The Exact Solutions of Mathematical Models by Using "Mayan" Transform and Its Applications

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Abstract

This paper focuses on the Mayan integral transform, which is used to obtain exact solutions for linear ordinary differential equations (LODEs) with constant coefficients. It has been applied in nuclear physics, chemistry, and some medical applications. Additionally, we use the Mayan transform to obtain exact solutions to two cardiovascular models. It is clear that the Mayan transform is a reliable, efficient, and straightforward method for resolving differential equations.

Keywords: Mayan transform; Tumor growth model; Mathematical models in health sciences, ODEs, Inverse Mayan Transform.

1 Introduction

Mayan Transform" is obtained from "Laplace Transform," which is essential, and its subsequent proof for some other integral transforms. "Mayan Transform". Eman A. Mansour, Emad A. Kuffi introduced "Mayan Transform" to apply "differential equations in time domain," [14].

Even though the fundamental integral transforms, like Fourier transform and Laplace transform, exist for quite some time, Mayan transforms continue to emerge for solving a particular problem as well as for obtaining different perspectives over existing ones. There exist numerous fields, including Physics (covering Nuclear Physics, and the field of Engineering in which the "New Integral transform: Mayan" can be applied for the resolution of some problems in Electrical Circuit, Medicine, Pharmacokinetics, Biotechnology, Aorta pressure, and the exploration for the resolution of Cancer and Heart problems, amongst others.

[13,14]The definition expression for the Mayan transform of time mapping g(t) represented by the operator M{g(t)} is:

$$M[g(\tau)] = \eta(v) = \frac{1}{v^{i\beta}} \int_0^{\infty} g(\tau) e^{-v^{i\alpha}\tau} d\tau \ , \ t \in [0, \infty).$$

In this manuscript, the concept of the Mayan integral transform and the essential characteristics of It will be resolving the problems in the physics of nuclei, mechanical engineering, or any living applications by converting the ordinary differential equation (ODE) to a simple algebraic equation, and then find the inverse of this new transform which is called “Mayan transform” to get the final result. [15, 16,17,18,19,20 ,21,22].

There is no preference between the different types of integral transforms with one parameter, two parameters, and so on that we have learned. However, each of them plays a vital role because each type of transform can transform differential, integral equations, and systems of equations to algebraic equations.

[23,24,25,26,27,28,29,30, 31,32,33,34]. Identify how this application can be simplified to make conversion easier.

What distinguishes the Mayan transform is the kernel, which differs from previous integral transforms in that it is complex and its conditions are based on the imaginary part. This kernel facilitates computational operations in finding exact solutions.[2,3,4, 7,8,9,10,11].

2 Methodology

We consider functions in the set A defined as:

$$A = \{g(\tau): \exists \quad H, l_1, l_2 > 0, \qquad |g(t)| \leq He^{-u\tau}\}.$$

Where H is any constant, real finite number and l_1 and l_2 may be finite or infinite. Mayan transform, denoted as the operator $[\cdot]$, is defined as equations

$$M[g(\tau)] = \eta(v) = \frac{1}{v^{i\beta}} \int_0^{\infty} g(\tau) e^{-v^{i\alpha}\tau} d\tau, \quad \tau \geq 0, \quad l_1 \leq v \leq l_2,$$

$Im(v^{i\alpha}) < 0$, $i \epsilon C$ [13-14].

(1)

The parameter v in this technique is applied to factor the variable τ in the argument of $g(\tau)$. This technique has connection with Laplace and Elzaki transform. Some propositions are given as:

i) Mayan technique of derivative and n^{th} order derivative of $g(t)$, respectively, are given as[14]:

$$M[g'(\tau)] = v^{i\alpha}\eta(u) - \frac{g(0)}{v^{i\beta}}$$

$$M[g''(\tau)] = v^{2i\alpha}\eta(v) - \frac{g'(0)}{v^{i\beta}} - \frac{v^{i\alpha}}{v^{i\beta}} g(0)$$

$$M[g'''(\tau)] = v^{3i\alpha}\eta(v) - \frac{v^{i\alpha}}{v^{i\beta}} g'(0) - \frac{g''(0)}{v^{i\beta}} - \frac{v^{2i\alpha}}{v^{i\beta}} g(0)$$

$$M[g^{(m)}(\tau)] = v^{mi\alpha}\eta(v) - \sum_{r=0}^{m-1} \frac{g^{(m-1)-r}(0) v^{ir\alpha}}{v^{i\beta}}, \quad m = 1,2,3, \ldots.$$

ii) When $g(t) = \tau^m$, $m = 1,2,3, \ldots.$

$$M[\tau^m] = \frac{m!}{u^{i(m+1)\alpha+\beta}}$$

If a, b are any constants and p(t) and q(t) are functions, then the linear property for Mayan transform is defined as

$$M[a\, p(t) \pm b\, q(t)] = a\, P(u) \pm b\, Q(u).$$

2.1 Mayan Transform for the common Functions

It shall be assumed that equation (1) is true. The function g(t) should have an exponential form and be piece-wise continuous in the interval $0 < \tau < \infty$ ($\tau \geq$

0).The existence of the Mayan Transformation depends on certain conditions. Without these conditions, it is possible that the Mayan Transformation will not be true or that it will be true [1-12].

This section concentrates on the Mayan integral transform calculation for the fundamental functions.

Table Comprehensive Mayan transform [34]

$g(\tau)$	$M[g(\tau)] = G(u)$
1	$\frac{1}{v^{i(\alpha+\beta)}}$
τ	$\frac{1}{v^{i(2\alpha+\beta)}}$
τ^2	$\frac{2}{v^{i(3\alpha+\beta)}}$
τ^m	$\frac{m!}{v^{i(m+1)\alpha+\beta}}$ $m = 1,2,3,....$ or $\frac{\Gamma(m+1)}{v^{i(m+1)\alpha+\beta}}$ $m > -1$
$e^{b\tau}$	$\frac{1}{v^{i\beta}(v^{i\alpha} - b)}$
$sin\, b\, \tau$	$\frac{c}{v^{i\beta}(v^{2i\alpha}+b^2)}.$
$b\tau$	$\frac{v^{i\alpha}}{v^{i\beta}(v^{2i\alpha}+b^2)}.$
$sinh\, b\, \tau$	$\frac{b}{v^{i\beta}(v^{2i\alpha}-b^2)}.$
$\cosh b\, \tau$	$\frac{v^{i\alpha}}{v^{i\beta}(v^{2i\alpha}-b^2)}.$

2.2The Inverse of Mayan Integral Transform [13-14]

We demonstrate the inverse of Mayan integral transform of some known functions in this section:

(i)$M^{-1}\left\{\frac{b}{v^{i(\alpha+\beta)}}\right\} =$ b, where b is a constant.

(ii) $M^{-1}\left\{\frac{m!}{v^{i(m+1)\alpha+\beta}}\right\} = \mathrm{t}^{\mathrm{m}}$, where $\tau > 0$ integer number.

(iii) $M^{-1}\left\{\frac{1}{v^{i\beta}(v^{i\alpha}-b)}\right\} = \mathrm{e}^{\mathrm{b}\tau}$, where b is a constant.

(iv) $M^{-1}\left\{\frac{b}{v^{i\beta}(v^{2i\alpha}+b^2)}\right\} = \sin(\mathrm{b}\tau)$, where b is a constant.

(v) $M^{-1}\left\{\frac{v^{i\alpha}}{v^{i\beta}(v^{2i\alpha}+b^2)}\right\} = \cos(\mathrm{b}\tau)$, where b is a constant.

(vi) $M^{-1}\left\{\frac{b}{v^{i\beta}(v^{2i\alpha}-b^2)}\right\} = \sinh(\mathrm{b}\tau)$, where b is a constant.

vii) $M^{-1}\left\{\frac{v^{i\alpha}}{v^{i\beta}(v^{2i\alpha}-b^2)}\right\} = \cosh(\mathrm{b}\tau)$.

3 Applications:

In this section , the Mayan transform has been applied to many real life applications , and this transform is characterized by the ease of finding exact solutions .[5,6,36,37,38].

3.1 Mayan Integral Transform in physical problems (Radioactive decay).

The foundational ideas of nuclear physics form the basis of this application as Radioactive decay. Examine the ordinary differential equation of the homogeneous first order [5].

$\frac{dR}{dt} = -kR(t)$.

This equation represents the essential formula that defines the decay process. Here, the decay constant λ represents a steady rate of decay, while the function R(t) represents the number of remaining atoms that have not decayed in a time interval t. By the Mayan integral transform denoted as M{.}, one may derive the following:

$$M\{R'(t)\} + \mathrm{kM}\{\mathrm{R}(t)\} = 0,$$

There,

$$v^{i\alpha}M\{R(t)\} - \frac{\mathrm{R}(0)}{v^{i\beta}} + kM\{R(t)\} = 0.$$

Here $R(0) = R_0$.So,

$$v^{i\alpha}M\{R(t)\} - \frac{\mathrm{R}(0)}{v^{i\beta}} + kM\{R(t)\} = 0.$$

Then:

$$M\{R(t)\} = \frac{R(0)}{v^{i\beta}(v^{i\alpha} + k)}$$

Now, applying inverse Mayan integral transform on both sides, we have:

$$\mathrm{R}(t) = R_0 e^{-kt}$$

This is the proper form of radioactive decay.

3.2 Mayan Integral Transform in Tumor Growth Model

In this section, we apply Mayan transform to solve tumor growth model, which was introduced on medical problems based on mathematical models [37-38]. The differential equation of the form

$$\frac{dR}{dt} = rR(1 - \frac{R}{k}) = 0 \qquad (2)$$

usually describes the change in cell numbers, where t represents time, r represents the growth rate of the tumor cells, N represents the number of tumor cells, K represents the limit of environmental accommodation. In equation (2), $(1 - \frac{R}{k})$ can be explained as the limiting effect of the environment on the number of growing tumor cells. Equation (2) can be rewritten as

$$\frac{dR}{dt} - rR + r\frac{R^2}{k} = 0$$

By taking Mayan transform for both sides, we obtain

$$v^{i\alpha}M\{R\} - \frac{\mathrm{R}(0)}{v^{i\beta}} - rM\{R\} + \frac{r}{k}M\{R^2\} = 0.$$

$$v^{i\alpha}M\{R\} - \frac{\mathrm{R}(0)}{v^{i\beta}} - rM\{R\} + r\frac{1}{k}[\frac{2}{v^{i(3\alpha+\beta)}}] = 0.$$

Let $\mathrm{R}(0) = b$, and Simple simplifications, we get

$$M\{R\} = \frac{1}{v^{i\alpha} - r}[\frac{b}{v^{i\beta}} - \frac{r}{k}[\frac{2}{v^{i(3\alpha+\beta)}}]$$

By applying the inverse Mayan transform, we have

$$M^{-1}\{R\} = M^{-1}\left[\frac{b}{v^{i\beta}(v^{i\alpha}-r)}\right] - \frac{r}{k}M^{-1}[\frac{2}{(v^{i\alpha}-r)v^{i(3\alpha+\beta)}}]$$

$M^{-1}\{R\} = First\ term - second\ term$ *

By using partial fraction for second term, we get

$$-\frac{r}{k}M^{-1}\left[\frac{2}{(v^{i\alpha}-r)v^{i(3\alpha+\beta)}}\right] = \frac{-2r}{k}[\frac{A}{v^{i\alpha}-r} + \frac{B}{v^{3i\alpha}} + \frac{C}{v^{2i\alpha}} + \frac{D}{v^{i\alpha}}]$$

We find;

$$A = \frac{1}{r^3}\ ,\ B = \frac{-1}{r}\ ,\ C = \frac{-1}{r^2}\ ,\ D = -\frac{1}{r^3}$$

Then the inverse Mayan transform for * is,

$$\mathrm{R}(t) = \left(b - \frac{2}{r^2}\right)e^{rt} + \frac{1}{k}(t^2) + \frac{2}{kr^2}(1) + \frac{2}{kr}(t)$$

3.3 Application of Chemistry

We apply the Mayan Transform to chemistry in this part. In chemistry, the blending problem plays an important role. Consider a blending problem mentioned below. In a system, a tank holding a mixture of a fixed capacity and well-stirred substance (for example, salt) is a regular example of a blending problem. A private concentration get rate and a private rate of existence for the substance to leave the tank will enter the tank after being well-stirred. If, at time t, the quantity of the substance in the tank is denoted by the quantity z (t), then dz/dt = z'(t) gives the rate of addition to the substance in the tank, subtracted by the rate at which it leaves the tank. A First Order differential equation often leads to the mathematical expression of this condition. If the quantity of material within the tank at time t is symbolically given by the quantity x (t), then dz/dt = z'(t) gives the rate at which addition to the material within the tank occurs, subtracted by the rate at which material leaves the tank.

The solution:

Let z(t) represent the salt content (in kilograms) after t minutes. The question states that the tank initially contains 20 kg of salt (t=0), or x (20)).Our main goal is to determine how much salt is left after 30 minus. (i.e., z (30)). To do

this, we represent the problem as a differential equation satisfied by z(t).Furthermore, we note that the rate of salt content is represented by dz/dt, so

dz/dt = (rate in) - (rate out) (3)

where "rate in" and "rate out," respectively, appear the rates at which salt in puts and out puts to the tank. (0.03 kg/L) (25 L/min) = 0.75 kg/min is our rate. The concentration at time t is z(t) / 5000 (in kilograms per liter), since the tank contains 5000L of liquid. We have $rate\ out$ = (z(t) /5000) ($Kg\ L$) (25) ($L\ min$) = z(t)/ 200 $Kg\ min$, from (1), we obtain;

$\frac{dz}{dt} + \frac{z(t)}{200} = \frac{3}{4}$, z(0) = 20 (4)

Equation (4) has an initial condition and is an ordinary differential equation and (4) can be generalized as:

$\frac{dz}{dt} + kz(t) = r$, z(0)=20 (5)

By taking Mayan transform for two sides from Equation (5) and with initial condition,

$$M\{z'(t)\} + \mathrm{kM}\{\mathrm{z}(t)\} = \mathrm{M(r)}\{1\},$$

$$(v^{i\alpha} + k)M\{Z\} = \frac{20}{v^{i\beta}} + \frac{r}{v^{i(\alpha+\beta)}}.$$

$$M\{Z\} = \frac{20}{v^{i\beta}(v^{i\alpha} + k)} + \frac{r}{v^{i(\alpha+\beta)}(v^{i\alpha} + k)}$$

$M\{Z\} = First\ term$ + Second term *

Using partial fraction for second term and simplifications for the second term,

$$\frac{r}{v^{i(\alpha+\beta)}(v^{i\alpha} + k)} = \frac{A}{v^{i\beta}(v^{i\alpha} + k)} + \frac{B}{v^{i\alpha}(v^{i\alpha} + k)}$$

We find;

$A = \frac{-r}{k}$, $B = \frac{r}{kv^{i\beta}}$

By taking the inverse Mayan transform for *, we get

$\mathrm{z}(t) = -\frac{r}{k}e^{-kt} + \frac{r}{k}(1) + 20e^{-kt}$.

Then,

$z(t) = \frac{r}{k} - [\frac{r-20k}{k}]e^{-kt}$.

3.4 Application in chemistry as the Bouguer Lamber Law

[6] In chemistry, this is the most significant law. It is expressed as follows: Along the path length (t) through a uniform absorbing medium, the electromagnetic radiation's intensity decreases. In terms of mathematics

$$\frac{d}{dt}I(t) + kcI(t) = 0$$

Taking GML transform for two sides, we get

$$v^{i\alpha}M\{I(t)\} - \frac{I(0)}{v^{i\beta}} + kcM\{I(t)\} = 0.$$

$$M\{I(t)\} = \frac{I(0)}{v^{i\beta}(v^{i\alpha} + kc)}$$

Applying inverse Mayan transform, we get

$$I(t) = I(0)e^{-ckt}$$

4 Applications for (Mayan transform to cardiovascular Models)

[35]This section provides Mayan transform applications to two Cardiovascular Models.

4.1 Application I. (Glucose concentration in the blood)

Ordinary differential equations are used in pharmacokinetics to analyze the rate at which a medication's concentration (C) decreases as a function of time (t). This information is crucial for determining the dosage, frequency, and other details [36].

Suppose that the problem of Pharmacokinetics of the form:

$$\frac{d}{dt}c(t) + \lambda c(t) = \frac{b}{VOL}, \quad \text{where} \quad t > 0, \quad \text{with} \quad c(0) = 0$$

The function $c(t)$ denotes the concentration of the drug in the bloodstream at time t. (concentration time function)

The symbol (k) represents the elimination rate constant.

Vol. stands for the volume of distribution of the drug.

Symbol (b) represents the proportion of the infusion being delivered in milligrams per minute (mg/min).

Mayan transformation can be applied on both sides of the equation giving:

$$\boldsymbol{M\{c'(t)\}} + \mathrm{kM\{c(}\boldsymbol{t}\mathrm{)\}} = \frac{\mathbf{b}}{\boldsymbol{VOL}}\boldsymbol{M}\{1\}$$

Then

$$v^{i\alpha}M\{C(t)\} - \frac{C(0)}{v^{i\beta}} + kM\{C(t)\} = \frac{\mathrm{b}}{VOL}\cdot\frac{1}{v^{i(\alpha+\beta)}}$$

So,

$$M\{C(t)\} = \frac{\mathrm{b}}{VOL}\frac{1}{v^{i(\alpha+\beta)}(v^{i\alpha}+k)}$$

Using the partial fraction and simple simplifiations, we get

$$\frac{1}{v^{i(\alpha+\beta)}(v^{i\alpha}+k)} = \frac{A}{v^{i(\alpha+\beta)}} + \frac{B}{(v^{i\alpha}+k)}$$

$A = \frac{1}{k}$, $B = -\frac{1}{kv^{i\beta}}$

Taking the inverse of Mayan transform, we have:

$$C(t) = \frac{b}{VOL}[1 - e^{-kt}]$$

4.2 Application II: (Pressure in the Aorta)

The contraction of the heart makes it easier for blood to pass into the aorta. The aortic pressure function p(t) is the subject of the initial value problem as follows:

$$\boldsymbol{p'(t)} + \frac{\boldsymbol{a}}{\boldsymbol{k}}\boldsymbol{p(t)} = \boldsymbol{aAsin(wt)}$$

Take Mayan transform into sides, we get

$$v^{i\alpha}M\{p(t)\} - \frac{p(0)}{v^{i\beta}} + \frac{\boldsymbol{a}}{\boldsymbol{k}}M\{p(t)\} = a\mathrm{A}\frac{w}{v^{i\beta}(v^{2i\alpha}+w^2)}$$

$$M\{p(t)\} = \frac{p(0)}{v^{i\beta}(v^{i\alpha}+\frac{a}{k})} + \frac{aAwk}{kv^{i\beta}(v^{2i\alpha}+w^2)(v^{i\alpha}+\frac{a}{k})}$$

$M\{p(t)\} = First\ term + second\ term$ *

Where

The first term=$\frac{p(0)}{v^{i\beta}(v^{i\alpha}+\frac{a}{k})}$ and the second term=$\frac{aAwk}{kv^{i\beta}(v^{2i\alpha}+w^2)(v^{i\alpha}+\frac{a}{k})}$

Using partial fraction for the second term and simplifications, we get

$$\boldsymbol{D} = \frac{k^2}{k^2w^2 + a^2}, \qquad E = \frac{k}{-v^{i\beta}(k^2w^2 + a^2)}, \quad F = \frac{a}{v^{i\beta}(k^2w^2 + a^2)}$$

Second term=$\frac{aAwk}{kv^{i\beta}(v^{2i\alpha}+w^2)(v^{i\alpha}+\frac{a}{k})} = \frac{aAwk^2}{k^2w^2+a^2}\left[\frac{1}{v^{i\beta}(v^{i\alpha}+\frac{a}{k})} + \frac{a-kv^{i\alpha}}{v^{i\beta}(v^{2i\alpha}+w^2)}\right]$

By taking the inverse of Mayan transform for *; we have

$$p(t) = \frac{aAwk^2}{k^2w^2 + a^2}[e^{-\alpha t} + \frac{a}{kw}[\sin(wt) - \cos(wt)]$$

Then,

$p(t) = p_0e^{-\alpha t} + \frac{aAw}{w^2+\alpha^2}[\frac{\alpha}{w}\sin(wt) - \cos(wt) + e^{-\alpha t}]$,

Where $\alpha=\frac{a}{k}$

5 Conclusions

In our research, we can pinpoint exactly the solutions to these models of high significance within medicine and epistemology with the aid of the Mayan integral transform. The exactness in solving these models and their ability to be scaled corresponded to this transformation. In our research, we can prove that the Mayan integral transform has real-world significance in solving a model of cancer growth. The formula involving the amount of cancer cells at any particular time can be solved using known constants of initial cancer cells b, and Environment's limit, k, in the final formula. Our research primarily focused on significance within medicine, as well as significance in nuclear Physics and Chemistry. There are many real life applications where finding precise presents difficulties in the solution steps ,leading to the proposal of new solution methods of overcome these difficulties , such as Mayan transform.

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الحلول الدقيقة للنماذج الرياضية باستخدام "المايا"
التحويل وتطبيقاته

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مستخلص البحث: تركز هذه الورقة البحثية على تحويل مايان التكاملي، المستخدم للحصول على حلول دقيقة للمعادلات التفاضلية الخطية العادية ذات المعاملات الثابتة. وقد طُبِّق هذا التحويل في الفيزياء النووية والكيمياء وبعض التطبيقات الطبية. بالإضافة إلى ذلك، نستخدم تحويل مايان للحصول على حلول دقيقة لنموذجين قلبيين وعائيين. من الواضح أن تحويل مايان طريقة موثوقة وفعالة ومباشرة لحل المعادلات التفاضلية.

الكلمات المفتاحية: تحويل مايان؛ نموذج نمو الورم؛ النماذج الرياضية في العلوم الصحية، المعادلات التفاضلية العادية، تحويل مايان العكسي.