

# Route Network Construction with Location-Direction-Enabled Photographs

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**Abstract:** We propose a method for constructing a geometric graph for generating routes that summarize a geographical area and also have visual continuity by using a set of location-direction-enabled photographs. A location-direction-enabled photograph is a photograph that has information about the location (position of the camera at the time of shooting) and the direction (direction of the camera at the time of shooting). Each node of the graph corresponds to a location-direction-enabled photograph. The location of each node is the location of the corresponding photograph, and a route on the graph corresponds to a route in the geographic area and a sequence of photographs. The proposed graph is constructed to represent characteristic spots and paths linking the spots, and it is assumed to be a kind of a spatial summarization of the area with the photographs. Therefore, we call the routes on the graph as spatial summary route. Each route on the proposed graph also has a visual continuity, which means that we can understand the spatial relationship among the continuous photographs on the route such as moving forward, backward, turning right, etc. In this study, when the changes in the shooting position and shooting direction satisfied a given threshold, the route was defined to have visual continuity. By presenting the photographs in order along the generated route, information can be presented sequentially, while maintaining visual continuity to a great extent.

**Keywords:** Geometric graph, Directional information, Data storytelling, Visualization, Location-direction-enabled photograph

## 1. Framework

First, the characteristic regions, namely, the regions which are the shooting targets of several photographs (named Authority spots) and the regions where several photographs were taken from there (named Hub spot) are extracted. Then, the fragmented routes that have the locational and directional continuity (named the walk-through) are extracted as a graph (named Location-direction-enabled proximity graph). Then, authority / hub spots are embedded as sub-graphs of the graph. Finally, spatial summary routes are generated from the graph. The authority spot and hub spot extraction techniques are summarized in our previous paper.

## 2. Related work

Trajectory pattern mining is aiming to extract the various information, including the route networks, from a large amount of trajectory data. However, this cannot be directly applied to the present study because the nature of the input data is different. The input data of trajectory pattern mining is a set of trajectories. A trajectory is a sequence of points. Therefore, each point is treated as a point on a certain trajectory. In contrast, the input data of the present study is point data. Each point is not assumed to be on a trajectory. In addition, in trajectory pattern mining, each point constructing a trajectory is said to have a direction. It is the moving direction from one point to another.

In contrast, the input data of the present study is points-with-directions (location-direction-enabled photographs), and each of them has the direction (shooting direction) by

itself. Routes (sequences of points) are created by a set of location-direction-enabled photographs. Therefore, each point on a route has two directions, i.e., the shooting direction and the moving direction.

As far as we know, only a few studies have been conducted on points-with-directions. There are researches on trip planning, clustering, and object extraction using location-direction-enabled photographs. We have also proposed a method for spatial search, metadata sharing, creating animation, and location extraction. Noah Snavely et al. proposed a method that synthesizes images by using the image information to achieve information presentation that is close to the image and with a very high degree of visual continuity. However, it is different from the present study as it requires a group of overlapping images as input data.

Narrative visualization and data storytelling techniques, which present the target data in a story format, have been proposed in the field of information visualization and are being applied extensively. The methods proposed by Hossain et al. and Kim and Xing aid in the understanding of large-scale data that are difficult for humans to comprehend and grasp. The technique proposed in this paper may also be regarded as a data storytelling technique for location-direction-enabled photo data.

## 3. Location-direction-enabled proximity graph

The location-direction-enabled proximity graph is a geometric directed graph. A location-direction-enabled photograph is treated as a point in space that has both locational and directional information and is used as a

node of the graph. The input information for creating the graph is bounds of target area (rectangular areas on the map) and Location-direction-enabled photographs whose locations are within the bounds. The graph requirements are summarized below.

- a) Locational relationship requirements
  - Considering the locational and directional relationship of nodes, if a node that is a relay point between any two nodes exists, then, the two nodes are connected through the relay point and not directly.
- b) Directional relationship requirements
  - The directions (shooting direction) of the two nodes that are connected on the graph must not differ significantly.
  - When moving between the two connected nodes along the edge on the graph, proceed in a direction that does not change significantly from the direction of the starting node.

Considering these requirements, we defined the graph formally by the conditions for connecting arbitrary two nodes.

#### 4. Evaluation and conclusion

The following results were confirmed on evaluating the proposed method by using actual data collected from Flickr, etc.

- The proposed graph is capable of generating a route with visual continuity as the shortest route with any arbitrary node as the starting point or endpoint.
- The proposed graph has a high reproduction ratio for real-world route structuring in a region for which photo data is available.

Based on the above results, the proposed proximity graph is applicable to several existing methods used to generate routes and can therefore be considered capable of generating spatial summary routes with a high degree of visual continuity.

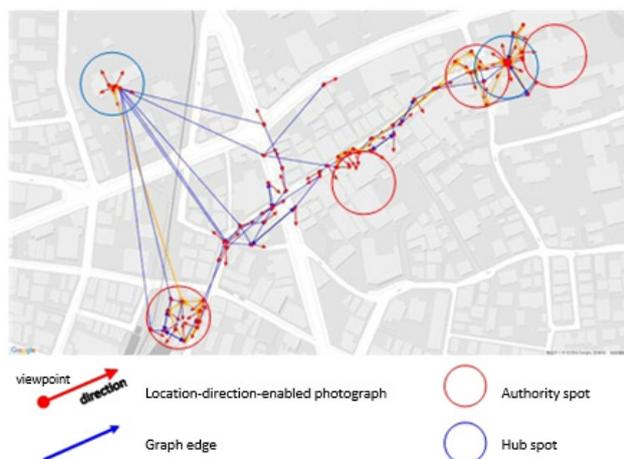


Fig. 1. Location-direction-enabled proximity graph with input Location-direction-enabled photographs

#### 5. References

- Berinato, S. (2013). Visualizing Data: A Harvard Business Review Insight Center Report.
- Crandall, D.J., Backstrom, L., Huttenlocher, D., Kleinberg, J. (2009). Mapping the world's photos. Proceedings of the 18th International Conference on World Wide Web (WWW 2009), 761-770.
- Clark, B.N., Colbourn, C.J. (1990). Unit disk graphs, *Discrete Mathematics*, 86(1-3), 165-177.
- Fujita, H., Arikawa, M. (2006). Complementary data development of photographs and annotations based on spatial relationships. *Journal of the Information Processing Society of Japan*, 35(5), 63-76 (In Japanese).
- Fujita, H., Arikawa, M. (2008). Animation of mapped photo collections for storytelling. *IEICE Transactions on Information and Systems*, E91-D (6), 1681-1692.
- Gabriel, K.R., Sokal, R.R. (1969). A new statistical approach to geographic variation analysis. *Systematic Zoology*, 18(3), 259-278.
- Giannotti, F., Nanni, M., Pinelli, F., Pedreschi, D. (2007). Trajectory pattern mining, Proceedings of the 13th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD 2007), 330-339.
- Hossain, M.S., Butler, P., Boedihardjo, A.P., Ramakrishnan, N. (2012). Storytelling in entity networks to support intelligence analysts. Proceedings of the 18th ACM SIGKDD International conference on Knowledge Discovery and Data Mining (KDD 2012), 1375- 1383.
- Jaromczyk, J.W., Toussaint, G.T. (1992). Relative neighborhood graphs and their relatives. Proceedings of the IEEE, 80(9), 1502-1517.
- Kim, G., Xing, E.P. (2014). Reconstructing storyline graphs for image recommendation from web community photos. Proceedings of the 27th IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2014), 3882-3889.
- Lu, X., Wang, C., Yang, J., Pang, Y., Zhang, L. (2010). Photo2Trip: Generating travel routes from geo-tagged photos for trip planning. Proceedings of the 18th ACM International Conference on Multimedia (MM 2010), 143-152.
- Osaragi, T., Hiraga, Y. (2014). Street network created by proximity graphs: Its topological structure and travel efficiency. Proceedings of the AGILE'2014 International Conference on Geographic Information Science.
- Sagara, S., Fujita, H., Omori, T., Shintani, T. (2015). Storyline creation method for data storytelling using location direction enabled photographs. Proceedings of the 14th Forum on Information Technology (FIT 2015), D-029 (In Japanese).
- Segel, E., Heer, J. (2010). Narrative visualization telling stories with data. *IEEE Transactions on Visualization and Computer Graphics (InfoVis 2010)*, 1139-1148.

- Shirai, M., Hirota, M., Ishikawa, H., Yokoyama, S. (2014). Discovery of the region of interest and the shooting spot with a geo-tagged photograph. *Journal of the Institute of Electronics, Information and Communication Engineers*, J97-D(4), 835-844.
- Snavely, N., Garg, R., Seitz, S.M., Szeliski, R. (2008). Finding paths through the world's photos. *ACM Transactions on Graphics (SIGGRAPH 2008)*, 11-21.
- Thomee, B. (2013). Localization of points of interest from georeferenced and oriented photographs. *Proceedings of the 2nd ACM International Workshop on Geotagging and its Applications in Multimedia (GeoMM 2013)*, 19-24.
- Wang, J., Wang, X. (2012) A spatial clustering method for points-with-directions. *Proceedings of the 7th International Conference on Rough Sets and Knowledge Technology (RSKT 2012)*, 194-199.