



# A feast of time series tools



Rob J Hyndman

June 2019

# Outline

- 1 Overview
- 2 Tsibbles
- 3 Graphics
- 4 Decompositions
- 5 Features

# Outline

1 Overview

2 Tsibbles

3 Graphics

4 Decompositions

5 Features



**tsibble**



**tsibbledata**



**feasts**



**Sable**



## Feature Extraction And Statistics for Time Series

- works with tidy temporal data provided by the tsibble package.
- produces time series features, decompositions, statistical summaries and visualisations.

# Outline

1 Overview

2 Tsibbles

3 Graphics

4 Decompositions

5 Features

# tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
## # Key:          Country [263]
##       Year Country      GDP Imports Exports Population
##       <dbl> <fct>         <dbl>   <dbl>   <dbl>         <dbl>
## 1  1960 Afghanistan 5377777811.    7.02    4.13    8996351
## 2  1961 Afghanistan 5488888896.    8.10    4.45    9166764
## 3  1962 Afghanistan 5466666678.    9.35    4.88    9345868
## 4  1963 Afghanistan 7511111191.   16.9     9.17    9533954
## 5  1964 Afghanistan 8000000044.   18.1     8.89    9731361
## 6  1965 Afghanistan 10066666638.  21.4    11.3    9938414
## 7  1966 Afghanistan 13999999967.  18.6     8.57   10152331
## 8  1967 Afghanistan 16733333418.  14.2     6.77   10372630
## 9  1968 Afghanistan 13733333367.  15.2     8.90   10604346
## 10 1969 Afghanistan 14088888922.  15.0    10.1   10854428
## # ... with 15,140 more rows
```

# tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
## # Key:      Country [263]
##   Year Country      GDP Imports Exports Population
##   Index <fct>      <dbl>   <dbl>   <dbl>         <dbl>
## 1 1960 Afghanistan 5377777811.    7.02    4.13    8996351
## 2 1961 Afghanistan 5488888896.    8.10    4.45    9166764
## 3 1962 Afghanistan 5466666678.    9.35    4.88    9345868
## 4 1963 Afghanistan 7511111191.   16.9    9.17    9533954
## 5 1964 Afghanistan 8000000044.   18.1    8.89    9731361
## 6 1965 Afghanistan 10066666638.  21.4   11.3    9938414
## 7 1966 Afghanistan 13999999967.  18.6    8.57   10152331
## 8 1967 Afghanistan 16733333418.  14.2    6.77   10372630
## 9 1968 Afghanistan 13733333367.  15.2    8.90   10604346
## 10 1969 Afghanistan 14088888922.  15.0   10.1   10854428
## # ... with 15,140 more rows
```



# tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
```

```
## # Key:          Country [263]
```

```
##      Year Country      GDP Imports Exports Population
##      Index  Key      <dbl>   <dbl>   <dbl>         <dbl>
##  1  1960 Afghanistan 5377777811.    7.02    4.13    8996351
##  2  1961 Afghanistan 5488888896.    8.10    4.45    9166764
##  3  1962 Afghanistan 5466666678.    9.35    4.88    9345868
##  4  1963 Afghanistan 7511111191.   16.9    9.17    9533954
##  5  1964 Afghanistan 8000000044.   18.1    8.89    9731361
##  6  1965 Afghanistan 10066666638.   21.4   11.3    9938414
##  7  1966 Afghanistan 13999999967.   18.6    8.57   10152331
##  8  1967 Afghanistan 16733333418.   14.2    6.77   10372630
##  9  1968 Afghanistan 13733333367.   15.2    8.90   10604346
## 10  1969 Afghanistan 14088888922.   15.0   10.1   10854428
## # ... with 15,140 more rows
```

# tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
```

```
## # Key:      Country [263]
```

```
##      Year Country      GDP Imports Exports Population
```

```
##      Index  Key      Measured variables
```

```
## 1  1960 Afghanistan 5377777811.    7.02    4.13    8996351
```

```
## 2  1961 Afghanistan 5488888896.    8.10    4.45    9166764
```

```
## 3  1962 Afghanistan 546666678.    9.35    4.88    9345868
```

```
## 4  1963 Afghanistan 7511111191.   16.9    9.17    9533954
```

```
## 5  1964 Afghanistan 8000000044.   18.1    8.89    9731361
```

```
## 6  1965 Afghanistan 1006666638.   21.4   11.3    9938414
```

```
## 7  1966 Afghanistan 1399999967.   18.6    8.57   10152331
```

```
## 8  1967 Afghanistan 1673333418.   14.2    6.77   10372630
```

```
## 9  1968 Afghanistan 1373333367.   15.2    8.90   10604346
```

```
## 10 1969 Afghanistan 1408888922.   15.0   10.1   10854428
```

```
## # ... with 15,140 more rows
```

# tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:           Region, State, Purpose [304]
##   Quarter Region   State Purpose   Trips
##   <qtr> <chr>      <chr> <chr>    <dbl>
## 1 1998 Q1 Adelaide SA      Business 135.
## 2 1998 Q2 Adelaide SA      Business 110.
## 3 1998 Q3 Adelaide SA      Business 166.
## 4 1998 Q4 Adelaide SA      Business 127.
## 5 1999 Q1 Adelaide SA      Business 137.
## 6 1999 Q2 Adelaide SA      Business 200.
## 7 1999 Q3 Adelaide SA      Business 169.
## 8 1999 Q4 Adelaide SA      Business 134.
## 9 2000 Q1 Adelaide SA      Business 154.
## 10 2000 Q2 Adelaide SA      Business 169.
## # ... with 24,310 more rows
```

# tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:           Region, State, Purpose [304]
##   Quarter Region  State Purpose  Trips
##   Index  <chr>    <chr> <chr>    <dbl>
## 1 1998 Q1 Adelaide SA      Business 135.
## 2 1998 Q2 Adelaide SA      Business 110.
## 3 1998 Q3 Adelaide SA      Business 166.
## 4 1998 Q4 Adelaide SA      Business 127.
## 5 1999 Q1 Adelaide SA      Business 137.
## 6 1999 Q2 Adelaide SA      Business 200.
## 7 1999 Q3 Adelaide SA      Business 169.
## 8 1999 Q4 Adelaide SA      Business 134.
## 9 2000 Q1 Adelaide SA      Business 154.
## 10 2000 Q2 Adelaide SA      Business 169.
## # ... with 24,310 more rows
```

# tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:      Region, State, Purpose [304]
##   Quarter Region  State Purpose  Trips
##   Index      Keys      <dbl>
## 1 1998 Q1 Adelaide SA      Business 135.
## 2 1998 Q2 Adelaide SA      Business 110.
## 3 1998 Q3 Adelaide SA      Business 166.
## 4 1998 Q4 Adelaide SA      Business 127.
## 5 1999 Q1 Adelaide SA      Business 137.
## 6 1999 Q2 Adelaide SA      Business 200.
## 7 1999 Q3 Adelaide SA      Business 169.
## 8 1999 Q4 Adelaide SA      Business 134.
## 9 2000 Q1 Adelaide SA      Business 154.
## 10 2000 Q2 Adelaide SA      Business 169.
## # ... with 24,310 more rows
```

# tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
```

```
## # Key:           Region, State, Purpose [304]
```

```
##   Quarter Region State Purpose Trips
```

```
##   Index      Keys      Measure
```

```
## 1 1998 Q1 Adelaide SA      Business 135.
```

```
## 2 1998 Q2 Adelaide SA      Business 110.
```

```
## 3 1998 Q3 Adelaide SA      Business 166.
```

```
## 4 1998 Q4 Adelaide SA      Business 127.
```

```
## 5 1999 Q1 Adelaide SA      Business 137.
```

```
## 6 1999 Q2 Adelaide SA      Business 200.
```

```
## 7 1999 Q3 Adelaide SA      Business 169.
```

```
## 8 1999 Q4 Adelaide SA      Business 134.
```

```
## 9 2000 Q1 Adelaide SA      Business 154.
```

```
## 10 2000 Q2 Adelaide SA      Business 169.
```

```
## # ... with 24,310 more rows
```

# tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
```

```
## # Key:           Region, State, Purpose [304]
```

```
##   Quarter Region State Purpose Trips
```

```
##   Index      Keys      Measure
```

```
## 1 1998 Q1 Adelaide SA      Business 135.
```

```
## 2 1998 Q2 Adelaide SA      Business 110.
```

```
## 3 1998 Q3 Adelaide SA      Business 166.
```

```
## 4 1998 Q4 Adelaide SA      Business 127.
```

```
## 5 1999 Q1 Adelaide SA      Business 137.
```

```
## 6 1999 Q2 Adelaide SA      Business 200.
```

```
## 7 1999 Q3 Adelaide SA      Business 169.
```

```
## 8 1999 Q4 Adelaide SA      Business 134.
```

```
## 9 2000 Q1 Adelaide SA      Business 154.
```

```
## 10 2000 Q2 Adelaide SA      Business 169.
```

```
## # ... with 24,310 more rows
```

Domestic visitor  
nights in thousands  
by state/region and  
purpose.

# Holidays by state

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

```
## # A tsibble: 640 x 3 [1Q]  
## # Key:      State [8]  
##   Quarter State Trips  
##   <qtr> <chr> <dbl>  
## 1 1998 Q1 ACT    183.  
## 2 1998 Q2 ACT    172.  
## 3 1998 Q3 ACT    173.  
## 4 1998 Q4 ACT    146.  
## 5 1999 Q1 ACT    162.  
## 6 1999 Q2 ACT    165.  
## 7 1999 Q3 ACT    151.  
## 8 1999 Q4 ACT    200.  
## 9 2000 Q1 ACT    279.  
## 10 2000 Q2 ACT    157.
```

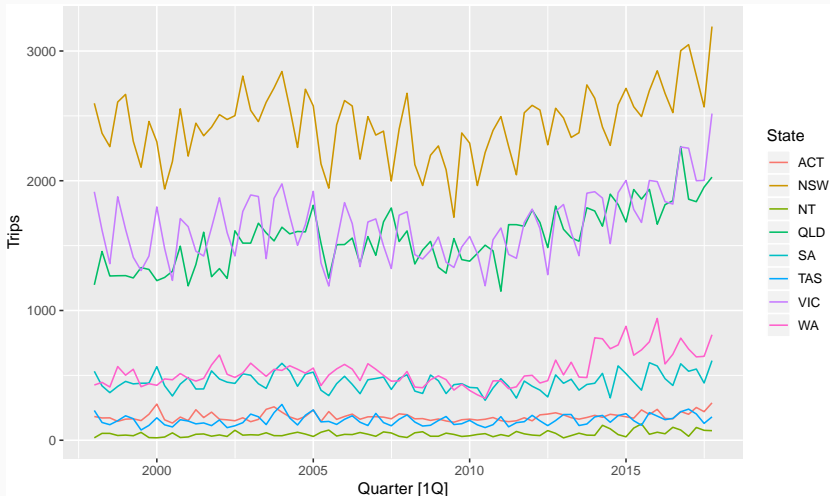


# Outline

- 1 Overview
- 2 Tsibbles
- 3 Graphics**
- 4 Decompositions
- 5 Features

# Time plots

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



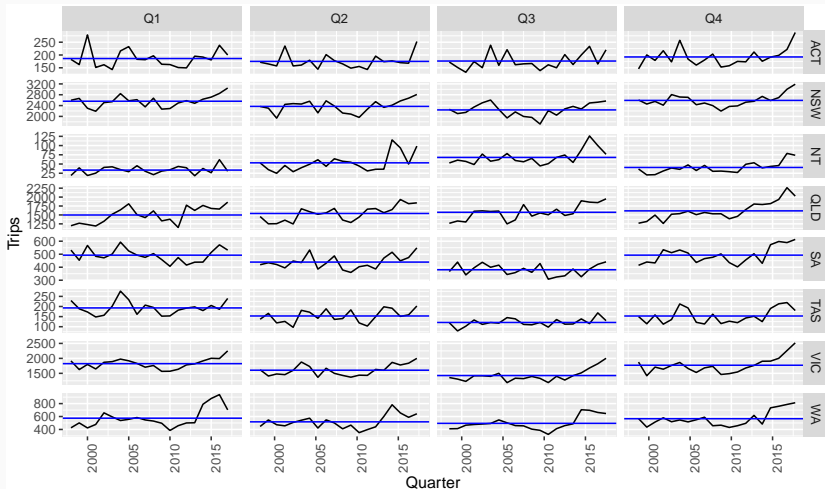
# Season plots

```
holidays %>% gg_season(Trips)
```



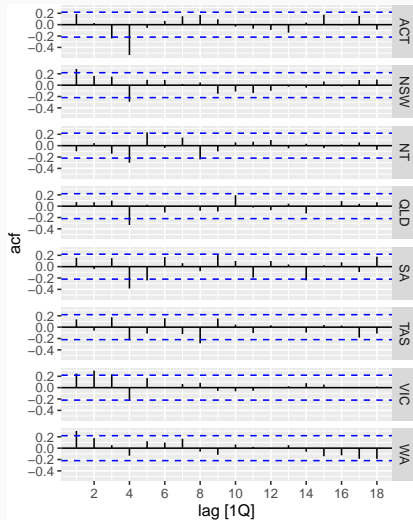
# Graphics

```
holidays %>% gg_subseries(Trips)
```



# Graphics

```
holidays %>% ACF(difference(Trips, 4)) %>% autoplot()
```



# Outline

- 1 Overview
- 2 Tsibbles
- 3 Graphics
- 4 Decompositions**
- 5 Features

# Decompositions

The feasts package supports four common time series decomposition methods:

- Classical decomposition
- STL decomposition
- X11 decomposition
- X-13ARIMA-SEATS decomposition

# Decompositions

```
holidays %>% STL(Trips ~ season(window = "periodic")) %>%  
autoplot()
```





# Outline

- 1 Overview
- 2 Tsibbles
- 3 Graphics
- 4 Decompositions
- 5 Features

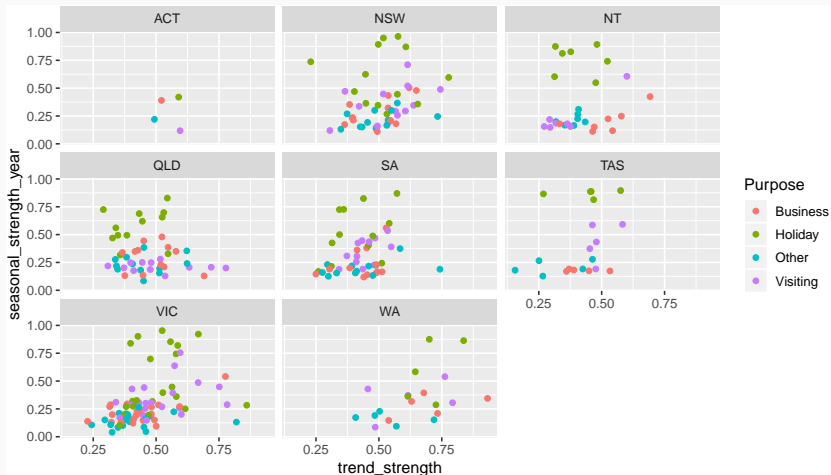
# Feature extraction and statistics

```
tourism %>% features(Trips, feature_set(tags="stl"))
```

```
## # A tibble: 304 x 10
##   Region State Purpose trend_strength seasonal_streng~
##   <chr>   <chr> <chr>          <dbl>          <dbl>
## 1 Adela~ SA     Busine~         0.451          0.380
## 2 Adela~ SA     Holiday        0.541          0.601
## 3 Adela~ SA     Other          0.743          0.189
## 4 Adela~ SA     Visiti~         0.433          0.446
## 5 Adela~ SA     Busine~         0.453          0.140
## 6 Adela~ SA     Holiday        0.512          0.244
## 7 Adela~ SA     Other          0.584          0.374
## 8 Adela~ SA     Visiti~         0.481          0.228
## 9 Alice~ NT     Busine~         0.526          0.224
## 10 Alice~ NT     Holiday        0.377          0.827
## # ... with 294 more rows, and 5 more variables:
## #   spikiness <dbl>, linearity <dbl>, curvature <dbl>,
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>
```

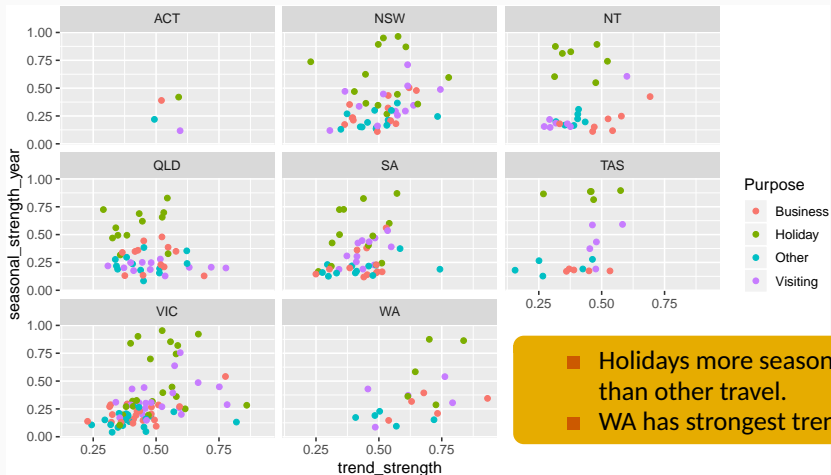
# Feature extraction and statistics

```
tourism %>% features(Trips, feature_set(tags=c("stl"))) %>%  
ggplot(aes(x=trend_strength, y=seasonal_strength_year, col=Purpose)) +  
  geom_point() + facet_wrap(vars(State))
```



# Feature extraction and statistics

```
tourism %>% features(Trips, feature_set(tags=c("stl"))) %>%  
ggplot(aes(x=trend_strength, y=seasonal_strength_year, col=Purpose)) +  
  geom_point() + facet_wrap(vars(State))
```



- Holidays more seasonal than other travel.
- WA has strongest trends.

# Feature extraction and statistics

Find the most seasonal time series:

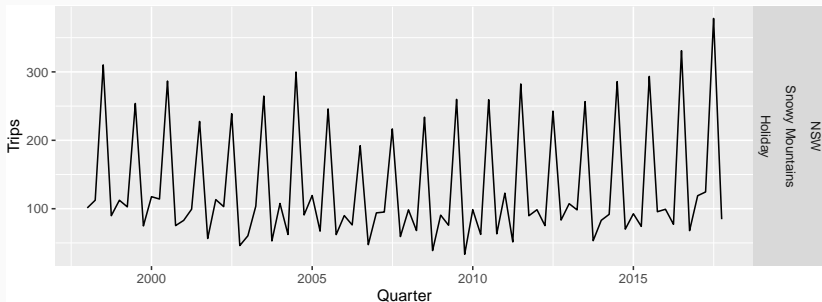
```
most_seasonal <- tourism %>%  
  features(Trips, feature_set(tags="stl")) %>%  
  filter(seasonal_strength_year == max(seasonal_strength_year))
```

# Feature extraction and statistics

Find the most seasonal time series:

```
most_seasonal <- tourism %>%  
  features(Trips, feature_set(tags="stl")) %>%  
  filter(seasonal_strength_year == max(seasonal_strength_year))
```

```
tourism %>%  
  right_join(most_seasonal, by = c("State", "Region", "Purpose")) %>%  
  ggplot(aes(x = Quarter, y = Trips)) + geom_line() +  
  facet_grid(vars(State, Region, Purpose))
```



# Feature extraction and statistics

```
tourism_features <- tourism %>%  
  features(Trips, feature_set(pkgs="feasts"))
```

All features from  
the feasts  
package

```
## # A tibble: 304 x 45  
##   Region State Purpose trend_strength seasonal_strength  
##   <chr> <chr> <chr>          <dbl>          <dbl>  
## 1 Adela~ SA     Busine~          0.451          0.380  
## 2 Adela~ SA     Holiday        0.541          0.601  
## 3 Adela~ SA     Other          0.743          0.189  
## 4 Adela~ SA     Visiti~          0.433          0.446  
## 5 Adela~ SA     Busine~          0.453          0.140  
## 6 Adela~ SA     Holiday        0.512          0.244  
## 7 Adela~ SA     Other          0.584          0.374  
## 8 Adela~ SA     Visiti~          0.481          0.228  
## 9 Alice~ NT     Busine~          0.526          0.224  
## 10 Alice~ NT     Holiday        0.377          0.827  
## # ... with 294 more rows, and 40 more variables:  
## #   spikiness <dbl>, linearity <dbl>, curvature <dbl>,  
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>,  
## #   acf1 <dbl>, acf10 <dbl>, diff1_acf1 <dbl>,  
## #   diff1_acf10 <dbl>, diff2_acf1 <dbl>, diff2_acf10 <dbl>,  
## #   ...
```

# Feature extraction and statistics

```
pcs <- tourism_features %>% select(-State, -Region, -Purpose) %>%  
  prcomp(scale=TRUE) %>% augment(tourism_features)
```

```
## # A tibble: 304 x 88  
##   .rownames Region State Purpose trend_strength  
##   <fct>      <chr> <chr> <chr>          <dbl>  
## 1 1        Adela~ SA    Busine~      0.451  
## 2 2        Adela~ SA    Holiday     0.541  
## 3 3        Adela~ SA    Other       0.743  
## 4 4        Adela~ SA    Visiti~     0.433  
## 5 5        Adela~ SA    Busine~     0.453  
## 6 6        Adela~ SA    Holiday     0.512  
## 7 7        Adela~ SA    Other       0.584  
## 8 8        Adela~ SA    Visiti~     0.481  
## 9 9        Alice~ NT    Busine~     0.526  
## 10 10       Alice~ NT    Holiday     0.377  
## # ... with 294 more rows, and 83 more variables:  
## #   seasonal_strength_year <dbl>, spikiness <dbl>,  
## #   linearity <dbl>, curvature <dbl>,  
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>,  
## #   acf1 <dbl>, acf10 <dbl>, diff1_acf1 <dbl>,  
## #   diff2_acf1 <dbl>, diff3_acf1 <dbl>, diff4_acf1 <dbl>,  
## #   diff5_acf1 <dbl>, diff6_acf1 <dbl>, diff7_acf1 <dbl>,  
## #   diff8_acf1 <dbl>, diff9_acf1 <dbl>, diff10_acf1 <dbl>,  
## #   diff11_acf1 <dbl>, diff12_acf1 <dbl>, diff13_acf1 <dbl>,  
## #   diff14_acf1 <dbl>, diff15_acf1 <dbl>, diff16_acf1 <dbl>,  
## #   diff17_acf1 <dbl>, diff18_acf1 <dbl>, diff19_acf1 <dbl>,  
## #   diff20_acf1 <dbl>, diff21_acf1 <dbl>, diff22_acf1 <dbl>,  
## #   diff23_acf1 <dbl>, diff24_acf1 <dbl>, diff25_acf1 <dbl>,  
## #   diff26_acf1 <dbl>, diff27_acf1 <dbl>, diff28_acf1 <dbl>,  
## #   diff29_acf1 <dbl>, diff30_acf1 <dbl>, diff31_acf1 <dbl>,  
## #   diff32_acf1 <dbl>, diff33_acf1 <dbl>, diff34_acf1 <dbl>,  
## #   diff35_acf1 <dbl>, diff36_acf1 <dbl>, diff37_acf1 <dbl>,  
## #   diff38_acf1 <dbl>, diff39_acf1 <dbl>, diff40_acf1 <dbl>,  
## #   diff41_acf1 <dbl>, diff42_acf1 <dbl>, diff43_acf1 <dbl>,  
## #   diff44_acf1 <dbl>, diff45_acf1 <dbl>, diff46_acf1 <dbl>,  
## #   diff47_acf1 <dbl>, diff48_acf1 <dbl>, diff49_acf1 <dbl>,  
## #   diff50_acf1 <dbl>, diff51_acf1 <dbl>, diff52_acf1 <dbl>,  
## #   diff53_acf1 <dbl>, diff54_acf1 <dbl>, diff55_acf1 <dbl>,  
## #   diff56_acf1 <dbl>, diff57_acf1 <dbl>, diff58_acf1 <dbl>,  
## #   diff59_acf1 <dbl>, diff60_acf1 <dbl>, diff61_acf1 <dbl>,  
## #   diff62_acf1 <dbl>, diff63_acf1 <dbl>, diff64_acf1 <dbl>,  
## #   diff65_acf1 <dbl>, diff66_acf1 <dbl>, diff67_acf1 <dbl>,  
## #   diff68_acf1 <dbl>, diff69_acf1 <dbl>, diff70_acf1 <dbl>,  
## #   diff71_acf1 <dbl>, diff72_acf1 <dbl>, diff73_acf1 <dbl>,  
## #   diff74_acf1 <dbl>, diff75_acf1 <dbl>, diff76_acf1 <dbl>,  
## #   diff77_acf1 <dbl>, diff78_acf1 <dbl>, diff79_acf1 <dbl>,  
## #   diff80_acf1 <dbl>, diff81_acf1 <dbl>, diff82_acf1 <dbl>,  
## #   diff83_acf1 <dbl>
```

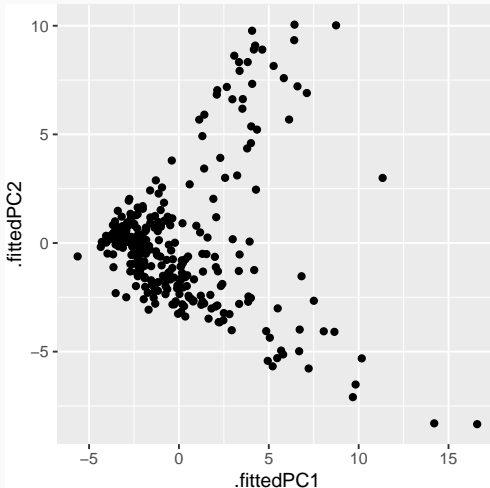
Principal  
components  
based on all  
features from the  
feasts package



# Feature extraction and statistics

```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2)) +  
  geom_point() + theme(aspect.ratio=1)
```

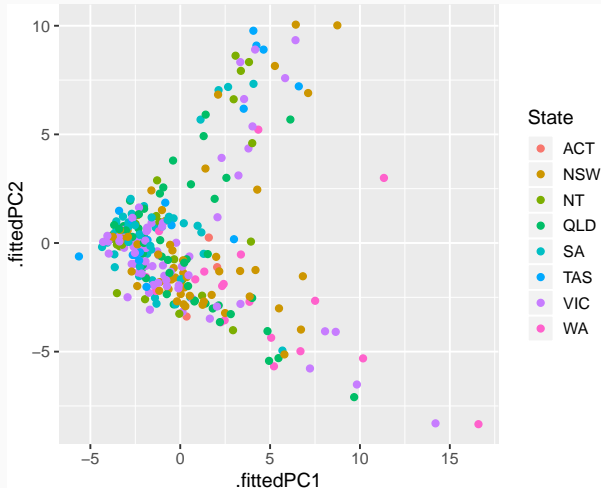
Principal components  
based on all features  
from the feasts  
package



# Feature extraction and statistics

```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2, col=State)) +  
  geom_point() + theme(aspect.ratio=1)
```

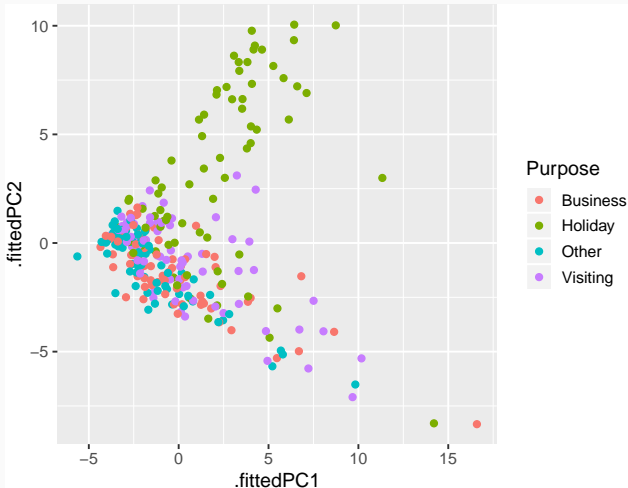
Principal components  
based on all features  
from the feasts  
package



# Feature extraction and statistics

```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2, col=Purpose)) +  
  geom_point() + theme(aspect.ratio=1)
```

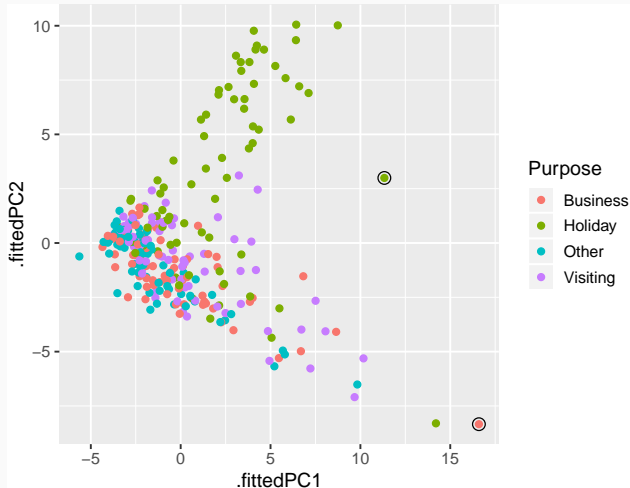
Principal components  
based on all features  
from the feasts  
package



# Feature extraction and statistics

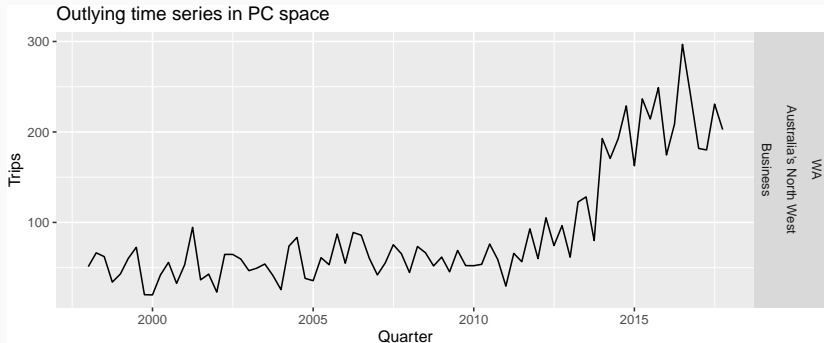
```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2, col=Purpose)) +  
  geom_point() + theme(aspect.ratio=1)
```

Principal components  
based on all features  
from the feasts  
package



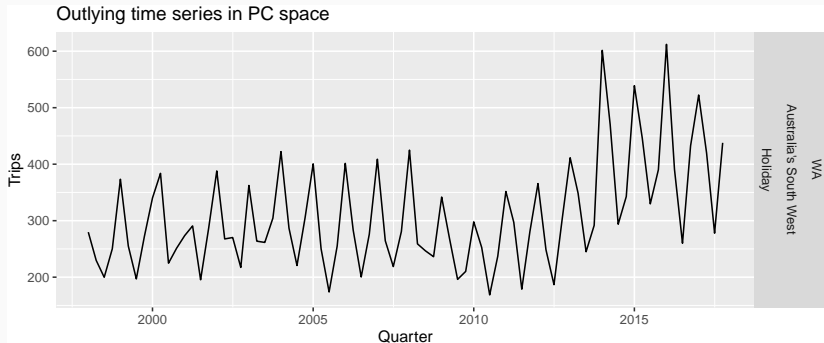
# Feature extraction and statistics

```
pcs %>%  
  filter(.fittedPC1 == max(.fittedPC1)) %>%  
  left_join(tourism, by = c("State", "Region", "Purpose")) %>%  
  ggplot(aes(x = Quarter, y = Trips)) +  
    geom_line() +  
    facet_grid(vars(State, Region, Purpose)) +  
    ggtitle("Outlying time series in PC space") +  
    theme(legend.position = "none")
```



# Feature extraction and statistics

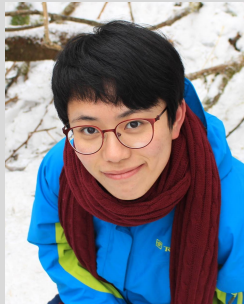
```
pcs %>%  
  filter(.fittedPC1 > 10 & .fittedPC2 > 2.5) %>%  
  left_join(tourism, by = c("State", "Region", "Purpose")) %>%  
  ggplot(aes(x = Quarter, y = Trips)) +  
    geom_line() +  
    facet_grid(vars(State, Region, Purpose)) +  
    ggtitle("Outlying time series in PC space") +  
    theme(legend.position = "none")
```



# Acknowledgements



Mitchell O'Hara-Wild



Earo Wang

**[feasts.tidyverts.org](https://feasts.tidyverts.org)**  
**[robjhyndman.com](https://robjhyndman.com)**

# Acknowledgements



Mitchell O'Hara-Wild



Earo Wang

**[feasts.tidyverts.org](https://feasts.tidyverts.org)**  
**[robjhyndman.com](https://robjhyndman.com)**

Monash Uni is now hiring in business analytics.  
See **[bit.ly/monash-ba](https://bit.ly/monash-ba)** for details.