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User Interface to Control Integrated Orthographic, Oblique, Perspective and Reverse Perspective Projections for Yamato-e and Ukiyo-e Style

Fujiko YOSHIMURA†, Yuri YAMAMOTO† and Suguru SAITO‡
† Department of Information Sciences, Ochanomizu University
‡ School of Computing, Tokyo Institute of Technology

ABSTRACT

In this paper, a new user interface to control integrated projections, which are orthographic, oblique, reverse and normal perspective projections, to produce Yamato-e and Ukiyo-e style images with 3D models is described. It is designed to allow intuitive and continuous projection related view changing operations with *the projection reference plane* that fixes the appearance of its intersection to a scene during the operations. Other operations such as scaling, shift, and rotation are also defined by the projection reference plane centered design. The definition of projection matrices for homogeneous coordinate system behind this user interface is also explained. The experimental results show that images of the similar composition to actual Ukiyo-e images can be made with the proposed user interface.

1. INTRODUCTION

It is said that the Western geometric perspective drawing was introduced to Japan in the middle of 18th century, and called as ”Uki-e”. It caused a fashion because drawing of a whole scene as a perspective view gave a great impact on the viewer. However, such geometrical correct perspective view declined and Ukiyo-e has been popular instead, which utilized the mixture of projection techniques such as incomplete perspective projection, orthographic projection, and bird’s-eye view oblique projection, which is the traditional technique from Yamato-e[1]. In fact, though the incomplete perspective projection, Ukiyo-e has formalized projection rules that are linearity and verticality.

In this paper, we assume that the projection used in Ukiyo-e can be generated by a 4×4 projection matrix with homogeneous coordinate system, which is a common method in computer graphics and is widely embedded in existing graphics rendering pipelines. As the definition of the matrix, perspective or orthographic projection matrix is typically used. However, those expressive abilities are not enough for Ukiyo-e style. In addition, as those matrices are completely different forms though the transformation facilities are seamlessly continued, transition between projections has to be considered. Therefore, we provide a projection matrix definition method which gives more general projections and which also gives seamless changes between perspective and orthographic as well as orthographic and reverse perspective projections. Based on this definition, an intuitive user interface to control projection parameters is realized.

2. RELATED WORK

The method to integrate perspective, orthographic, and reverse perspective projections in the way of ray-tracing was proposed by Osa et al.[2]. This integration was achieved by

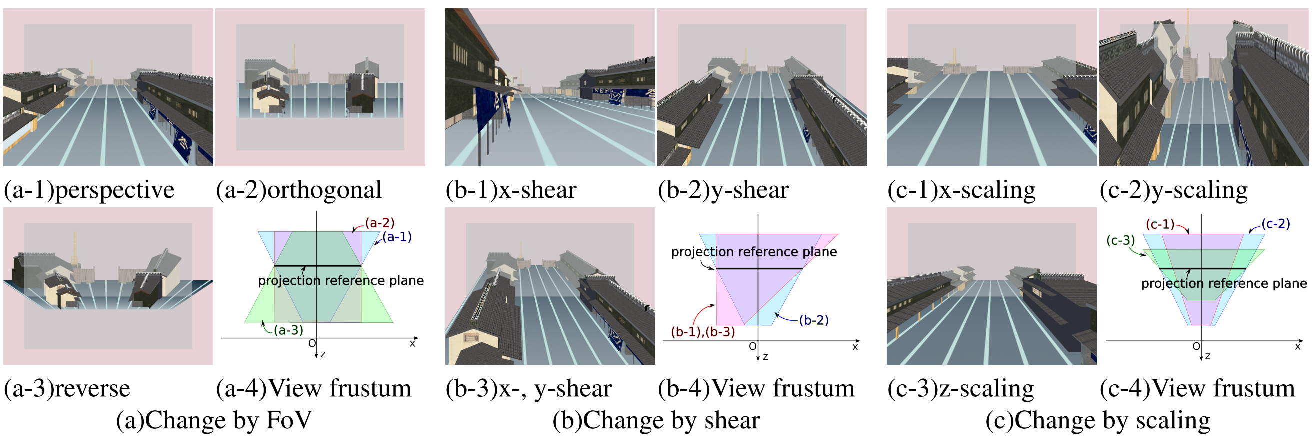


Figure 1: Projections and the corresponding view frustums

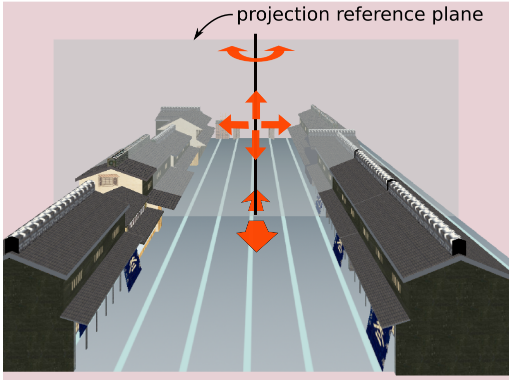


Figure 2: Camera move and rotation

adopting a pseudo screen and a parameter to move the ray starting point from the camera origin. This screen works as our *projection reference plane*, as the intersection between the screen and a scene is constant while changing the parameter. However, this method does not support oblique projection.

Another method to integrate projections was proposed by Baba et al.[3]. This method utilizes the focal length whose range is from $-\infty$ to ∞ as the parameter to integrate them, and considers oblique projection too. The subset of this method was also presented in [4]. Since user interaction is not considered, there is no helpful plane like *projection reference plane* for interaction in it.

These previous methods do not utilize the conventional projection technique to use a 4×4 matrix with homogeneous coordinate system. In contrast, our method is based on the conventional projection technique with a view frustum deformation[6]. Therefore it works with z-buffering. Another advantage of our method is that the design of it considers interactive usability. The main parameter, the horizontal half angle of Field of View (FoV) gives more constant change to the resultant projection than the parameters used in the previous work.

Although Kubo et al.[5] mentions that multi-perspective projections are used in Ukiyo-e landscapes in 19th, our method follows single view projection because of its easy controllability. Instead, a multi-perspective image is made by a combination of single projections.

3. PROPOSED METHOD

3.1. USER INTERFACE

We implement a user interface that can intuitively determine parameters for projection transformation. First of all, we introduce *the projection reference plane* which is put in a scene in parallel with the screen, as a translucent gray board shown in Figure 1 and 2. It fixes the appearance of its intersection to a scene and makes it easy for the user to control projection parameters.

Increasing and decreasing the horizontal half angle of FoV, x- and y-shearing values, and x-, y-, and z-scaling ratios are changed interactively by dragging the mouse on the screen. During these operations, the positions of the intersection points on *the projection reference plane* are not moved except for x values in the x-scaling operation and y values in the y-scaling operation. Figure 1(a) shows changes of FoV angle and the corresponding view frustums. The range of the FoV angle is allowed from negative to positive angles. When the angle is negative, the projection becomes reverse perspective projection and when the angle is 0, it becomes orthogonal projection. Figure 1(b) shows x- and y-sheared projections and the corresponding view frustums. The range of shearing values is also from negative to positive. When both x- and y-shearing values are zero, the projection is non-shearing one. Figure 1(c) shows x-, y-, and z-scaling and the corresponding view frustums as well. The user obtains a desired projection by combining these operations. In order to allow these operations, simultaneous controls for the shape and position of the view frustum are required. This is described in the next subsection.

In addition to the above operations, the camera move in parallel with and in visually perpendicular to *the projection reference plane*, the plane centered rotation where the vertical direction is the rotation axis, and the plane shift along with the its perpendicular direction are also prepared as interactive operations illustrated in Figure 2. Note that the rotation axis is limited to the vertical. This ensures vertical lines in a scene are always projected into vertical lines on the screen.

3.2. PROJECTION TRANSFORMATION

When an operation for FoV or shear change is ordered, the projection matrix P is decided under the condition that the intersection of *the projection reference plane* with the view frustum is fixed in a scene. P is selected from the following

$$P_1 = \begin{pmatrix} \frac{1}{\tan\theta} & 0 & 0 & 0 \\ 0 & \frac{W}{H\tan\theta} & 0 & 0 \\ 0 & 0 & -\frac{f_1+n_1}{F-N} & -\frac{2f_1n_1}{F-N} \\ 0 & 0 & -1 & 0 \end{pmatrix} \begin{pmatrix} 1 & 0 & \alpha & \alpha\lambda \\ 0 & 1 & \beta & \beta\lambda \\ 0 & 0 & 1 & \lambda - \frac{W}{2\tan\theta} \\ 0 & 0 & 0 & 1 \end{pmatrix},$$

$$P_2 = \begin{pmatrix} \frac{2}{W} & 0 & 0 & 0 \\ 0 & \frac{2}{H} & 0 & 0 \\ 0 & 0 & -\frac{2}{F-N} & -\frac{F+N-2\lambda}{F-N} \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & \alpha & \alpha\lambda \\ 0 & 1 & \beta & \beta\lambda \\ 0 & 0 & 1 & \lambda \\ 0 & 0 & 0 & 1 \end{pmatrix}, \textit{and}$$

$$P_3 = \begin{pmatrix} -\frac{1}{\tan\theta} & 0 & 0 & 0 \\ 0 & -\frac{W}{H\tan\theta} & 0 & 0 \\ 0 & 0 & -\frac{f_3+n_3}{F-N} & \frac{2f_3n_3}{F-N} \\ 0 & 0 & -1 & 0 \end{pmatrix} \begin{pmatrix} 1 & 0 & \alpha & \alpha\lambda \\ 0 & 1 & \beta & \beta\lambda \\ 0 & 0 & 1 & \lambda - \frac{W}{2\tan\theta} \\ 0 & 0 & 0 & 1 \end{pmatrix},$$

where W and H are the width and height of *the projection reference plane*, N and F are the distances from the origin to the near and far planes of the view frustum, α and β are respectively the shearing values in x and y directions. $n_1 = N + \frac{W}{2\tan\theta} - \lambda$, $f_1 = F + \frac{W}{2\tan\theta} - \lambda$, $n_3 = -f_1$, and $f_3 = -n_1$. P is selected from P_1, P_2, and P_3 in case of $\theta > 0$, $\theta = 0$, and $\theta < 0$ respectively. These matrices ensure continuity at $\theta = 0$ with the transform from the homogeneous space to the 3D space. The left and right matrices in these matrices are to decide the shape of the view frustum and to move its focal point.

For the operations of z-scaling (depth scaling), camera move in x and y directions, and rotation, usual transform matrices are applied to scene objects before the projection matrix. However the camera move direction for the screen depth direction is not in perpendicular to the screen plane, but in the direction that is considered with the shearing effect instead. X- and y-scaling (scaling in the direction along with the screen) are also different from the usual scaling transform matrix for 3D objects. Those are realized by changing W and H to obtain a 2D scaling effect, which does not cause occlusion changes. Following the change of W, θ is also adjusted not to move the focal point of the projection.

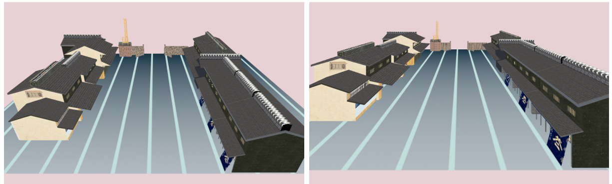
4. EXPERIMENT

4.1. COMPARISON WITH CONVENTIONAL METHOD

The comparison between a conventional user interface for camera control and our interface to confirm the advantage of our method to produce Yamato-e and Ukiyo-e style images was performed. A system which had a conventional user interface for camera control was implemented for this purpose. The system has functions for camera move in front, back, left, right, top, and bottom directions, focal length change, and pan and tilt angle change.

When creating a bird's-eye view image by a normal perspective projection, the camera has to have a lower view at a raised position. It breaks the parallel appearance of the vertical lines, as shown in Figure 3(a). In contrast, our user interface guides shearing instead of tilting and helps to find a Ukiyo-e style projection that vertical line appearance is preserved, as shown in Figure 3(b), because shearing does not break verticality of vertical lines.

Another advantage of the shearing projection is that it can move the vanishing point from the center of an image, while conventional projections cannot. This characteristic is very useful to make images similar in composition to Ukiyo-e images. If the same result were to be created with a conventional projection system, cropping would be required.



(a)conventional projection (b)our projection

Figure 3: Comparison of created bird's-eye view images

4.2. RESULT AND DISCUSSION

In order to evaluate how much similar composition to actual Ukiyo-e can be realized by the projection of 3D models with our user interface, an experienced user to the user interface performed to make the best matched view of Nihonbashi street as illustrated in Ukiyo-e images. Figure 4 and 5 show the Ukiyo-e master examples and the corresponding created images, which consist of the projected street and other 2D layered illustrations such as far background, people, and minor objects. The left and right side of the street in Figure 5(a) are projected separately.

The similarity was measured by the difference of line tangent angles. The lines in the images were classified into three groups. The first is the group of vertical lines in 3D (green lines in Figure 4 and 5). The second is the group of the lines which are horizontal and parallel with the screen (blue lines). The third is the group of the lines which are parallel with the camera viewing direction (red lines).

In the master examples, the green lines are almost vertical (the tangent angle is between 89 and 90 degrees) and blue lines are almost horizontal (the tangent angle is between ± 1 degree). These are characteristics of Ukiyo-e style. The corresponding lines in the created images are also completely vertical or horizontal. This is ensured by the constraint of our utilized projection transformation.

In contrast, there are various tangent angles for the red liens in the master example. The user has to tune parameters to follow them. In the created images, the corresponding lines are adjusted well and the differences are less than 5 degrees. In consequence, the average difference of all lines in tangent angle is about 2 degrees.

5. CONCLUSION

In this paper, we proposed a user interface for controlling parameters of the integrated projection transform. It allows the intuitive control by *the projection reference plane* and the choice of the parameter which gives more continuous appearance change than previous work. Since the projection behind this user interface is calculated by a 4×4 matrix in the conventional projection way in CG, it is applicable to various CG tools. The created images with this method show it can realize Ukiyo-e style projections. The extension of this user interface to animation is future work.

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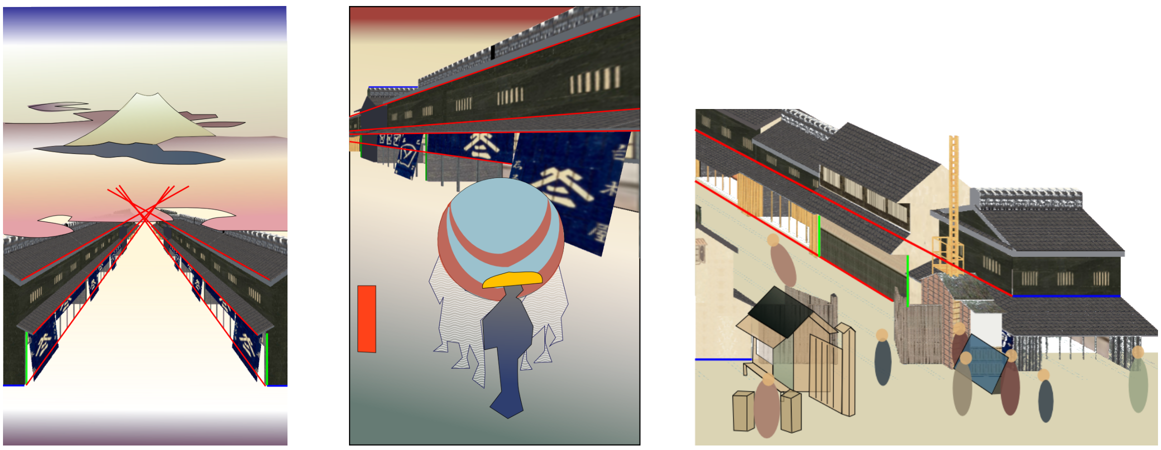
(a) “Surugacho” in [7]　(b)“Nihonbashi-dori 1Chome Ryakuzu” in [7]　(c) “Kitaisyoran”[8]

Figure 4: Master example Ukiyo-e images



(a)image in reference to Figure 4(a)　(b)image in reference to Figure 4(b)　(c)image in reference to Figure 4(c)

Figure 5: Created images with our proposed method