

Parameter estimation and distribution selection by ExtDist

Haizhen Wu, A. Jonathan R. Godfrey and Sarah Pirikahu

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Introduction

Parameter estimation and distribution selections are common tasks in statistical analysis. In the context of variables acceptance sampling (see Wu and Govindaraju 2014 etc.), when the underlying distribution model of the quality characteristic is determined, the estimated quality of a product batch measured by the proportion nonconforming, is computed through the estimated parameter(s) of the underlying distribution based on a sample. Conversely, if a collection of candidate distributions are considered to be eligible, then selection of a distribution that best describes the data becomes necessary.

The **ExtDist** package is devoted to provide a consistent and unified framework for these tasks.

```
library(ExtDist)
```

Parameter Estimation

Suppose we have a set of data, which has been randomly generated from a Weibull distributed population,

```
set.seed(1234)
head(X <- rWeibull(50, shape = 2, scale = 3))
```

```
[1] 4.423512 2.066157 2.111723 2.062377 1.160961 2.003052
```

It is possible to write code to obtain parameters via a maximum likelihood estimation procedure for the data. However, it is more convenient to use a single function to achieve this task.

```
est.par <- eWeibull(X)
```

The *e*- prefix we introduced in **ExtDist** is a logical extension to the *d*-, *p*-, *q*-, *r*- prefixes of the distribution-related functions in R base package. Moreover, the output of *e*- functions is defined as a S3 class object.

```
class(est.par)
```

```
[1] "eDist"
```

The estimated parameters stored in the “eDist” object can be easily plugged into other *d*-, *p*-, *q*-, *r*- functions in **ExtDist** to get the density, percentile, quantile and random variates for a distribution with estimated parameters.

```
dWeibull(seq(0,2,0.4), params = est.par)
pWeibull(seq(0,2,0.4), params = est.par)
qWeibull(seq(0,1,0.2), params = est.par)
rWeibull(10, params = est.par)
```

To remain compatible with current convention, these functions also accept the parameters as individual arguments, so the following code variations are also permissible.

```
dWeibull(seq(0,2,0.4), shape = est.par$shape, scale = est.par$scale)
pWeibull(seq(0,2,0.4), shape = est.par$shape, scale = est.par$scale)
qWeibull(seq(0,1,0.2), shape = est.par$shape, scale = est.par$scale)
rWeibull(10, shape = est.par$shape, scale = est.par$scale)
```

Distribution selection

As a S3 class object, several S3 methods have been developed in **ExtDist** to extract the distribution selection criteria and other relevant information.

```
logLik(est.par) # log likelihood
```

```
[1] -79.99344
```

```
AIC(est.par) # Akaike information criterion
```

```
AICc(est.par) # corrected Akaike information criterion
```

```
[1] 164.2422
```

```
BIC(est.par) # Bayes' Information Criterion.
```

```
[1] 167.8109
```

```
MDL(est.par) # minimum description length
```

```
[1] 83.03809
```

```
vcov(est.par) # variance-covariance matrix of the parameters of the fitted distribution
```

```
      shape      scale
shape 0.06609441 0.01566200
scale 0.01566200 0.03801099
```

Based on these criteria, for any sample, the best fitting distribution can be obtained from a list of candidate distributions. For example:

```
Ozone <- airquality$Ozone
Ozone <- Ozone[!is.na(Ozone)] # Removing the NA's from Ozone data
summary(Ozone)
```

```
      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
1.00   18.00   31.50   42.13   63.25   168.00
```

```
best <- bestDist(Ozone, candDist=c("Gamma", "Weibull", "Normal", "Exp"), criterion = "logLik");best
```

```
[1] "Weibull"
```

```
attr("best.dist.par")
```

Parameters for the Weibull distribution.
(found using the numerical.MLE method.)

```
Parameter Type Estimate      S.E.
shape shape  1.340187 0.09541768
scale scale 46.081330 3.37566671
```

```
attr("criterion.value")
```

```
Gamma  Weibull   Normal      Exp
-Inf -542.6103 -569.6492 -549.9263
```

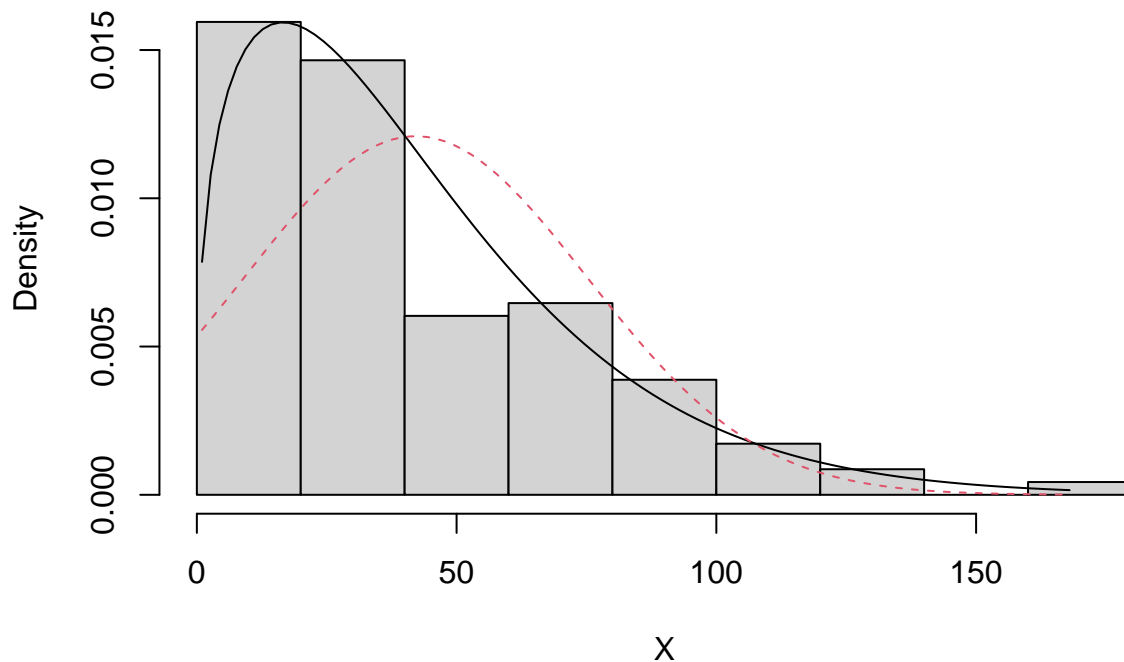
When more than one set of results are of interest for a list of candidate distribution fits, a summary table can be output by using the function `DistSelCriteria`.

```
DistSelCriteria(Ozone, candDist = c("Gamma", "Weibull", "Normal", "Exp"),
               criteria = c("logLik", "AIC", "AICc", "BIC"))
```

	Gamma	Weibull	Normal	Exp
logLik	-Inf	-542.6103	-569.6492	-549.9263
AIC	Inf	1089.221	1143.298	1101.853
AICc	Inf	1089.327	1143.404	1101.888
BIC	Inf	1094.728	1148.805	1104.606

Multiple distributions can also be compared visually using the `compareDist` function.

```
compareDist(Ozone, attributes(best)$best.dist.par, eNormal(Ozone))
```

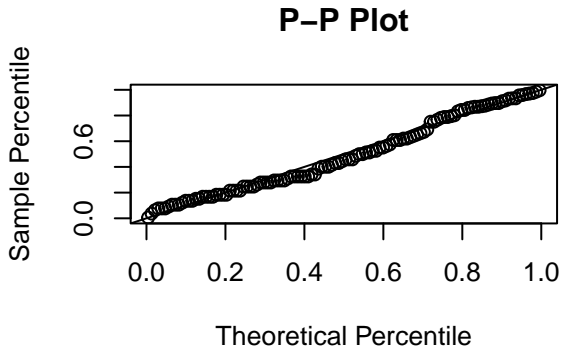
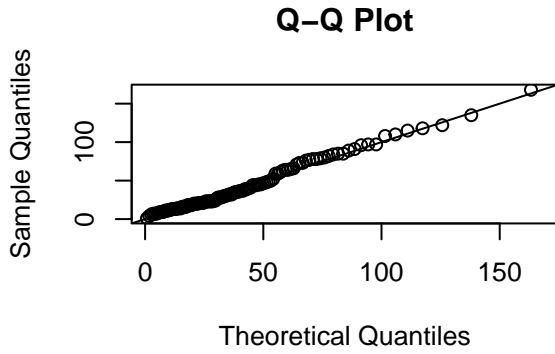
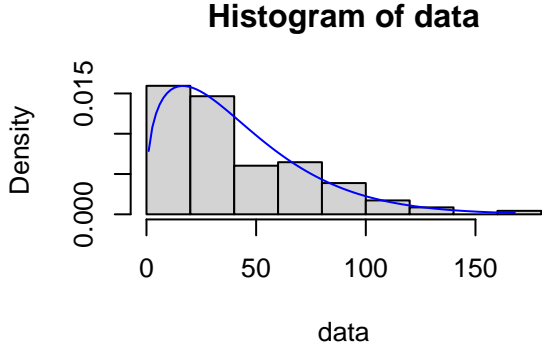


If the best fit distribution has been determined `plot.eDist` can provide the corresponding histogram with fitted density curve, Q-Q and P-P plot for this distribution.

```
plot(attributes(best)$best.dist.par)
```

Parameters for the Weibull distribution.
(found using the numerical.MLE method.)

Parameter	Type	Estimate	S.E.
shape	shape	1.340187	0.09541768
scale	scale	46.081330	3.37566671



Weighted sample

Another notable feature of the **ExtDist** package is that it can deal with weighted samples. Weighted samples appear in many contexts, e.g.: in non-parametric and semi-parametric deconvolution (see e.g. Hazelton and Turlach 2010 etc.) the deconvoluted distribution can be represented as a pair (Y, w) where w is a vector of weights with same length as Y . In size-biased (unequal probability) sampling, the true population is more appropriately described by the weighted (with reciprocal of the inclusion probability as weights) observations rather than the observations themselves. In Bayesian inference, the posterior distribution can be regarded as a weighted version of the prior distribution. Weighted distributions can also play an interesting role in stochastic population dynamics.

In **ExtDist**, the parameter estimation was conducted by maximum weighted likelihood estimation, with the estimate $\hat{\theta}^w$ of θ being defined by

$$\hat{\theta}^w = \arg \max_{\theta} \sum_{i=1}^n w_i \ln f(Y_i; \theta), \quad (1)$$

where f is the density function of the distribution to be fitted.

For example, for a weighted sample with

```
Y <- c(0.1703, 0.4307, 0.6085, 0.0503, 0.4625, 0.479, 0.2695, 0.2744, 0.2713, 0.2177,
       0.2865, 0.2009, 0.2359, 0.3877, 0.5799, 0.3537, 0.2805, 0.2144, 0.2261, 0.4016)
w <- c(0.85, 1.11, 0.88, 1.34, 1.01, 0.96, 0.86, 1.34, 0.87, 1.34, 0.84, 0.84, 0.83, 1.09,
       0.95, 0.77, 0.96, 1.24, 0.78, 1.12)
```

the parameter estimation and distribution selection for weighted samples can be achieved by including the extra argument w :

```
eBeta(Y,w)
```

Parameters for the Beta distribution.
(found using the MOM method.)

Parameter	Type	Estimate
shape1	shape	3.016450
shape2	shape	6.561803

```
bestDist(Y, w, candDist = c("Beta_ab", "Laplace", "Normal"), criterion = "AIC")
```

```
[1] "Normal"  
attr(,"best.dist.par")
```

Parameters for the Normal distribution.
(found using the unbiased.MLE method.)

Parameter	Type	Estimate	S.E.
mean	location	0.3149269	0.03157766
sd	scale	0.1412196	0.02290885

```
attr("criterion.value")  
Beta_ab Laplace Normal  
-14.76974 -17.67491 -18.10897
```

```
DistSelCriteria(Y, w, candDist = c("Beta_ab", "Laplace", "Normal"),  
                criteria = c("logLik", "AIC", "AICc", "BIC"))
```

	Beta_ab	Laplace	Normal
logLik	11.38487	10.83745	11.05448
AIC	-14.76974	-17.67491	-18.10897
AICc	-12.10308	-16.96903	-17.40309
BIC	-10.78682	-15.68344	-16.11751

References

- Hazelton, Martin L., and Berwin A. Turlach. 2010. "Semiparametric Density Deconvolution." *Scandinavian Journal of Statistics* 37 (1): 91–108.
- Wu, Haizhen, and Kondaswamy Govindaraju. 2014. "Computer-aided variables sampling inspection plans for compositional proportions and measurement error adjustment." *Computers & Industrial Engineering* 72 (June): 239–46.