Digital Image Analysis

also

Theory of Image Processing

Topic 1: Background

Contents:

- History and Development
- Digital Image Processing Tasks
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- Digital Images
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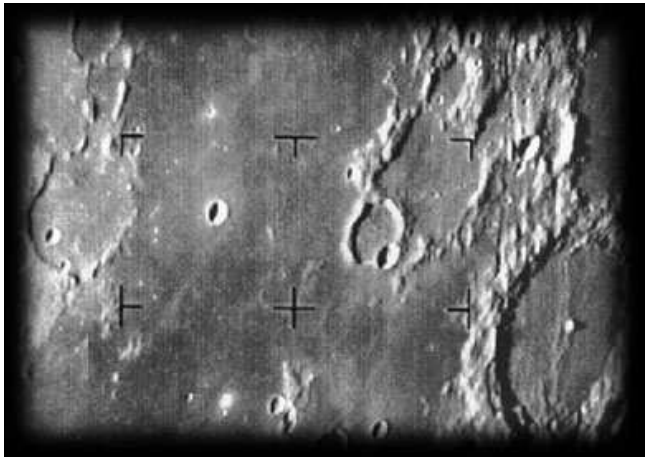
History and Development

Initial ideas back to 1920 for cable transmission of pictures.

First Computer Processing introduced about 1964 at JPL Used in images from *Ranger-7* video images.



Last Ranger 7 image transmitted 2.5 second before impact on moon.

History and Development

Developed for *Surveyor* and *Mariner* space missions.

- Early work associated with geometric corrections and data transmission errors.
- Processing performed in large Mainframe computers.

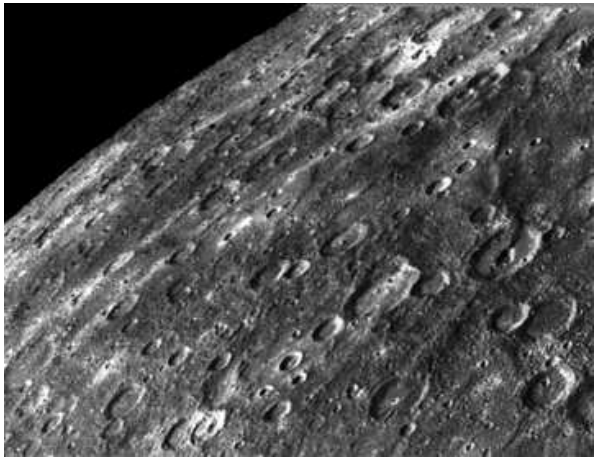


Image from Mercury Mariner 10 29-3-1974

Early work limited to space projects, due to cost of computer systems and especially display systems.

First Textbook *Picture Processing by Computer*, A. Rosenfeld, Academic Press, 1969.

Advancements

Main growth started in mid/late 1970, and followed development of computer hardware.

Late ’70s: Development of the *Super-Minis*:

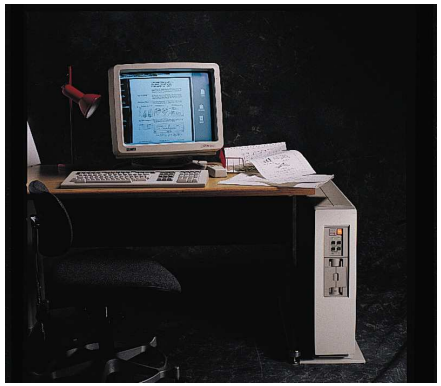
- Wardrobe size 32-bit, 1 MIP, (1 MHz), Cheap enough for small research groups.
- First image display devices (frame stores).
- Major UK push via Starlink network.

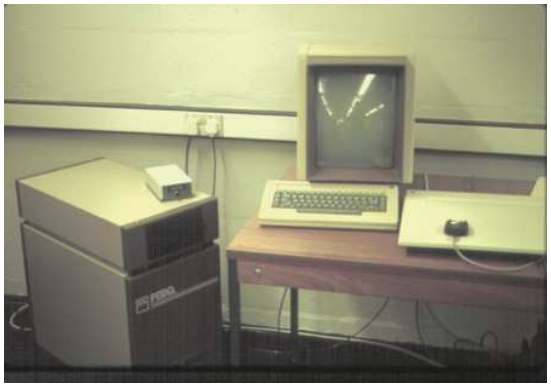
Start of remote sensing, weather observations and astronomical digital analysis.

Advancements I

Early/Mid 1980: Graphics workstations, (SUN, Apollo, VaxStation)

- *Fast* processor, (PC-386), with integrated display. (solved the image display problem)
- Desk-side size.
- Cheap enough for single researcher.
- Put big computer power on the desk-top.





Main area of growth of subject. Most of the theory and implementation developed.

Start of industrial inspection, scientific imaging, computer vision.

Advancements II

Late 1980/early 1990s *Supercomputer* graphics workstations, (Sun 10/40, HP-9000, Dec-Alpha, Silicon-Graphics)

- *Very fast* desk-top machines (100 Mips now common)
- Common environment (X-windows)
- Cheap, available for teaching.
- Also custom graphics/imaging hardware

Start of all-digital publishing, image processing going outside the research lab.

Advancements III

2000s The PC comes of age. Modern Pentium machines have power and memory of *Supercomputer* graphics workstations.

- Many big image processing packages written, or ported to PC.
- Vast growth in digital photography, all PC based.
- Digital imaging to PC systems now routine in many scientific applications.

2003-onwards Digital imaging makes the mass market.

- Digital camera in mobiles, PDA.
- Image processing packages come free on PC.
- Self-service digital image printing and enhancement.
- All video and TV going digital.

Basic theory of digital sampling and processing common to all these techniques.

Digital Image Processing Tasks

Image Reconstruction

- Removal of system or imaging aberrations.
- Aims to reconstruct the *best* image from collected data.
- Typically output images for visual inspection.

Example of maximum entropy reconstruction.

Digital Image Processing Tasks I

Image Analysis

- Computer analysis of images.
- Extract *features* or *regions*
- Recognition of objects.
- High level pattern recognition.

Example of extraction of linear features using Hough Transform.

Digital Image Processing Tasks II

Image Formation Image formed by computer,

1. Computer Tomography (medical/astronomical)
2. Aperture Synthesis (astronomical)
3. Synthetic aperture radar (SAR)
4. Also CAD/CAM and Computer Graphics, video games.

Digital Image Processing Tasks II

Image Compression and Encoding

- Document and image storage.
- Image transmission (video Telephone), digital TV, Interactive video. (MPEG).

Example of Jpeg compression.

Applications of Image Processing

- **Remote Sensing:** satellite of aircraft images for earth resource, weather, sea surface, etc.
- **Inspection and Automation:** robotic control, manufacture control, quality inspection, safety monitoring.
- **Medical Imaging:** X-ray, Computer tomography, MRI, PET, γ-camera, thermal-IR, sample inspection.
- **Astronomical Applications:** main observation tool, photon camera, radio image formation, aperture synthesis, radio interferometry.
- **Scientific:** microscope sample analysis, confocal imaging, x-ray analysis, surface inspection, STM, AFM, etc.
- **Data Compression:** document storage, data reduction, JPEG/MPEG, digital image transmission.
- **Communications:** video telephone, multi-media computer links, document transmission, secure data links.
- **Military Applications:** target tracking, surveillance, smart weapons, automated guidance, secure data links.

Digital Images Parameters

An *Image* is reflected or emitted radiation from object or scene

Image is stored in the computer as *array of numbers*, obtained from:

- Sampled from an analogue source, (photographic film, video signal).
- Directly digitally sampled, (CCD array camera, point by point measurement)

Images usually sampled on a regular grid, although rectangular, or even hexagonal possible.

An example of a 128×128 8 bit image (that you are going to see a lot off!!)

Digital Images Parameters I

Noise: Effect of film grain, electrical noise, quantum nature of light, data transmission errors, non-linear detector systems.

Grey Level Sampling: Number of *bits* used to represent one image point or pixel. Typically 8-bits from video quality image, 24-bits for full colour. (more for specialist imaging systems).

Spatial Sampling: Separation of points on sampling grid, so gives the image size. Depends on the bandwidth of the imaging system and quality of the images required.

Image Spatial Resolution

Spatial resolution gives image size, and amount of data that has to be processed.

Low Resolution : Typically 640×480

- Video quality image, computer vision.
- WWW images (most at 640×480)
- Very cheap digital cameras
- Basic size used in inspection surveillance etc.
- True video images are optimally sampled at 768 by 586 pixels (UK standard).

Medium Resolution: Typically 1280×960 or 1280×720

- The new hi-resolution digital video
- Output from DVD players, still from camcorders.
- Current mass-market digital cameras (2 MegaPixel)
- Current good quality flat screens and data projectors.

Image Spatial Resolution I

High Resolution : Up to 3000 square

- Satellite remote sensing up to 3000 by 4000 pixels
- Radar image typically 3800 by 2800,
- Photo-CD images.
- High quality digital cameras (10 MegPixel)
- Few display at this size, but are coming!!

Many of these images are “multi-spectral” with up to 7-bands.

Super High Resolution: Up to 8000 square

- Colour separations for printing
- Computer synthesised image for movie films
- Professional digital cameras.

Both typically 4-colours (red, green, blue & black).

Computational Problem

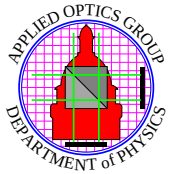
Large data arrays, (up top 8000 by 8000), large storage and memory problems. (one image is 56 Mbytes)

Real Time Processing :

$$\begin{array}{rcl} \text{Standard video} & \Rightarrow & 6.5 \text{ Mbytes/sec} \\ 3 \times 3 \text{ filter} & \Rightarrow & 200 \text{ Mips} \end{array}$$

Up the the last few years needed special hardware, not standard PC just about fast enough.

Can use *all available speed* by working with *bigger images*.



Summary

We have just seen,

- Vast range of applications.
- Mixture of physics (optics), mathematics, computing and electrical engineering. (could be taught in a range of Departments).
- Very large growth area, especially with WWW, digital publishing.

Common lectures will cover:

1. Basic image formation (a little optics)
2. Digital sampling of data including images.
3. Elementary processing and its implications.
4. Noise models in images
5. Filtering of images in real and Fourier space
6. Image reconstruction by deconvolution.
7. Tomographic image formation and its implications.

Summary I

then in **Theory of Image Processing** only,

1. Edge and Line detection.
2. Stereo imaging and processing techniques.
3. Target tracking and elementary Pattern Recognition.
4. Something else if time allows. . .