Pontifícia Universidade Católica do Rio de Janeiro

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A Comparison of Segmentation Algorithms for Remote Sensing

Dissertação de Mestrado

Dissertation presented to the Programa de Pós-Graduação em Engenharia Elétrica of the Departamento de Engenharia Elétrica, PUC-Rio as partial fulfillment of the requirements for the degree of Mestre em Engenharia Elétrica.

Advisor: Prof. Raul Queiroz Feitosa

Rio de Janeiro
May 2014

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Bibliographic Data

Achanccaray Diaz, Pedro Marco

A Comparison of Segmentation Algorithms for Remote Sensing / Pedro Marco Achanccaray Diaz; advisor: Raul Queiroz Feitosa. – 2014.

84 f. : il. (color.) ; 30 cm

Dissertação (Mestrado em Engenharia Eletrica) – Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Engenharia Elétrica, 2014.

Incluí bibliografia.

1. Engenharia Elétrica – Teses. 2. Segmentação de Imagens. 3. Sensoriamento remoto. 4. Sintonização de Parâmetros. I. Feitosa, Raul Queiroz. II. Pontifícia Universidade Católica do Rio de Janeiro. Departamento de Engenharia Elétrica. III. Titulo.

CDD: 621.3

For my grandparents, Maximo and Liduvina.
For my parents, Pedro and Mercedes.
For my brothers, Ever, Saul and David.
For Karen, my love.

Acknowledgments

I am truly grateful to my advisor, Prof. Raul Queiroz Feitosa, for the encouragement, his advices, stimulating talks and generous support throughout the development of my dissertation.

I thank my parents, Pedro and Mercedes, my brothers, Ever, Saul and David, for their support and unconditional love.

I want to thank all my colleagues from LVC, for the companionship and valuable scientific discussion, and all my friends I met during my studies.

I also gratefully acknowledge the financial support of CAPES and FAPERJ.

Resumo

Achanccaray Diaz, Pedro Marco; Feitosa, Raul Queiroz. **Uma avaliação de Métodos de Segmentação para Aplicações em Sensoriamento Remoto.** Rio de Janeiro, 2014. 84p. Dissertação de Mestrado - Departamento de Engenharia Elétrica, Pontifícia Universidade Católica do Rio de Janeiro.

Esta dissertação tem como objetivo avaliar algoritmos de segmentação para imagens de sensoriamento remoto. Quatro algoritmos de segmentação foram considerados neste estudo. Esses algoritmos têm abordagens diferentes tais como baseado em agrupamento, em crescimento de regiões, em modelos bayesianos e em grafos. Como cada algoritmo tem os seus próprios parâmetros, o processo de encontrar seus parâmetros ótimos foi feito usando um algoritmo de otimização, Nelder - Mead. O algoritmo Nelder - Mead procura os melhores parâmetros para cada algoritmo de segmentação, isto é, os parâmetros que proporcionam os resultados mais exatos com respeito a uma referência dada. A função objetivo foi definida a partir de sete métricas diferentes. Eles avaliam qualitativamente o resultado da segmentação baseadas na sua referência. Os experimentos foram realizados ao longo de três imagens de sensoriamento remoto de diferentes localidades do Brasil. Isso envolveu um total de 84 experimentos. Os resultados mostraram que as abordagens baseadas em grafos produzem os melhores resultados baseados em todas as métricas. As abordagens baseadas no crescimento de regiões e agrupamento apresentaram-se como boas opções para imagens de sensoriamento remoto.

Palavras-chave

Segmentação; Sensoriamento Remoto; Sintonização de Parâmetros.

Abstract

Achanccaray Diaz, Pedro Marco; Feitosa, Raul Queiroz (Advisor). **A Comparison of Segmentation Algorithms for Remote Sensing.** Rio de Janeiro, 2014. 84p. Master Dissertation - Departamento de Engenharia Elétrica, Pontifícia Universidade Católica do Rio de Janeiro.

This dissertation aims to evaluate segmentation algorithms for remote sensing images. Four segmentation algorithms were considered in this study. These algorithms have different approaches such as clustering-based, region growing-based, bayesian-based and graph-based. As each algorithm has its own parameters, the process to find their optimum values was done using an optimization algorithm, Nelder – Mead. Nelder – Mead algorithm looks for the best parameters for each segmentation algorithm, i.e. the parameters that provide the most accurate results with respect to a given reference. The objective function was defined by seven different metrics. These metrics assess qualitatively the segmentation result based on its reference. The experiments were performed over three remote sensing images from different locations of Brazil. A total of 84 experiments have been performed. The results have shown that graph-based approaches produce the best results based on each metric. The region growing- and clustering-based approaches have shown to be good alternatives for remote sensing images.

Keywords

Segmentation; Remote Sensing; Parameter Tuning

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MS	Mean-Shift segmentation.
Gb	Graph-based segmentation.
Rm	Region Merging-based segmentation.
$CRFb$	Conditional Random Fields-based segmentation.
NM	Nelder – Mead algorithm.
K	Kernel function.
d	Represents the number of dimensions in a space.
$\boldsymbol{x}$	d – dimensional feature vector.
$\boldsymbol{x_i}$	d – dimensional feature vector of pixel i.
μ	Mean vector.
Σ	Covariance matrix.
σ	Standard deviation.
η	Number of Gaussians.
$P(\boldsymbol{x})$	Probability density function (pdf)
Ω	Constant associated to Gaussian pdfs.
$\nabla P(\boldsymbol{x})$	Gradient of a function.
$\overline{\boldsymbol{x}}$	Position of the center of mass.
$\Delta\overline{\boldsymbol{x}}$	Mean-shift vector.
G	An undirected graph.
G'	A sub-graph.
V	Vertices of a graph G.
E	Edges of a graph G.
$w()$	Weight of an edge.
S	A segmentation outcome or machine segmentation.
GT	Ground truth.
C	A component of a segmentation S, a segment.
N	Number of pixels in an image.
N_S	Number of segments in segmentation S.
N_{GT}	Number of segments in ground truth GT.
O_i	Number of pixels in the segment C_i from S.

O_j	Number of pixels in the segment C_j from GT.
O_{ij}	Number of pixels in both segments C_i and C_j.
D	A predicate defined to find boundaries.
T	A tree from a graph.
ST	A spanning tree.
MST	A minimum spanning tree.
$Int(C)$	Internal difference of a component C
$Dif(C_1, C_2)$	Difference between two components C_1 and C_2.
$MInt(C_1, C_2)$	Minimum internal difference between C_1 and C_2.
τ	Threshold function.
θ	Constant parameter related to graph-based segmentation.
f	Merging cost or degree of fitting.
h_{color}, h_{shape}	Spectral and shape components.
ω_{color}, ω_L	Spectral and band weights.
A	Area of a region or segment in pixels.
L	Spectral band.
$C_1 \cup C_2$	Resulting region after merging C_1 and C_2.
Sol	Solidity.
$Comp$	Compactness.
$Abox$	Area of a bounding box.
$dmax$	Length of the major axis of an ellipse.
$E(\boldsymbol{x})$	Energy function.
$\psi_i(x_i)$	Unary potentials.
$\psi_{ij}(x_i, x_j)$	Pairwise cliques.
N_i	Neighborhood of pixel i.
$\Gamma(i, j)$	Edge feature based on spectral difference of neighboring pixels.
n	Number of variables.
$P_0, P_1, \dots, P_n$	Points in n – dimensional space defining a simplex.
y_i	Value of the objective function at P_i
P_l, P_h	Points where y_i take its lowest and highest values respectively.
P_m	Centroid of the points without considering P_h.
α	Reflection constant.

β	Contraction constant.
γ	Expansion constant.
P_r	Point determined by reflection.
P_e	Point determined by expansion.
P_c	Point determined by contraction.
CD	Number of correct detections.
ρ_k	Perimeter of a segment C_k.
$A_{l.i.}$	Area, in pixels, of the segment with largest intersection.