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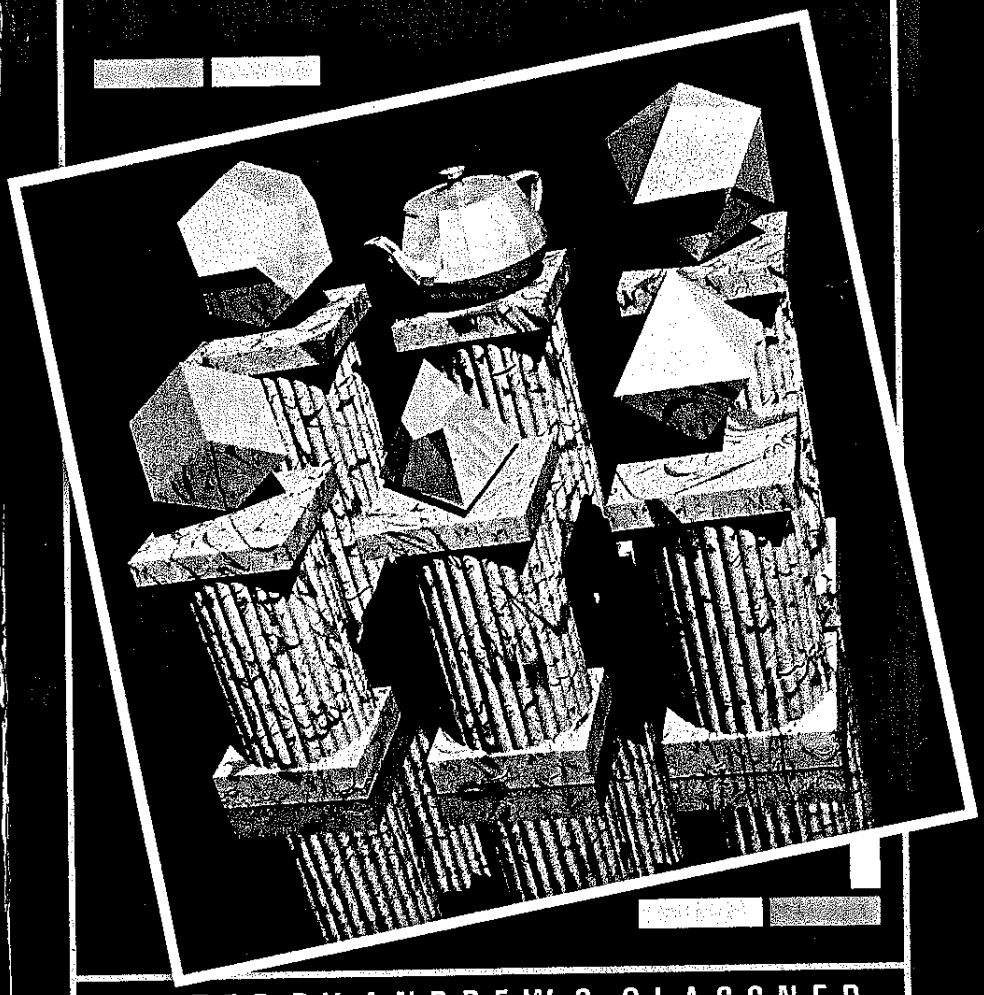
AN INTRODUCTION TO RAY TRACING



EDITED BY ANDREW S. GLASSNER

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2.6 Reflection Rays

If we look at a perfectly flat, shiny table, we will see reflections of other objects in the tabletop. We see those reflections because light is arriving at the tabletop from the other objects, bouncing off of the tabletop, and then arriving in our eye. For a fixed eyepoint, each position on the table has exactly one direction from which light can come that will be bounced back into our eye.

For example, *Figure 9* shows a photon of light bouncing around a scene, ending up finally passing through the screen and into the eye. On its last bounce, the photon hit point P and then went into the eye. Photon B also hit point P, but it was bounced (or reflected) into a direction that didn't end up going into our eye. So for that eyepoint and that object, only a photon travelling along the path marked A could have been reflected into our direction of interest.

When we wish to find what light is reflected from a particular point into the direction of the incident ray, we find the *reflected ray* (or *reflection ray*) for that point and direction; this is the ray that can carry light to the surface that will be perfectly reflected into the direction of the incident ray. To find the color of the reflected ray, we follow it backwards to find from which object it began. The color of the light leaving that object along the line of the reflected ray is the color of that reflected ray. When we know the reflected ray's color, we can contribute it to any other light leaving the original surface struck by the incident ray.

Note the peculiar terminology of backward ray tracing: light arrives along the reflected ray and departs along the incident ray.

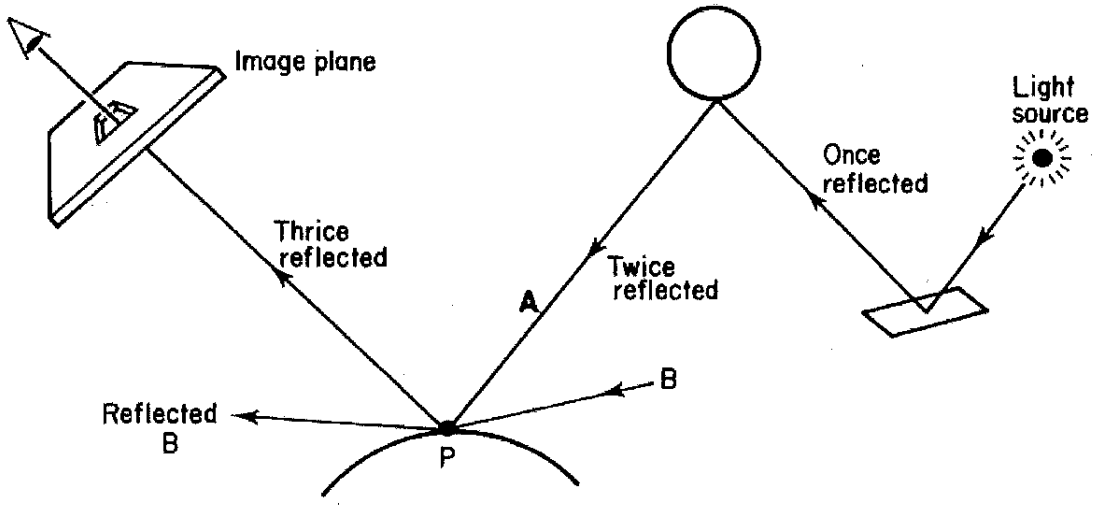

Fig. 9. The color of perfectly reflected light is dependent on the color of the object and the color of the incoming light that bounces off in the direction we care about. For example, at point P we want to know the color of the light

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```
for each entity, A, from which rays can originate do begin
  for each object B do begin
    d = lower bound on distance between A and B;
    S = direction bound for rays from A which hit B;
    for each direction cell of A which intersects S do begin
      insert B into the cell's sorted candidate list
      according to the distance d;
      endfor
    endfor
  endfor
```

Fig. 21. The pre-processing algorithm of the 'ray coherence' algorithm. The sorting operation can be performed by insertion, as shown here, or after all the candidate lists have been formed.

Figure 21, is greater than the distance to a known point of intersection. This is the distance interval optimization yet again.

An outline of the pre-processing algorithm which creates the candidate lists is shown in *Figure 21*. It is assumed that bounding volumes are all spheres or all convex polyhedra. The direction bound, S, will be a unit vector and an angle (or cosine) defining a cone in the case of bounding spheres and a spherical convex hull in the case of bounding polyhedra.

6.4 Ray Classification

The ray classification algorithm, described by Arvo and Kirk [3], does not use explicit direction cubes except in the special case of first-generation rays. The data structure used to accelerate the intersection process for other rays is closely tied to the concept of a direction cube, however. Ray classification is based upon the observation that rays in three-space have five degrees of freedom and correspond to the points of $R^3 \times S^2$, where S^2 is the unit sphere in three-space. The algorithm proceeds by partitioning the five-dimensional space of rays into small neighborhoods, encoded as 5-D hypercubes, and associating a complete list of candidate objects with each. A hypercube represents a collection of rays with similar origins and similar directions, and its associated candidate list contains all objects which are hit by any of these rays (neglecting occlusion). To intersect a ray with the environment, we locate the hypercube which contains the 5-D equivalent of the ray and test only the objects in the associated candidate list.

Rays with a given dominant direction can be conveniently encoded as 5-tuples, (x, y, z, u, v), where the first three elements specify the origin of the ray, and the last two are the UV direction coordinates obtained from a face of the direction cube. Any ray in three-space can be specified by such a 5-tuple

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