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SUBJECT : CHARACTERISTIC FUNCTION AND HIS MOMENTS, REVERSAL FORMULAS

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ABSTRACT
This A characteristic function in the article is an independent one central limit theorems of uniformly distributed randomness, theorems of Lindeberg, Feller and Lyupanov, some limit theorems of random branching process, theorems about the rate of approximation to the exponential distribution law and their proofs are considered.

Annotation
In this article deals with the characteristic function, the theorems of randomly distributed central limits of independent distribution, the theorems of Lindeberg , Feller and Lyupanov , some limit theorems of random branching process, theorems on the estimation of the rate of approach to the exponential distribution law and their proofs.

Higher order moments .
Random of quantities another numerous also referring to the characteristics let 's go Such characteristics as a lot cases high in order moments is used .

If ξ the distribution function of a random variable is *F* (*x*),

$$m_k = \int_{-\infty}^{\infty} x^k dF(x) = E\xi^k, \quad k \ge 0 \tag{1.1}$$

integral *k* - *order* random variable *moment* or *k* - *order initial moment* is called Of course , if

$$E|\xi|^k = \beta_k = \int_{-\infty}^{\infty} |x|^k \, dF(x) < \infty \tag{1.2}$$

integral approximant be *k* - ordered _ m_k moment will exist $\left(|m_k| \le \beta_k\right)$. Probabilities in theory m_k of torque that it exists β_k *k* - order absolute torque is equal to the existing case .

If ξ distribution function of random variables $F\left(x\right)$ is of discrete type and its breakpoints

$$x_1, x_2, \ldots, x_n, \ldots$$

sequence organize if he does , then Stilts of the integral to the x axis according to *k* - order moment

$$m_k = \sum_{n=1}^{\infty} x_n{}^k P_n$$

equality with is determined. Here

$$P_n = F(x_n + 0) - F(x_n - 0) = F(x_n + 0) - F(x_n) = P(\xi = x_n)$$

being _

$$\sum_{n=1}^{\infty} |x_n|^k P_n < \infty$$
(1.3)

assuming that the series converges to be done .

If ξ the distribution function of the random variable *F* (*x*) is of continuous type, and the function *f* (*x*) is its density function $\left(F'(x) = f(x)\right)$, then based on the property of the Stiltes integral

$$m_k = \int_{-\infty}^{\infty} x^k f(x)dx, \quad k \geq 0$$
(1.4)

equality is determined by In this case

$$\int_{-\infty}^{\infty} |x|^k f(x)dx < \infty$$
(1 5)

integral assuming that it approaches will be done . The zeroth order moment is always there is and

$$m_0 = F(+\infty) - F(-\infty) = 1.$$

First order moment

$$m_1 = \int_{-\infty}^{\infty} xdF(x) = E\xi$$
(1.6)

ξ is the mean or mathematical expectation of a random variable . If *c* is a constant number ,

$$E(\xi - c)^k = \int_{-\infty}^{\infty} (x-c)^k dF(x)$$
(1.7)

Integral g a ξ is called *the k -order moment* of the random variable with respect to *c* . Mathematician don't wait relatively moments

$$\alpha_k = \int_{-\infty}^{\infty} \left(x - E\xi\right)^k dF(x) = E\left(\xi - E\xi\right)^k$$
(1.8)

ξ are called *k* - order central moments of the random variable .

Here _ $\left(x - m_1\right)^k$ The expression is explained by Newton's binomial formula , as follows formulas harvest we do :

$$\alpha_0 = 1, \quad \alpha_1 = 0,$$
$$\alpha_2 = m_2 - m_1^2,$$
$$\alpha_3 = m_3 - 3m_1 m_2 + 2m_1^2,$$
$$\alpha_4 = m_4 - 4m_1 m_3 + 6m_1^2 m_2 - 3m_1^4$$

and that's right . They are moments m_k of order k lar central moments α_k connect with Immutable *c* to relatively second for the ordered torque

$$E(\xi - c)^2 = E\left[(\xi - m_1) + (m_1 - c)\right]^2 = \alpha_2 + (m_1 - c)^2 \geq \alpha_2$$

to the relationship have we will be and from him

$$\alpha_2 = \min_c E(\xi - c)^2 = E(\xi - m_1)^2 \qquad (1.9)$$

equality we can It is known that this moment is random amount ξ is called the variance of and ξ from the main numerical characteristic for is considered Proof relation (1.9). ξ ng can be taken as the definition of the variance of a random variable .

If $E\xi = 0$ if , the central moment is initial to the moment equal to will be

ξ random of the amount *k* - *order central absolute* as *the moment*

$$E|\xi - E\xi|^k = \int_{-\infty}^{\infty} |x - E\xi|^k \, dF(x) \qquad (1.10)$$

to expression it is said .

X ususan , if $E\xi = 0$ is *k* - ordered _ central absolute moment *k* - order initial with absolute torque on top of each other falls _

Higher order moments for inequalities

Cauchy-Buniakovsky inequality

Second in order to the moment has i x theory ξ and η random amounts for the following inequality suitable for :

$$E|\xi\eta| \leq \sqrt{E\xi^2} \cdot \sqrt{E\eta^2} \qquad (1.11)$$

Proof . It is $|\xi\eta| \leq \frac{1}{2}(\xi^2 + \eta^2)$known that and $E\xi^2$ and $E\eta^2$ moments from its finiteness $E|\xi\eta| < \infty$ that come comes out *x* and to the variables *y* depends has been positive determined this

$$E\left(x|\xi| + y|\eta|\right)^2 = x^2 E\xi^2 + 2xyE\left(|\xi| \cdot |\eta|\right) + y^2 E\eta^2$$

discriminant of the quadratic form

$$\left(2E(\xi\eta)\right)^2 - 4E\xi^2 E\eta^2 \leq 0$$

from which (1) the inequality holds since i arises.

Golder's inequality

Suppose 1 is probable with $\xi \geq 0, \eta \geq 0 \; va \; p, q$ let the relations for numbers $p > 1, q > 1, \frac{1}{p} + \frac{1}{q} = 1$be appropriate.

If $E\xi^p < \infty$ and $E\eta^q < \infty$, then

$$E\xi\eta \leq \left(E\xi^p\right)^{\frac{1}{p}} \cdot \left(E\eta^q\right)^{\frac{1}{q}} \qquad (1.12)$$

the inequality becomes relevant.

p=q =2 is taken in Golder's inequality , the Cauchy-Buniakovsky inequality is derived.

Work with linear combinations of given random variables in many cases ξ have to see, for their higher order moments

$$E(a\xi+b)^k = a^k m_k + C_k^1 a^{k-1} b m_{k-1} + \ldots + b^k$$

the formula can be proved.

Now higher order $(k \geq 2)$ absolute moments β_k Let us prove the following property related to . For u and ν with respect to variables

$$\int_{-\infty}^{\infty} [u|x|^{\frac{k-1}{2}} + \nu |x|^{\frac{k+1}{2}}]^2 dF(x) = \beta_{k-1} u^2 + 2\beta_k u\nu + \beta_{k+1} \nu^2 \geq 0$$

Minus didn't happen quadratic form let's see . It is quadratic form determinant counting _

$$\beta_k^{2k} \leq \beta_{k-1}{}^k \cdot \beta_{k+1}{}^k$$

we form the inequality. In this inequality, if the turn b $k = 1, 2, \ldots$ is considered ,

$$\beta_1^2 \leq \beta_2, \;\; \beta_2{}^4 \leq \beta_1^2 \beta_3^2, \;\; \beta_3{}^6 \leq \beta_2^3 \cdot \beta_4^3 \ldots$$

If we multiply the resulting inequalities ,

$$\beta_k^{k+1} \leq \beta_{k+1}{}^k \quad k = 1, 2, \ldots$$

inequalities come comes out O x irg while

$$\beta_k^{\frac{1}{k}} \leq \beta_{k+1}^{\frac{1}{k+1}}, \;\; k = 1, 2, \ldots$$

the fact that come comes out In particular ,

$$\beta_1 \leq \beta_2^{\frac{1}{2}}, \;\; \beta_2^{\frac{1}{2}} \leq \beta_3^{\frac{1}{3}}, \ldots$$

And those inequalities are called *Lyapunov inequalities .*

I x theory distribution function of *F* (*x*). everyone in order moments

$$m_1, m_2, \ldots, m_n, \ldots$$

be available. These moments of the function *F* (*x*) are single- valued that determines

let's put the issue. This problem is mathematical in the analysis "problem of moments"

The following is related to the so-called general problem and its solution

results. If

$$\sum_{n=1}^{\infty} \frac{m_n}{n!} r^n < \infty \qquad (1.13)$$

the series converges for some *r* >0, the function *F* (*x*) $m_1, m_2, \ldots, m_n, \ldots$ is the only function with moments.

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The dispersion (second-order central moment) of a random variable characterizes how scattered the values of this quantity are around the mean value. Based on this, we will dwell on the probabilistic meanings of higher-order moments.

If F (x) is a symmetric distribution function (i.e ξ is a symmetric random variable), then all its moments of odd order are equal to 0 (of course, if these moments exist). B to him this is a symbol for

$$F(-x)=1-F(x) \quad x>0$$

it is possible to be sure of the equality . Therefore, all moments of odd order, which are not equal to 0, can be taken as an asymmetric characteristic of the distribution. In this sense, the 3rd order moment of the given distribution is taken as the simplest asymmetry characteristic . Given the homogeneity of the scale

$$\gamma=\frac{\alpha_3}{\sigma^3}, \quad \sigma^2=D\xi \tag{1.2.14}$$

expression of distribution asymmetry taken as the coefficient

will be done . Even order to (higher order with respect to dispersion) moments

probability can be given. For example ,

$$\gamma_e=\frac{\alpha_4}{\sigma^4}-3$$

The expression F (x) is called the excess coefficient of the distribution, which characterizes the level of "smoothness" of F (x) around the "center" (mean value).

It is not difficult to check that the moments of the given distribution exist, since this problem depends on the asymptotics of the "left residual" F (- x) and the "right residual" (1- F (x)) . $x \to \infty$ For example,

$$F(-x)=O\left(x^{-k}\right),$$

$$1-F(x)=O\left(x^{-k}\right), \quad x \to \infty$$

, then $\nu<k$ all moments in the order exist for this distribution.

Reversal formula

Har one F(x) distribution function for

$$f_\xi(t)=\int_{-\infty}^{\infty} e^{itx} p(x)dx \tag{1.15}$$

formula through determined $f\left(t\right)$ characteristic function suitable will come This is your opinion the opposite is also appropriate , i.e distribution function characteristic function through one valuable is determined .

Theorem a (reversal formula). $F=F\left(x\right)$ - distribution function and

$$\text{f(t)}=\int_{-\infty}^{\infty} e^{itx} dF(x) \tag{1.16 }$$

to him suitable came characteristic function let it be

1 °) A gar a and b $(a<b)$ s F(x) of the function continuity points bo'Isa , in that case

$$F(b)-F(a)=\lim_{A\to\infty}\frac{1}{2\pi}\int_{-A}^{A}\frac{e^{-ita}-e^{itb}}{it}f(t)dt \qquad (1.17)$$

2 °) If $\int_{-\infty}^{\infty}|f(t)|dt<\infty$ if , then $F(x)$ absolute continuously distribution function being his _ density function

$$p(x)=\frac{1}{2\pi}\int_{-\infty}^{\infty}e^{-itx}f(t)dt \qquad (1.18)$$

Through the formula is expressed .

Proof : First $F(x)$ absolute continuously has been without let's see .

In this case (1.15) to the formula according to

$$f(t)=\int_{-\infty}^{\infty}e^{itx}p(x)dx$$

and therefore The formula (1.18) is also integrable for f(t) of the function Fourier from replacement consists of (1.18) and the left of Eq right sides integrated , result has been in expression integration order Substituting , we find :

$$F(b)-F(a)=\int_{a}^{b}p(x)dx=\frac{1}{2}\int_{a}^{b}[\int_{-\infty}^{\infty}e^{-itx}f(t)dt]dx=\frac{1}{2\pi}\int_{-\infty}^{\infty}f(t)dt[\int_{a}^{b}e^{-itx}dx]dt=\frac{1}{2\pi}\int_{-\infty}^{\infty}\frac{e^{ita}-e^{itb}}{it}dt$$

So this is it private without reverse formula Fourier integral transform from the result consists of Now (1.17) formula common without let's move on to the proof .

1 °. $f_{\xi}^{\nu}(t)=i^{\nu}\int_{-\infty}^{\infty}x^{\nu}e^{itx}dF_{\xi}(x),\ \nu=1,2,\dots,k$

from the formula this

$$J_A=\frac{1}{2\pi}\int_{-A}^{A}\frac{e^{-ita}-e^{itb}}{it}f(t)dt=\frac{1}{2\pi}\int_{-A}^{A}\frac{e^{-ita}-e^{itb}}{it}[\int_{-\infty}^{\infty}e^{-itx}dF(x)]dt \qquad (1.19)$$

of equality appropriate the fact that come comes out

$$2^{\circ}.\ \left|e^{ix}-e^{iy}\right|=\left|\int_{x}^{y}e^{it}du\right|\le\left|\int_{x}^{y}du\right|=\left|x-y\right|$$

from inequality

$$\left|\frac{e^{-ita}-e^{itb}}{it}e^{itx}\right|=\left|\frac{e^{-ita}-e^{itb}}{it}\right|\le b-a$$

the fact that come comes out That's it with together

$$\int_{-A}^{A}\int_{-\infty}^{\infty}(b-a)dF(x)<2A(b-a)<\infty$$

relationship appropriate what happened _ for (1.19) in the integral Fubini according to the theorem integration order replacement can _ So by doing

$$J_A = \frac{1}{2\pi}\int_{-\infty}^{\infty}[\int_{-A}^{A}\frac{e^{-ita} - e^{itb}}{it}e^{itx}dt]dF(x) =$$

$$= \frac{1}{2\pi}\int_{-\infty}^{\infty}[\int_{-A}^{A}\frac{\sin t(x-a) - \sin t(x-b)}{t}dt]dF(x) =$$

$$= \frac{1}{2\pi}\int_{-\infty}^{\infty}[\int_{-A(x-a)}^{A(x-a)}\frac{\sin z}{z}dz - \int_{-A(x-b)}^{A(x-b)}\frac{\sin z}{z}dz]dF(x) = \int_{-\infty}^{\infty}G_A(x)dF(x), \quad (1.2.20)$$

this on the ground

$$G_A(x) = \frac{1}{2\pi}[\int_{-A(x-a)}^{A(x-a)}\frac{\sin z}{z}dz - \int_{-A(x-b)}^{A(x-b)}\frac{\sin z}{z}dz] \quad (1.21)$$

$g(x,y) = \int_x^y \frac{\sin z}{z}dz$ function x and y arguments according to flat continuously and

$$\lim_{x\to-\infty, x\to\infty} g(x,y) = \pi \quad (1.22)$$

equality appropriate . From this all *A* and *x* numbers for so S a fixed number is found such that its for $|G_A(x)| \leq C < \infty$ of inequality execution come it clicks . That's it with together , from equations (1.21) and (1.22).

$$\lim_{A\to\infty} G_A(x) = G(x)$$

of the limit existence easily to prove can _ Here _

$$G(x) = \begin{cases} 0, x < a, x > b; \\ \frac{1}{2}, x = a, x = b; \\ 1, a < x < b. \end{cases}$$

From this and Lebesgue's Majorant approach about to the theorem according to the integral sign under $A \to \infty$ to the limit at transition from possible using the following we find :

$$\lim_{A\to\infty} J_A = \lim_{A\to\infty}\int_{-\infty}^{\infty}G_A(x)dF(x) = \int_{-\infty}^{\infty}G(x)dF(x) =$$

$$= \int_{-\infty}^{a}G(x)dF(x) + \int_{a}^{b}G(x)dF(x) + \int_{b}^{\infty}G(x)dF(x) =$$

$$F(b-) - F(a) + \frac{1}{2}[F(a) - F(a-) + F(b) - F(b-)]$$

If *a* and *b* points of the function *F(x).* interruption points that attention the last one from equality

$$f_{\xi}^{\nu}(0) = i^{\nu}M\xi^{\nu}$$

of the formula appropriate the fact that come comes out

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