Interoperable Web-based 3D Analysis of Laser Scanning Data for Location-based Mobile Applications

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Abstract. One of the current trends of mobile computing are location-based services. For those services and many other applications like navigation systems it is often necessary to know what portion of the client's environment is visible from the current location. For this purpose analyses of three-dimensional elevation data are necessary, which are increasingly acquired by airborne laser scanning. 3D analyses available for mobile devices require a fast query response as the position of the client device may change quickly. This work shows the possibility to make 3D analysis based on highly accurate airborne laser data available for mobile applications using the example of line-of-sight analysis. A service-oriented architecture based on the OGC Web Processing Service is set up and used to evaluate performance of Web-based 3D analysis for mobile devices. The results indicate that LBS on mobile devices using 3D laser data can be provided with appropriate request time via standardized web interfaces.

Keywords. 3D analysis, Web Processing Service (WPS), location-based services (LBS), line-of-sight analysis, interoperability, laser scanning data

1. Introduction

One of the most seminal trends these days in the field of mobile computing are location-based services [3]. For many applications like navigation systems it is necessary to know what portion of the client's environment is visible from the current location. Thus, analyses of three-dimensional elevation data are necessary. In recent years 3D data acquisition is increasingly performed via airborne laser scanning, providing high accuracy and point density (e.g. >20 pts./m^2) [13].

Implementations of 3D analyses for mobile devices require this information in the very moment and not after a certain time in which the position of the client has changed again. Due to the high volume of the elevation data, storage and processing has to be sourced out from the mobile device to a server-side system provided over the Internet. Based on the oftentimes limited bandwidth of mobile data networks it is necessary to reduce the amount of data transferred via the Internet.

This work shows the possibility to provide 3D analysis based on high density elevation data for mobile applications using the example of the line-of-sight analysis. The motivation of this study is based on the development of an augmented reality client

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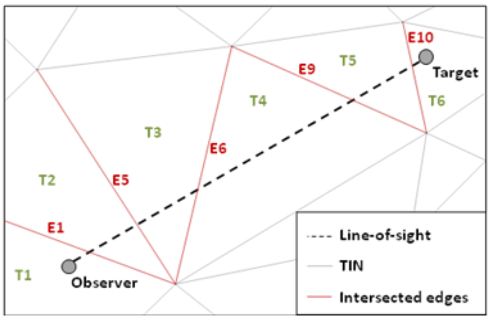
for smartphones which renders the visible points of interest (POIs) surrounding the client directly into the camera view of the smartphone.

2. Visibility analysis

The traditional way of presenting elevations is the raster data model, in which the data are stored in a regular grid in the x-y-plane with a specific resolution [5]. This makes the raster a simple data model and therefore straightforward to process [1]. The triangulated irregular network (TIN), presented by [8], has already been applied in several studies (see [2], [4], [5], [6], [10]). The TIN is a network of non-overlapping triangles built out of a set of irregular arranged points.

Visibility in the context of this work stands for the intervisibility of two or more locations and is based on the direct line between an observer point (in our case the location of the mobile device) and a target point (e.g. POI), called *line-of-sight* (LOS). If the LOS is intersected by any part of the terrain, we assume that the corresponding target is not visible by the observer. [6] presents an algorithm for the intervisibility calculation on a TIN, which is the basis for our study. First, two triangles enclosing the observer and target have to be identified. Second, the intersection points from the LOS with the triangles edges in the x-y-plane are calculated (Fig. 1) and their height has to be determined by linear interpolation of the two edge nodes. Finally, the angles from the observer to the intersection points are compared with the angle of the LOS. If the angle to an intersection point is higher than the angle of the LOS, the target is not visible.

Regarding the high amount of TIN triangles, data has to be organized in a proper way to ensure a fast visibility calculation. The R-tree index (see [12]) is used to determine the triangles surrounding the observer and target points. The triangles are stored in a modified topological data structure in which every triangle knows its corresponding neighbors. Starting at the triangle containing the observer point, the algorithm can walk through the triangles by using the stored neighborhood information without the need for any spatial query (see Fig. 1).



Triangle	Edges
T1	E1, E2, E3
T2	E1, E4, E5
T3	E5, E6, E7
T4	E6, E8, E9
T5	E9, E10, E11
T6	E10, E12, E13

Triangle	Neighbor triangles
T1	(T2, ..., ...)
T2	(T1, ..., T3)
T3	(T2, T4, ...)
T4	(T3, ..., T5)
T5	(T4, T6, ...)
T6	(T5, ..., ...)

Figure 1. General idea of the visibility analysis using a topological data structure.

3. Visibility calculation as a Web service

Due to the high data volume of the laser scanning elevation data, server-side data storage and processing are implemented and provided as Web service. For this purpose, a system has to be created providing the described functionality which can be accessed by the mobile device via the Internet. In the proposed client-server-system the amount of data sent and received have to be minimized to account for the oftentimes limited bandwidth of mobile data networks.

Therefore, a service-oriented architecture (SOA) was built based on the PyWPS, an implementation of the OGC Web Processing Service (WPS) in the programming language Python (see [7], [9]). In general a Web service receives the data to be processed from a client via HTTP request. In our study the data volume for the required data structures is larger than 1 GB. In order to avoid upload of the elevation data with each service request, a simple XML-RPC[2] server is implemented which communicates with the PyWPS via Hypertext Transfer Protocol (HTTP) and guarantees access to the TIN data structures by loading it to the server memory (see [11]). Figure 2 shows the system design in a schematic diagram.

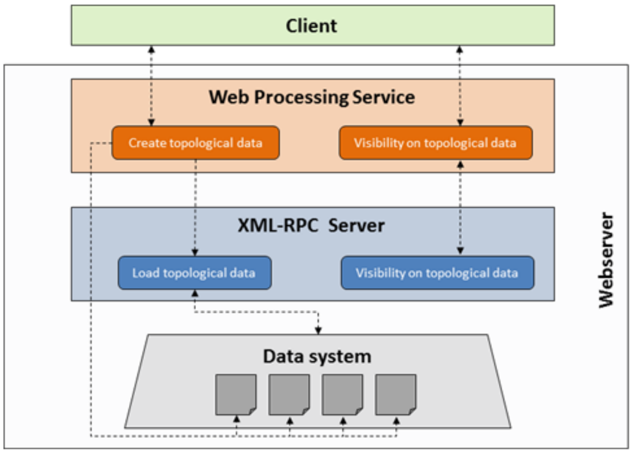


Figure 2. Schematic diagram of the system design.

The WPS interface provides two operations for the client: the first operation creates the data structure and loads it to the server memory. The client receives an identification number for the respective dataset with which the second operation, the actual visibility analysis, can be triggered. For a visibility request, the client has to provide the location of the observer and the target location to the WPS and simply returns visible "true" or "false". It is also possible to input a set of observer-target pairs to minimize the amount of data connections for the mobile device.

4. Results and Conclusions

The system was evaluated with 52 randomly placed observer-target pairs on four different TIN resolutions (z-tolerances 15, 10, 8 and 2 m) for the study area (18.9 km²) in the city of Osnabrück. The distance between the pairs varies between 48 m and 5,900 m and the most pairs (approx. 65%) are within 500 m. A performance test procedure was implemented, which directly calls the visibility functions on the server

[2] Extensible Markup Language Remote Procedure Call (see http://xmlrpc.scripting.com/)

and records the average time taken for 50 calculations for each observer-target pair on every available TIN resolution.

Table 1. Results of the recorded time from sending the request to receiving the result (mean for all observer-target pairs) for the different TIN resolutions.

TIN resolution	Mean total time in % of highest resolution (TIN 2m)
15 m	3.68 %
10 m	9.20 %
8 m	13.50 %
2 m	100.00 % (1.63 sec)

For a rough approximation of the urban structure, a z-tolerance of 8 m is appropriate for which the evaluation shows a mean calculation time of just 3.7% of the time needed for the highest resolution TIN with 2 m z-tolerance (see table 1). If even higher accuracy is needed, a tolerance of 2 m or better is recommended resulting in a rise of calculation time up to 1.63 s. Such a response time is still acceptable for clients and satisfies the needs of mobile applications.

This work shows that 3D analysis functionality using high-resolution elevation data can be provided for mobile devices via standardized OGC Web services. Future research will concentrate on the utilization of spatial database management systems for TIN storage and the implementation of the visibility analysis as database function. This may further decrease calculation time and offers all advantages of a database management system such as spatial indexing. This will allow the handling of larger laser datasets (e.g. country-wide). Furthermore, the OGC Catalogue Service (CSW) can be used to create a metadata catalogue that is automatically filled once a client uploads new data to the server and thus previously uploaded data sets can be used.

References

[1] Andrade, M. V. A., Magalhães, S. V. G., Magalhães, M. A., Franklin, W. R., Cutler, B. M., 2011. Efficient viewshed computation on terrain in external memory. Geoinformatica, 15(2), pp. 381-397.

[2] Goodchild, M. F., Lee, J., 1989. Coverage Problems and Visibility Regions on Topographic Surfaces. Annals of Operations Research, 18 (1989), pp. 175-186.

[3] GSM Association, 2003. Permanent Reference Document: SE.23. Location Based Services, Version: 3.1.0. URL: http://www.gsmworld.com/documents/se23.pdf. Last accessed: 19.01.2012.

[4] Lee, J., 1991. Analyses of visibility sites on topographic surfaces. International Journal of Geographical Information Systems, 1991, 5(4), pp. 413-429.

[5] Kidner, D. B., Ware, J. M., Sparkes, A. J., Jones, C. B., 2000. Multiscale Terrain and Topographic Modelling with the Implicit TIN. Transactions in GIS, 2000, 4(4), pp. 379-408.

[6] Kidner, D. B., Sparkes, A. J., Dorey, M. I., Ware, J. M., Jones, C. B., 2001. Visibility Analysis with the Multiscale Implicit TIN. Transactions in GIS, 2001, 5(1), pp. 19-37.

[7] Open Geospatial Consortium, 2007. OpenGIS Web Processing Service, Version 1.0.0. URL: http://portal.opengeospatial.org/files/?artifact_id=24151

[8] Peucker, T. K., Fowler, R. J., Little, J. J., Mark, D. M., 1978. The Triangulated Irregular Network. Proceedings of the DTM Symposium, ASP-ACSM, pp. 24-31.

[9] PyWPS, 2011. Welcome to PyWPS - PyWPS. URL: http://pywps.wald.intevation.org/

[10] Rana, S., Morley, J., 2002. Optimising visibility analyses using topographic features on the terrain. Centre for Advanced Spatial Analysis Working Paper Series. Paper 44.

[11] XML-RPC, 2010. XML-RPC Home Page. URL: http://www.xmlrpc.com/

[12] Guttman, A., 1984. R-Trees: A Dynamic Index Structure for Spatial Searching. Proceedings of the 1984 ACM SIGMOD International Conference on Management of Data, pp. 47-57.

[13] Vosselman, G., 2008. Analysis of planimetric accuracy of airborne laser scanning surveys. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science 37 (Part B3a), pp. 99-104.