

# JQuantile

The class JQuantile resides in the JTOOLS namespace and constitutes a kind of zero-dimensional histogram. It contains a running mean and standard deviation and can optionally be used to determine quantiles.

The following code extract:

```
const double x      = 0.0;
const double sigma = 1.0;

JQuantile quantile;

for (int i = 0; i != 1000; ++i) {
    quantile.put(gRandom->Gaus(x, sigma));
}

NOTICE("quantity " << CENTER(10) << "calculated" << " | " << CENTER(10) << "true" << endl);
NOTICE("mean      " << FIXED(10,3) << quantile.getMean() << " | " << FIXED(10,3) << x << endl);
NOTICE("RMS      " << FIXED(10,3) << quantile.getSTDev() << " | " << FIXED(10,3) << sigma << endl);
```

could produce:

```
quantity  calculated |      true
mean      -0.006    |      0.000
RMS       1.024    |      1.000
```

Recurrence relations exists for the running mean and standard deviation [1]. Here, the recurrence relations for the weighed mean and standard deviation are presented.

For a data sample  $\{(w_1, x_1), \dots, (w_n, x_n)\}$ , the following definitions are adopted.

$$W_n \equiv \sum_{i=1}^n w_i \quad (1)$$

$$\mu_n \equiv \frac{1}{W_n} \sum_{i=1}^n w_i x_i \quad (2)$$

$$\sigma_n^2 \equiv \frac{1}{\langle W_n \rangle (n-1)} \sum_{i=1}^n w_i (x_i - \mu_n)^2 \quad (3)$$

where  $W_n$  is the total weight,  $\mu_n$  the weighed mean value and  $\sigma_n^2$  the square of the weighed standard deviation. In this,  $\langle W_n \rangle$  corresponds to the average weight  $\langle W_n \rangle \equiv \frac{W_n}{n}$ .

We start with the derivation of the recurrence relation for the weighed mean value  $\mu$ .

$$\mu_n = \frac{1}{W_n} \sum_{i=1}^n w_i x_i \quad (4)$$

$$= \frac{1}{W_n} \left[ \sum_{i=1}^{n-1} w_i x_i + w_n x_n \right] \quad (5)$$

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$$= \frac{1}{W_n} [\mu_{n-1}W_{n-1} + w_n x_n] \quad (6)$$

$$= \frac{1}{W_n} [\mu_{n-1}W_n - \mu_{n-1}w_n + w_n x_n] \quad (7)$$

$$= \mu_{n-1} + \frac{w_n}{W_n} [x_n - \mu_{n-1}] \quad (8)$$

For the weighed standard deviation, we define first:

$$s_n^2 \equiv \langle W_n \rangle (n-1) \sigma_n^2 \quad (9)$$

It then follows that:

$$s_n^2 = \sum_{i=1}^n w_i x_i^2 - W_n \mu_n^2 \quad (10)$$

$$= \sum_{i=1}^{n-1} w_i x_i^2 + w_n x_n^2 - W_n \left[ \mu_{n-1}^2 - 2\mu_{n-1} \frac{w_n}{W_n} (x_n - \mu_{n-1}) + \left( \frac{w_n}{W_n} (x_n - \mu_{n-1}) \right)^2 \right] \quad (11)$$

$$= \sum_{i=1}^{n-1} w_i x_i^2 + w_n x_n^2 - W_{n-1} \mu_{n-1}^2 - w_n \mu_{n-1}^2 - 2\mu_{n-1} w_n (x_n - \mu_{n-1}) - \frac{w_n^2 (x_n - \mu_{n-1})^2}{W_n} \quad (12)$$

$$= s_{n-1}^2 + w_n (x_n - \mu_{n-1})^2 + w_n (\mu_n - \mu_{n-1}) (x_n - \mu_{n-1}) \quad (13)$$

$$= s_{n-1}^2 + w_n (x_n - \mu_{n-1}) (x_n - \mu_n) \quad (14)$$

Hence:

$$\sigma_n^2 = \frac{1}{\langle W_n \rangle (n-1)} s_n^2 \quad (15)$$

$$= \frac{1}{\langle W_n \rangle (n-1)} [s_{n-1}^2 + w_n (x_n - \mu_{n-1}) (x_n - \mu_n)] \quad (16)$$

## References

- [1] Knuth TAOCP vol 2, 3rd edition, page 232.