Advances in Computer Vision and Pattern Recognition

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Multispectral Satellite Image Understanding

From Land Classification to Building and Road Detection

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To our families.
Foreword

In the first decade of the twenty first century, remote sensing has undergone a rapid development, boosting many new or improved application possibilities. This is due to higher spatial resolution of satellite image data as well as better data availability regarding quality, frequency and coverage. On the other hand, the scientific development of image and signal processing has lead to more powerful and reliable methods, which in turn result in better and faster evaluation of the huge amounts of data sets using fully automatic procedures. The book at hand contributes to this development by combining methods from image processing and electrical engineering stimulated by computer science and computer vision technologies.

There have been many publications in journals and also books on the mentioned topics, but in most cases they show certain specializations either on theory or on applications. The special value of this book is that it presents a complete chain of image processing methods to derive reliable information for land use, especially in residential areas. The authors know very well how to combine a theoretical framework like graph formalism with very practical applications. They use well known methods (e.g., NDVI) together with new techniques from computer vision to arrive at a system which allows detecting single objects like houses and streets in very high resolution optical images (e.g., IKONOS) effectively. The presented system can be applied for change detection as well as other quantitative analysis of urban development.

Due to the fast growth of the remote sensing market, automatic image processing methods exhibit an increasing potential for more and more applications. Through tailoring the described methods for fitting his task, the reader will be able to set up his own system to extract the desired information or develop new methods based on the given techniques. Therefore, I hope the book will be a further milestone from scientific remote sensing to practical applications.

Wessling, Germany

Prof. Dr. Peter Reinartz
As the resolution of satellite images increased, more detailed analysis on them became possible. On the other hand, the time required to manually analyze them became prohibitive. Hence, the need for automated systems for such analysis tasks emerged. This book is about such an end-to-end image analysis system to understand land development from satellite images. Our focus is on residential regions. The main building blocks of the proposed system are as follows.

We benefit from vegetation and shadow–water indices in summarizing the multispectral information in the proposed system. Vegetation indices have been used extensively to estimate the vegetation density from satellite and airborne images for many years. We focus on the normalized difference vegetation index ($NDVI$) and introduce a statistical framework to analyze and extend it. Using the established statistical framework, we introduce new a group of shadow–water indices. We use these as the source of multispectral information in land use classification and house and street network detection in residential regions.

Next, we introduce a set of measures based on straight lines to assess land development levels in high resolution satellite images. Urban areas exhibit a preponderance of straight line features. Rural areas produce line structures in more random spatial arrangements. We use this observation to perform an initial triage on the image to restrict the attention of subsequent, more computationally intensive analyses. We then extend our straight line based measures by developing a synergistic approach that combines structural and multispectral information. In particular, the structural features serve as cue regions for multispectral features.

After the initial classification of regions, we introduce computationally more expensive but more precise graph-theoretical measures over panchromatic images to detect residential regions. The graphs are constructed using straight lines as vertices, while graph edges encode their spatial relationships. We introduce a set of measures based on various properties of the graph. These measures are monotonic with increasing structure (organization) in the image. We present a theoretical basis for the measures. In a similar manner, we developed a novel method using feature based grouping to detect residential regions.

Having detected the residential regions, we introduce a novel subsystem to detect houses and street networks in these. This system is composed of four main blocks:
detecting possible house and street pixels by the help of multispectral information; grouping these candidate pixels using a variant of k-means clustering; decomposing the clustering results by a novel balloon algorithm; and finally, representing the balloons in a graph formalism to detect houses and the street network.

We statistically evaluated the performance of the proposed system step by step and obtained very promising results. Especially, the performance in house and street network detection in residential regions is noteworthy. These results indicate the functionality of our satellite image understanding system.

The brief summary above indicates that this book may be useful for both remote sensing and computer vision communities. For the remote sensing community, it proposes a novel end-to-end system to analyze multispectral satellite images. Hence, it may be counted as one of the pioneering works for future automated satellite and aerial image understanding systems. For the computer vision community, the book emphasizes that many new and fruitful research problems are waiting to be solved. For both communities, the book clearly shows that more collaboration between both disciplines is mandatory for developing techniques to improve human life.

Istanbul, Turkey
Troy, NY, USA

Cem Ünsalan
Kim L. Boyer
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