forecast package

Pre 2003	Private functions used for consulting projects
July/August 2003	**ets** and **thetaf** added
August 2006	v1.0 available on CRAN
May 2007	**auto.arima** added
May 2010	**arfima** added
Feb/March 2011	**tslm**, **stlf**, **naive**, **snaive** added
August 2011	v3.0. Box Cox transformations added
December 2011	**tbats** added
April 2012	Package moved to github
November 2012	v4.0. **nnetar** added
June 2013	Major speed-up of **ets**
February 2016	v7.0. Added ggplot2 graphics
February 2017	v8.0. Added **checkresiduals**, **tsCV** and **%>%**
April 2018	v8.3. Added **mstl**
June 2018	$\approx$ 100,000 package downloads per month

fable package

A replacement for the forecast package.

Why change?

- Integrating with tidyverse packages
- Designed for forecasting many related time series
- Consistency of interface using formulas
- Distribution forecasting rather than point + interval
- Flexible transformations
- Sub-daily data and multiple seasonal data handled more easily
- Simpler interface for forecast reconciliation

Example: Australian eating-out expenditure

```
fpp2::auscafe
```

```
##         Jan    Feb    Mar    Apr    May    Jun    Jul    Aug    Sep
## 1982                        0.342  0.342  0.329  0.339  0.332  0.342
## 1983  0.369  0.348  0.366  0.351  0.360  0.347  0.364  0.376  0.378
## 1984  0.389  0.377  0.398  0.383  0.414  0.382  0.393  0.409  0.395
## 1985  0.426  0.392  0.416  0.420  0.446  0.407  0.449  0.466  0.455
## 1986  0.504  0.453  0.480  0.497  0.531  0.485  0.526  0.538  0.537
## 1987  0.572  0.525  0.544  0.558  0.565  0.542  0.599  0.584  0.593
## 1988  0.605  0.586  0.625  0.612  0.630  0.635  0.659  0.656  0.660
## 1989  0.733  0.661  0.713  0.694  0.710  0.722  0.741  0.746  0.767
## 1990  0.858  0.764  0.840  0.805  0.809  0.799  0.815  0.828  0.812
## 1991  0.862  0.771  0.813  0.797  0.821  0.801  0.829  0.854  0.882
## 1992  0.938  0.862  0.936  0.932  0.929  0.869  0.891  0.875  0.914
## 1993  0.918  0.838  0.870  0.862  0.852  0.828  0.882  0.867  0.905
## 1994  0.985  0.902  1.015  0.939  0.941  0.935  1.013  1.018  1.041
## 1995  1.076  0.982  1.099  1.068  1.083  1.045  1.094  1.110  1.126
## 1996  1.213  1.128  1.180  1.169  1.146  1.109  1.138  1.146  1.105
## 1997  1.180  1.060  1.148  1.141  1.170  1.113  1.165  1.173  1.154
## 1998  1.186  1.050  1.141  1.107  1.144  1.088  1.162  1.145  1.149
## 1999  1.244  1.124  1.245  1.236  1.271  1.208  1.219  1.234  1.261
## 2000  1.297  1.207  1.325  1.252  1.282  1.275  1.318  1.329  1.432
```

Example: Australian eating-out expenditure

```
library(tsibble)
cafe <- as_tsibble(fpp2::auscafe)
cafe
```

```
## # A tsibble: 426 x 2 [1MONTH]
##          index value
##          <mth> <dbl>
##   1 1982 Apr 0.342
##   2 1982 May 0.342
##   3 1982 Jun 0.329
##   4 1982 Jul 0.338
##   5 1982 Aug 0.332
##   6 1982 Sep 0.342
##   7 1982 Oct 0.358
##   8 1982 Nov 0.375
##   9 1982 Dec 0.433
## 10 1983 Jan 0.369
## # ... with 416 more rows
```

Example: Australian eating-out expenditure

```
library(fable)
cafe %>% ETS(value)
```

```
## # A mable: 1 model [1MONTH]
##   data                  model
##   <list>                <model>
## 1 <tsibble [426 x 2]> ETS(M,A,M)
```

Example: Australian eating-out expenditure

```r
cafe %>% ETS(value) %>% summary()
```

```
## ETS(M,A,M)
##
## Call:
##  ETS(data = ., formula = value)
##
##    Smoothing parameters:
##      alpha = 0.6263
##      beta  = 0.0065
##      gamma = 0.0755
##
##    Initial states:
##      l = 0.3477
##      b = 0.0038
##      s = 0.996 0.936 1.01 1.15 1.01 1.01
##          0.983 0.991 0.992 0.951 0.997 0.971
##
##    sigma:  0.0249
##
##  AIC AICc  BIC
## -319 -318 -250
```

Example: Australian eating-out expenditure

```
cafe %>% ETS(value) %>% forecast()
```

```
## # A fable: 1 forecast [1MONTH]
##   data                  model       forecast
##   <list>                <model>     <fc>
## 1 <tsibble [426 x 2]>   ETS(M,A,M)  ~N [h=24]
```

Example: Australian eating-out expenditure

```
cafe %>% ETS(value) %>% forecast() %>%
  summary()
```

```
## # A tsibble: 24 x 4 [1MONTH]
##        index  mean              80%              95%
##        <mth> <dbl>            <hilo>           <hilo>
##  1 2017 Oct   3.83 [3.71, 3.96]80 [3.65, 4.02]95
##  2 2017 Nov   3.81 [3.67, 3.96]80 [3.59, 4.03]95
##  3 2017 Dec   4.22 [4.04, 4.40]80 [3.94, 4.49]95
##  4 2018 Jan   3.83 [3.64, 4.01]80 [3.55, 4.10]95
##  5 2018 Feb   3.51 [3.33, 3.70]80 [3.24, 3.79]95
##  6 2018 Mar   3.87 [3.65, 4.09]80 [3.54, 4.20]95
##  7 2018 Apr   3.78 [3.56, 4.01]80 [3.44, 4.13]95
##  8 2018 May   3.81 [3.57, 4.05]80 [3.44, 4.18]95
##  9 2018 Jun   3.68 [3.43, 3.92]80 [3.30, 4.05]95
## 10 2018 Jul   3.88 [3.60, 4.15]80 [3.46, 4.29]95
## # ... with 14 more rows
```
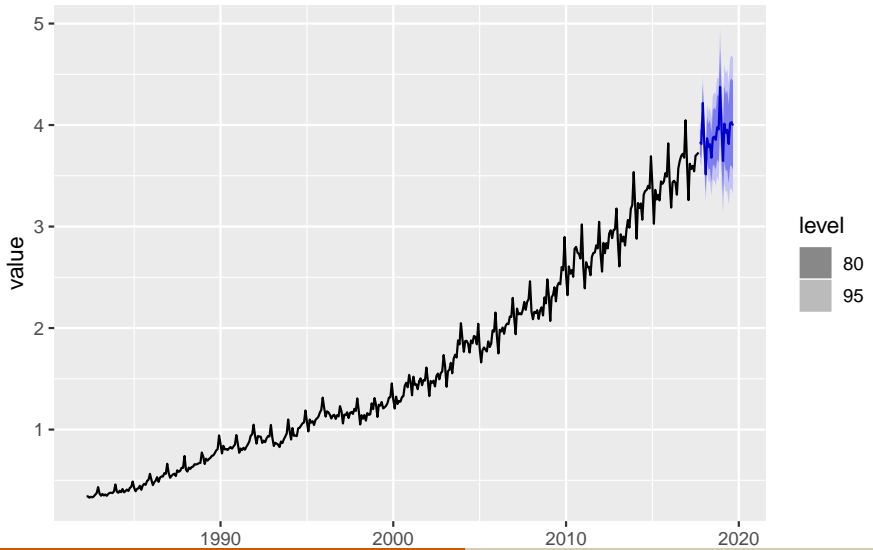
Example: Australian eating-out expenditure

```
cafe %>% ETS(value) %>% forecast() %>%
  summary(level=90)
```

```
## # A tsibble: 24 x 3 [1MONTH]
##        index  mean          90%
##        <mth> <dbl>        <hilo>
##  1 2017 Oct   3.83 [3.68, 3.99]90
##  2 2017 Nov   3.81 [3.63, 4.00]90
##  3 2017 Dec   4.22 [3.99, 4.45]90
##  4 2018 Jan   3.83 [3.59, 4.06]90
##  5 2018 Feb   3.51 [3.28, 3.75]90
##  6 2018 Mar   3.87 [3.59, 4.15]90
##  7 2018 Apr   3.78 [3.49, 4.07]90
##  8 2018 May   3.81 [3.50, 4.12]90
##  9 2018 Jun   3.68 [3.36, 3.99]90
## 10 2018 Jul   3.88 [3.53, 4.22]90
## # ... with 14 more rows
```

Example: Australian eating-out expenditure

```r
cafe %>% ETS(value) %>% forecast() %>% autoplot()
```

Example: Australian eating-out expenditure

```
cafe %>% ARIMA(log(value)) %>%
  forecast() %>% summary()

## # A tsibble: 24 x 4 [1MONTH]
##        index  mean            80%              95%
##        <mth> <dbl>           <hilo>           <hilo>
##  1 2017 Oct  3.81 [3.70, 3.93]80 [3.64, 3.99]95
##  2 2017 Nov  3.79 [3.65, 3.93]80 [3.58, 4.00]95
##  3 2017 Dec  4.17 [3.99, 4.34]80 [3.91, 4.43]95
##  4 2018 Jan  3.73 [3.55, 3.90]80 [3.46, 4.00]95
##  5 2018 Feb  3.40 [3.22, 3.57]80 [3.14, 3.67]95
##  6 2018 Mar  3.77 [3.56, 3.99]80 [3.46, 4.10]95
##  7 2018 Apr  3.70 [3.48, 3.93]80 [3.37, 4.05]95
##  8 2018 May  3.76 [3.52, 4.00]80 [3.40, 4.13]95
##  9 2018 Jun  3.66 [3.41, 3.90]80 [3.29, 4.04]95
## 10 2018 Jul  3.88 [3.61, 4.15]80 [3.48, 4.31]95
## # ... with 14 more rows
```

Example: Australian prison population

```
fpp2::prisonLF
```

```
## # A tibble: 1,536 x 5
##    state gender legal    t          count
##    <fct> <fct>  <fct>    <date>     <dbl>
##  1 ACT   Female Remanded 2005-03-01     2
##  2 ACT   Female Remanded 2005-06-01     4
##  3 ACT   Female Remanded 2005-09-01     1
##  4 ACT   Female Remanded 2005-12-01     4
##  5 ACT   Female Remanded 2006-03-01     4
##  6 ACT   Female Remanded 2006-06-01     6
##  7 ACT   Female Remanded 2006-09-01     9
##  8 ACT   Female Remanded 2006-12-01     6
##  9 ACT   Female Remanded 2007-03-01     4
## 10 ACT   Female Remanded 2007-06-01     4
## # ... with 1,526 more rows
```

Example: Australian prison population

```
prison <- fpp2::prisonLF %>%
  mutate(qtr=yearquarter(t)) %>%
  select(-t) %>%
  as_tsibble(index=qtr, key=id(state,gender,legal))
prison
```

```
## # A tsibble: 1,536 x 5 [1QUARTER]
## # Key:        state, gender, legal [32]
##     state gender legal      count      qtr
##     <fct> <fct> <fct>      <dbl>    <qtr>
##   1 ACT   Female Remanded       2 2005 Q1
##   2 ACT   Female Remanded       4 2005 Q2
##   3 ACT   Female Remanded       1 2005 Q3
##   4 ACT   Female Remanded       4 2005 Q4
##   5 ACT   Female Remanded       4 2006 Q1
##   6 ACT   Female Remanded       6 2006 Q2
##   7 ACT   Female Remanded       9 2006 Q3
```

Example: Australian prison population

```
prison %>% ETS(count)
```

```
## # A mable: 32 models [1QUARTER]
## # Key:     state, gender, legal [32]
##    state gender legal      data          model
##    <fct> <fct>  <fct>      <list>        <model>
##  1 ACT   Female Remanded  <tsibble [48 x 2]> ETS(M,A,N)
##  2 ACT   Female Sentenced <tsibble [48 x 2]> ETS(A,A,N)
##  3 ACT   Male   Remanded  <tsibble [48 x 2]> ETS(M,N,N)
##  4 ACT   Male   Sentenced <tsibble [48 x 2]> ETS(A,N,N)
##  5 NSW   Female Remanded  <tsibble [48 x 2]> ETS(M,N,M)
##  6 NSW   Female Sentenced <tsibble [48 x 2]> ETS(M,N,M)
##  7 NSW   Male   Remanded  <tsibble [48 x 2]> ETS(M,A,A)
##  8 NSW   Male   Sentenced <tsibble [48 x 2]> ETS(M,A,A)
##  9 NT    Female Remanded  <tsibble [48 x 2]> ETS(M,N,N)
## 10 NT    Female Sentenced <tsibble [48 x 2]> ETS(M,A,A)
## # ... with 22 more rows
```

Example: Australian prison population

```
prison %>% ETS(count) %>% forecast()
```

```
## # A fable: 32 forecasts [1QUARTER]
## # Key:     state, gender, legal [32]
##    state gender legal       data          model     forecast
##    <fct> <fct>  <fct>       <list>         <model>   <fc>
##  1 ACT   Female Remanded  <tsibble [48 x 2]> ETS(M,A,N) ~N [h=8]
##  2 ACT   Female Sentenced <tsibble [48 x 2]> ETS(A,A,N) ~N [h=8]
##  3 ACT   Male   Remanded  <tsibble [48 x 2]> ETS(M,N,N) ~N [h=8]
##  4 ACT   Male   Sentenced <tsibble [48 x 2]> ETS(A,N,N) ~N [h=8]
##  5 NSW   Female Remanded  <tsibble [48 x 2]> ETS(M,N,M) ~N [h=8]
##  6 NSW   Female Sentenced <tsibble [48 x 2]> ETS(M,N,M) ~N [h=8]
##  7 NSW   Male   Remanded  <tsibble [48 x 2]> ETS(M,A,A) ~N [h=8]
##  8 NSW   Male   Sentenced <tsibble [48 x 2]> ETS(M,A,A) ~N [h=8]
##  9 NT    Female Remanded  <tsibble [48 x 2]> ETS(M,N,N) ~N [h=8]
## 10 NT    Female Sentenced <tsibble [48 x 2]> ETS(M,A,A) ~N [h=8]
## # ... with 22 more rows
```

Aggregation and reconciliation not yet implemented.

Example: Half-hourly electricity demand

```
elecdemand
```

```
## # A tsibble: 17,520 x 4 [30MINUTE]
##    index               Demand Temperature WorkDay
##    <dttm>               <dbl>       <dbl>   <dbl>
##  1 2014-01-01 00:00:00   3.91        18.2       0
##  2 2014-01-01 00:30:00   3.67        17.9       0
##  3 2014-01-01 01:00:00   3.50        17.6       0
##  4 2014-01-01 01:30:00   3.34        16.8       0
##  5 2014-01-01 02:00:00   3.20        16.3       0
##  6 2014-01-01 02:30:00   3.10        16.6       0
##  7 2014-01-01 03:00:00   3.04        16.6       0
##  8 2014-01-01 03:30:00   3.01        16.7       0
##  9 2014-01-01 04:00:00   3.02        16.2       0
## 10 2014-01-01 04:30:00   3.03        16.6       0
## # ... with 17,510 more rows
```

Example: Half-hourly electricity demand

```
fit2 <- ARIMA(elecdemand,
  Demand ~ Temperature + I(Temperature^2) + WorkDay)
summary(fit2)
```

```
## Series: Demand
## Regression with ARIMA(1,1,0)(2,0,2)[2] errors
##
## Coefficients:
##          ar1    sar1    sar2    sma1    sma2   Temperature
##        0.853  -0.181   0.523  -0.066  -0.792        -0.009
## s.e.   0.005   0.015   0.012   0.012   0.011         0.002
##        I(Temperature^2)  WorkDay
##                       0    0.016
## s.e.                  0    0.006
##
## sigma^2 estimated as 0.00846:  log likelihood=16949
## AIC=-33881   AICc=-33881   BIC=-33811
##
## Training set error measures:
##                       ME   RMSE     MAE     MPE  MAPE  MASE   ACF1
## Training set 6.51e-06  0.092  0.0634  0.00633  1.39  0.292  0.103
```

```
forecast(fit2, newdata=elecdemandfuture) %>% autoplot()
```

Equivalent methods: forecast ⟶ fable

```
auto.arima  ⟶ ARIMA
ets         ⟶ ETS
tslm/lm     ⟶ LM
tbats       ⟶ TBATS
nnetar      ⟶ NNAR
stlm        ⟶ STL %>%
                modelcomponents(
                    ETS(seasadj),SNAIVE(season))
```

- All functions have a formula interface with automatic modelling if no formula provided.
- All functions produce `mable` class objects.
- Some of these functions not yet implemented

Equivalent methods: forecast $\longrightarrow$ fable

```
naive    ⟶ NAIVE %>% forecast
snaive   ⟶ SNAIVE %>% forecast
thetaf   ⟶ THETA %>% forecast
stlf     ⟶ STL %>%
              modelcomponents(
                ETS(seasadj),SNAIVE(season)) %>%
              forecast
hw       ⟶ HW %>% forecast
holt     ⟶ HOLT %>% forecast
ses      ⟶ SES %>% forecast
splinef  ⟶ SPLINE %>% forecast
croston  ⟶ CROSTON %>% forecast
```

- `forecast` produces `fable` class objects.

More information

```
devtools::install_github("tidyverts/tsibble")
devtools::install_github("tidyverts/fable")
```


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Follow our progress

- tidyverts.org
- robjhyndman.com/hyndsight