Autonomous Navigation for the Movement of the Robot in the Tube

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Abstract

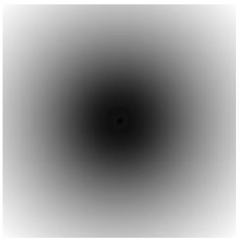
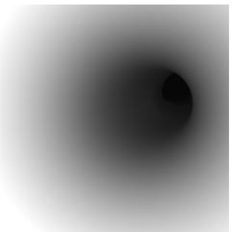
The paper deals with the issue of autonomous navigation for the movement of a robot in a tube. The solution is to determine the center of a given conic section using three operations in the Geometric Algebra for Conic Sections (GAC). The article describes an engine that renders given conic sections through basic operations in the GAC

Problem Statement

Goal of this paper is to find a conic that follows elliptic contour, that can be seen in a curved tube and make path using the center of the conic. We create a testing tube and develop an algorithm, the first part of which generates such conic. The second part extracts point in space as the center of that conic.

Solution

Suppose a camera, lying somewhere on the tube axis, with a point light source illuminating some neighborhoods. Let the camera be rotated, so that it is oriented to same direction as a tangent of the axis. Then the camera can capture 2 types of images (Figure 1: Camera view in a straight tube Figure 2: Camera view in a curved tube)

If we use certain image filters, we can extract a set of points (pixels of the image) highlighting a character of the tube in certain distance in front of the camera. These points (pixels) are using conic fitting algorithm to get conic (in this case our aim is to always get an ellipse) in IPNS representation (vector in R5,3 ⊂ G5,3).

From the ellipse properties we can further estimate a navigation trajectory through the tube.

Tube generation

In this Subsection we briefly introduce computer graphic software (Unity) on tube generation. Tube assumed in this paper can be an object that consist of 2 types of segments; cylinder and torus. Tube can have only constant diameter and its surface has to be continuous and transition between the cylinder and the torus has to be smooth. Then the tube axis is either a line or part of a circle, which follow each other smoothly. In Unity, first we have to create a set of points, which lie on the tube. After that we create a set which connects the points in particular way. Important is the order of points, because it carries also information about the normal of the triangle.

Pixels Selection

In this subsection we introduce two methods how to get a set of points, which we will fill the conic fitting algorithm. Suppose a camera that lies on the tube axis and in addition, it is pointed in the direction of a tangent to the axis. If the conic, produced by the fitting algorithm, is centered in the middle of the image, then the tube is straight in some neighborhood in front of the camera. If the center is not in the middle of the image, then the tube is curved in some distance.

The first algorithm for finding such set is taking points with certain brightness (color value). Let I be considered as a cameras screen. Unity has function 2DTexture.GetPixel(i,j).grayscale, which can be understood as the brightness (converts a color value to a gray scale) of the pixel, because it converts ARGB format into number within zero and one.

The second algorithm of highlighting points is based on the difference in brightness between neighborhoods

Tube Axis Recovery

If we want to recover the tube axis using the algorithms (resulting in a single ellipse), we have to find the connection between the shape and position of the ellipse on the screen and known environment properties. We can use projective geometry in computer graphics to see how the point in 3D is projected on the screen.

Now we estimate the tube axis. Suppose that the camera is moving along an exact axis trough a part of the tube with the following restrictions. The look rotation of the camera goes with a tangent of the axis at a point where the camera is placed. Every step I ϵ {1, …, n} camera captures an image, from which we will obtain highlight matrix. Using conic fitting algorithm, we compute the ellipse properties. From those properties and the camera properties, we can compute the i-th point of estimated tube. Then the tube sector is divided into n points and the estimate of the axis is then set of points ĉi ϵ ℝ3, i = 1, …, n

Conclusion

This paper deal with to a tube axis estimation, which consists of projected ellipse centers into environment of the tube.

This process consists of:

- implementation necessary algorithms to be able to perform geometric, inner and outer product;
- creation 3D environment including light source, camera and tube;
- an image processing to reduce the inaccuracy, or even compute the inaccuracy from the shape of the ellipse. Even considerable are self-learning algorithms that can choose points based on different tube examples and textures. The result is that using three operations it is possible to determine the center of a given conic section, with all the configuration taking place in the GAC, so the result is a conic section in the GAC;
- "Transformation in C#".