Image-Based Rendering and Light Fields

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Abstract

The idea of Image-Based rendering emerged from the hopes of easily creating photorealistic scenes without having to go through the process of creating a geometric, reflectance, or lighting approximation. This lecture will explore what Image-Based rendering is, and explore both its advantages and disadvantages, its success and shortcomings, and two basic approaches to the idea.

1 Introduction and History

The history of Image-Based Rendering goes back to the texture maps, bump maps, environment maps of the 1970s. The idea of representing graphics through images instead of geometry, even though in a basic form, existed here. However, it wasn't until 20 years later, where discovery of new algorithms and advancement of hardware would revitalize the interest in IBR. Amongst the researches done in this time were Facial Analysis and Synthesis Using Image-Based Models [Poggio 96], View interpolation for image synthesis [Williams and Chen 93], Quicktime VR [Chen 95], Plenoptic Modeling [Bishop 95], Light Fields Rendering [Levoy and Hanrahan 96], Layered Depth Images [Shade et al. 98] and many more. The hope of these IBR researches were that it would be able to replace the traditional graphics pipeline of using geometry and lighting models with one that does not need these complex approximations(Figure 1).

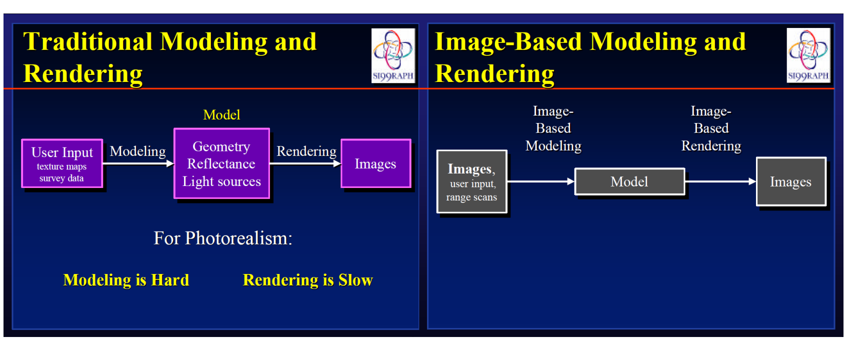


Figure 1: Two Different Pipelines *Courtesy of Paul Debevec; SIGGRAPH 99*

However, due to limitations of non-geometric representations, this ideal failed to fully realize itself. As can be seen in Figure 2, *pure* IBR, compared to having some type of geometric or material representation had built in structural qualities that were not easily achievable. The computer graphics research community by the end of the 90s realized this, and the original hope that this would replace the traditional graphics pipeline would not succeed.

Model	**Movement**	**Geometry**	**Lighting**
Geometry + Material	Continuous	Global	Dynamic
Geometry + Images	Continuuos	Global	Fixed
Images + Depth	Continuous	Local	Fixed
Light Field	Continuous	None	Fixed
Movie Map	Discrete	None	Fixed
Panorama	Rotation	None	Fixed
Image	None	None	Fixed

Figure 2: Limitations of Image Based Models *Courtesy of Paul Debevec; SIGGRAPH 99*

However, this didn't mean that IBR failed entirely. Research done in IBR are still used often in the field, especially in synthetic, sample-driven, and data-driven graphics, geometry, and animation. Below are some of the advantages and disadvantages of IBR that led to its shortcomings compared to geometric modeling, but also to its successes.

- Advantages
  - Easy to capture images
  - Photorealistic by definition
  - Simple, universal representation
  - Often can bypass geometeric representation(?)
  - Independent of scene representation(?)
- Disadvantages
  - WYSIWYG, but also WYSIAYG
  - Explosion of data(higher dimensions) as flexibility increases
  - Often discards intrinsic structure of model(?)

The (?) next to the items are some properties that were believed to be true during the initial phase of IBR research, but through further research has been proven to be a gray area. For example, the advantage that it can often bypass geometric representation is hard to say in IBR nowadays. This is due to the fact, as we will see later on, that data compression of the samples becomes much easier when there is some geometric

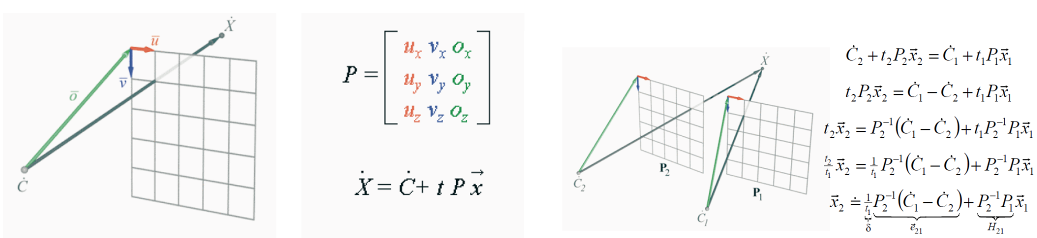
represenation of the object included. Also, researches that go beyond simple image warping has suggested that IBR can take into account structures and hierarchies intrinsic to the model as well.
Generally speaking though, today, IBR hasn't completely replaced conventional rendering pipelines but nonetheless has deeply impacted the field in various ways, for example, bringing forth the general concept of sample and data-driven representation to computer graphics.

2 Image Warping

In this section of the lecture, the general concept of what IBR is, and how one of its basic approaches, Image Warping, will be examined. First of all, it is important to recognize images as collection of rays. In this case, we can think of IBR as reconstructing the Plenoptic Function(1) from a set of samples or images, and replacing the represented quantities using that equation.

$$p = P(\theta, \phi, x, y, z, \lambda, t) \tag{1}$$

We begin by defining a mapping from image points to rays in space, using a simple parametrized ray equation. From here, given $\dot{X}$, $\vec{x1}$, $\vec{x2}$, we can find a corresponding mapping much like in Figure 3. The δ in the correspondence equation here gives the intuition that the disparity of the two coordinates in the respective view spaces are inversely proportional to t_1, the distance or depth.



(a) Mapping from Ray to Point

(b) Correspondence

Figure 3: Finding Correspondence *Courtesy of Leonard McMillian; SIGGRAPH 99*

Note that finding these three quantities from image samples is not a solved problem yet, and is in fact a huge research topic in computer vision.

However, as you can see in Figure 4(a), Simply figuring out where points go by the warping equation is not enough, due to occlusion and visibility issues. This is solved by proper ordering of the points to be solved. First of all, we project the desired center in the new image onto the reference image much like Figure5(a). Then the image is partitioned into 4 parts around this center, allowing us to draw towards the projected center point(Figure5(b)). This gives us an *Occlusion Compatible* ordering much like

that of the Painter's algorithm. This solves the visibility issue without any auxiliary information, and can be generalized to any scene or viewing surface.
Though, within image warping, the problem of reconstruction still remains, as images are discrete, and we do not have a continuos spectrum we can interpolate from.

3 Light Fields

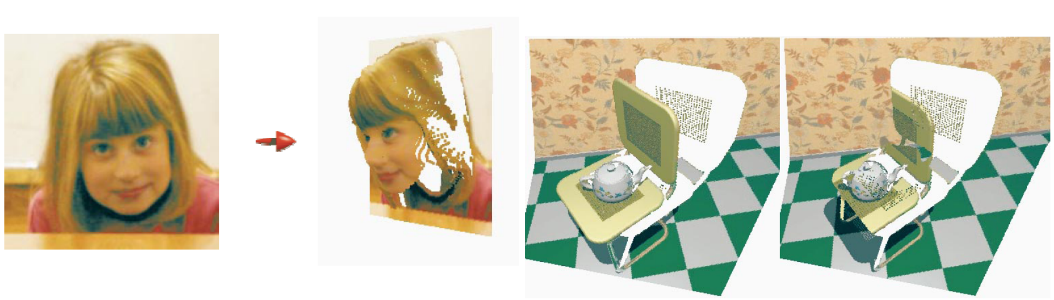
Light Fields were introduced to the graphics field specifically to solve the issue of reconstructing new viewpoints in IBR. To represent a light field, one thinks radiance as a 4D function of position and direction in free space. Then, an image becomes a 2D sample of this representation. With many such 2D images, the light field representation allows a new image to be generated by simple linear combinations of the existing images. Also, this allows not only rotations, but translations of the eye and hence completely different viewpoints as well.

Even though the light field idea is an extremely robust and simple representation, a number of problems arise. The issue of acquiring these light field images to sample from is not a cheap proceses. Also, even after obtaining these images, the required number of samples means an issue of data representation and compression. Hence, even though light fields are extremely robust, the amount of data needed to truly realize pure IBR in terms of light fields is not as simple.

4 Recent Works

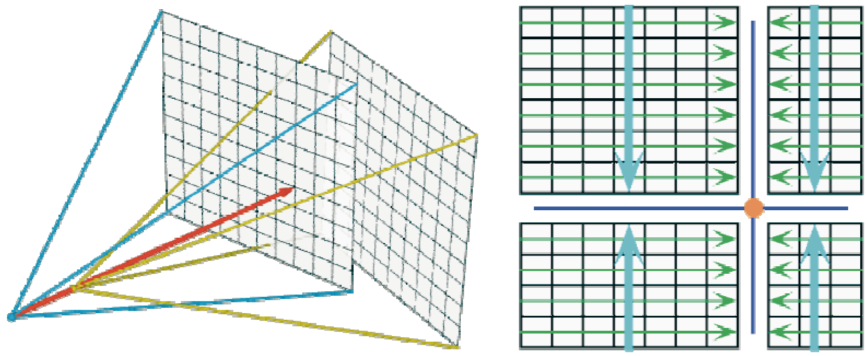
Recent works in IBR have generally extended the Light Field representations to make it a truly more solvable problem. Using the idea of free space, the Layered Depth Image method[Shade 98], views the world as a collection of layered images and sorting them by depth, allowing warping to happen accordingly.

Also, more work has been done to further optimize Light Fields in terms of compression. Surface Light Fields[Miller 98, Nishino 99, Wood 00] finds out the reflected



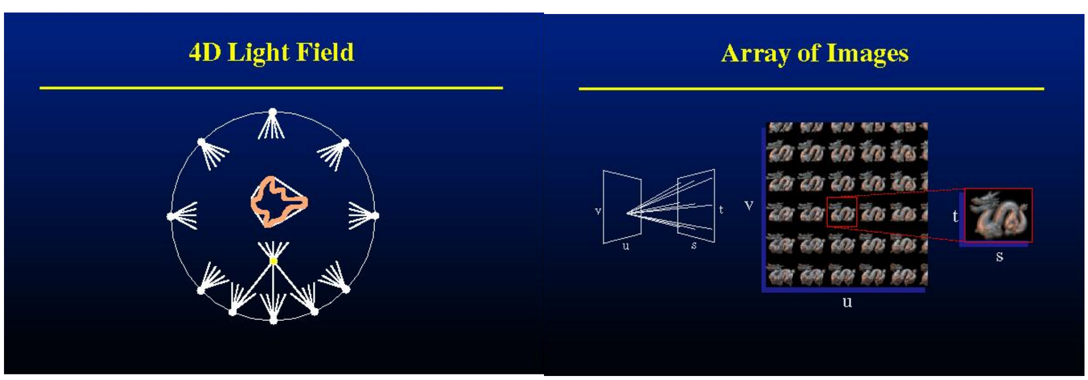
(a) (b)

Figure 4: Warping in Action *Courtesy of Leonard McMillian; SIGGRAPH 99*



(a) Projecting onto the reference (b) Partition and Enumeration

Figure 5: Warping in Action *Courtesy of Leonard McMillian; SIGGRAPH 99*



(a) 4D Light Field (b) 4D Array of Images referenced by uvst

Figure 6: 4D Light Field Representations *Courtesy of Pat Hanrahan; SIGGRAPH 99*

light field from an explicit geometry as opposed to pure Light Field representation and makes the data more easily compressible. Also, work has been done to acquire reflectance models such as of a human face [Debevec et al. 00], and linearly combine any light configuration by linearly combining the given configurations.(However, this does not allow any different viewpoints, and only different light configurations)

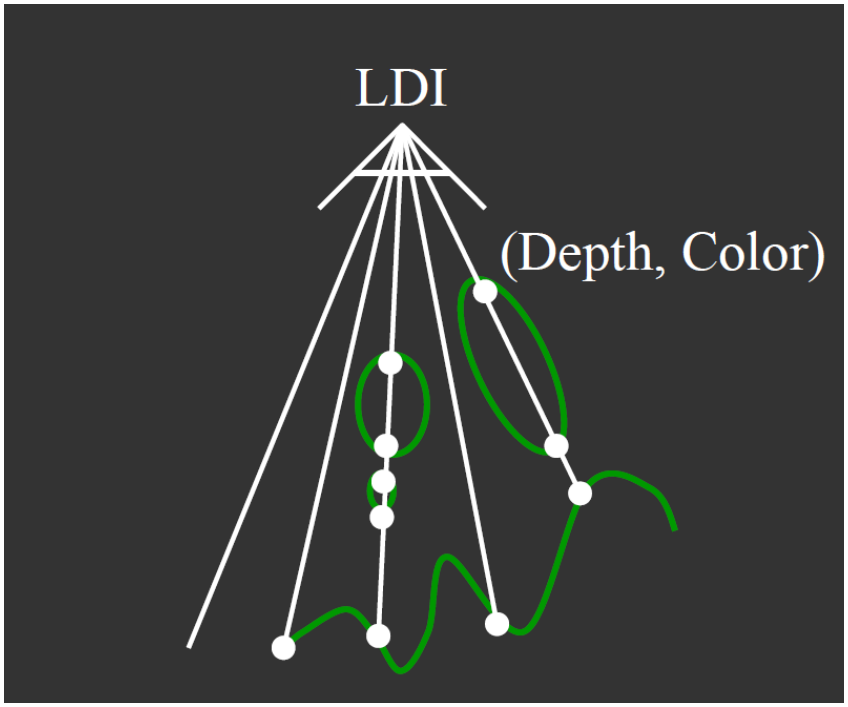


Figure 7: LDI Diagram *Courtesy of Ravi Ramamoorthi; SIGGRAPH 00*

Figure 8: Reflectance Model of a Human Face *Courtesy of Debevec; SIGGRAPH 00*

5 Conclusion

In conclusion, IBR had been a subject of great excitement as it initially promised a replacement of the traditional graphics pipeline. However, it became apparent that the idea in its "pure" form is not practical. This was because of the WYSIAYG property of

IBR, and the explosion of data as well as the compression issues that arose with it as more flexibility was desired. The methods that followed, rather, incorporated at least an implicit definition of geometry or BRDF(which even if not defined, Lambertian assumptions were being made of).

However, researhces in IBR brought in Sampled representations and data-driven methods to the graphics field along with advanced research for representations of these data for fast interpolation and rendering. Also, the data acquired and compressed through these IBR research gives empirical data even to traditinoal graphics pipelines as well. Further, the extensive use of signal processing to research sampling rates, reconstruction filters, factored representations to tame the data complexity helped introduce a signal processing viewpoint into the field. Also, the notion of Light Fields specifically created for IBR, has become fundamental in the graphics field in general, especially in imaging.
The pure goal of IBR may have not succeded in terms of replacing the traditional graphics pipeline due to some of its shortcoming. However, extensive research in the subject has left many legacies to the computer graphics field.

References

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