Advances in Image and Video Segmentation

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Outline

- **Introduction**
- **An Overview of Segmentation in Last 40 Years**
- **Some Examples:** *Image Segmentation, Video Segmentation, Segmenting Particular Images, Special Segmentation Applications*
- **A General Framework for Segmentation and Its Evaluation**
- **A Summary of Recent Progresses for Segmentation Evaluation**
- **Concluding Remarks**

Introduction

- **Image (Video) Segmentation**
  - A process consists of subdividing an image into its constituent parts and extracting these parts of interest (objects) from the image
  - A critical process for image engineering
  - A focused research topic for more than 40 years
  - There is no general theory for image segmentation, yet. So *ad hoc* techniques are often developed

Introduction

- **Three Levels of Research**

  Research works on image and video segmentation are currently conducted in three levels:

(0) Base level:
Segmentation algorithm development

(1) Middle level:
Evaluation of segmentation techniques

(2) Top level:
Systematic study and comparison of evaluation

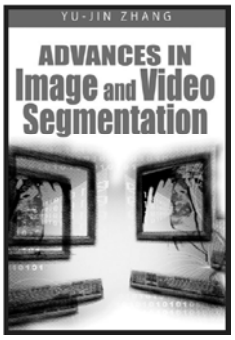
Introduction

- **Few Specialized Books Being Published**
  - Gerbrands, J.J. Segmentation of Noisy Images. Ph.D. dissertation, Delft University, The Netherlands, 1988
  - Medioni, G., Lee, M. S., Tang, C. K. A. Computational Framework for Segmentation and Grouping. Elsevier, 2000
  - Zhang, Y.J. Image Segmentation. Science Press, 2001

Introduction

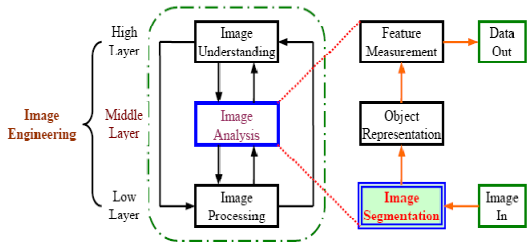
Yu-Jin ZHANG (ed.),
"Advances in Image and Video Segmentation",
IRM Press, 2006

- **Introduction**
- **Image Segmentation**
- **Video Segmentation**
- **Segmenting Particular Images**
- **Special Segmentation Applications**
- **Segmentation Evaluation**



An Overview of Segmentation in Last 40 Years

- **Position of Image Segmentation**



An Overview of Segmentation in Last 40 Years

- **Definition of Image Segmentation**

Low Level Process

(1) $\bigcup_{i=1}^{n} R_i = R$;

(2) for all i and j, $i \neq j$, there exits $R_i \cap R_j = \varnothing$;

(3) for $i = 1, 2, \ldots, n$, it must have $P(R_i) = TRUE$;

(4) for all $i \neq j$, there exits $P(R_i \cup R_j) = FALSE$;

(5) For all $i = 1, 2, \ldots, n$, R_i is a connected component.

High Level Process

An Overview of Segmentation in Last 40 Years

- **Number of Developed Algorithms (1)**

- The history of segmentation of digital images using computers could be traced back to more than 40 years' ago [Roberts 1965]
- Over the last 40 years, the research and development of segmentation techniques are going on steadily and have resulted a large number of developed algorithms
- It is estimated 10 years' ago that the number of developed algorithm has attend 4 digits

An Overview of Segmentation in Last 40 Years

- **Number of Developed Algorithms (2)**

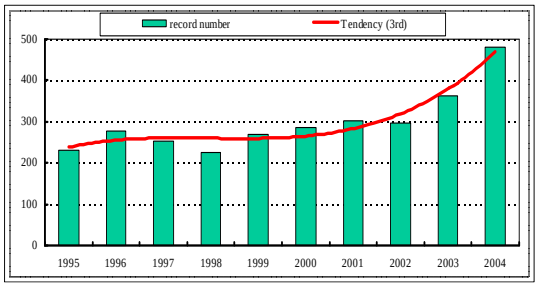
⇨ Search the number of records by using the term "image segmentation" only in the title field from "EI Compendex" gives the following results:

1965-1994	1995	1996	1997	1998	1999
965	232	278	253	226	268

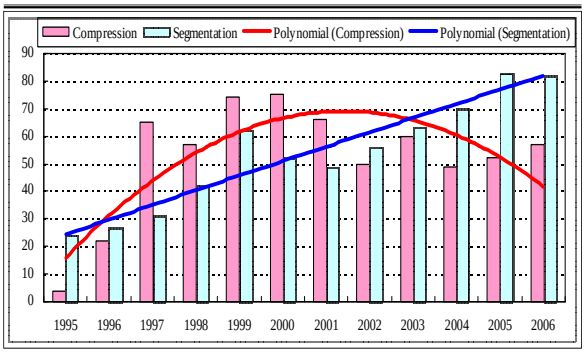
2000	2001	2002	2003	2004	Total
287	303	297	364	481	4344

An Overview of Segmentation in Last 40 Years

- **Tendency of Development**



An Overview of Segmentation in Last 40 Years



An Overview of Segmentation in Last 40 Years

- **Summary of Survey Papers (1)**

A number of survey papers for general image segmentation algorithms:

- **1975-1984**: [Davis, 1975]; [Zucker, 1976]; [Riseman, 1977]; [Zucker, 1977]; [Weszka, 1978]; [Fu, 1981]; [Rosenfeld, 1981]; [Peli, 1982];
- **1985-1994**: [Haralick, 1985]; [Nevatia, 1986]; [Pavlidis, 1986]; [Borisenko, 1987]; [Sahoo, 1988]; [Buf, 1990]; [Sarkar, 1993]; [Pal, 1993]

An Overview of Segmentation in Last 40 Years

- **Summary of Survey Papers (2)**

- All these survey papers are dated in the second and third decades
- The reason for no survey in the first decade should be that the research results were just cumulating in that period
- The reason for no survey in the last decade might be attributed to the factor that so many techniques have already been presented, thus a comprehensive survey becomes less feasible

An Overview of Segmentation in Last 40 Years

- **Summary of Survey Papers (3)**

Various theories and models have been employed, for example:

Brownian string, Evolution theory, Expert system, Fractal, Fuzzy logic, Gabor filter, Gaussian mixture model, Genetic algorithm, Gibbs random field, Graph theory, Hidden Markov model, Level set, Markov random field, Neural network, Rough set, Simulated annealing, Wavelet, **……**

An Overview of Segmentation in Last 40 Years

- **Summary of Survey Papers (4)**

Some specialized / particular surveys have been published in the last 10 years

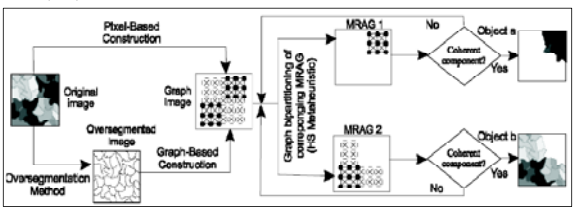
(1) Focused on particular group of segmentation algorithms: [Olabarriaga, 2001], [Freixenet, 2002], [Behiels, 2002], [Marcello, 2004]

(2) Focused on a particular application of image segmentation: [Pham, 2000], [Koprinska, 2001], [Lefèvre, 2003], [Kirbas, 2003], [Prati, 2003]

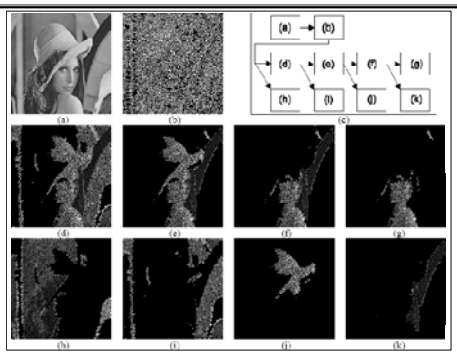
Some Examples: Image Segmentation

- **Graph Theory**

- This graph-partitioning task is solved as a variant of the min-cut problem (normalized cut) using a Hierarchical Social (HS) meta-heuristic.

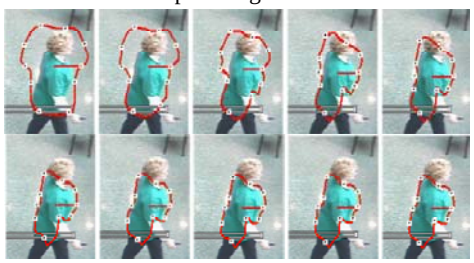


Some Examples: Image Segmentation



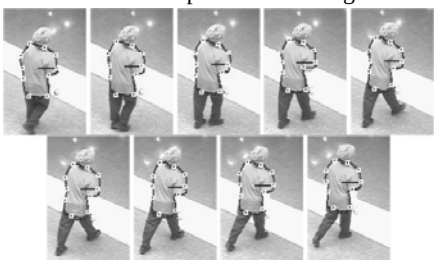
Some Examples: Video Segmentation

- **Tracking with Active Contour Model**
  - Within-frame shape fitting



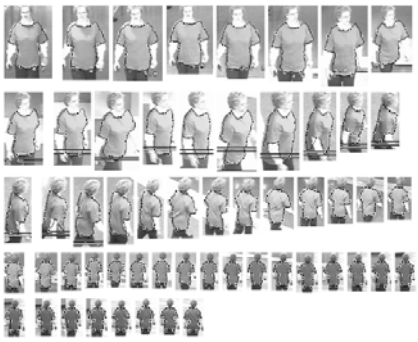
Some Examples: Video Segmentation

- **Tracking with Active Contour Model**
  - Between-frame shape-based tracking



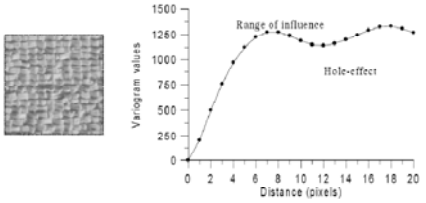
Some Examples: Video Segmentation

- Zooming
- Rotating
- Pan
- Tilt
- Zoom

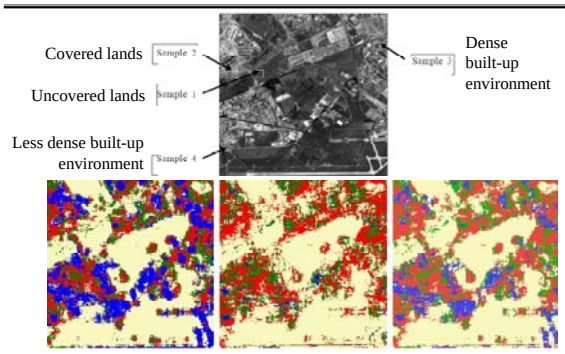


Some Examples: Segmenting Particular Images

- **Texture Image Segmentation**
  - Variagram: Graphs measure the difference between grade values relative to the distance separating them in a particular orientation

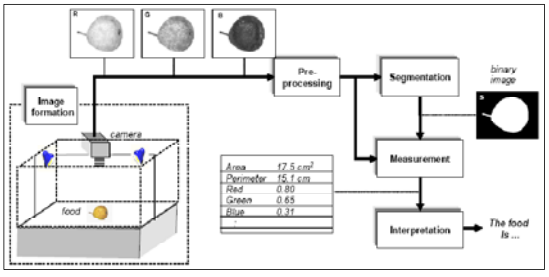


Some Examples: Segmenting Particular Images

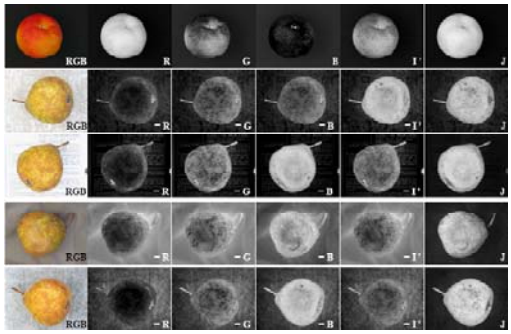


Some Examples: Special Segmentation Applications

- **Segmentation in Food Industry**



Some Examples: Special Segmentation Applications



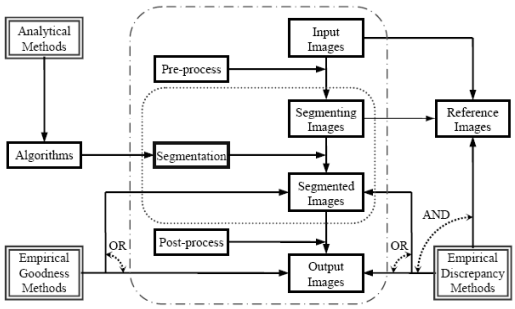
A General Framework for Segmentation and Its Evaluation

- **Segmentation Evaluation**
  - None of the developed segmentation algorithms are generally applicable to all kinds of images, and different algorithms are not equally suitable for a particular application
  - Necessity of evaluation has been justified
  - The history of segmentation evaluation could be traced back to 30 years' ago [Fram 1975]
  - More than 100 major works have been reported

A General Framework for Segmentation and Its Evaluation

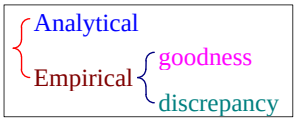
- **Segmentation Characterization**
  Intra-technique task
- **Segmentation Comparison**
  Inter-technique task
- **Qualitative Evaluation**
  Ranking: good, acceptable, or unacceptable
- **Quantitative Evaluation**
  Numeral score values: [0, 1]

A General Framework for Segmentation and Its Evaluation



A General Framework for Segmentation and Its Evaluation

- **Analytical Method**
- **Empirical Goodness Method**
  Un-supervised, Standalone
- **Empirical Discrepancy Method**
  Supervised, Relative objective



A General Framework for Segmentation and Its Evaluation

Class	Criterion name	Method group
G-1	Intra-region uniformity	Goodness
G-2	Inter-region contrast	Goodness
G-3	Region shape	Goodness
G-4	Moderate number of regions	Goodness
D-1	Number of mis-segmented pixels	Discrepancy
D-2	Position of mis-segmented pixels	Discrepancy
D-3	Number of objects in the image	Discrepancy
D-4	Feature values of segmented objects	Discrepancy
D-5a	Region consistency	Discrepancy
D-5b	Grey level difference	Discrepancy
D-5c	Symmetric divergence (cross-entropy)	Discrepancy
S1	Amount of editing operations	Special
S2	Visual inspection	Discrepancy like
S3	Correlation between original image and bi-level image	Goodness like

A Summary of Recent Progresses for Segmentation Evaluation

- **New Progresses in Segmentation Evaluation**
- **Three Categories:**

Recent evaluation works, mainly according to the criteria used, can be classified into three categories

(1) Evaluation Works Based on Existing Criteria

(2) Evaluation Works Made with Modifications / Improvements (of existing criteria)

(3) Evaluation Works Supplying New Inspiration

A Summary of Recent Progresses for Segmentation Evaluation

- **Evaluation Works Based on Existing Criteria**

Method #	Source	Criteria used	Method #	Source	Criteria used
M-1	(Hoover, 1996)	D-5a	M-10	(Huo, 2000)	D-1, D-4
M-2	(Zhang, 1997)	D-4	M-11	(Cavallaro, 2002)	D-1, D-2
M-3	(Borsotti, 1998)	G-1, G-2, G-4	M-12	(Prati, 2003)	D-1
M-4	(Xu, 1998)	S-3	M-13	(Rosin, 2003)	D-1
M-5	(Chang, 1999)	D-5a	M-14	(Lievers, 2004)	G-1
M-6	(Yang,1999)	D-1	M-15	(Marcello, 2004)	S-2
M-7	(Mattana, 1999)	D-4	M-16	(Renno, 2004)	D-1, D-4
M-8	(Rosenberger, 2000)	G-1, G-2	M-17	(Carleer, 2004)	D-1, D-3
M-9	(Betanzos, 2000)	D-1	M-18	(Ladak, 2004)	D-1, S-1

A Summary of Recent Progresses for Segmentation Evaluation

- **Evaluation Works Made with Modifications / Improvements (of existing criteria)**

Method #	Source	Criteria used (modification)
M-19	(Oberti, 1999)	D-1 (ROC, curve of FP vs. FN)
M-20	(Gao, 2000)	D-1 (ROC, curve of FP vs. FN)
M-21	(Correia, 2000)	D-1 (with spatial and temporal extension)
M-22	(Udupa, 2002)	D-1, S-1 like (efficiency)
M-23	(Li, 2003)	D-1 and D-2, (contour matching, temporal consistency), S-1
M-24	(Zhang, 2004)	G-1, G-2, G-4 (using region entropy)
M-25	(Erdem, 2004)	G-1, G-2 (with extension to color, motion, color histograms)
M-26	(Niemeijer, 2004)	D-1 (ROC, curve of TP vs. FP)
M-27	(Udupa, 2004)	D-1 (DOC, curve of TP vs. FP)
M-28	(Kim, 2004)	D-1 (PDR, modified detection rate)

A Summary of Recent Progresses for Segmentation Evaluation

- **Evaluation Works Supplying New Inspiration**

Method #	Source	Novelty
M-29	(Everingham, 2002)	Finding out the Pareto front in a multi-dimensional fitness space
M-30	(Li, 2003)	Finding out the Pareto front in a 4-D fitness space
M-31	(Correia, 2003)	Using contextual relevance metric to match human visual system (HVS)
M-32	(Zhang, 2005)	Using weighted majority (WM), Bayesian and support vector machine (SVM)
M-33	(Desurmont, 2005)	Performing evaluation in different semantic levels

A Summary of Recent Progresses for Segmentation Evaluation

- Some **Observations**
  - Most new works based on existing criteria use empirical discrepancy criteria
  - Many new works made with modifications / improvements on existing criteria use ROC and its variations: DOC, PDR
  - New inspirations are mainly on how to combine several criteria into a composite criterion

Concluding Remarks

- **Numbers of Works Made**

Level	Description	Publication #
0 $f(x)$	Segmentation Algorithms	$O(10^3)$
1 $f'(x)$	Technique Evaluation	$O(10^2)$
2 $f''(x)$	Comparison of Evaluation Methods	$O(10^1)$

Concluding Remarks

- **Potential Research Directions**

(1) Combine multiple metrics efficiently

(2) Make evaluation in considering the final goal of segmentation

(3) Construct common databases for segmentation evaluation

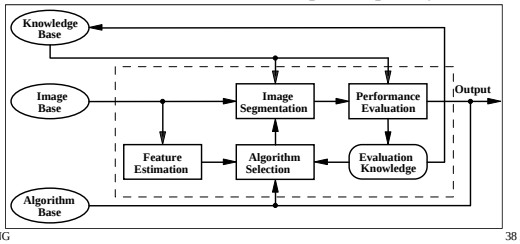
(4) Characterize and compare various evaluation methods

(5) Real use of evaluation results for segmentation

Concluding Remarks

- **One Example: Utilization of Evaluation**

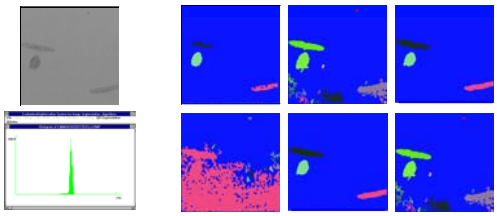
Optimal selection of segmentation algorithms based on evaluation with the help of expert system



Concluding Remarks

- **One Example: Utilization of Evaluation**

40 tests: 75% investigating two algorithms
25% investigating three algorithms



Thanks for Your Attention !

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