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Region Filling with Super Resolution Algorithm

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Abstract: ***Region filling which has another name inpainting, is an approach to find the values of missing pixels from data available in the remaining portion of the image. The missing information must be recalculated in a distinctly convincing manner, such that, image look seamless. This research work has built a methodology for completely automating patch priority based region filling process. To reduce the computational time, low resolution image is constructed from input image. Based on texel of an image, patch size is determined. Several low resolution image with missing region filled is generated using region filling algorithm. Pixel information from these low resolution images is consolidated to produce single low resolution region filled image. Finally, super resolution algorithm is applied to enhance the quality of image and regain all specifics of image. This methodology of identifying patch size based on input fed has an advantage over filling algorithms which in true sense automate the process of region filling, to deal with sensitivity in region filling, algorithm different parameter settings are used and functioning with coarse version of image will notably reduce the computational time.***

Keywords: Image Processing, Object Removal; Region Filling; Patch Priority; Texture Synthesis, Sparsity Based Priority; Super Resolution Inpainitng;

I. INTRODUCTION

Rejuvenating the damaged regions of an image and restoring them based on the information available in background is known as Region filling. This need to be done in visibly persuasive way. Digital image region filling tries to simulate this process and executes the entire filling process automatically. The algorithm automatically does this in a way that it looks reasonable to the human eye. Details that are hidden/occluded completely by the object to be removed cannot be recovered by any mathematical method. Therefore the objective for this method is not to recover the original image, but to create some image that has a close resemblance with the original image. Patch priority based region filling attempts to imbrute the clone tool process. Holes in the image is filled by hunting for the most similar patches in the local neighborhood and replicating the pixel values from most similar patch into holes. Blurring effect present in prior techniques can be reduced by filling the region at the patch level as contrary to the pixel level. This technique is very valuable with lot of applications in various fields. In the field of art and movie theatre, it is used for reconstructing film, to recover the damage caused due to cracks in portraits and small cut or mark on pictures. It is also used for creative effect by removing certain object, removing red eye effect and for removing logos from picture [1]. In The blocks which are vanished transmission of images can be restored using this technique. During the transmission of images over a network, there may be some parts of an image that are missing. These parts can then be reconstructed using region filling based on patch priority, for example, in a streaming video. Nonessential objects such as microphones, some unwanted animals, person and logos, stamped dates and text etc. in the image can also be removed [1]. To remove unwanted object and fill the region, patch priority based region filling technique will be used. Firstly, user will select an object to be removed and image without an object will be created. Now, the low resolution version of the image is created. This image is fed as the input to the patch priority based region filling algorithm and output is completely filled low resolution image. This algorithm will run multiple times with different parameter setting and images obtained will be combined together to yield a single low resolution region filled image. At the end all technicalities and minutiae of image is regain by using super resolution algorithm. The remaining part of paper is structured as follows: Section 2, states current research and literature review. Section 3 explains the patch priority based region filling algorithm which explains confidence term, data term and texture synthesis. Section 4, explains about super resolution algorithm. Section 4, proposes framework which uses the region filling algorithm, generating multiple images with different parameters and combining them together to reduce blurring artifact in final image. Section 5, discuss the evaluation of proposed framework. Section 6, provides a concluding remark.

II. BACKGROUND AND LITERATURE REVIEW

Nowadays, the region filling technology is one of the most emerging and trending topic in computer graphics. And it has many applications such as restoring cultural heritage, producing extraordinary effects in movie and television, removing redundant and undesirable items etc [2]. Generally, working of most of the region filling methods has following steps, in the first step user will physically select target region from the original image that will be restored. The target region will be rejuvenated automatically, by replicating these regions with the pixel values available from the rest of the image. Currently, there are various methods available for region filling that is also known as image inpainting.

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And these methods can be organized as follows:-

1) Texture synthesis based region filling.
2) PDE based region filling.
3) Patch priority based region filling.

A. *Texture Synthesis Based Region Filling*

These algorithms fill in the occluded area or target region using analogous proximity of the damaged pixels. In this new image pixel synthesis begins from initial seed and then algorithm struggles to maintain the local structure of the image. Most of the prior techniques employ these methods to fill in the occluded area by sampling and copying pixel from closest proximity [2].

The main objective of texture synthesis is to develop texture patterns, which is identical to a given sample pattern. The generated pattern must hold the statistical properties of the parent texture i.e. original image. Due to which there is no tiled rearrangement of the parent texture in the final image [2].

B. *PDE Based Region Filling*

Bertalmio et.al has first suggested Partial Differential Equation (PDE) based algorithm for region filling. This algorithm works in a recursive fashion. The vital aim of these algorithms is to propagate geometric and photometric information that is present at the boundary of the target region into the region itself [3]. This is achieved by using isophote lines that is information is proliferated in the direction where change is minimum. When the target region is small, this algorithm produces very effective results. But the quality of result degrades and even it takes longer time to produce output when the target region is large. This method is much useful for noise removal application and for smaller regions. But the main limitation of this method is that it can neither connect separate or disintegrated edges nor can develop good texture patterns [3].

C. *Patch Priority Based Region Filling*

Patch priority based region filling is also known as exemplar based approach, an important class of inpainting i.e. region filling algorithms. And they are one of the most efficient region filling algorithms. Generally this category of algorithm has two main steps:

1) Patch priority assignment
2) Selecting best similar patch for synthesis

The exemplar based approach identifies the identical matching patches from the remaining part of the image, with the help of certain metrics similarity is measured between the patches from known and unknown region and matching patch is copied into the target region. This method works very effectively for restoring larger target regions. Generally, an patch priority based region filling algorithm includes the following four basic steps:

a) Identify and isolate the target region, in which the occluded regions are separated and expressed with relevant data structure.
b) Computing patch priorities, in this an already defined priority function is used to calculate the filling order i.e. priorities of unfilled patches at the start of each filling iteration.
c) Searching best match and propagating, in which the best matching candidate is searched from the source region to replicate and paste the patch in the missing region.
d) Updating target region information, in which the fill front of the target region and the necessary information for calculating patch priorities is updated [2].

Numerous algorithms are developed for the patch priority based region filling such as Criminisi [4] developed an efficient and simple approach that combines the advantages of two approaches. Firstly, Both texture and structure information is propagated with the process of exemplar-based texture synthesis. The filling order highly defines the gain of structure propagation. And then a best-first algorithm in which the confidence of the synthesized patches is replicated in a similar fashion as to the propagation of information in region filling.

Xu [9] proposed two unique concepts for calculating the priority of the patch and for representation of patch using Sparsity at the patch level.

D. *Super Resolution Algorithm*

Generally, these algorithms can be categorized in two types:

1) Super resolution from single image.
2) Super resolution from multiple images.

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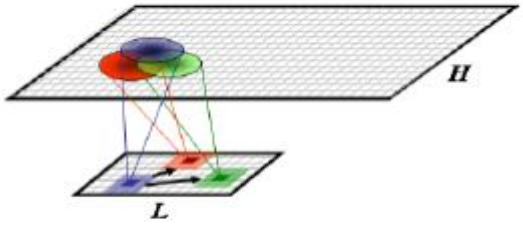


Fig. 1 Single Image Multi Patch Super Resolution

Single image super resolution is also known as example based super resolution. In this method, a high resolution image is rejuvenated using a single low resolution image, as shown in figure 1. A database of well-known high and low resolution image combination is used to determine the reciprocity between the low resolution image and the interrelated high resolution image. The most promising high resolution image is achieved by practicing the database knowledge on a new low resolution image [14].

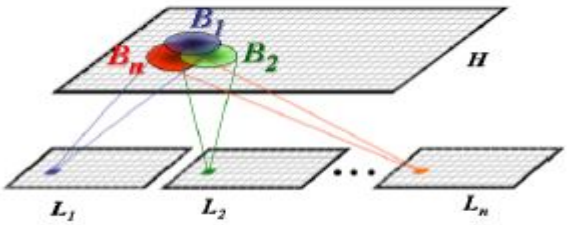


Fig. 2 Classical Multi-Image Super Resolution

As shown in figure 2, various low resolution image of same view is used to develop the high resolution image [14]. This method generally includes three steps:

- Image Registration, this includes veraciously adjusting low resolution image and parameter settings.
- Image Fusion, these steps includes merging significant details from two or more low resolution images into a single high resolution image.
- Interpolation, to get the final high resolution image.

In comparison with other approaches, patch priority based region filling approach has acquired splendid output in rejuvenating missing area and in terms of space and time complexity single mage super resolution has edge over the other.

III. PATCH PRIORITY REGION FILLING ALGORITHM

The notations used in this paper are same as the one use in [4], which deals with region filling. I denotes the input, i.e. original image. Ω denotes occluded area or region to be filled Φ represents the source region, i.e. remaining part of the image which is used to fill missing area. Basically, Φ = I - Ω. δΩ represents boundary of the missing region or the target region.

A. Patch Priority

The filling order computation defines a measure of priority for each patch in order to distinguish the structures from the textures. Basically, the presence of structure is represented by high priority. Given a patch Ψp which is centered on pixel p, its priority P (p) is given by a data and confidence term [4], that is,

P (p) = C (p) x D (p) (1) where C (p) is the confidence term and D (p) is the data term.

The confidence term, can be thought as a measure which determines the amount of useful and concrete information surrounding the pixel p, which is define as,

$$\mathbf{C(p)} = \frac{\sum_{q \in \Psi p \cap \Omega} C(q)}{|\Psi p|}$$ (2) Where |Ψp| is the area of Ψp. While initializing, the function C (p) is set to C (p) = 0 ∀p ∈ Ω and C (p) = 1 ∀ p ∈ I - Ω. The patches from the target region which have many of their pixels already replete to be fill first is the main aim, with extra importance given to pixels that were filled early on (or which were never the member of the occluded area) [4].

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For data term, the Sparsity-based priority will be used. In a search window, a template matching will be performed between the current patch and neighboring patches that belong to the source region of the image. By using a non-local means approach, a similarity weight w_{pxpj} (i.e. proportional to the similarity between the two patches centered on p_x and p_j) will be computed for each pair of patches [9]. The Sparsity term is defined as:

$$\mathbf{D(px)} = \|\mathbf{w_{px}}\|_2 \times \sqrt{\frac{|\mathbf{Ns\,(px)}|}{|\mathbf{N(px)}|}} \quad (3)$$

where Ns and N represent the number of valid patches (having all its pixels known) and the total number of candidates in the search window. Larger sparseness means this $\|w_{px}\|_2$ value is high whereas a small value represents that the current input patch is highly calculable by many other patches in source region [9].

B. Texture Synthesis

The patch with the highest priority will be filled first. Unknown part of the patch under observation ψ^{uk}_p will be filled using a similarity measure, for this the most similar patch located in a local neighbourhood *W* centered on the current patch will be sought. The chosen patch ψ^*_p maximizes the similarity between the known pixel values of the current patch to be filled in ψ^k_{px} and co-located pixel values of patches belonging to *W*:

$$\psi^*_p = \arg \min_{\psi q \in W} (\psi p, \psi q)$$

$$\text{s.t. Coh } (\psi^{uk}_p) < \lambda_{coh} \quad (4)$$

where d(.) is the weighted Bhattacharya [8]. Coh(.) is the coherence measure initially proposed by Wexler et al.

$$\text{Coh}(\psi^{uk}_p) = \min_{q \in S} d_{SSD}(\psi^{uk}_p, \psi^{uk}_q) \quad (5)$$

where d_{SSD} is the sum of square differences. The degree of similarity between the synthesized patch ψ^{uk}_p and original patches is given by the coherence measure Coh. Due to the constraint in equation (4) the texture which is very different from the root texture will not be copied. If none of the candidates fulfill the constraint (4), the filling process is stopped and the priority of the current patch is decreased. The process restarts by seeking the patch having the highest priority.

C. Recalculating Confidence Values

After the patch $\psi_{p'}$ has been permeated with new pixel values, the confidence C (p) will be updated in the area delimited by $\psi_{p'}$ as follows [4]:

$$C(q) = C(p') \qquad \forall q \in \psi_{p'} \cap \Omega \quad (6)$$

This simple update rule will allow us to gauge the proportionate confidence of patches on the boundary of target region, without image-specific parameters. As filling algorithm executes, there is a decline in confidence value which represents that we are less sure of the color values of pixels near the center of the target region**.**

IV. SUPER RESOLUTION ALGORITHM

To restore the specific high resolution information of the image, a single image super resolution algorithm is practised on final low resolution region filled image. There are three main steps in this algorithm [11]:

A. Dictionary Building, correlated low and high resolution image patches are included in the dictionary. The high resolution patches in the dictionary must be valid i.e. all the pixel values of a patch must be is known, is an important compulsion. The known region of the image is used to derive the high resolution valid patches. And the law resolution patches can be inferred by using the decimation factor as 2.

B. Filling order of the high resolution image, the filling order is calculated using Sparsity based method on high resolution image as explained in section 3.1. The filling procedure dawns with high resolution patch which has highest priority and this patch has both known and unknown regions.

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C. For the low resolution patch interrelated to the highest priority high resolution patch, its neighbour in the low resolution region filled image is searched. The best low resolution patch is selected by searching in the dictionary. The high resolution patch can be ratiocinated from the selected low resolution patch. The unknown part of the high resolution patch under consideration can be obtained from this inferred high resolution patch.

Once the pixel values are copies in current patch, priority values are recalculated and entire algorithm is repeated until all missing region is filled.

V. PROPOSED SYSTEM

The proposed framework consist of five phases : (1) Low resolution image (2) Texture detection (3) Mask creation (4) Patch priority based region filling algorithm (5) Combining region filled images (6) Super resolution algorithm.

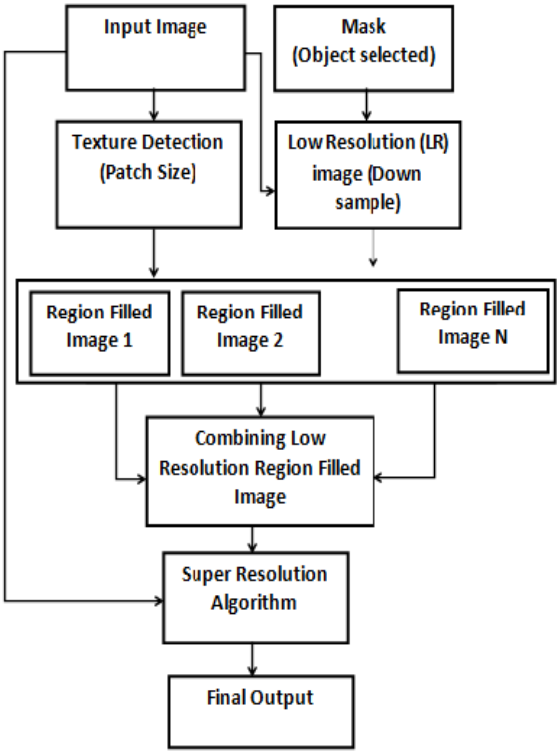


Fig. 3 Proposed framework for region filling with super resolution

A. Low Resolution Image

The original image is first downsampled to create coarse version of the image. Low resolution version of image easily retains structural properties and added benefits are it is less corrupted with noise and will notably reduce computational time.

B. Texture Detection

Practically, the patch size to be used in region filling algorithm must be marginally bigger than the largest perceptible texture element in the source image [4]. Image will be fed to the texture detection module to determine the smallest texture, which will eventually decide various parameters. To identify the texture of an image we will identify all the key points in an image since key points denote specific features or change in texture for an image. The smallest distance between two key points will be treated as the diagonal length of the patch and the most frequent distance will be treated as the window size.

C. Mask Creation

Object is the region that is to be removed and then filled with the help of information available in the rest of the image. This object could be a complete object that is to eliminated or damage part of the image that is to be repaired. User will manually select object to be removes from the image.

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D. Region Filling Algorithm

Region filling algorithm is explained in section 3, can be summarized into following steps as shown in figure 4.

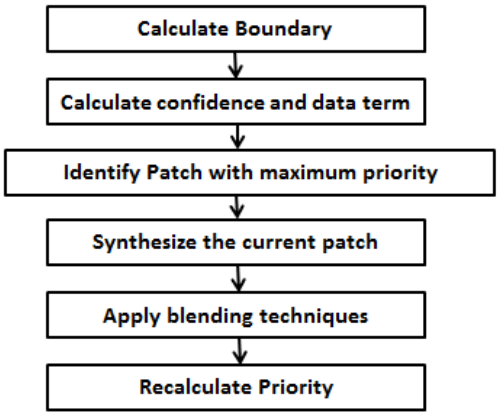


Fig. 4 Region Filling Algorithm

The fill front i.e. boundary of the target region is selected. Priority is computed for all the patches in the target region, then identify the patch with the highest priority. Now, synthesize the current patch by identifying the most similar exemplar from the source region.

E. Combining Multiple Region Filled Image

One pass greedy algorithm is one of the most common problems with region filling algorithm. To overcome this problem, we will be running region filling algorithm multiple times with different parameter setting such as patch size and filling order. To obtain final single region filled image, average or median operator can be used [10]. Following equations can be used to obtain pixel values:

$$I(p_x) = \frac{1}{n}\sum_{i=1}^{n} I^{(i)}(p_x) \qquad (7)$$

Combining images will definitely reduce the blur effect in the output image. Output will be completely filled image with less blur and seam.

F. Super Resolution Algorithm

Super Resolution algorithm is explained in section 4, can be summarized into following steps as shown in figure 5.

Dictionary consists of interrelated high and low resolution patches. Priority is calculated for all high resolution patches, then the highest patch is selected. For this high resolution patch corresponding low resolution region filled patch is selected. Using similarity measure, dictionary is searched within local neighborhood to find the similar low resolution patch. And then the corresponding high resolution patch pixel values are replicated in the unknown part of the patch under consideration.

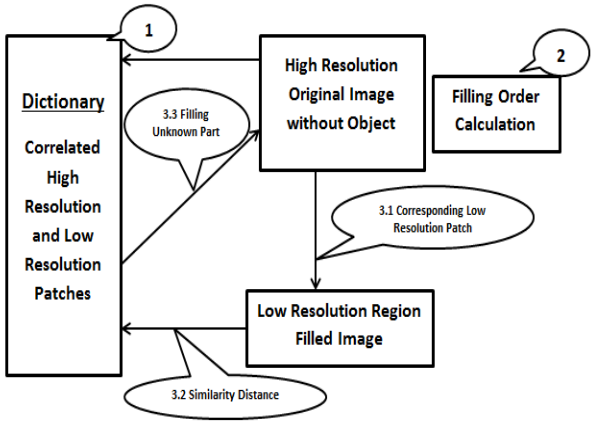


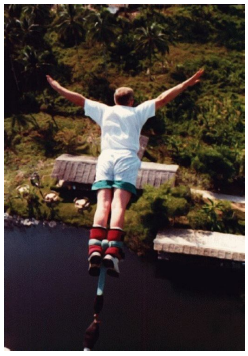
Fig. 5 Super Resolution Algorithm

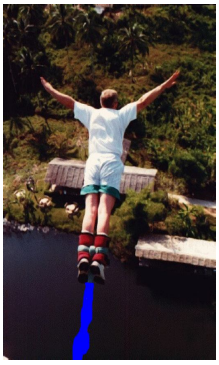
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VI. RESULTS

Despite of the fact that the proposed approach fills the missing region in visually plausible way, algorithm may still languish from one pass greedy problem. To reduce the impact of this issue, algorithm will generate four region filled low resolution image with different patch sizes. Depending on texture of image, suppose texture detection modules detects patch size p then four patch size used by the algorithm is p x p, (p+1) x (p+1) , (p+2) x (p+2) and (p+3) x (p+3).

The output of the system is as shown.


(a) Original Image


(b) Mask Creation


i) P X P


ii) (P+1) X (P+1)


iii) (P+2) X (P+2)


iv) (P+3) X (P+3)

(c) Low Resolution (LR) Region Filled Images with different patch sizes


(d) Final LR Image


(e) Final Output after Super Resolution Algorithm

Fig. 6 Bungee – Test Image 1

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VII. CONCLUSION

Patch priority based region filling technique is one of the trending and important topics in computer vision and graphics. Region filling algorithm has wide range of application in various domains such as art, theatre, photography, monument preservation, adding special effect etc. The proposed algorithm can fill in the missing region in visibly persuasive fashion.

Uniqueness of this algorithm is it detects patch size based on texture of input image rather than using predefined one. The proposed algorithm first creates low resolution image and then calculates priority of patches, highest priority patch is synthesized and patch will be blended in the target region. Multiple images with different parameters setting will be amalgamated to create single region filled low resolution image with reduce blurring effect. Ultimately, the resolution of the image is intensified by super resolution algorithm to create final image.

The output quality of image can be further strengthen by considering spatial or structural constraints of image and higher level information. This approach can also be applied on videos.

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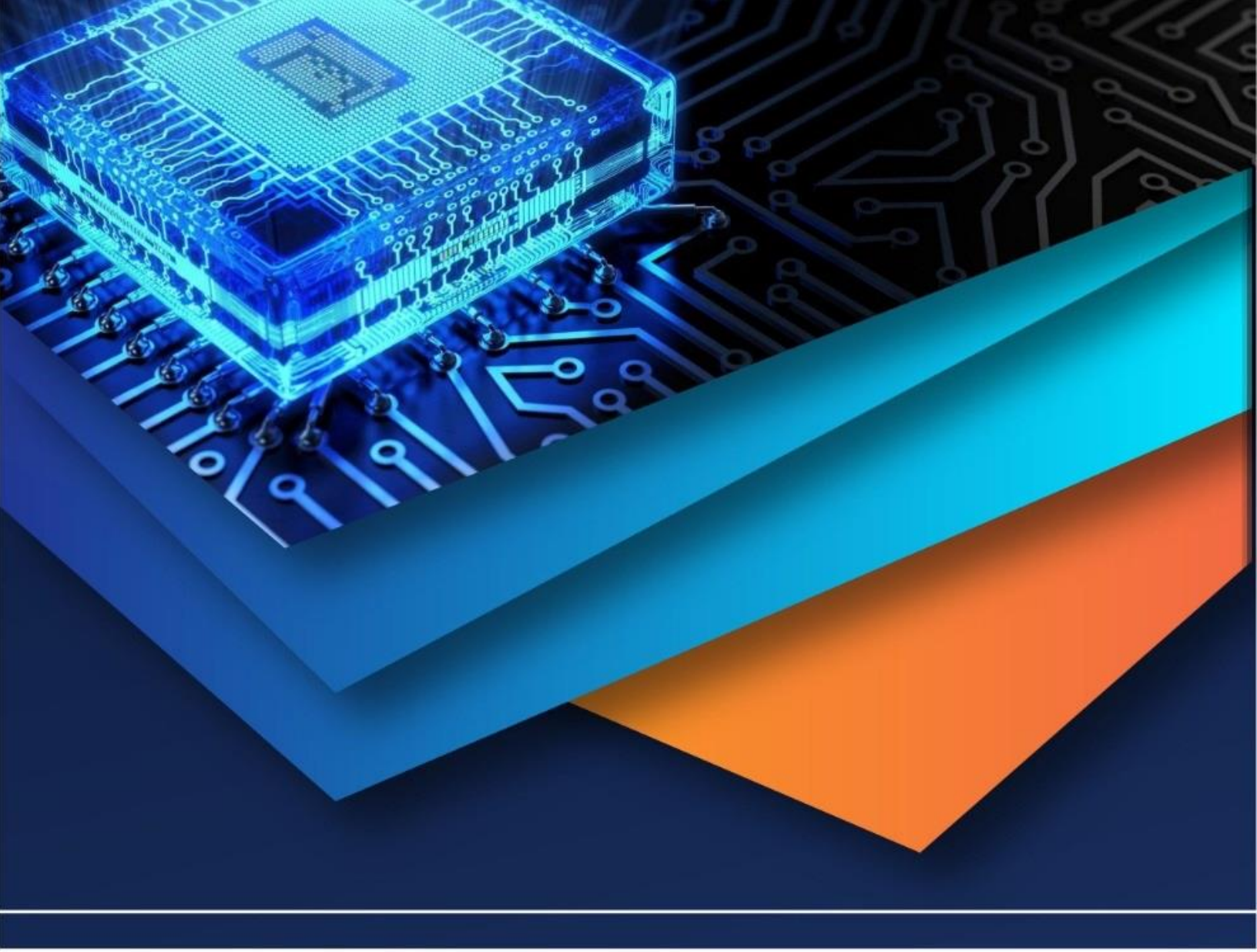
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