Cube Art

Naoki Kita* Kazunori Miyata
Japan Advanced Institute of Science and Technology

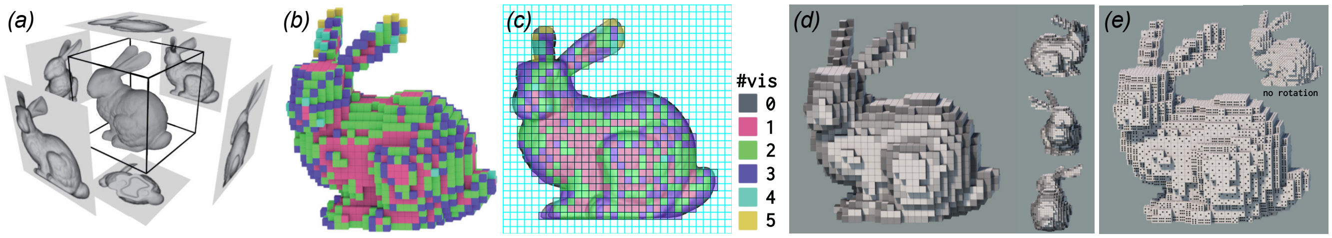


Figure 1: *Cube Art representing a 3D model assembled from same cubes. (a) Given a model, the shaded model is captured from six-orthogonal directions. (b) A voxelization of the model is also computed and the visibility of each voxel is calculated. (c) Under these visibility constraints, the optimal cube poses (rotations) are computed as an energy (defined by the dissimilarity of a cube face patch and a corresponding shaded image patch) minimization problem. (d-e) The resulting cube models (Cube Art and Dice Art) have enhanced perceptions of the original model due to the cube's face textures compared to* `no rotation` *and* `random rotation` *on the upper right of (e) and Figure 2. The cubes used are same cubes that only allow orientation-preserving rotations and translations.*

Abstract

In this study, we propose *Cube Art*, a representation of a 3D model assembled from *same* cubes. Here the term *same* is defined as two cubes that are regarded as the same, in that they can be rotated in space such that the textures (or the *Dice* numbers) on the corresponding sides become equal. Since such a cubic model lacks most of original geometric properties, the model has poorer expressiveness than the original one. To enhance the resulting shading to be more expressive, each cube needs to be properly positioned such that the textures on each face of the cube approximate the shading of the original models. The goal of this study is to determine the positioning of each cube so that the textures on each face of the cubes best approximate the original shading model under face visibility constraints of the model's orthogonal directions. We measure the similarities between each face's texture of the cubes and the textures resulting from the orthogonal projections onto a hexahedron of the original shading model for each cube position, and choose the best cube position. Our results show that properly rotated cubes enhance the perception of the shading and its aesthetics.

Keywords: computational design, human visual perception

Concepts: •**Computing methodologies** → *Perception;*

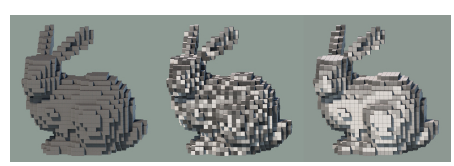
1 Motivation

Cubes are one of the most basic primitives and are used as a unit in wide various fields from architectures (e.g., *Bricks*) to recreational puzzles (e.g., *Rubik's Cube* and *Dice*). A cube's basic structure is very simple, and its mathematical properties have been explored in depth. In group theory, the symmetries of a cube have some intriguing properties (e.g., there are 24 orientation-preserving symmetries or rotations of a cube), and therefore recreational math attracted the interest of mathematicians and puzzle lover's since a long time. Although there are researches of generating cubic puzzles (e.g., [Song et al. 2012]), little attention has been paid to the use of textured cubes to give a model composed of assembled *same* cubes a similar expressiveness to the original model.

2 Our Approach

We first generate a texture of each face of the bounding volume by means of an orthographic projection of a shaded model. We then voxelize a given polygonal model and compute the visibilities of each voxel by casting a ray from each face in its normal direction. If there are no obstacles and the ray reaches the model's bounding volume, the face is considered to be visible. Next, we compute the dissimilarity between a voxel and a cube. The score obtained from this computation is the weighted sum of each face's dissimilarity between a voxel and its corresponding cube. We employ the sum of squared difference (SSD), or a log-polar histogram approach for better capturing the texture's local alignments, and the weight is calculated by the cube's visibility multiplied by its importance (e.g., viewing direction of the human eye). In addition, if a cube texture is not specified by a user, we can extract a color palette from a shaded target model. In this case, we need to consider how to assign colors to each cube face, which in total amounts to 30 patterns (= permutation of the six colors divided by the number of orientation-preserving symmetries/rotations; $6!/24$). This coloring problem is also known as *MacMahon's Cube* in mathematical puzzles. We can compute such mapping in the same way we compute texture similarity. Figure 2 shows that our result has enhanced perceptions of the original model compared to initial cube positioning (no rotation) and random rotation.

Figure 2: *Left to right: no rotation, random rotation, and our results.*



*e-mail:naoki-kt@jaist.ac.jp

SA '16, December 05-08, 2016, , Macao
ISBN: 978-1-4503-4540-8/16/12
DOI: http://dx.doi.org/10.1145/3005274.3005305

References

Song, P., Fu, C.-W., and Cohen-Or, D. 2012. Recursive interlocking puzzles. *In Proc. of SIGGRAPH Asia 2012*, 1–10.