



Tidy Time Series & Forecasting in R



2. Time series graphics

Outline

- 1 Seasonal plots
- 2 Lab Session 3
- 3 Seasonal or cyclic?
- 4 Lag plots and autocorrelation
- 5 Lab Session 4
- 6 White noise
- 7 Lab Session 5

Outline

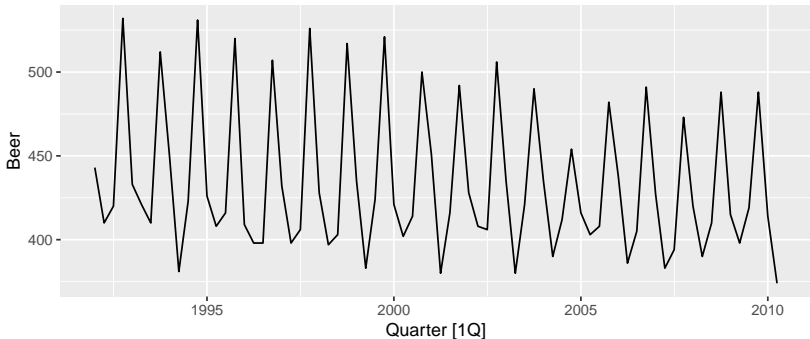
- 1 Seasonal plots
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Seasonal plots

- Data plotted against the individual “seasons” in which the data were observed. (In this case a “season” is a month.)
- Something like a time plot except that the data from each season are overlapped.
- Enables the underlying seasonal pattern to be seen more clearly, and also allows any substantial departures from the seasonal pattern to be easily identified.
- In R: `gg_season()`

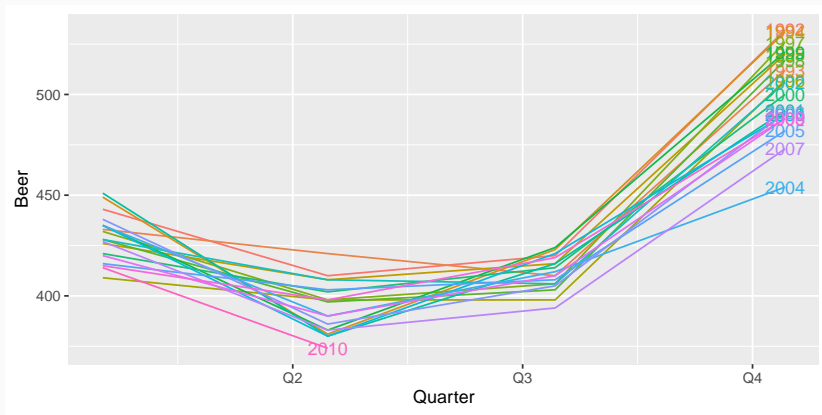
Quarterly Australian Beer Production

```
beer <- aus_production %>%  
  select(Quarter, Beer) %>%  
  filter(year(Quarter) >= 1992)  
beer %>% autoplot(Beer)
```



Quarterly Australian Beer Production

```
beer %>% gg_season(Beer, labels="right")
```



Multiple seasonal periods

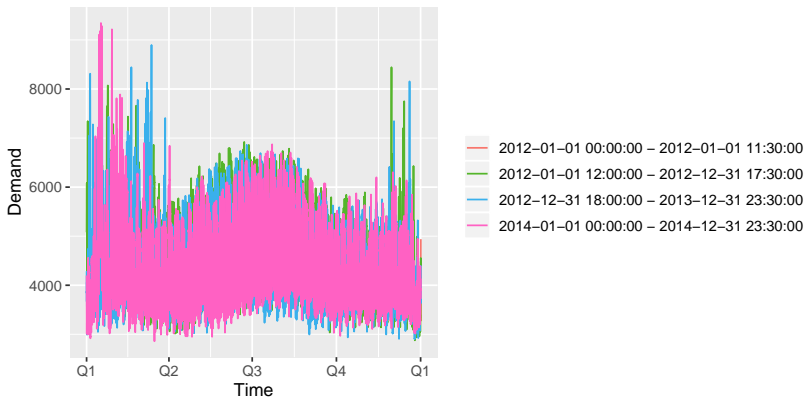
```
vic_elec
```

```
## # A tsibble: 52,608 x 5 [30m] <UTC>
```

##	Time	Demand	Temperature	Date	Holiday
##	<dtm>	<dbl>	<dbl>	<date>	<lgl>
##	1 2012-01-01 00:00:00	4263.	21.0	2012-01-01	TRUE
##	2 2012-01-01 00:30:00	4049.	20.7	2012-01-01	TRUE
##	3 2012-01-01 01:00:00	3878.	20.6	2012-01-01	TRUE
##	4 2012-01-01 01:30:00	4036.	20.4	2012-01-01	TRUE
##	5 2012-01-01 02:00:00	3866.	20.2	2012-01-01	TRUE
##	6 2012-01-01 02:30:00	3694.	20.1	2012-01-01	TRUE
##	7 2012-01-01 03:00:00	3562.	19.6	2012-01-01	TRUE
##	8 2012-01-01 03:30:00	3433.	19.1	2012-01-01	TRUE
##	9 2012-01-01 04:00:00	3359.	19.0	2012-01-01	TRUE
##	10 2012-01-01 04:30:00	3331.	18.8	2012-01-01	TRUE
##	# ... with 52,598 more rows				

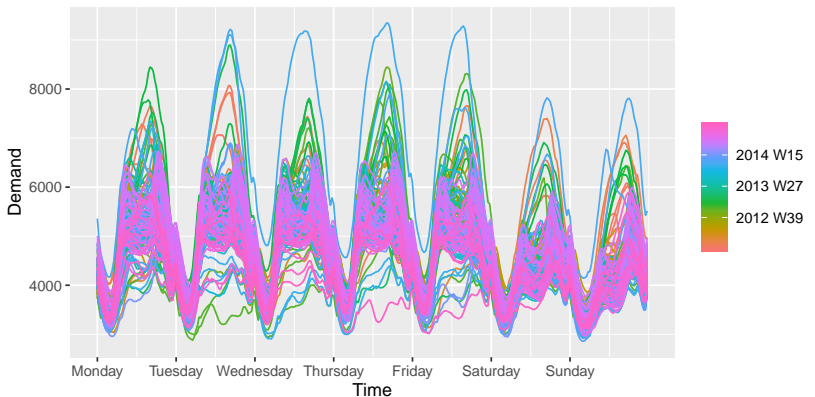
Multiple seasonal periods

```
vic_elec %>% gg_season(Demand)
```



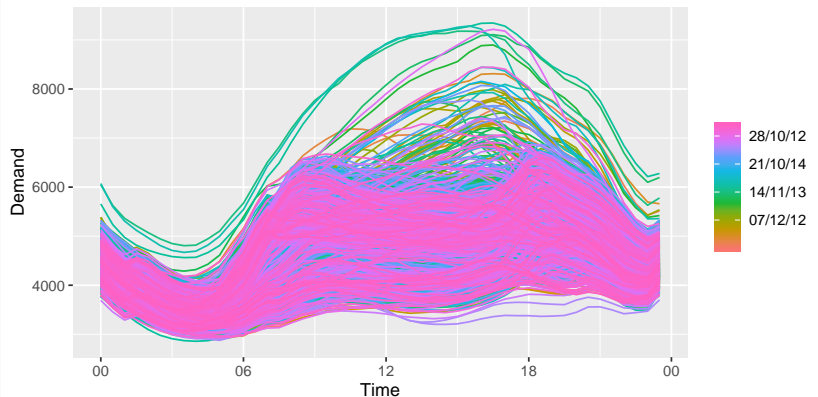
Multiple seasonal periods

```
vic_elec %>% gg_season(Demand, period="week")
```



Multiple seasonal periods

```
vic_elec %>% gg_season(Demand, period="day")
```

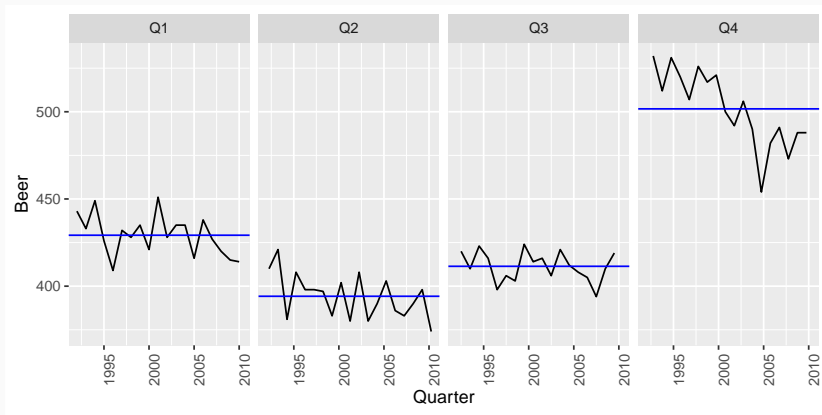


Seasonal subseries plots

- Data for each season collected together in time plot as separate time series.
- Enables the underlying seasonal pattern to be seen clearly, and changes in seasonality over time to be visualized.
- In R: `gg_subseries()`

Quarterly Australian Beer Production

```
beer %>% gg_subseries(Beer)
```



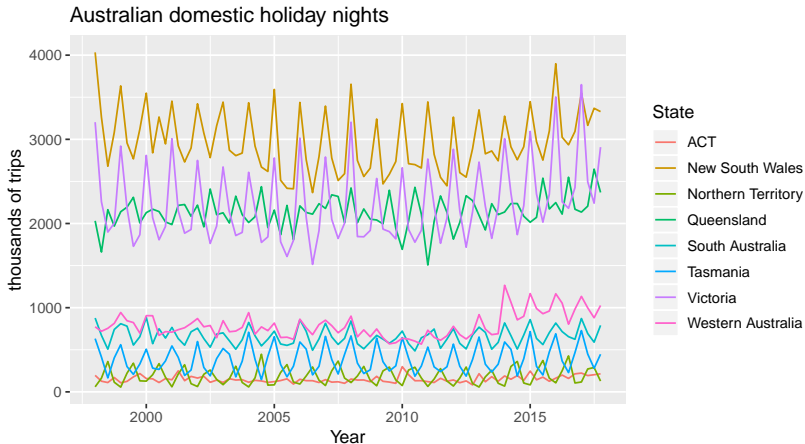
Australian holidays

```
holidays <- tourism %>%  
  filter(Purpose=="Holiday") %>%  
  group_by(State) %>%  
  summarise(Trips = sum(Trips))
```

```
## # A tsibble: 640 x 3 [1Q]  
## # Key:           State [8]  
##   State Quarter Trips  
##   <chr>   <qtr> <dbl>  
## 1 ACT    1998 Q1  196.  
## 2 ACT    1998 Q2  127.  
## 3 ACT    1998 Q3  111.  
## 4 ACT    1998 Q4  170.  
## 5 ACT    1999 Q1  108.  
## 6 ACT    1999 Q2  125.  
## 7 ACT    1999 Q3  178.  
## 8 ACT    1999 Q4  218.  
## 9 ACT    2000 Q1  158.  
## 10 ACT   2000 Q2  155.
```

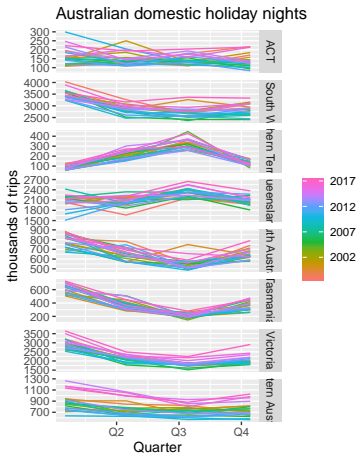
Australian holidays

```
holidays %>% autoplot(Trips) +  
  ylab("thousands of trips") + xlab("Year") +  
  ggtitle("Australian domestic holiday nights")
```



Seasonal plots

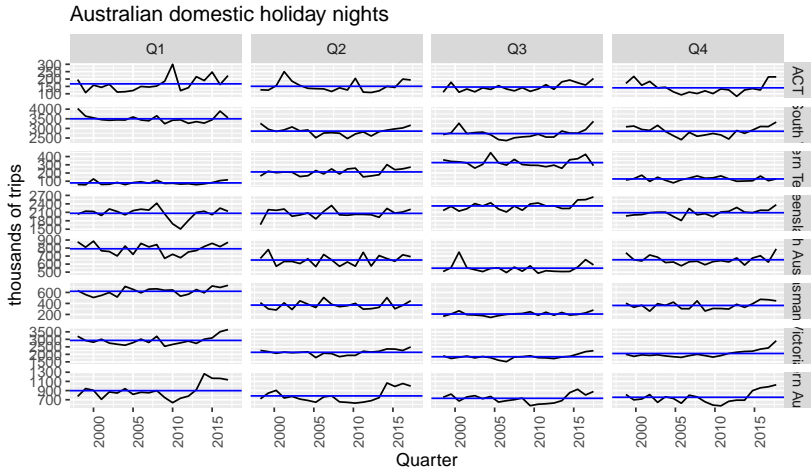
```
holidays %>% gg_season(Trips) +  
  ylab("thousands of trips") +  
  ggtitle("Australian domestic holiday nights")
```



Seasonal subseries plots

holidays %>%

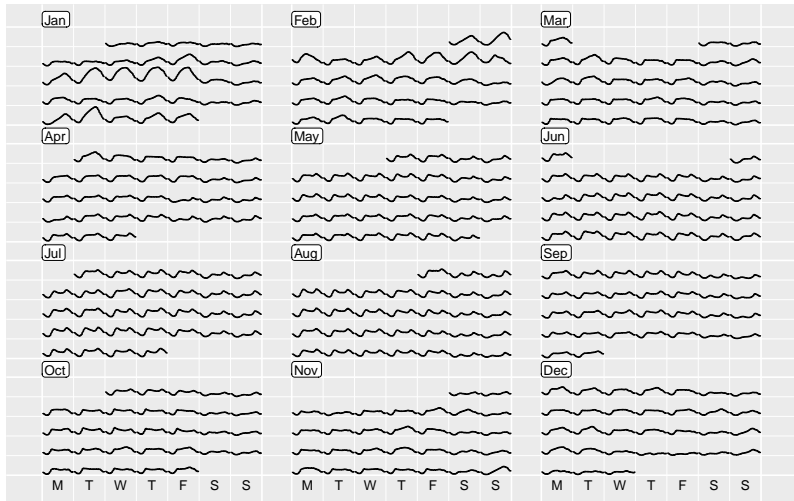
```
gg_subseries(Trips) + ylab("thousands of trips") +  
ggtitle("Australian domestic holiday nights")
```



Calendar plots

```
library(sugrrants)
vic_elec %>%
  filter(year(Date) == 2014) %>%
  mutate(Hour = hour(Time)) %>%
  frame_calendar(x = Hour, y = Demand, date = Date,
    nrow = 4) %>%
  ggplot(aes(x = .Hour, y = .Demand, group = Date)) +
  geom_line() -> p1
prettify(p1, size = 3,
  label.padding = unit(0.15, "lines"))
```

Calendar plots



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Lab Session 3

- 1 Look at the quarterly tourism data for the Snowy Mountains

```
snowy <- filter(tourism,  
  Region == "Snowy Mountains")
```

- ▶ Use `autoplot()`, `gg_season()` and `gg_subseries()` to explore the data.
 - ▶ What do you learn?
- 2 Produce a calendar plot for the pedestrian data from one location and one year.

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Time series patterns

Trend pattern exists when there is a long-term increase or decrease in the data.

Seasonal pattern exists when a series is influenced by seasonal factors (e.g., the quarter of the year, the month, or day of the week).

Cyclic pattern exists when data exhibit rises and falls that are *not of fixed period* (duration usually of at least 2 years).

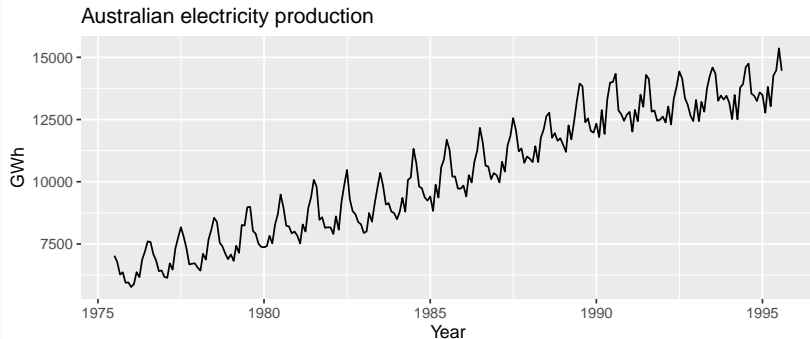
Time series components

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

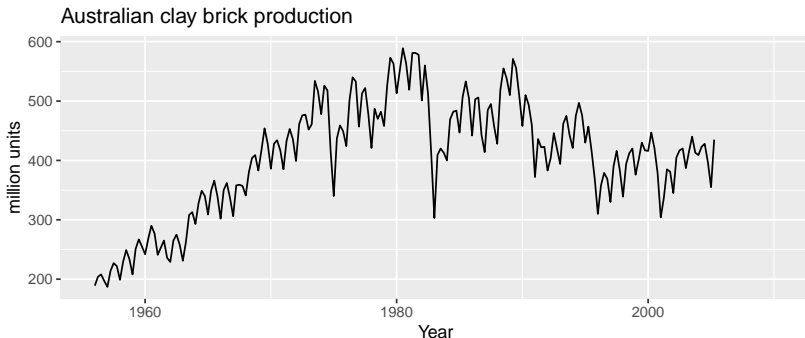
Time series patterns

```
as_tsibble(fma::elec) %>%  
  filter(index >= 1980) %>%  
  autoplot(value) + xlab("Year") + ylab("GWh") +  
  ggtitle("Australian electricity production")
```



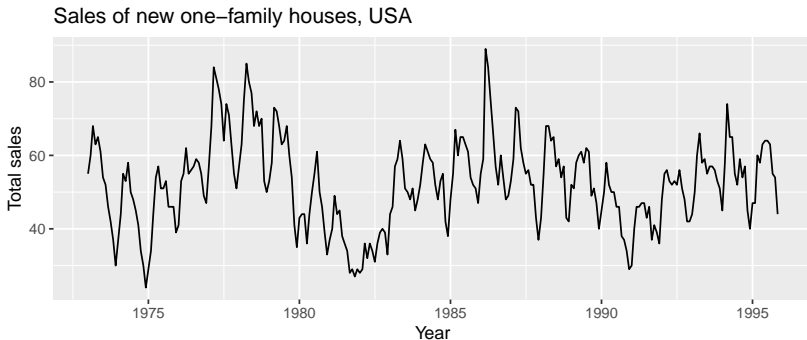
Time series patterns

```
aus_production %>%  
  autoplot(Bricks) +  
  ggtitle("Australian clay brick production") +  
  xlab("Year") + ylab("million units")
```



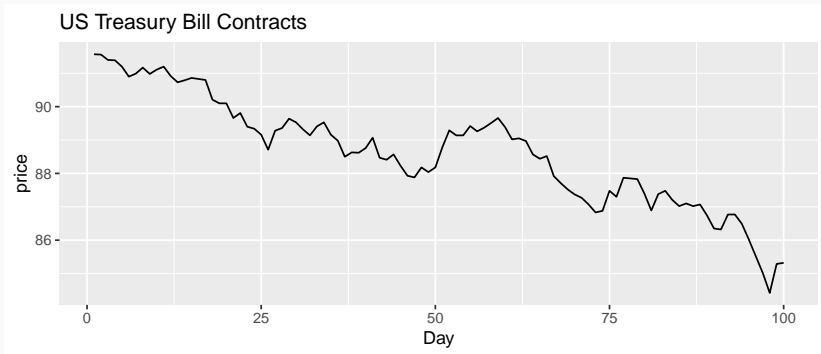
Time series patterns

```
as_tsibble(fma::hsales) %>%  
  autoplot(value) +  
  ggtitle("Sales of new one-family houses, USA") +  
  xlab("Year") + ylab("Total sales")
```



Time series patterns

```
as_tsibble(fma::ustreas) %>%  
  autoplot(value) +  
  ggtitle("US Treasury Bill Contracts") +  
  xlab("Day") + ylab("price")
```



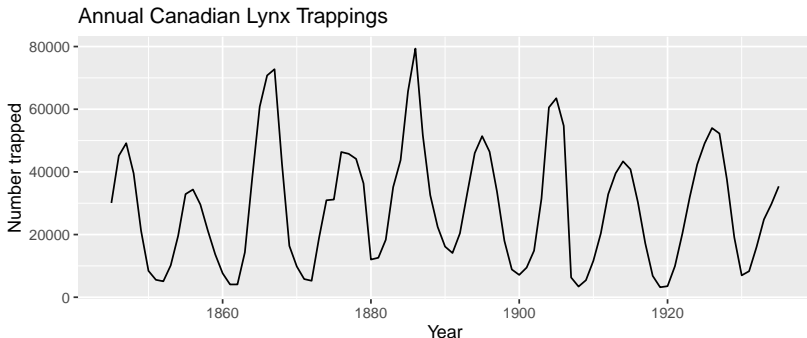
Time series patterns

```
pelt %>%
```

```
  autoplot(Lynx) +
```

```
  ggtitle("Annual Canadian Lynx Trappings") +
```

```
  xlab("Year") + ylab("Number trapped")
```



Seasonal or cyclic?

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

Seasonal or cyclic?

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

The timing of peaks and troughs is predictable with seasonal data, but unpredictable in the long term with cyclic data.

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Example: Beer production

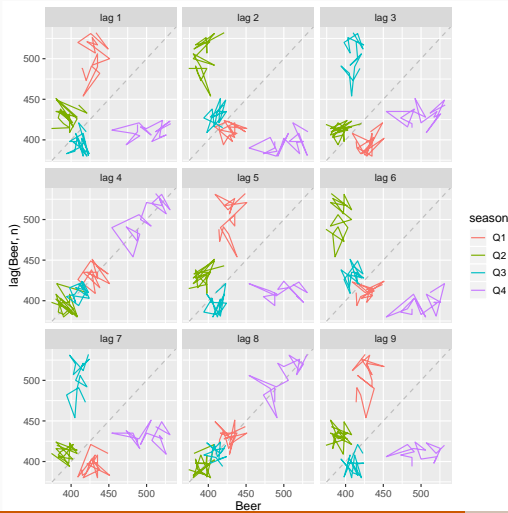
```
new_production <- aus_production %>%  
  filter(year(Quarter) >= 1992)  
new_production
```

```
## # A tsibble: 74 x 7 [1Q]
```

##		Quarter	Beer	Tobacco	Bricks	Cement	Electricity	Gas
##		<qtr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
##	1	1992 Q1	443	5777	383	1289	38332	117
##	2	1992 Q2	410	5853	404	1501	39774	151
##	3	1992 Q3	420	6416	446	1539	42246	175
##	4	1992 Q4	532	5825	420	1568	38498	129
##	5	1993 Q1	433	5724	394	1450	39460	116
##	6	1993 Q2	421	6036	462	1668	41356	149
##	7	1993 Q3	410	6570	475	1648	42949	163
##	8	1993 Q4	512	5675	443	1863	40974	138
##	9	1994 Q1	449	5311	421	1468	40162	127

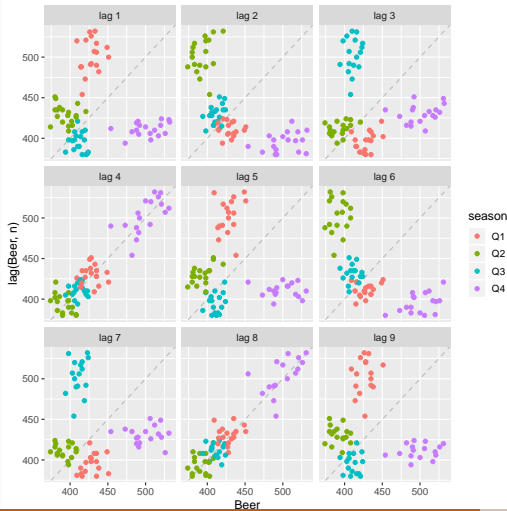
Example: Beer production

```
new_production %>% gg_lag(Beer)
```



Example: Beer production

```
new_production %>% gg_lag(Beer, geom='point')
```



Lagged scatterplots

- Each graph shows y_t plotted against y_{t-k} for different values of k .
- The autocorrelations are the correlations associated with these scatterplots.
- ACF (autocorrelation function):
 - ▶ $r_1 = \text{Correlation}(y_t, y_{t-1})$
 - ▶ $r_2 = \text{Correlation}(y_t, y_{t-2})$
 - ▶ $r_3 = \text{Correlation}(y_t, y_{t-3})$
 - ▶ etc.
- If there is **seasonality**, the ACF at the seasonal lag (e.g., 12 for monthly data) will be **large and positive**.

Autocorrelation

Results for first 9 lags for beer data:

```
new_production %>% ACF(Beer, lag_max = 9)
```

```
## # A tsibble: 9 x 2 [1Q]
```

```
##   lag    acf
```

```
##   <lag>  <dbl>
```

```
## 1     1Q -0.102
```

```
## 2     2Q -0.657
```

```
## 3     3Q -0.0603
```

```
## 4     4Q  0.869
```

```
## 5     5Q -0.0892
```

```
## 6     6Q -0.635
```

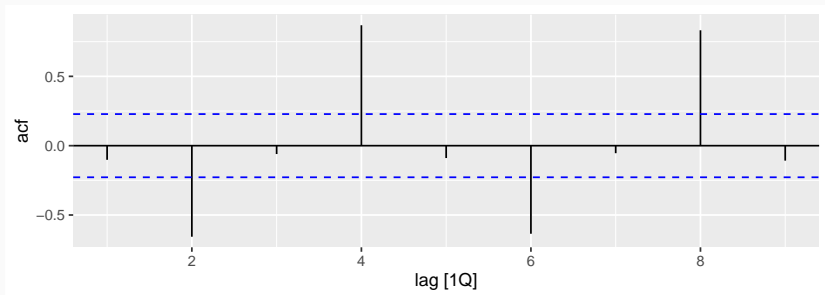
```
## 7     7Q -0.0542
```

```
## 8     8Q  0.832
```

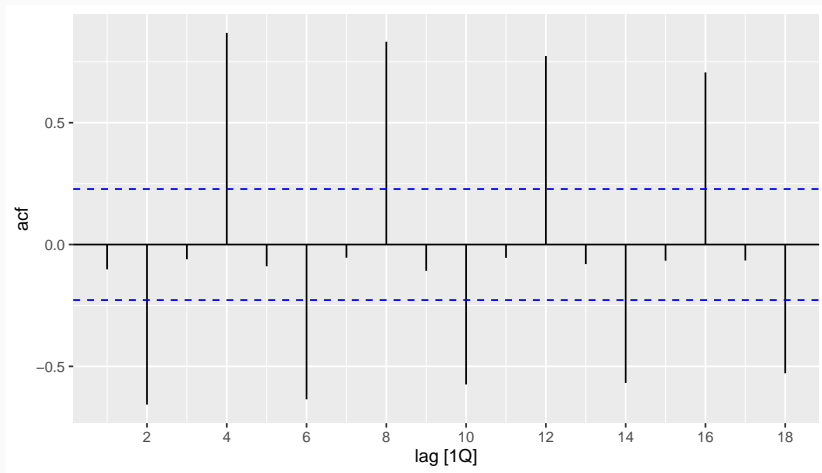
Autocorrelation

Results for first 9 lags for beer data:

```
new_production %>% ACF(Beer, lag_max = 9) %>% autoplot()
```



```
new_production %>% ACF(Beer) %>% autoplot()
```



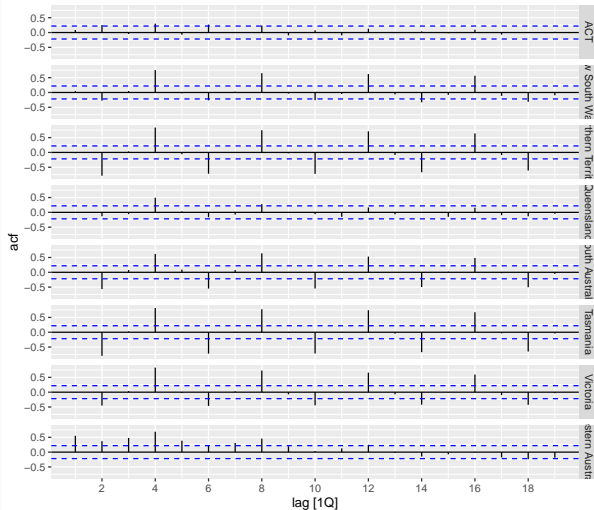
Australian holidays

```
holidays %>% ACF(Trips)
```

```
## # A tsibble: 152 x 3 [1Q]
## # Key:      State [8]
##   State lag      acf
##   <chr> <lag>    <dbl>
## 1 ACT    1Q  0.0877
## 2 ACT    2Q  0.252
## 3 ACT    3Q -0.0496
## 4 ACT    4Q  0.300
## 5 ACT    5Q -0.0741
## 6 ACT    6Q  0.269
## 7 ACT    7Q -0.00504
## 8 ACT    8Q  0.236
## 9 ACT    9Q -0.0953
## 10 ACT   10Q  0.0750
## # ... with 142 more rows
```

Australian holidays

```
holidays %>% ACF(Trips) %>% autoplot()
```

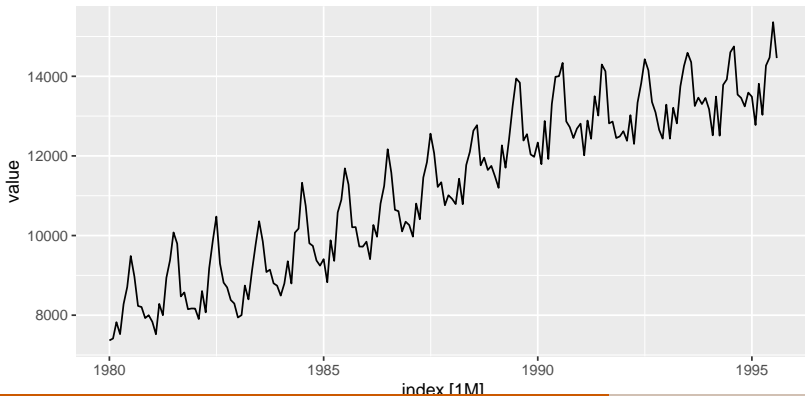


Trend and seasonality in ACF plots

- When data have a trend, the autocorrelations for small lags tend to be large and positive.
- When data are seasonal, the autocorrelations will be larger at the seasonal lags (i.e., at multiples of the seasonal frequency)
- When data are trended and seasonal, you see a combination of these effects.

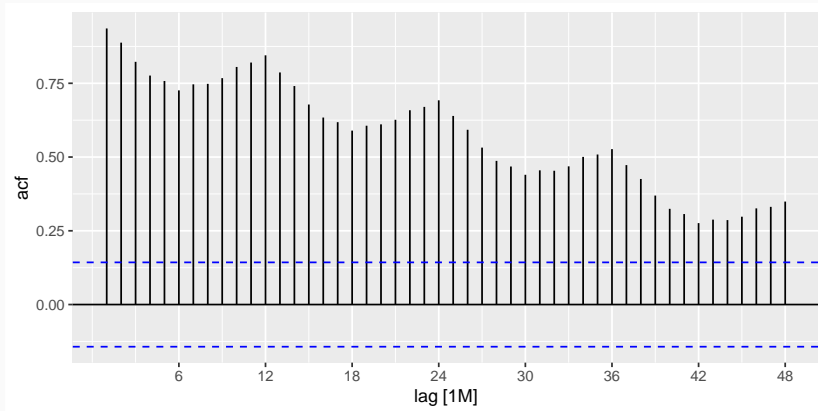
Aus monthly electricity production

```
elec2 <- as_tsibble(fma::elec) %>%  
  filter(year(index) >= 1980)  
elec2 %>% autoplot(value)
```



Aus monthly electricity production

```
elec2 %>% ACF(value, lag_max=48) %>%  
  autoplot()
```



Google stock price

```
google_2015 <- gafa_stock %>%  
  filter(Symbol == "GOOG", year(Date) == 2015) %>%  
  select(Date, Close)  
google_2015
```

```
## # A tsibble: 252 x 2 [!]
```

```
##   Date      Close
```

```
##   <date>    <dbl>
```

```
## 1 2015-01-02  522.
```

```
## 2 2015-01-05  511.
```

```
## 3 2015-01-06  499.
```

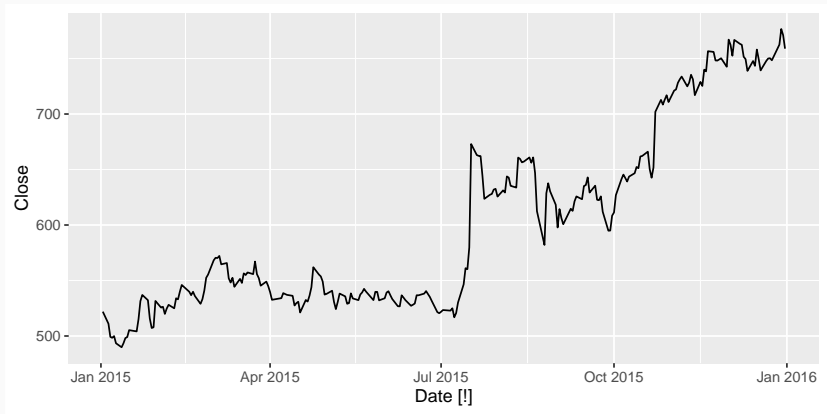
```
## 4 2015-01-07  498.
```

```
## 5 2015-01-08  500.
```

```
## 6 2015-01-09  493.
```

Google stock price

```
google_2015 %>% autoplot(Close)
```



Google stock price

```
google_2015 %>%  
  ACF(Close, lag_max=100)  
# Error: Can't handle tsibble of irregular interval.
```

Google stock price

```
google_2015 %>%  
  ACF(Close, lag_max=100)  
# Error: Can't handle tsibble of irregular interval.
```

```
google_2015
```

```
## # A tsibble: 252 x 2 [!]  
##   Date      Close  
##   <date>    <dbl>  
## 1 2015-01-02  522.  
## 2 2015-01-05  511.  
## 3 2015-01-06  499.
```

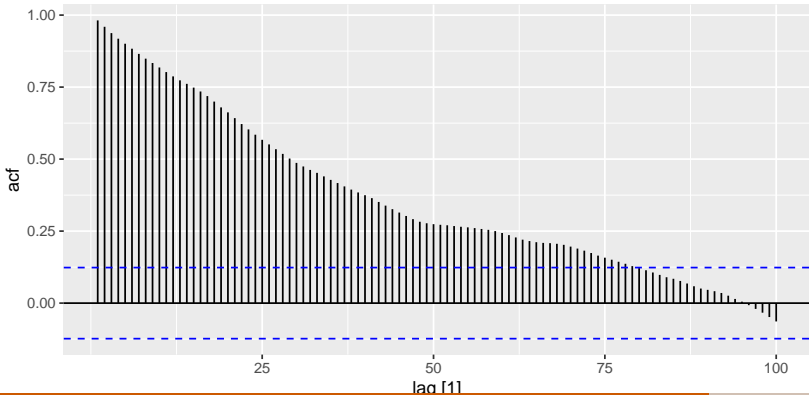
Google stock price

```
google_2015 <- google_2015 %>%  
  mutate(trading_day = row_number()) %>%  
  update_tsibble(index=trading_day, regular=TRUE)  
google_2015
```

```
## # A tsibble: 252 x 3 [1]  
##   Date      Close trading_day  
##   <date>    <dbl>      <int>  
## 1 2015-01-02 522.        1  
## 2 2015-01-05 511.        2  
## 3 2015-01-06 499.        3  
## 4 2015-01-07 498.        4  
## 5 2015-01-08 500.        5  
## 6 2015-01-09 493.        6
```


Google stock price

```
google_2015 %>%  
  ACF(Close, lag_max=100) %>%  
  autoplot()
```



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Lab Session 4

We have introduced the following functions:

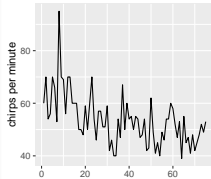
- `gg_lag`
- `ACF`

Explore the following time series using these functions. Can you spot any seasonality, cyclicity and trend? What do you learn about the series?

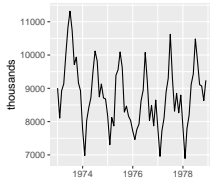
- Bricks from `aus_production`
- Lynx from `pel_t`
- Victorian Electricity Demand from `vic_elec`

Which is which?

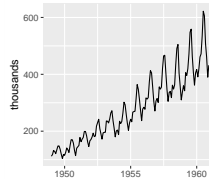
1. Daily temperature of cow



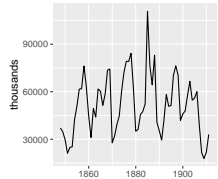
2. Monthly accidental deaths



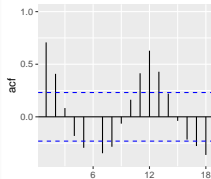
3. Monthly air passengers



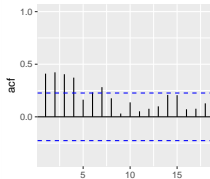
4. Annual mink trappings



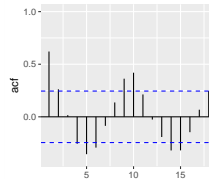
A



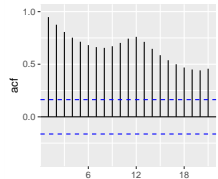
B



C



D

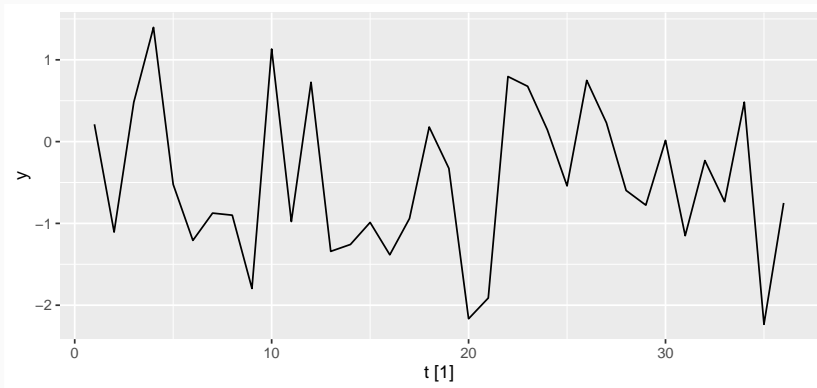


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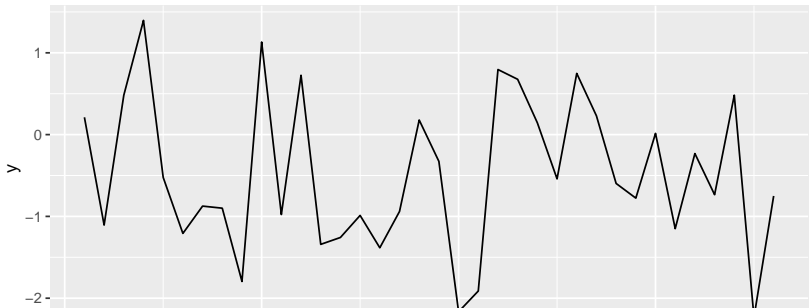
Example: White noise

```
wn <- tsibble(t=seq(36), y=rnorm(36), index=t)  
wn %>% autoplot(y)
```



Example: White noise

```
wn <- tsibble(t=seq(36), y=rnorm(36), index=t)
wn %>% autoplot(y)
```

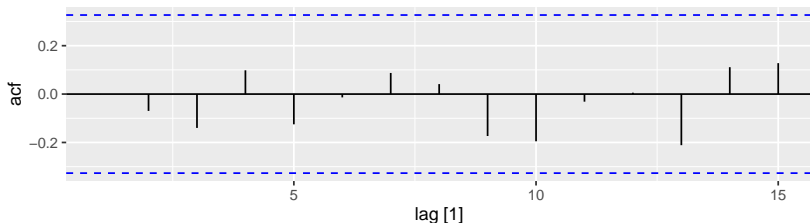


White noise data is uncorrelated across time with zero mean and constant variance.
(Technically, we require independence as well.)

Example: White noise

```
wn %>% ACF(y)
```

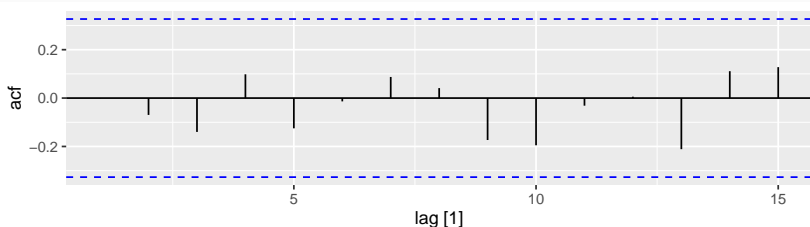
r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}
-0.001	-0.070	-0.140	0.098	-0.125	-0.014	0.087	0.041	-0.173	-0.195



Example: White noise

wn %>% ACF(y)

r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}
-0.001	-0.070	-0.140	0.098	-0.125	-0.014	0.087	0.041	-0.173	-0.195



- Sample autocorrelations for white noise series.
- Expect each autocorrelation to be close to zero.
- Blue lines show 95% critical values.

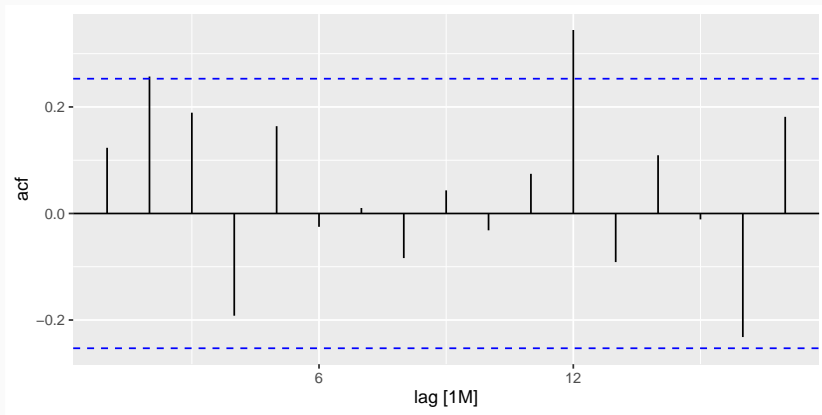
Example: Pigs slaughtered

```
pigs <- aus_livestock %>%  
  filter(State == "Victoria", Animal == "Pigs",  
         year(Month) >= 2014)  
pigs %>% autoplot(Count/1e3) +  
  xlab("Year") + ylab("Thousands") +  
  ggtitle("Number of pigs slaughtered in Victoria")
```



Example: Pigs slaughtered

```
pigs %>% ACF(Count) %>% autoplot()
```



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Monthly total number of pigs slaughtered in the state of Victoria, Australia, from January 2014 through December 2018 (Source: Australian Bureau of Statistics.)

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These show the series is **not a white noise series**.

Outline

- 1 Seasonal plots
- 2 Lab Session 3
- 3 Seasonal or cyclic?
- 4 Lag plots and autocorrelation
- 5 Lab Session 4
- 6 White noise
- 7 Lab Session 5

Lab Session 5

You can compute the daily changes in the Google stock price in 2018 using

```
dgoog <- gafa_stock %>%  
  filter(Symbol == "GOOG", year(Date) >= 2018) %>%  
  mutate(trading_day = row_number()) %>%  
  update_tsibble(index=trading_day, regular=TRUE) %>%  
  mutate(diff = difference(Close))
```

Does `diff` look like white noise?