AUTOMATION OF OBJECT EXTRACTION FROM LIDAR IN URBAN AREAS

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1. INTRODUCTION

Light Detection and Ranging (LiDAR) has become a valuable data source for urban data acquisition. Firstly, LiDAR is well-suited for the generation of accurate digital terrain models in urban environments. The explicit height information contained in LiDAR data helps to distinguish elevated objects from the ground. By evaluating this information together with other cues such as surface roughness, intensity, the number of returned pulses or even the full waveform of the returned signal, objects such as buildings and trees can be extracted automatically. The 3D information provided by LiDAR also helps in urban road extraction where image based techniques suffer from problems related to poor contrast between roofs and roads. Due to the fact that urban data do already exist in many countries, the automation of change detection has been added to the list of LiDAR applications. This paper gives an overview about the state of the art and current trends in object extraction from LiDAR data with a focus on urban areas.

2. STATE OF THE ART IN AUTOMATED OBJECT EXTRACTION FROM LIDAR

The state of the art in urban object extraction could be summarized as follows [1]. There have been considerable efforts in the automation of the detection and geometrical reconstruction of buildings and roads. It has been shown that these tasks can be automated for extracting the most important structures using first and last pulse LiDAR data of a resolution of about 1 m. There are large-scale tests for the reconstruction of buildings from LiDAR data and existing ground plans, though the level of detail of the reconstructed models is limited by the LiDAR resolution [2]. The planimetric accuracy of the reconstructed buildings or roads is in the order of magnitude of the point spacing. In building extraction, the main problem is that small roof structures may not only lead to a poor resemblance of the model to reality, but that they may lead to a complete failure of the automated approach. In road extraction the major problems are encountered at road crossings, where many model assumptions do not hold [3]. The characterization of trees based on LiDAR has been one of the main topics of research in forestry [4]. However, in an urban context trees were mainly of interest because they were the object class most likely to be mixed up with buildings and thus had to be considered in the classification process. There has not been much work on the characterization of trees in urban areas yet.

3. TRENDS IN AUTOMATED OBJECT EXTRACTION FROM LIDAR

3.1. Data Resolution

The first trend to be observed in LiDAR processing is the availability of higher point densities. Typical topographical LiDAR surveys provide point densities of 2-5 points/m^2. Higher point densities can be achieved by helicopter-based systems or by acquiring data with multiple overlap. On the one hand, higher point densities provide a better description of the surface. For instance, this improves the prospects of building reconstruction techniques, because smaller roof details can be modeled. On the other hand, higher point densities may result in problems for common object extraction techniques if they are obtained by multiple-overlap data. Firstly, mis-registration errors between overlapping strips have to be eliminated [5], and secondly, 2.5 D algorithms may no longer be suitable (cf. Section 3.3). However, high point densities also open up opportunities for new applications (cf. Section 3.4).

3.2. Full Waveform Processing

Full waveform data provide challenges in terms of data handling and manipulation. Quite some efforts are spent trying to find appropriate models for decomposing the returned signals and for extracting not only the positions of objects where a larger portion of the signal is reflected, but also significant features that are useful for any classification process [6]. Currently, the focus of full waveform processing is on applications in forestry, where these data can improve the characterization of trees [7]. However, it can also be used to for urban classification [8], where the separation of trees from buildings and other objects has been a problem for a long time and where new work on characterizing trees might lead to more realistic 3D city models.

3.3. Improved Processing Techniques

In order to fully exploit the benefits of the new developments on the sensor side, new processing techniques have to be developed as well. Apart from the work on the decomposition of full waveform data already mentioned [6] there is a trend to adapt methodology from Pattern Recognition and Computer Vision, for instance by applying statistical classification methods such as Support Vector Machines [6] or Random Forests [8]. In the future this could also be extended to statistical models of context as they have already been applied to images, e.g. models based on Conditional Random Fields [9]. The second trend is to use real 3D processing. Rather than generating a 2.5D digital surface model that is then analyzed, the points should be used directly for the analysis, and the 3D structure of the scene should be taken into account. For instance, many of the problems of current algorithms for building reconstruction are related to problems at building outlines, where in overlapping LiDAR strips one might not only get points on the roof, but also on building walls. A real 3D view on building reconstruction can help to overcome this problem while at the same time pushing the limits of what has been achieved by LiDAR processing so far by extracting the walls [10].

3.4. New Applications

Finally, the progress in sensor technology along with new processing techniques has brought about the opportunity to tackle problems that could not be dealt with previously. The extraction of walls in airborne LiDAR data [11] and the characterization of trees in urban areas [6] have already been mentioned. In very high-density LiDAR data, curbstones can be detected [12], which helps to improve the positional accuracy of roads. If a 3D city model is available, LiDAR data can be matched with these existing models, which can in turn be used for improved navigation [13]. Finally, with the availability of urban data increasing all over the world, the problem of change detection [14] or improving the positional accuracy of generalized GIS data [15] will become more and more important.

4. CONCLUSION

LiDAR has proven to be a technique that is well-suited for urban object extraction. The advantages of LiDAR over aerial imagery are its ability to penetrate vegetation and the fact that it is an active sensor so that there are no problems with natural illumination and shadows. However, the lack of resolution and spectral information is still an obstacle to make automatic object extraction from of LiDAR fully operational. In order to achieve this, the fusion of LiDAR and image data may be the key to success.

5. REFERENCES

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