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Rangaig integral transform for handling exponentialgrowth and decay problems.

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Abstract: Growth and decay problems are solved by various methods. Recently integral transform is well-known and very much useful tool to solve differential equations Rangaig transform is recently developed integral transform. In this paper we use Rangaig integral Transform to solve the problems of growth and decay.

Keywords: Integral Transform, Rangaig Transform, growth problems, decay problems.

1.Introduction: Recently, integral transforms are one of the most useful and simple mathematical technique for obtaining the solutions of advance problems occurred in many fields like science, Engineering, technology, commerce and economics.

Many researchers are attracted to this field, due to this important feature of the integral transforms and are engaged in introducing various integral transforms. Recently in 2022 Mansour [1] introduced Rangaig transform. Double general Rangaig transform is introduced by Derle et al [2].As researchers are interested in introducing the new integral transforms at the same time they are also interested in applying the transforms to various fields, various equations in different domain. In January 2022, Sanap and Patil [3] used Kushare transform for obtaining the solution of the problems on Newton's law of Cooling.

In April 2022 D. P. Patil, et al [4] used Kushare transform for solving the problems on population growth and decay. D.P. Patil [5] also used Sawi transform in Bessel functions. Further, Patil [6] evaluate improper integrals by using Sawi transform of error functions. Laplace transforms and Shehu transforms are used in chemical sciences by Patil [7]. Dinkar Patil [8] used Sawi transform and its convolution theorem for solving wave equation. Using Mahgoub transform, parabolic boundary value problems are solved by D .P. Patil [9].

D .P. Patil [10] used double Laplace and double Sumudu transforms to obtain the solution of wave equation. Further Dr. Patil [11] also obtained dualities between double integral transforms. Kandalkar, Gatkal and Patil [12] solved the system of differential equations using Kushare transform. D. P. Patil [13] used Aboodh and Mahgoub transforms to solve boundary value problems of the system of ordinary differential equations. Double Mahgoub transformed is used by Patil [14] to solve parabolic boundary value problems.

Laplace, Sumudu ,Aboodh , Elazki and Mahagoub transforms are compared and used it for solving boundary value problems by Dinkar Patil [15]. D. P. Patil et al [16] obtained solution of Volterra Integral equations of first kind by using Emad-Sara transform. Futher Patil with Tile and Shinde [17] used Anuj transform for solving Volterra integral equations of first kind. Rathi sisters and D. P. Patil [18] solved system of differential equations by using Soham transform. Vispute, Jadhav and Patil [19] used Emad Sara transform for solving telegraph equation. Kandalkar, Zankar and Patil [20] evaluate the improper integrals by using general integral transform of error function. Dinkar Patil, PreranaThakare and Prajakta Patil [21] obtained the solution of parabolic boundary value problems by using double general integral transform. Dinkar Patil used Emad- Falih transform for solving problems based on Newton's law of cooling [22].

D. P. Patil et al [23] used Soham transform to obtain the solution of Newton's law of cooling. Dinkar Patil et al [24] used HY integral transform for handling growth and Decay problems, D. P. Patil et al used HY integral transform for Newton's law of cooling [25]. D. P. Patil et al [26] used Emad-Falih transform for general solution of telegraph equation. Dinkar Patil et al [27] introduced double kushare transform. Recently, D. P. Patil et al [28] solved population growth and decay problems by using Emad Sara transform. Alenzi transform is used in population growth and decay problems by Patil et al [29]. Thete, et al [30] used Emad Falih transform for handling growth and decay problems. Nikam, Patil et al [31] used, Kushare transform of error functions in evaluating improper integrals.

Wagh sisters and Patil used Kushare [32] and Soham [33] transform in chemical Sciences. Malpani, Shinde and Patil [34] used Convolution theorem for Kushare transform and applications in convolution type Volterra integral equations of first kind. Raundal and Patil [35] used double general integral transform for solving boundary value problems in partial differential equations. Rahane, Derle and Patil [36] developed generalized double rangaig integral transform.

Shinde, et al [37] used Kushare transform is used for solving Volterra Integro-Differential equations of first kind. Kandekar et al [38] used new general integral equation to solve Abel's integral equations. Pardeshi, Shaikh and Patil [39] used Kharrat Toma transform for solving population growth and decay problems. Patil et al [40] used Kushare transform for evaluating integrals containing Bessel's functions. Thakare and Patil [41] used general integral transform for solving mathematical models from health sciences. Rathi sisters used Soham transform for analysis of impulsive response of Mechanical and Electrical oscillators with Patil [42]. Patil [43, 45] used KKAT transform for solving growth and decay problems and Newton's law of cooling. Suryawanshi et al [44] used Soham transform for solving models in health sciences and biotechnology.

We organize this paper as follows. Introduction is included in first section. Second section is devoted for preliminary concepts. Rangaig transform is used to the problems of growth and decay in third section.

2.Preliminary: In this section we state preliminary concepts like definitions theorems and formulae of Rangaig transform which are useful for solving growth and decay problems.

Rangaig Transform: Rangaig integral Transform of a function $h(t)$can be defined as:

$$\eta[h(t)] = \Lambda(\mu) = \frac{1}{\mu}\int_{-\infty}^{0} e^{(\mu t)}\, h(t)dt\,, \qquad \frac{1}{\lambda_1} \le \mu \le \frac{1}{\lambda_2}. \tag{2.1}$$

General Rangaig Integral Transform: letus consider the set

$$H_{(g)} = \left\{\begin{matrix} h(t) : \text{ there exist } N, \lambda_1 \text{and } \lambda_2 > 0, |h(t)| > Ne^{(\lambda_j |t|)}, \qquad t\epsilon{-1}^{j-1} \times (-\infty, 0) \\ \text{where } j = 1,2 \end{matrix}\right\} \tag{2.2}$$

In this equation (2.2):

N= finite constant, $\lambda_1 and\ \lambda_2$ = finite or infinite constant

General Rangaig Integral Transform that defined for the set $H_{(g)}$ in equation (2.2), can be written as:

$$\eta_g\{\mathrm{h(t)}\} = \Lambda_g(\mu) = \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\, h(t)dt$$

Where $\Lambda_g(\mu)$ denote the General Rangaig Integral Transform of h(t) ϵ $H_{(g)}$.

$$\frac{1}{\lambda_1} \le \mu \le \frac{1}{\lambda_2}\ , n\epsilon Z$$

n is an integer number, p(μ) is a function of parameter μ.

For the function h(t), t is factorized by μ or the function h(t) is mapped into the function $\Lambda_g(\mu)$ of μ space.

Formulaeof elementary functions:

h(t)	$\eta_g\{\mathrm{h(t)}\} = \Lambda_g(\mu)$	$= \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\, h(t)dt$	Final formula
1	$\eta_g\{1\}$	$= \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\,(1)dt$	$\frac{1}{\mu^n p(\mu)}$
t	$\eta_g\{t\}$	$= \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\,(t)dt$	$\frac{1}{\mu^n[p(\mu)]^2}$
t^m	$\eta_g\{t^m\}$	$= \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\,(t^m)dt$	$= \frac{(-1)^m m!}{\mu^n[p(\mu)]^{m+1}}$
$e^{at\}}$	$\eta_g\{e^{at}\}$	$= \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\,(e^{at})dt$	$= \frac{1}{\frac{1}{\mu^n[p(\mu)+a]}}$
$sint$	$\eta_g\{sint\}$	$= \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\,(sint)dt$	$= \frac{1}{\mu^n([p(\mu)]^2+1)}$
$cost$	$\eta_g\{cost\}$	$= \frac{1}{\mu^n}\int_{t=-\infty}^{0} e^{p(\mu)t}\,(cost)dt$	$= \frac{p(\mu)}{\mu^n([p(\mu)]^2+1)}$

General Rangaig transform of derivatives of functions:

If h(t), h'(t), ……….,$h^m(t)\ \epsilon H_{(g)}$,m≥0 then

$\eta_g\{\mathrm{h'(t)}\}$	$=\frac{1}{\mu^n}h(0) - p(\mu)\eta_g\{\mathrm{h(t)}\}$
$\eta_g\{\mathrm{h''}(t)\}$	$=\frac{1}{\mu^n}h'(0) - \frac{p(\mu)}{\mu^n}h(0) + [p(\mu)]^2\eta_g\{\mathrm{h(t)}\}$
$\eta_g\{\mathrm{h^m}(t)\}$	$=\frac{1}{\mu^n}\sum_{k=0}^{m-1}(-1)^k\,[p(\mu)]^k h(0)^{(m-1-k)} + (-1)^m[p(\mu)]^m\eta_g\{\mathrm{h(t)}\}$

3)Applications of General Rangaig Integral Transform in Growth and Decay Problems:

In this section we solve some problems on growth and decay problems.

Problem 1) Population of the city grows at the rate proportional to the number of people presently living in the city. If after two years, the population has doubled and after three years the population is 20000, Estimate the number of people initially in the city.

Solution: Let N= number of people living in the country, T= time, C= constant of proportionality.

This problem can be written in the mathematical form as:$\frac{dN}{dt} = CN$

It can be written as $N'(t) = C\,N(t)$ (3.1)

We apply GeneralRangaig Integral Transform on both sides of equation (3.1),

$$\eta_g\{N'(t)\} = \eta_g\{C\,N(t)\}$$

$$\therefore \frac{1}{\mu^n} N(0) - p(\mu)\eta_g\{\mathrm{N(t)}\} = C\, \eta_g\{N(t)\}$$

Here $N(0)$ is the number of people initially living in the city.

$$\therefore \frac{1}{\mu^n} N(0) = \eta_g\{\mathrm{N(t)}\}\, [C + p(\mu)]$$

$$\Rightarrow \eta_g\{\mathrm{N(t)}\} = \frac{1}{\mu^n}\frac{N_0}{(C + p(\mu))} = \frac{1}{\mu^n}\frac{1}{(p(\mu) + C)} N_0$$

Now applying inverse Rangaig Integral Transform on both sides of aboveequation,

$$\eta_g{}^{-1}\left\{\eta_g\{\mathrm{N(t)}\}\right\} = \eta_g{}^{-1}\{\frac{1}{\mu^n}\frac{N_0}{\left(C + p(\mu)\right)} = \frac{1}{\mu^n}\frac{1}{(p(\mu) + C)}\} N_0$$

$$N(t) = e^{Ct} N_0 \qquad (3.2)$$

Now we use given initial condition which says that after two years, the population has doubled

i.e. t=2, N=2N_0 therefore equation (3.2) becomes2N_0=$N_0 e^{2C}$ $\Rightarrow 2 = e^{2C}$

$$\therefore C = \frac{1}{2} log_e 2 = 0.34657$$

Now for next condition which saysafter three years the population is 20000

i.e. t=3, N=20000therefore equation (3.2) becomes

$$20000 = e^{3(0.34657)} N_0$$

$$\Rightarrow N_0 = \frac{20000}{e^{3(0.34657)}}$$

$$\Rightarrow N_0 = \frac{20000}{e^{1.03972}}$$

$$\Rightarrow N_0 = \frac{20000}{2.828439}$$

$$\Rightarrow N_0 = 7071.16$$

It is the required number of people living in the city initially.

Problem 2: A radioactive substance is known to decay at a rate proportional to the amount present. If initially there is 100 milligrams of the radioactive substance present and after two hours it is observed that the radioactive substance has lost 10 percent of its original mass. Find the half life of the radioactive substance.

Solution: let N denote the amount of radioactive substance at time t and C is the proportionality constant.

This problem can be written in the mathematical form as:$\frac{dN}{dt} = -CN$

It can be written as:$N'(t) = -C\, N(t)$ (3.3)

We apply GeneralRangaig Integral Transform on both sides of equation (3.3),

$$\eta_g\{N'(t)\} = \eta_g\{-C\, N(t)\}$$

$$\therefore \frac{1}{\mu^n} N(0) - p(\mu)\eta_g\{\mathrm{N(t)}\} = -C\, \eta_g\{N(t)\}$$

Here N(0) is the initial amount of radioactive substance at time t=0 and is denoted as N_0.

$$\frac{1}{\mu^n} N(0) = p(\mu)\eta_g\{\mathrm{N(t)}\} - C\, \eta_g\{N(t)\}$$

$$\Rightarrow \frac{1}{\mu^n} N(0) = \eta_g\{\mathrm{N(t)}\}[\, p(\mu) - C]$$

$$\Rightarrow \ \eta_g\{\mathrm{N(t)}\} = \frac{N_0}{\mu^n[\, p(\mu) - C]}$$

Applying inverse Rangaig Integral Transform on both sides of aboveequation,

$$\eta_g{}^{-1}\left\{\eta_g\{\mathrm{N(t)}\}\right\} = \eta_g{}^{-1}\{\frac{1}{\mu^n[\, p(\mu) - C]}\}N_0$$

$$\Rightarrow N(t) = N_0 e^{-Ct} \qquad (3.4)$$

Now we use given initial condition which saysinitially there is 100 milligrams of the radioactive substance present

i.e att=0, N_0 =100therefore equation (3.4) becomes

$$\mathrm{N(t)} = 100e^{-Ct} \qquad (3.5)$$

Now by next given condition after two hours it is observed that the radioactive substance has lost 10 percent of its original mass

i.e.,for t=2 hours, N(t)=100-10=90as initially there is 100 milligrams of the radioactive substance present, therefore equation (3.5) becomes

$$90 = 100.\, e^{-Ct}$$

$$\Rightarrow \ e^{-Ct} = \frac{90}{100}$$

$$\Rightarrow \ -2C = \ log_e \frac{90}{100}$$

$$\Rightarrow -2C = \ log_e 0.9$$

$$\Rightarrow C = \frac{-1}{2} log_e 0.9$$

$$\Rightarrow C = 0.052680$$

We required half life time of radioactive substance i.e. t

Therefore we use half rate of decay of radioactive substance to find half time

$$N = \frac{N_0}{2} = \frac{100}{2} = 50$$

Put this value and value of C in equation (3.5) we get

$$50 = 100e^{-0.052680t}$$

$$\Rightarrow e^{-0.052680t} = log_e\left(\frac{50}{100}\right)$$

$$\Rightarrow e^{-0.052680t} = log_e(0.5)$$

$$\Rightarrow -0.052680t = -0.69314$$

$$\Rightarrow t = \frac{0.69314}{0.052680} = 13.15256\, hours$$

Thus required half time of radioactive substance is $13.15256\, hours$.

Problem:3 The population of the Australia grows at the rate proportional to the number of people presently living in theAustralia. If afterfiveyears, the population has doubled and after ten years the population is 20000. Estimate the number of people initially in the Australia.

Solution: Let N= number of people living in the country, T= time, C= constant of proportionality.

This problem can be written in the mathematical form as:

$$\frac{dN}{dt} = CN$$

It can be written as: $N'(t) = C\,N(t)$ $\quad (3.6)$

We apply GeneralRangier Integral Transform on both sides of equation (3.6),

$$\eta_g\{N'(t)\} = \eta_g\{C\,N(t)\}$$

$$\therefore \frac{1}{\mu^n}N(0) - p(\mu)\eta_g\{\mathrm{N(t)}\} = C\,\eta_g\{N(t)\}$$

Where $N(0) = N_0$ is the number of people initially living in the city we have,

$$\frac{1}{\mu^n}N(0) = \eta_g\{\mathrm{N(t)}\}\,[C + p(\mu)]$$

$$\Rightarrow \eta_g\{\mathrm{N(t)}\} = \frac{1}{\mu^n}\frac{N_0}{(C + p(\mu))} = \frac{1}{\mu^n}\frac{1}{(p(\mu) + C)}N_0$$

Now applying inverse Rangaig Integral Transform on both sides of above equation ,

$${\eta_g}^{-1}\left\{\eta_g\{\mathrm{N(t)}\}\right\} = {\eta_g}^{-1}\{\frac{1}{\mu^n}\frac{N_0}{\left(C + p(\mu)\right)} = \frac{1}{\mu^n}\frac{1}{(p(\mu) + C)}\}N_0$$

$$\mathrm{N(t)} = e^{Ct}N_0 \qquad (3.7)$$

Now we use given initial condition which says that after five years, the population has doubled

i.e. at t=5, N=$2N_0$ therefor equation (3.7) becomes $2N_0 = N_0e^{5C}$

$$\Rightarrow 2 = e^{5C}$$

$$\Rightarrow 5\mathrm{C} = log_e 2$$

$$\therefore C = \frac{1}{5}log_e 2 = \frac{1}{5}0.6931 = 0.1386$$

Now for next condition which saysafter three years the population is 20000

i.e. at t=10, N=20000therefore equation (3.7) becomes

$$20000 = e^{10(0.1386)}N_0$$

$$\Rightarrow N_0 = \frac{20000}{e^{10(0.1386)}}$$

$$\Rightarrow N_0 = \frac{20000}{e^{1.386}}$$

$$\Rightarrow N_0 = \frac{20000}{3.9988}$$

$$\Rightarrow N_0 = 5001.50$$

Thus required number of people living in the Australia initiallyis 5001.

Problem: 4 A radioactive materialsare known to decay at a rate proportional to the amount present. If initially there is 500 milligrams of the radioactive material present and after five hours it is observed that the radioactive substance has lost 25 percent of its original mass. Find the half life of the radioactive material.

Solution: let N denote the amount of radioactive substance at time t and C is the proportionality constant.

This problem can be written in the mathematical form as:$\frac{dN}{dt} = -CN$

It can be written as:$N'(t) = -C\,N(t)$ $\qquad (3.8)$

Applying General Rangaig Integral Transform on both sides of equation (3.3),

$$\eta_g\{N'(t)\} = \eta_g\{-C\,N(t)\}$$

=$\frac{1}{\mu^n}N(0) - p(\mu)\eta_g\{\mathrm{N(t)}\} = -C\,\eta_g\{N(t)\}$

Where N(0) is the initial amount of radioactive substance at time t=0

$$\frac{1}{\mu^n}N(0) = p(\mu)\eta_g\{\mathrm{N(t)}\} - C\,\eta_g\{N(t)\}$$

$$\Rightarrow \frac{1}{\mu^n}N(0) = \eta_g\{\mathrm{N(t)}\}[\,p(\mu) - C]$$

$$\Rightarrow\ \eta_g\{\mathrm{N(t)}\} = \frac{N_0}{\mu^n[\,p(\mu) - C]}$$

Now applying inverse Rangaig Integral Transform on both sides of aboveequation,

$$\eta_g{}^{-1}\left\{\eta_g\{\mathrm{N(t)}\}\right\} = \eta_g{}^{-1}\{\frac{1}{\mu^n[\,p(\mu) - C]}\}N_0$$

$$\Rightarrow N(t) = N_0 e^{-Ct} \qquad (3.8)$$

Now we use given initial condition which saysinitially there is 100 milligrams of the radioactive substance present. i.e. at t=0, N_0 =500therefore equation (3.8) becomes

$$\mathrm{N(t)} = 100e^{-Ct} \qquad (3.9)$$

Now by using second given condition: after two hours it is observed that the radioactive substance has lost 25 percent of its original mass

i.e., at t=2 hours,$N(t) = 500 - 500 \times \frac{25}{100} = 375$as initially there is 500 miligrams of the radioactive substance present, therefore equation (3.9) becomes

$$375 = 500.\,e^{-Ct} \Rightarrow\ e^{-Ct} = \frac{375}{500} \Rightarrow\ -5C =\ log_e\frac{375}{500} \Rightarrow -5C =\ log_e 0.75 \Rightarrow C = \frac{-1}{5}log_e 0.75$$

$$\Rightarrow C = 0.05753$$

We required half time of radioactive substance i.e. t

Therefor we use half rate of decay of radioactive substance to find half time

$$N = \frac{N_0}{2} = \frac{500}{2} = 250$$

Put this value and value of C in equation (3.5) we get

$$250 = 500e^{-0.05753t} \Rightarrow e^{-0.05753t} = log_e(\frac{250}{500}) \Rightarrow e^{-0.05753t} = log_e(0.5)$$

$$\Rightarrow -0.05753t = -0.69314 \Rightarrow t = \frac{0.69314}{0.05753} = 12.048\ hours$$

Thus required half time of radioactive substance is $12.048\ hours$.

Conclusion: we have usedRangaig integral Transform to solve the problems of exponential growth and decay problems.

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