# Information Visualization using Transparent Shape Impostors

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**Abstract**
*Transparency is a graphical effect used in visualizations to present co-located graphical glyphs. Accomplishing a visually convincing transparency effect requires complex calculations of light absorption and refraction in object space. Alternatively, screen-space sorted rendering of graphical primitives using colour-blending techniques can be used for interactive applications. In this paper an efficient way is presented to render transparent glyphs for information visualization. The technique combines random dot surface plots with pre-computed transparent shape impostors to present different levels of transparency for co-located graphical glyphs. It is shown that this rendering method is faster than ordered polygon rendering using blending.*

Categories and Subject Descriptors (according to ACM CSS): I.3.7 [Computer Graphics]: Colour, shading, shadowing, and texture

## 1. Introduction

Visual simulation of transparent surfaces is a vital issue in photo-realistic rendering of natural scenes. For this purpose, advanced radiosity methods have been presented earlier that model both specular and diffuse light transmission in the process of synthetic image generation[7,15,20]. In the context of non-photorealistic rendering, transparency is important for simultaneous visualization of inter-positioned structures that occlude each other in camera coordinate space. Typical examples can be found in scientific visualizations where many layers of information must be presented simultaneously[14,17]. In medical applications, transparent renderings of both surface models and volumetric medical datasets are essential for assessment of anatomical structures in their three-dimensional context [6,12]. In the field of information visualization, transparency can be used to provide a see-through view upon densely populated scatter plots or densely arranged graphical glyphs, which express spatially positioned information.

For the sole purpose of seeing through and segregating multiple transparent objects there is apparently no need to modulate various levels of transparency. Obviously, occluding objects can be perceived satisfactory by observers if these objects or their graphical primitives, respectively, are rendered in screen space order using opacity blending techniques such as proposed by Porter and Duff [8]. Maintaining the correct rendering order requires, however, sorting of graphical primitives, which is a time consuming procedure. The problem of efficiently rendering transparent primitives has been addressed by Kelley et al., who present a hardware supported solution to the problem[9]. The twofold aim of the presented work is to investigate a fast and simpler method for rendering of transparent glyphs in interactive information visualizations.

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## 2. Previous Work

An alternative method to render the effect of transparent materials is referred to as screen-door rendering[5,13]. This method renders transparent surfaces using a more or less perforated surface, hence creating the illusion of partly seeing through the surface. In practice the visual effect of transparency is accomplished by using 2D dither patterns to fill surfaces in screen coordinate space which creates the visual effect of transparency. In consequence, multiple overlapping surfaces lead to interactions between the different dither patterns and hence cause visual artefacts. The problem has been addressed by Mulder et al., who improved on 2D fill patterns to reduce the artefacts found in enhanced screen-door rendering[13].

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A well-established method to represent object surfaces with non-continuously filled areas is utilising point based drawing techniques. Hereby, shape and shades are visualized through more or less densely scattered points with varying point sizes, thus creating different tones of a colour. In the field of 2D print techniques, this method is referred to as half-toning or dithering. The principle technique and its various adaptations are described in numerous publications[3,4,16,19]. More recently, point based rendering has received attention in rendering of 3D objects. Point based rendering technique has proven to be efficient in situations where model complexity is generally high in terms of number of polygons. Alexa et.al. use point based surface rendering to efficiently display densely sampled surface data[1]. The authors use a systematic distribution of surface points to preserve surface curvature properties.

Another typical scenario for complex scene rendering can be found in visual simulation of complex plant systems. Deussen et al. suggest to render tree foliage as points rather than as triangles arguing that for small structures processing of two points is significantly faster than processing a triangle[2]. In a current paper by Lu et al. stipple rendering is applied to rendering of volumetric datasets[11]. The authors describe stipple pattern representations of re-sampled volume data for interactive rendering of medical 3D data sets. They present for the first time point based drawing as a means to accomplish transparent or see-through visualizations in a specific application context.

Interrante et al. have studied effects of synthetic texture patterns that were applied upon surfaces of transparent medical objects[6]. The authors show that overlaying texture glyphs upon transparent surfaces can enhance perception of shape and structure of transparent three-dimensional objects. In another article by Rheingans, the author describes the usage of partly transparent textures in scientific visualizations for the purpose of enhanced perception of spatial surface structure[14].

Stippling techniques as previously described in the literature are until now predominantly used in order to visualize opaque surfaces, whereby dot density and stipple distribution is controlled by local surface illumination or silhouette properties[2,3,11]. In the field of vision research, random dot surface representations have been used to study human perception of structure from moving transparent objects[10,21].

## 3. Transparent rendering using random dot surface plots (RDSP)

For the purpose of 3D information visualization, I suggest to use simple and known geometrical objects as

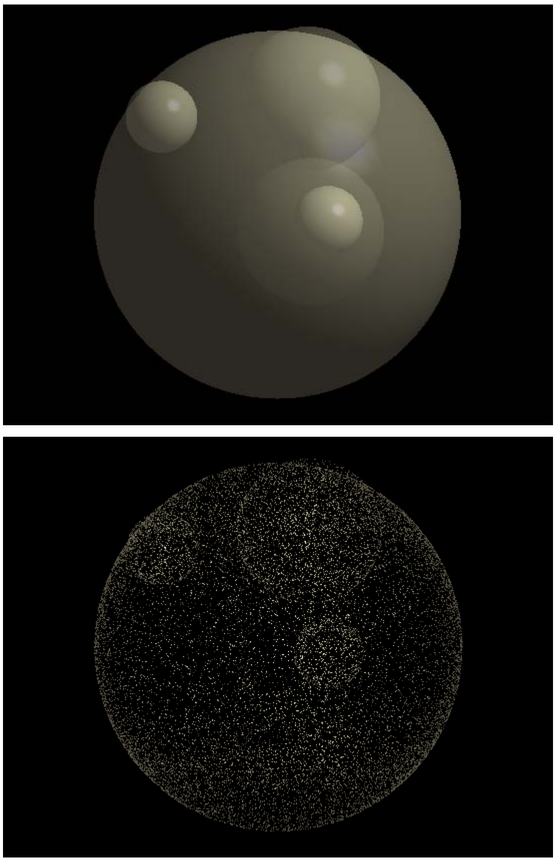

**Figure 1:** *Transparent spheres. Top: Polygonal surface rendering with blending. Bottom: Simple random dot surface plot (RDSP).*

glyphs, hence introducing transparent spheres as glyphs to visualize 3D scatter plots of five-component feature vectors. Three out of the five parameters can self-evidently be mapped upon the spatial position of the sphere. The remaining two parameters can be visualized by modulating the radius and the level of transparency, respectively. In this context, rendering of transparency effects can become a time critical issue. In order to approximate a smoothly appearing curved sphere, the surface tessellation must contain a significant amount of polygons. If the polygon based representation of the spheres is to be rendered with blending techniques, graphical primitives must again be sorted in a back-to-front order prior to rendering such as to avoid visual artefacts. For a visualization of numerous feature vectors, the resulting number of polygons can grow significantly and cause time penalties, both due to prior to render sorting and due to polygon throughput limitations in the graphics system.

Therefore an alternative representation of the glyphs surface is chosen which is based on a randomised distri-

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bution of stipples across the actual object surface. Hereby, stipple density is adjusted according to an intended level of transparency. Sparse sampling of the surface corresponds to a high level of transparency, whereas densely sampled stipple patterns represent opaque surfaces. Similar representations of spatial geometry have been studied in vision research and it has been shown that the human visual system is capable of interpolating and integrating entire object surface[10,18].

The bottom picture in Figure 1 illustrates an example of five spherical glyphs visualized using a random dot surface plot. In this simple variant, the footprint of a stipple corresponds to one pixel on the screen. Stipples are shaded using the material and illumination model of the OpenGL API. There is no removal of stipples on the back facing surface of the spheres. The upper picture in Figure 1 shows the same configuration of glyphs based on a polygonal representation, which is rendered using alpha blending as supported by OpenGL.

## 4. Visual augmentation using transparent shape impostors (TSI)

As with perception of colour stimuli, it appears that human perception sets limits to how many different levels of transparency can be distinguished by the observer. This holds true in particular with regard to several transparent objects that are positioned along the line of sight (Figure 1, top). Furthermore, the sample pictures show clearly, that for multiple collocated glyphs the random dot surface plot does not always guarantee that objects can be visually identified if there is not significant difference in the density of the dot patterns. At a first glance, only four out of a total of five spheres are evident, due to the low stipple frequency of the inner sphere (Figure 1, bottom).

On the other hand, a too densely chosen dot distribution will result in solidly filled areas on screen as several spheres overlap in screen space. Finally, if sample density of the random dot pattern is far too low, the human brain will not be capable of integrating the dot pattern into a coherent shape. Hence, for a final application the dot pattern density must be adapted to glyph size in screen space, colour and size of the stipples, and colour of the background. Figure 1 (bottom) illustrates that non-systematic stipple rendering of objects hampers recognition of the object's silhouette.

In order to tackle this problem, a pre-rendered view upon an illuminated fully opaque sphere is used. This 2D picture was rendered using POV-ray, and we used the same material and illumination settings as for the transparent sphere that was rendered using blending OpenGL. This pre-rendered view of size 512x512 pixels

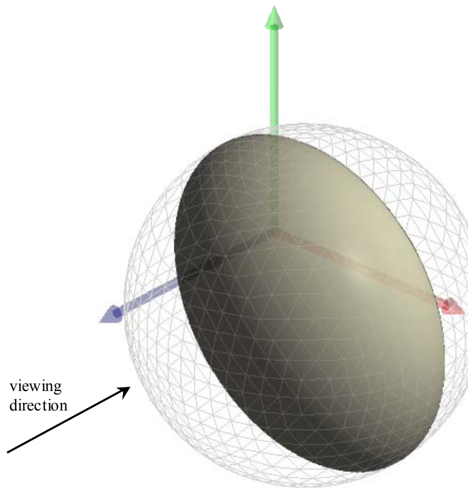


**Figure 2:** *A pre-rendered two-dimensional shape impostor is aligned with the sphere centre and oriented towards the centre of projection. The alpha-value of the impostor is modulated at runtime depending on the desired level of transparency.*

is further used as a texture impostor that is aligned with the RDSP of a glyph and facing towards the centre of projection. The impostor image is scaled to match the silhouette of a sphere. Depending on the actual transparency level of a glyph, the alpha value of the impostor texture is modulated at runtime. Figure 2 illustrates a transparent shape impostor in the context of a wireframe model of the sphere that it is representing. The impostor images, along with the stipples are rendered without depth testing in an unsorted order. This is chosen deliberately and it is taken into account that there are visual occlusion artefacts that are most apparent in still images of the glyphs. The purpose of the transparent shape impostor image is primarily to efficiently visualize the shape and contour of glyphs while allowing for seeing through the glyph. Other important features such as spatial interposition and level of transparency are visualized through the RDSP, which are further enhanced by modulating stipple size and by rotating the glyphs depending on their transparency level. The role of motion for three-dimensional perception has been studied extensively in the field of structure-from-motion research[10,18]. Therefore, in this visualization context, glyphs with sparse stipples patterns are rotated at higher angular velocities than glyphs with dense stipple patterns. Consequently, the magnitudes of optical flow observed in the sparsely dotted surfaces are amplified which compensates for their lower overall contribution to the visual image in terms of number of pixels.

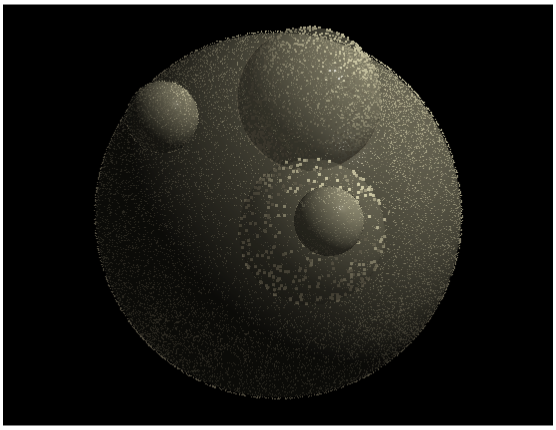

**Figure 3:** *Glyphs rendered with enhanced random dot surface plots (RDSP) in combination with transparent shape impostors (TSI).*

| **Transparency Level** | **1** | **2** | **3** |
|---|---|---|---|
| RDSP with TSI | | | |
| Stipples | 3000 | 2000 | 1000 |
| Stipple size (pixels) | 1 | 2 | 4 |
| Velocity (deg./sec.) | 5 | 15 | 45 |
| Polygon blending | | | |
| Triangles | 3200 | 3200 | 3200 |
| Alpha | 0.5 | 0.35 | 0.2 |

**Table 1:** *Parameters for different rendering styles and three levels of transparency. The number of stipples/triangles refers to a unit sphere, which after projection upon screen covers 100000 pixels.*

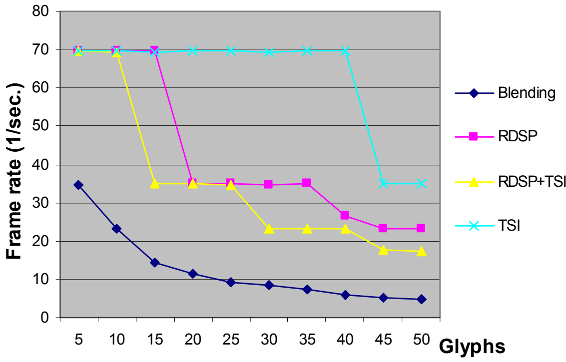


**Figure 4:** *Performance of different rendering methods for increasing number of transparent glyphs.*

## 5. Results and discussion

An example of a visualization of the five glyphs can be seen in Figure 3. What this figure cannot illustrate is the effect of the horizontal rotation of the glyphs, which enhances both perception of the depth structure of the sphere and which intrinsically represents a measure of transparency. In our explorative studies, we have worked with different combinations of angular velocity and stipple pattern densities for the RDSP glyphs in three different transparency levels. Table 1 shows a parameterisation of the rendering method that proved most comfortable for recognition and discrimination of differently transparent sphere glyphs. The number of stipples has been chosen based on a specific viewing frustum for a sphere, which, after projection upon screen, covers an area of 100000 pixels. Depending on the actual scale of spheres, the number of dots is adapted in proportion to the sphere surface. For the polygon rendered images of the glyphs it showed that a surface tessellation of at least 3200 triangles per sphere had to be used in order to achieve a contour curvature fidelity comparable to the one achieve with the 512x512 texel shape impostors. Figure 4 shows the results of a benchmarking of the different rendering methods. Ten series of between 5 and 50 spherical glyphs of different transparency levels were generated with random position, size, and level of transparency. These identical series were rendered for each of the four basic rendering methods. The test system was a PC with Pentium 4/1.7 GHz processor, 512 MB of RAM and a nVidia GeForce3 Ti200 graphics card with 64 MB local memory. In each rendering condition, the rendering times for ten frames were recorded. Out of these, the median value was chosen to calculate the frame rate.

The obtained values show, that up to a number of 40 glyphs, the efforts for rasterizing textures do not significantly affect the frame rate. Also, for stipple rendering only, frame-rates of above 30Hz could be observed for up to 35 glyphs. Remarkable is the sudden drop in the frame rate for vertex rendering only at the point where 15 glyphs are rendered, which corresponds to approximately 150000 stipples. The rendering times for shaded and alpha-blended polygon rendering increase linearly as expected. The values shown in Figure 4 refer only to rendering times and do not include processing overhead for polygon sorting. The obtained overall measures show, that random dot surface plots combined with transparent shape impostors provide an efficient alternative to rendering of opacity-blended polygons. Without taking into account additional time penalties due to primitive sorting, the performance increase for all measures in the series is at least by a factor two when using

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RDSP with TSI when compared to polygon rendering with blending.

In regard to the visual and perceptual effect of the proposed rendering method, there are at this moment subjective assessments of four different individuals, which show that recognition of spatial structure of spherical glyphs is comparable to conventional rendering methods. Fast recognition of spherical glyphs is mainly supported by the transparent shape impostors, which create a visual stimulus with an apparent silhouette contour. The 2D shape impostors when used alone, however, cannot convey any structural spatial information. Here, obviously, the animated random dot surface plots provide enough visual cues to obtain spatial references. The first assessments have furthermore indicated, that quantification of transparency levels might be better when using RDSP with TSI instead of polygon rendering using blending techniques.

## 6. Conclusion and future work

In this paper, a new method was presented for efficiently visualizing information by using transparent glyphs to mediate attributes of mutli-dimensional datasets. A rendering technique was introduced that simplifies drawing of graphical glyphs by using pre-computed transparent shape impostors. Results of a benchmark are presented, which prove significant performance improvements compared to conventional transparent rendering techniques.

Preliminary assessment suggests that this new technique can be used to better quantify transparency when multiple layers of different transparent structures are rendered. It could be observed that the segregation of multiple transparent objects and quantification of their varying transparency level is difficult when colour blending only is used to render transparency. A presumed hypothesis for my current work is, that the role of correct colour blending in transparent rendering is dispensable for assessment of layered transparent objects when surface stippling techniques are used to augment transparent visualizations. In the ongoing work controlled observer studies are currently performed to fortify this initial perceptual result.

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