Introduction to Image Processing #1/7

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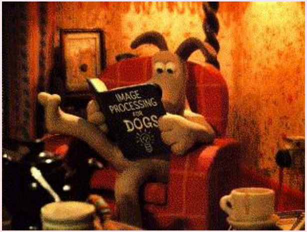

2006

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Objectives (1/2)

Several objectives for this course:

- introduce you to techniques used in image processing
- give you an overview of several theoretical domains

Objectives (2/2)

Intents:

- make you realize that theories are effectively applied!
- picking the field of image processing is only a pretext
- reinforce your common engineering knowledge

Materials (electronic)

this lecture material is powered by Wikipedia

a selection of online courses

- `http://homepages.inf.ed.ac.uk/rbf/HIPR2/`
- `http://www.ph.tn.tudelft.nl/Courses/FIP/noframes/fip.html`
- `http://www.icaen.uiowa.edu/~dip/LECTURE/lecture.html`
- `http://www.cs.bris.ac.uk/Teaching/Resources/COMS30121/slidesIP/`
- FIXME

Materials (book)

recommended book:

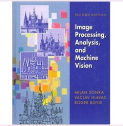

Image Processing : Analysis and Machine Vision by Milan Sonka, Vaclav Hlavac, Roger Boyle, Thomson Learning September 1998, 2nd edition, ISBN: 053495393X

Contents (1/2)

theoretical domains:

- functions and distributions
  http://en.wikipedia.org/wiki/Distribution_(mathematics)
- discrete topology
  http://en.wikipedia.org/wiki/Discrete_topology
- information theory
  http://en.wikipedia.org/wiki/Information_theory
- signal processing
  http://en.wikipedia.org/wiki/Signal_processing
- probability
  http://en.wikipedia.org/wiki/Probability

Contents (2/2)

theoretical domains:

- statistical classification
  http://en.wikipedia.org/wiki/Statistical_classification
- information management
  http://en.wikipedia.org/wiki/Information_management
- alternative set theory
  http://en.wikipedia.org/wiki/Alternative_set_theory
- physical models
  http://en.wikipedia.org/wiki/Model_(physical)
- meta heuristics
  http://en.wikipedia.org/wiki/Meta_heuristics

How-to (deal with this course)

- during class:
  - listen
  - take notes
  - ask questions
- after class
  - re-read the slides
  - follow the hyper-links and read
- validation: a practical project

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From Low-Level to High-Level

- image processing—or image filtering
  - *deals with pixels*
  - low-level processing
  - `http://en.wikipedia.org/wiki/Image_processing`
- pattern recognition
  - *deals with features—or primitives*
  - `http://en.wikipedia.org/wiki/Pattern_recognition`
- computer vision—or image understanding
  - *deals with a scene description*
  - high-level processing
  - `http://en.wikipedia.org/wiki/Computer_vision`
    `http://computervision.wikia.com/wiki/Main_Page`

Data v. Semantics

- raw images:
  - are large buffers of data (so poorly structured)
  - with no semantics associated with theirs contents
- primitives:
  - are objects (for instance, regions, contours, and so on)
  - have data (features) associated with them
- scenes:
  - have their contents described with high-level information so bear a high degree of semantics
  - are encoded by lightweight structures
  - and should lead to understanding

Illustration

- data size is a very few Ko
- yet information weight is high
- indeed, you can recognize the picture!

- left as exercise:
  - what is your description of this scene?
  - what is the nature of objects you use?
  - what kind of information do you associate with objects?

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About Artificial Intelligence

A few quotes from pioneers:

- “*Machines will be capable of doing any work that a man can do.*” —Herbert Simon, Carnegie Mellon University, 1965.
- “*Within a generation the problem of creating ’artificial intelligence’ will be substantially solved.*” —Marvin Minsky, MIT, 1967.

`http://en.wikipedia.org/wiki/Artificial_Intelligence`

Test

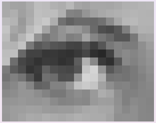
This is a simple image as known by a computer:

169	163	162	172	189	187	177	173	184	165	161	167	167	166	170	176	177	180	181
170	175	160	170	191	188	189	176	131	128	149	161	168	173	176	179	181	179	178
185	180	153	173	193	200	174	113	097	106	106	104	113	138	166	183	185	179	179
196	167	158	186	200	164	131	147	157	153	138	106	079	073	088	127	168	177	176
188	157	180	200	146	118	132	146	126	131	164	133	117	104	086	086	120	163	166
180	179	194	121	088	097	085	081	068	066	085	062	086	120	130	124	124	143	157
189	190	104	066	066	055	056	052	049	057	070	047	039	066	129	138	133	141	150
192	110	070	060	050	059	058	049	054	093	177	136	058	047	086	136	130	139	147
124	092	076	051	060	097	078	073	070	085	197	212	147	088	107	114	122	134	143
116	128	116	086	056	112	108	078	080	148	212	208	178	115	118	115	122	129	139
129	136	149	133	098	102	130	130	150	193	202	196	162	142	129	131	124	132	136
138	141	149	149	141	131	120	120	134	142	137	154	173	166	142	128	129	133	134
148	149	152	149	148	151	139	131	133	137	135	153	158	157	144	128	138	135	132
153	157	158	161	160	155	153	155	155	161	168	170	167	166	147	136	143	135	133
151	157	163	170	168	174	170	167	171	176	173	171	171	163	143	144	143	135	134

can you tell what is it?

Solution

Actually the image is this one:



- actually it is *not* so a difficult problem to recognize an eye
- however think about the distance existing between having raw data and taking a decision
- and remember...

never say too quickly: “that’s easy”!

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A Non Exhaustive List of Applications (1/2)

field	*applications*
photography	de-blurring de-noising
satellite imaging	world forest watching cultivation estimation
aerial imaging	map construction and update
medical imaging	tumor detection surgery planning tissue or fluid analysis
computer graphics	special effects artistic creation

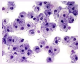
...

A Non Exhaustive List of Applications (2/2)

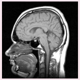
field	*applications*
video	traffic control area surveillance indexing and searching
culture	painting/movie restoration ancient ruins detection
industrial	mass production quality control paper mail processing
...	

Several Kinds of Image Construction Devices

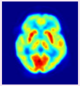
for instance, in use in medical imaging:

photography 

fluoroscopy 

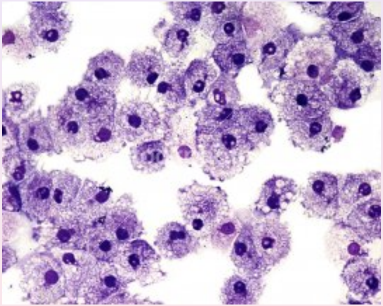
MRI 

radiography 

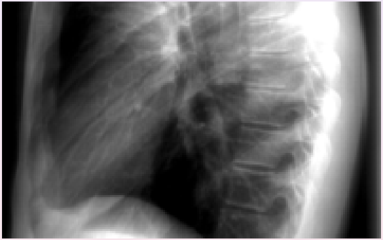
tomography 

ultrasonography 

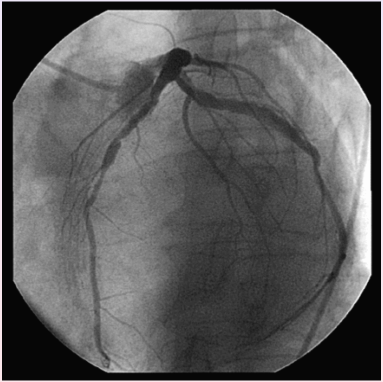
Photography



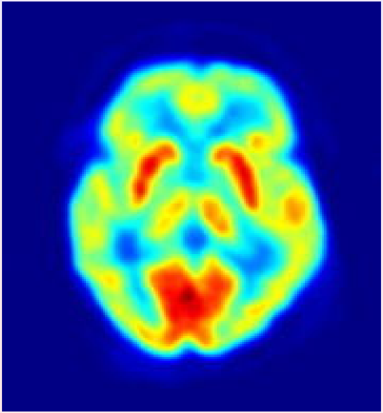
Radiography



Fluoroscopy



Tomography



Magnetic Resonance Imaging

Ultrasonography

Diversity But...

in all these images:

- noise is different
- objects to be recognized are different
- their context (scene) is different
- but we usually recourse to the same “tools / methods” provided by the context

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A Classical Image (1/2)

Consider that we have a gray picture, an image I, taken with a digital camera:

- a point p is located at (r, c)
  - r and c respectively being the row and column index
  - we have $p = (r, c)$
  - let us denote by D the set of points; $D \subset \mathbb{N}^2$
- a gray-level value is associated with every point
  - such values are integers between 0 and 255
  - 0 and 255 resp. mean black and white; in-between values are grays
  - with $V = [0, 255] \cap \mathbb{N}$, we have $I(p) \in V$

A Classical Image (2/2)

cont'd:

- the image represents a scene
  - the scene is composed of objects
  - the set of objects is $S = \{T, L, B, M\}$
  - respectively:
    - a table,
    - lines (painted on the table),
    - a ball (rolling on the table),
    - and miscellaneous objects (e.g., people around the table)

Objectives

We want to:

- recognize the objects
- put differently, find the function $O(p) \in S$
- express this problem within a particular context
- use the tools provided by this context
- focus on the quadruplet “image / points / values / objects”

Contexts ⇒ Lectures

Many contexts exist:

- by context we mean a theoretical background
- so we have to pick one
- then our problem falls within a well-known framework
- and we can use the many sound tools from this context

the lectures are about how to apply several theoretical backgrounds to image processing

In the following we focus on “what a point is”...

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Probability (1/3)

An image is *one* observation of a random phenomenon.

Indeed:

- another photographer may not have taken exactly the same picture at the same time
  and that would globally be the same scene
- many physical aspects that lead to the image have a random flavor
  think of the butterfly, of the noise

See also: `http://en.wikipedia.org/wiki/Probability`

Probability (2/3)

To recognize the ball, we can estimate:

$$P(\, I(p) \,|\, O(p) = B \,)$$

that is, the probability of having a given gray-level at the point p, knowing that this point belongs to the ball

Probability (3/3)

If we want to identify the object present at point p,
we can take a Bayesian decision:

$$O(p) = arg \max_{s \in S} P(\, O(r, c) = s \mid I \,)$$

meaning that we assign to each point the object having the higher likelihood, knowing the observation I

Signal (1/2)

An image is a *digital* signal representing an analog scene.

Indeed we have:

- both sampling and quantization
  image values are only known at discrete points
  and *the set of possible values is limited*
- but the real scene is continuous

See also:

`http://en.wikipedia.org/wiki/Signal_(information_theory)`

Signal (2/2)

the scene is the following function

$$i : \begin{cases} \mathbb{R}^2 & \mapsto & \mathbb{R} \\ (x, y) & \rightarrow & i(x, y) \end{cases}$$

when digitalized it becomes

$$I_{r,c} \in V \qquad \text{for instance } I_{5,1} = 12$$

that is, a discrete function from D to V.

Topology

An image is finite grid *graph* —or square lattice, and its points are nodes.

Then add notions like:

- neighborhood
- cliques
- connected components

See also: `http://en.wikipedia.org/wiki/Grid_graph`

Alternative Set Theory (1/2)

An image is a *set* of elements, so a point is an element.

So:

- the ball is the set B of image points (so $B \subset D$)
- more generally we search the partition of D into $T \cup L \cup B \cup M$
- the recognition process is to assign every point p to the proper sub-set (B or another one)

See also: `http://en.wikipedia.org/wiki/Alternative_Set_Theory`

Alternative Set Theory (2/2)

So:

- put differently we want to know the indicator functions for instance:

$$1_B : \begin{cases} D & \mapsto & \mathbb{B} \\ p & \longrightarrow & \textit{true} \text{ or } \textit{false} \end{cases}$$

- however we cannot be so sure about the belonging of a given point to a particular set
- we have to deal with imprecision, vagueness, and uncertainty
- we do not want classical sets any more

Information Management

Different solutions are disparate sources of information.

So:

- we have O_1, O_2, .., O_n solutions
- we have to fuse those sources of information to take a final decision O
- we can have concordant information at the same time as discordant one
- we may want to be either severe or tolerant towards those sources; otherwise, we want to take a compromise

See also: http://en.wikipedia.org/wiki/Information_Management

Statistical Classification

An image is a *population* of items.

So:

- a point is an individual item
- every item is known by a vector of features
- in feature space, items are grouped into clusters
- a cluster is homogeneous w.r.t. the item features
  a cluster is representative of the presence of an object in the scene
- thus we aim at identifying clusters

See also:

`http://en.wikipedia.org/wiki/Statistical_classification`

Meta Heuristics

The expected solution can be expressed as the result of an *optimization* problem.

So:

- the image O to be found has $\overline{D}$ points
  for instance consider a small image where $\overline{D} = 100^2$
- every point in O has a value in S
  so $\overline{S} = 4$
- so the search space contains 4^{100^2} different potential solutions (they are about 10^{6000}...)
- thus we need heuristics to avoid exploring the whole space

See also: `http://en.wikipedia.org/wiki/Meta_heuristics`

Physical Models

A physical model is *applied* to image processing to drive a filter or a transform.

For instance:

- elastic deformation
- optical flow
- diffusion
- and so on...

See also: `http://en.wikipedia.org/wiki/Model_(physical)`

Recap

what a point is	*context*
node of a graph	topology
sample of a discrete function	signal
element	alternative set theory
site of a random variable	probability
subject of information sources	information management
part of a body or space location	physical model
item in a population	statistical classification
variable of a problem	meta heuristics
...	

And Also...

what a point is	*context*
...	
point of a landscape	mathematical morphology
token	grammar
...	

Two Important Ideas

- replace “point” by “feature—or pattern” and you end up with higher-level methods
- all these contexts are of prime importance in computer science