Outline

Outline

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

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  537777811.    7.02    4.13    8996351
## 2  1961 Afghanistan  548888896.    8.10    4.45    9166764
## 3  1962 Afghanistan  546666678.    9.35    4.88    9345868
## 4  1963 Afghanistan  751111191.   16.9     9.17    9533954
## 5  1964 Afghanistan  800000044.   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

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  537777811.    7.02    4.13    8996351
##  2  1961 Afghanistan  548888896.    8.10    4.45    9166764
##  3  1962 Afghanistan  546666678.    9.35    4.88    9345868
##  4  1963 Afghanistan  751111191.   16.9     9.17    9533954
##  5  1964 Afghanistan  800000044.   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

```
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  537777811.    7.02    4.13    8996351
##  2  1961 Afghanistan  548888896.    8.10    4.45    9166764
##  3  1962 Afghanistan  546666678.    9.35    4.88    9345868
##  4  1963 Afghanistan  751111191.   16.9     9.17    9533954
##  5  1964 Afghanistan  800000044.   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

```
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  537777811.    7.02    4.13    8996351
##  2  1961 Afghanistan  548888896.    8.10    4.45    9166764
##  3  1962 Afghanistan  546666678.    9.35    4.88    9345868
##  4  1963 Afghanistan  751111191.   16.9     9.17    9533954
##  5  1964 Afghanistan  800000044.   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
```

8

tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:        Region, State, Purpose [304]
##    Quarter Region    State Purpose  Trips
##                                          <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
```

Index

Keys

tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:       Region, State, Purpose [304]
##    Quarter Region    State Purpose  Trips
##
##  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
```

Index Keys Measure

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

```r
holidays <- tourism %>%
  filter(Purpose=="Holiday") %>%
  group_by(State) %>%
  summarise(Trips = sum(Trips))
```
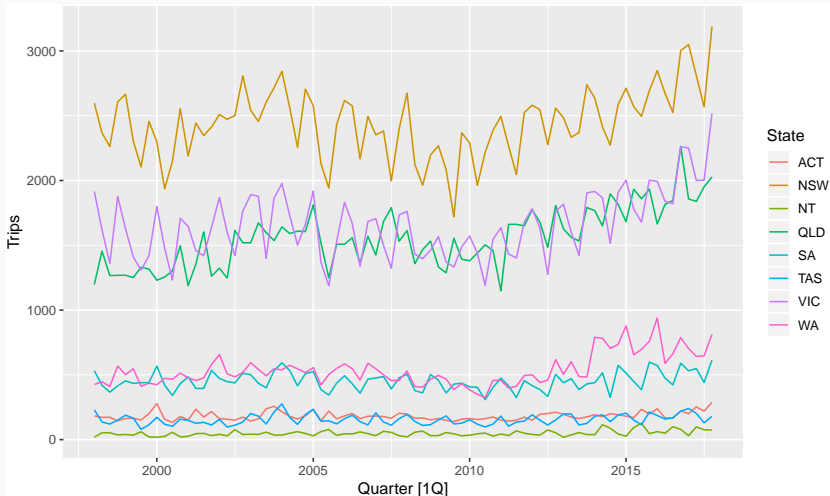
```
## # A tsibble: 640 x 3 [1Q]
## # Key:        State [8]
##     Quarter State Trips
##       <qtr> <chr> <dbl>
##  1 1998 Q1 ACT     183.
##  2 1998 Q2 ACT     172.
##  3 1998 Q3 ACT     173.
##  4 1998 Q4 ACT     146.
##  5 1999 Q1 ACT     162.
##  6 1999 Q2 ACT     165.
##  7 1999 Q3 ACT     151.
##  8 1999 Q4 ACT     200.
##  9 2000 Q1 ACT     279.
## 10 2000 Q2 ACT     157.
```

Outline

Time plots

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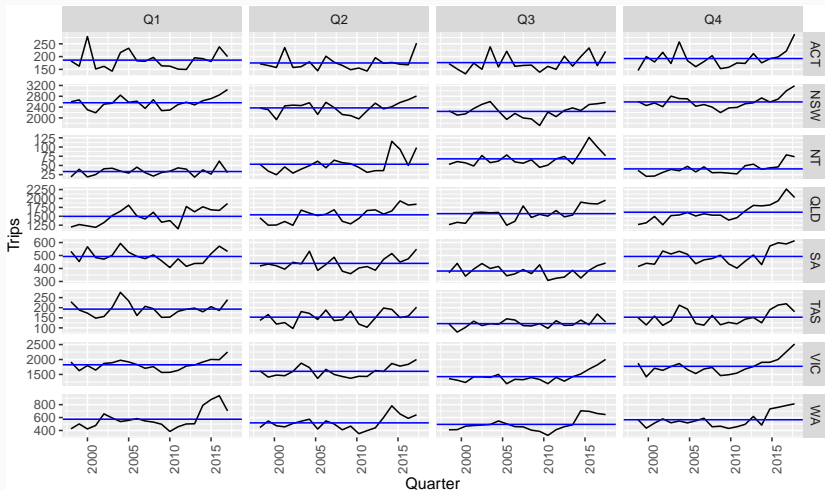
Season plots

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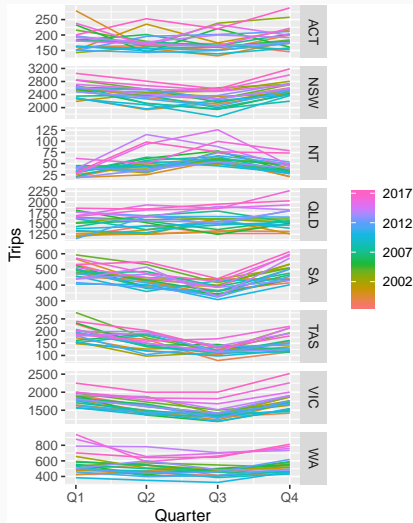
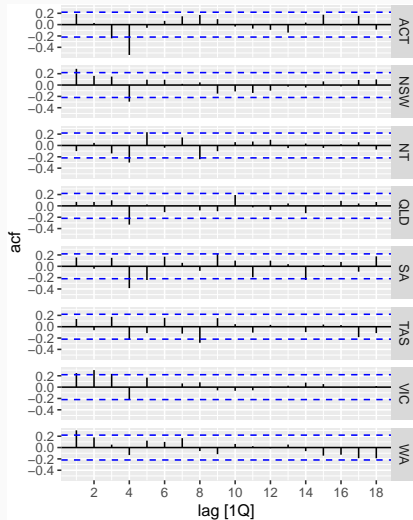# Graphics

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

Graphics

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

Outline

15

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()
```


STL decomposition
Trips = trend + season_year + remainder
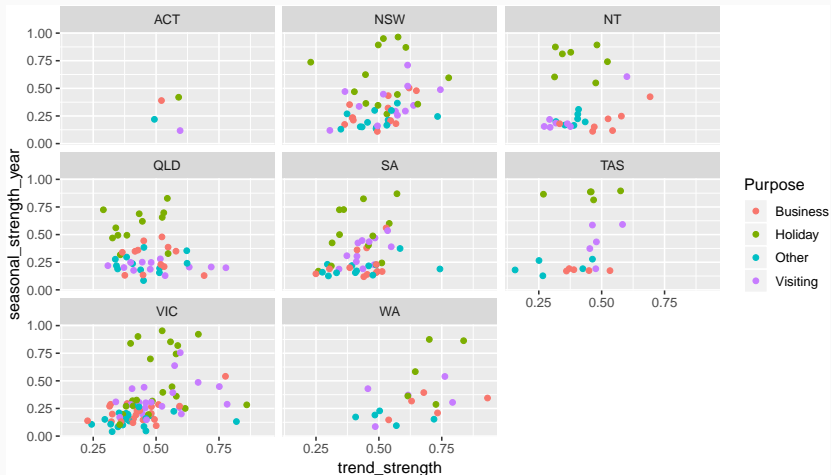
Outline

Feature extraction and statistics

```
tourism %>% features(Trips, features_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:
## #   spike <dbl>, linearity <dbl>, curvature <dbl>,
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>
```
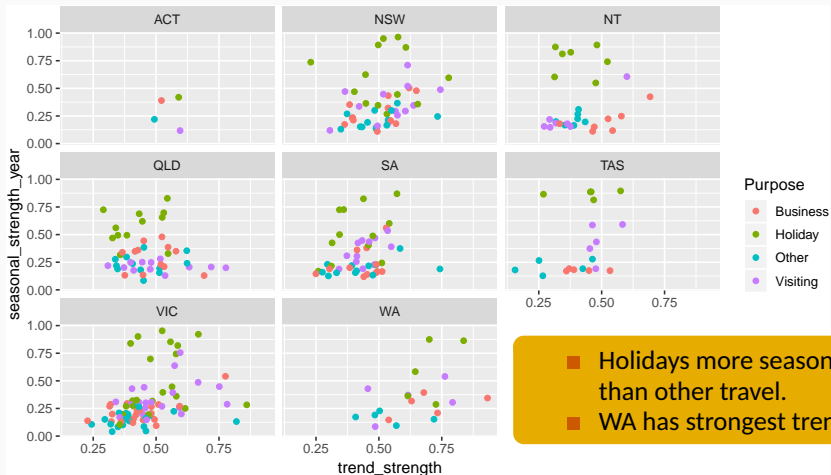
Feature extraction and statistics

```
tourism %>% features(Trips, features_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, features_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, features_stl) %>%
  filter(seasonal_strength_year == max(seasonal_strength_year))
```

Feature extraction and statistics

Find the most seasonal time series:

```
most_seasonal <- tourism %>%
  features(Trips, features_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))
```
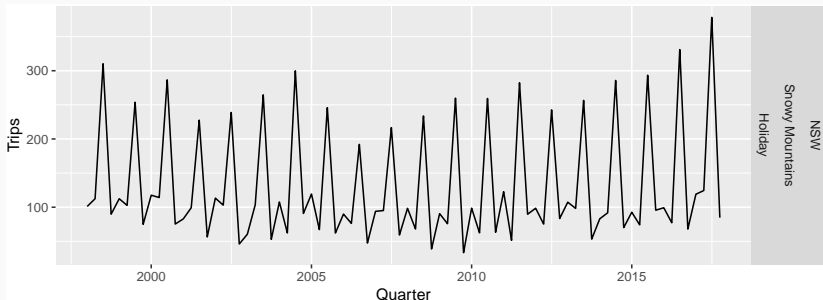
Feature extraction and statistics

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

All features from
the feasts
package

```
## # A tibble: 304 x 21
##    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 16 more variables:
## #   spike <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 40
##    .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 35 more variables:
## #   seasonal_strength_year <dbl>, spike <dbl>,
## #   linearity <dbl>, curvature <dbl>,
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>,
## #   acf1 <dbl>, acf10 <dbl>, diff1_acf1 <dbl>,
```
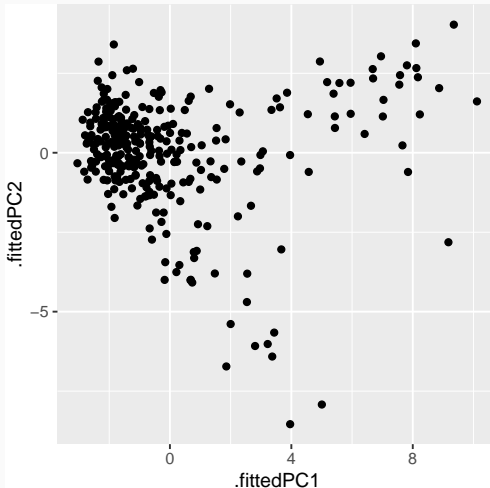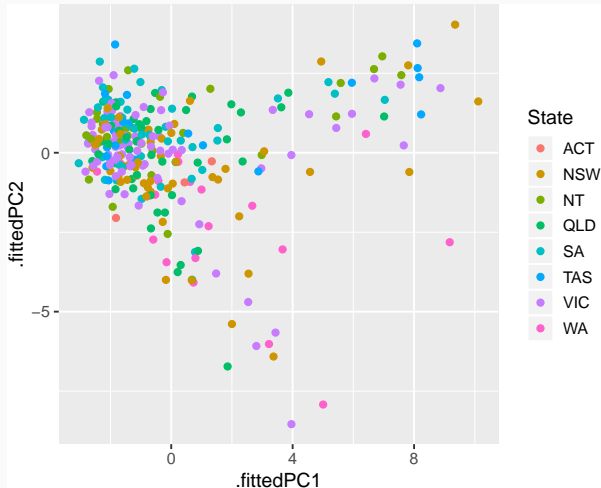
> Principal components based on all features from the feasts package

23

Feature extraction and statistics

```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2)) +
  geom_point() + theme(aspect.ratio=1)
```
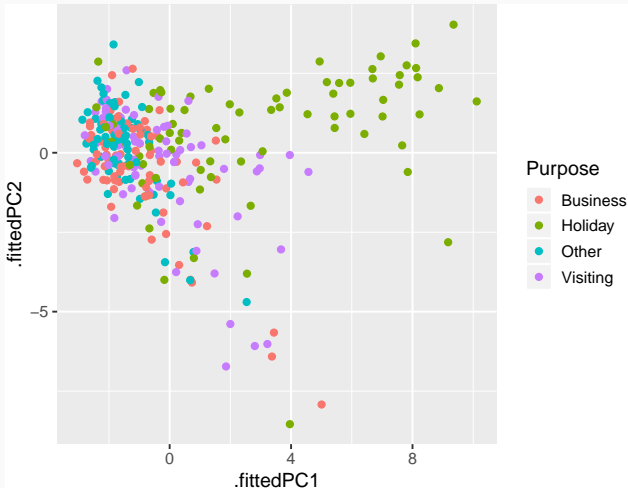
Principal components based on all features from the feasts package

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
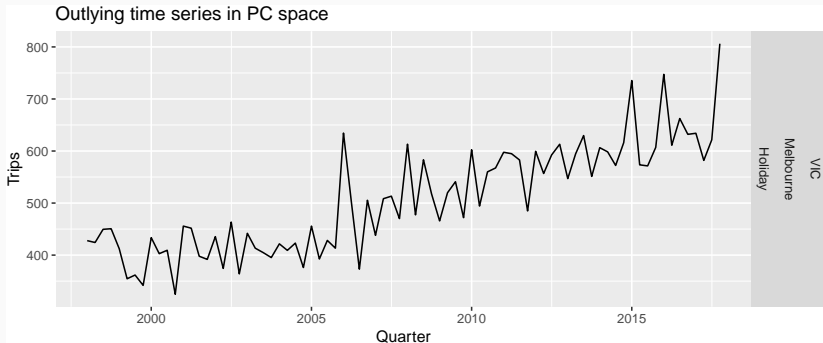
Feature extraction and statistics

```
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
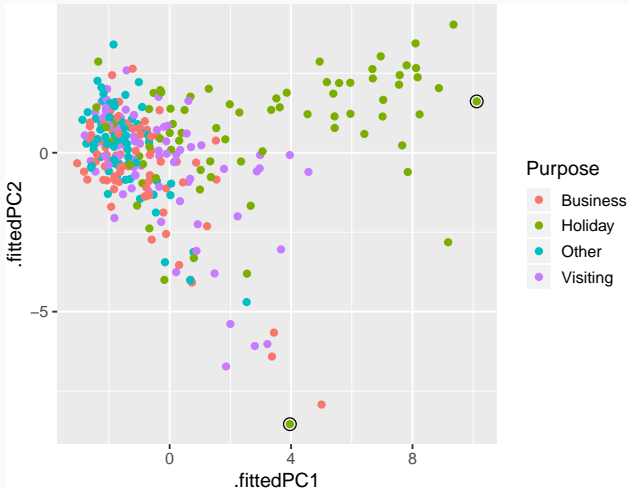
Feature extraction and statistics

```
pcs %>%
  filter(.fittedPC2 == min(.fittedPC2)) %>%
  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")
```


Outlying time series in PC space

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")
```


Outlying time series in PC space
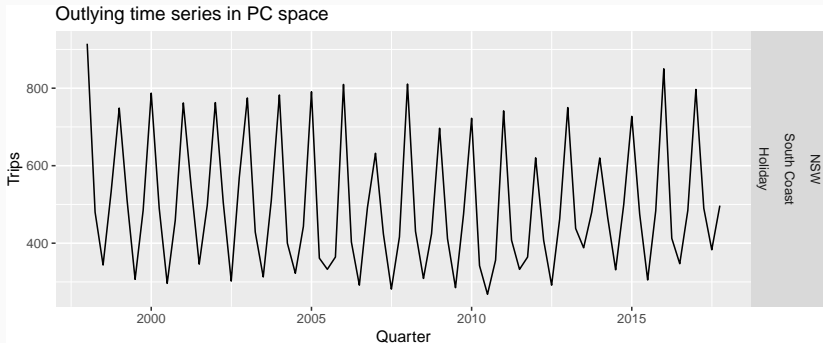
Acknowledgements

Mitchell O'Hara-Wild

Earo Wang

feasts.tidyverts.org

robjhyndman.com