

Time Series Analysis and Its Applications: With R Examples

Second Edition

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This is the site for the second edition of the text and is no longer maintained.

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An R Time Series Tutorial

Here are some examples that may help you become familiar with analyzing time series using R. You can copy-and-paste the R commands (multiple lines are ok) from this page into R. Printed output is *blue*. I suggest that you have R up and running before you start this tutorial.

Please note that this is not a lesson in time series analysis. Also, the analyses performed on this page are simply demonstrations, they are not meant to be optimal or complete in any way. This is done intentionally so as not to spoil the fun you'll have working on the problems in the text.

If you're new to R/Splus, I suggest reading [R for Beginners](#) (a pdf file) first. Another good read for exploring time series is [Econometrics in R](#) (a pdf file). You may also want to poke around the [QuickR](#) website.

◇ Baby steps... your first R session. Get comfortable, then start her up and try some simple addition:

```
2+2
[1] 5
```

Ok, now you're an expert useR. It's time to move on to time series. What you'll see in the following examples should be enough to get you through the first four chapters of the text.

Let's play with the Johnson & Johnson data set. Download [jj.dat](#) to a directory called mydata (or wherever you choose ... the examples below and in the text assume the data are in that directory).

```
jj = scan("/mydata/jj.dat")      # read the data
jj <- scan("/mydata/jj.dat")    # read the data another way
scan("/mydata/jj.dat") -> jj    # and another
```

The *R people* (yes, they exist) prefer that you use the second [`<-`] or third [`->`] assignment operator, but your wrists and health care professionals prefer that you use the simpler first [`=`] method if you can.

Next, print `jj` (to the screen)

```
jj
[1] 0.71 0.63 0.85 0.44
[5] 0.61 0.69 0.92 0.55
.    .    .    .    .
.    .    .    .    .
[77] 14.04 12.96 14.85 9.99
[81] 16.20 14.67 16.02 11.61
```

and you see that `jj` is a collection of 84 numbers called an object. You can see all of your objects by typing

```
objects()
```

If you're a Matlab (or similar) user, you may think `jj` is an 84×1 vector, but it's not. It has order and length, but no dimensions (no rows, no columns). R call these objects vectors so you have to be careful. In R, matrices have dimensions but vectors do not. To wit:

```
jj[1]      # the first element
[1] 0.71
jj[84]     # the last element
[1] 11.61
jj[1:4]    # the first 4 elements
[1] 0.71 0.63 0.85 0.44
jj[-(1:80)] # everything EXCEPT the first 80 elements
[1] 16.20 14.67 16.02 11.61
length(jj) # the number of elements
[1] 84
```

```

dim(jj)      # but no dimensions ...
NULL
nrow(jj)     # ... no rows
NULL
ncol(jj)     # ... and no columns
NULL
#-- if you want it to be a column vector (in R, a matrix), an easy way to go is:
jj = as.matrix(jj)
dim(jj)
[1] 84 1

```

Now, let's make `jj` a time series object.

```
jj = ts(jj, start=1960, frequency=4)
```

Note that the data are *quarterly* earnings, hence the `frequency=4` statement. One nice thing about R is you can do a bunch of stuff (technical term) in one line. For example, you can read the data into `jj` and make it a time series object at the same time:

```
jj = ts(scan("/mydata/jj.dat"), start=1960, frequency=4)
```

In the lines above, you can replace `scan` by `read.table`. Inputting data using `read.table` is an easy way to read a data file that is laid out as a matrix and may have headers (column descriptions). At this point, you might want to find out about `read.table`, data frames, and time series objects:

```

jj = ts(read.table("/mydata/jj.dat"), start=1960, frequency=4)
help(read.table)
help(ts)
help(data.frame)

```

There is a difference between `scan` and `read.table`. The former produces a vector (no dimensions) while the latter produces a data frame (and has dimensions).

One final note on reading the data. If the data started on the third quarter of 1960, say, then you would have something like `ts(x, start=c(1960,3), frequency=4)` and so on. If you had monthly data that started from June, 1984, then you would have `ts(x, start=c(1984,6), frequency=12)`.

Let's view the data again as a time series object:

```

jj
      Qtr1  Qtr2  Qtr3  Qtr4
1960  0.71  0.63  0.85  0.44
1961  0.61  0.69  0.92  0.55
.      .      .      .      .
.      .      .      .      .
1979 14.04 12.96 14.85  9.99
1980 16.20 14.67 16.02 11.61

```

Notice the difference? You also get some nice things with the `ts` object, for example, the corresponding time values:

```

time(jj)
      Qtr1      Qtr2      Qtr3      Qtr4
1960 1960.00 1960.25 1960.50 1960.75
1961 1961.00 1961.25 1961.50 1961.75
.      .      .      .      .
.      .      .      .      .
1979 1979.00 1979.25 1979.50 1979.75
1980 1980.00 1980.25 1980.50 1980.75

```

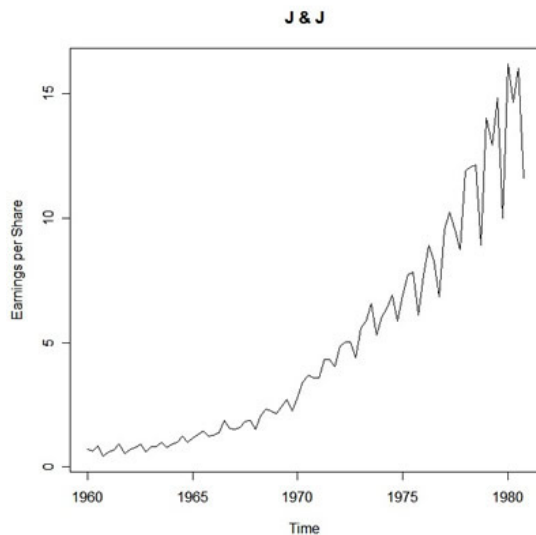
By the way, you could have put the data into `jj` and printed it at the same time by enclosing the command:

```
(jj = ts(scan("/mydata/jj.dat"), start=1960, frequency=4))
```

Now try a plot of the data:

```
plot(jj, ylab="Earnings per Share", main="J & J")
```

with the result being:

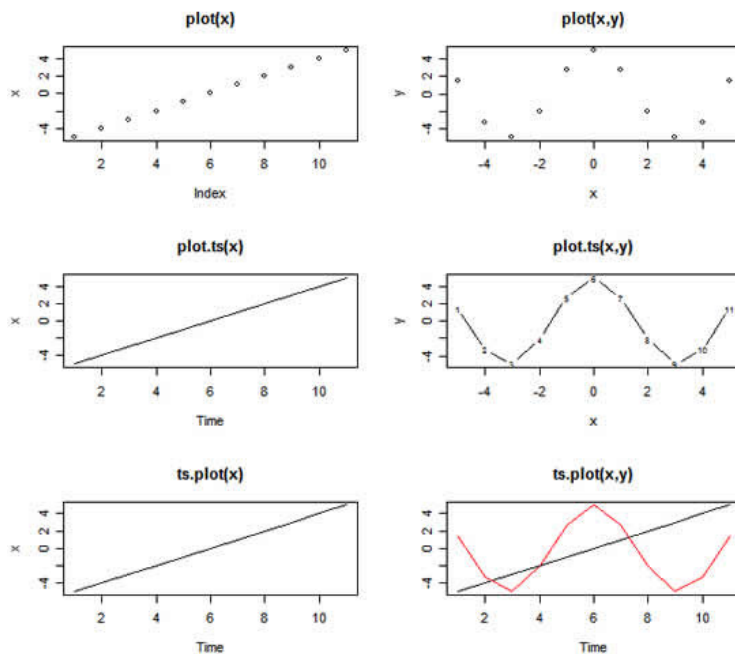


Try these and see what happens:

```
plot(jj, type="o", col="blue", lty="dashed")
plot(diff(log(jj)), main="logged and diffed")
```

and while you're here, check out `plot.ts` and `ts.plot`:

```
x = -5:5                # sequence of integers from -5 to 5
y = 5*cos(x)            # guess
par(mfrow=c(3,2))       # multiframe setup: 3 rows, 2 cols
#--- plot:
plot(x, main="plot(x)")
plot(x, y, main="plot(x,y)")
#--- plot.ts:
plot.ts(x, main="plot.ts(x)")
plot.ts(x, y, main="plot.ts(x,y)")
#--- ts.plot:
ts.plot(x, main="ts.plot(x)")
ts.plot(ts(x), ts(y), col=1:2, main="ts.plot(x,y)") # note- x and y are ts objects
#--- the help files [? and help()] are the same]:
?plot.ts
help(ts.plot)
?par                # might as well skim the graphical parameters help file while you're here
```



Note that if your data are a time series object, `plot()` will do the trick (for a simple time plot, that is). Otherwise, `plot.ts()` will coerce the graphic into a time plot.

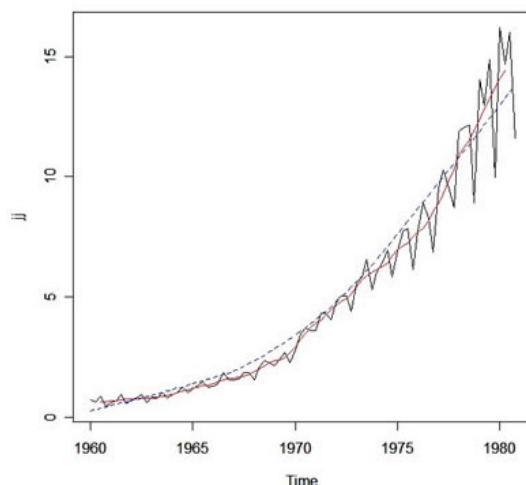
How about filtering/smoothing the Johnson & Johnson series using a two-sided moving average? Let's try this:

$$f_{jj}(t) = \frac{1}{8} jj(t-2) + \frac{1}{4} jj(t-1) + \frac{1}{4} jj(t) + \frac{1}{4} jj(t+1) + \frac{1}{8} jj(t+2)$$

and we'll add a lowess fit for fun.

```
k = c(.5,1,1,1,.5)           # k is the vector of weights
(k = k/sum(k))
[1] 0.125 0.250 0.250 0.250 0.125
fjj = filter(jj, sides=2, k) # ?filter for help [but you knew that already]
plot(jj)
lines(fjj, col="red")        # adds a line to the existing plot
lines(lowess(jj), col="blue", lty="dashed")
```

... and the result:



Let's difference the logged data and call it `dljj`. Then we'll play with `dljj`:

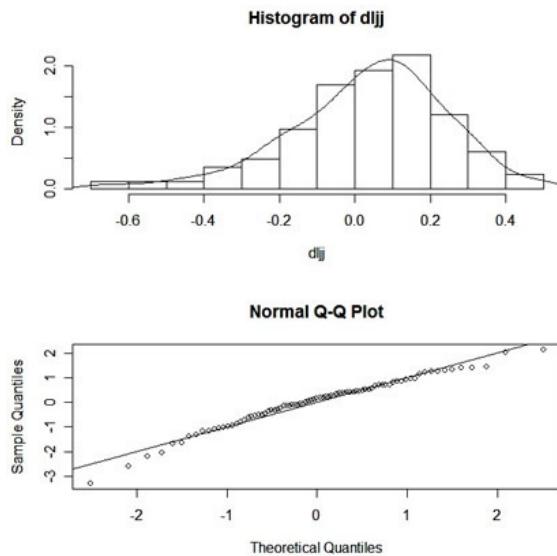
```
dljj = diff(log(jj))          # difference the logged data
plot(dljj)                   # plot it if you haven't already
shapiro.test(dljj)           # test for normality
  Shapiro-Wilk normality test
data:  dljj
```

$W = 0.9725$, $p\text{-value} = 0.07211$

Now a histogram and a Q-Q plot, one on top of the other:

```
par(mfrow=c(2,1))      # set up the graphics
hist(dljj, prob=TRUE, 12) # histogram
lines(density(dljj))    # smooth it - ?density for details
qqnorm(dljj)            # normal Q-Q plot
qqline(dljj)            # add a line
```

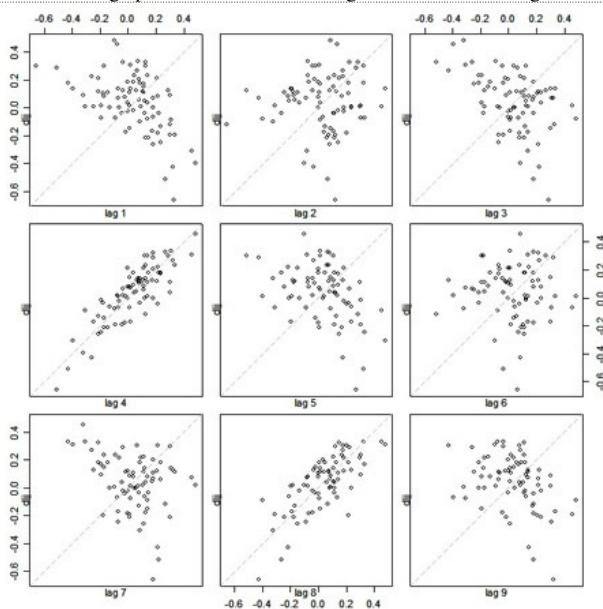
and the results:



Let's check out the correlation structure of `dljj` using various techniques. First, we'll look at a grid of scatterplots of `dljj(t-lag)` vs `dljj(t)` for $\text{lag}=1, 2, \dots, 9$.

```
lag.plot(dljj, 9, do.lines=FALSE) # why the do.lines=FALSE? ... try leaving it out
```

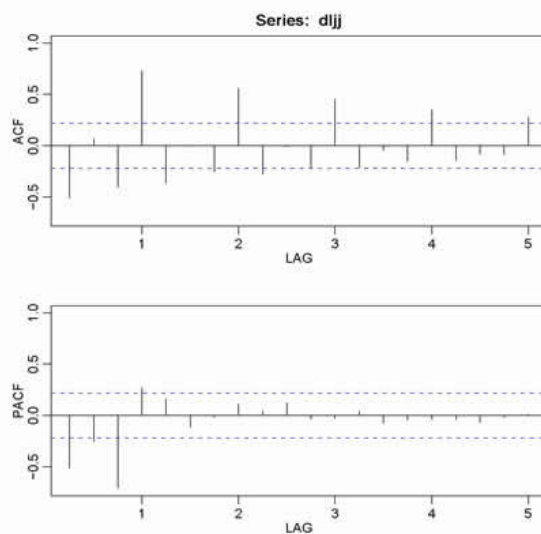
Notice the large positive correlation at lags 4 and 8 and the negative correlations at a few other lags:



Now let's take a look at the ACF and PACF of `dljj`:

```
par(mfrow=c(2,1)) # The power of accurate observation is commonly called cynicism
                  # by those who have not got it. - George Bernard Shaw
acf(dljj, 20)     # ACF to lag 20 - no graph shown... keep reading
pacf(dljj, 20)    # PACF to lag 20 - no graph shown... keep reading
```

```
# !!NOTE!! acf2 on the line below is NOT available in R... details follow the graph below
acf2(dljj)          # this is what you'll see below
```



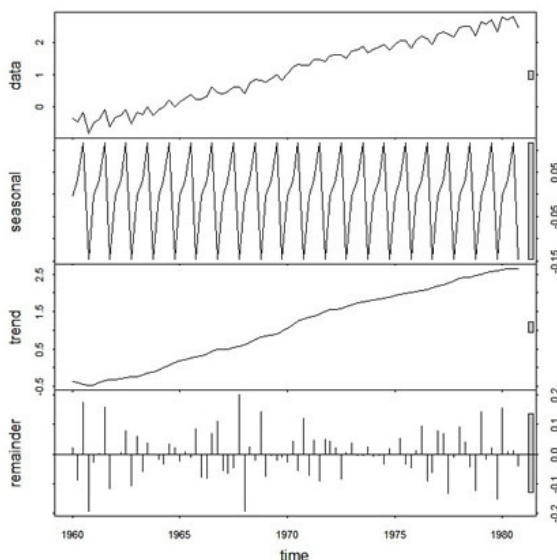
Note that the LAG axis is in terms of `frequency`, so 1,2,3,4,5 correspond to lags 4,8,12,16,20 because `frequency=4` here. If you don't like this type of labeling, you can replace `dljj` in any of the above by `ts(dljj, freq=1)`; e.g., `acf(ts(dljj, freq=1), 20)`

◊ Ok- here's the story on `acf2`. I like my ACF and PACF a certain way, which is not the default R way. So, I wrote a little script called `acf2.R` that you can read about and obtain here: [Examples](#) (there are other goodies there).

Moving on, let's try a structural decomposition of $\log(jj) = \text{trend} + \text{season} + \text{error}$ using `lowess`. Note, this example works only if `jj` is dimensionless (i.e., you didn't read it in using `read.table` ... thanks to Jon Moore of the University of Reading, U.K., for pointing this out.)

```
plot(dog <- stl(log(jj), "per"))
```

Here's what you get:



If you want to inspect the residuals, for example, they're in `dog$time.series[,3]`, the third column of the resulting series (the seasonal and trend components are in columns 1 and 2). Check out the ACF of the residuals, `acf(dog$time.series[,3])`; the residuals aren't white- not even close. You can do a little (very little) better using a local seasonal window, `plot(dog <- stl(log(jj), s.win=4))`, as opposed to the global one used by specifying "per". Type `?stl` for details. There's also something called `StructTS` that will fit parametric structural models. We don't use these functions in the text when we present structural modeling in Chapter 6 because we prefer to use our own programs.

◊ This is a good time to explain `$`. In the above, `dog` is an object containing a bunch of things (technical term). If you type `dog`, you'll see the components, and if you type `summary(dog)` you'll get a little summary of the results. One of the components of `dog` is `time.series`, which contains the resulting series (seasonal, trend, remainder). To see this component of the object `dog`, you type `dog$time.series` (and you'll see 3 series, the last of which contains the residuals). And that's the story of `$` ... you'll see more examples as we move along.

And now, we'll do some of Problem 2.1. We're going to fit the regression

$$\log(jj) = \beta \cdot \text{time} + \alpha_1 \cdot Q1 + \alpha_2 \cdot Q2 + \alpha_3 \cdot Q3 + \alpha_4 \cdot Q4 + \varepsilon$$

where Q_i is an indicator of the quarter $i = 1, 2, 3, 4$. Then we'll inspect the residuals.

```
Q = factor(rep(1:4,21))      # make (Q)uarter factors [that's repeat 1,2,3,4, 21 times]
trend = time(jj)-1970        # not necessary to "center" time, but the results look nicer
reg = lm(log(jj)~0+trend+Q, na.action=NULL) # run the regression without an intercept
#-- the na.action statement is to retain time series attributes
summary(reg)
      Call:
lm(formula = log(jj) ~ 0 + trend + Q, na.action = NULL)
```

Residuals:

Min	1Q	Median	3Q	Max
-0.29318	-0.09062	-0.01180	0.08460	0.27644

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
trend	0.167172	0.002259	74.00	<2e-16 ***
Q1	1.052793	0.027359	38.48	<2e-16 ***
Q2	1.080916	0.027365	39.50	<2e-16 ***
Q3	1.151024	0.027383	42.03	<2e-16 ***
Q4	0.882266	0.027412	32.19	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1254 on 79 degrees of freedom
Multiple R-squared: 0.9935, Adjusted R-squared: 0.9931
F-statistic: 2407 on 5 and 79 DF, p-value: < 2.2e-16

You can view the model matrix (with the dummy variables) this way:

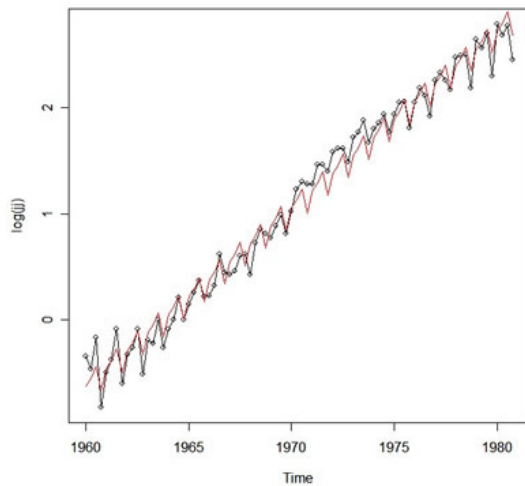
```
model.matrix(reg)

      trend Q1 Q2 Q3 Q4 (remember trend is time centered at 1970)
1 -10.00  1  0  0  0
2  -9.75  0  1  0  0
3  -9.50  0  0  1  0
4  -9.25  0  0  0  1
5  -9.00  1  0  0  0
6  -8.75  0  1  0  0
7  -8.50  0  0  1  0
8  -8.25  0  0  0  1
.      .      .      .      .
.      .      .      .      .
81  10.00  1  0  0  0
82  10.25  0  1  0  0
83  10.50  0  0  1  0
84  10.75  0  0  0  1
```

Now check out what happened. Look at a plot of the observations and their fitted values:

```
plot(log(jj), type="o") # the data in black with little dots
lines(fitted(reg), col=2) # the fitted values in bloody red - or use lines(reg$fitted, col=2)
```

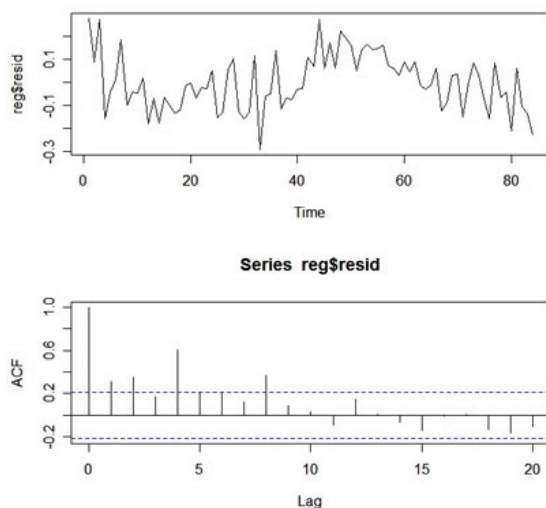
you get:



... and a plot of the residuals and the ACF of the residuals:

```
par(mfrow=c(2,1))
plot(resid(reg))      # residuals - reg$resid is same as resid(reg)
acf(resid(reg),20)    # acf of the resids
```

and you get:



Do those residuals look white? [Ignore the 0-lag correlation, it's always 1.]

You have to be careful when you **regress one time series on lagged components of another** using `lm()`. There is a package called `dynlm` that makes it easy to fit lagged regressions, and I'll discuss that right after this example. If you use `lm()`, then what you have to do is "tie" the series together using `ts.intersect`. If you don't tie the series together, they won't be aligned properly. Here's an example regressing weekly cardiovascular mortality ([cmort.dat](#)) on particulate pollution ([part.dat](#)) at the present value and lagged four weeks (about a month). For details about the data set, see Chapter 2.

```
mort = ts(scan("/mydata/cmort.dat"),start=1970, frequency=52) # make these time series objects
Read 508 items
part = ts(scan("/mydata/part.dat"),start=1970, frequency=52)
Read 508 items
ded = ts.intersect(mort,part,part4=lag(part,-4), dframe=TRUE) # tie them together in a data frame
fit = lm(mort~part+part4, data=ded, na.action=NULL)           # now the regression will work
summary(fit)

Call:
lm(formula = mort ~ part + part4, data = ded, na.action = NULL)

Residuals:
    Min       1Q   Median       3Q      Max
-22.7429  -5.3677  -0.4136   5.2694  37.8539
```



```

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  69.01020    1.37498  50.190 < 2e-16 ***
part         0.15140    0.02898   5.225 2.56e-07 ***
part4        0.26297    0.02899   9.071 < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 8.323 on 501 degrees of freedom
Multiple R-Squared: 0.3091,    Adjusted R-squared: 0.3063
F-statistic: 112.1 on 2 and 501 DF,  p-value: < 2.2e-16

```

Note: There was no need to rename `lag(part, -4)` to `part4`, it's just an example of what you can do.

An alternative to the above is the package `dynlm`, which has to be installed [for details, in R type `help(INSTALL)` or `help("install.packages")`]. After the package is installed, you can do the previous example as follows:

```

library(dynlm)                                # load the package
fit = dynlm(mort~part + lag(part,-4))          # assumes mort and part are ts objects
# fit = dynlm(mort~part + L(part,4)) is the same thing.
summary(fit)
Call:
dynlm(formula = mort ~ part + lag(part, -4))

Residuals:
    Min       1Q   Median       3Q      Max
-22.7429  -5.3677  -0.4136   5.2694  37.8539

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  69.01020    1.37498  50.190 < 2e-16 ***
part         0.15140    0.02898   5.225 2.56e-07 ***
lag(part, -4) 0.26297    0.02899   9.071 < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 8.323 on 501 degrees of freedom
Multiple R-Squared: 0.3091,    Adjusted R-squared: 0.3063
F-statistic: 112.1 on 2 and 501 DF,  p-value: < 2.2e-16

```

Well, it's time to simulate. The workhorse for ARIMA simulations is `arima.sim()`. Here are some examples; no output is shown here so you're on your own.

```

# some AR1s
x1 = arima.sim(list(order=c(1,0,0), ar=.9), n=100)
x2 = arima.sim(list(order=c(1,0,0), ar=-.9), n=100)
par(mfrow=c(2,1))
plot(x1, main=(expression(AR(1)~~~phi==+.9)))      # ~ is a space and == is equal
plot(x2, main=(expression(AR(1)~~~phi==-.9)))
x1l()                                                # open another graphics device if you wish
par(mfcol=c(2,2))
acf(x1, 20)
acf(x2, 20)
pacf(x1, 20)
pacf(x2, 20)
# you could have, for example, used acf2(x1)
# to get the ACF and PACF of x1 (or x2)... if you had acf2.R, of course.

# an MA1
x = arima.sim(list(order=c(0,0,1), ma=.8), n=100)
par(mfcol=c(3,1))
plot(x, main=(expression(MA(1)~~~theta==.8)))
acf(x, 20)
pacf(x, 20)

```

```
# an AR2
x = arima.sim(list(order=c(2,0,0), ar=c(1,-.9)), n=100)
par(mfcol=c(3,1))
plot(x, main=(expression(AR(2)~~~phi[1]==1~~~phi[2]==-.9)))
acf(x, 20)
pacf(x, 20)

# an ARIMA(1,1,1)
x = arima.sim(list(order=c(1,1,1), ar=.9, ma=-.5), n=200)
par(mfcol=c(3,1))
plot(x, main=(expression(ARIMA(1,1,1)~~~phi==.9~~~theta==-.5)))
acf(x, 30) # the process is not stationary, so there is no population [P]ACF ...
pacf(x, 30) # but look at the sample values to see how they differ from the examples above
```

◊ Next, we're going to do some ARIMA estimation. This gets a bit tricky because R is not user friendly when it comes to fitting ARIMA models. Much of the story is spelled out in our [R Issues](#) page. I'll be as gentle as I can at first.

First, we'll fit an ARMA model to some simulated data (with diagnostics and forecasting):

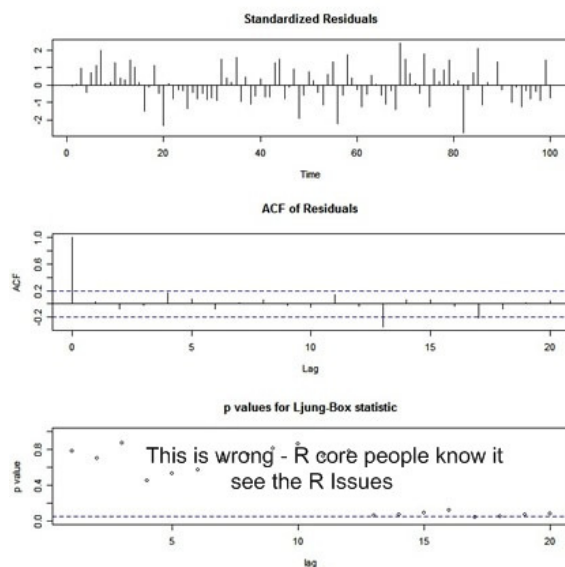
```
x = arima.sim(list(order=c(1,0,1), ar=.9, ma=-.5), n=100) # simulate some data
(x.fit = arima(x, order = c(1, 0, 1))) # fit the model and print the results

Call: arima(x = x, order = c(1, 0, 1))
Coefficients:
      ar1      ma1 intercept <-- NOT the intercept - see R Issue 1
    0.8465 -0.5021     0.5006
s.e.  0.0837  0.1356     0.3150
sigma^2 estimated as 1.027: log likelihood = -143.44, aic = 294.89
```

... diagnostics:

```
tsdiag(x.fit, gof.lag=20) # you know the routine- ?tsdiag for details
```

... and the output

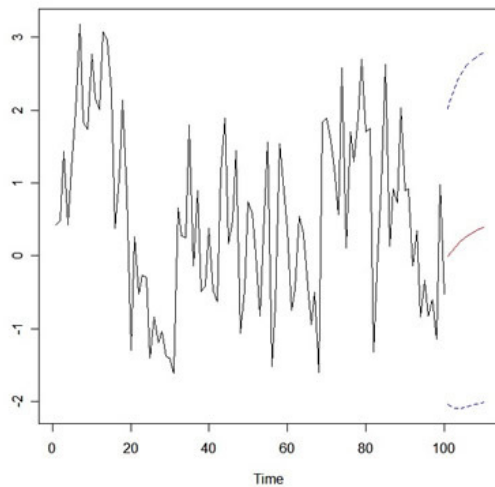


... forecast 10 ahead:

```
x.fore = predict(x.fit, n.ahead=10)
# plot the forecasts
U = x.fore$pred + 2*x.fore$se
L = x.fore$pred - 2*x.fore$se
minx=min(x,L)
maxx=max(x,U)
```

```
ts.plot(x,x.fore$pred,col=1:2, ylim=c(minx,maxx))
lines(U, col="blue", lty="dashed")
lines(L, col="blue", lty="dashed")
```

... and here's the plot of the data and the forecasts (with error bounds):



That wasn't too bad... but hold on. We're going to work with the global temperature data from Chapter 3. The data are in the file [globtemp2.dat](#). There are three columns in the file, the second column has the yearly global temperature deviations from 1880 to 2004. If you download the data to the mydata directory, you can pull out the global temperatures like this:

```
u = read.table("/mydata/globtemp2.dat") # read the data
gtemp = ts(u[,2], start=1880, freq=1) # yearly temp in col 2
plot(gtemp) # graph the series (not shown here)
```

... long story short, the data appear to be an ARIMA(1,1,1) with a drift of about +.6 °C per century (and hence the global warming hypothesis). Let's fit the model:

```
arima(gtemp, order=c(1,1,1))
Coefficients:
    ar1      ma1
    0.2545 -0.7742
s.e.  0.1141  0.0651
```

So what's wrong? well, there's no estimate of the drift!! With no drift, the global warming hypothesis is kaput (technical term)... that is, the temps are just basically taking a random walk. How do you get the estimate of drift?... do this:

```
arima(diff(gtemp), order=c(1,0,1)) # diff the data and fit an arma to the diffed data
Coefficients:
    ar1      ma1  intercept
    0.2695 -0.8180   0.0061
s.e.  0.1122  0.0624   0.0030
```

What happened? The two runs should have given the same results, but the default models for the two cases are different. I won't go into detail here because the details can be found on the [R Issues](#) page. And, of course, this problem continues if you try to do forecasting. There are remedies. One remedy is to do the following:

```
drift = 1:length(gtemp)
arima(gtemp, order=c(1,1,1), xreg=drift)
Coefficients:
    ar1      ma1  drift
    0.2695 -0.8180  0.0061
s.e.  0.1122  0.0624  0.0030
```

and then make sure you continue the along these lines when you forecast. Another remedy is to use the scripts called `sarima.R` for model fitting, and `sarima.for.R` for forecasting. You can get those scripts with some details on this page: [Examples](#).

◊ You may not have understood all the details of this example, but at least you should realize that you may get into trouble when fitting ARIMA models with R. In particular, you should come away from this realizing that, in R, `arima(x, order=c(1,1,1))` is different than `arima(diff(x), order=c(1,0,1))` and `arima` calls the estimate of the *mean* the *intercept*. Again, much of the story is spelled out in our [R Issues](#) page.

And now for some **regression with autocorrelated errors**. This can be accomplished two different ways. First, we'll use `gls()` from the package `nlme`, which you have to load. We're going to fit the model $M_t = \alpha + \beta t + \gamma P_t + e_t$ where M_t and P_t are the mortality and particulates series from a previous example, and e_t is autocorrelated error.

```
library(nlme)           # load the package
trend = time(mort)      # assumes mort and part are there from previous examples
fit.lm = lm(mort~trend + part) # ols
acf(resid(fit.lm))      # check acf and pacf of the resids
pacf(resid(fit.lm))     # or use acf2(resid(fit.lm)) if you have acf2
# resids appear to be AR(2) ... now use gls() from nlme:
fit.gls = gls(mort~trend + part, correlation=corARMA(p=2), method="ML")
# take 5 .....
# .....
# .....
# .....
# done:
summary(fit.gls)
      Parameter estimate(s):
              Phil      Phi2
0.3980566 0.4134305
Coefficients:      Value Std.Error  t-value  p-value
(Intercept)    3131.5452   857.2141  3.653166   3e-04
trend           -1.5444    0.4340 -3.558021   4e-04
part             0.1503    0.0210  7.162408   0e+00

# resid analysis- we assumed  $e_t = \phi_1 e_{t-1} + \phi_2 e_{t-2} + w_t$  where  $w_t$  is white.
w = filter(resid(fit.gls), filter=c(1,-.3980566, -.4134305), sides=1) # get resids
w = w[-2:-1]                  # first two are NA
Box.test(w, 12, type="Ljung") # check whiteness via Ljung-Box-Pierce statistic
X-squared = 8.6074, df = 12, p-value = 0.736
pchisq(8.6074, 10, lower=FALSE) # the p-value (they are resids from an ar2 fit)
[1] 0.569723
```

Now, we'll doing the same thing using `arima()`, which is easier and a little quicker.

```
(fit2.gls = arima(mort, order=c(2,0,0), xreg=cbind(trend, part)))
Coefficients:
      ar1      ar2 intercept  trend  part
0.3980 0.4135 3132.7085 -1.5449 0.1503
s.e. 0.0405 0.0404 854.6662 0.4328 0.0211
sigma^2 estimated as 28.99: log likelihood = -1576.56, aic = 3165.13

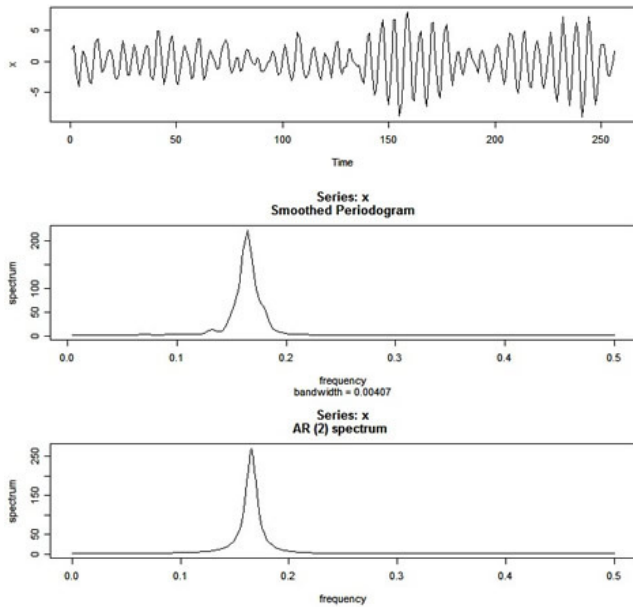
Box.test(resid(fit2.gls), 12, type="Ljung") # and so on ...
```

◊ ARMAX: If you want to fit an ARMAX model you have to do it via a state space model... more details will follow on the Chapter 6 page when I have the time. As seen above, using `xreg` in `arima()` does NOT fit an ARMAX model, which is too bad, but the help file (`?arima`) didn't say it did. For more info, head on over to the [R Issues](#) page and check out Issue 2.

Finally, a spectral analysis quickly:

```
x = arima.sim(list(order=c(2,0,0), ar=c(1,-.9)), n=2^8) # some data
(u = polyroot(c(1,-1,.9))) # x is AR(2) w/complex roots
[1] 0.5555556+0.8958064i 0.5555556-0.8958064i
Arg(u[1])/(2*pi) # dominant frequency around .16:
[1] 0.1616497
par(mfcol=c(3,1))
plot.ts(x)
spec.pgram(x, spans=c(3,3), log="no") # nonparametric spectral estimate; also see spectrum()
?spec.pgram # some help
'spec.pgram' calculates the periodogram using a fast Fourier
transform, and optionally smooths the result with a series of
modified Daniell smoothers (moving averages giving half weight to
the end values).
spec.ar(x, log="no") # parametric spectral estimate
```

and the graph:



Finally, note that R tapers and logs by default, so if you simply want the periodogram of a series, the command is `spec.pgram(x, taper=0, fast=FALSE, detrend=FALSE, log="no")`. If you just asked for `spec.pgram(x)`, you wouldn't get the RAW periodogram because the data are detrended, possibly padded, and tapered in `spec.pgram`, even though the title of the resulting graphic would say *Raw Periodogram*. An easier way to get a raw periodogram is this: `per=abs(fft(x))^2` duh. The moral of this story ... and the bottom line: pay special attention to the defaults of the functions you're using.

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