Advances of Image Engineering in the Last Fifteen Years

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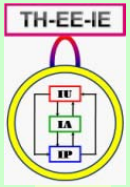
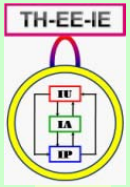


Outline

- Introduction
- Image Engineering (IE)
- A Survey Series on IE
- Advances of IE in 15 Years
- Concluding Remarks



Introduction

- Image is considered as a very important medium from which human beings observe the majority of the information they received from the real world
- Image Engineering (IE) is an integrated discipline comprising the study of all the different branches of image techniques operating on images
- In the last fifteen years, IE has gone a tremendous progress in various aspects

Introduction

- Based on the data collected in a survey series for image engineering for the last 15 years, a statistic investigation on the growing trend of publication numbers and on the selected records of related publication for all specialty categories and sub-categories has been conducted
- Some analysis and discussions about the statistics made on the results of classifications by journal and by category are also provided

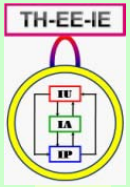
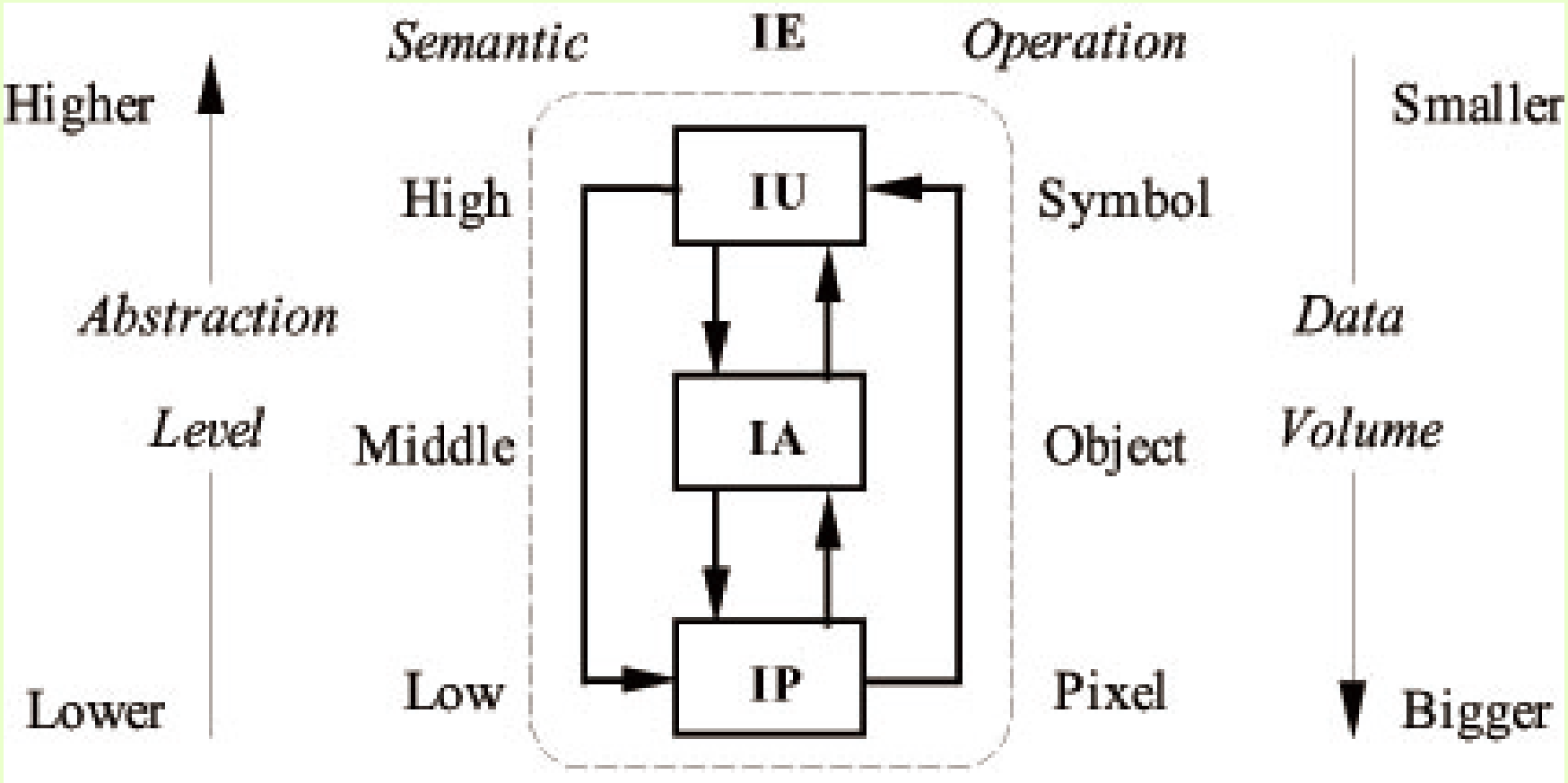


Image Engineering

- Image Engineering, IE, from a perspective more oriented to technique, could be referred to as the collection of three related and partially overlapped groups of image techniques: Image Processing (IP), Image Analysis (IA) and Image Understanding (IU)
- In a structural sense, IP, IA and IU build up three inter-connected layers of IE as shown in the following figure

Image Engineering

- **Three Layers of Image Engineering**



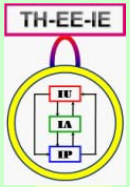


Image Engineering

- Each of them operates on different elements (IP's operand is pixel, IA's operand is object, and IU's operand is symbol)
- Each of them works with altered semantic levels (from low at IP via middle at IA to high at IU)
- The three layers follow a progression of increasing abstractness and of decreasing compactness from IP to IU

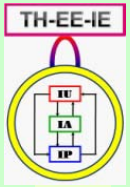


Image Engineering

- IE is a broad subject encompassing studies of mathematics, physics, biology, physiology, psychology, electrical engineering, computer science, automation, *etc*.
- IE's advances are closely related to the development of biomedical engineering, document processing, industrial applications, remote sensing, telecommunications, *etc*.

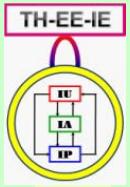
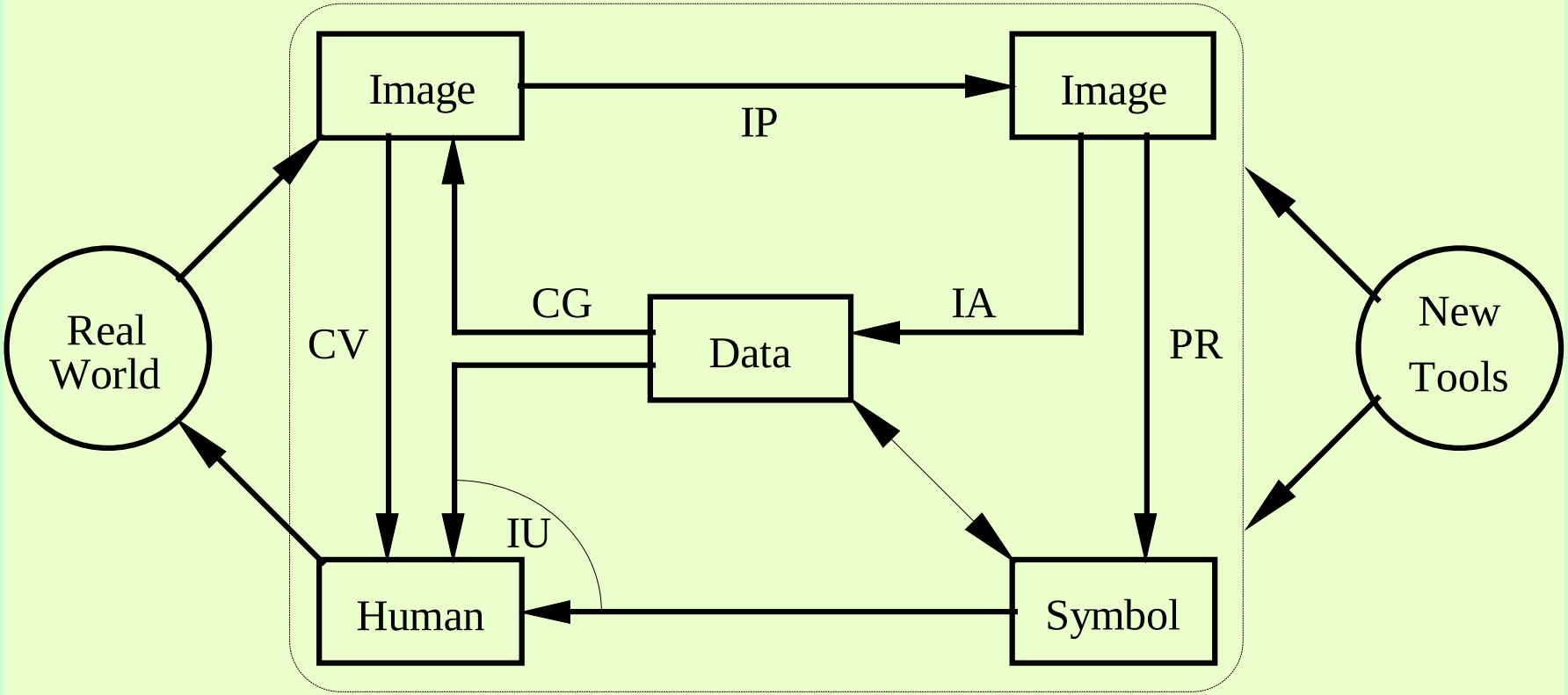


Image Engineering

- According to different science politics/ perspectives, various terms such as Computer Graphics (CG), Pattern Recognition (PR), Computer Vision (CV), Scene Analysis (just counted as another name of CV) *etc*., are (partially) overlapped with IP, IA and/or IU.
- A diagram describing the relationship among the above-mentioned subjects is given in the following figure

Image Engineering

- **Related Disciplines and Fields**



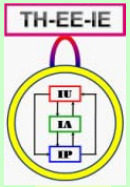
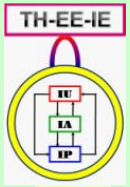


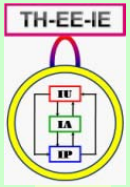
Image Engineering

- Images are captured from the real world and processed to furnish the basis for IA or PR. The former produces data that can be visualized by CG techniques, while the latter continually classifies them into one of several categories.
- Results produced by both of them can be further interpreted for human beings to understand the real world. The whole process aims to make computers capable of understanding environments from visual information, which is also the purpose of CV



A Survey Series on IE

- What is the current "picture" of IE?
- A survey series on IE, has been started since 1996
- The purpose is to capture the development of IE, to make available a convenient means of literature searching facility for readers working in related areas, and to supply a useful reference for the editors of journals and potential authors of papers
- Selecting reference sources and classifying them according to contents are two important factors



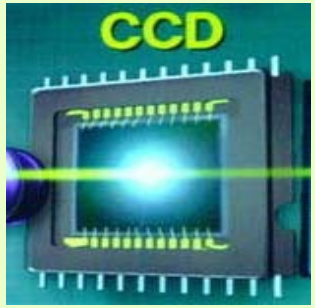
A Survey Series on IE

The Classification Scheme of IE

Category	Sub-category
A: Image Processing	A1: Image capturing and storage (including camera calibration) A2: Image reconstruction from projections A3: Filtering, transformation, enhancement, restoration A4: Image/Video coding and standards A5: Image digital watermarking and image information hiding A6: Multi-scale processing and super-resolution

A Survey Series on IE

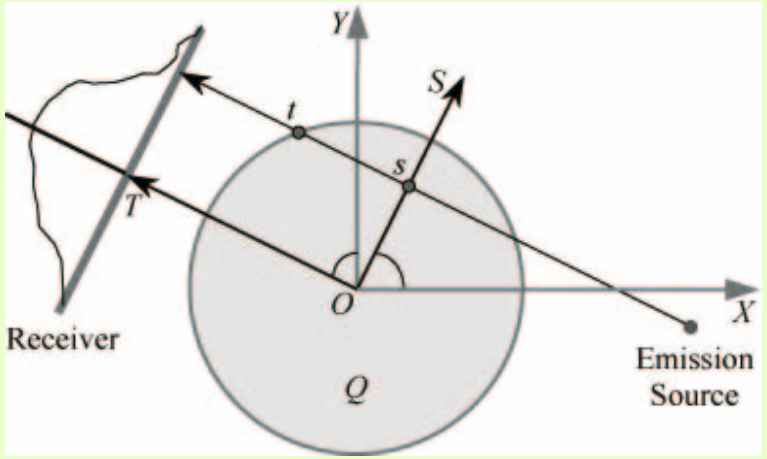
- **A: Image Processing**
- A1: Image capturing



122	104	122	113	201	201	15	15
203	203	97	171	198	15	15	15
203	172	101	203	15	15	15	15
203	172	101	97	122	201	122	15
147	172	172	172	198	15	201	122
147	172	172	172	201	15	15	122
147	123	187	201	123	123	15	15
101	123	187	201	123	201	15	15

A Survey Series on IE

- **A: Image Processing**
- A2: Image reconstruction from projections



A Survey Series on IE

- **A: Image Processing**
- A3: Filtering, enhancement, restoration

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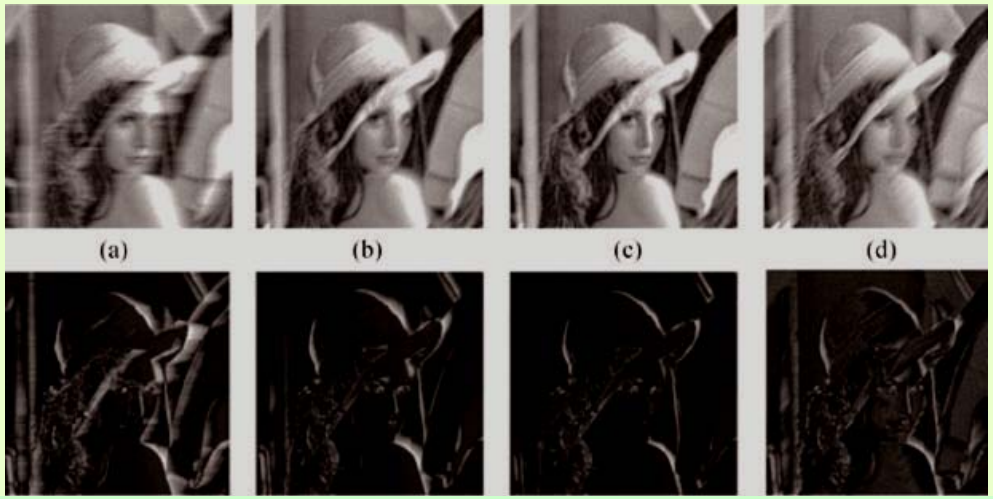
A Survey Series on IE

- **A: Image Processing**
- A4: Image/Video coding and standards



➢ Standards

- MPEG-1
- MPEG-2
- MPEG-4
- H.261
- H.263
- H.264
- H.265?

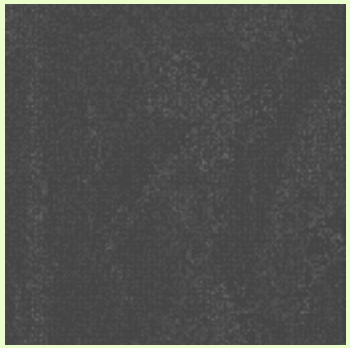
A Survey Series on IE

- **A: Image Processing**
- A5: Image watermarking

Original

Embedded

Difference



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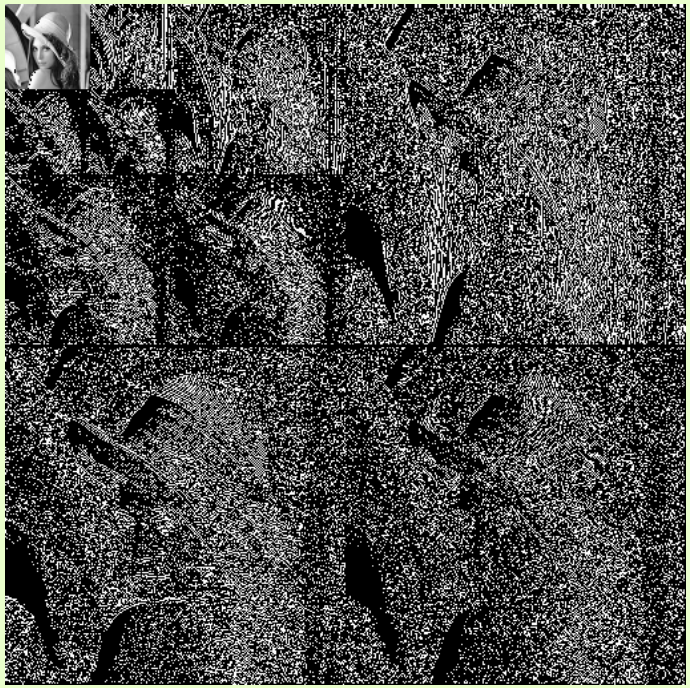
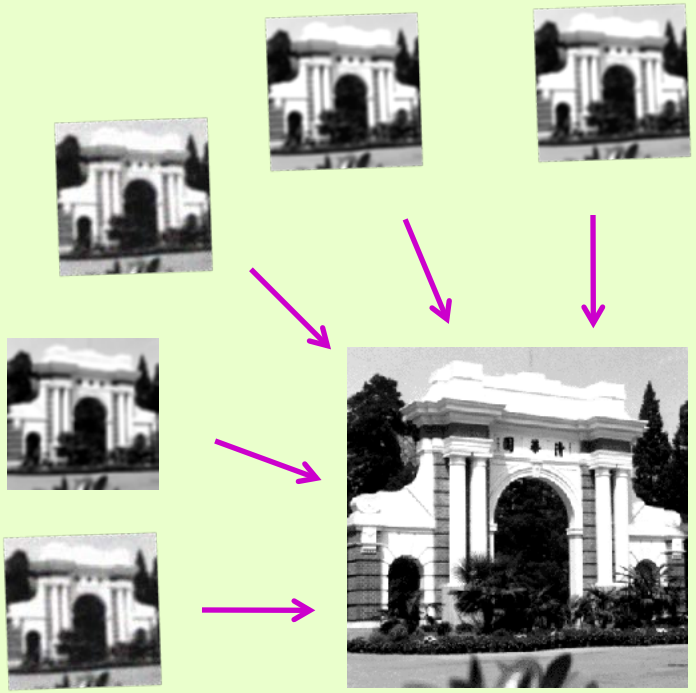
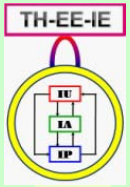
A Survey Series on IE

- **A: Image Processing**
- A6: Multi-scale processing and super-resolution







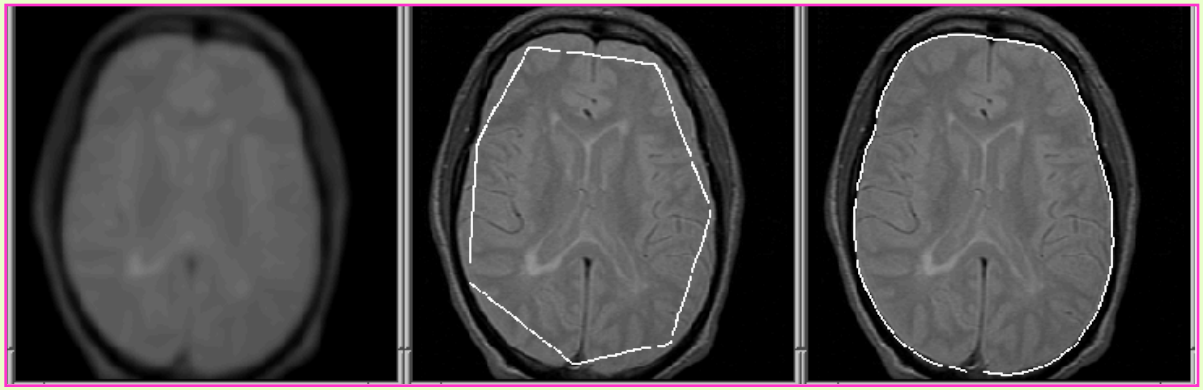
A Survey Series on IE

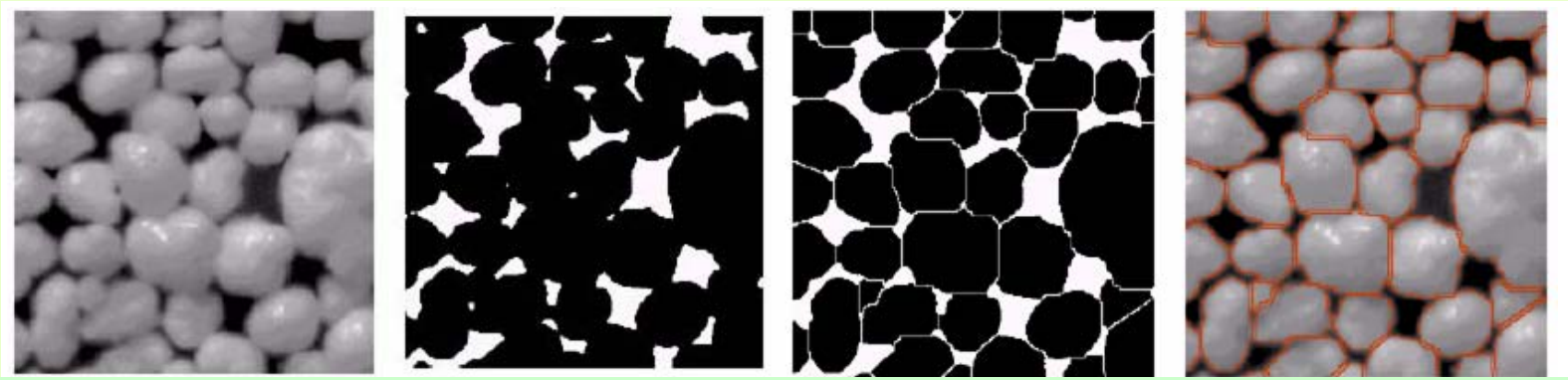
The Classification Scheme of IE

Category	Sub-category
B: Image Analysis	B1: Edge detection, image segmentation B2: Representation, description, measurement (bi-level image) B3: Analysis of color, shape, texture, position, motion, etc. B4: (2-D) object recognition, extraction, tracking, classification B5: Human face and organ detection and location

A Survey Series on IE

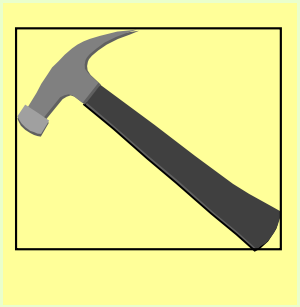
- **B: Image Analysis**
- B1: Edge detection, image segmentation



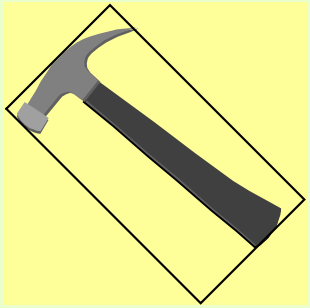


A Survey Series on IE

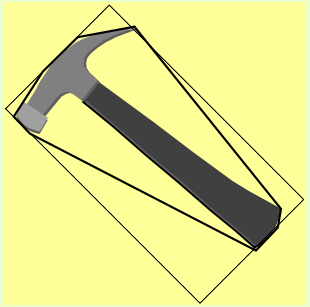
- **B: Image Analysis**
- B2: Representation, description, measurement



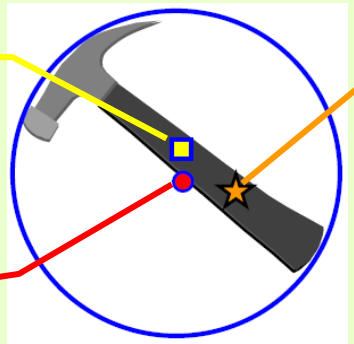
Feret box



minimum enclosing rectangle

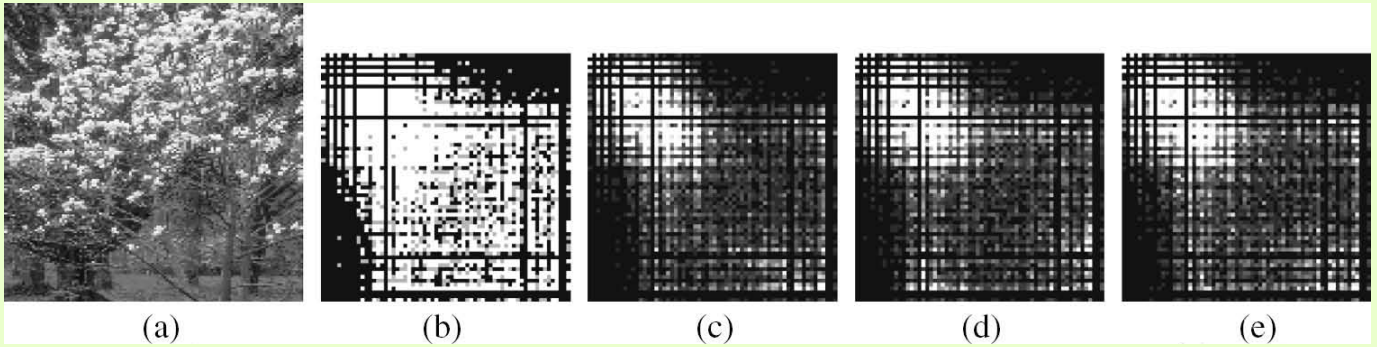


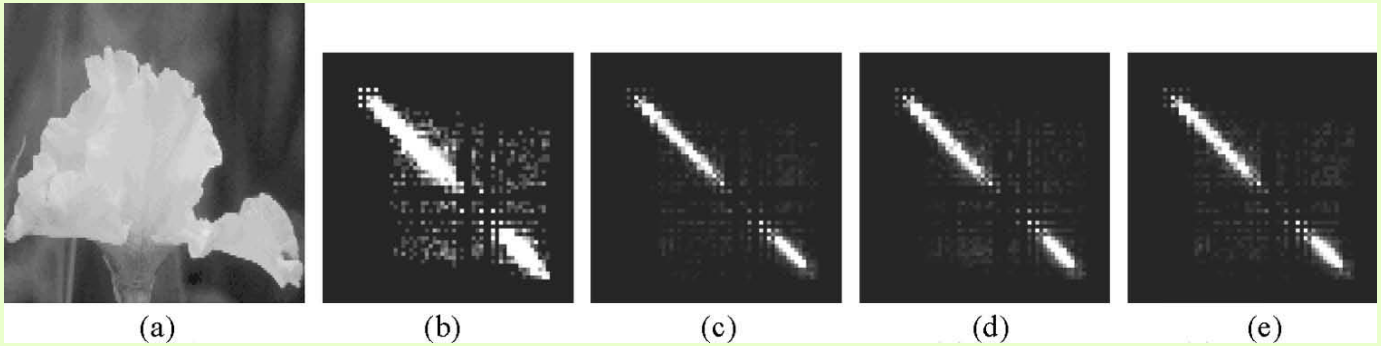
convex hull



A Survey Series on IE

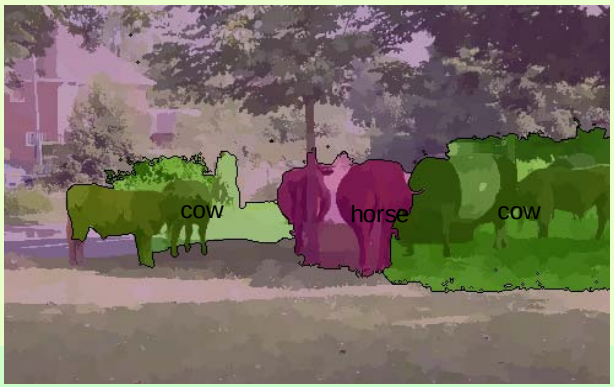
- **B: Image Analysis**
- B3: Analysis of color, shape, texture, position, motion

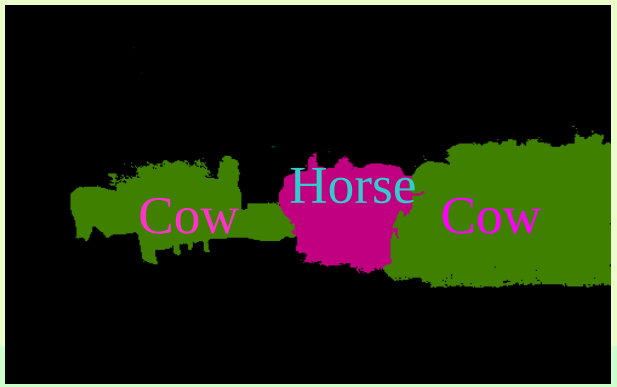




A Survey Series on IE

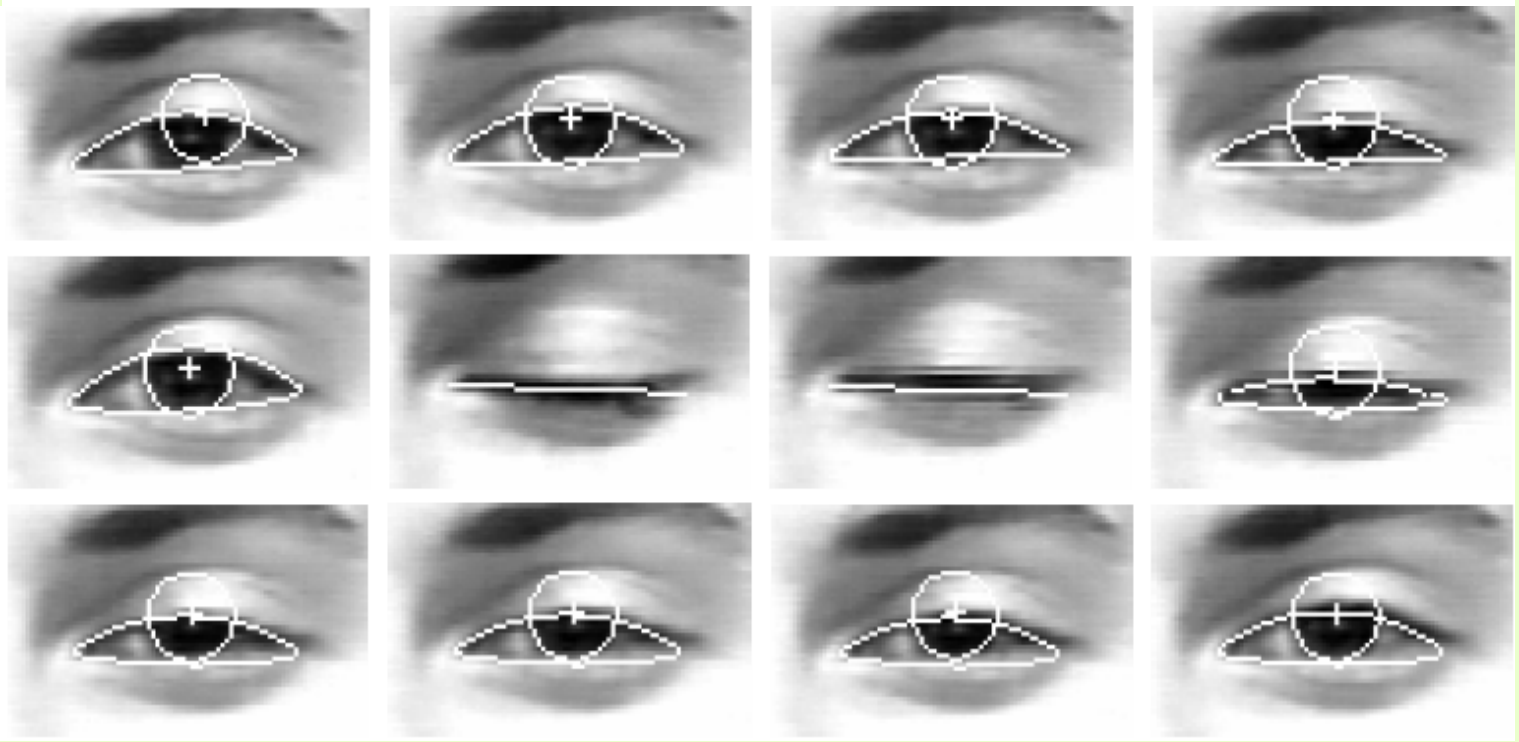
- **B: Image Analysis**
- B4: Object detection and classification





A Survey Series on IE

- **B: Image Analysis**
- B5: Human face and organ tracking, identification



A Survey Series on IE

The Classification Scheme of IE

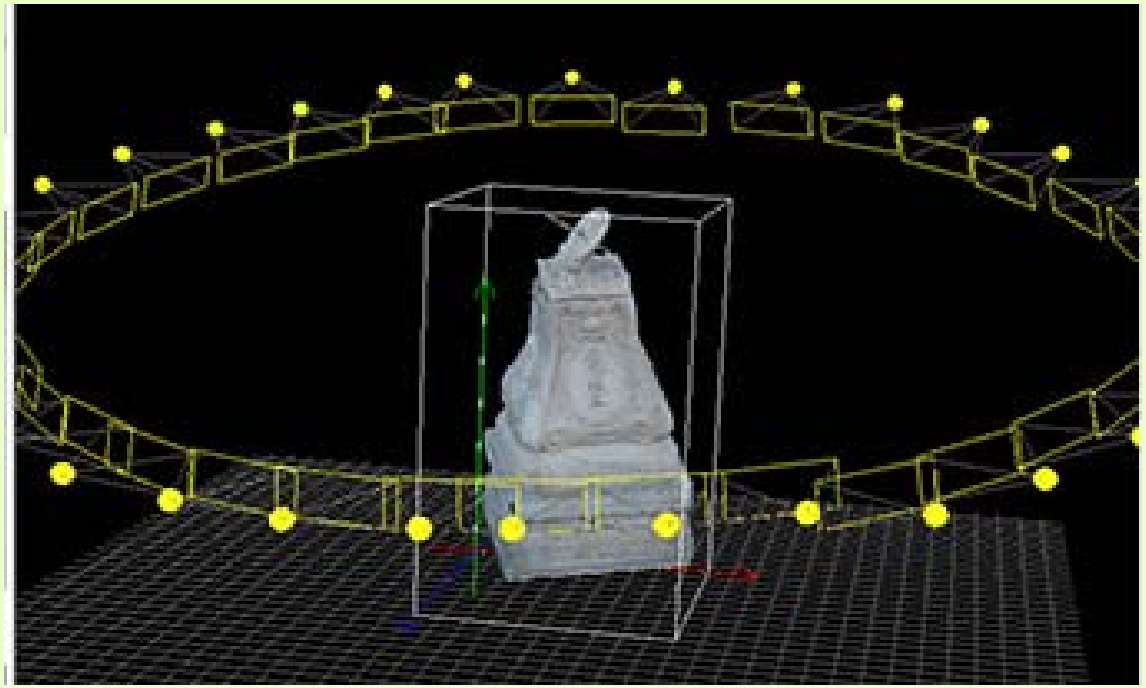
Category	Sub-category
C: Image Understanding	C1: (Sequential, Volumetric) image registration and matching C2: 3-D modeling, representation, and real world recovery C3: Image interpretation reasoning (semantic, expert system) C4: Content-based image and video retrieval C5: Spatio-temporal techniques for object understanding

A Survey Series on IE

- **C: Image Understanding**
- C1: Image registration, matching, fusion

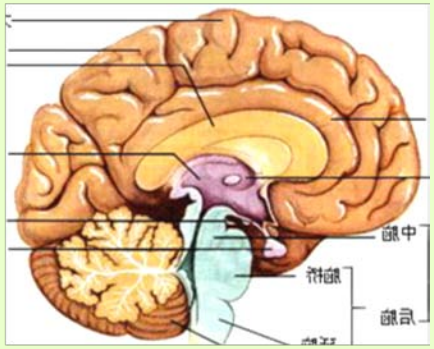
A Survey Series on IE

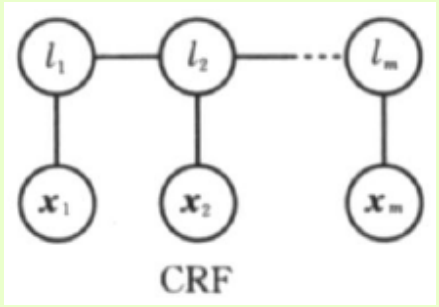
- **C: Image Understanding**
- C2: 3-D modeling, representation, recovery

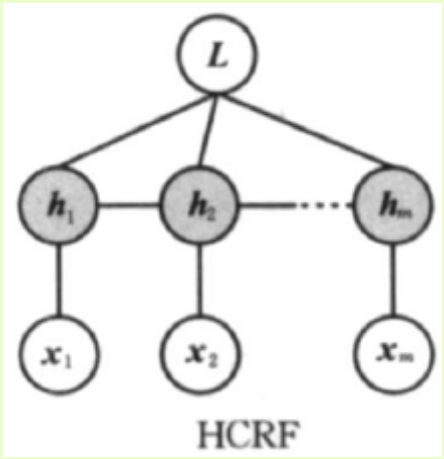


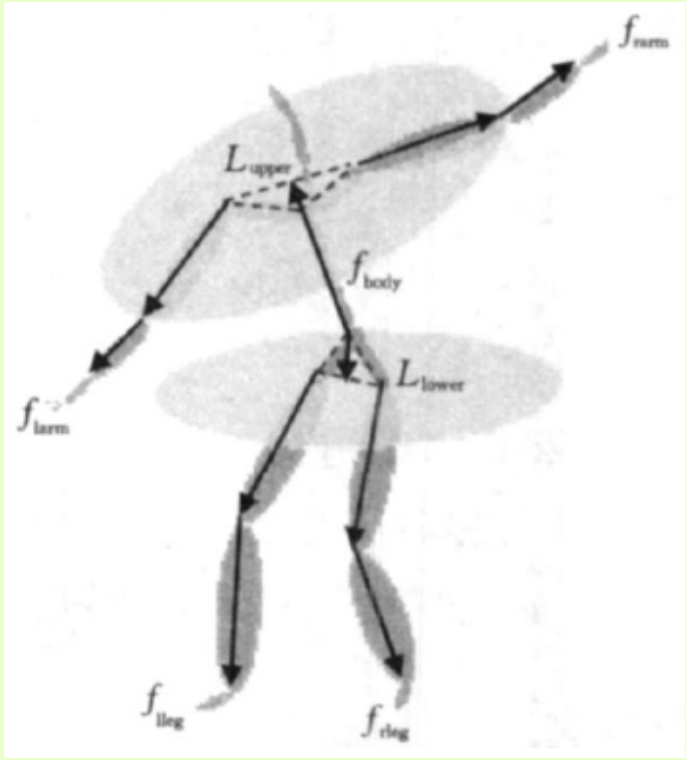
A Survey Series on IE

- **C: Image Understanding**
- C3: Image interpretation, reasoning



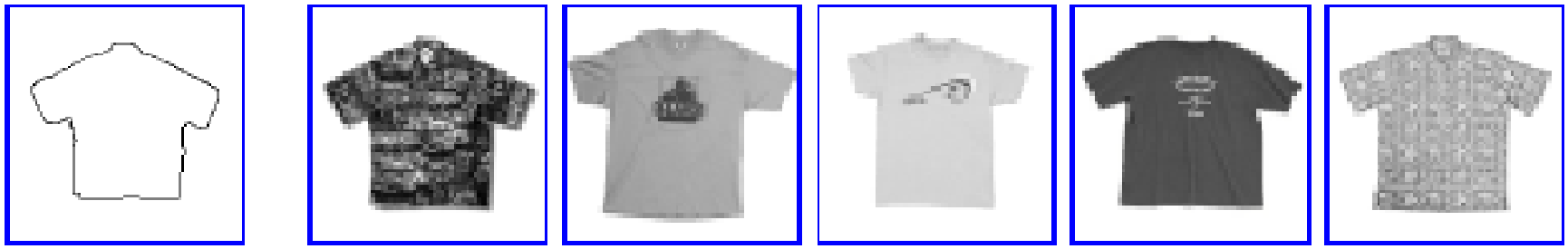






A Survey Series on IE

- **C: Image Understanding**
- C4: Content-based image and video retrieval



day, tree, outdoor, house

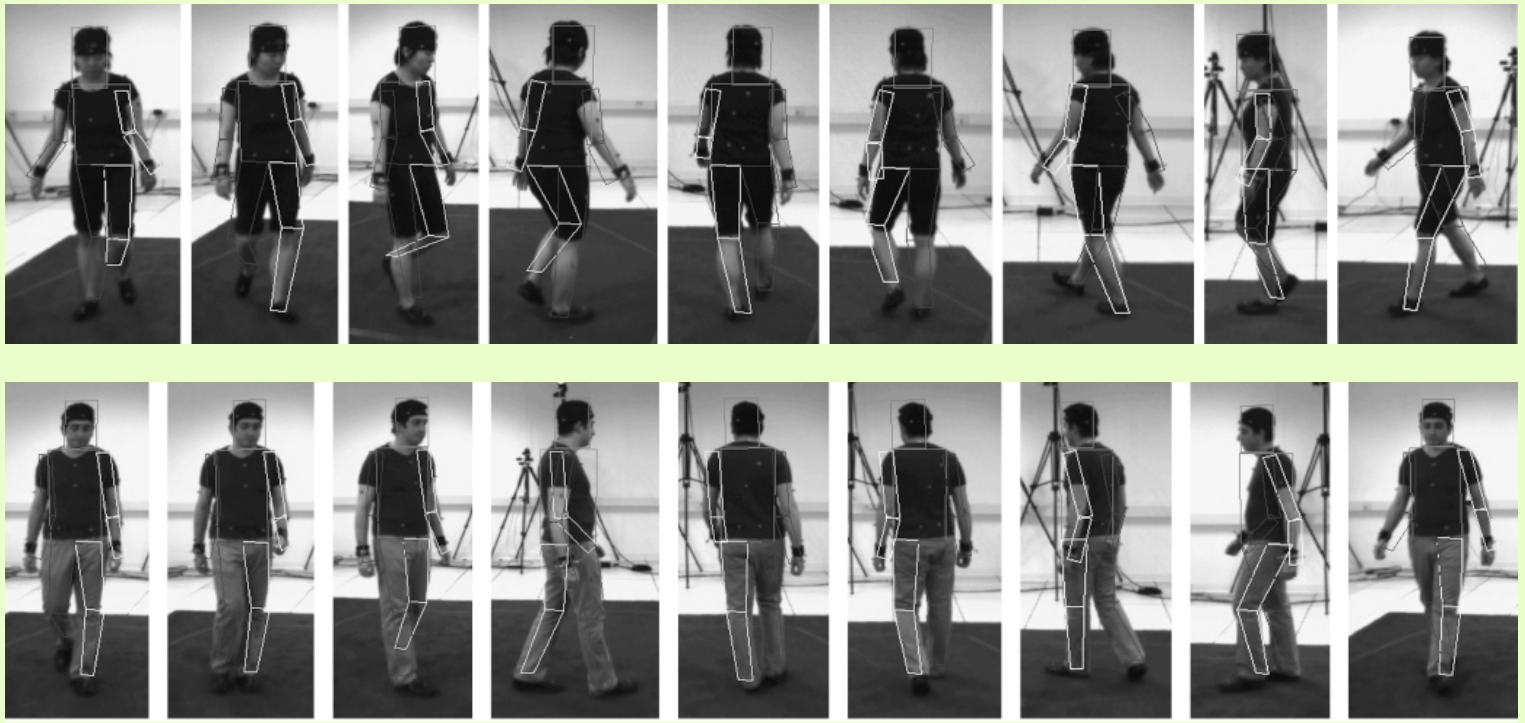
cloud, lake, mountain, forest

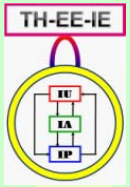
beach, day, summer, sand

autumn, forest, leaf, tree

A Survey Series on IE

- **C: Image Understanding**
- C5: Spatio-temporal techniques





A Survey Series on IE

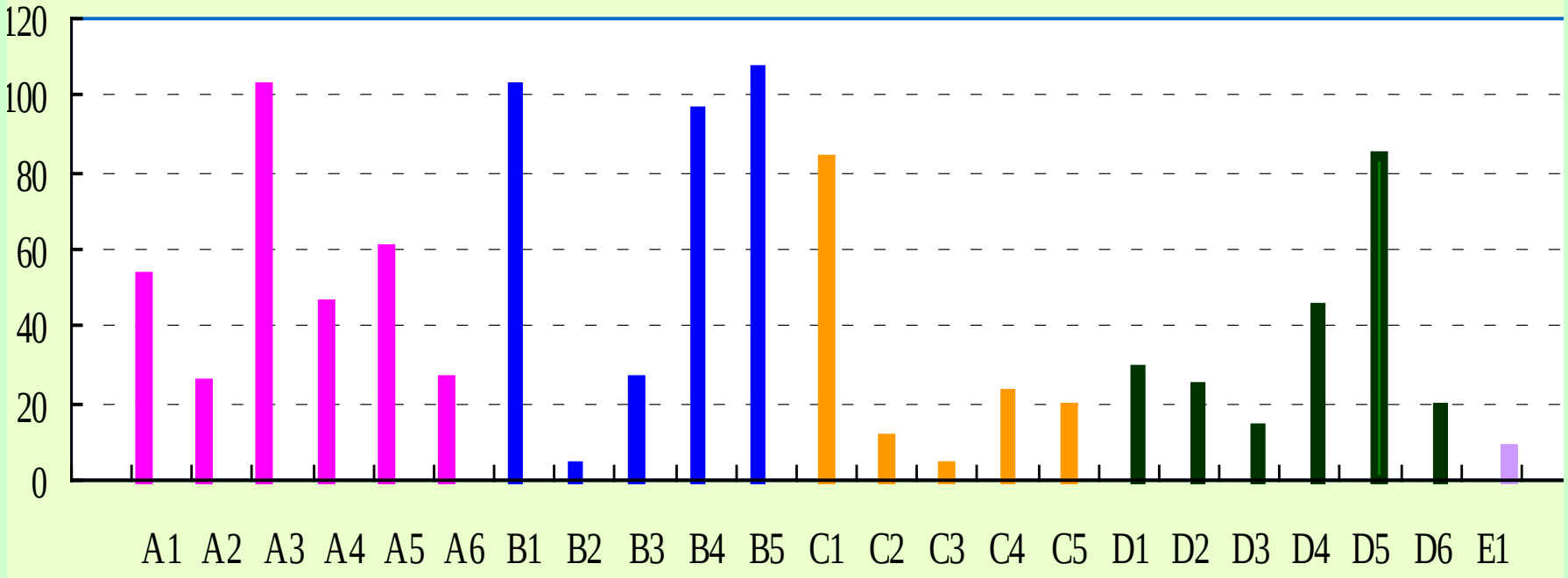
The Classification Scheme of IE

Category	Sub-category
D: Technique Applications	D1: System and hardware (fast algorithm implementation) D2: Telecommunication, television D3: Documents (texts, digits, symbols) D4: Bio-medical imaging D5: Remote sensing, surveying, and mapping D6: Others
E: Survey and Review	E1: Survey (covering IP, IA, IU)

A Survey Series on IE

- **Classification Results**

For year 2009 (#1008 / #3604)

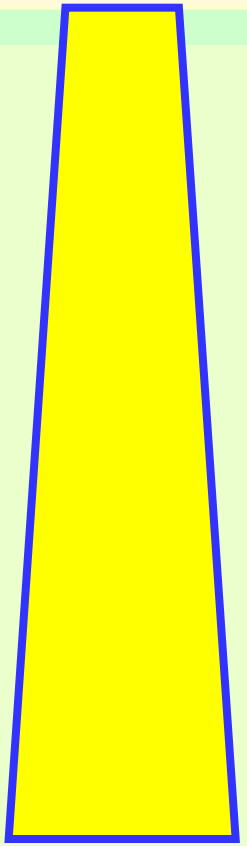


Advances of IE in 15 Years

- **Selected IE publications for 15 years**
- By combining the information made from this survey series, a number of useful statistics can be obtained. In the following table, the numbers of publications for the last 15 years are listed, where the "Total #" indicates the total number of papers published in the selected journals, the "Selected #" indicates the number of papers selected for survey as they are related to IE, and the selection ratio is computed by taking Selected # / Total #

Year	Total #	Selected #	Selection ratio
1995	997	147	14.74
1996	1205	212	17.59
1997	1438	280	19.47
1998	1477	306	20.72
1999	2048	388	18.95
2000	2117	464	21.92
2001	2297	481	20.94
2002	2426	545	22.46
2003	2341	577	24.65
2004	2473	632	25.60
2005	2734	656	23.99
2006	3013	711	23.60
2007	3312	895	27.02
2008	3359	915	27.24
2009	3604	1008	27.97
Summary	**34841**	**8217**	**—**
Average	**2323**	**548**	**23.58**

≈ 1/7



Doubled

Advances of IE in 15 Years

- **Selected IE publications for 15 years**

- (1) The total number of papers published in these journals for each year increases almost every year, it means that all the subjects covered (including IE) are progressed in this period
- (2) The number of papers selected for the survey as they are related to IE increases every year gradually, it shows the research results of IE become more and more important

Advances of IE in 15 Years

- **Selected IE publications for 15 years**

- (3) The most important point is that IE publication evolves quite steadily. In 15 years, the "Selection ratio" has almost been doubled. In fact, IE becomes more and more important in electronic engineering, computer science and automation.

  At the 15 years ago, only one over seventh publications is related to IE, while it becomes more than one over fourth just 15 years late

Advances of IE in 15 Years

- **Categories and statistics of publications**
- The statistics for IE publications in 5 categories are given in the following table.

  For each category, the total number of IE publications in 15 years (Total #), the ratio of the number of publications for this category over the total number of IE publications in 15 years (Ratio), and the average number of IE publications per year (Average #) are provided

Advances of IE in 15 Years

- **Categories and statistics of publications**

Category	Total #	Ratio (%)	Average #
A	2720	33.1	181
B	2434	29.6	162
C	1192	14.5	79
D	1797	21.9	120
E	74	0.90	5

Advances of IE in 15 Years

- **Categories and statistics of publications**
- It is seen that the number of publications for IP is around the one third of the total number of publications for IE, the number of publications for IA is near the one third of the total number of publications for IE, while the numbers of publications for IU and TA is just a little more than the one third of the total number of publications for IE.

  These numbers and percentages indicate that IP and IA are currently main parts of IE, and the research on IU should be still put forward

Advances of IE in 15 Years

- **Sub-categories and statistics of publications**
- The statistics for IE publications in 23 sub-categories are given in the following table.

  For each category, the total number of IE publications in 15 years (Total #), the ratio of the number of publications for this sub-category over the total number of IE publications in 15 years (Ratio), and the average number of IE publications per year (Average #) are provided

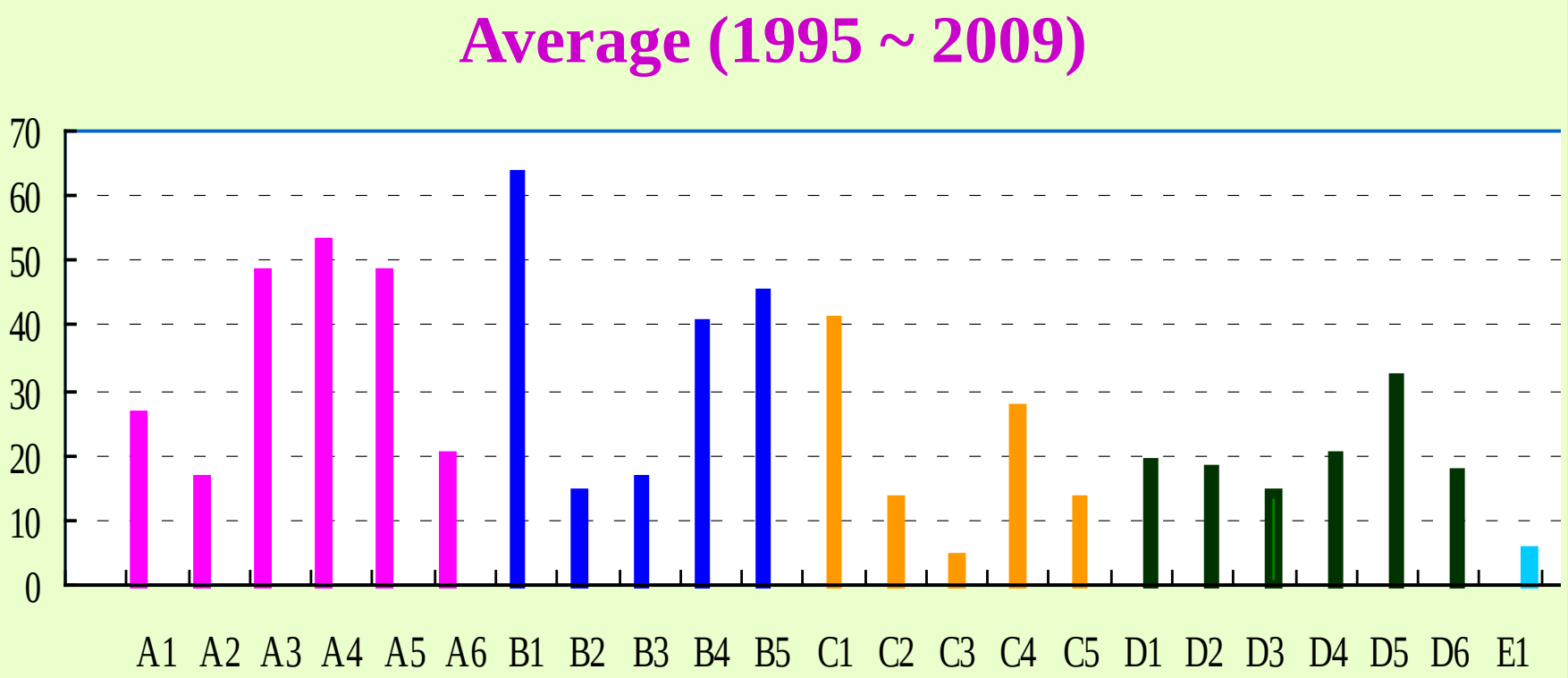
Advances of IE in 15 Years

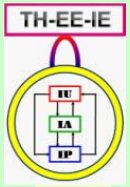
Sub-Category	Total #	Ratio (%)	Average #
A1	391	4.76	26.1
A2	238	2.90	15.9
A3	714	8.69	47.6
A4	800	9.74	53.3
A5	479	5.83	47.9
A6	98	1.19	19.6
B1	945	11.5	63.0
B2	206	2.51	13.7
B3	234	2.85	15.6
B4	596	7.25	39.7
B5	453	5.51	45.4

Sub-Category	Total #	Ratio (%)	Average #
C1	609	7.41	40.6
C2	196	2.39	13.1
C3	56	0.68	3.7
C4	268	3.26	26.8
C5	63	0.77	12.6
D1	282	3.43	18.8
D2	269	3.27	17.9
D3	216	2.63	14.4
D4	301	3.66	20.1
D5	474	5.77	31.6
D6	255	3.10	17
E1	74	0.90	4.9

Advances of IE in 15 Years

- **Sub-categories and statistics of publications**





Advances of IE in 15 Years

- **Sub-categories and statistics of publications**

(1) Sub-category B1 is ranked first among all sub-categories

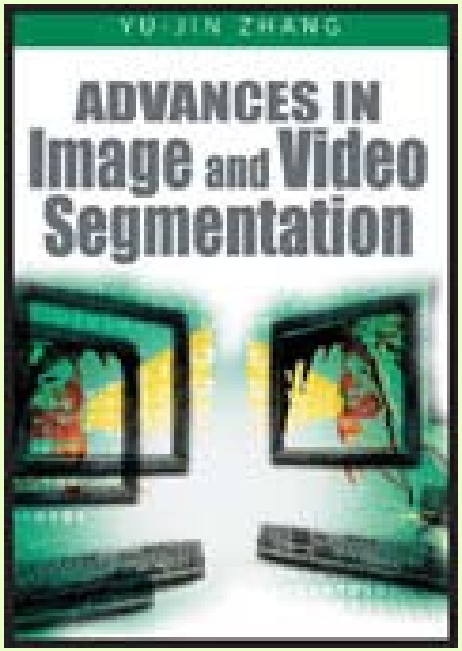
In fact, image segmentation is for long time a focusing spot for image analysis. Though many progresses have been made, there are still a lot of problems to be solved, a large number of publications appears every year

Advances of IE in 15 Years

- Yu-Jin ZHANG (ed.).

  "Advances in Image and Video Segmentation".

  IRM Press, 2006.



Totally 51 authors from 16 countries and regions:

21 from Asia

20 from Europe

4 from North America

4 from South America

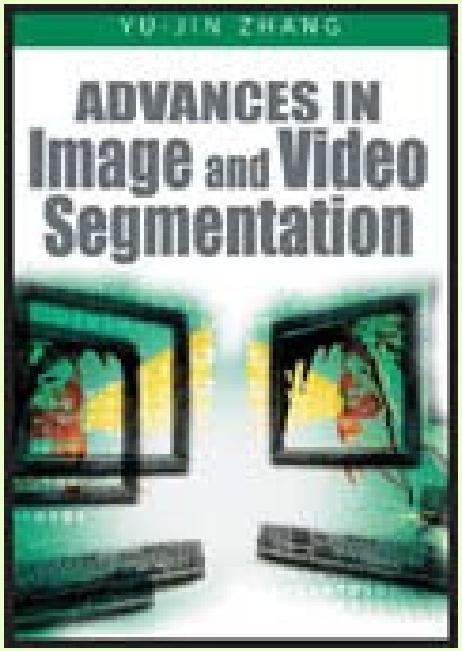
2 from Africa

Advances of IE in 15 Years

- Yu-Jin ZHANG (ed.).

  "Advances in Image and Video Segmentation".

  IRM Press, 2006.



20 Chapters in 6 Sections

(1) Introduction

(2) Image Segmentation

(3) Video Segmentation

(4) Segmenting Particular Images

(5) Special Segmentation Applications

(6) Segmentation Evaluation

Advances of IE in 15 Years

- **Sub-categories and statistics of publications**

(2) Sub-category A4 is ranked second among all sub-categories

However, in contrast to image segmentation, research on image coding goes down after attending a summit at 10 years ago. From the Figure for 2009, it is seen that the number of publications for image coding is just at the average level of 23 sub-categories

Advances of IE in 15 Years

- **Sub-categories and statistics of publications**

(3) Different from the above two sub-categories, the sub-categories ranked 3rd to 8th places in “Total #” list are not those sub-categories ranked 3rd to 8th places in “Average” list.

For a sub-category, if its rank in “Average” list is higher than its rank in “Total #” list, it means this sub-category gets more attention in recent years

Advances of IE in 15 Years

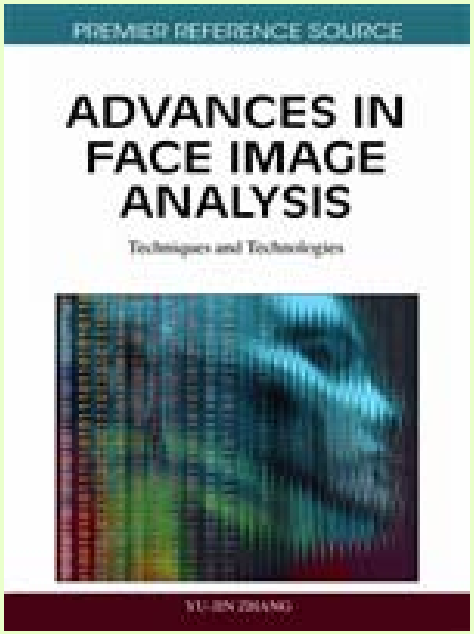
- **Sub-categories and statistics of publications**

For example, A5 is ranked 6th in "Total #" list but 3rd in "Average" list. The fast increasing of publication number is due to the protection of intellectual properties of digital products

Another example is B5 that has been ranked first in 2009. Most works are on face recognition, or more generally, on face image analysis

Advances of IE in 15 Years

- Yu-Jin ZHANG (ed.) "Advances in Face Image Analysis -- Techniques and Technologies ". IGI Global. 2011.



Totally 33 authors from 16 countries and regions:

10 from Asia

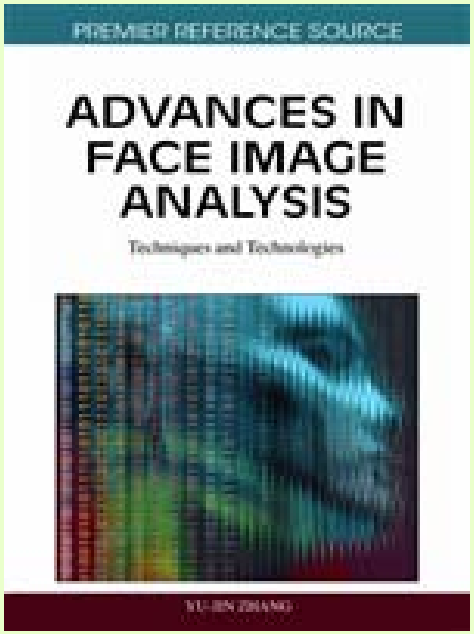
18 from Europe

2 from North America

3 from Oceania

Advances of IE in 15 Years

- Yu-Jin ZHANG (ed.) "Advances in Face Image Analysis -- Techniques and Technologies ". IGI Global. 2011.



17 Chapters in 6 Sections:

(1) Introduction and Background

(2) Facial Feature Extraction

(3) Feature Dimensionality Reduction

(4) Face Recognition

(5) Facial Expression Classification

(6) Invariance Techniques

Advances of IE in 15 Years

- **Sub-categories and statistics of publications**

(4) Two sub-categories needs to be mentioned also here are A3 and C1

Both of them are quite matured (they are ranked 3rd and 4th in "Total #" list)

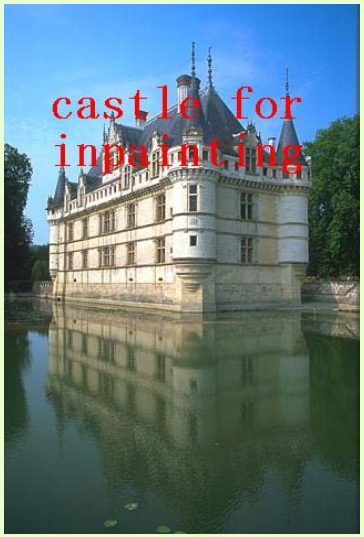
However, some new image applications make them active again these years

Take the example of A3

Advances of IE in 15 Years

- **Sub-categories and statistics of publications**

A3: image inpainting



Concluding Remarks

- This work/talk

  - Gives a sketch of the promising discipline – Image Engineering (IE), which has been changed enormously from its initial status
  - Shows a general and off-the-shelf picture of the progress, maturity and expansion of IE in the last 15 years

Concluding Remarks

- This work/talk
  - Reveals a strong tendency of continuing development of IE, and its various layers and branches in the feature
  - Provides some useful guidelines for further research directions, as well as those researching and working in this discipline

Thanks for Your Attention !

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