Requirements drive technology
Factors influencing utilization of images
- Nature of the object of interest and its surrounding
- Imaging technology
- Interactions between object and surroundings with beam (image formation)
- Information transfer to observer’s eye (image processing and display)
- Observer’s cognition and action
Morgan 1966

[1895-1900] Early days

[c 1900] Fluoro QA Tools

[c 1897] Fluoroscopic examination

[1897] Customs inspection
[1905] Fluoroscopy radiation protection

- Dr. Price's Original Gloves
- Protective Spectacles

C 1940

[1905-1910] Fluoro set with a QA tool

[1910] Clinical

[1926, 1940] Radiographic/Fluoroscopic table

[1947] Chest Fluoroscopy

[1942] Light sensitivity of the eye

Dynamic range = $10^{10}$
Dark adaptation effects

![Graph showing dark adaptation effects](image)

[c 1950] Dark adaptation

![Image of dark adaptation](image)

Fluoro screen photon-flux diagram

![Fluoro screen photon-flux diagram](image)

[1949] Dose limited perception

![Graph showing dose limited perception](image)

[1940] Image intensifier patent (GE)

![Image of image intensifier patent](image)

[1948] Image intensifier

![Image of image intensifier](image)
Video tubes and cameras

[c 1965] Video viewing

[c 1965] Cine + video + mirror

- Camera is likely to be a vidicon.
  - Target technology causes ghosting (due to signal decay).
  - Orthicons used for broadcast TV to eliminate ghosting artifacts.
  - Beneficial for fluoro because lag integration reduces image noise.
- Plumbicons (later tech) had faster targets and almost no lag.
  - Complaints about noisy images (SVH-1972)
  - Lag reintroduced via digital processing (recursive filtering)

Optical distributor with film camera

[c 1970] Cardiac Catheterization Labs

[c 1970] Under table image intensifiers

[c 1975] Dual mode II tube & II factory

Image Intensifier / Optical - Artifacts

[c 1970] Radiographic rapid film changers

[c 1975] ZnCdS – CsI Input screens

[1980] Close-coupled video pickup
**[1980] forecast for 2000**

- **[1979] IV Analog Subtraction Angiography**

- **[1980] Digital Subtraction (DSA)**

- **[c 1980] DSA Hardware**

- **[c 1990] Spectral shaping**

- **[c 2000] Digital fluorography replaces film and analog**
Spatial Resolution = f(detector & image handling)

| TABLE 1: Illustrative specifications of two current (2019) flat-panel fluoroscopic image receptors. (adapted from published specifications of commercially available devices) |
|--------------|-----------------|-----------------|-----------------|
| DEVICE CLASS | Large (nominal 43 cm diagonal) | Small (nominal 25 cm diagonal) |
| Nominal pixel size | 0.15 x 0.15 mm | 0.18 x 0.18 mm |
| Field of View (FOV) Matrix | Usually labeled as diagonal 43 cm (30 cm) | 21 cm (15 cm) |
| | (corresponding edge of field) | 20 cm (15 cm) |
| | 18 cm (13 cm) | 17 cm (12 cm) |
| | 15 cm (10 cm) | 14 cm (9 cm) |
| Digital Output Specification | Radiologic Output (< 6 fps) | Fluoro Output (@ 30 fps) |
| | 2048 x 2048 | 1024 x 1024 |
| | Fluoro Output (@ 60 fps) | 512 x 512 |

Comparison with normal

Pt. Gender? Finding?
Clinical protocol development

Welcome to multi-parameter space......
What are the relevant parameters?

**APPLICATION**
- Fluoroscopy
- (cine) exposure
- Digital subtraction angiography
- Roadmap

**Requirements differ**

### Image processing

- Typical image processing pipeline
  - Look-up tables, windowing
  - Spatial filters
  - Temporal filters

**Basic goal:**
- Transfer maximal information from detector into the eye/brain
- Consider the channel to the eye

**Challenges:**
- Grey level dynamics and resolution
- Spatial resolution
- Temporal resolution
- "Relevant information"

Advanced image processing: building blocks

- Spatial noise reduction
- Temporal noise reduction
- Automatic live motion compensation
- Image Enhancement

Global Recursive Filtering

\[
y(t) = \frac{1}{k} x(t) + \left(1 - \frac{1}{k}\right) y(t-1)\]

\[
\sigma_{\text{avg}}^2 = \frac{1}{2k-1} \sigma^2 + \frac{1}{2(2k-1)} \sigma_{\text{new}}^2
\]
Content-Aware Image Processing

Simulation of Local Image Processing

Optimization for material of objects of interest

Goals for processing

What's past is prologue*

Questions?

* Shakespeare – Tempest

• 1896 – 1925 Open systems requiring considerable operator interaction
• 1920 – 1970 Closed systems with fluoroscopic screens
• 1955 – 2000 Image intensifiers with analog image handling & film
• 1980 – 2019 DSA
• 1990 – 2019 Image intensifiers with X-ray spectral management, digital image handling & PACS
• 2000 – 2019 Flat Panel detectors, IEC standards for fluoro
• 2010 – 2019 Adaptive processing

• Adjust image processing to the clinical task
  – A-priori knowledge for the specific clinical task
  – Consider (image) context
  – Model-based approach
    (for finding devices, like wires and stents)
  – Configure image pipeline for dedicated protocols
• Optimize image presentation to the eye / brain
  – Grey level dynamics, contrast (coarse and detail), noise, size of structures
• Create image presentation preferred by user
  – Image presentation is subjective
  – There is no “one fits all”