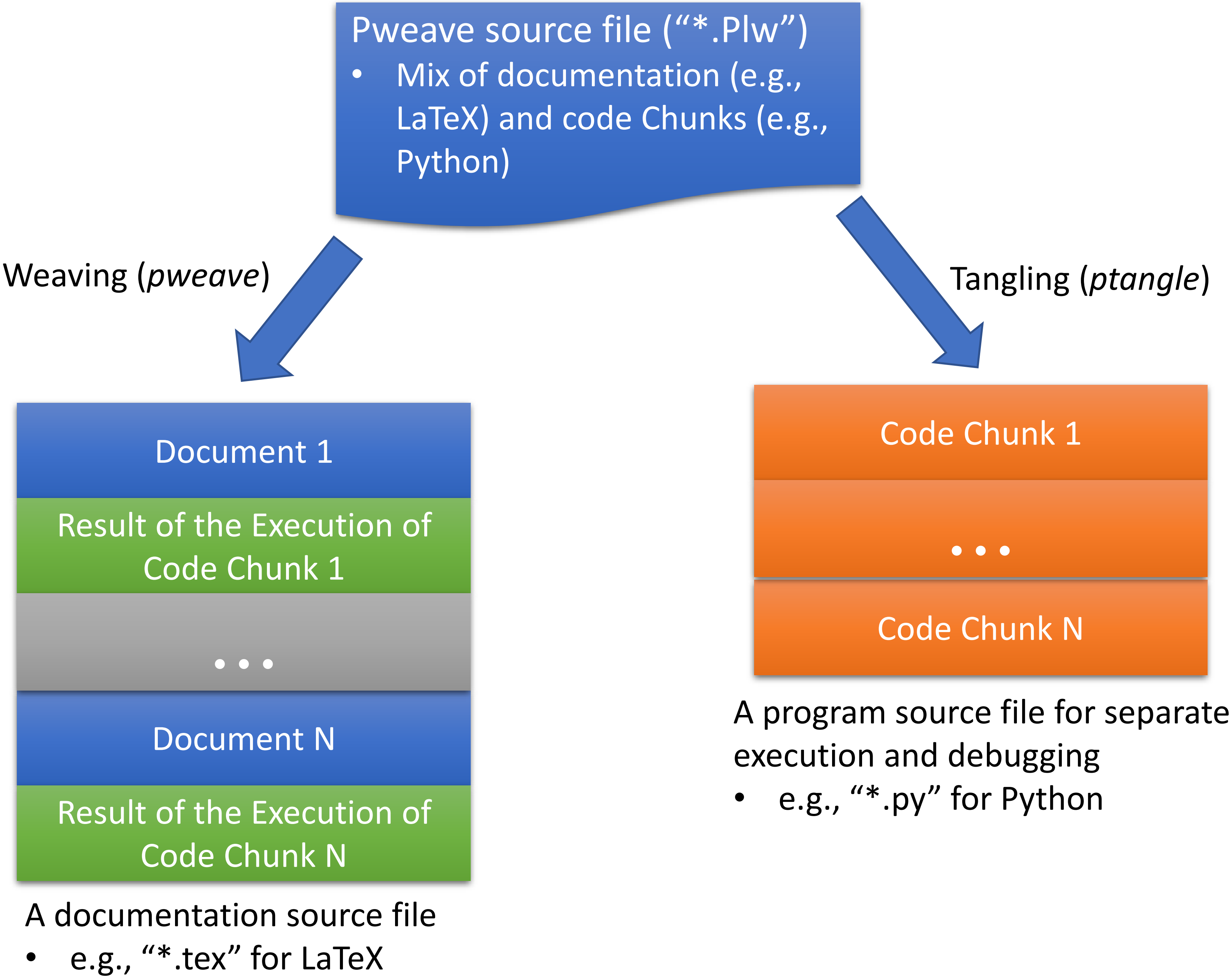


```
### customize
.old <- theme_set(theme_bw())
.pt_size <- 3.5

### generate summary plots for reference architecture with N=1
.rf_N1.data <- paste(.rf_N1.wd, paste(.rf_N1.base, "data", sep="."), sep="/")
.df <- read.csv(.rf_N1.data, header=TRUE)
## .df <- .df[order(.df$N, .df$n, .df$dr, .df$br, .df$repetition), ] # order data frame
.df <- sort_df(.df, vars=c("N", "n", "dr", "br", "repetition"))   # sort data frame
.rf_N1.df <- ddply(.df, c(.(n), .(dr)), function(df) {return(GetMeansAndCiWidths(df))})
.rf_N1.plots <- list()
for (.i in 1:7) {
    .df <- subset(.rf_N1.df, select = c(1, 2, (.i*2+1):((.i+1)*2)))
    names(.df)[3:4] <- c("mean", "ci.width")
    .limits <- aes(ymin = mean - ci.width, ymax = mean +ci.width)
    .p <- ggplot(data=.df, aes(group=dr, colour=factor(dr), x=n, y=mean)) + geom_line() + scal
.width)))
    .p <- .p + xlab("Number of Users per ONU (n)") + ylab(.labels.measure[.i])
    ## .p <- .p + geom_point(aes(group=dr, colour=factor(dr), x=n, y=mean), size=.pt_size)
    .p <- .p + geom_point(aes(group=dr, shape=factor(dr), x=n, y=mean), size=.pt_size) + scale
    .p <- .p + geom_errorbar(.limits, width=0.1) + scale_colour_discrete("Line Rate\n[Gb/s]")
    .rf_N1.plots[[.i]] <- .p
}
```

Snippets of R Source Code and Sweave File for LaTeX



```
\subsection{Hybrid PON}
%%%
%%% tables for dedicated access
%%%
<<echo=F,results=tex>>=
.df <- subset(.hp.df, select=c(1:8))
names(.df)[3:8] <- c(
"dly.mean", "dly.ci.width",
"thr.mean", "thr.ci.width",
"trf.mean", "trf.ci.width"
)
.tabledf <- xtable(.df, caption="Peformance measures of FTTP traffic
digits(.tabledf)[2:9] <- c(0, 1, rep(-4, 6))
print(.tabledf,
      tabular.environment="longtable", caption.placement="top",
      include.rownames=FALSE, floating=FALSE, NA.string="NA")
@
```



Pweave source file (“*.Plw”)

- Mix of documentation (e.g., LaTeX) and code Chunks (e.g., Python)

Weaving (*pweave*)

Tangling (*ptangle*)

Document 1

Result of the Execution of Code Chunk 1

• • •

Document N

Result of the Execution of Code Chunk N

A documentation source file

- e.g., “*.tex” for LaTeX

Code Chunk 1

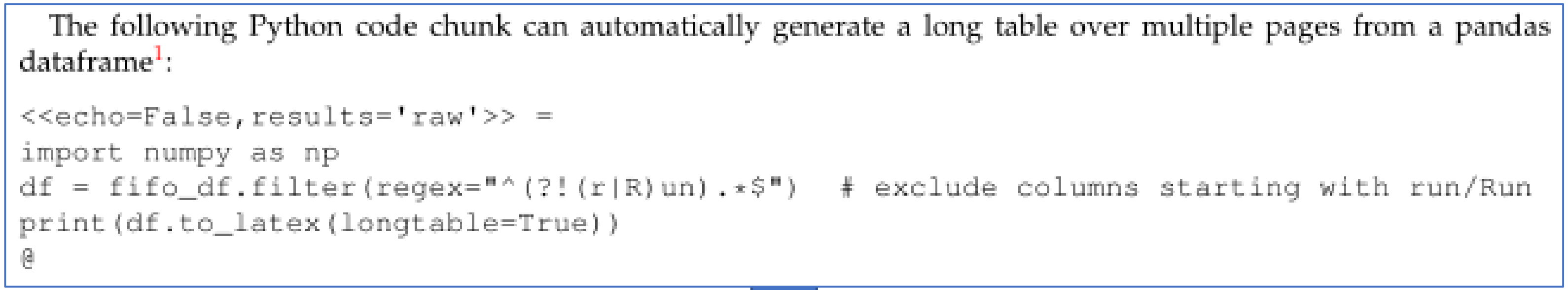
• • •

Code Chunk N

A program source file for separate execution and debugging

- e.g., “*.py” for Python

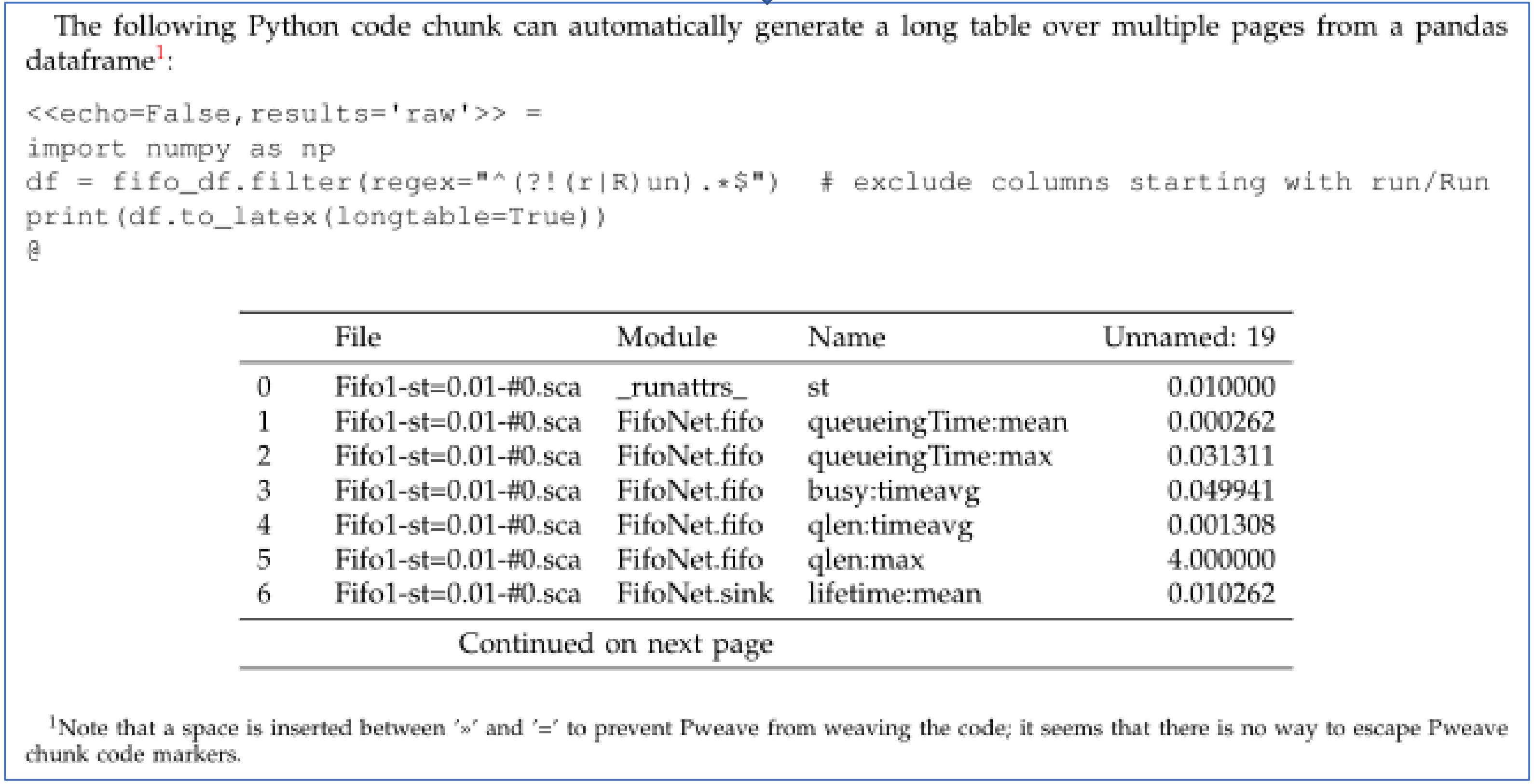
Weaving Example: Automatic Table Generation



The following Python code chunk can automatically generate a long table over multiple pages from a pandas dataframe[1]:

```
<<echo=False,results='raw'>> =
import numpy as np
df = fifo_df.filter(regex="^(?!(r|R)un).*$")  # exclude columns starting with run/Run
print(df.to_latex(longtable=True))
@
```

Weaving & LaTeXing



The following Python code chunk can automatically generate a long table over multiple pages from a pandas dataframe[1]:

```
<<echo=False,results='raw'>> =
import numpy as np
df = fifo_df.filter(regex="^(?!(r|R)un).*$")  # exclude columns starting with run/Run
print(df.to_latex(longtable=True))
@
```

	File	Module	Name	Unnamed: 19
0	Fifo1-st=0.01-#0.sca	_runattrs_	st	0.010000
1	Fifo1-st=0.01-#0.sca	FifoNet.fifo	queueingTime:mean	0.000262
2	Fifo1-st=0.01-#0.sca	FifoNet.fifo	queueingTime:max	0.031311
3	Fifo1-st=0.01-#0.sca	FifoNet.fifo	busy:timeavg	0.049941
4	Fifo1-st=0.01-#0.sca	FifoNet.fifo	qlen:timeavg	0.001308
5	Fifo1-st=0.01-#0.sca	FifoNet.fifo	qlen:max	4.000000
6	Fifo1-st=0.01-#0.sca	FifoNet.sink	lifetime:mean	0.010262

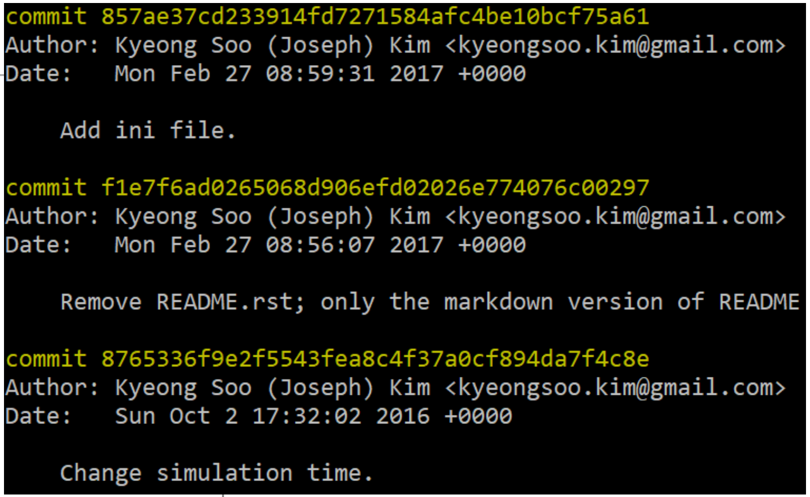
Continued on next page

[1] Note that a space is inserted between ’»’ and ’=’ to prevent Pweave from weaving the code; it seems that there is no way to escape Pweave chunk code markers.

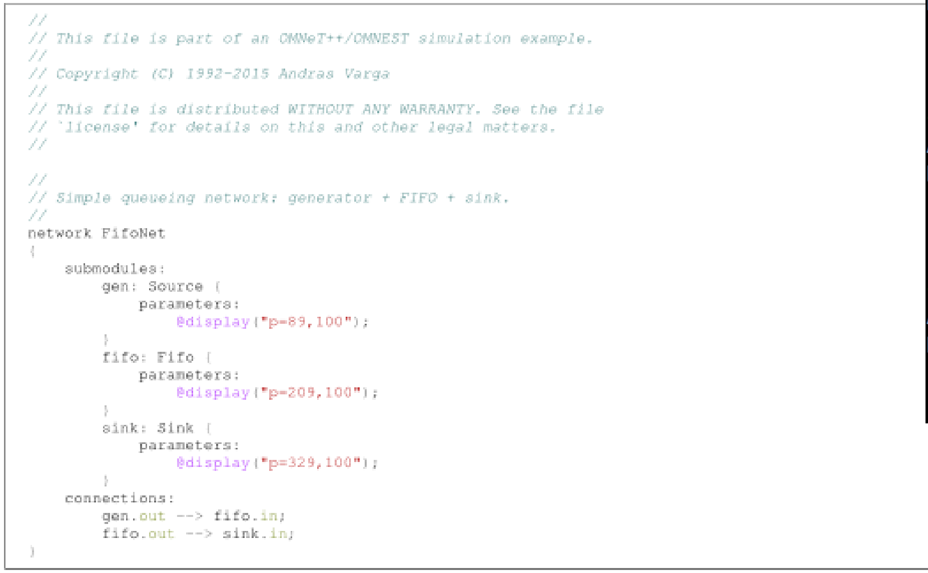
Reproducible Research for OMNeT++

How to Deal with Simulation Input Files

- Include them the document.
    - OK for small simulations
- Use a snapshot of the whole configurations.
    - e.g., git commit hashes



```
commit 857ae37cd233914fd7271584afc4be10bcf75a61
Author: Kyeong Soo (Joseph) Kim <kyeongsoo.kim@gmail.com>
Date:   Mon Feb 27 08:59:31 2017 +0000

    Add ini file.

commit f1e7f6ad0265068d906efd02026e774076c00297
Author: Kyeong Soo (Joseph) Kim <kyeongsoo.kim@gmail.com>
Date:   Mon Feb 27 08:56:07 2017 +0000

    Remove README.rst; only the markdown version of README

commit 8765336f9e2f5543fea8c4f37a0cf894da7f4c8e
Author: Kyeong Soo (Joseph) Kim <kyeongsoo.kim@gmail.com>
Date:   Sun Oct 2 17:32:02 2016 +0000

    Change simulation time.
```



```
//
// This file is part of an OMNeT++/OMNEST simulation example.
//
// Copyright (C) 1992-2015 Andras Varga
//
// This file is distributed WITHOUT ANY WARRANTY. See the file
// `license' for details on this and other legal matters.
//

//
// Simple queueing network: generator + FIFO + sink.
//
network FifoNet
{
    submodules:
        gen: Source {
            parameters:
                @display("p=89,100");
        }
        fifo: Fifo {
            parameters:
                @display("p=209,100");
        }
        sink: Sink {
            parameters:
                @display("p=329,100");
        }
    connections:
        gen.out --> fifo.in;
        fifo.out --> sink.in;
}
```

Listing 1: 'FifoNet.ned' for FIFO sample model.

How to Guarantee Match Between Input Files and Output Data

- Online generation of results
  - Include simulation execution code within a document
    - Refer to the provided sample Pweave file.
  - OK for smaller simulations, but not for larger simulations.

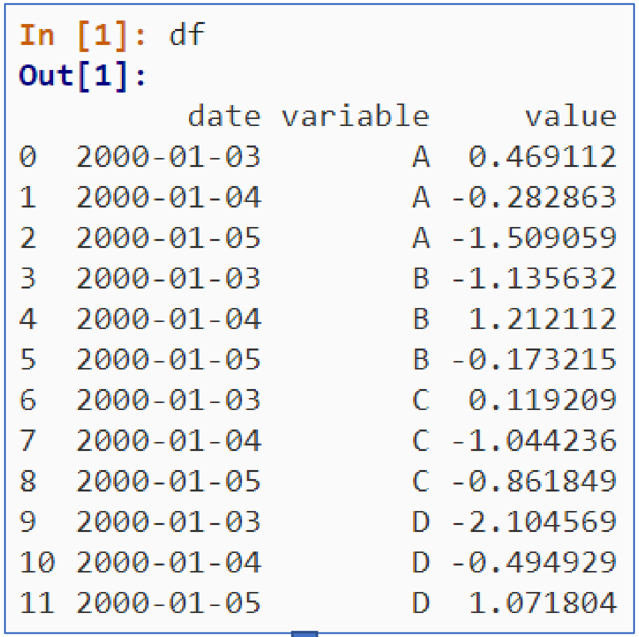
- Use a snapshot of the whole configurations and data
  - e.g., git commit hashes
  - Version controlling output data together with source code and input configuration files, however, may greatly increase the size of a repository.

How to Present and Analyze Output Data

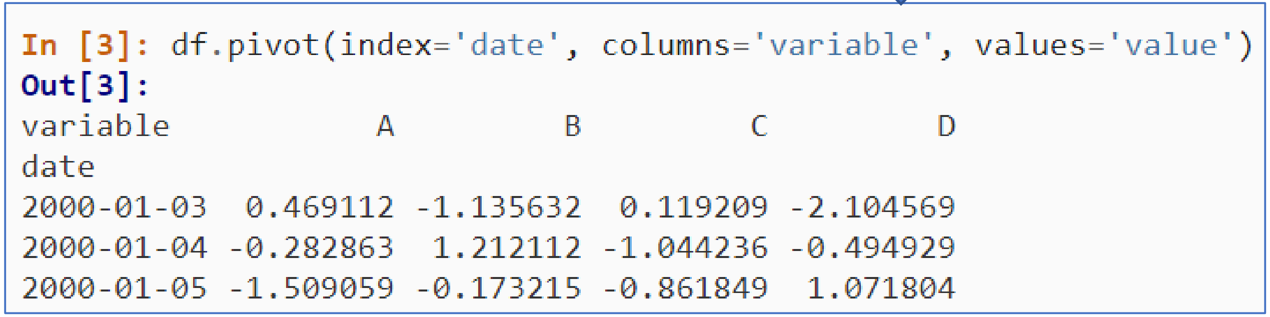
- Unstacking of stacked DataFrame
  - Use *pivot* function (see the example shown here).

- Aggregated processing of measurement data over independent variables
  - Use *pivot_table* function.
  - Useful for the calculation of mean and confidence intervals over multiple iterations.

- Online calculation of confidence intervals
  - Confidence intervals (CIs) can be calculated by assigning a custom function for CI to *aggfunc* paramenter of *pivot_table* function.
  - Now pandas support error bars in its own plot functions.



```
In [1]: df
Out[1]:
          date variable     value
0   2000-01-03        A  0.469112
1   2000-01-04        A -0.282863
2   2000-01-05        A -1.509059
3   2000-01-03        B -1.135632
4   2000-01-04        B  1.212112
5   2000-01-05        B -0.173215
6   2000-01-03        C  0.119209
7   2000-01-04        C -1.044236
8   2000-01-05        C -0.861849
9   2000-01-03        D -2.104569
10  2000-01-04        D -0.494929
11  2000-01-05        D  1.071804
```



```
In [3]: df.pivot(index='date', columns='variable', values='value')
Out[3]:
variable           A         B         C         D
date
2000-01-03  0.469112 -1.135632  0.119209 -2.104569
2000-01-04 -0.282863  1.212112 -1.044236 -0.494929
2000-01-05 -1.509059 -0.173215 -0.861849  1.071804
```

Example: OMNeT++ FIFO Simulation