Phase Shifting Fourier Positive – Negative Single Pixel Imaging

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Abstract

In this work, a different Fourier single-pixel imaging technique that uses an intensity correlation algorithm to reconstruct images from obtained Fourier positive–negative imagesis used. The research is based on Fourier positivenegative intensity correlation for single pixel image processing.In single-pixel imaging, a set of mask patterns is employed to filter the scene. Single pixel imaging is a type of imaging that uses only one detector device.The goal of this study is to use the concept of positive – negative intensity correlation to obtain a clear image.Using intensity correlation, the negative and positive pictures are used to recreate a picture. To carry out the simulation, a Fourier matrix is created and divided into two parts: real cosine and imaginary sine.After obtaining discrete sampling points we reshaped these points to form a 2D square pattern. The pattern so obtained finally overlayed on the target image. The size of target image is selected on basis of Fourier matrix. Positive and negative images are obtained by overlaying the pattern on target image. The simulation is carried out using Python programming. We use the overlaying technique to combine positive and negative images to create a clearer image.An endless superposition of sine waves of varying frequencies can be characterised as any continuous signal. This theory is applied to a two-dimensional space, and a technique for imaging is proposed.Theexecuted simulations resulted in production of high-quality photographs, proving the technologies' viability.

Keywords: Single pixel imaging; Positive-negative intensity correlation; Fourier matrix; overlaying.
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1. Introduction

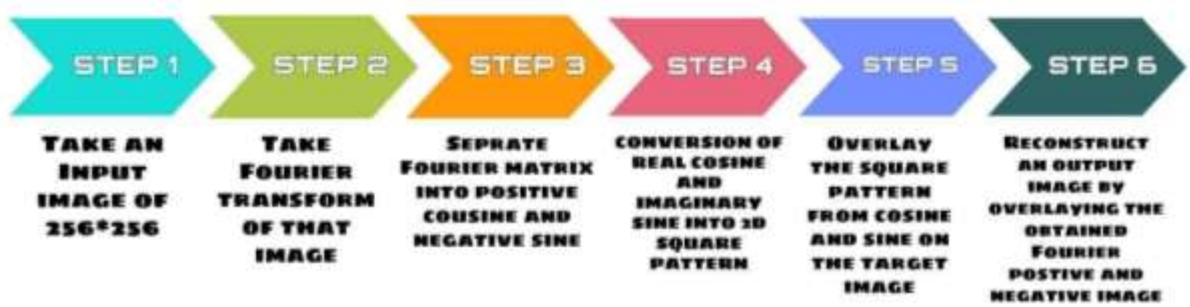
One of the first and most often used remote sensing technologies is optical cameras.A photosensitive unit and a lens unit are the two main components of an optical camera. A pixel, also known as a picture element in digital imaging, is the smallest unit of data in an image. Pixels are represented by squares and are arranged in a two-dimensional grid. Each pixel's intensity is adjustable.A matrix is a two-dimensional array of values, and an image is the same. The values of a grayscale image are scalars that indicate the intensities of each pixel, but the values of a color image are triples that contain the values of the three color channels i.e red, green, and blue. Imaging is one of the most popular and helpful methods for gathering data. Imaging has traditionally been done with cameras that use detector arrays. Single-pixel imaging is similar to standard ghost imaging in that it uses only one detector (CGI).Rather than using a pixilated array to capture a two-dimensional (2D) image, these methods extract spatial information by storing just the total light intensity in each spatial sample base component. Single-pixel imaging illuminates an object with a collection of spatially distributed lights before extracting the powers of transmitted/reflected light from the object using a single-pixel detector. A fascinating alternative to classic imaging is single-pixel imaging (SPI) or computational imaging with a single-pixel camera (SPC). Researchers have demonstrated that a single pixel may capture an image using spatially structured lighting and several temporal domain measurements. This approach is known as computational single-pixel imaging (SPI), which is also known as ghost imaging. Fourier single-pixel imaging is a single- pixel imaging approach that has recently shown to be effective. The image of an item could be recreated using the link between spatially distributed lighting patterns and light powers. The acquisition of the Fourier spectrum is the foundation of Fourier single-pixel imaging. We employed grayscale cosine patterns and sinusoidal patterns that is the real part and the imaginary part of Fourier matrix. The Fourier Transform separates an image into sine and cosine components and is a useful image processing approach. Low-frequency information is the most important component of general images, which provides the image's fundamental grey level. The image's edges and details are formed by highfrequency information. The Fourier matrix's inherent characteristic is responsible for the positive and negative pictures obtained here. There are two parts to the imaging course.The structured light is modulated with sine and cosine functions to create the first two intensity images. Second, the phase of the two images is adjusted to provide a clear image. There are visible ringing effects around the image's margins, resulting in data loss throughout the imaging process, notably high-frequency data. As a result, the reconstructed image's quality suffers, making it impossible to apply a later image-processing method to it.Due of missing phase information, we use the Fourier matrix to build sinusoidal and cosine structural illumination patterns. In the imaging course, both programmers may recreate images/pictures with symmetrical overlaying shadows. After phase correction using the intensity correlation on negative and positive images, a clear image is ultimately reconstructed. We used greyscale cosine patterns and sinusoidal patterns (the actual part of the Fourier matrix) (the imaginary part of Fourier matrix).Basic principle used while performing image processing using programming language is that any continuous signal can be expressed as superposition of sinusoidal waves which implies to conversion of 1D signal to 2D pattern. We start by generating a Fourier matrix of dimension 256 x 256. For projecting, each pattern corresponds to a reconstruction coefficient, and element values are normalized to a range of 0 to 255. A total of 65,536 pixels were created. Following the production of the Fourier matrix, we divide it into two parts: real cosine and imaginary sine.The resulting matrix is then converted into 2D square pattern giving rise to two such patterns. These patterns are then overlayed on the target image. To obtain final output image we overlay the positive and negative image obtained. Clearly there are ringing effects which led to loss of information.Because the sampling ratio is low, this loss occurs towards the image's edges. The clarity of image at the center increases as compared to the positive and negative image that we obtained by overlaying. The objectives achieved by this research work are: Firstly, the quality of image improved: an unclear image results in the loss of some critical information. Image processing can enhance the quality of an image. After improving we get an enlarged, sharper, and enhanced quality image. Secondly, application of Fourier transforms in image processing: Fourier transform plays vital role in image processing. It's used to separate sine and cosine components in a picture.Feature extraction, feature detection, picture reconstruction, and image compression can all benefit from the Fourier transform.The image output is represented in Fourier form and finally we obtain positive and negative image using python programming: When any image is stored in computer then their pixel values also stored. Using python, we obtained Fourier positive and negative image. In negative image, the brightest area is transformed into the darkest and the darkest area into the brightest. After that we used to merge these positive and negative images to get clear and better-quality image.

2. Literature Review

The presence of noisy environmental illumination makes obtaining high-quality pictures difficult. To address these issues, phase-shifting sinusoid structured lighting with inverse Fourier transform is used for spectrum capture. This method can capture a scene without having a direct view of it. It allows for the positioning of detectors to be practical. Because of this, even with noise supplied by external illuminations, clear images can be acquired by using a detector that is not located in an indirect view of the imaged scene [1]. One of the approaches to get a clean image is to use fast Fourier single pixel imaging, which requires grayscale Fourier basis pattern for illumination. A digital micro mirror device that produces grey scale patterns at a low refresh rate can be used. Binarization and error diffusion dithering are utilized on the up-sampled Fourier basis patterns. The picture capture speed of Fourier Single Pixel Imaging is significantly accelerated with this technology [2]. To increase the quality of real-time images, the Wasserstein Generative Adversarial Network (WGAN) and Gradient Penalty (GP) concepts are applied. Some picture losses, such as resistance loss and content loss, occur, which is why confronting training is done first, followed by the connection of an additional generator to improve the reconstructed image's fidelity.This model is used to denoise low-quality photos and restore high-frequency detail. We acquire a better image by employing this method [3].Fourier single pixel imaging relies on under-sampled reconstructions, which results in poor image quality. A quick image reconstruction system based on deep learning is suggested to improve image quality. The network has been trained on a big image set and can rebuild a variety of images that were not observed during training.Therefore by using Deep learning (DL-FSPI) we get better image quality at very slow rates than previous [4] Software as well as hardware simulation can be done to obtain clear image. Mostly hardware setup can be used [5]. Calculations of various graph morphism, designed with overall performance and scalability leads to clear image. In this method first break a complex network into subgraphs after that transform these subgraphs into intermediary structures which is used to produce grey-scaled bitmap images and finally performing image comparison with the help of Fast Fourier Transform [6]. In signal processing, the Fast Fourier Transform is a necessary element. The sparse Fast Fourier Transform model is discussed in this paper when used in lithography optimization, cancer detection, evolutionary arts, and wastewater treatment to handle computing challenges while assisting with multi-dimensional signal analysis in image processing.The need for sparse Fast Fourier transforms As the demand for high-dimensional signals in many applications, notably multimedia applications, grows, transform evolves [7].Problems like image timing and their quality, the orthogonal patterns technique is used to reduce these problems. Hadamard and Fourier sinusoidal patterns are the most well-known among them. Fourier matrix is used to get Fourier negative and Fourier positive images and intensity correlation to get high quality image [8]. Fourier single pixel imaging is used to reconstruct sharp images. But the image quality is not balanced and efficient. For this Complementary Fourier Single pixel imaging introduced. Digital micromirror device is used where they get complementary nature. To obtain two patterns four light intensity values were used. This technique works better than other to get image quality [9]. When image is reconstructed, it has image details quality and noise suppression problem. To deal with it Adaptive Fourier single pixel imaging can be used. The radial correlation between low and high frequencies was investigated, and the position of high frequency components was determined as a result. For picture reconstruction, the suggested technique employs the inverse Fourier transform [10]. Sinusoidal and phase-shifting sinusoid-modulated structural lighting patterns, which correspond to negative and positive Fourier imaging, can be generated using the Fourier matrix.In the intermediate imaging course, you must obtain two centrosymmetric pictures. For phase compensation, intensity correlation can be used to both negative and positive images, resulting in high-quality images. It's utilized for images that have been sub-sampled. [11,12].

3. Methodology

Fig.1: Block Diagram for Image Reconstruction



First an input image of 256 x 256 size was taken for generation of 256 X 256 Fourier matrixes. Through simulation Fourier transform of the input image was obtained. Then the separation of Fourier matrix into real cosine and imaginary sine part was done. Further conversion of real cosine matrix and imaginary sine matrix into 2D square patterns was done to obtain the square pattern by converting cosine matrix. The two patterns for cosine and sine which is obtained results in positive and negative square patterns respectively. Then the pattern formed from real cosine and imaginary sine matrix was plotted for checking the result of simulation acquired the target image of dimension 256 X 256. Then the target image is converted to grayscale image. Overlay the square pattern obtained from cosine and sine matrix on the target image by adding weights. Finally obtained Fourier positive and negative images were overlayed to get the output image and then reconstruction of the image takes place, as shown in " Fig.1" The simulation was done on four target images to verify the results. The image size should be 256 X 256 only since we are generating Fourier matrix of dimension 256X256. The similar process was performed for different phases and the reconstructed image quality was analyzed.

3.1. Selection of Test Image

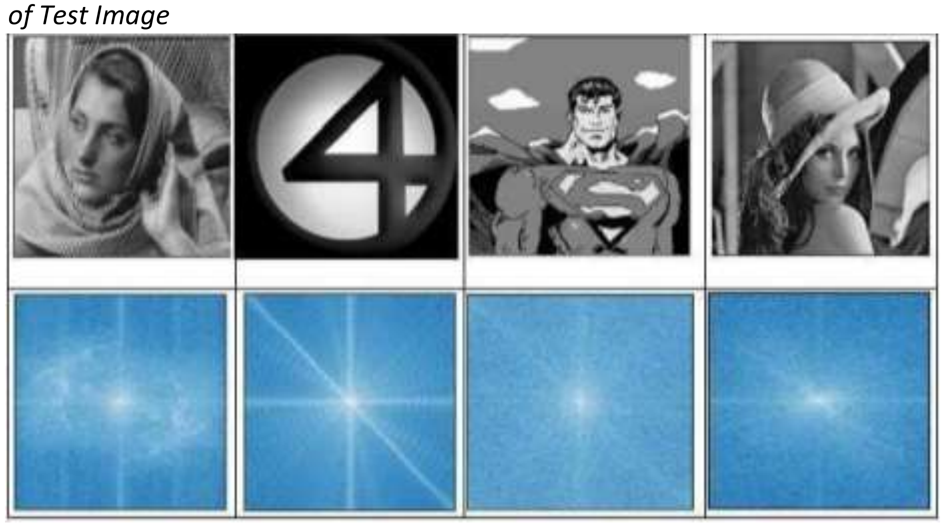


Fig.2: Input images used in the simulations (first row) and their Fourier transform (second row): (a) Barbara (b) Number (c) Superman (d) Lena.

Simulations are performed to produce a high quality image using Fourier positive – negative correlation. The four alternative photos are compared which are based on different stages to ensure quality, efficiency, noise resistance, complexity, algorithm, and legibility.In the simulations, four different test photos are used without sacrificing generality.Each image has its own distinct/unique qualities, as seen in Fig. 2. In image (a) which is of "Barbara" is a natural image which after Fourier transform concentrates on low frequency band. In image (b) which is a "Number" has white background has slight low frequency than image (a). Now in image (c) which is of "Superman" which after Fourier transform their energy concentrates on high frequency after that we see on image (d) which is of "Lena", in this image after Fourier transformation we find slightly higher frequency concentration at the center than image (c). From these various images we get an idea regarding the frequency domain of an image which seems different in different images. We are using the strategy of integral measurement. All simulations were conducted on a PC with an Intel(R) Core(TM) i3-6006U CPU running at 2.00GHz, 8.00 GB of RAM, and Visual Studio Code.

3.2 Pattern Generation

Various patterns can be generated by changing the phase while generating the Fourier patterns. Firstly, a 16 point DFT matrix was generated to check if the matrix is orthogonal or not we need to take the conjugate and its transform and multiply them in order to obtain identity matrix. Here after doing the multiplication of matrix and its conjugate's transform we will find the absolute value of the matrix so formed in order to obtain value. Since this pattern will be unscaled we will be scaling them. The product that we are taking is just to check whether it is orthogonal matrix or not. After scaling is done we will use Kronecker product in order to generate the matrix. Once the matrix is generated we will reshape it. Now to generate the matrix we will change the phase by taking the transform.

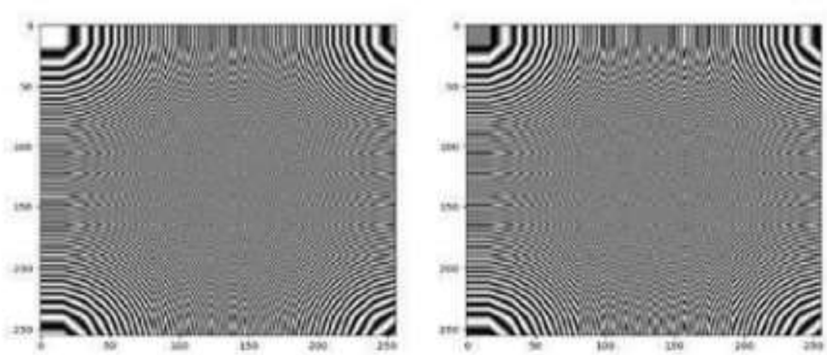


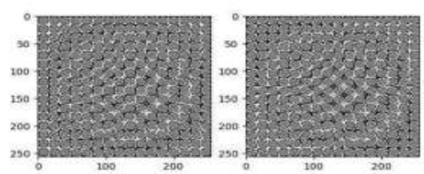
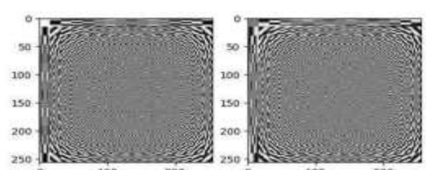
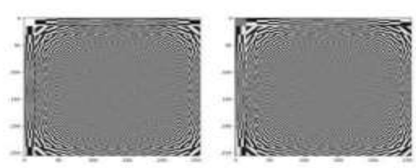
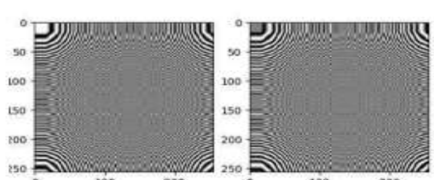
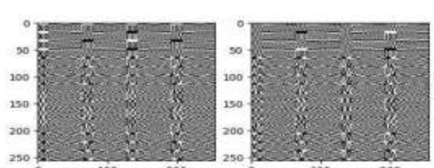
Fig. 3. Pattern Generation using real cosine and imaginary sine matrix

The pattern on left is 2D pattern formed due to real cosine matrix while that on right side is the 2D pattern formed due to imaginary sine matrix as shown above in "Fig. 3". Following the generation of various patterns, we can overlay them to produce Fourier positive(using cosine part) and negative images(using sine part).Once overlaying of pattern is done, we can again overlay them in order to get a hold of the original picture. So, we need to generate as many patterns as possible and then we can overlay the resulting image to get a clear input image. Basically, it's a game of how pattern is generated by changing the phase and how overlaying is done. Along with this the interpolation ratio also plays a vital role while overlaying. The pattern generated on the righthand side is of negative sine while that on left-hand side is of real cosine. Moreover, at various different phases, the pattern generated will have 180 degree of phase shift and hence if we overlay such patterns, we will obtain the clear input image that we require as our output. So, it can be inferred that it is a case of Fourier positive – negative phase correlation Test images are taken for experimentation and overlaying is done. "Table. 1" shows the outputs that we obtained after selecting the image of dimension 256 X 256.

3.3 Reconstruction of Image

Overlaying square pattern formed due to cosine on target image i.e. obtaining positive image (Image 1) and Overlaying square pattern formed due to sine on target image i.e obtaining negative image (Image 2). After overlaying both the positive and negative images we get the output in the form of reconstructed image as shown below in "Table. 1":

Table 1. Reconstruction of different test images of dimension 256x256 for different phases.

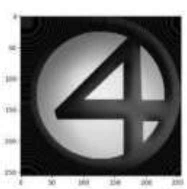
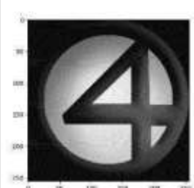
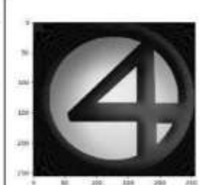
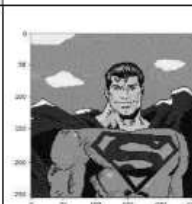
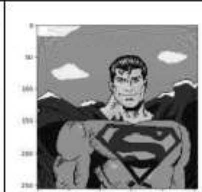
Pattern	Positive Image	Negative Image	Reconstructed Image/Output Image
			
			
			
			
			

The output of software simulation is as shown above. Clearly it can be concluded that high quality image can be reconstructed from Fourier positive and negative images. When the sampling ratio is modest, ringing effects can be seen in the image's edges. The clarity of image at the center increases as compared to the positive and negative image that we obtained by overlaying. Similarly the four images test images can be reconstructed by taking different phases as shown in “Table 2”.

3.4. Reconstruction of Test Images for different phases.

For different phases we have reconstructed the image. There is ringing effect in pattern 4 when we are reconstructing it due to different phase. Some patterns have ringing effect at centre, bottom, and top due to different phase we are selecting while generating the pattern. For some images, clarity is increasing at the centre, for some it is increasing throughout the image. Most of the time after overlaying the Fourier positive and Fourier negative images we are able to construct the original image.

Table 2. Reconstruction of different test images (dimension256x256) for different phases

Input Image	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
					
					
					
					

4. Conclusion and Future Scope

Following the generation of various patterns, they can be overlayed to produce Fourier positive and negative images. Once the pattern overlaying is complete, they can be re-overlayed to obtain the original image.So, further as many patterns as possible can be generated and then overlay the resulting image in order to obtain the clear input image. Basically, it’s a game of how pattern is generated by changing the phase and how overlaying is done. Along with this the interpolation ratio also plays a vital role while overlaying. The pattern generated on the right-hand side is of negative sine while that on left-hand side is of real cosine. Moreover, at various different phases, the pattern generated will have 180 degree of phase shift and hence if we overlay such patterns, we will obtain the clear input image that we require as our output. So, it can be inferred that it is a case of Fourier positive – negative phase correlation test images are taken for experimentation and overlaying is done. “Table. 1” shows the outputs obtained after selecting the image of dimension 256 X 256.

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