Abstract
The article is devoted to the development and implementation of new mathematical functions, differential integral functions that provide differentiation and integration operations not only according to existing algorithms described in textbooks on higher mathematics, but also by substituting a certain parameter $k$ into formulas developed in advance, forming the necessary derivatives and integrals from these formulas. The Purpose of the Research: The expansion of the concept of number, in particular, in classical mechanics, physics, optics and other sciences, including biological and economic, which makes it possible to expand some understanding of the essence of space, time and their derivatives. Materials and Methods: The idea of fractional space, time and its application is given. The usual elementary functions and the Laplace transform were chosen as the object of research. New functions, differential integral functions, have been developed for them. A graphical representation of these functions is given, based on the example of the calculation of the sine wave. Examples of calculating these functions for elementary functions are given. Of particular interest is the differential integral function, in which the parameter $k$ is a complex number $s, s = a + i \beta$, although in general, the parameter $k$ can be any function of a real or complex argument, as well as the differential integral function itself. Research Results: As a result of the research, it is shown how the Laplace transform and Borel’s theorem are used to calculate differential integral functions. It is shown how to use these functions to carry out differentiation and integration. It is presented how fractional derivatives and fractional integrals should be obtained. Dependencies for their calculation are obtained. Examples of their application for such functions as $\cos(x), \exp(x)$ and loudness curves in music, Fletcher-Manson or Robinson-Dadson curves are shown. Conclusions: Studies show the possibility of a wide application of differential integral functions in modern scientific research. These functions can be used both in office and in specialized programs where calculations of fractional derivatives and fractional integrals are needed.

Index terms — differential integral functions, derivative, fractional derivative, integral, fractional integral.

1 I. Introduction

In modern sciences, such as mathematics, physics, astronomy, economics and other sciences, there is little use of differential functions in calculations, because with the help of fractional derivatives and integrals, very few physical, natural, social and other processes are described that use not only the first and second derivatives, single and double integrals, but fractional derivatives and fractional integrals. So in classical mechanics, the first derivative is used as velocity, the second as acceleration, and the third as a jerk. A one-time integral is used to calculate the area under the curve, the mass of an inhomogeneous body, a two-time integral is used to calculate the volume of a cylindrical beam, a three-time integral is used to calculate the volume of the body.

They can be found in the equations of mathematical physics, where, in particular, generalized functions and convolutional operations on them are used, and in spectral analysis, and in operational calculus based on
2 Figure 1: Notation of integrals and derivatives

As can be seen from Figure 1, all the variety of these notations has one property common to all: they try to reflect in various ways, either with the help of numbers or graphically, the order of derivatives or the multiplicity of the integral.

In order to unify the record of derivatives and integrals, consider them relative to a certain numerical axis "K" (Figure 2), where the value of the parameter k corresponds to the multiplicity of the integral or the order of the derivative. So, in this scenario of notation, k = -1 corresponds to the designation of a single integral \( \int \) \( y(x) \) \( dx \) from the 2nd line and the designation of the same integral \( f \) \( y \) from the 3rd row, and for \( k = 1 \) we have the designation of the first derivative \( y' \) from the 1st row and the designation of the same first derivative \( d \) \( y / dx \) from the 2nd row.

The third line contains the notation of differentials and integrals based on convolutional operations of generalized functions: \( y(k) = f \cdot k \cdot y \), where \( k > 0 \), a value unequal to an integer is called a fractional derivative of order \( k \). An expression of the form: \( y(k) = f \cdot k \cdot y \) is called a primitive of order \( k \), i.e. an integral of multiplicity \( k \).

3 \(<-1>\)

The angle brackets denote the order of the derivative or the multiplicity of the integral, for example, \( y(<0>) = y(x) \) is the function under study, and \( y(<-1>) = \frac{dy}{dx} \) is its integral, multiplicity 1. So \( y(<2>) = \int \frac{dy}{dx} \) = \( y^2 \) is the second derivative, and \( y(<-0.46>) \) is the integral, multiplicity 0.46. For example, a certain derivative of the order of 1.35 is denoted as \( y(<1.35>) \).

To bring these notations in line with the numerical axis "K", the 4th line contains universal notations for derivatives of any order and integrals of any multiplicity, using angle brackets.

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4 II. MATERIALS AND METHODS

This method of calculating derivatives reduces the efficiency of using the differentiation operation, for example, in series expansions, because it requires calculating derivatives of a "high" order, and this is time-consuming and involves calculation errors. Therefore, in such calculations, only the first few terms of the decomposition are taken, and the rest are discarded, which increases the calculation error.

As for calculating integrals, especially multiplicities greater than 2, this is an even more difficult task. Thus, the lack of a simple, reliable and accurate method of differentiation and/or integration significantly hinders computational progress in mathematics.

The same problem is observed in physics. Many laws of mathematical physics, most often appearing in simple, accessible calculations, are based on the use, mainly, of the 1st, maximum 2nd derivative (for example, current \( i = \frac{dq}{dt} \), force \( F = m \cdot \frac{d^2 y}{dt^2} \)) and a single integral, for example, voltage across the capacitor \( u(t) = 1 / C \).
It is very rare in everyday physics or mathematics to find a 3rd derivative or a 3-fold integral. This does not happen often. One of the ways to use a 3-fold integral is the Ostrogradsky-Gauss integral to calculate the volume of a body if the surface bounding this body is known.

And if you look more broadly, then neither in physics nor in mathematics have the everyday laws of the universe using fractional derivatives and integrals been discovered so far, because their calculation is fraught with great difficulties [1]. At the same time, it is possible that all the diversity of the world exists exactly there, in a fractional dimension, which can be described and studied, precisely with the help of fractional (analog), and not integer (discrete) integrals and differentials.

Take, for example, the mechanism of describing multidimensional structures, for example, multidimensional space. Our 3-dimensional space and one-dimensional time are described by discrete (integer) coordinate values, in this case one and three. At the same time, the question of the existence of a space having, not 3, but, say, 2,345 coordinates is of great scientific and practical interest. In other words, the structure of a special "fractional" space, no longer two-dimensional, is a plane (because to describe the plane, you need 2 coordinates, and we have more -2,345), but also not a three-dimensional volume (where 3 coordinates are needed), i.e. something average between the plane and the volume. It is very difficult to imagine such a structure. In nature, such a space does not seem to exist.

It is even more difficult to determine the velocity or acceleration in such a space, i.e. to describe the kinematics of the motion of bodies. If it is possible to define the force in such a space (or to use the already existing classical method of specifying forces), then we can count on success in creating the dynamics of such structures, i.e., in other words, to create the mechanics of multidimensional space. At the same time, our classical 3-dimensional mechanics will turn out to be a special case of a more general mechanics -the mechanics of multidimensional spaces. This can be said about other physical laws of the universe.

And whether our idea of the world will change with the emergence of a new, more general, idea of space. So far we don’t know much about this, because our concepts are tied to a three-dimensional dimensional space, and all the diversity of the world "lies" in a multidimensional "fractional" world that has not been studied at all.

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6 A number of legitimate questions arise:

-What kind of space is "located", say, between a plane (2-dimensional space) and a volume (3-dimensional), i.e. a substance with the dimension of space R, where 2< R<3? -What kind of physical quantity, which is between speed and acceleration between y <1> and y <2> from the move, i.e. a physical quantity, defined, for example, the fractional derivative of y <1,23> , the order of 1,23 (not 1 or 2)? -Whether Newton’s laws are applicable to the so-called fractional space? -How will the definition of force in fractional space change (if it changes)? -Will it be possible to apply the classical laws of mechanics to fractional space, or will it be necessary to create a new, more general, mechanics of the macro and microcosm? -Will the interaction between space and time change if we "replace" the classical concept of space with a fractional one? -Will there be changes in Einstein’s theory of relativity and will the concepts of "gravitational, electromagnetic and other interactions" and much, much more remain the same? Year 2023 ( )

Application of Differential Integral Functions a calculation algorithm, simple and convenient, especially for novice researchers, where instead of calculating integrals/differentials, it would be possible to use the usual substitution of numbers, in which the desired order or multiplicity could be set without performing calculations, but simply substitute the desired parameter into the desired formula and get a ready derivative/integral without their calculations, i.e. immediately. Such a tool, which could be called, for example, functions -SL(x, k), would greatly simplify the process of calculating derivatives and integrals and significantly expand the boundaries of our knowledge. First, we introduce the concepts of a differential integral function based on the definition of a differential integral. The differential integral function SL(x, k) is an ordinary function of several arguments, where, separated by commas, its arguments (in this case one -x) and the parameter k, the order of future derivatives and/or the multiplicity of integrals are indicated 2 For example, for a parabola y(x) = x 2 , such a differential integral function SL(x, k) will have the form where, x is the argument of the function, k is a parameter that specifies the order of the derivative or the multiplicity of the integral. 4 For example, for a parabola, we substitute k= 0 into it. Then, for k= by (x, k) = x 2 , (D'' (3-k) = 2)

(the main, mother function). How to use it? You need to set the parameter k and get the desired derivative or integral. The function (parabola) does not change. When k = 1y (x, k) = 2x and the parabola is transformed into its 1st derivativer <1> . When k = -1 y (x, k) = x 3 /3 and the function becomes its one-time integral -y <-1> , and for k = -2 y (x, k) = x 4 /12 -double -y <-2> . No calculations, just substitution.

Fractional derivatives and integrals are of particular interest, because there is no simple and reliable way to calculate them, except for the method indicated above [2]. In this case, the method of obtaining is the same. To calculate them, it is enough to substitute the necessary value of the derivative instead of the parameter k, for example, k = 0.123 and the parabola becomes its derivative of the order 0.123 -y <0.123> :

\[
\text{If it is necessary to obtain an integral of multiplicity 3.45 -y <3.45> , it is enough to substitute k = -3.45 into the differential function (1) and the parabola becomes its integral of multiplicity 3.45 -y <3.45> :}
\]
7 III. Research Results

Let's consider some examples of the use of differential integral functions in solving approximation problems. Let's consider one of the main properties of this transformation—the differentiation of the original function. Let \( L[f(t)] = F(s) \). Let's find \( L[f(t)\ <1>] \),

\[
L[f(t)\ <1>] = \frac{F(s)}{s-1}
\]

where \( f(t) \) is the 1st derivative, and \( L[f(t)\ <1>] \) is its image. 

This is a direct conversion of the original into an image. The inverse Laplace transform

\[
L^{-1}[\frac{F(s)}{s-1}] = e^t f(t)
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is necessary to find the original of the function by its image.

Let's consider another important property of the image of the function.

\[
L[g^2(t)] = \frac{L[f(t)]^2}{s^2}
\]

Thus, the integration of the function corresponds to the division of the image by \( s \) which forms the derivative of the function.

The method of calculating fractional derivatives is no different from the method of obtaining integer (discrete) derivatives—the same substitution. There is no difference between an integer or fractional derivative/integral. Simple substitution to get a given result.

Consider another example: \( y(x) = \sin(x) \). For a sine wave, the differential integral function \( SL(x,k) \) will have the following form:

For the exponent \( y(x) = e^x \) the differential integral function \( SL(x,k) \) does not depend on \( k \) and all its derivatives and integrals are equal to one another and equal to the exponent itself. For \( y(x) = \sin(x) \), \( \cos(x) \), \( \tan(x) \), and to the tangent function, namely, the parameter \( k \) represents a part of the right angle for unit orts. At \( k = 1 \), the function \( SL(x,1) \) becomes the 1st derivative, such a unit ort is perpendicular to the abscissa axis, and at \( k = \varphi \) it is a fractional derivative of \( k \) order and the angle \( \varphi \) (in values from 0 to 1 or in \% of 90 degrees) it is only a part of the right angle.

Examples of calculation of derivatives and integrals can be summarized in Table ??, whose derivatives and integrals are given for some elementary functions.

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The differential integral function for the sine wave \( \sin(x) \) is a graphical representation of the differential integral function, in which the parameter \( k \) represents a part of the right angle for unit orits. At \( k = 1 \), the function \( SL(x,1) \) becomes the 1st derivative, such a unit ort is perpendicular to the abscissa axis, and at \( k = \varphi \) it is a fractional derivative of \( k \) order and the angle \( \varphi \) (in values from 0 to 1 or in \% of 90 degrees) it is only a part of the right angle.

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cos(x), and choose the polynomial coefficients a 0 ...a 5 so as to minimize the mean square error of approximation of this polynomial are elder at the selected point is known for its derivatives and differentials, as an integer and the fraction. To do this, we fulfill the approximation conditions according to which the value of the polynomial _cos(x) and its fractional derivatives (for simplicity of calculation, only six (5) derivatives are used). To increase the accuracy, you can use more, for example, several dozen derivatives, the computer allows it. Instead of derivatives, its integrals can also be used in the same way) in the vicinity of a given point x0, from the domain of the polynomial definition, should equal the corresponding values of the desired function cos(x) and its fractional derivatives (and integrals). 2 points are selected as points x = 3 and x = 15. The fractional derivatives/integrals for the elements of the polynomial are defined as

\[ D^n(??+1) = a^n + ??(??+1) \]

where x - is the matrix of diagnostic information; n - is the exponent of the polynomial; k-is a parameter that sets the multiplicity of the integral or the order of derivatives. The solution was made in the MathCad program, the calculation listing is given for the point x = 3 and additionally for x = 15.

Another example. In addition to the approximation at a point, using the differential integral functions, it is possible to approximate on a given segment. Examples of this approximation are given below.

Let it be necessary to approximate, for simplicity, the known functions cos(x) and the exponent exp(x), as well as cos(x) on the plot 4 < x < 6, as well as volume curves, according to the type of Fletcher-Manson or Robinson-Dudson curves. For ease of calculation, we approximate 6 points for 2 cos(x) functions, 4 (four) points for the exponent exp(x) and 23 for volume curves.

For a sine wave, the desired points will be of two types. In the first case, these are the points -5, -4, -2, 1, 3, 5. In the second case, this is -5, -3, -1, 1, 3, 5. We will approximate the sinusoid using the differential integral functions of order 6.

**8 Exponent - exponent.**

These expressions (18) and (19) define fractional derivatives/integrals of order k, and are the differential functions of the desired function f(t). Examples of these functions are shown in Table ??, as shown in (17) will have the following form.

As a result of calculating the series rjad_cos(x), we get the values of cos(x) at x = 4 and x = 6, and the initial data obtained by formula (17) will have the following form.

The graphs of these two functions cos(x) and rjad_1_cos(x) and some values of these graphs are shown in Figure ??.

The graphs of these two functions cos(x) and rjad_2_cos(x) and some values of these graphs are shown in Figure ??.

The graphs of these two functions cos(x) and rjad_3_cos(x) and some values of these graphs are shown in Figure ??.

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The graphs of these two functions cos(x) and rjad_5_cos(x) and some values of these graphs are shown in Figure ??.

The graphs of these two functions cos(x) and rjad_6_cos(x) and some values of these graphs are shown in Figure ??.

The graphs of these two functions cos(x) and rjad_7_cos(x) and some values of these graphs are shown in Figure ??.

The graphs of these two functions cos(x) and rjad_8_cos(x) and some values of these graphs are shown in Figure ??.
IV. Conclusions

Differential integral functions, this is the Riemann-Liouville differential integral, written in a convenient form, as a function of two variables. There may be other parameters, for example, integration limits, constants, etc.

: the usual argument and the parameter which sets the multiplicity of the integral or the order of the derivative. These functions allow you to calculate the desired integral or derivative by substituting the parameter k into the established formula. The formula does not change, only one parameter changes. Classical tables of integrals and differentials are not required. Only tables of pre-prepared formulas of differential functions are used, which can be represented in simple calculations in the form of icons, and in the form of SL (x, k) functions in computer programs written in programming languages such as VBasic, C++, Excel, MathCad, Python, etc.

These differential integral functions are of great practical importance, for example, they allow us to approximate a certain given function in the vicinity of the desired point (by the type of decomposition into a Taylor, Maclaurin, Fourier series or Z transformation) or on a segment. At the same time, the conditions of equality of not only the function itself, but also the selected derivatives and differentials, integer and fractional, are observed at the desired approximation points themselves.

Examples of approximation of some elementary functions are shown, for example, using a standard polynomial. It is also possible to approximate trigonometric, power functions and their combinations.

To simplify working with differential integral functions, they can be represented in two forms: for a graphic image-as a function with angle brackets, and for writing in the program text-as a function SL (x, k) of two or more arguments (Application B). Year 2023 The system consists of the polynomial cos (x) and its six fractional derivatives k!, with a maximum multiplicity of 1.25. The order of the derivatives of k changes after 0.25. Year 2023 © 2023 Global Journals A _SL i j, ( ) SL x i n j,0 , ( ) ? := x 2.0 7, 11, 14, 16, 17, 19, 21, 22, 23, j 0 23.

\[ \text{SL}_x (k, n) := A_1 1 \mu 0.25 ? \text{SL}_x 1 (k) := \mu 0.25 \]
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1 Here SL(x, k) is another form of writing a power differential function, different from writing the form y<k>. 3 As the latter, there may be the differential integral functions themselves. In this case, the parameter k can also be a complex value. 5 G(x) - gamma function.

To approximate in this case, it is to decompose into a power series using differential integral functions in the vicinity of the point x 0, bearing in mind that these points are the values of the function f(x) = cos(x).

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Figure 1: Figure 2:

Figure 2:

Figure 3: 3
$n := i_n, n = 0.123$

$k := i_k, k = -1.93$

$kG(n, k) := \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)}$

nk(n, k) := n - k

$y(x, n, k) = kG(n, k) \cdot x^{nk(n, k)}$

$y(x, n, k) \text{ float, } 3 \rightarrow 0.448 \cdot x^{2.05}$

Figure 4:
\[
\begin{align*}
n &:= \text{in}_n \quad n = 0.123 \\
k &:= \text{in}_k \quad k = 0 \\
\kG(n,k) &:= \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)} \\
nk(n,k) &:= n - k \\
y(x,n,k) &:= \kG(n,k) \cdot x^{nk(n,k)} \\
y(x,n,k) \text{ float, } 3 &\rightarrow 1.0 \cdot x^{0.123}
\end{align*}
\]
9 IV. CONCLUSIONS

\[ n := \text{in}_n \quad n = 1.234 \]
\[ k := \text{in}_k \quad k = 0.37 \]
\[ kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)} \]
\[ nk(n,k) := n - k \]
\[ y(x,n,k) := kG(n,k) \cdot x^{nk(n,k)} \]
\[ y(x,n,k) \text{ float,3 } \rightarrow 1.18 \cdot x^{0.864} \]

Figure 7: Figure 5:

Figure 8: Figure 6:
\[
\begin{align*}
n &:= \text{in}_n \quad n = 2 \\
k &:= \text{in}_k \quad k = -2 \\
kG(n, k) &:= \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)} \\
nk(n, k) &:= n - k \\
y(x, n, k) &:= kG(n, k) \cdot x^{nk(n, k)} \\
y(x, n, k) \text{ float, } 3 &\rightarrow 0.0833 \cdot x^4
\end{align*}
\]
\begin{align*}
    n &:= \text{int}_n & n &= 2 \\
    k &:= \text{int}_k & k &= -1.64 \\
    kG(n,k) &:= \frac{\Gamma(n+1)}{\Gamma(n+1-k)} \\
    nk(n,k) &:= n - k \\
    y(x,n,k) &:= kG(n,k) \cdot x^{nk(n,k)} \\
    y(x,n,k) \text{ float, } 3 &\rightarrow 0.141 - x^{3.64}
\end{align*}

Figure 11: Figure 9:

Figure 12: Figure A. 1:
\[ n := \text{in}_n \quad n = 2 \]
\[ k := \text{in}_k \quad k = -1 \]

\[ kG(n,k) := \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)} \quad \text{and} \quad nk(n,k) := n - k \]

\[ y(x,n,k) := kG(n,k) \cdot x^{nk(n,k)} \]

\[ y(x,n,k) \text{ float, } 3 \rightarrow 0.333 \cdot x^3 \]

Figure 13: Table B.1:

Figure 14:

Figure 15:
\begin{align*}
n &:= \text{in}_n \quad n = 2 \\
k &:= \text{in}_k \quad k = 0 \\
kG(n, k) &:= \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)} \\
kn(n, k) &:= n - k \\
y(x, n, k) &:= \frac{kG(n, k) \cdot x^{nk(n, k)}}{nk(n, k)} \\
y(x, n, k) &\rightarrow x^2
\end{align*}

Figure 16:
\begin{align*}
\text{Figure 17:} \\
n := \ln n & \quad n = 2 \\
k := \ln k & \quad k = 1 \\
kgi(x, k) &= \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)} \\
nk(n, k) &= x - k \\
\phi(x, n, k) &= kgi(n, k) \cdot k^t(x, k) \\
y(x, n, k) &= \text{float} 0.3 \rightarrow 2.0 \cdot x \\
\end{align*}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure17}
\caption{}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure18}
\caption{}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure19}
\caption{}
\end{figure}
Figure 20:
\[ n := \text{in}_n \quad n = 2 \]
\[ k := \text{in}_k \quad k = 2 \]

\[ kG(s,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)} \quad nk(n,k) := n - k \]

\[ y(s,n,k) := kG(s,k) \cdot n^{\delta(n,k)} \quad y(s,n,k) \mid s=1 \to 2.0 \]

Figure 21:

Figure 22:

Figure 23:
Введите показатель степенной функции $n$

$$n := \begin{array}{c}
12.34
\end{array}$$

Введите порядок производной или интеграла $k$
Для производной $k > 0$ для интеграла $k < 0$

$$k := \begin{array}{c}
-0.45
\end{array}$$

Дифферинтегральная Функция $Y$ равна

$$y(x, n, k) := \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)} x^{n-k}$$

$$y(x, n, k) \text{ float, } 3 \rightarrow 0.315 \times 12.8$$

Вид этой функции представлен на графике

Figure 24:
Введите показатель степенной функции \(< n >\)

\[ n := \frac{12.34}{2} \]

Введите порядок производной или интеграла \(< k >\)
Для производной \( k > 0 \) для интеграла \( k < 0 \)

\[ k := 0 \]

Дифферинтегральная Функция \( Y \) равна

\[ y(x, n, k) := \frac{\Gamma(n + 1)}{\Gamma(n + 1 - k)} x^{n - k} \]

\[ y(x, n, k) \text{ float,3} \rightarrow 1.0 \times 12.3 \]

Вид этой функции представлен на графике

Figure 25:

Figure 26:

Figure 27:

\[ e^x \quad e^x \quad 1.5 \quad 2.256 x \quad 0.5 \quad \frac{\Gamma(3-k)}{2 x 2-k} \]

\[ \sin(x-\frac{\pi}{2}) \quad \sin(x-0.5 \frac{\pi}{2}) \quad \sin(x) \quad \sin(x+0.5 \frac{\pi}{2}) \quad \sin(x+1.5 \frac{\pi}{2}) \quad \sin(x+k \frac{\pi}{2}) \]

Figure 28:
[Voronenko et al. ()] Analytical description of the process of non-stationary thermal conductivity. Study. Method.


[Gustav Dech Guide to practical application of the Laplace transform and Z-transform (Series "Physical and mathematical library of an engineer")]


