International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)
Volume VII, Issue XI, November 2018 | ISSN 2278-2540

Analysis of Analogy between Optical and Digital Domain 2D Fourier Transforms for Real Time Image Processing

Dr. J. Veerappan[1], Dr. R. Ganesan[2]

[1]*Professor, Department of Electronics and Communication Engineering, Vel Tech High Tech Dr.Rangarajan Dr. Sakunthala Engineering College, Avadi, Chennai, Tamilnadu, India*

[2]*Professor, Department of Electronics and Instrumentation Engineering, Saveetha Engineering College, Chennai, Tamilnadu, India*

Abstract: **Selection of a conventional Digital domain Image Processing (DIP) for real time applications depends upon its processing speed (frames per second (FPS)). At present, the Digital domain Fourier Transformer (DFT) and Inverse Digital domain Fourier Transformer (IDFT) in DIP consume much time in signal/image processing which is a constraint so that DIP is found to be widely applicable for the processing of various still images. The salient feature of Optical Fourier Transformer (OFT) in Optical Image Processor (OIP) is that it produces spectra of given image within few nanoseconds, whereas DFT in DIP produces the same in the order of milliseconds. Hence, the entire processing speed of OIP is similar to light propagation speed. In this paper, the analogy between Fourier Transforms in DIP and OIP also the replacement possibility of DFT by OFT in DIP are analyzed. It is found that any DFT in DIP may be replaced by OFT. This replacement would give an impetus to develop a new Hybrid Image Processing (HIP) and more suitable for real time applications.**

Keywords: **DIP, OIP, DFT, OFT.**

I. INTRODUCTION

In image processing, the emphasis must be given to the term, "Real time applications". If any process completed within the rate of incoming signal, then it is said to be suitable for real time applications [1-3]. Image processing may be viewed in two broad senses – Digital domain Image Processing (DIP) using computers and Optical domain Image Processing (OIP) using optics.

DIP is found to be widely applicable for the processing of various still images obtained from space, aircraft, underwater etc. and works to give satisfactory results for such complicated images. DIP has been further enhanced by the introduction of various recent advanced techniques [4]. In spite of all these advantages, nowadays DIP is not widely preferred for real time applications because of its lesser processing speed. Since DFT and IDFT in DIP consume much more time in image processing, it is more suitable for still images. Even though DIP is applicable for moving image frames or video images (real time applications) by means of reducing their input frame rate (number of frames per second), the quality of the output is poor.

The other method of image processing is Optical domain Image Processing (OIP). Comparing to DIP, OIP can process any complicated still images, video pictures or moving images [5] more successfully and the processing time is in the order of nanosecond, therefore its speed is in the order of 10^8 FPS. An ordinary lens can act as both Optical Fourier Transformer (OFT) and Optical Inverse Fourier Transformer (OIFT). So OFT in OIP would not be much expensive; also it can cut processing time significantly. But OIP has certain drawbacks too: i) it requires certain manual operations [4] to be performed during the filtering section. ii) It is highly difficult to perform spatial domain image processing techniques such as edge detection, and pixel extraction etc. This paper proves the advantages of OFT in DIP rather than DFT in DIP by taking a real time application [6,7].

II. MOTIVATION OF OFT

OFT is a simultaneous process rather than the DFT which is under pixel by pixel processing. That is, the spectra of the entire image can be obtained by manipulating the pixels simultaneously which is in a single step. But the real time application of DIP is only possible by either reducing their input frame rate or reducing the processing time lower than the real time of an image frame. One of the ways to reduce the processing time is the replacement of DFT in DIP by OFT. An ordinary lens can act as both Optical Fourier Transformer and Optical Inverse Fourier Transformer. So the replacement of DFT in DIP by OFT would not be much expensive and also it can cut processing time of DIP significantly.

III. REPLACEMENT OF DFT BY OFT IN DIP

It is convenient to replace DFT by OFT in any DIP for real time applications if the output spectra of these two are close to each other for a given input image. This proof of spectral identity is illustrated below in the sub sections (3a and 3b).

3 a. Identical Equations of DFT and OFT

In DIP, DFT algorithm forms the spectra(u, v) , which are the Fourier transform of the input$g(x, y)$ [8].

$$G(u,v) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} g(x,y)e^{-j2\pi(ux+vy)}\,dxdy \qquad \ldots(1)$$

where $u$and v are (electrical) spatial domain frequencies.

In the OIP, according to scalar diffraction theory and Fraunhofer diffraction theory [6], the OFT lens forms the spectra$G(u', v')$in its back focal plane, which is the Fourier transform of object image$g(x, y)$.

$$G(u',v') = G\left(\frac{u}{\lambda f}, \frac{v}{\lambda f}\right) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} g(x,y)e^{-j2\pi(u'x+v'y)}\,dxdy \qquad \ldots(2)$$

Where u' and $v'$are (optical) spatial domain frequencies.

These equations 1 and 2 show that the basic equations of DFT and OFT are similar [6].

3 b. Analogy between DFT and OFT

The (spatial domain) relation between the electrical spectra $G(u, v)$ and optical spectra $G(u', v')$ are derived from the Fraunhofer diffraction theory [6]. On comparing the equations 1 and 2, the relationship between electrical spatial domain frequencies, u and$v$ and optical spatial domain frequencies, $u'$and v' is obtained as

$$u' = \frac{u}{\lambda f} \quad \text{and} \quad v' = \frac{v}{\lambda f} \qquad \ldots(3)$$

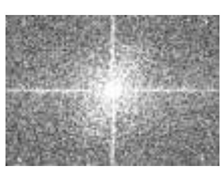
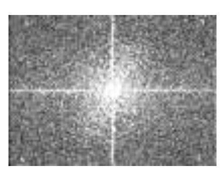
where λ is the wavelength of the light which is passing through OIP and f is the focal length of the lens.

From the equation 3, the OFT spectra $G(u', v')$are equal to scaled DFT spectra $G(u, v)$with scaling factor of$1/\lambda f$. Hence, both DFT and OFT spectra are same when this scaling factor becomes unity. Therefore, it is concluded that OFT is analogous to DFT with a phase factor.

IV. EXPERIMENTAL

The spectra of OFT , DFT and its difference of some Bio-medical images [9] which are simulated using MATLAB (version 7) program [10,11] in Pentium-4 computer are shown in table.1. It is clear from the table (Table1) that though the spectra obtained by DFT are much closer to the spectra of OFT under these simulations, normal OFT spectra contain more spectral contents than DFT. Because the absent of inherent errors due to sampling, quantizing and aliasing process in OFT whereas these errors are obvious in DFT. Hence, it comes to the conclusion from the above illustrations that DFT by OFT in DIP can be replaced thereby, reducing the processing time of the entire system. This feature allows for a real-time image processing.

Table1: Comparison of DFT, OFT and (OFT-DFT) spectra

Images	DFT spectra	OFT spectra	OFT-DFT spectra
			
			

However, this replacement requires certain modifications. The concept of modification required for the replacement of DFT by OFT in DIP has been shown in figures 1(a) and (b).

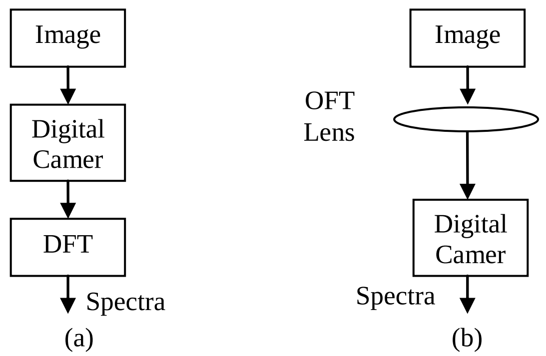


Fig.1 (a) Actual system (b) Modified System

In the actual system (fig 1a) the given image is converted to electrical and then spectra of the image are obtained by DFT. In the modified system (fig 1b), the spectra of the given image obtained by OFT lens and then converted to electrical using a Digital camera.

V. CONCLUSION

This paper proves the spectral identity of DFT in DIP and OFT in OIP with suitable illustrations. Hence, it is concluded that any DFT in DIP may be replaced by OFT. This replacement would give an impetus to develop a new Hybrid (optical and digital) Image processing (HIP) and more suitable for real time applications. Because the processing time of OFT is in the order of nanoseconds whereas in DFT it is in the order of milliseconds. Hence, the concept of OFT in DIP is highly suitable for real time applications.

REFERENCES

[1]. Ichiro Tamitani, Member, IEEE, Hidenobu Harasaki, Member, IEEE, Takao Nishitani,Member, IEEE, Yukio Endo, Member, IEEE, Masakazu Yamashina, Member, IEEE And Tadayoshi Enomoto, Member, IEEE AReal-Time Video Signal Processor Suitable for Motion Picture Coding Applications IEEE Transactions on Circuits and Systems, **36** (2016), 1259-1266

[2]. R. R. Gulathi Television pictures-chapter2 in Modern Television Practice, 2nd edition, (2014), pp10-22 (New age international (p) Ltd Publishers)

[3]. Richard L. Marks, Stephen M. Rock, and Michael J. Lee 1995 Real-Time Video Mosaicking of the Ocean Floor IEEE Journal Of Oceanic Engineering, **20(3)** 229-241

[4]. David G. Zawada, Image Processing of under water multispectral Imagery IEEE Journal of Oceanic Engineering **28 (**2013**),** 583-594

[5]. Brandley G.Boone 'Fourier transform and imaging properties of optical systems' and 'Signal processing analogies for optics'-chapter6 in Signal Processing using Optics, Oxford University Press, 2017, pp137-162.

[6]. W. G. Joseph, Spatial filtering and optical information processing-chapter 7 in Introduction to Fourier Optics, 2017, pp141-198.

[7]. M.Francon Elements of optical processing of information-chapter10 in Optical Image Formation and Processing, Academic Press, INC, London, 2016, pp145-165.

[8]. R.C.Gonzalez and R.E.Woods, Image enhancement in the frequency domain-chapter4 in Digital Image Processing, 2014, pp148-251 (Pearson Education, INC).

[9]. R. Sai Santosh Kumar, Edge-Enhancement Technique in Optical Fourier Processing: Applications to Medical Images at Dept of Physics, Sai Sathya Sai Institute of Higher Learning (Deemed University) Prasanthi Nilayam, Andhra Pradesh, 2013.

[10]. T. Chung and P.P.Banerjee, Single and double lens Image processing systems chapter 5 in Contemporary Optical Image Processing with MATLAB, 2011, pp133-169.

[11]. W.Lauterboru, T. Kurz and M.Wiesenfeldt, Fourier Optics-chapter 9 in Coherent Optics fundamental and applications, McGraw-Hill,2016, pp147-178