History of Computer Vision
A Personal Perspective

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Pattern Recognition and Image Processing Group

What is CV?
What is CV?

*Computer vision is the science and technology of machines that see.*

- **As a scientific discipline:**
  the theory for building artificial systems that obtain **information** from images.
- **image data:** a video sequence, views from multiple cameras, or multi-dimensional data from a medical scanner.
- **As a technological discipline:** construction of computer vision systems.

\[
CV = \text{Camera} + \text{Computer} + ?
\]

Pattern Recognition \( \text{PR} = \text{(Data} \rightarrow \text{Information)} \)

\( CV \subset \text{PR} \)

May 7, 2008
Computer Vision Systems are used for . . .

- Controlling processes (e.g. an industrial robot or an autonomous vehicle).
- Detecting events (e.g. for visual surveillance or people counting).
- Organizing information (e.g. for indexing databases of images and image sequences).
- Modeling objects or environments (e.g. industrial inspection, medical image analysis or topographical modeling).
- Interaction (e.g. as the input to a device for computer-human interaction).
- ...

May 7, 2008
**Computer Vision ↔ Biological Vision**

<table>
<thead>
<tr>
<th>Computer vision</th>
<th>Biological vision</th>
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</thead>
<tbody>
<tr>
<td>studies and describes artificial vision systems implemented in software and/or hardware.</td>
<td>visual perception of humans and animals resulting in models how these systems operate in terms of physiological processes.</td>
</tr>
</tbody>
</table>

Interdisciplinary exchange between biological and computer vision has proven increasingly fruitful for both fields.

Example **NFN Cognitive Vision**
Perception

- process of attaining awareness or understanding of sensory information.
- a task far more complex than was imagined in the 1950s and 1960s: "building perceiving machines would take about a decade" but still very far from reality.

- Aristotle’s five senses are sight, hearing, touch, smell, taste.
- sensory illusions → theory of active perception (Richard L. Gregory).
- conjectures a dynamic relationship between

  "description" (in the brain) ↔ senses ↔ surrounding.
CONTENTS

• What is Vision?
• Early History
• Learning the discipline and people
• CV in Austria
• IAPR
• Next 40 Years?
• Conclusion - Vision

May 7, 2008
Early CV History (A. Rosenfeld, 1998)

since 1960 Digital image processing by computer


1970 1. International Conference on Pattern Recognition (*ICPR*)

1977 1. Computer Vision and Pattern Recognition (*CVPR*)

1978 International Association for Pattern Recognition (*IAPR*)

1979 IEEE Transactions on Pattern Analysis and Machine Intelligence (*PAMI*)

1987 1. International Conference on Computer Vision (*ICCV*)
Early CV @ TU Graz

1974 Franz LEBERL to NASA JPL
1975 Johannes G. MOIK to NASA Goddard SFC
1978/79 Leberl & Kropatsch: DIBAG @ JR
    CV @ basement(TU Graz)
DIBAG around 1980

1st IP software from Joachim Wiesel (Karlsruhe): DIDAK transformed/extended into DIBAG

<table>
<thead>
<tr>
<th>input</th>
<th>output</th>
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<tbody>
<tr>
<td>artificially created matrices</td>
<td>arrays of numbers</td>
</tr>
<tr>
<td>magn. tapes of LANDSAT MSS</td>
<td>overprinted printout of several $m^2$</td>
</tr>
<tr>
<td>small donated pictures</td>
<td>overprints, diapositives</td>
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</tbody>
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May 7, 2008
NATO ASI Bonas 1978

James Crowley and Alice Parker
Transfer Function Analysis of Picture Processing Operators

V. Cappellini
Enhancement, Filtering and Preprocessing Techniques

II. NEIGHBORHOOD OPERATORS

V. Goetcherian
CLIP--A User's Viewpoint

J. Serra
Principles, Criteria and Algorithms in Mathematical Morphology

III. DISCRETE AND PROBABILISTIC RELAXATION

J.R. Ullmann
A Relational View of Text Image Processing

Larry Davis
Cooperative Processes

Steven W. Zucker
Local Structure, Consistency and Continuous Relaxation

Robert M. Haralick
Scene Matching Methods
NATO ASI Maratea 1979

Freeman, H., Pieroni, G. G. (Eds.):
Map Data Processing.
NATO ASI Bonas 1982

I. NEIGHBORHOOD OPERATORS: AN OUTLOOK
S. Levialdi ........................................... 1

II. LINEAR APPROXIMATION OF QUANTIZED THIN LINES
S.H.Y. Hung, T. Kasvand ............................. 15

III. QUADTREES AND PYRAMIDS: HIERARCHICAL REPRESENTATION OF IMAGES
A. Rosenfeld .......................................... 29

VII. SEGMENTATION OF DIGITAL IMAGES USING A PRIORI INFORMATION
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VIII. A SYNTACTIC-SEMANTIC APPROACH TO PICTORIAL PATTERN ANALYSIS
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IX. RELATIONAL MATCHING
J.R. Ullmann ........................................ 147

X. REPRESENTATION AND CONTROL IN VISION
Takeo Kanade ..................................... 171

XI. COMPUTER VISION SYSTEMS: PAST, PRESENT, AND FUTURE
Linda G. Shapiro ................................. 199

XII. ARTIFICIAL INTELLIGENCE: MAKING COMPUTERS MORE USEFUL
Pierpaolo Degano ............................... 239
NATO ASI Cetraro 1983

1. Algorithm-Driven Architecture for Parallel Image Processing
   Per-Erik Danielsson

2. Architectures of SIMD Cellular Logic Image Processing Arrays
   M.J.B. Duff

3. Classification Schemes for Image Processing Architectures
   V. Cantoni

12. Pyramid Architectures for Image Analysis
    Azriel Rosenfeld

13. Using Quadtrees to Represent Spatial Data
    Hanan Samet

    H. Freeman and D. Meagher

15. Efficient Storage of Quadtrees and Octrees
    Markku Tanimoto

16. Image Processing with Hierarchical Cellular Logic
    S.I. Tanimoto

7. Considerations on Pyramidal Pipelines for Spatial Analysis of Geoscience Map Data
   T. Kasvand and A.G. Fabbri
CV Systems (Linda G. Shapiro, 1983)

1965 Roberts’ PhD@MIT: 1st CV system
1968 Guzman’s PhD@MIT: SEE, blocks world
1971-77 Binford, Agin, Nevatia, Marr: generalized cylinders

1971-78 Huffman, Clowes, Waltz label line drawings of 3D objects
1976 Rosenfeld, Hummel, Zucker: MSYS, relaxation
1974-78 Hanson, Riseman VISIONS, ’schema’
1981 Brooks’ PhD@Stanford: ACRONYM, contains graphs for: objects, restrictions, predictions, observations, interpretations.
1982 Haralick, Shapiro@VPI: GIPSY, rel. data structure, spatial reasoning
CV in Austria

1980 DIBAG @ Graz: Digitale Bildauswertung Graz (10...30 researchers)

1981/1987 Österreichische Arbeitsgemeinschaft für Mustererkennung (ÖAGM, 10...100 members)

1984, 1994, 2005 DAGM Symposia in Österreich, 200 participants

1990 PRIP @ TU Wien: Pattern Recognition and Image Processing group

1994-2000 FWF FSP S70: Image Processing

1996 13. ICPR in Wien, 1000 participants

1992 ICG @ TU Graz: Computer Graphics and Vision


2004-2009 FWF NFN S91: Cognitive Vision
ÖAGM-Meetings

- were held since 1979
- The following list contains:
  - the dates,
  - where it was held,
  - the "title of the meeting", and
  - the invited speakers.
<table>
<thead>
<tr>
<th>Nb.</th>
<th>When</th>
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<th>Title, Invited</th>
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<td>2</td>
<td>6.- 7.11.1980</td>
<td>Ramsau: ”Mustererkennung und Bildverarbeitung in Österreich”</td>
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<td>3</td>
<td>7.- 8. 5.1982</td>
<td>Gallneukirchen: ”Robotik und Bildverarbeitung”</td>
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<td>4</td>
<td>29.-30.10.1982</td>
<td>Wien: ”Bildverarbeitung: Datenstrukturen, Anwendungen”, Hanan Samet (CfAR)</td>
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<td>6</td>
<td>18.-19. 5.1984</td>
<td>Innsbruck: ”Mustererkennung bei der Sprachsignalverarbeitung”, H. Kindler (Hannover)</td>
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<td>7</td>
<td>2.- 4.10.1984</td>
<td>Graz: ”Mustererkennung 1984 (gem. mit DAGM)”, Linda G. Shapiro, Werner Horn</td>
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<td>8</td>
<td>7.- 8. 6.1985</td>
<td>Wien: ”Bildverarbeitung und Mustererkennung in der Medizin”, Michael L. Rhodes (USA)</td>
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<td>9</td>
<td>8.- 9.11.1985</td>
<td>Klagenfurt: ”Bildverarbeitung in den Geowissenschaften”</td>
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<td>10</td>
<td>4.- 5. 7.1986</td>
<td>Graz: ”Bildpyramiden”, Azriel Rosenfeld (CfAR)</td>
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<td>11</td>
<td>15.-16. 5.1987</td>
<td>Linz: ”Statistik und Mustererkennung”, Josef Kittler (Surrey), Eckhard Hundt (Siemens D)</td>
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<td>12</td>
<td>17.-18. 6.1988</td>
<td>Innsbruck: ”Mustererkennung in Medizin und Biologie”, Siegfried J. Pöppl (München)</td>
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<td>13</td>
<td>26.-27. 5.1989</td>
<td>Wien: ”Wissensbasierte Mustererkennung”, Peter J. Burt (Sarnoff)</td>
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<td>14</td>
<td>3.- 4. 5.1990</td>
<td>Salzburg: ”Image Acquisition and Real-Time Visualization”</td>
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<td>17</td>
<td>2.- 4. 6.1993</td>
<td>Graz: ”Image Analysis and Synthesis”, B. Batchelor (Wales), A. Soifer (Samara), P. Yaroslavsky (NIH)</td>
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<td>18</td>
<td>21.-23. 9.1994</td>
<td>Wien: ”Mustererkennung 1994 ’Erkennen und Lernen’ (gem. mit DAGM)”, Yiannis Aloimonos (UMD), Franz Leberl (TUG), Werner von Seelen (Bochum)</td>
<td></td>
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<td>19</td>
<td>11.-12. 5.1995</td>
<td>Maribor, SLO: ”Visual Modules”, Greg Hager(Yale)</td>
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<td>21</td>
<td>26.-27. 5.1997</td>
<td>Hallstadt: ”Pattern Recognition 1997”, Terry Caelli (Perth, ASU), C.P. Suarez Araujo (Gran Canaria)</td>
<td></td>
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<td>22</td>
<td>14.-15. 5.1998</td>
<td>Illmitz: ”Pattern Recognition and Medical Computer Vision”, H.P. Meinzer (DKFZ), E. Wenger (ÖAW)</td>
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<td>23</td>
<td>27.-28. 5.1999</td>
<td>Steyr: ”Robust Vision for Industrial Applications”, Giulio Sandini (Genoa), Henrik I. Christensen (KTH)</td>
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<td>24</td>
<td>25.-26. 5.2000</td>
<td>Villach: ”Applications of 3D-Imaging and Graph-based Modelling”, Pierre Boulanger (NRC Canada)</td>
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<td>26</td>
<td>10.-11. 9.2002</td>
<td>Graz:”Vision with Non-Traditional Sensors”, Luv van Gool (ETH), Gerd Hirzinger (DLR)</td>
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<td>27</td>
<td>5.- 6. 6.2003</td>
<td>Laxenburg:”Vision in a Dynamic World”, Anil Jain (MSU)</td>
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<td>28</td>
<td>17.-18. 6.2004</td>
<td>Hagenberg:”Digital Imaging in Media and Education”, Pascal Fua (EPFL)</td>
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<td>30</td>
<td>2.- 3. 3.2006</td>
<td>Obergurgl:”Digital Imaging and Pattern Recognition”</td>
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<td>31</td>
<td>3.- 4. 5.2007</td>
<td>Krumbach:”Performance Evaluation for Computer Vision”, Cordelia Schmid (INRIA)</td>
<td></td>
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<tr>
<td>32</td>
<td>26.-27. 5.2008</td>
<td>Linz:”Challenges in the Biosciences: Image Analysis and Pattern Recognition Aspects”, Lucas J. van Vliet (Delft), Wiro Niessen (Erasmus MC), Fred A. Hamprecht (Heidelberg)</td>
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## Austria meets the CV-World

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<tr>
<th>A → World</th>
<th>World → A</th>
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<tr>
<td>1984/85 1990-</td>
<td>invited speakers to ÖAGM</td>
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<tr>
<td>ERASMUS student, teacher exchange, intensive programs</td>
<td>DAGM 84, 94, 06</td>
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<tr>
<td>Ed./Rev. major Journals (PRL, PR, CVIU, IEEE-PAMI, SPIE-JEI,...)</td>
<td>PRIP guest professors (Hlavac 95, Lienhard 01, Gonzalez-Diaz 08)</td>
</tr>
<tr>
<td>involved in IAPR TC: 7, 15, 19</td>
<td>ICPR 96, ECCV 06, CAIP 07</td>
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<td>ExCo: Treasurer, 1st VP, president 2004-2006</td>
<td>CVWW yearly since 97 (PRIP+CMP+CVL+ICG)</td>
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</table>
ICPR + K.S.Fu Award Winners 2006-1998

2006 Hong Kong: Josef Kittler, On Context, Modelling, Dimensionality ...
2004 Cambridge: J. K. Aggarwal, structure and motion from image sequences
2002 Quebec City: Thomas S. Huang, 3D motion
2000 Barcelona: Theo Pavlidis, structural pattern recognition
    Lecture: http://www.theopavlidis.com/technology/KSFuLecture.htm
1998 Brisbane: Jean-Claude Simon, automated recognition of handwritten words
ICPR + K.S.Fu Award Winners 1996-1988

1996 Vienna: Teuvo Kohonen, Self-organizing map

1994 Jerusalem: Herbert Freeman, Chain Code; Automated Cartographic Text Placement

1992 The Hague: Levin Kanal

1990 Atlantic City: R.L. Kashyap

1988 Rome: Azriel Rosenfeld, computer image analysis, digital geometry and topology
Celebrating 40 years of Pattern Recognition

1. Volume 41, Issue 7, Pages 2137-2434 (July 2008)
2. Celebrating 40 years of Pattern Recognition-Introductory remarks Page 2137
   Robert S. Ledley, Ching Y. Suen
3. Celebrating 40 years of Pattern Recognition-In his own words Page 2138
   Robert S. Ledley
4. Celebrating 40 years of Pattern Recognition-Reflections Pages 2139-2144
   Henry M. Beisner

Research Strategy for the Future (Julian R. Ullman)
Research Strategy for the Future (Julian R. Ullman)

... 

PP: *Can you identify the object*
SE: *No.*

PP: *You can’t recognize it but you can see it?*
SE: *That’s right.*

PP: *So we can see things that we can’t recognize?*

...
We can sometimes see the reason for failure

PP: ... A smudge could cause a machine to misrecognize the ‘1’ as a ‘7’.
You and I can see that the smudge affects all the characters.
Ink spots could cause a machine to misrecognize the ‘P’ as ‘R’.
You and I can see that this region of the document is affected by ink spots.

SE: We simply need a training set that includes smudged and ink-spotted characters.

PP: We need that when the system can’t see for itself.
But can we rely on having a training set that includes all possible eventualities?
I think George Nagy was right when he said that the training set is never big enough.

SE: Some people might disagree with that.

...
Next 40 Years:

PP: ...there will be more effort towards devising processes 
that can be implemented in highly parallel associative hardware 
instead of some kind of stored-instruction computer. 
The currently fashionable preoccupation with mathematics needs to be coun-
terbalanced by more exploration of parallel hardware implementation.

PP: .... Human recognition capability greatly exceeds that of machines. 
We don’t have an exact and complete wiring diagram for the human visual 
system, but we can reasonably assert that it is highly parallel. 
After a neuron has fired, it can’t fire again until after about ten milliseconds. 
Without high parallelism, the human visual system couldn’t work as rapidly 
as it actually does.

...
Fashions, Trends...

EVS Expert Vision Systems 1982++
ANN Artificial Neural Networks 1985++
CV Computer Vision 1987++
CogVis Cognitive Vision 2002++
Trends last about 5 years, boost grant money
mislead sometimes.
Conclusion

- INPUT available in large quantities
- COMPUTERS are by magnitudes faster
- picturial OUTPUT in excellent quality
- higher level OUTPUT?

• personal experience: CONTACTS, CONTACTS, CONTACTS

Computers will SEE

Mt. Rainier, 9/11/01

Marco Gori, Simone Marinai, Walter Kropatsch

but moreover ALSO
Conclusion

VISION

- Computers will SEE
- Computers will HEAR
- Computers will SMELL
- Computers will TOUCH
- Computers will TALK to YOU ... like HUMANS do
- as ACTIVE PARTS of our WORLD