Practical 3D Decoration on Flat Media with Anisotropic Reflection

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1 Introduction

We have proposed a method called Bump Mapping onto Real Objects (BMRO)[1] for displaying the appearance of curved surface on flat media. The method converts normal vectors of modeled curved surface into directions of grooves by which anisotropic reflection occurs for displaying a curved surface. Although curved surfaces can appear on media by BMRO, it is still insufficient for practical use because the streamlines used for a pattern of grooves are often placed too closely or too sparsely to one another due to the vector plot employed for generating them. The simplest solution to avoid the non-uniformity is to divide the entire region into regular square or hexagonal cells and to fill each cell with parallel lines in a given direction instead of tracing the direction field strictly with streamlines, but this improvement causes aliasing to noticeably appear at the edges and ridges of the original model. In this article, we propose an improvement on generating cells that reduces aliasing for BMRO and makes it practical for industrial applications.

2 Method

Arranging cells in a way that adapts to edges and ridges (feature lines) could reduce aliasing around feature lines for BMRO. Noda et al discussed a similar problem on generating mosaic images from 3D models, and proposed a method for arranging square tiles adaptively to the feature lines of 3D objects [2]. The method consists of the following three steps. First, feature lines are extracted from the surface of 3D objects based on the spatial variance in curvature and depth. Then, the entire region is divided into some belts with a fixed width depending on the distance from the nearest feature line. Finally, square tiles are arranged along the centerlines of all belts at a fixed interval. Figure 1 shows extracted feature lines and belts, and Figure 2(a) shows a part of the final mosaic image obtained by steps mentioned above. Although feature lines are preserved and the aliasing on BMRO is reduced by employing the arranged squares as cells as shown in Figure 2(b), gaps between the adjacent cells cause visual artifacts due to vacancy of grooves. It is necessary to cover the entire region with cells and with no gaps so as to eliminate artifacts. However it is impossible to avoid gaps by just inlaying congruent squares. The advantage of Noda's method is that the belts preserve the feature lines. On the one hand, Voronoi division divides an arbitrary region into cells with no gaps. Then we combine the advantages of Noda's belts and Voronoi division to both preserve feature lines and avoid gaps. Our new method starts with Noda's belts as the first stage of a two-pass division. Then we apply Voronoi division on each of the belts independently. We put Voronoi seeds on the centerline of each belt with a certain interval then apply Voronoi division within the target belt. Figure 2(c) shows a result of the new method in which cells cover the entire region without gaps and feature lines are preserved. All the cells appear as a similar size and the outcome is sufficient for reproduction processes such as embossing and foil stamping. The average area of these adaptive cells S that satisfies the ideal condition of the specific post process can be almost ensured by setting $\sqrt{S}$ as both width of belts and seed interval.

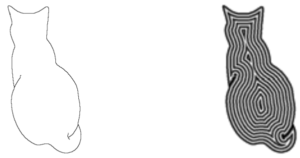

Figure 1: Noda's (a) feature lines and (b) belts

Figure 2: (a) Noda's mosaic, (b) BMRO with Noda's tiles, (c) our adaptive cells

3 Results

We made BMROs with regular hexagonal cells and with adaptive cells. We gave 1.0 square millimeter as the average area of cells and filled each cell with parallel lines 80 micrometers wide at intervals of 120 micrometers. After substantiating parallel lines onto a brass mould with approximately 30 micrometers in depth by etching, we embossed grooves onto pieces of paper by foil stamping them with attaching aluminum foil. Figure 3 shows two BMROs and their magnified images with hexagonal cells (a, b) and adaptive cells (c, d).

Aliasing around feature lines is reduced for BMRO when using adaptive cells comparing with regular cells, and our proposed method makes three-dimensional decoration onto the surface of printed matter practical.

Figure 3: (a) BMRO with hexagonal cells, (b) magnified image of (a), (c) BMRO with adaptive cells, (d) magnified image of (c)

References

[1] Kawai, N, Bump Mapping onto Real Objects.*ACM SIGGRAPH 2005 Sketches.*

[2] Noda, T et al, Mosaic Image Generation using 3D Models. *ASIAGRAPH 2009 PROCEEDINGS pp.110-115.*