Mathematical and statistical applications for HP Prime

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Abstract

Applications for HP Prime *CAS*, *User* functions and *Applications*, an overview of the methods and their origins is given.

1. Introduction

Mathematical and statistical applications HP_Prime_MATH[1] for (1) the Computer Algebra System *CAS*, by means of the *Pascal* based *HP Prime Programming Language* (HP PPL), (2) the HP Prime *User* functions and (3) HP Prime *Applications* (s. HP Inc., 2017), including methods for (1) *correlation*, (2) *exposure*, (3) *integration*, (4) *distribution*, (5) *probability*, (6) *combinatorics*, (7) *resampling* and (8) *complex plane* calculations (Schrausser, 2025a).

The description of the *underlying* algorithms and functions is deliberately omitted, as these are presented and discussed in detail in Schrausser (2025b). Instead, an *overview* of the implemented methods is given and *additionally* their *historical development* is outlined (c.f. Tab. 1).

2. Functions

2.1. Correlation

To measure the degree of a linear *relation* between variables, Karl Pearson (1904) was developing statistical procedures for biometry including the *correlation* and *regression* coefficients based on the works of Bravais (1844) and Galton (1877) who introduced the symbol r, on the then designation of the term *reversion*.

The methodological apparatus of *factor analysis* as a further and broader concept, based on *multiple regression* and *matrix* calculation was first discussed by Charles Edward Spearman (1904), later the *initial* developed took place by Louis Leon Thurstone (1931, 1934, 1935; s. also Cattell, 1966).

The following functions for *correlation*- and *regression*-techniques are implemented, c.f. also Schrausser (2025b):

(1) Pearson *product-moment* correlation coefficient r_{xy}, see Pearson (1904, 1905).
(2) Spearman's ρ, being equivalent to the *product moment* correlation when *rank* values are present (s. Spearman, 1904).
(3) Kendall's tau τ_a, i.e. without adjustment for *ties* (s. Kendall, 1938).
(4) Somers' D, for *binary* data [0,1] (s. Somers, 1962).
(5) *Point biserial* correlation coefficient r_{pb} or also *point biseral*.
(6) *Biserial* correlation coefficient r_{bis}, Pearson (1909), s. Tate (1955), also called *biseral*.
(7) *Rank biserial* correlation coefficient r_{bisR} or *rank biseral*, corresponding to the *effect size* for the *Mann–Whitney U-test* (Mann & Whitney, 1947).
(8) *Phi* coefficient Φ, Yule (1912).
(9) *Tetrachoric* correlation r_{tet}, Pearson (1900a), Everitt (1910, 1912), s. e.g. Brown (1977), Digby (1983), also Bonett and Price (2005) or Long et al. (2009), *proposed* approximate algorithm.
(10) *Partial* correlation $r_{xy \cdot z}$.
(11) Fisher Z-transformation, Fisher (1915).
(12) Fisher Z *difference*, also Cohen's q (Cohen, 1988, p. 110).
(13) *Averaged* Fisher Z.
(14) Coefficient of *multiple* correlation $R_{c,12}$, for $\hat{R}^2_{c,12}$ see Olkin and Pratt (1958), with the *effect size* for *multiple* regression f^2 (Cohen, 1988, p. 410).

2.2. Exposure

To determine the appropriate *time-aperture-speed* combination for given *light values* on a logarithmic scale (c.f. Allbright, 1991; Marsden & Weinstein, 1985; Howie, 2001 and Sobot, 2021), following functions are included for the calculation of (1) *exposure values* Ev, where $Ev = \frac{\log(Tv \cdot Av^2)}{\log(2)}$, (2) *aperture* Av for time Tv or speed S with given Ev, (3) *aperture* Av *shift* from time Tv or speed S in *steps* k and (4) *speed* S in *logarithmic* $ISO°$ or *arithmetic* ISO values.

2.3. Functions of integration for π and Γ

Gottfried Wilhelm Leibniz (1684, 1686, 1693) along with Sir Isaac Newton (1687, 1713, 1726) are considered the discoverers of *differential* and *integral calculus*. According to current consensus, both developed the methods independently of each other, see the so-called *Leibniz-Newton calculus controversy* (c.f. Cajori, 1919; Cassirer, 1943; Rosenthal, 1951; Schrader, 1962; Kossovsky, 2020).

Newton *began* working on a *geometric* form of *calculus* (the method of *fluxions and fluents*) in 1666, published in 1687 (c.f. Roero, 2005), yet, it was Leibniz who *introduced* the symbols $\int$ and ∂.

Here, the functions are primarily intended to display and calculate π and Γ within the coordinate system:

(1) *Circular* function for π, where Weierstraß (1894, p. 53) describes $\frac{\pi}{2} = \int_0^\infty \frac{1}{1-x^2} dx$, which *may* be less heuristic (s. Schrausser, 2025b).
(2) *Spherical* functions for π, for source codes to *volume integrals* of the *sphere* see Schrausser (2024d).
(3) *Gamma* function Γ, meant to extend the *factorial* to *non-integer* arguments, was first considered by Daniel Bernoulli and Christian Goldbach (Bernoulli, 1729), later Leonhard Euler (1738) and Johann Carl Friedrich Gauss (s. Remmert, 1998), first *tables* were given by Jahnke and Emde (1909, 1933, 1938, 1945), Knoll (1939) and Jahnke et al. (1966).

2.4. Distribution functions

The discovery of the *normal distribution* is attributed to Abraham de Moivre (1738), later Gauss (1809) described the *arithmetic mean* as an estimator in context with the *normal law of errors*. Beneath the *normal distribution*, Gauss (1823) also introduces several important statistical concepts, such as the methods of *least squares* and of *maximum likelihood*.

The *t-distribution* first derived as a posterior distribution by Lüroth (1876), appearing later as *Pearson Type IV* (Pearson, 1895), however gets its name as *Student's t-distribution* from William Sealy Gosset (1908), who published it using the pseudonym *Student*, though it was actually through the *extensive* works of Sir Ronald Aylmer Fisher that the distribution became well known.

The χ^2-*distribution* was first described by Friedrich Robert Helmert (1876) and independently *rediscovered* by Pearson (1900b) in context with the *goodness of fit* paradigm, where he developed the χ^2-test with computed *table* of values, published by Elderton (1902), s. further Pearson (1914) or Plackett (1983).

Fisher (1918, 1921, 1925) introduced the term *variance* and proposed its formal analysis, as well as the F-*distribution* (Fisher, 1924; s. also Snedecor, 1934 and Scheffé, 1959). The methods became widely known from *Methods for Research Workers* (Fisher, 1925, 1954, 1973, 2017).

Following functions for the most *relevant* methods are available:

[1] https://github.com/Schrausser/HP_Prime_MATH

(1) *Standardizing*, i.e. z-values and ζ-values.
(2) *Quantity proportion* of a at N for $n_{\geq_p}$.
(3) *Weighted arithmetic* mean $\ddot{\bar{x}}$.
(4) *Geometric* mean $\dot{x}$, for the *weighted geometric* mean $\ddot{x}$ s. Siegel (1942).
(5) *Harmonic* mean $\bar{\bar{x}}$.
(6) Coefficient of *variation* ω.
(7) *Mean dispersion* $\bar{d}$, Schrausser (2022a, p. 33).
(8) *Standard normal distribution* $f(x = z)$, de Moivre (1738), Gauss (1809, 1823).
(9) *Bivariate normal distribution* $f(z_1, z_2)$.
(10) *Student's t-distribution* $f(x = t)$, Lüroth (1876), Pearson (1895), Gosset (1908).
(11) χ^2-*distribution* $f(x = \chi^2)$, Helmert (1876), Pearson (1900b, 1914), Elderton (1902), Plackett (1983).
(12) F-*distribution* $f(x = F)$, Fisher (1924), Snedecor (1934), Scheffé (1959).
(13) *Third* standardized moment, skewness α_3.
(14) *Fourth* standardized moment, excess kurtosis α_4.
(15) *Estimated standard error* of *mean* $\hat{\sigma}_{\bar{x}}$, *confidence interval* CI_p. Neyman (1937) introduced the *confidence interval* into statistical hypothesis testing vs. Fisher's *null hypothesis* testing, the *Neyman–Pearson lemma* (Neyman & Pearson, 1933; Lehmann, 1993).
(16) *Standard error* of *prediction* $\sigma_{\hat{y}x}$, *confidence interval* CI_p.
(17) *Effect size* ϵ, Cohen's d (Cohen, 1977, 1988, p. 20, p. 49, 1992), Borenstein et al. (1997), Borenstein et al. (2001).
(18) *Optimal effect size* ϵ_p.
(19) *Optimal alpha level*.
(20) *Variance difference* t-test for *paired* samples $(x_1|x_2)$.
(21) *Paired* 2-sample t-test.
(22) *Unpaired* 2-sample t-test.
(23) *One-sample* t-test.
(24) χ^2-test for *independence*.
(25) *2 × 2* χ^2-test for *independence*, for Yates's correction for *continuity* see Yates (1934).
(26) McNemar's χ^2-test for *paired 2 × 2 contingency* tables with *dichotomous* trait, McNemar (1947).

2.5. Probability

Since until the Renaissance a *probable* opinion was merely *confirmed* by an authority and hence there was no further concept of *inductive* evidence (see Hacking, 1975; Hald, 2003, p. 31), an *objective* representation of *probability* as such was first discussed by Antoine Arnauld and Pierre Nicole (1662, 1682, 1693; c.f. also Arnauld et al., 1970; van Evra, 1997; Dessì & Albury, 1997 or Finocchiaro, 1997).

The *binomial distribution* is primarily attributable to de Moivre (1711, 1718, 1738) and Jacob Bernoulli (1713), see also Schneider (2005a, b). Although not included as function, due to its *considerability* in this context, the *configuration frequency analysis, CFA* should be mentioned particularly (c.f. Krauth, 1973; Krauth & Lienert, 1993).

An account of the *systematics and logic* of *dependent probabilities* within the framework of *Bayes' theorem* (Bayes & Price, 1763; c.f. Stigler, 2018) can be found in Schrausser (2024c).

The arguably *most* important methods regarding the calculation of *probability parameters* are implemented as follows:

(1) *Arcsine transformation*, Cohen's h (Cohen, 1988, p. 181).
(2) *Additive probability* for *independent* events ${}^{u}p(\cup_n A)$, which corresponding to the *geometric distribution* $f(X \leq r|p)$.
(3) *Geometric distribution* $f(X \leq r|p)$, corresponding to the *additive* probability ${}^{u}p(\cup_n A)$.
(4) *Negative binomial distribution* $f(X \leq r|r, p)$, with $k = 1$ it corresponds to the *geometric distribution* $f(X \leq r|p)$ and the *additive* probability ${}^{u}p(\cup_n A)$.
(5) *Exact binomial* test.
(6) *Exact hypergeometric 2 × 2* test, the so-called *Fisher Exact* test (Fisher, 1922; Agresti, 1992).

2.6. Combinatorics

After Gersonides' *pioneering* work from 1321 dealing with *arithmetical* operations and *combinatorics* (s. Abraham Bar Hiyya Savasorda, 1450; Rabinovitch, 1970), the methods, being a fundamental part for *probability calculations*, are *mainly* based on Blaise Pascal (1665), Bernoulli (1713) and Euler (1753), c.f. Ettingshausen (1826).

See further Sylvester (1904, 1908, 1909, 1912) and MacMahon (1915, 1916), giving fundamental contributions to *matrix-theory* and *combinatorics*.

The following functions to *generate permutation* and *variation* matrices are available, *primarily* to support the *resampling* procedures described below:

(1) *Permutation* matrix $\boldsymbol{P_n}$, with n elements to $k = 1$ class.
(2) *Variation* matrix ${}^{w}\boldsymbol{V_2^m}$ for the *dependent* 2 sample design, with $n = 2$ elements to class m.
(3) *Variation* matrix ${}^{w}\boldsymbol{V_n^m}$, with n elements to class m.
(4) *Permutation* matrix ${}^{w}\boldsymbol{P_n^{(k_m, k_{n-m})}}$, with n elements to class m.

2.7. Resampling

Permutation or *randomization tests* were first mentioned by Fisher (1935), based on experiments in agriculture (Fisher, 1926; Neyman, 1923). In this context see Pitman (1937a, b, 1938), Fisher (1966, 1971, res.), especially Eugene Sinclair Edgington (1964, 1980, 1987, 2011) or Edgington and Onghena (2007).

The *bootstrap* method was introduced by Bradley Efron (1979, 1981, 1982) as a further development (Quenouille, 1949; Metropolis & Ulam, 1949), for *software* solutions see e.g. Solomon (1982), Dallal (1986, 1988), Peladeau (1993), Wooff and Peladeau (1994), Mehta et al. (2014), also Schrausser (2024d).

Following functions were *developed*:

(1) *Permutation test P* for 2 *paired* samples $(x_1|x_2)$. Random sampling model, *systematic* permutation, p-value *not* randomized, *variation* matrix ${}^{w}\boldsymbol{V_2^m}$ *required*, s. Scambor (1997), Scambor and Schrausser (2022, p. 7), respectively.
(2) *Randomized permutation test mP* for 2 *paired* samples $(x_1|x_2)$. Random sampling model, p-value *not* randomized.
(3) *Permutation test P* for 2 *independent* samples $(x|g)$. Random sampling model, *systematic* permutation, p-value *not* randomized, *permutation* matrix ${}^{w}\boldsymbol{P_n^{(k_m, k_{n-m})}}$ *required*, see Schrausser (1996, 1998b, 2022b, p. 2).
(4) *Randomized permutation test mP* for 2 *independent* samples $(x|g)$. Random sampling model, p-value *not* randomized.
(5) *Bootstrap* test *Bt* for 2 *independent* samples $(x|g)$, c.f. Quenouille (1949), Efron (1979, 1981, 1982).

2.8. Complex plane

It was the Italian mathematician Gerolamo Cardano (1545a, b) who *first* conceived the term *imaginary*, for the further historical development of *imaginary* or *complex numbers* see René Descartes (1664, 2012, res.) and Gauss (1828, 1832), c.f. also Wirtinger (1927).

Here finally realized are (1) the *geometric* representation of *complex numbers* z in the complex plane, the *Argand diagram* (s. Argand, 1813, 1874, res.) and (2) the *graph* of the *complex function*, where $z = \Re + \Im$.

At this point, one should recall the *definitional* importance of *geometry* and *trigonometry* in context with the calculation of *complex numbers* itself, where $|z|$ is *calculated* according to Pythagoras (c.f. Ratdolt, 1482, propositio 46) by $|z| = r = \sqrt{x^2 + y^2}$.

After the fundamental change in mathematics from *geometric* to *algebraic* representation took place in the 16th century (c.f. Heath, 1908a, b, c; Bochner, 1978; Anglin & Lambek, 1995; Malet, 2006 or Alten et al., 2014), the origins of *trigonometric series* of *tangents* and *sine* can be seen following early attempts (s. Jyesthadeva, 1530; Whish, 1834; Gupta, 1974 or Divakaran, 2007) during the European *reinvention* in the works of Gregory (1671, 1668a, b), Leibniz (1682, 2012), Newton (1669, 1711) and Brook Taylor (1715, 1717) with the definition of the *Taylor series* of *sine*, where $\sin x = \sum_{n=0}^{\infty} \frac{(-1)^n}{(2 \cdot n+1)!} \cdot x^{2 \cdot n+1}$ (c.f. Gregory & Collins, 1939; Boyer, 1968, p. 422 ff.; Feigenbaum, 1985).

Finally, Euler (1748a, b) established the *analytic* treatment of *trigonometric* functions, defining them in relation with *complex exponential* functions by $\mathrm{e}^{ix} = \cos x + i\sin\, x$, where $\mathrm{e} = \sum_{n=0}^{\infty}\frac{1}{n!}$ and thus laid the foundation of *modern* mathematical analysis (c.f. Finkel, 1897; Walter, 1982; Koyama & Kurokawa, 2005; Calinger, 2016 and Schrausser, 2024b).

3. Conclusion

In addition to the *source codes* of the functions, *raw* data sets are provided for *correlation*- as well as *resampling*-methods. *CAS* programs, HP Prime *User* functions and functions for HP Prime *Applications* in comparison to corresponding *SCHRAUSSER-MAT* functions (Schrausser, 2022a) are displayed in Schrausser (2025b). Furthermore, the application *FunktionWin* for a precise calculation of *probability distributions* can additionally be considered (Schrausser, 2023c) as well as the author's further software applications for *mathematical* and *statistical* analyses (Schrausser, 2023a, b, d).

On *mathematical statistical* methods in general see e.g. Cox and Hinkley (1974), Bortz and Weber (2005), Lehmann and Romano (2008) or Bortz and Schuster (2010), Schrausser (2024a) provides a comprehensive overview of the most important *distribution functions* and corresponding *algorithms*.

For *calculus* and *theory of functions* see e.g. Meyberg and Vachenauer (2001a, b) or Remmert and Schumacher (2002), on *complex numbers* in the *complex plane* see e.g. Burckel (2021) and Vince (2021), introducing works on *resampling* methods are given by e.g. Good (2006) or Beasley and Rodgers (2009).

For the history of *statistical inference* in general see e.g. Stigler (1986) and Hald (1990, 1998, 2003, 2007), the *historical foundations* of mathematics are thematized and discussed in e.g. Suter (1887), Heath (1921a, b), Boyer (1968), Neugebauer (1969), Ewald (1996a, b), Katz (2009) or Merzbach and Boyer (2011), c.f. Tab. 1.

Table 1. Timeline (*year*) of initial *work* on the *methods*, corresponding authors with *origin* and *field* of expertise.

Year	*n*	*Name*	*Origin*	*from*	*to*	*Field*	*n*	*Method*	*Work*
1290	1	Rabbi Levi ben Gershon	France	1288	1344	Theologian			
1300									
1310									
1320									
1330							1	Combinatorics	1321
1340									
:									
:									
1500									
1510	2	Gerolamo Cardano	Italy	1501	1576	Polymath			
1520									
1530									
1540									
1550							2	"imaginary"	1545
1560									
1570									
1580									
1590									
1600	3	René Descartes	France	1596	1650	Philosopher			
1610									
1620	4	Antoine Arnauld	France	1618	1698	Theologian			
	5	Blaise Pascal	France	1623	1662	Philosopher			
1630	4	Pierre Nicole	France	1625	1685	Theologian			
1640	6	Sir Isaac Newton	England	1643	1727	Polymath			
1650	7	Gottfried Wilhelm Leibniz	Germany	1646	1716	Polymath			
1660	8	Jacob Bernoulli	Switzerland	1655	1705	Mathematician	4	Probability	1662
1670	9	Abraham de Moivre	France	1667	1754	Mathematician	3	Complex numbers	1664
							5	Combinatorics	1665
1680									
1690	10	Brook Taylor	England	1685	1731	Mathematician	6,7	Calculus	1684
1700	11	Daniel Bernoulli	Switzerland	1700	1782	Mathematician			
	12	Rev. Thomas Bayes	England	1701	1761	Theologian			
	13	Leonhard Euler	Switzerland	1707	1783	Mathematician			
1710							9,8	Binomial distribution	1711
1720							10	Taylor series of sine	1715
1730							11	Gamma	1729
1740							9	Normal distribution	1738
1750							13	Complex exponential functions	1748
1760							12	Bayes' theorem	1763
1770	14	Jean-Robert Argand	Switzerland	1768	1822	Polymath			
1780	15	Johann Carl Friedrich Gauss	Germany	1777	1855	Mathematician			
1790									
1800									
1810							15	Estimator of mean	1809
1820							14	Argand diagram	1813
1830	16	Sir Francis Galton	England	1822	1911	Anthropology			
1840									
1850	17	Friedrich Robert Helmert	Germany	1843	1917	Geodesy, mathematics			
	18	Jacob Lüroth	Germany	1844	1910	Mathematics			
1860	19	Karl Pearson	England	1857	1936	Biology, mathematics			
1870							17,18	t-, χ^2-distribution	1876
1880							16	Reversion	1877
1890	20	Louis Leon Thurstone	USA	1887	1955	Psychophysics			
1900	21	Sir Ronald Aylmer Fisher	England	1890	1962	Biology, mathematics			
1910							19	Correlation	1904
1920									
1930	22	Jacob Cohen	USA	1923	1998	Psychology, statistics	21	F-distribution	1924
1940							20	Factor analysis	1931
							21	Permutation test	1935
	23	Bradley Efron	USA	1938		Statistics			
1950									
1960									
1970									
1980							23	Bootstrap	1979
1990							22	Effect size	1988
2000									

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