Rectification of mirror images

And estimation of mirror shapes

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Introduction

Nowadays, Object shape Detection is used in industrial to measure quality of product. It has many method to detect shape of object such as using camera. In uneven or reflective surface object is hard to use general method such as camera, because of reflection of light. It use tactile device to detection shape object by checks the distance to the surface at one spot. To get all of the object it has to be scanned in two dimensions which takes a lot of time. And the object has to be touched! Therefor, this research want to estimate a shape of the mirror that has a face of a plane mirror as a reference and rectify the mirror images.

Method

Mirror shape estimation has many procedure. We separate to 2 main step. First main step is about preprocessing to get information for estimate mirror such as straight lines and facial that reflex on mirror in image. Second step is use this information to estimate a mirror surface, which we studied 2 case:

1. Local mirror surface estimation by given position of object, camera, image is known.
2. Reflex image simulation by given position of object, camera, and mirror shape.

Flow chart

In Blue block is method make from [1] which must have known object position. Consequently, we research in green block to estimate mirror which object position is unknown. And in Grey colour block is a future method we will do.

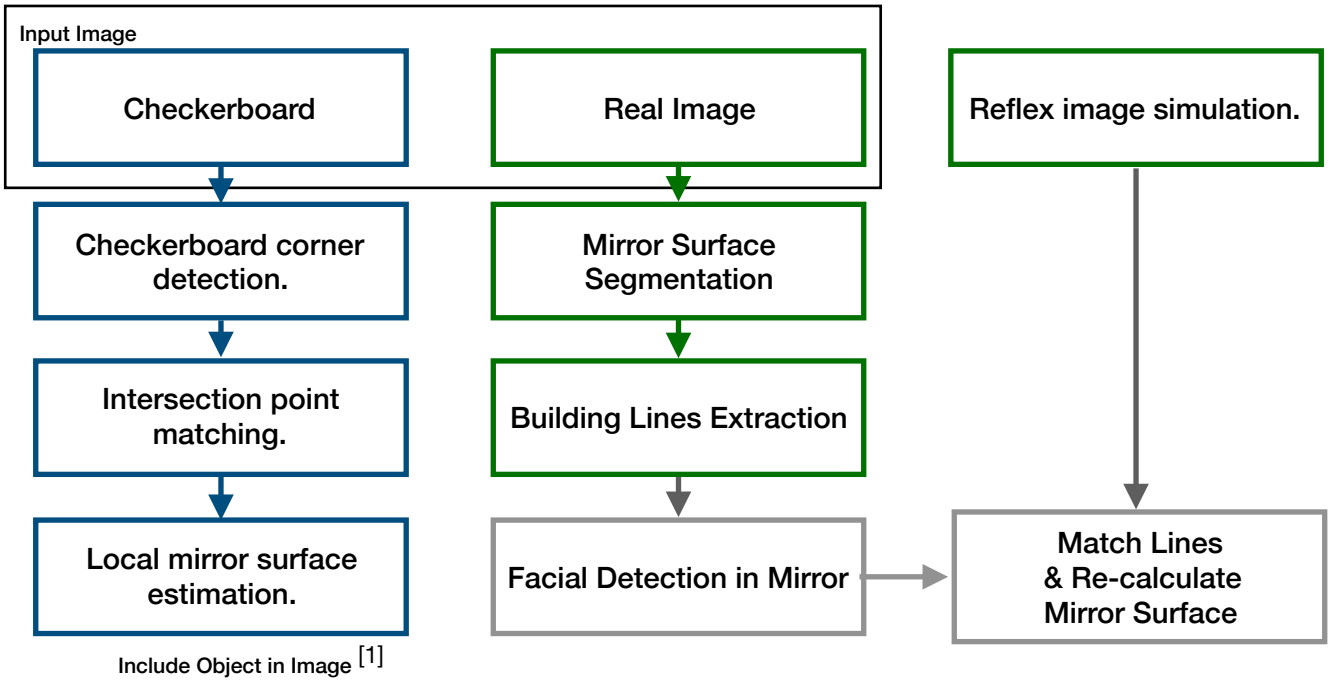

Figure 1 Flow chart.

Intersection point of checkerboard detection and matching.

In the beginning, we use checkerboard to studied reflexion process that introduce in [1] which must know a position of object in world coordinate and pair of these point in mirror on image. Therefor, this method is a semiautomatic to detect a corner of checkerboard, both in object and mirror on image. Then, use these corner match points to estimate local mirror surface in next step.

Checkerboard corner detection.

Triangle and rectangle checkerboards type are used in this project. To detect corner checkerboard, We create a block processing (Neighbourhood) size k and scan entire image. In each pixel image, we get a pixel around edge block and change it to 1 dimension, we call “sequence in edge block SEB” shown on figure 2. If block is on corner, SEB must have only 4 group in rectangle checkerboard and 6 group in triangle checkerboard.

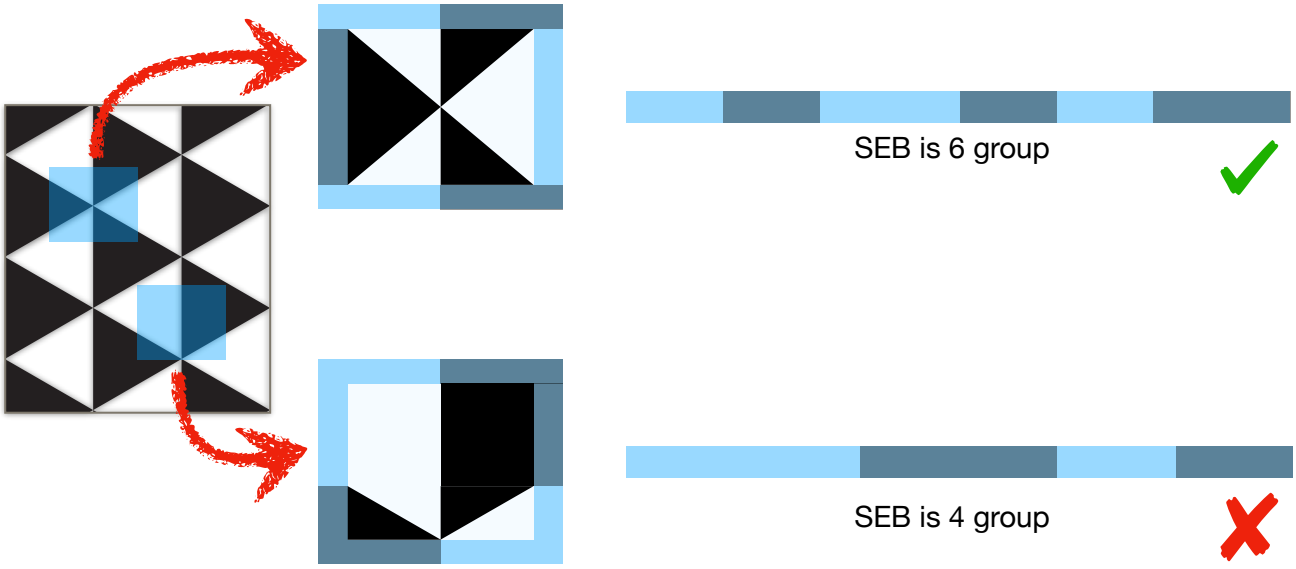

Figure 2 Block Processing to SEB Method.

This method has error occur when scan on some part of image. Example is shown on figure … . we use equality score to avoid this error which measure from equality area of black and white in each block. Equality score is calculated from equation 1.

$$score = 1 - \left| \frac{Area_{White}}{Area_{Total}} - \frac{1}{2} \right| \qquad 1.$$

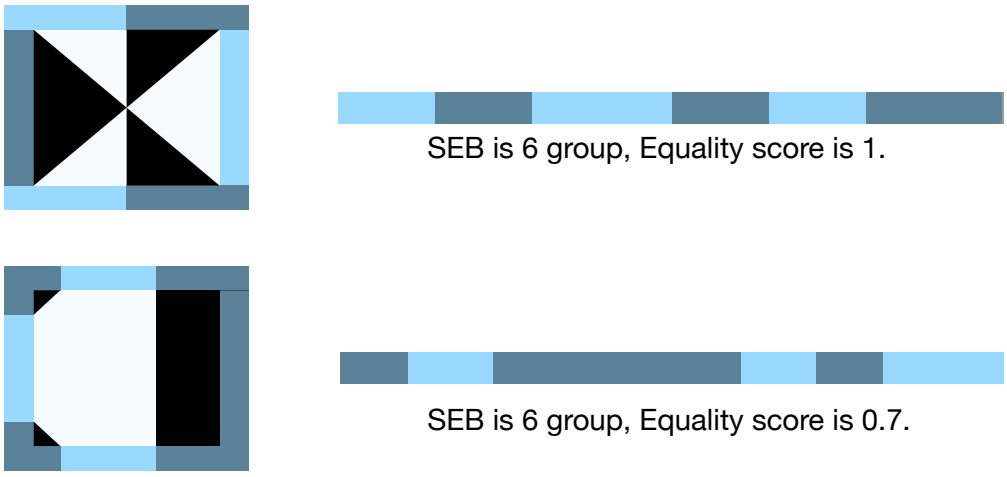

Figure 3 Relation of SEB and Equality Score.

Then, we threshold equality score. And use a centre of each area to be a position of corners in checkerboard. Because most of a corners position have equality score slightly less than near position due to noise, blur, or distortion.

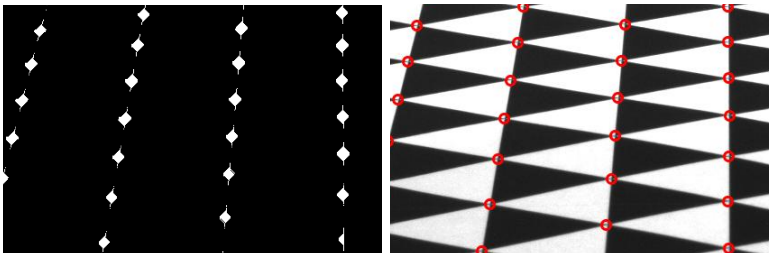

Figure 4 Equality Score Threshold(Left) and Corner Detection Result(Right).

Intersection point matching.

We mark each point to 2 group: object and mirror. We use Support Vector Machine (SVM) to find a line that separate group. And exclude a point that it is position on separate line. Then, we calculate distance from each point to separate line and sort them. And find a match point from mirror to object that have minimum distance which start at point that we sorted.

This matching may be fail when has outlier point or miss some point. To avoid this problems, our program has deselect point manually system for exclude outlier points.

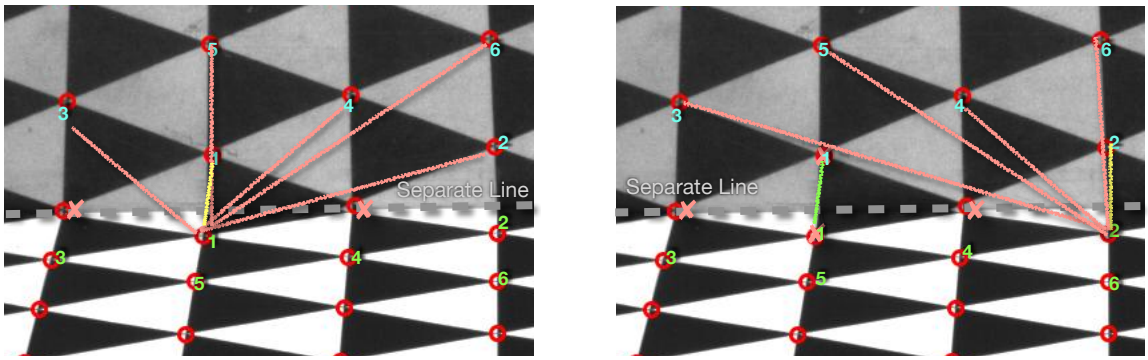

Figure 5 Matching Corner Points.

Local mirror surface estimation.

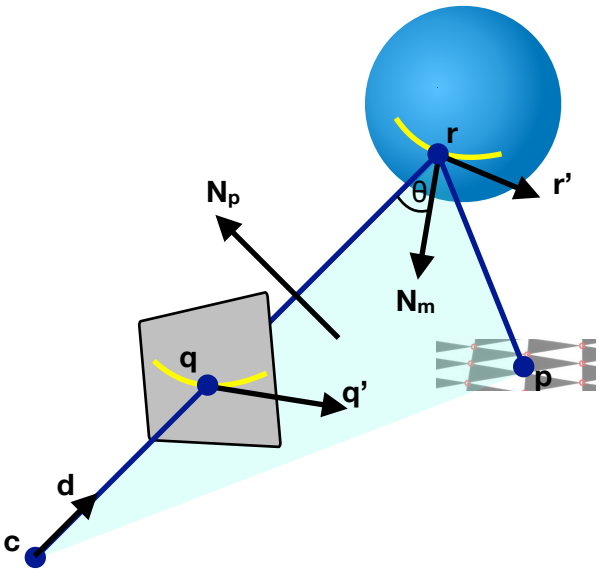

Figure 6 Mirror Reflection Model.

In present, Local mirror surface estimation is known when know position of camera and object. Consequently, It must have both object and mirror in image. And these images are calibrated.

Let c be position the camera centre at origin. p be point on object that reflex at r on mirror and q be a same r point but be in image plane. Shown on figure.

we assume that the camera and the scene pattern are calibrated, p and q are known, whereas r and the unit normal N_m to the surface at r are unknown. From figure, The point r must belong to the line defined by c and q in the following relationship:

$$\boldsymbol{r} = \boldsymbol{c} + s\boldsymbol{d} \qquad 2$$

Where the unit vector d = (q−c)/‖q−c‖ is unit vector of line c to q, and s = ‖r − c‖ is the distance from c to r. If we can find s, we will know r. From shortest distance theory of Fermat Principle [2], — the reflection point is a point that belongs to the mirror surface that locally minimizes the specular path length from the pattern to the observer — we can solve distance s by minimizing the path length c pass r to q as follow

$$\min l = \|\boldsymbol{r} - \boldsymbol{p}\| + \|\boldsymbol{r} - \boldsymbol{c}\| \qquad 3$$

The plane define by c, r, and p be call principal plane which same plane from c, q and p. Let N_p be its unit normal vector of this plane. N_m be a unit normal vector of local mirror surface which have θ reflection angle and belong on principal plane. Namely,

$$\boldsymbol{N}_m \cdot \boldsymbol{N}_p = 0 \qquad 4$$

From [1] N_m can know from this follow.

$$\boldsymbol{N}_m = \left[\boldsymbol{d} - \frac{(\boldsymbol{r} - \boldsymbol{p})}{\|\boldsymbol{r} - \boldsymbol{p}\|}\right] \times \boldsymbol{N}_p$$

Advance method by use derivative can see in [1]. It use relationship of tangent vector q' and r' of pattern lines that reflex on mirror.

Reflex image simulation.

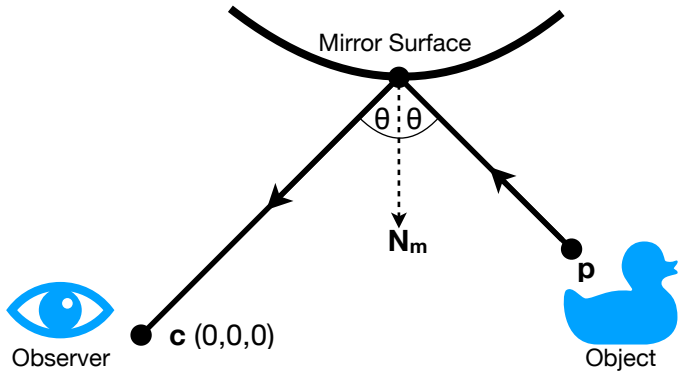

Figure 7 Mirror Reflection Model 2.

In laws of reflection on smooth mirror surface, angle between incident rays and reflected ray to normal vector must equal. Let p be a point on object which it has incident ray to mirror at r position and reflect to observer c. N_m be normal vector of mirror which angle θ to both incident ray and reflected ray. If we set observer c at origin (0,0), we will get relation on follow equation.

$$\boldsymbol{N}_m \cdot \boldsymbol{r} = |\boldsymbol{N}_m||\boldsymbol{r}|\cos\theta$$

$$\boldsymbol{N}_m \cdot (\boldsymbol{r} - \boldsymbol{p}) = |\boldsymbol{N}_m||\boldsymbol{r} - \boldsymbol{p}|\cos\theta$$

From eq.5 and eq.6, Angle θ is equal, Therefor

$$\frac{\boldsymbol{N}_m \cdot \boldsymbol{r}}{|\boldsymbol{r}|} = \frac{\boldsymbol{N}_m \cdot (\boldsymbol{r} - \boldsymbol{p})}{|\boldsymbol{r} - \boldsymbol{p}|}$$

Next condition is normal vector N_m must be in principal plane (p, r, c). Let N_p be a normal vector of principle plane.

$$\boldsymbol{N}_p = \boldsymbol{p} \times \boldsymbol{r}$$

From eq.3, then

$$\boldsymbol{N}_m \cdot (\boldsymbol{p} \times \boldsymbol{r}) = 0$$

To find r position, we give a simple mirror equation, such as

Flat mirror (Given normal vector (N_m) and point on mirror (p_m))

$$\boldsymbol{N}_m \cdot \boldsymbol{r} = \boldsymbol{N}_m \cdot \boldsymbol{p}_m$$

Sphere mirror (Given centre of sphere (c_m) and radius (R))

$$(\boldsymbol{r} - \boldsymbol{c}_m) \cdot (\boldsymbol{r} - \boldsymbol{c}_m) = R^2$$

We use 3 equation, such as eq.7, eq.9 and eq.10 or eq.11 to solve equations numerically. In sometime, result of this solving has two answer which can select by angle θ must not be zero. Because, one of them has same incident ray and reflected ray.

Application

This project has 3 application.

1. Local mirror estimation application.
2. Mirror simulation.

Local mirror estimation application.

This application is use for estimate local mirror from checkerboard. Input image must calibrated by load calibrate images set to this program. Then, semi auto to detect and match point on mirror and object. And this program will auto estimate local mirror. To use this program, you can use by following step below.

1. Starting Program.

Start program by run script in MATLAB program. This script is locate at below and shown on following figure.

/pathToFolder/MirrorRectification/Code/LocalMirrorSurfaceEstimationGUI/GUI.m

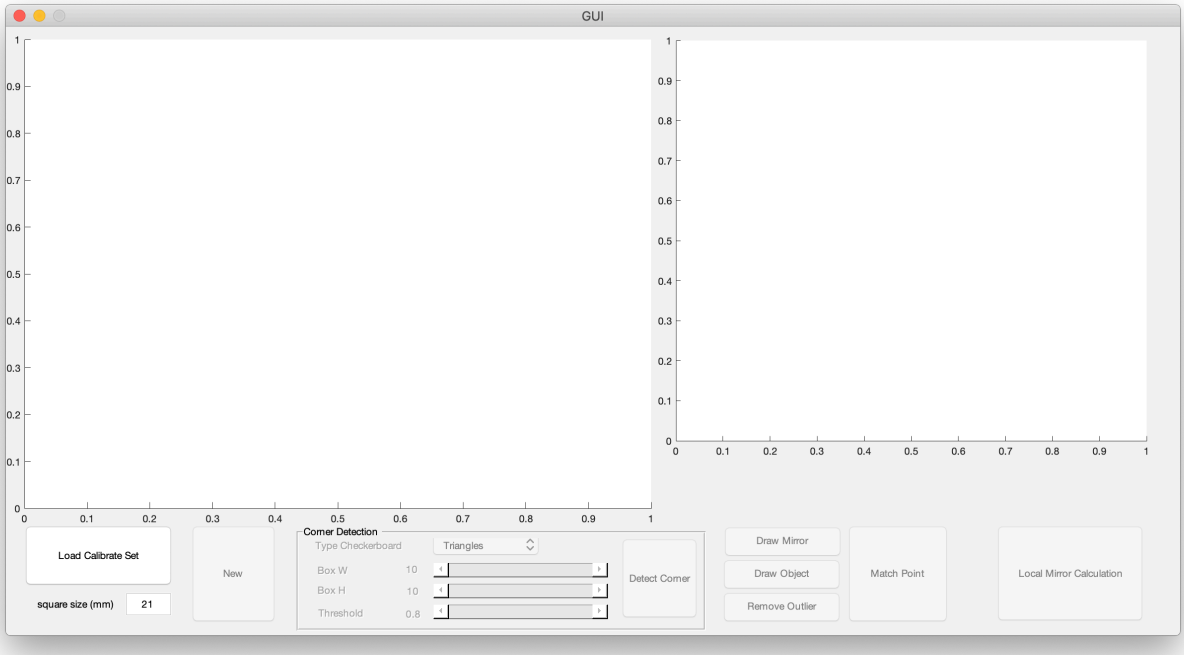

Figure 8 Local mirror estimation application.

2. Calibrating images set.

After program started, Click “Load Calibrate Set” button. Program will show new window to select images set. You can select multiple files. In sample test, you can use images set in

/pathToFolder/MirrorRectification/Data/calibrate_image/checkerboard_calibrate2/*.bmp

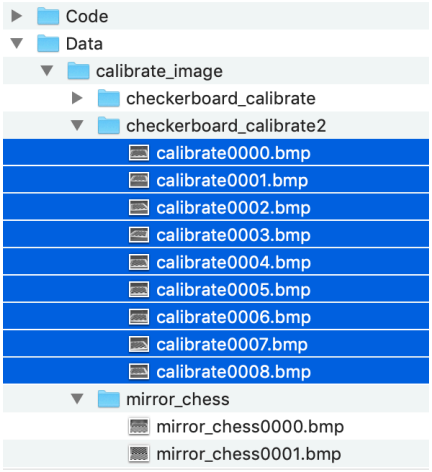

Figure 9 Local mirror estimation application : Path of Calibration Files.

3. New input image.

After Loaded Calibrate images set, wait 1-2 minute, button “New” will enable, you can click this button and select one image which is same setting from calibrated images.

Sample image is in /pathToFolder/MirrorRectification/Data/calibrate_image/mirror_triangle/mirror_triangle0001.bmp

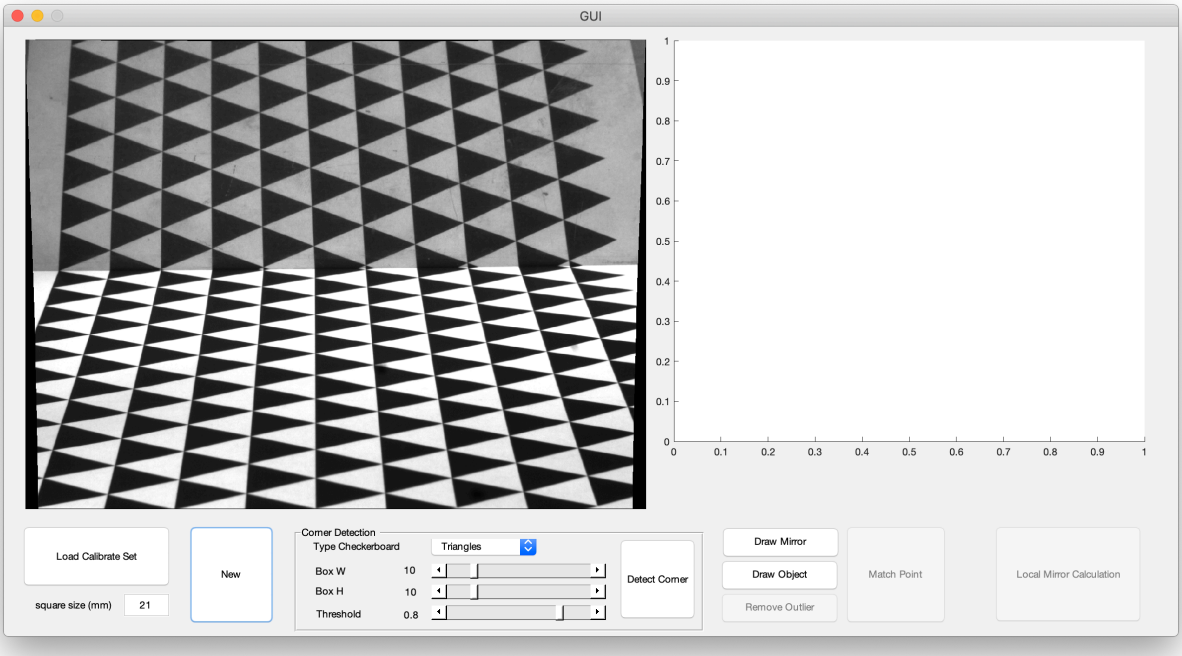

Figure 10 Local mirror estimation application : New Input Image.

4. Corner Detection

In panel Corner Detection, you can setting parameter such as

- Type Checkerboard : It has Triangle and rectangle option type of checkerboard in image.
- Box W : is width of block processing in pixel unit.
- Box H : is height of block processing in pixel unit.
- Threshold : is threshold value for equality score.

Then, click “Detect Corner” button, Result is mark on left image in yellow-red color.

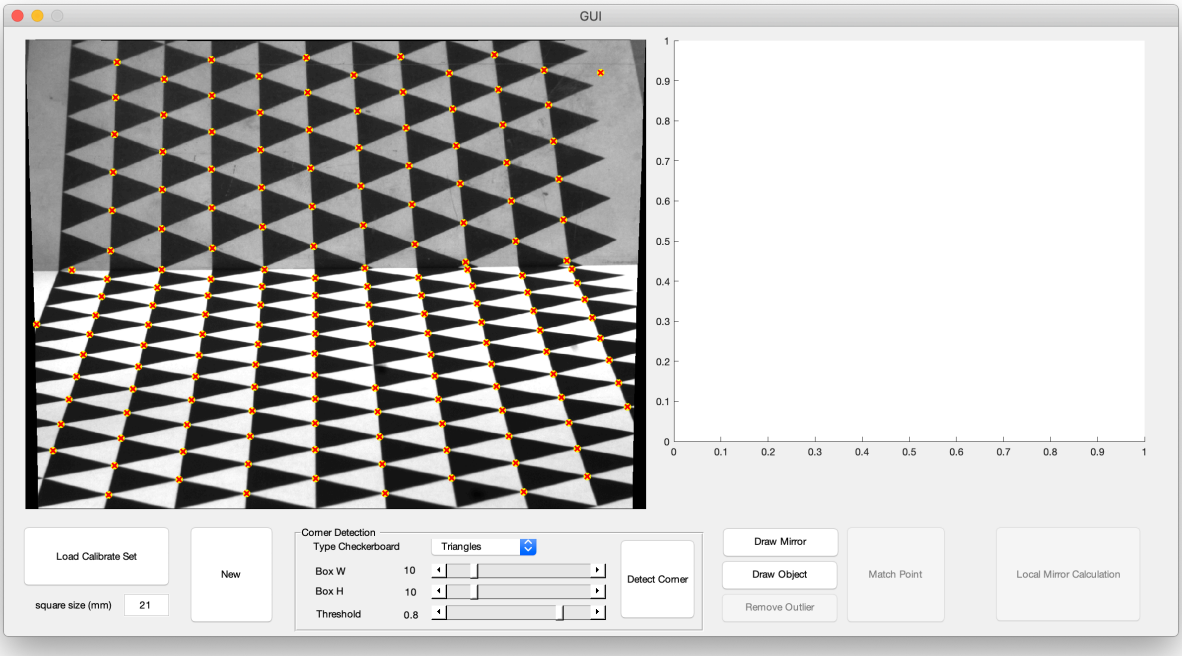

Figure 11 Local mirror estimation application : Corner Detection.

5. Mirror and object point classification

Click “Draw Mirror” button. Then, click on image more than 2 times to select region and click “Draw Mirror” button again to confirm. After confirm, region is shown in blue colour on following figure.

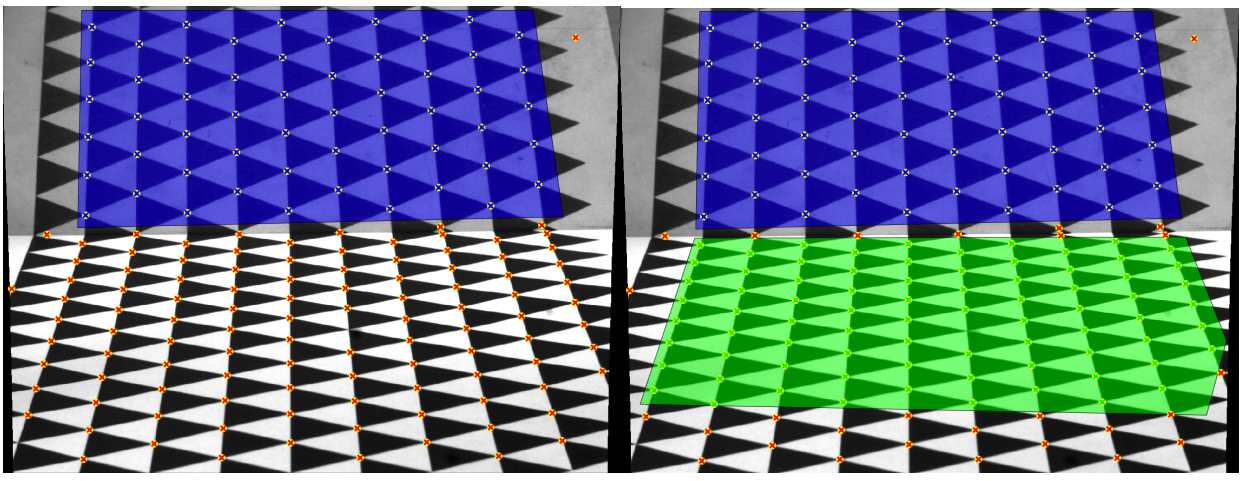

Figure 12 Local mirror estimation application : Drawing Region of Mirror(Left) and Object(Right).

Do it again in “Draw Object” mode, The colour shown on image is green colour. Finally, click “Remove Outlier” button to select corner point on image and exclude it. The ignore points are shown in red colour.

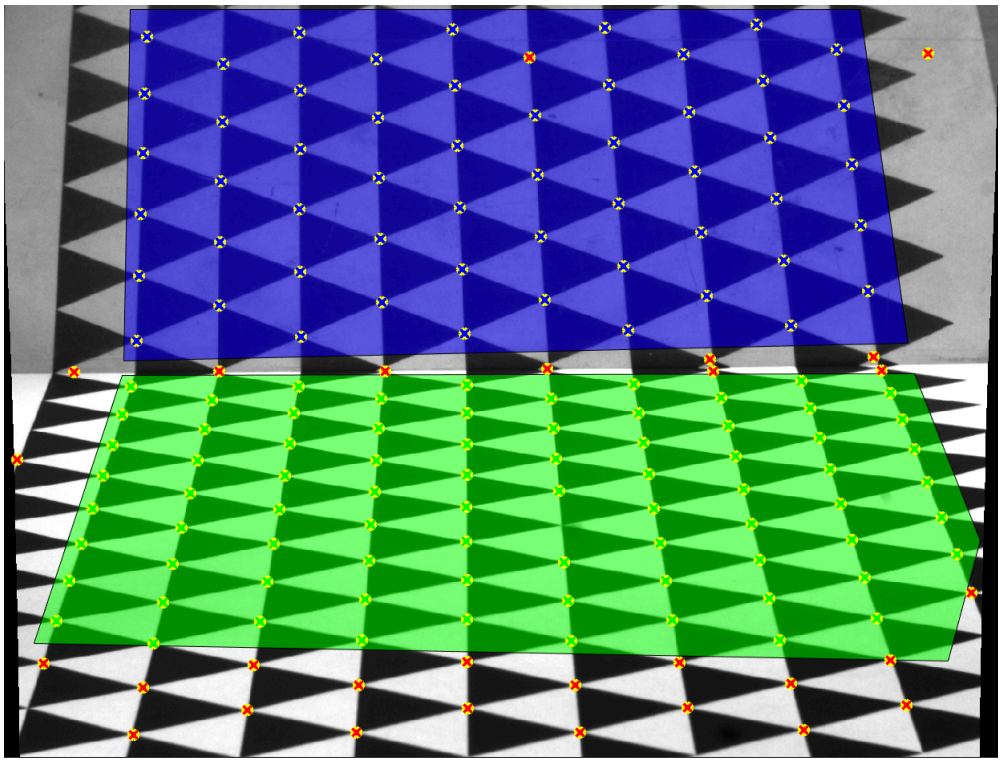

Figure 13 Local mirror estimation application : Removing Outlier.

6. Matching Points

Click “Match Point” button. Then, system will automatic to matching points. If matching point fail, you can remove more outlier to improve result.

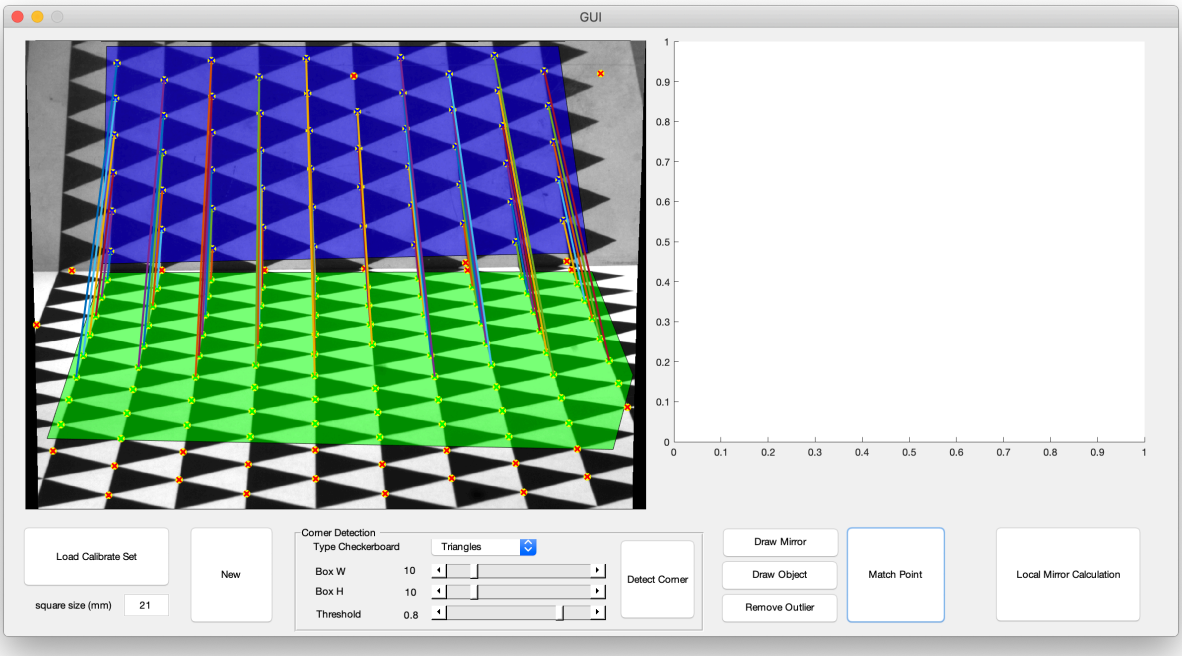

Figure 14 Local mirror estimation application : Matching Points.

7. Local Mirror Estimation

Click “Local Mirror Calculation” button. Result of local mirror estimation will show in right graft of application. You can click on this graft for rotation.

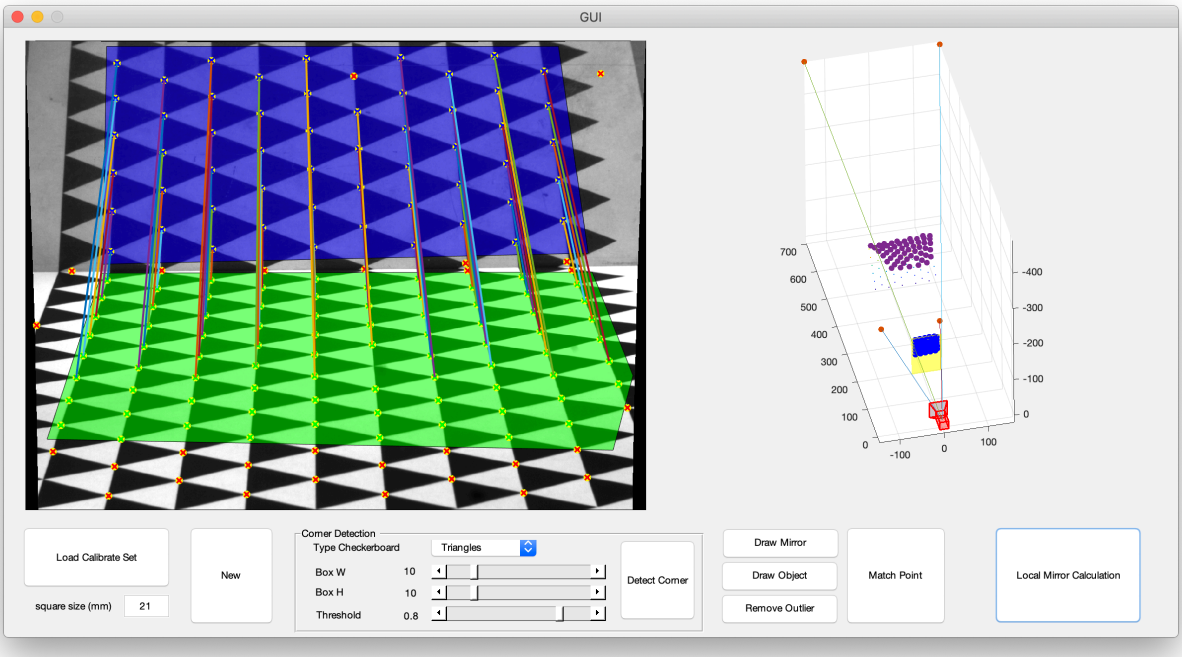

Figure 15 Local mirror estimation application : Result of Local Mirror Estimation.

Mirror Simulation application.

This application is use for simulate image from reflection mirror by given mirror equation, object and camera.

1. Starting Program.

Start program by run script in MATLAB program. This script is locate at below and shown on figure.

/pathToFolder/MirrorRectification/Code/mirrorSimulationGUI/GUI.m

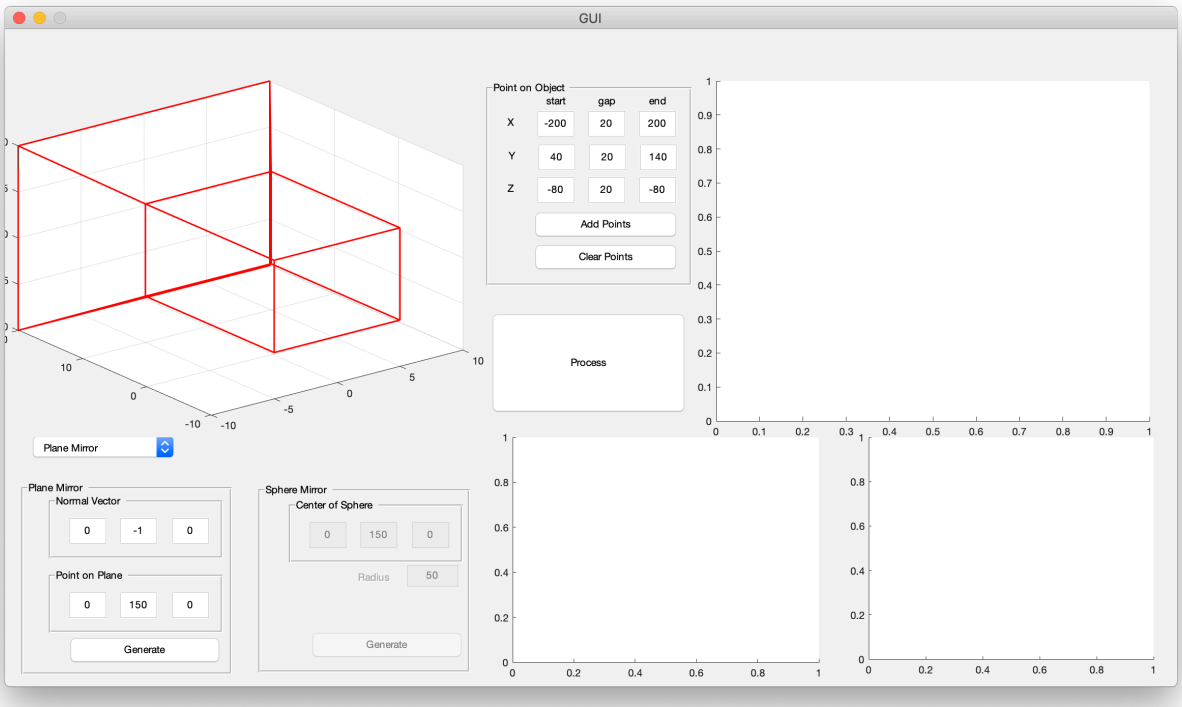

Figure 16 Mirror Simulation application.

2. Mirror creation

First, select type of mirror in select panel. In present, It has 2 option: Flat and Sphere. And setting in each panel such as

Plane Mirror : Normal Vector, Point on Plane

Sphere mirror : Center of sphere, Radius

Then, Click “Generate” button. The mirror will show on left graft as following figure.

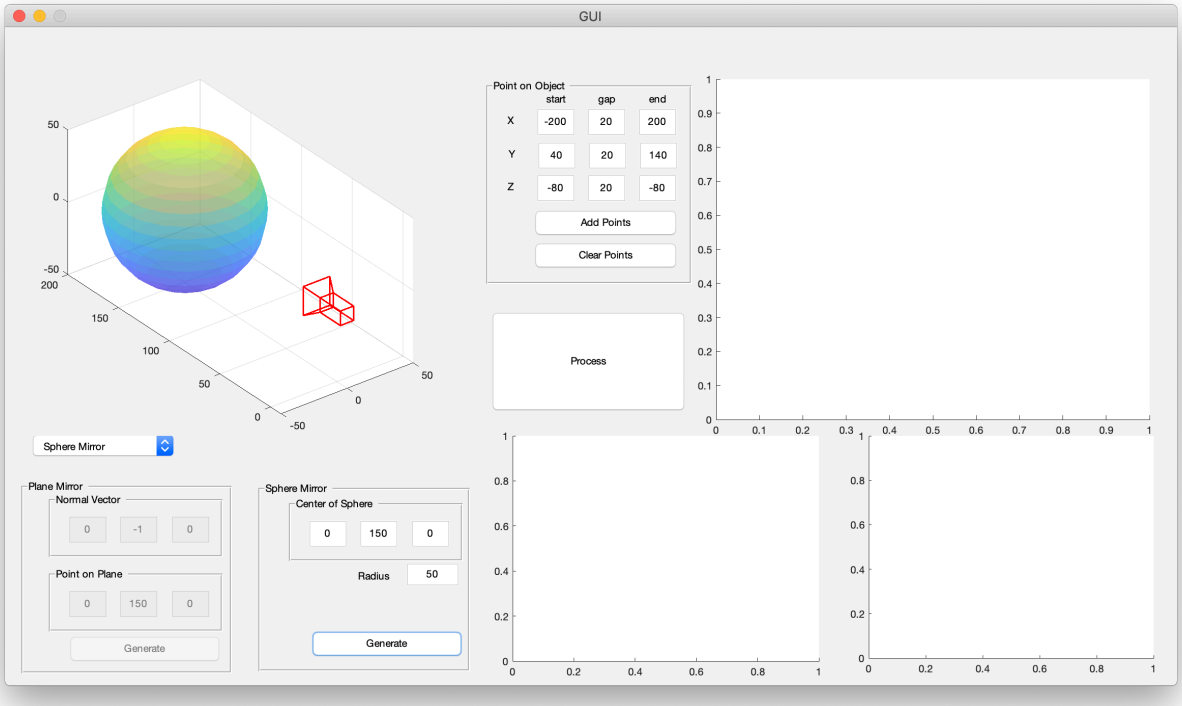

Figure 17 Mirror Simulation application : Mirror Creation.

3. Object Creation

In This application, We create object in points term. We can create set of points by setting a starting point, end point, and gap of this in “Point on Object” panel. And click “Add Points” button to plot on left graft.

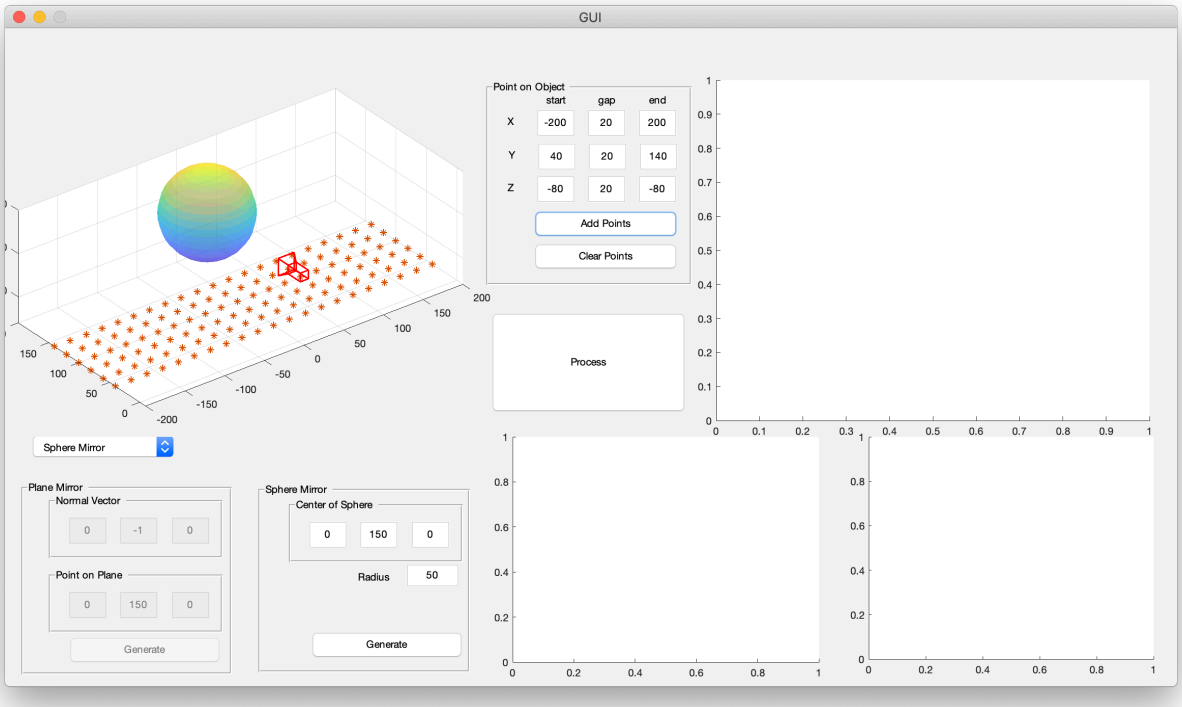

Figure 18 Mirror Simulation application : Object Creation.

4. Simulation

Click “Process” button to simulate image. The result image will show on right graft. And other graft is a first second derivative of image respectively.

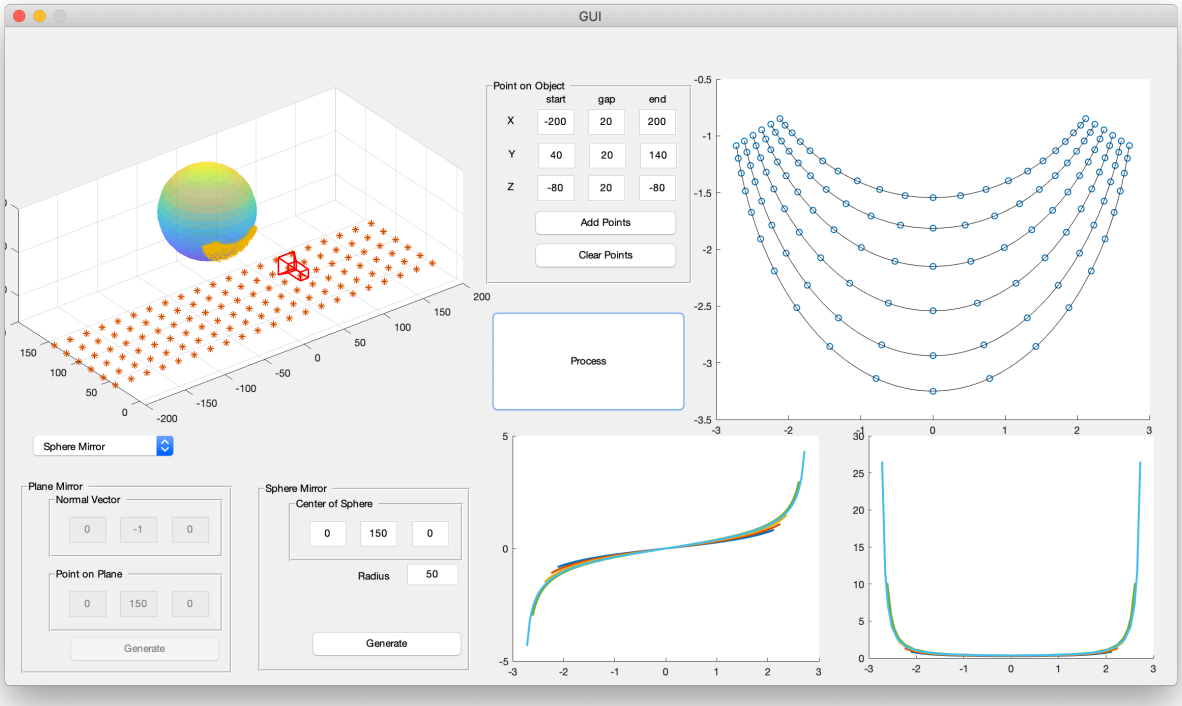

Figure 19 Mirror Simulation application : Image Result.

Reference

[1] S. Savarese, M. Chen and P. Perona. Local Shape from Mirror Reflections. International Journal of Computer Vision 64(1), 31–67, 2005

[2] M. Born and E. Wolf. Principle of optics: Electromagnetic theory and propagation. O Pergamon Press, 1965.