3DArcLens: A Technique for the Exploration of Geographical Networks

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Abstract

Many geographical datasets can be depicted as a graph layered over a map for motion and spatial relations analyses. In this work we present a novel and real-time exploration system that interactively distorts 3D graph layouts without information loss. The 3D visualisation technique is camera dependent. Therefore, it is affected by all three navigation axes, in contrast to traditional interactions in 2D spaces.

Index Terms: I.3.3 [COMPUTER GRAPHICS]: Picture/Image Generation —Line and curve generation;

1 Introduction

A considerable amount of geographical data, that is nowadays available, is used to describe the movement of entities between geographical locations. Usually, in these datasets, only the origin, the destination and flow magnitude are known. Examples include international telecommunications traffic, financial flows, trading patterns, and national migration patterns [4].

According to the First Law of Geography, ”Everything is related to everything else, but near things are more related than distant things” [3], the perception of the distance is extremely important. For that reason, the use of flat maps is not recommended for datasets that cover the entire world – a straight line in flat maps does not correspond always to the shortest distance between the two points it connects.

Representing the Earth as a virtual globe can overcome this limitation because distances are true to scale, the shortest distance between two points is the length of the arc (portion of a circle) that connects them. This aspect is particularly important in the case where the connection between geographical locations is depicted.

A known limitation of this visualization is visible in scenarios where a large the number of links has to be displayed. If too many links fly over an area then it generates a visual clutter, and the information concerning nodes and geographical areas that are occluded is lost. Although the user can move, pan, tilt and zoom the camera, in some situations, this in not enough to reveal the hidden information, see Figure 1(a).

In this paper, we introduce a novel data visualisation tool called 3DArcLens. It implements a lens technique to solve the occlusion problem without removing edges or moving nodes; it deforms the arcs affected by the lens with aesthetically pleasing curves that highlight certain nodes as well as edges' paths. This interactive lens is specifically designed to support the exploration of geographical networks in the 3D space.

2 Arc congestions over a virtual globe

The research question is: how can we reduce the visual cluster in a given area, without loss of information and independently of a camera view?

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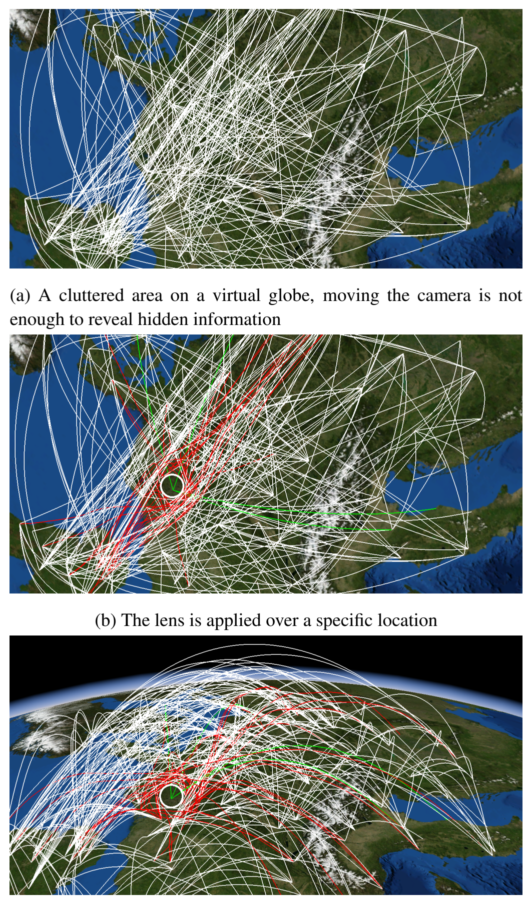
The solution has to satisfy the following requirements: (1) No arc or node is removed from the scene. In addition, nodes are not moved due to the meaning of their geographical location. (2) Only the visible hemisphere is affected. (3) It must be possible to identify the nodes that are relevant to a selected area.

There are cases in which the user simply has to change the camera position to visualize all the information related to a particular area, however in many cases this operation is not enough.

3 3DArcLens: our proposed approach

Our proposed technique uses a lens metaphor that is defined by a point of focus and a radius that includes the region of interest.

In the context of this work, users can drag the lens to a preferred geo-location, and then navigate, tilt or pan the camera to distort the edges over that location, with the exception of the arcs with nodes located inside the lens area, see Figure 1(b).



(a) A cluttered area on a virtual globe, moving the camera is not enough to reveal hidden information

(b) The lens is applied over a specific location

(c) While the camera is moving the lens still working

Figure 1: Navigation and panning using the lens to distort the edges over a given location.

Its movement around the globe is snapped to the terrain to improve the system usability; the camera movement affects the lens position in screen coordinates but not its position in the world coordinates, see Figure 1(c).

Each link is depicted as a 3D arc, that is a relaxed cubic spline composed by a sequence of equal-distant control points $cp_1, cp_2, ..., cp_n \in R^3$ where cp_1 is the source node and cp_n is the target node, see Figure 2(a).

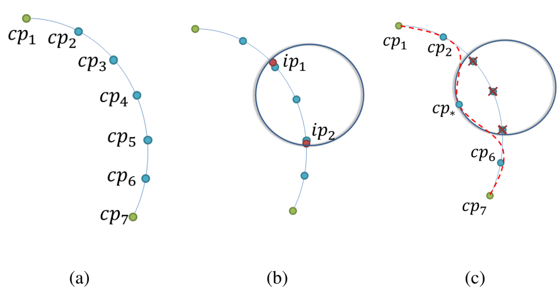


Figure 2: The steps required to apply the effects of the lens to the 3D arcs are: (a) each arc is composed by n control points, (b) the intersecting points are detected, (c) a new control point is used to deform the 3D arc.

The altitude of the control points follows the formula of similar works [1, 2]: $1 + H\sin(x\pi)$ where H is the maximum height and x varies between 0 and 1 along the arc's path. To take into account the path length l, we define the parameter H to be equal to $l/4$.

The 3DArcLens algorithm is defined by 2 steps that are executed at every frame, before the main rendering phase: (1) Find the arcs that intersect the lens. Then detect the intersection points between those arcs and the circumference of the lens. The arcs with the source node or the target node inside the lens are omitted. For each intersecting arc, the algorithm detects the intersecting points that will be used to create the new control points of the cubic curve, see Figure 2(b). (2) Calculate a set of control points and redraw the arcs. As shown in Figure 2(c), for each intersection arc, the set of control points that are located inside the lens are removed and a new control point $cp_\star$ is created and placed over the lens circumference.

The formula to calculate the screen position of the new control point $cp_\star$, for a pair of points $\{ip_1, ip_2\}$ that intersects the lens circumference, is the following:

$cp_\star = c + r * (\widehat{mp - c})$, where $mp = (ip_1 + ip_2)/2$;

mp is the middle point between ip_1 and ip_2, c is the center of the lens and r is the radius of the lens. The aforementioned formula is applied to the attributes x and y of $cp_\star$, and z is assigned to the middle value between the z of ip_1 and ip_2. All points are expressed in screen coordinates. The z is used to convert the screen coordinates in world coordinates.

It might happen that arcs overlap from a given perspective. In such cases, arcs are deformed to match partially the boundaries of the lens. Hence, arcs might loose their traceability, see Figure 3(a). Although this drawback can be solved by applying different colors for each arc, we have decided to follow a different road. Instead, we update the arcs's distance to the lens circumference based on its distance to the point of focus. The result is obtained after executing the following steps:

1. The lens is divided in p sections of equal area. For each new control point $cp_\star$, the distance in screen coordinates between its associated mp and the center lens is calculated, see Figure 3(b).
2. The control point is moved away from the lens, accordingly to the distance, as depicted in Figure 3(c). A maximum distance is defined in order to limit the effect in a closed area around the lens.

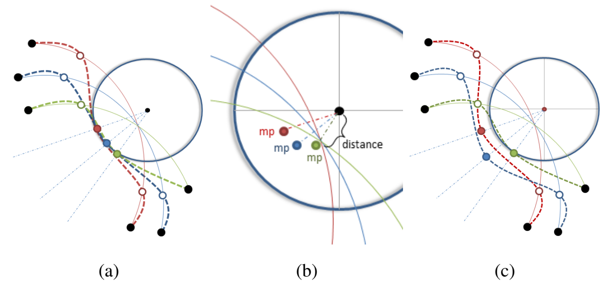


Figure 3: (a) the basic solution: new control points are added around the lens. (b) the lens is subdivided in sections. Control points are ordered accordingly to a distance factor, relative to their sector. (c) control points are placed at different distances, around the lens.

4 Differences between 3D arcs and 2D lines

EdgeLens [5] is a technique that iteratively curves graph edges that are represented by 2D straight lines, away from the point of focus in a 2D plane. This consents to disambiguate the relationship between nodes and edges without losing information. This technique can not be applied to a 3D context for the following reasons:

1. In a 2D plane, to deform a straight line only the start and end points (together with the lens focus and radius) are needed. With 3D arcs, the manipulation of these objects is more complex. The behavior of the lens depends also on the position of the view camera; if the view camera changes, the arcs affected can differ in both number and shape.
2. In 3D space the effect of occlusion has to be considered; arcs that intersect the lens with their extremities behind the globe can generate undesirable behaviors.
3. In 3D space if we want to distort an arc we use the screen coordinates of the control point, but then when the curve is created a conversion in world coordinates has to be performed.

5 Future Directions and Conclusion

The aim of this work, the 3DArcLens, is to describe a novel interacting system used to explore geographical networks in a 3D globe. It distorts the arcs in a given area without any loss of information and independently of the camera view. A comparison with other distortion techniques and a user study has to be performed.

References

[1] K. C. Cox, S. G. Eick, and T. He. 3d geographic network displays. *ACM Sigmod Record*, 25(4):50–54, 1996.

[2] T. Munzner, E. Hoffman, K. Claffy, and B. G. N. D. Fenner. Visualizing the global topology of the mbone. In *Information Visualization'96, Proceedings IEEE Symposium on*, pages 85–92. IEEE, 1996.

[3] W. R. Tobler. A computer movie simulating urban growth in the detroit region. *Economic geography*, pages 234–240, 1970.

[4] W. R. Tobler. Experiments in migration mapping by computer. *The American Cartographer*, 14(2):155–163, 1987.

[5] N. Wong, S. Carpendale, and S. Greenberg. Edgelens: An interactive method for managing edge congestion in graphs. In *Information Visualization, 2003. INFOVIS 2003. IEEE Symposium on*, pages 51–58. IEEE, 2003.