1.1 Rendering

In the real world, light sources emit photons that normally travel in straight lines until they interact with a surface. When a photon encounters a surface, it may be absorbed, reflected, or transmitted. Some of these photons may hit the retina of an observer where they are converted into signals. These signals are processed by the brain, thus forming an image. The formation of an image as a result of photons interacting with a three-dimensional (3D) environment may be simulated on the computer. The process of image synthesis by simulating light behavior in 3D environment is called rendering. In computer graphics, there are two different models to render photorealistic images [1]. These are:

- Geometry-based rendering (GBR), and
- Image-based rendering (IBR)

1.1.1 Geometry-based rendering

In geometry-based rendering, the scene to be simulated is described by 3D scene descriptions. 3D scene descriptions may include variety of information such as geometry
of scene objects, optical properties of the surfaces, viewer position etc. and this information is transferred to modeling program to get a model of the scene. This model is processed by the some rendering algorithm to generate the various views of the scene. A high level view of geometry-based rendering approach to generate the different views of 3D model (helicopter model) is shown in Fig. 1.1.

![Diagram](image)

**Figure 1.1:** High level view of geometry-based rendering approach

The main bottleneck of GBR pipeline is that model generation is a time consuming process and is highly dependent on the scene complexity. To achieve photorealism trained artists have to spend a lot of time trying to model the lighting, material, and optics of the scene. Thus to get a convincing image, both the geometrical model and the
rendering algorithms have to be complex. Even if we use complex model and rendering algorithms, the generated image still have artificial appearance.

1.1.2 Image-based rendering

In the 1990s, a new approach to photorealistic rendering known as image-based rendering (IBR) has emerged. IBR refers to a collection of techniques and representations that allows three-dimensional objects and scenes to be visualized in a realistic way without full 3D model reconstruction. These techniques use pre-acquired reference images together with other parameters like depth maps, positional correspondences etc. in order to synthesize the arbitrary views of an object or scene. Fig. 1.2 shows the basic pipeline of image-based rendering approach.

The concept of IBR was not well defined mathematically until 1995, when McMillan et al. [2] first introduced the term “Image-Based Rendering” and established the relationship of the IBR problem with the reconstruction of the plenoptic function [3]. IBR approach proved a powerful alternative to traditional GBR approach for rendering new (virtual) views. Prior to the introduction of image-based methods, the most popular method to attain improved realism was to include more and more knowledge of physics into simulation-based rendering systems. Generally, these improvements came with the cost of increased simulation time and the introduction of new, difficult to obtain, material parameters. Image-based rendering is a refreshing substitute because it suggests that we might extract the essence of realism from sample photographs. Furthermore, it shifted the
computational focus away from simulation, towards a more manageable interpolation-based approach.

Figure 1.2: Basic pipeline of image-based rendering approach

The researchers in the field of computer graphics have recently turned to image-based rendering due to many forces such as it is computationally less expensive, close to
photorealism, and its rendering time is usually constant and does not depend upon the scene complexity. With traditional GBR techniques, the time required to render an image increases with geometric complexity of the object. IBR replaces the three-dimensional scene descriptions with a set of images and rendering the scene is therefore independent of the scene complexity. IBR thus decouples scene complexity from rendering complexity by doing work proportional to the number of pixels in the final image instead of work proportional to the number of polygons in 3D scene model. The availability of inexpensive digital image acquisition hardware further motivates the use of IBR approach.

1.2 Application Areas of Image-based rendering Techniques

The creation of novel views using pre-stored images or image-based rendering has many potential applications in virtual reality, electronic games, sports broadcasting, 3D-Television, movie industry, mobile/ handheld devices etc. A few application areas are described as under:

- **Virtual Reality:** Virtual reality techniques employ large scale deployment of IBR. City visualization applications like Google Street View [4] and Microsoft Street Slide [5] render the city streets using a set of pre-captured photographs. Otherwise, it would have been impossible to model the textures, lighting, and materials to render such a large scale dataset.

- **Mobile/ Hand-held devices:** In mobile devices, the graphics applications like visualization, navigation system, games etc. have a lot of performance constraints
due to limited CPU speed, memory and hardware support for graphics. Therefore IBR methods, whose run time depends on the screen resolution rather than scene complexity are more suitable for these devices [6].

- **e-commerce**: In e-commerce, virtual try-on applications allow users to watch themselves wearing different clothes/ accessories without the effort of changing them physically. IBR methods can be used with real images of the user and previously recorded images of garments/ accessories to make quick buying decisions [7]. This also helps to improve the sales efficiency of retailers.

- **Movie Industry**: IBR techniques have become standard tool in science fiction movie making. A notable early use of image-based modeling and rendering in movie production was in the “bullet time shots” scene in the movie *The Matrix* [8]. The techniques continued their use in movies like The Matrix Reloaded, Mission Impossible II, Eye Vision etc.

- **Electronic Games**: IBR techniques are used extensively to provide realistic look alike environment in interactive electronic games [9]. To achieve realism, images are used to represent complex objects such as trees. By using images from the real world along with IBR techniques, it is also possible to capture complex light interactions such as self shadowing, inter-reflections, subsurface scattering etc. without modeling and simulation.

- **Sport-scences Visualization**: Using IBR techniques with multi-camera setup it is possible to provide additional virtual views from arbitrary positions in sports broadcast [10]. This allows the audience a more spectacular viewing experience and to inspect for events such as fouls in case of ambiguity.
• **3D-Television:** IBR techniques such as Depth Image Based Rendering (DIBR) allow different users of 3D-Television (3D-TV) systems to see different viewpoints of the same scene [11]. They generate new virtual viewpoints with the help of a set of color images and their associated per-pixel depth map.

### 1.3 Problem Statement

Our research is motivated by the desire to achieve efficiency and realism in rendering of images from novel viewpoints in computer and mobile/handheld devices. It is observed that a considerable overhead is introduced with the traditional geometry-based rendering approach as soon as the complexity of the scene to be rendered is increased. To achieve efficient photorealistic rendering of a complicated scene, it is more convenient to use pre-acquired reference images of a 3D scene together with other parameters such as depth maps, positional correspondences, viewing attributes etc. in order to synthesize new novel views of the scene. This has led to the use of images as primitives, which partially or wholly replaces geometry and modeling. Images naturally match the resolution of the frame buffer and as a consequence, the rendering cost becomes proportional to the number of pixels in the image rather than to scene complexity. The objective of this research is to design efficient algorithms which can provide better results for the image-based rendering in terms of rendering time, memory requirements and visual quality. This research study aims to contribute to the field of computer science a family of algorithms useful for novel view generation using image-based computer graphics. Main broad objectives of the research are:
• Literature survey of all the related work done on image-based rendering. During this survey, all the related problems to the image-based rendering as well as approaches followed by the researchers to solve the problem are to be explored.

• Determination of an efficient mapping function for image-based rendering that transform the pixels in the reference image to their corresponding coordinates in the target image as seen from a different viewpoint.

• Design of efficient image-based rendering algorithms for mobile/ handheld devices having limited computational capabilities and lack powerful 3D graphics hardware support to visualize real-world or synthetic scenes.

• Determination of efficient image-based rendering algorithms which can provide better results in terms of memory requirements and visual quality.

This work also compare and contrast the image-based and geometry-based approaches to computer graphics.

1.4 Organization of the Thesis

For the purpose of easy readability, the content has been divided into seven chapters.

This chapter, Chapter 1, gives an introduction about the geometry-based rendering and image-based rendering approaches to generate the views of an object or scene, application areas of image-based rendering and our problem statement.

Chapter 2 covers an overview of the various researches and techniques in the area of geometry-based rendering and in particular image-based rendering to date. Included in
this chapter, is a brief description of sampling and compression methods for different IBR representations.

Chapter 3 highlights the 3D image warping technique. Also discussed in this chapter are the derivations and assumptions leading to the essential steps involved in the proposed system framework.

Chapter 4 is an elaboration of the implementation of the proposed computationally efficient framework based on 3D warping technique for generating novel views for computer systems. Furthermore, the performance comparison in terms of rendering time between the proposed framework and our evaluated 3D warping technique is also done in this chapter.

Chapter 5 discusses the enhancement of the above proposed framework to perform interactive 3D rendering for mobile/ handheld devices using JavaME based MIDlet architecture. In this chapter, we also compare the results achieved by the implementation of the proposed framework with our evaluated GBR technique in terms of rendering time, visual quality and memory requirements.

Chapter 6 focuses on the issue of generating novel views of large images on mobile devices that takes considerable amount of time. This chapter presents a framework that uses computationally efficient 3D warping technique in wavelet-domain to render novel views of down-sampled images in mobile devices. The proposed framework is implemented using Android Development Tools (ADT) and its performance is evaluated on some real android smartphones in terms of rendering time.
Finally work is concluded into Chapter 7 with summary of important findings and discussion of future scope for further research work in the said direction.