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DUALITIES BETWEEN FOURIER COSINE AND INTEGRAL TRANSFORMATIONS

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Abstract

In many branches of engineering and technology, the most useful mathematical process used to solve a great many problems, including the bending of beams, electrical networks, hot-related problems. It's integral transformation methods. In our study we explored the duality of cosine transformations from Fourier and other efficient integral transformations namely Laplace transform, Mahgoub transform, Aboodh transform and Mohand transform. To explain the complexity of the dual relationship between the transformation of Fourier Cosine and other integral transformations. Here presented a table representing the integral transform that is, transform Laplace, transform Aboodh and transform Mohand of various functions used in Fourier Cosine and other integral transforms to signify fruitful dualities. In order to justify the extent of the dual relationship between Fourier Cosine transform and other comprehensive transforming functions. These integral transformations have been shown to be closely linked to Fourier Cosine transform.

Keywords: Laplace transform, Aboodh transform, Mahgoub transform, Mohand transform,and Fourier,Cosine transform

INTRODUCTION

An integral transform is a transformation in the form of an integral that generates new functions based on a different variable from given functions. These transforms are of particular interest since they can be used to solve ODEs, PDEs, and integral equations, as well as handling and applying special functions.

An integral transform integrates a function from its original function space into a new function space, where some of the original function's properties can be better characterised and manipulated than in the original function space. Integral transforms have a wide range of uses in engineering and science, and are among the most useful techniques in mathematics [17], That are used to solve a wide range of science and engineering problems.

The fundamental goal of integral transforms is to make a difficult problem easier to solve. Laplace transform,Mahgoub transform(Laplace-Carson transform), Aboodh transform Mohand transform,Sumudu transform,Fourier transform,Sawi transform and Elzaki transforms are examples of integral transforms that are used to solve a variety of numerical problems.

The Fourier Transform is a useful image processing technique for breaking down an image into sine and cosine components. The image in the Fourier or frequency domain is represented by the transformation's output, while the spatial domain equivalent is represented by the input image.

Fourier sine and cosine transformations are different types of Fourier integral transform in mathematics. The Fourier sine transform (FST) and Fourier Cosine Transform (FCT) are mathematical transformations [18] that decompose functions that are dependent on space or time into functions that are dependent on spatial or temporal frequency, such as the expression of a musical chord in terms of the volumes and frequencies of its concordant, such as a musical chord's expression in terms of the volumes and frequencies of its constituent notes. The frequency domain representation and the mathematical procedure that associates the frequency domain representation with a function of space or time are referred to as the Fourier sine and cosine transform.

Even functions are dealt with by the Fourier cosine transform. The Fourier cosine integral is used to obtain it. The Fourier cosine transform and its inverse are obtained using the Fourier Cosine integral formula [17].

METHODS

1. LAPLACE TRANSFORM

The function f(x), x≥0 has a Laplace transform[20] as:

F(s)=L{f(x)}=$\int_0^\infty e^{-st}$ f(x) dt. (1)

2. ABOODH TRANSFORM

The function f(x), x≥0 has a Aboodh transform [6] as:

G(s)=A{f(x)}=$\frac{1}{s}\int_0^\infty e^{-st}$ f(x) dt. (2)

3. MAHGOUB TRANSFORM

The function f(x), x≥0 has a Mahgoub transform [5] as:

H(s)=M*{f(x)}= $s\int_0^\infty e^{-st}$ f(x) dt. (3)

4. MOHAND TRANSFORM

The function f(x), x≥0 has a Mohand transform [21] as:

I(s)=M{f(x)}= $s^2\int_0^\infty e^{-st}$ f(x) dt. (4)

5. FOURIER COSINE TRANSFORM

The Fourier Cosine integral formula leads to the Fourier Cosine. Fourier Cosine transform of the function f(x), x≥0 is as: [17]

$F_c(K)=\mathcal{F}_c\{f(x)\}=\sqrt{\frac{2}{\pi}}\int_0^\infty cosx f(x)dx$ (5)

6. FOURIER COSINE - LAPLCE DUALITY

If Fourier Cosine and Laplace transform of f(x) are $F_c(K)$ and F(s)= L{f(x)} respectively then let us establish a duality relation between these transformation.

From (5),

$F_c(K) = \mathcal{F}_c\{f(x)\} = \sqrt{\frac{2}{\pi}} \int_0^\infty cosxf(x)dx$

As we know $Sinkx = \frac{e^{ikx}+e^{-ikx}}{2i}$, put in (6)

$F_c(K) = \sqrt{\frac{2}{\pi}} \int_0^\infty \frac{e^{ikx}+e^{-ikx}}{2} f(x)\, dx$

$F_c(K) = \sqrt{\frac{2}{\pi}} \times \frac{1}{2} \int_0^\infty (e^{ikx} + e^{-ikx}) f(x)\, dx$

$F_c(K) = \sqrt{\frac{1}{2\pi}} [\int_0^\infty e^{ikx} f(x)dx + \int_0^\infty e^{-ikx} f(x)dx]$

Put $ik = -s$ $in\ first\ term\ and$ $ik = s_1$ in second term

$F_c(K) = \sqrt{\frac{1}{2\pi}} [\int_0^\infty e^{-sx} f(x)dx + \int_0^\infty e^{-s_1 x} f(x)dx]$

From (1)

$F_c(K) = \sqrt{\frac{1}{2\pi}} [L\{f(x)\} + L_1\{f(x)\}]$

Or $c = \sqrt{\frac{1}{2\pi}}$

$F_c(K) = c\, [L\{f(x)\} + L_1\{f(x)\}]$ (6)

or

$F_c(K) = c\, [F(s) + F_1(s)]$

Here, $\sqrt{\frac{1}{2\pi}} = c$, $L\{f(x)\} = F(s)$, $L_1\{f(x)\} = F_1(s)$

This is required duality of Fourier Cosine transform with Laplace transform.

7. FOURIER COSINE - ABOODH DUALITY

If Fourier Cosine and Aboodh transform of f(x) are Fc(K) and G(s)= A{f(x)} respectively then let us establish a duality relation between these transformation.

From (5),

$F_c(K)= \mathcal{F}_c\{f(x)\}=\sqrt{\frac{2}{\pi}}\int_0^\infty cosxf(x)dx$

As we know $Sinkx = \frac{e^{ikx}+e^{-ikx}}{2i}$, put in (6)

$F_c(K)= \sqrt{\frac{2}{\pi}}\int_0^\infty \frac{e^{ikx}+e^{-ikx}}{2} f(x)\, dx$

$F_c(K)= \sqrt{\frac{2}{\pi}} \times\frac{1}{2}\int_0^\infty (e^{ikx}+e^{-ikx})f(x)\, dx$

$F_c(K)= \sqrt{\frac{1}{2\pi}}\ [\int_0^\infty e^{ikx}f(x)dx+\int_0^\infty e^{-ikx}f(x)dx]$

Put $ik = -s\ in\ first\ term\ and\quad ik = s_1$ in second term

$F_c(K)= \sqrt{\frac{1}{2\pi}}\ [\int_0^\infty e^{-sx}f(x)dx+\int_0^\infty e^{-s_1x}f(x)dx]$

Or $\sqrt{\frac{1}{2\pi}} = c$

$F_c(K)= c[\int_0^\infty e^{-sx}f(x)dx+\int_0^\infty e^{-s_1x}f(x)dx]$

$F_c(K)= c[\int_0^\infty e^{-sx}f(x)dx]+c[\int_0^\infty e^{-s_1x}f(x)dx]$

$F_c(K)= sc[\frac{1}{s}\int_0^\infty e^{-sx}f(x)dx]+s_1c[\frac{1}{s_1}\int_0^\infty e^{-s_1x}f(x)dx]$

From (2)

$F_c(K)= sc[A\{f(x)\}]+s_1c[A_1\{f(x)\}]$ (7)

or

$F_c(K)= sc\ [G(s)] + s_1c[G_1(s)]$

Where $\sqrt{\frac{1}{2\pi}} = c$, $A\{f(x)\}=G(s)$, $A_1\{f(x)\}= G_1(s)$, is required duality of Fourier Cosine transform with Aboodh transform.

8. FOURIER COSINE - MAHGOUB DUALITY

If Fourier Cosine and Mahgoub transform of f(x) are $F_c(K)$ and H(s)= M_* {f(x)} respectively then let us establish a duality relation between these transformation.

From (5),

$$F_c(K)=\mathcal{F}_c\{f(x)\}=\sqrt{\frac{2}{\pi}}\int_0^{\infty} cosxf(x)dx$$

As we know $Sinkx = \frac{e^{ikx}+e^{-ikx}}{2i}$, put in (6)

$$F_c(K)=\sqrt{\frac{2}{\pi}}\int_0^{\infty} \frac{e^{ikx}+e^{-ikx}}{2} f(x)\,dx$$

$$F_c(K)=\sqrt{\frac{2}{\pi}}\times\frac{1}{2}\int_0^{\infty} (e^{ikx}+e^{-ikx})f(x)\,dx$$

$$F_c(K)=\sqrt{\frac{1}{2\pi}}\left[\int_0^{\infty} e^{ikx}f(x)dx+\int_0^{\infty} e^{-ikx}f(x)dx\right]$$

Put $ik = -s\ in\ first\ term\ and\quad ik = s_1$ in second term

$$F_c(K)=\sqrt{\frac{1}{2\pi}}\left[\int_0^{\infty} e^{-sx}f(x)dx+\int_0^{\infty} e^{-s_1x}f(x)dx\right]$$

Or $\sqrt{\frac{1}{2\pi}} = c$

$$F_c(K)= c\left[\int_0^{\infty} e^{-sx}f(x)dx+\int_0^{\infty} e^{-s_1x}f(x)dx\right]$$

$$F_c(K)= c\left[\int_0^{\infty} e^{-sx}f(x)dx\right]+c\left[\int_0^{\infty} e^{-s_1x}f(x)dx\right]$$

$$F_c(K)=\frac{1}{s}c\left[s\int_0^{\infty} e^{-sx}f(x)dx\right]+\frac{1}{s_1}c\left[s_1\int_0^{\infty} e^{-s_1x}f(x)dx\right]$$

From (3)

$$F_c(K)=\frac{1}{s}c\,[M_*\{f(x)\}]+\frac{1}{s_1}c[M_{*1}\{f(x)\}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Or

$F_c(K)= sc\ [H(s)] + s_1 c[H_1(s)]$

Where $\sqrt{\frac{1}{2\pi}} = c$, $M_*\{f(x)\}=H(s)$, $M_{*1}\{f(x)\}= H_1(s)$

This is required duality of Fourier Cosine transform with Mahgoub transform.

9. FOURIER COSINE - MOHAND DUALITY

If Fourier Cosine and Mohand transform of f(x) are $F_c(K)$ and I(s)= M{f(x)} respectively then let us establish a duality relation between these transformation.

From (5),

$$F_c(K)= \mathcal{F}_c\{f(x)\}=\sqrt{\frac{2}{\pi}} \int_0^\infty cosxf(x)dx$$

As we know $Sinkx = \frac{e^{ikx}+e^{-ikx}}{2i}$, put in (6)

$$F_c(K)= \sqrt{\frac{2}{\pi}} \int_0^\infty \frac{e^{ikx}+e^{-ikx}}{2} f(x)\ dx$$

$$F_c(K)= \sqrt{\frac{2}{\pi}} \times\frac{1}{2} \int_0^\infty (e^{ikx} + e^{-ikx})f(x)\ dx$$

$$F_c(K)= \sqrt{\frac{1}{2\pi}}\ [\int_0^\infty e^{ikx}f(x)dx + \int_0^\infty e^{-ikx}f(x)dx]$$

Put $ik = -s\ in\ first\ term\ and\quad ik = s_1$ in second term

$$F_c(K)= \sqrt{\frac{1}{2\pi}}\ [\int_0^\infty e^{-sx}f(x)dx + \int_0^\infty e^{-s_1x}f(x)dx]$$

Or $\sqrt{\frac{1}{2\pi}} = c$

$$F_c(K)= c[\int_0^\infty e^{-sx}f(x)dx + \int_0^\infty e^{-s_1x}f(x)dx]$$

$$F_c(K)= c[\int_0^\infty e^{-sx}f(x)dx] + c[\int_0^\infty e^{-s_1x}f(x)dx]$$

$$F_c(K)= \frac{1}{s^2}c\ [s^2\int_0^\infty e^{-sx}f(x)dx]+\frac{1}{s_1^{\ 2}}c[s_1^{\ 2}\int_0^\infty e^{-s_1x}f(x)dx]$$

From (4)

$F_c(K) = \frac{c}{S^2}\ [M\{f(x)\}\ ] + \frac{c}{{S_1}^2}[M_1\{f(x)\}]$ (9)

or

$F_c(K) = c\,[\,I(s)\ + I_1(s)]$

Where $\frac{1}{\sqrt{2\pi}} = c$, $M\{f(x)\} = I(s)$, $M_1\{f(x)\} = I_1(s)$

This is required duality of Fourier Cosine transform with Mohand transform.

APPLICATIONS OF DUALITIES RELATIONS FOR FINDING INTEGRAL TRANSFORM (FOURIER COSINE) IN TABULAR FORM

Table 1 Fourier Cosine transform of some basic and useful function with succor of Fourier Cosine - Laplace duality relation.

Sr No.	$f(x)$	**Laplace transform**	**Fourier Cosine transform**
1	e^{-ax}	$\frac{1}{S+a}$	$\sqrt{\frac{2}{\pi}}\ (\frac{a}{a^2+k^2})$
2	1 $\quad 0 \le x \le a$	$\frac{e^{-as}}{-S} + \frac{1}{s}$	$\sqrt{\frac{2}{\pi}}\ (\frac{sinak}{k})$
3	xe^{-ax}	$\frac{1}{(s+a)^2}$	$\sqrt{\frac{2}{\pi}}\frac{a^2-k^2}{(k^2+a^2)^2}$
4	(1+x)e^{-x}	$\frac{s+2}{(s+1)^2}$	

			$\sqrt{\frac{2}{\pi}}\frac{2}{(1+k^2)^2}$
5	$\begin{Bmatrix} 0 & x>2 \\ 2-x & 1<x<2 \\ x & 0<x<1 \end{Bmatrix}$	$-2\frac{e^{-s}}{s^2}+\frac{e^{-2s}}{s^2}+\frac{1}{s^2}$	$\sqrt{\frac{2}{\pi}}\frac{2\cos k-1-\cos 2k}{k^2}$
6	sinx , 0≤x≤π	$\frac{1+e^{-s\pi}}{s^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{1+\cos k\pi}{1-k^2}$
7	cosx , 0≤x≤π	$\frac{s+se^{-s\pi}}{s^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{k\sin k\pi}{1-k^2}$
8	$e^{-x}\sin x$	$\frac{1}{(s+1)^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{2-k^2}{k^4+4}$
9	$e^{-x}\cos x$	$\frac{s+1}{(s+1)^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{k^2+2}{k^4+4}$
10	e^{-x}	$\frac{1}{S+1}$	$\sqrt{\frac{2}{\pi}}\left(\frac{1}{1+k^2}\right)$

Table 2 Fourier Cosine transform of some basic and useful function with succor of Fourier Cosine –Aboodh duality relation.

Sr No.	$f(x)$	Aboodh transform	Fourier Cosine transform
1	e^{-ax}	$\frac{1}{s(S+a)}$	$\sqrt{\frac{2}{\pi}}\ (\frac{a}{a^2+k^2})$
2	1 $\quad 0 \le x \le a$	$\frac{e^{-as}}{-s^2}+\frac{1}{s^2}$	$\sqrt{\frac{2}{\pi}}\ (\frac{sinak}{k})$
3	xe^{-ax}	$\frac{1}{s(s+a)^2}$	$\sqrt{\frac{2}{\pi}}\frac{a^2-k^2}{(k^2+a^2)^2}$
4	$(1+x)e^{-x}$	$\frac{s+2}{s(s+1)^2}$	$\sqrt{\frac{2}{\pi}}\frac{2}{(1+k^2)^2}$
5	$\begin{Bmatrix} 0 & x>2 \\ 2-x & 1<x<2 \\ x & 0<x<1 \end{Bmatrix}$	$-2\frac{e^{-s}}{s^3}+\frac{e^{-2s}}{s^3}+\frac{1}{s^3}$	$\sqrt{\frac{2}{\pi}}\frac{2\cos k-1-\cos 2k}{k^2}$
6	$\sin x \quad , \quad 0 \le x \le \pi$	$\frac{1+e^{-s\pi}}{s(s^2+1)}$	$\sqrt{\frac{2}{\pi}}\frac{1+\cos k\pi}{1-k^2}$

7	cosx , $0 \le x \le \pi$	$\frac{1+e^{-s\pi}}{s^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{\text{ksink}\pi}{1-\text{k}^2}$
8	$e^{-x}\text{sinx}$	$\frac{1}{s[(s+1)^2+1]}$	$\sqrt{\frac{2}{\pi}}\frac{2-k^2}{k^4+4}$
9	$e^{-x}\text{cosx}$	$\frac{s+1}{S[(s+1)^2+1]}$	$\sqrt{\frac{2}{\pi}}\frac{k^2+2}{k^4+4}$
10	e^{-x}	$\frac{1}{S(S+1)}$	$\sqrt{\frac{2}{\pi}}\ (\frac{1}{1+k^2})$

Table 3 Fourier Cosine transform of some basic and useful function with succor of Fourier Cosine –Mahgoub duality relation

Sr No.	$f(x)$	Mahgoub transform	Fourier Sine transform
1	e^{-ax}	$\frac{s}{S+a}$	$\sqrt{\frac{2}{\pi}}\ (\frac{a}{a^2+k^2})$
2	1 $0 \le x \le a$	$1-e^{-as}$	$\sqrt{\frac{2}{\pi}}\ (\frac{sinak}{k})$
3	$\text{x}e^{-ax}$	$\frac{s}{(s+a)^2}$	

			$\sqrt{\frac{2}{\pi}}\frac{a^2-k^2}{(k^2+a^2)^2}$
4	$(1+x)e^{-x}$	$\frac{s(s+2)}{(s+1)^2}$	$\sqrt{\frac{2}{\pi}}\frac{2}{(1+k^2)^2}$
5	$\begin{Bmatrix} 0 & x>2 \\ 2-x & 1<x<2 \\ x & 0<x<1 \end{Bmatrix}$	$-2\frac{e^{-s}}{s}+\frac{e^{-2s}}{s}+\frac{1}{s}$	$\sqrt{\frac{2}{\pi}}\frac{2\cos k-1-\cos 2k}{k^2}$
6	sinx , $0\leq x\leq\pi$	$\frac{s(1+e^{-s\pi})}{(s^2+1)}$	$\sqrt{\frac{2}{\pi}}\frac{1+\cos k\pi}{1-k^2}$
7	cosx , $0\leq x\leq\pi$	$\frac{s^2(1+e^{-s\pi})}{s^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{k\sin k\pi}{1-k^2}$
8	$e^{-x}\sin x$	$\frac{s}{(s+1)^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{2-k^2}{k^4+4}$
9	$e^{-x}\cos x$	$\frac{s(s+1)}{(s+1)^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{k^2+2}{k^4+4}$
10	e^{-x}	$\frac{s}{(S+1)}$	$\sqrt{\frac{2}{\pi}}\left(\frac{1}{1+k^2}\right)$

Table 4 Fourier Cosine transform of some basic and useful function with succor of Fourier Cosine –Mohand duality relation

Sr No.	$f(x)$	Mohand transform	Fourier Cosine transform
1	e^{-ax}	$\frac{s^2}{s+a}$	$\sqrt{\frac{2}{\pi}}\ \left(\frac{a}{a^2+k^2}\right)$
2	$1 \qquad 0 \le x \le a$	$s(1-e^{-as})$	$\sqrt{\frac{2}{\pi}}\ \left(\frac{sinak}{k}\right)$
3	xe^{-ax}	$\frac{S^2}{(s+a)^2}$	$\sqrt{\frac{2}{\pi}}\frac{a^2-k^2}{(k^2+a^2)^2}$
4	$(1+x)e^{-x}$	$\frac{S^2(s+2)}{(s+1)^2}$	$\sqrt{\frac{2}{\pi}}\frac{2}{(1+k^2)^2}$
5	$\begin{Bmatrix} 0 & x>2 \\ 2-x & 1<x<2 \\ x & 0<x<1 \end{Bmatrix}$	$-2e^{-s}+e^{-2s}+1$	$\sqrt{\frac{2}{\pi}}\frac{2\cos k-1-\cos 2k}{k^2}$
6	$\sin x \ , \quad 0 \le x \le \pi$	$\frac{s^2(1+e^{-s\pi})}{(s^2+1)}$	$\sqrt{\frac{2}{\pi}}\frac{1+\cos k\pi}{1-k^2}$
7	$\cos x \ , \quad 0 \le x \le \pi$		

		$\frac{s^3(1+e^{-s\pi})}{s^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{\text{ksink}\pi}{1-\text{k}^2}$
8	$e^{-x}\text{sinx}$	$\frac{s^2}{(s+1)^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{2-k^2}{k^4+4}$
9	$e^{-x}\text{cosx}$	$\frac{s^2(s+1)}{(s+1)^2+1}$	$\sqrt{\frac{2}{\pi}}\frac{k^2+2}{k^4+4}$
10	e^{-x}	$\frac{s^2}{(S+1)}$	$\sqrt{\frac{2}{\pi}}\left(\frac{1}{1+k^2}\right)$

CONCLUSION

In this article, dual relationship between Fourier Cosine and the transformation of Laplace as a useful integral, transforming Aboodh, transforming Mahgoub and transforming Mohand are satisfied. In order to visualize the importance of these dualities between Fourier Cosine and mention integral transformation, a table representation of the integral transform Laplace transform, Aboodh transform, Mahgoub transform(Laplace Carson transform), and Mohand transform, is provided of several simple and practical tasks in the context of the aid of these relationship dualities. Results demonstrated that in this paper Fourier Cosine transforms and note integral transforms. In the future we will solve many advanced science and engineering problems using the dual relationship.

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