Lecture 01 – Introduction to image processing

Prof. João Fernando Mari
joaofmari.github.io
joaof.mari@ufv.br

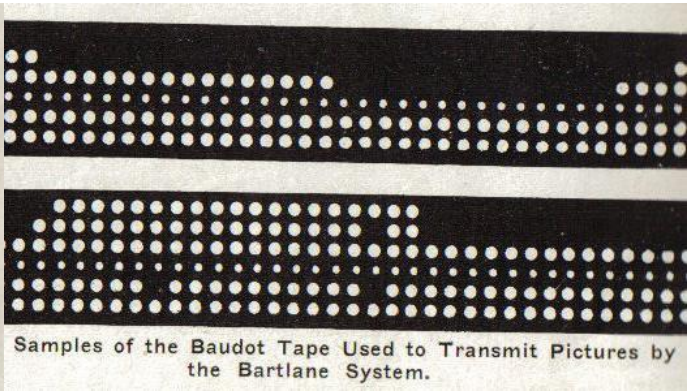
Agenda

- The Bartlane system
- The space program
- O electromagnetic spectrum
- Image processing in Brazil
- An application of image processing
  - Computer tomography

The Bartlane system

- One of the first applications of digital images
- Used to send digital images through submarine cable between London and New York
- It has reduced the time to send a photo across the Atlantic Ocean form over a week to less than three hours
- One equipment encoded the images for the cable transmission e latter reconstruct them on the receiving
- No image processing occurs

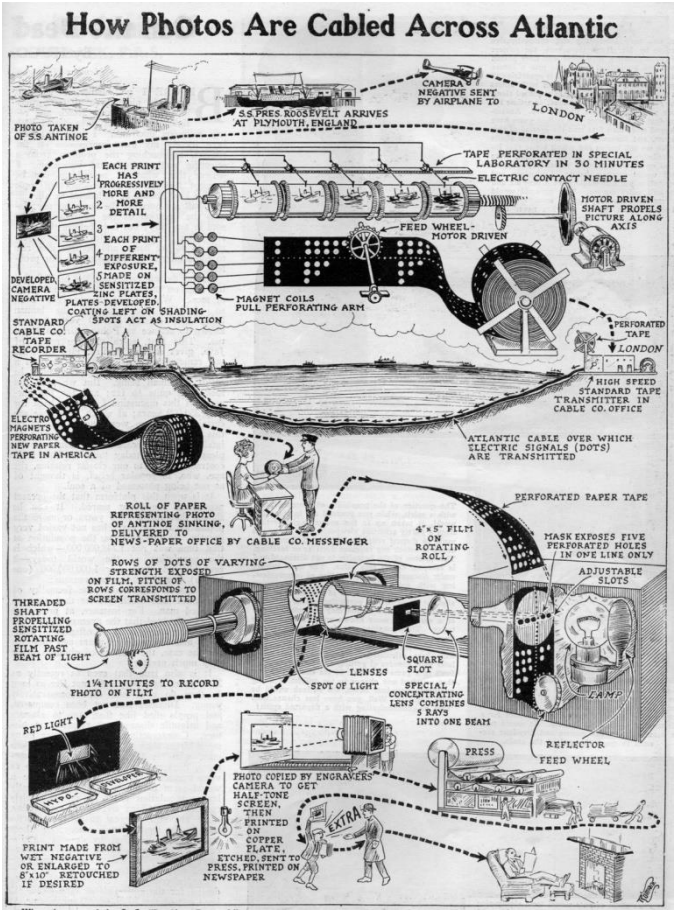
The Bartlane Transmitter.



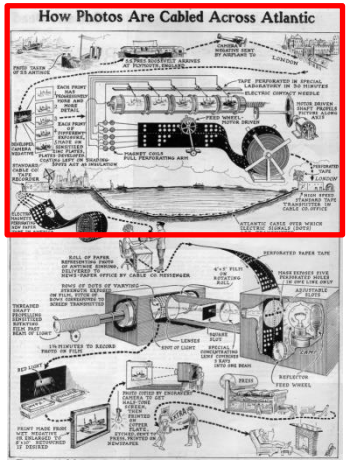
Samples of the Baudot Tape Used to Transmit Pictures by the Bartlane System.

http://www.hffax.de/history/html/bartlane.html

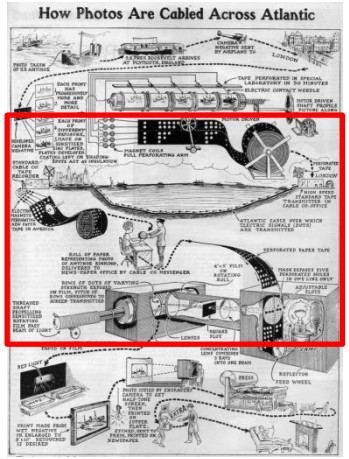
The Bartlane system



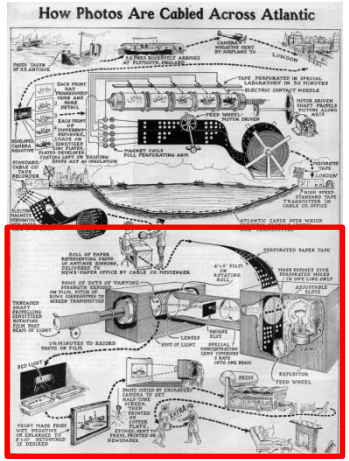
The Bartlane system

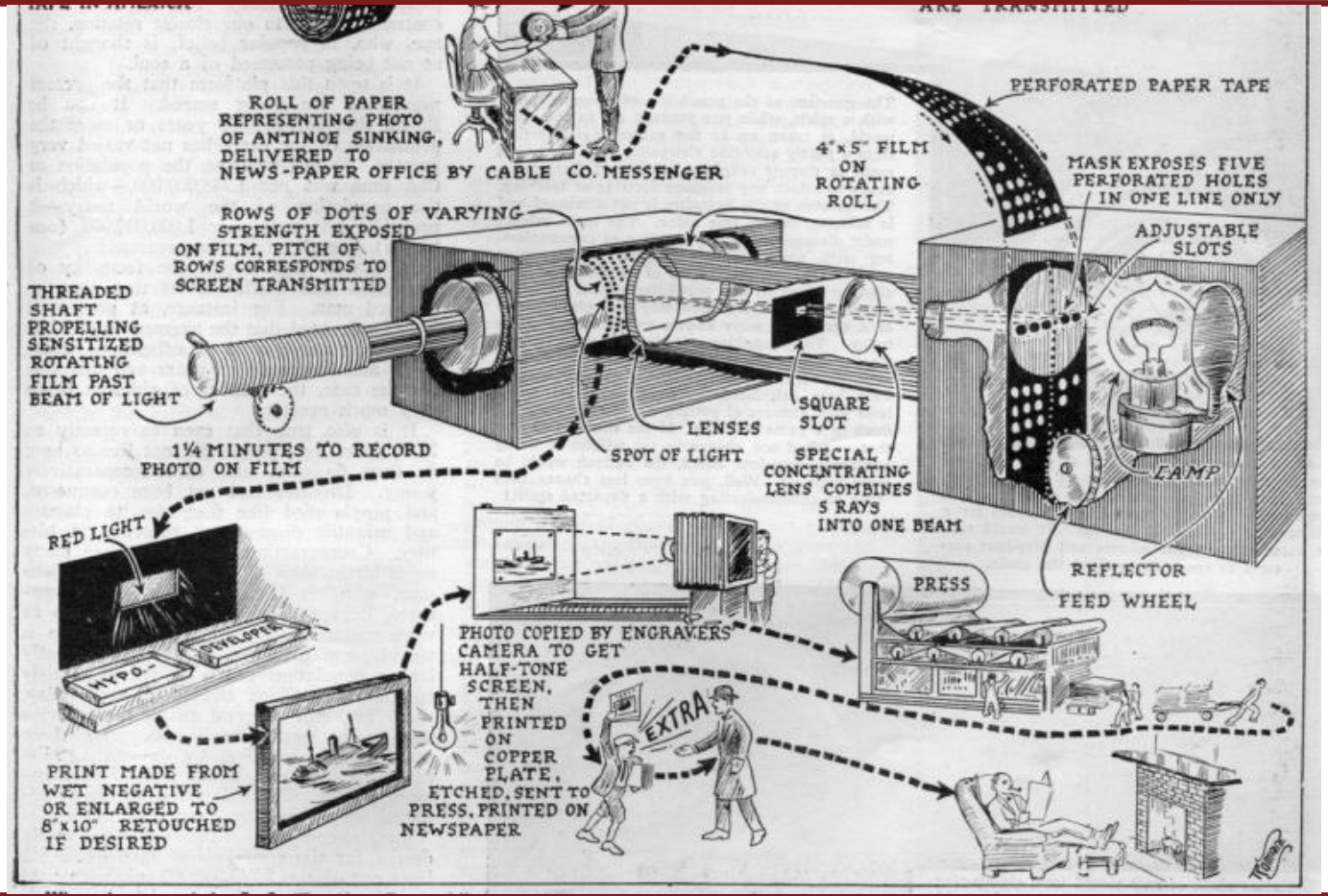


The Bartlane system



The Bartlane system





The space program

UFV
Universidade Federal de Viçosa

- JPL – Jet Propulsion Lab (Pasadena, California), 1964

- Ranger 7
  - Sonda espacial Ranger enviada para fotografar a Lua
  - Imagens eram obtidas por câmeras de televisão
  - Enviadas para a Terra por ondas de rádio
  - Necessidade de processar as imagens
    - Melhorar a qualidade das imagens
    - Obter a maior quantidade de informação possível

- Video Film Converter
  - Desenvolvido para converter os sinais de vídeo analógicos para imagens digitais

- Computador NCR 102D
  - Usado para processar as imagens digitais
  - Ajuste de contraste
  - Normalização da iluminação
  - Remoção da imagens residual proveniente de capturas anteriores
  - Remoção de ruído de transmissão
  - Correções geométricas usando marcas reseau.

The space program

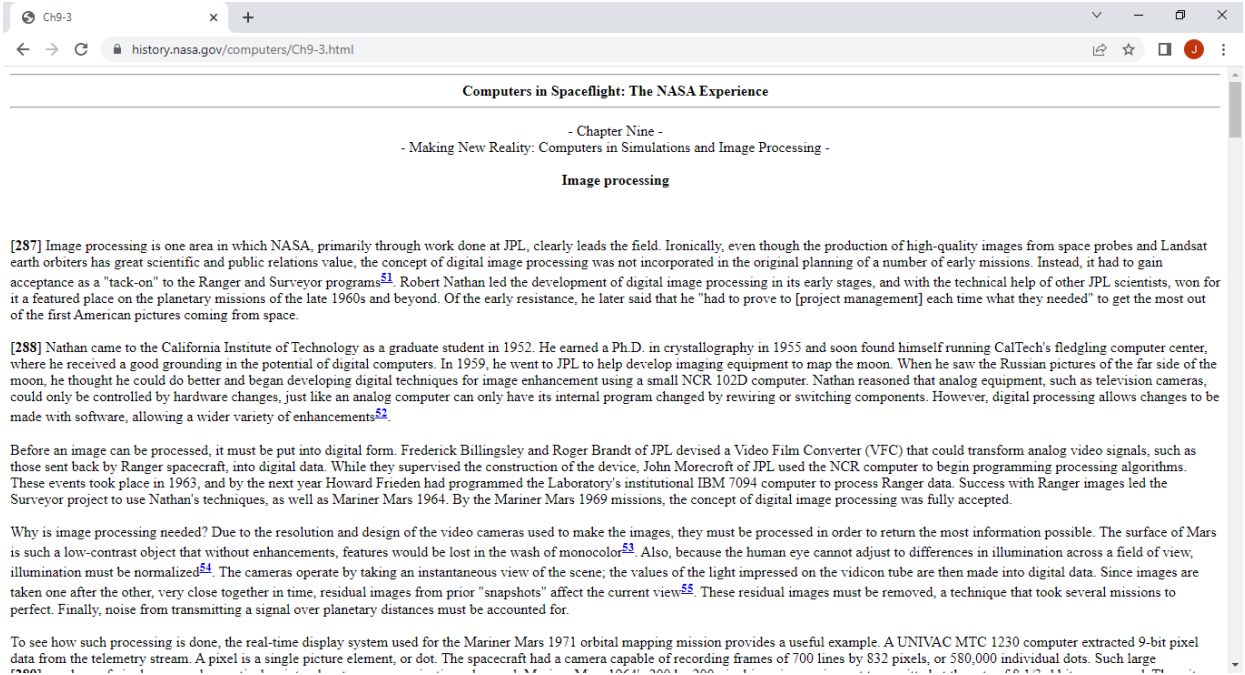
- Fist image of the moon taken by the Ranger 7.
- July 31, 1964
- About 17 minutes before the impact in the lunar surface.

The Ranger 7 probe.

https://pt.wikipedia.org/wiki/Ranger_7

The space program

- Computers in Spaceflight: The NASA Experience.
  - Chapter Nine. Making New Reality: Computers in Simulations and Image Processing.
    - https://history.nasa.gov/computers/Ch9-3.html



Ch9-3

history.nasa.gov/computers/Ch9-3.html

Computers in Spaceflight: The NASA Experience

- Chapter Nine -
- Making New Reality: Computers in Simulations and Image Processing -

Image processing

[287] Image processing is one area in which NASA, primarily through work done at JPL, clearly leads the field. Ironically, even though the production of high-quality images from space probes and Landsat earth orbiters has great scientific and public relations value, the concept of digital image processing was not incorporated in the original planning of a number of early missions. Instead, it had to gain acceptance as a "tack-on" to the Ranger and Surveyor programs[51]. Robert Nathan led the development of digital image processing in its early stages, and with the technical help of other JPL scientists, won for it a featured place on the planetary missions of the late 1960s and beyond. Of the early resistance, he later said that he "had to prove to [project management] each time what they needed" to get the most out of the first American pictures coming from space.

[288] Nathan came to the California Institute of Technology as a graduate student in 1952. He earned a Ph.D. in crystallography in 1955 and soon found himself running CalTech's fledgling computer center, where he received a good grounding in the potential of digital computers. In 1959, he went to JPL to help develop imaging equipment to map the moon. When he saw the Russian pictures of the far side of the moon, he thought he could do better and began developing digital techniques for image enhancement using a small NCR 102D computer. Nathan reasoned that analog equipment, such as television cameras, could only be controlled by hardware changes, just like an analog computer can only have its internal program changed by rewiring or switching components. However, digital processing allows changes to be made with software, allowing a wider variety of enhancements[52].

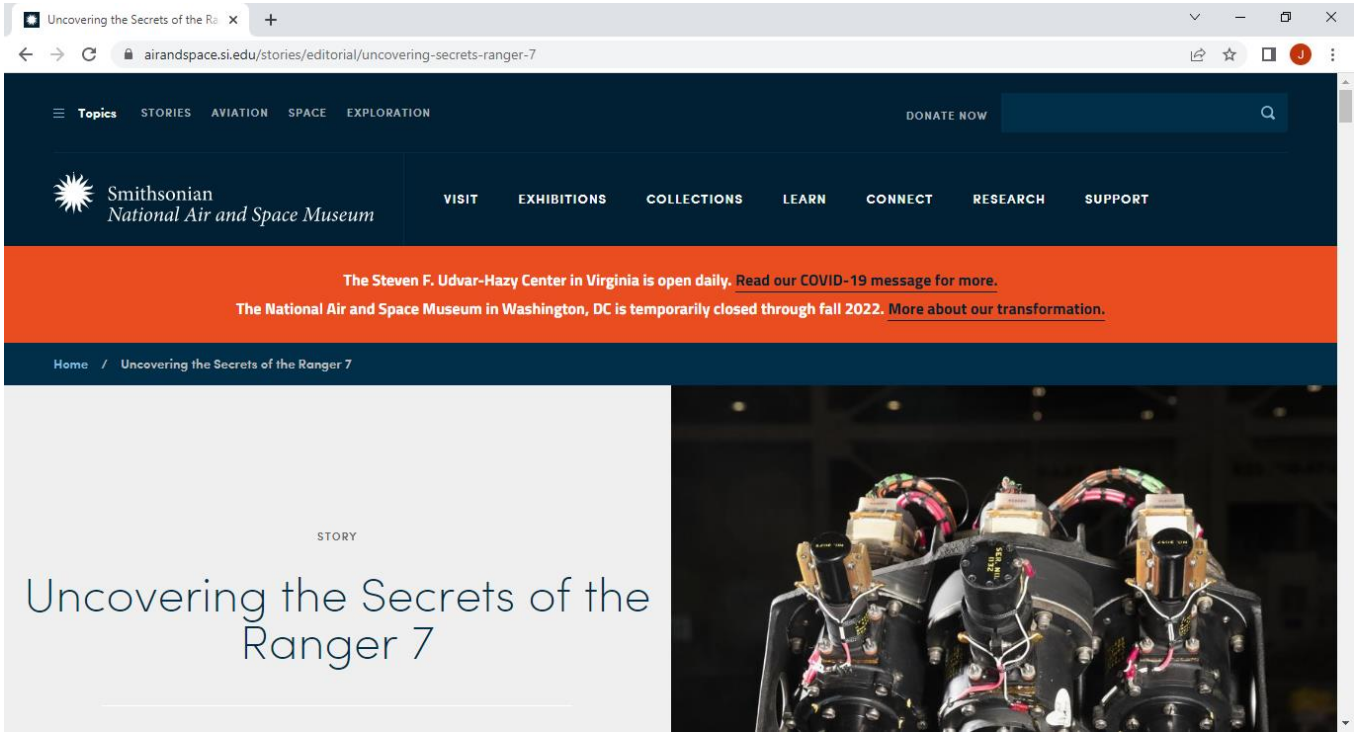
Before an image can be processed, it must be put into digital form. Frederick Billingsley and Roger Brandt of JPL devised a Video Film Converter (VFC) that could transform analog video signals, such as those sent back by Ranger spacecraft, into digital data. While they supervised the construction of the device, John Morecroft of JPL used the NCR computer to begin programming processing algorithms. These events took place in 1963, and by the next year Howard Frieden had programmed the Laboratory's institutional IBM 7094 computer to process Ranger data. Success with Ranger images led the Surveyor project to use Nathan's techniques, as well as Mariner Mars 1964. By the Mariner Mars 1969 missions, the concept of digital image processing was fully accepted.

Why is image processing needed? Due to the resolution and design of the video cameras used to make the images, they must be processed in order to return the most information possible. The surface of Mars is such a low-contrast object that without enhancements, features would be lost in the wash of monocolor[53]. Also, because the human eye cannot adjust to differences in illumination across a field of view, illumination must be normalized[54]. The cameras operate by taking an instantaneous view of the scene; the values of the light impressed on the vidicon tube are then made into digital data. Since images are taken one after the other, very close together in time, residual images from prior "snapshots" affect the current view[55]. These residual images must be removed, a technique that took several missions to perfect. Finally, noise from transmitting a signal over planetary distances must be accounted for.

To see how such processing is done, the real-time display system used for the Mariner Mars 1971 orbital mapping mission provides a useful example. A UNIVAC MTC 1230 computer extracted 9-bit pixel data from the telemetry stream. A pixel is a single picture element, or dot. The spacecraft had a camera capable of recording frames of 700 lines by 832 pixels, or 580,000 individual dots. Such large

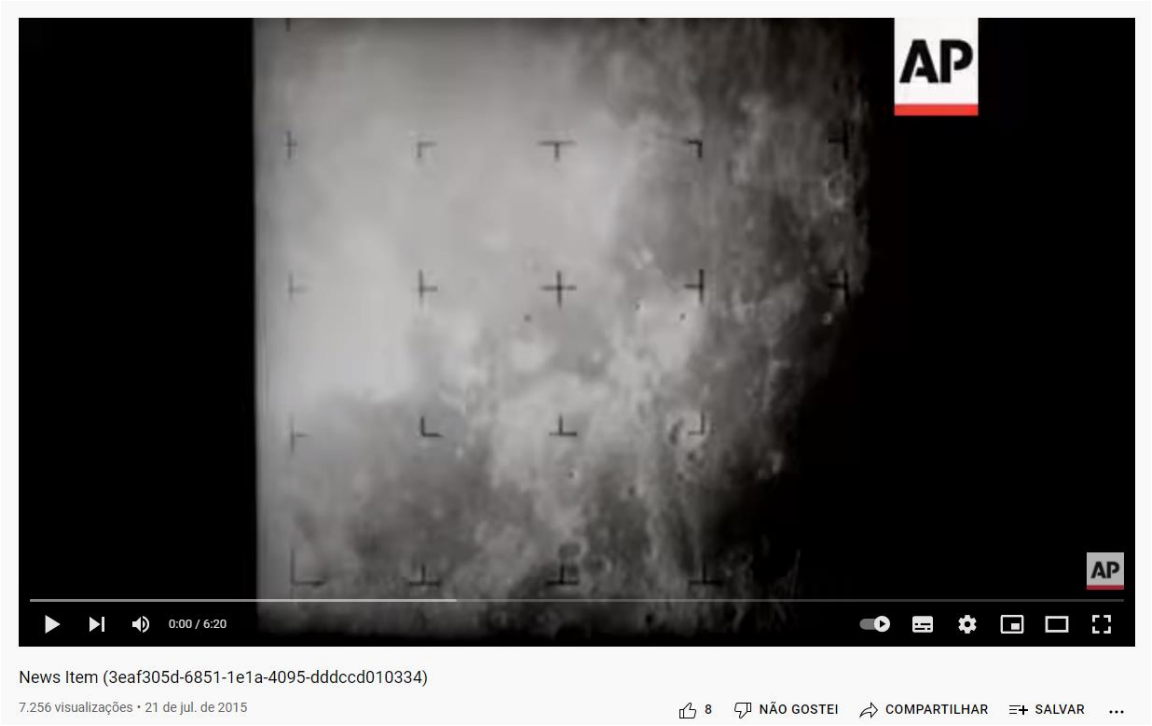
The space program

- Matthew Shindell. Uncovering the Secrets of the Ranger 7. July 31, 2018
  - https://airandspace.si.edu/stories/editorial/uncovering-secrets-ranger-7



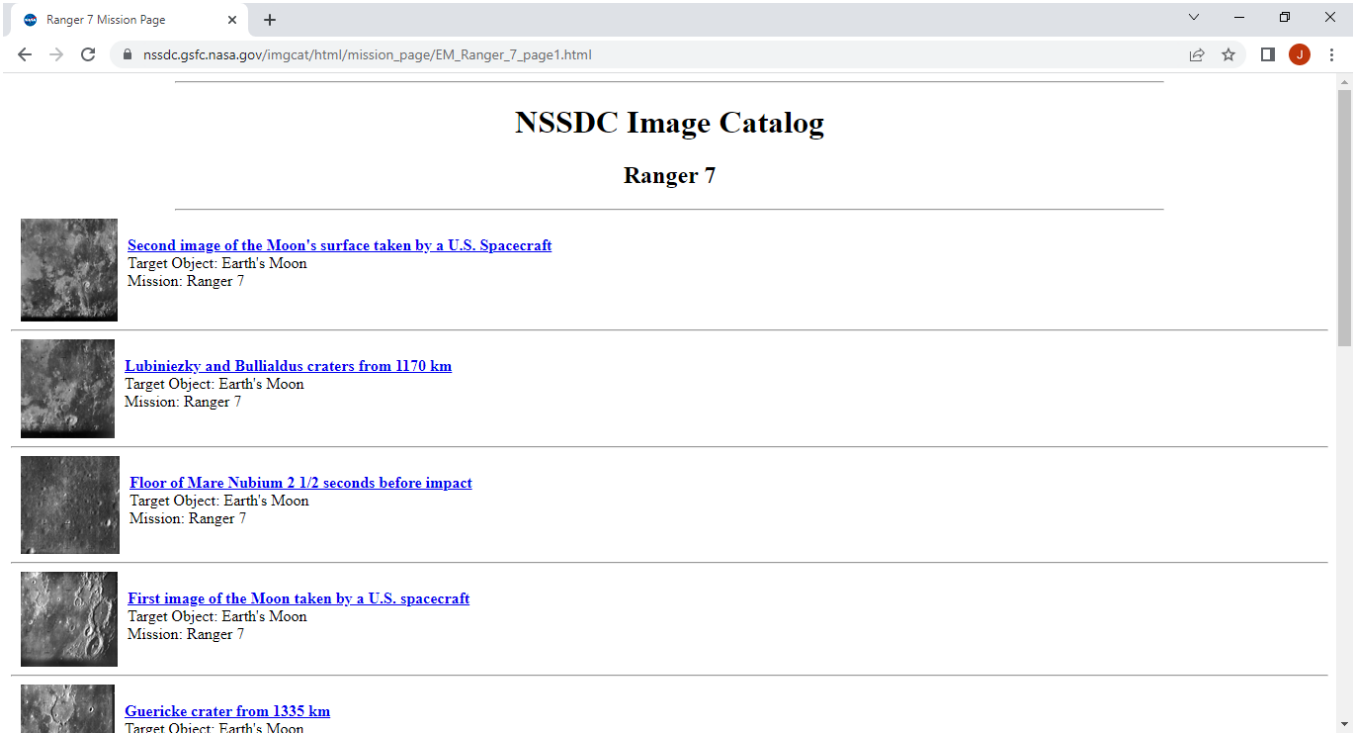
The space program

- US: Ranger 7 - 1964
  - https://www.youtube.com/watch?v=QGJbybcXd0c

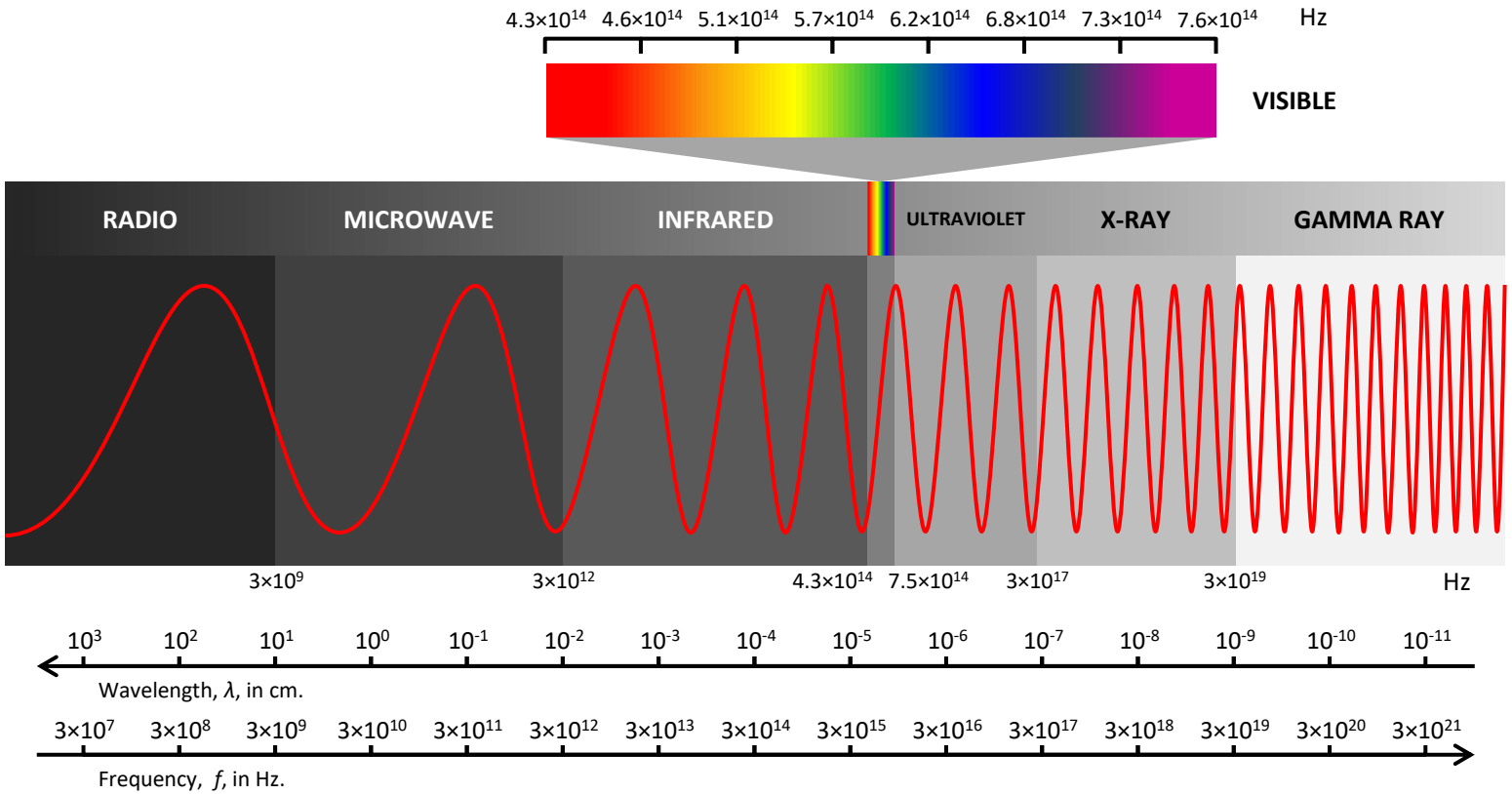


The space program

- NSSDC Image Catalog – Ranger 7
  - https://nssdc.gsfc.nasa.gov/imgcat/html/mission_page/EM_Ranger_7_page1.html



The electromagnetic spectrum



The electromagnetic spectrum

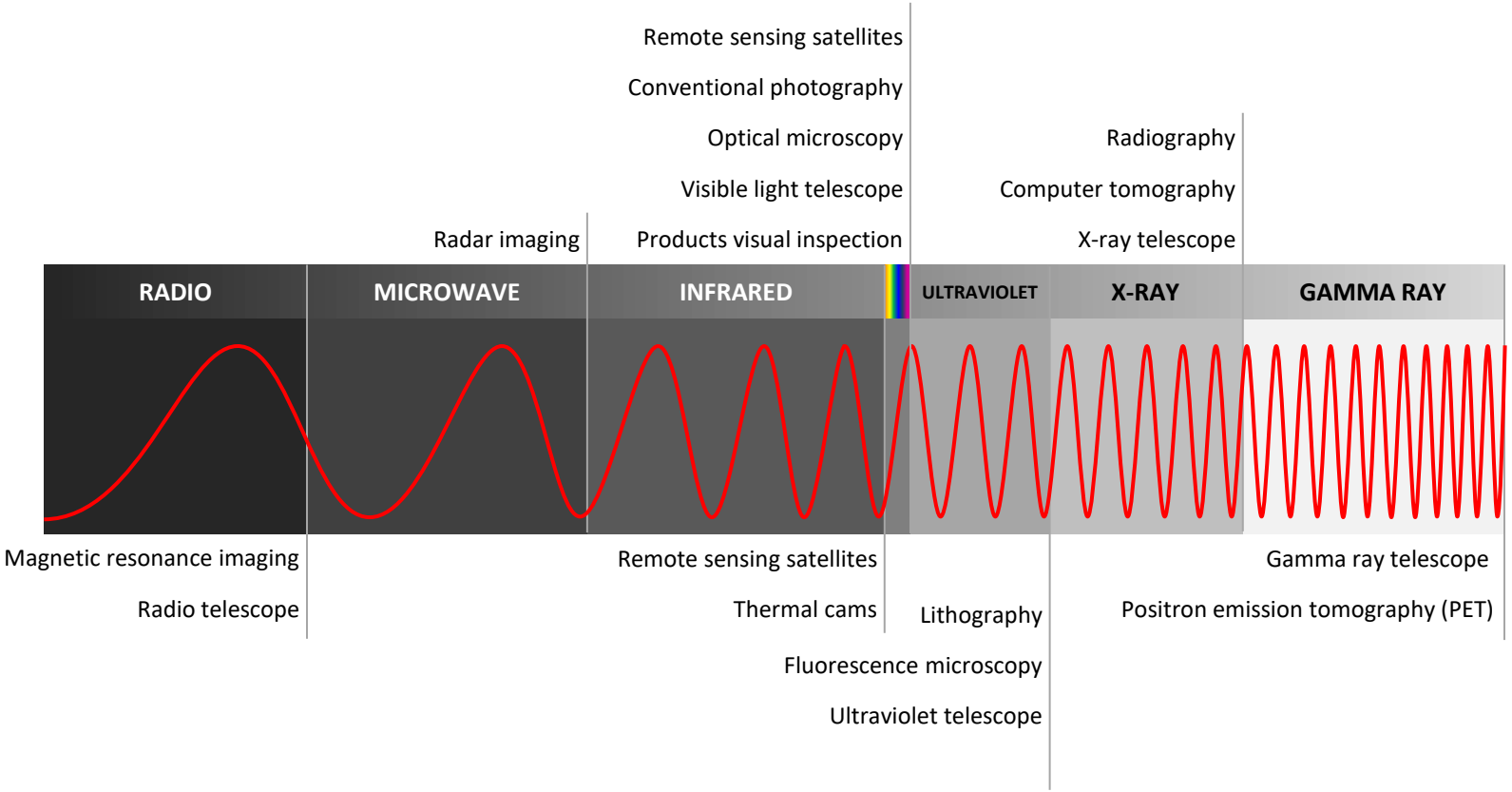


Image processing in Brazil

- INPE – National Institute for Space Research
  - (INPE – Instituto Nacional de Pesquisas Espaciais)

- GE IMAGE-100, 1974
  - Image Processing System
  - US$ 1.000.000,00
  - PDP/11-45 with 128 KB memory
  - Video memory of 512 x 512 pixels

INPE. http://www.inpe.br/noticias/galeria/

INPE: http://www.dpi.inpe.br/DPI/institucional/pessoal/historico

Image processing in Brazil

- INPE – National Institute for Space Research

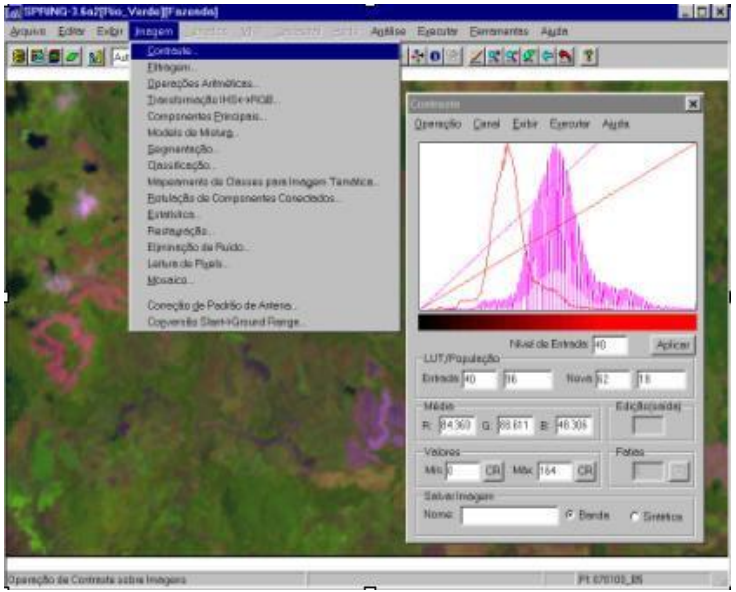
- SITIM – Sistema de Tratamento de Imagens, 1986
  - (in English, Image Treatment System).
  - PC-286 with 8 MHz and 256 Kb memory
  - Graphic card locally developed
  - Images with until 1024 x 1024 pixels and 24 bits per pixel
  - MS-DOS

INPE: http://www.dpi.inpe.br/DPI/institucional/pessoal/historico

Image processing in Brazil

- INPE – National Institute for Space Research

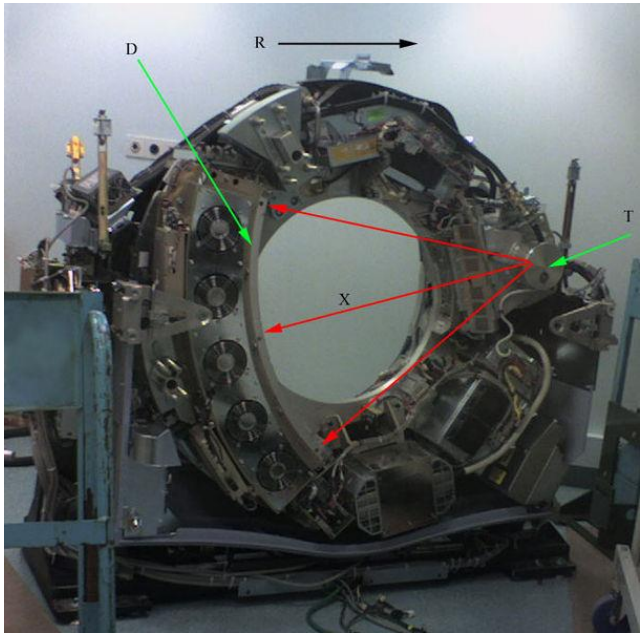
- SPRING – Sistema Integrado de Geoprocessamento e Processamento de Imagens, 1991
  - (in English, Integrated Geoprocessing and Image Processing System)
  - Graphical user interface
  - Currently available for download
    - http://www.dpi.inpe.br/spring/



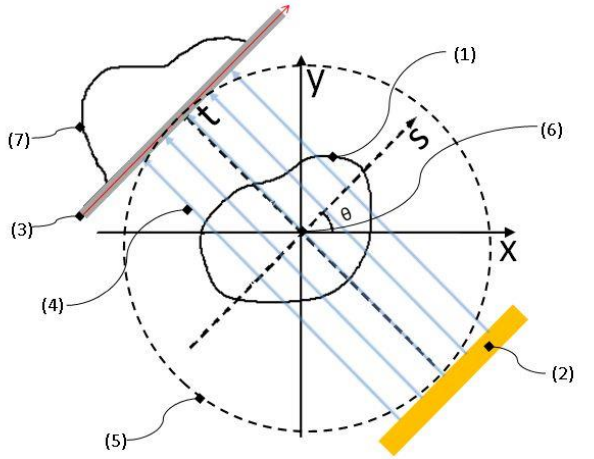
INPE: http://www.dpi.inpe.br/DPI/institucional/pessoal/historico

An image processing application

- Computer tomography
  - Allan Cormack and Newbold Hounsfield (1972)



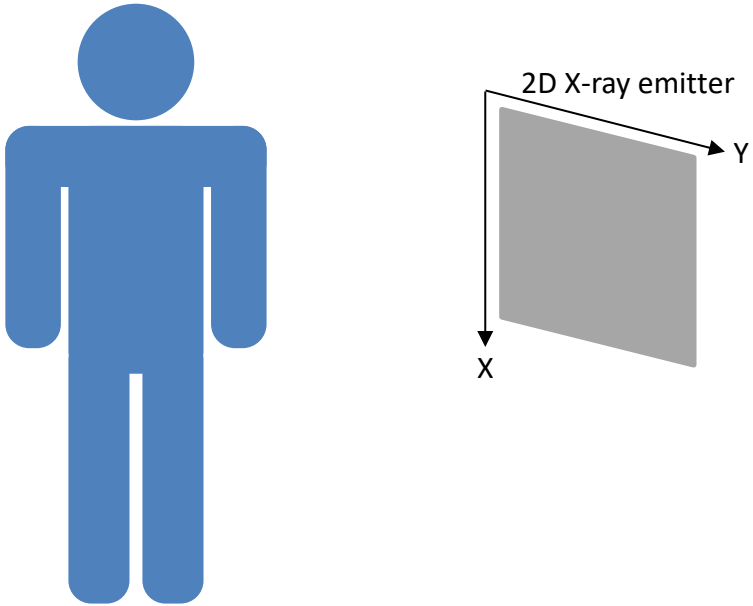
https://pt.wikipedia.org/wiki/Tomografia_computadorizada



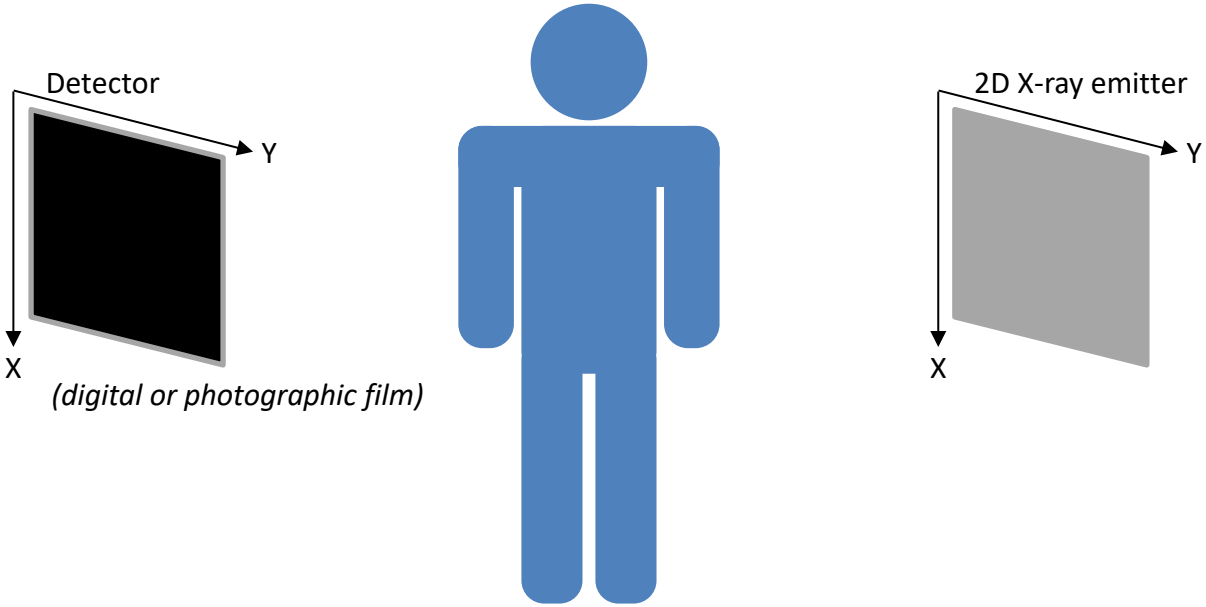
https://pt.wikipedia.org/wiki/Transformada_de_Radon

1. Objeto radiografado;
2. Emissor de raios X;
3. Sensor;
4. Feixe de raios que atravessa o objeto, sofrendo uma atenuação;
5. Limites do aparelho;
6. Origem dos sistemas de referência;
7. Medida obtida no detector.

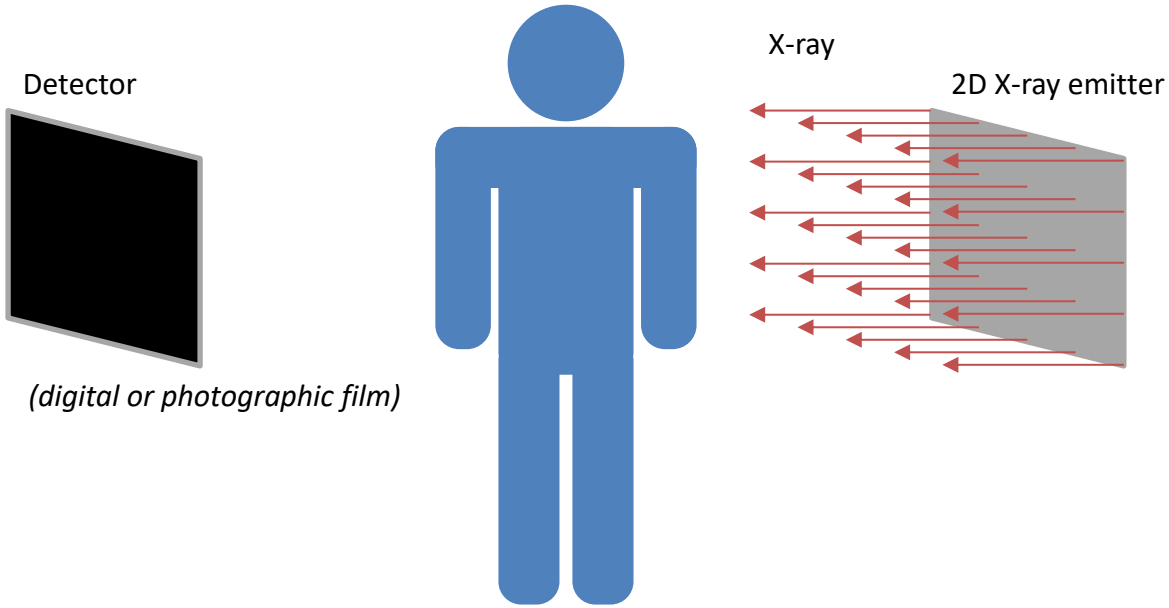
X-Ray



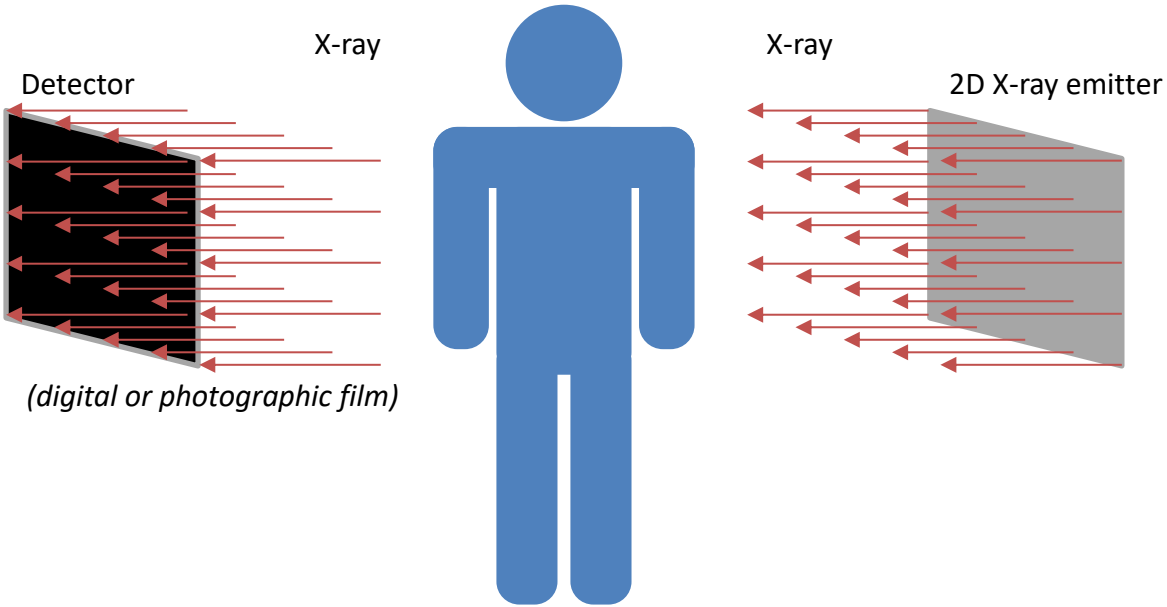
X-Ray

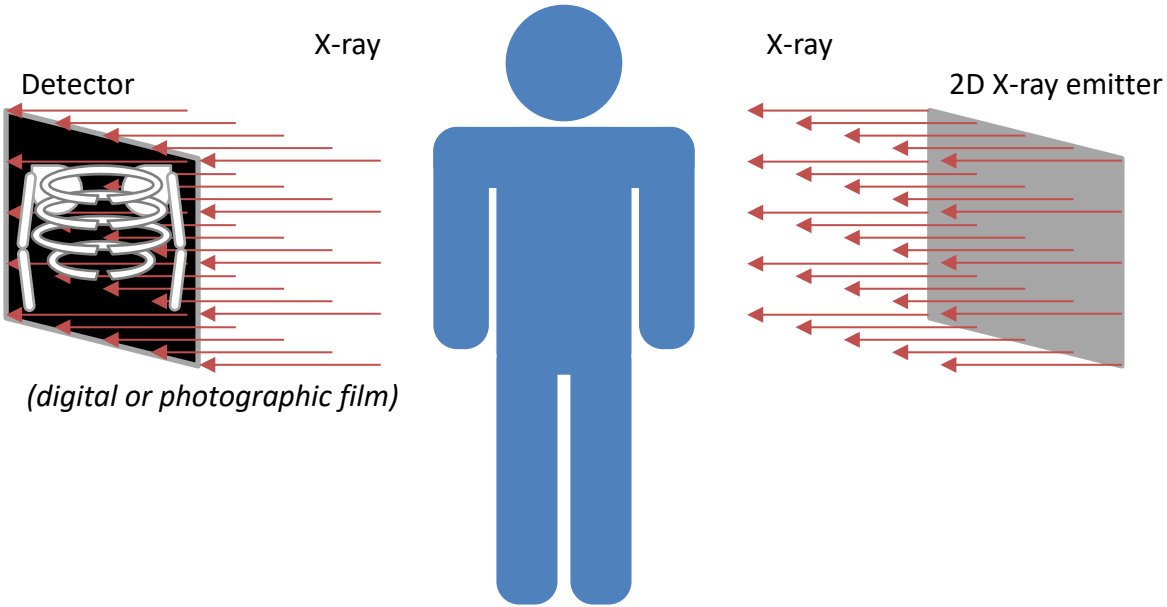

Detector
Y
X
(digital or photographic film)
2D X-ray emitter
Y
X

X-Ray

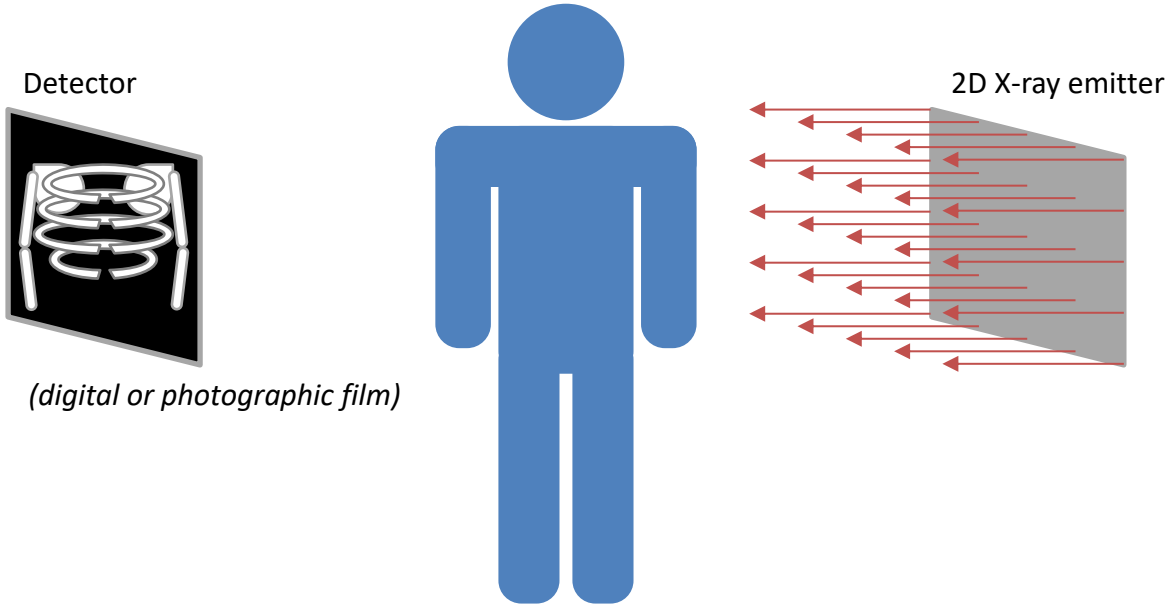

Detector
(digital or photographic film)
X-ray
2D X-ray emitter

X-Ray


X-ray
Detector
(digital or photographic film)
X-ray
2D X-ray emitter

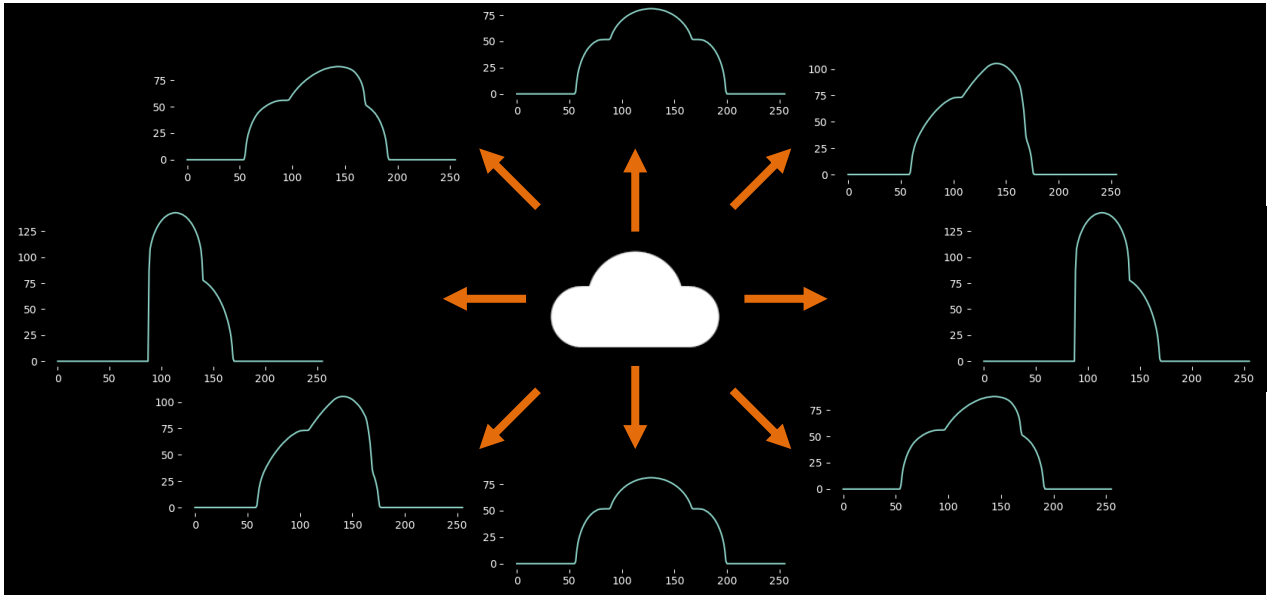

X-ray
Detector
X-ray
2D X-ray emitter
(digital or photographic film)

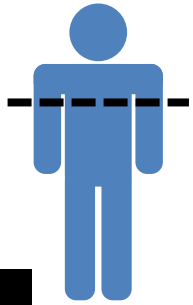
X-Ray

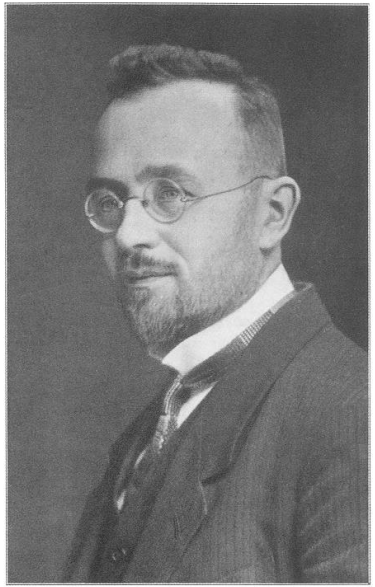


Computer tomography

- The Radon transform (1917)
  - Johann Radon (1887 - 1956)
  - Reconstruction of functions from projections

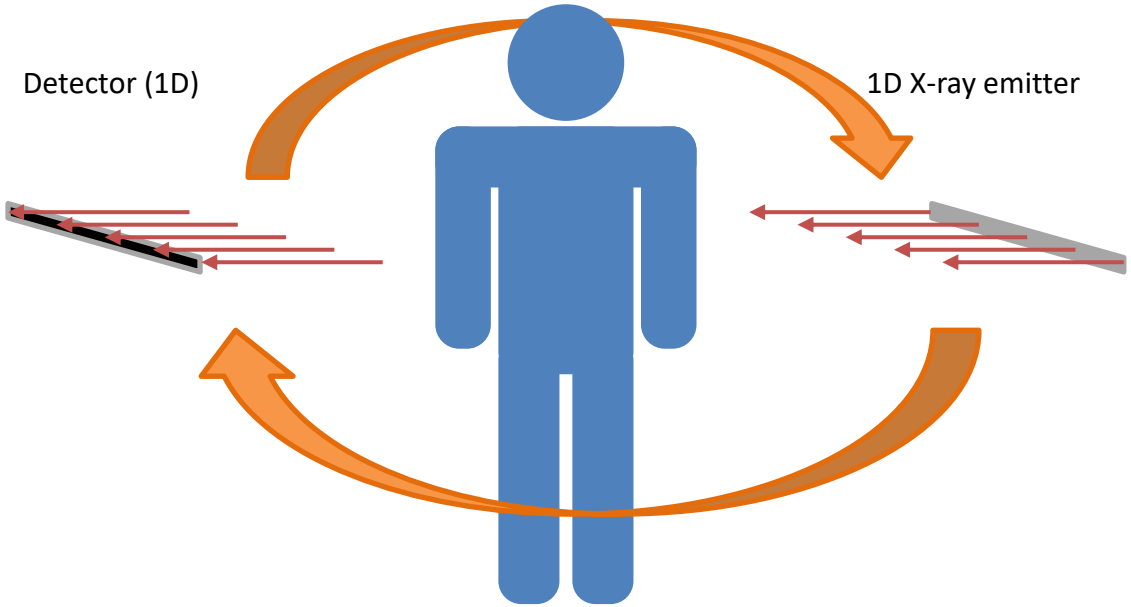




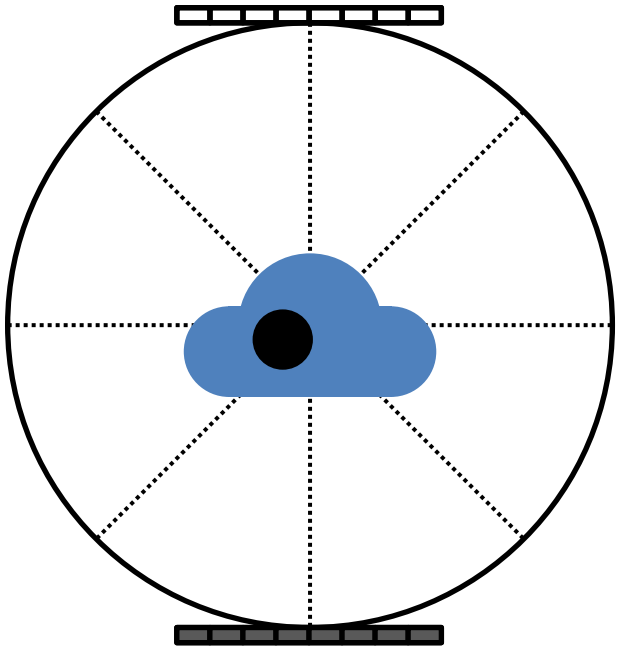


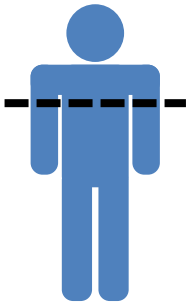
https://pt.wikipedia.org/wiki/Johann_Radon

Computer tomography

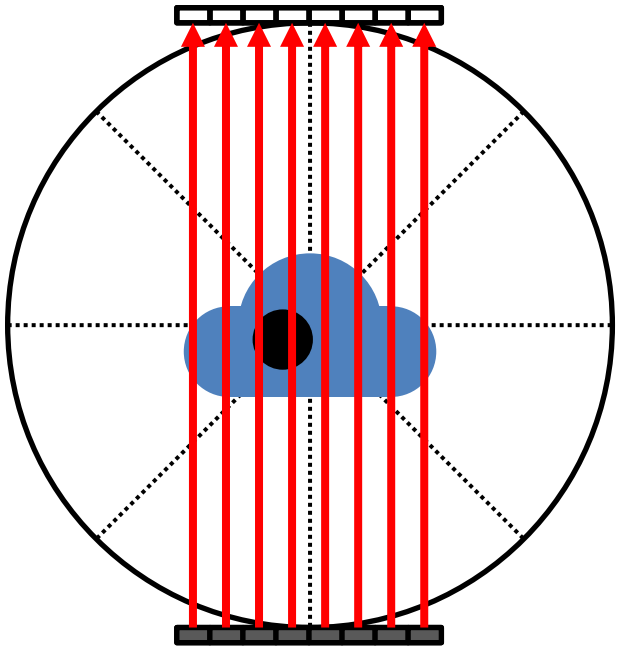


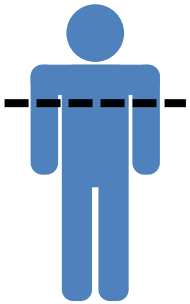
Computer tomography

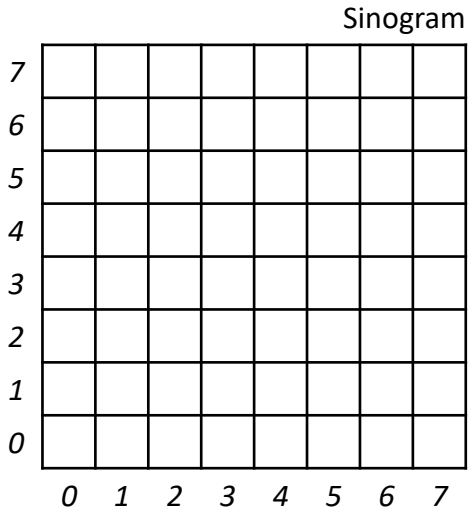




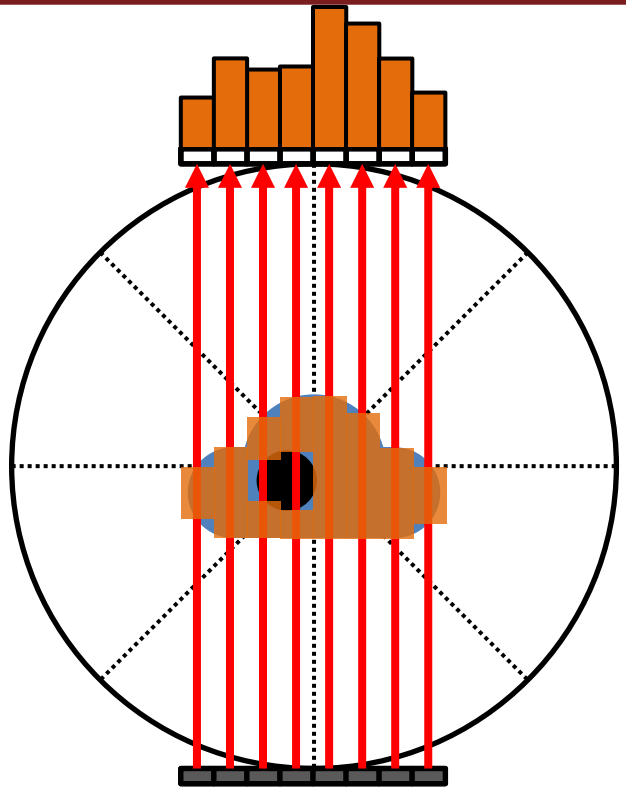
Computer tomography

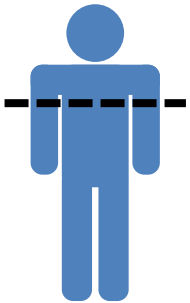




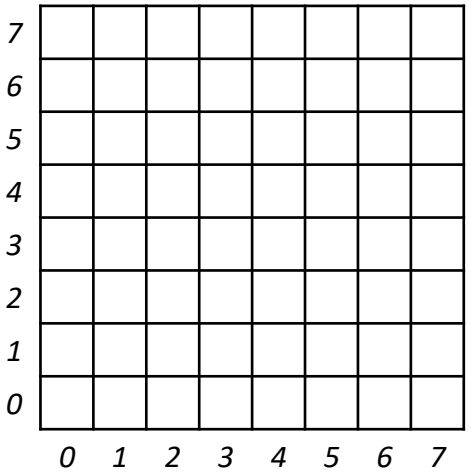


Computer tomography

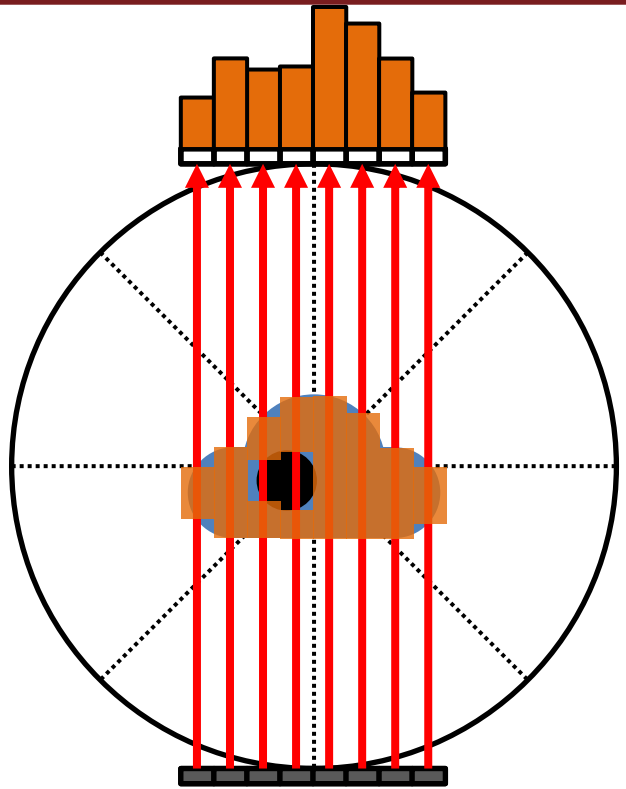


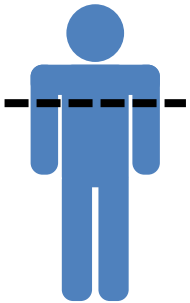


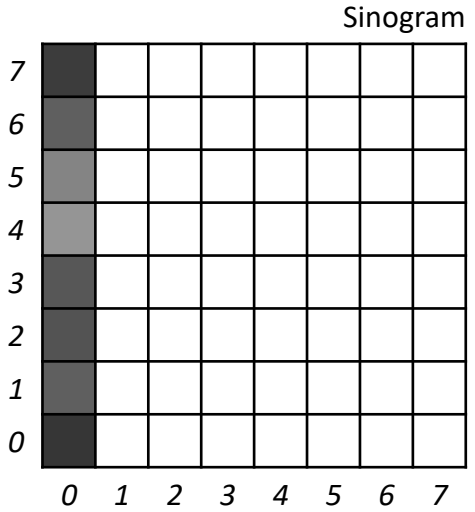
Sinogram



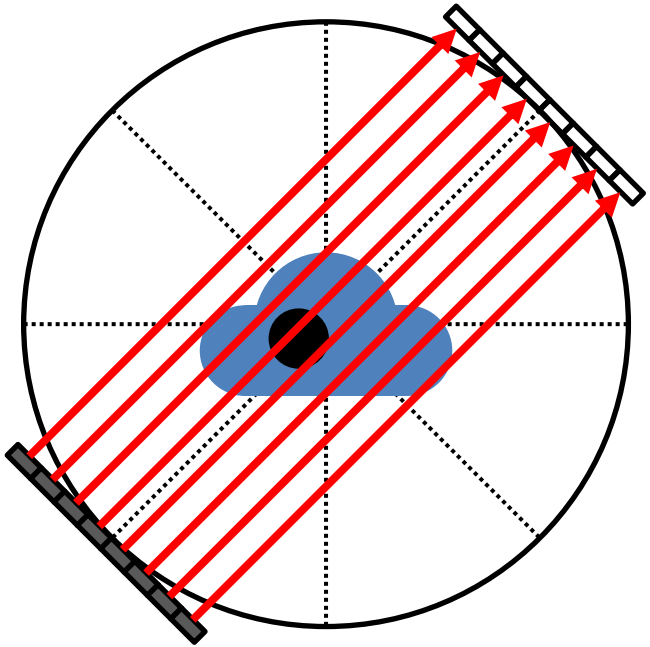
Computer tomography

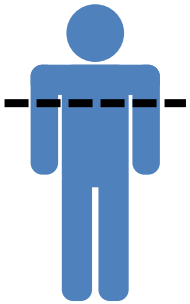


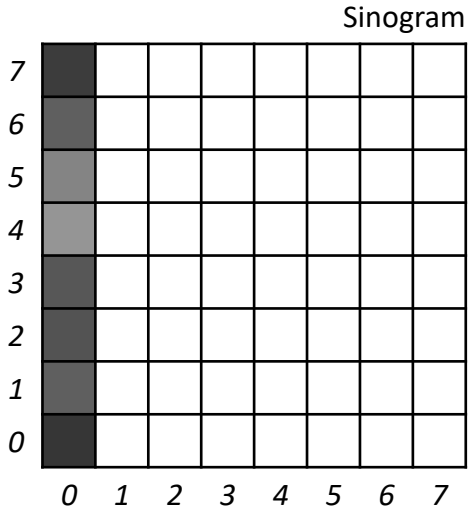




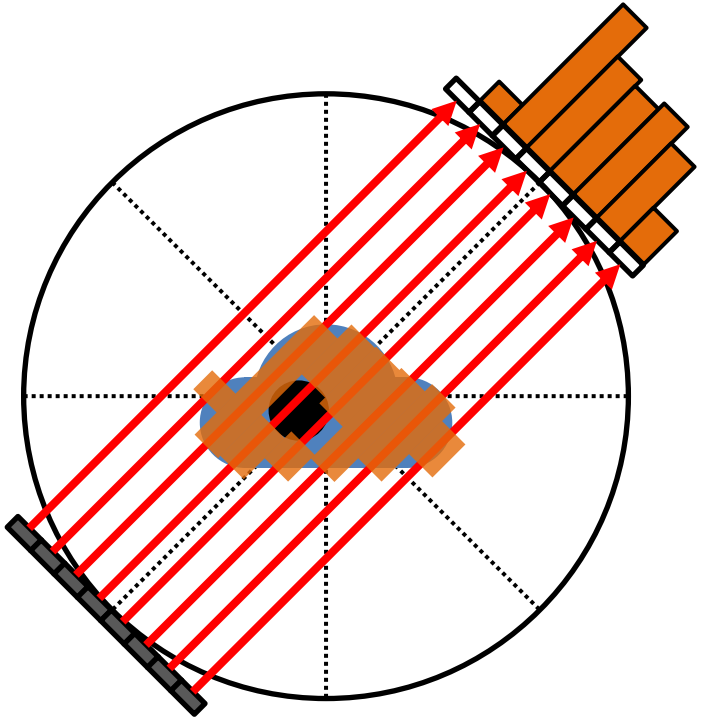
Computer tomography

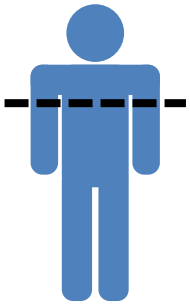


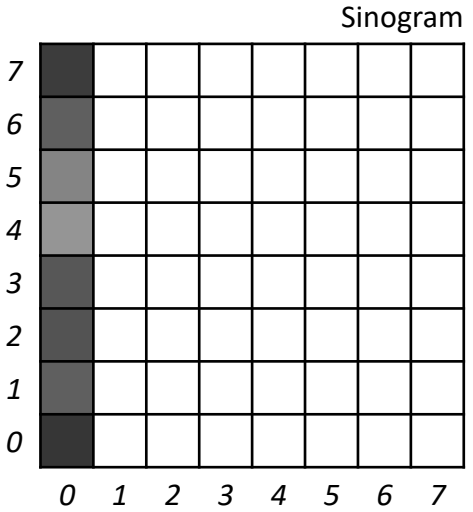




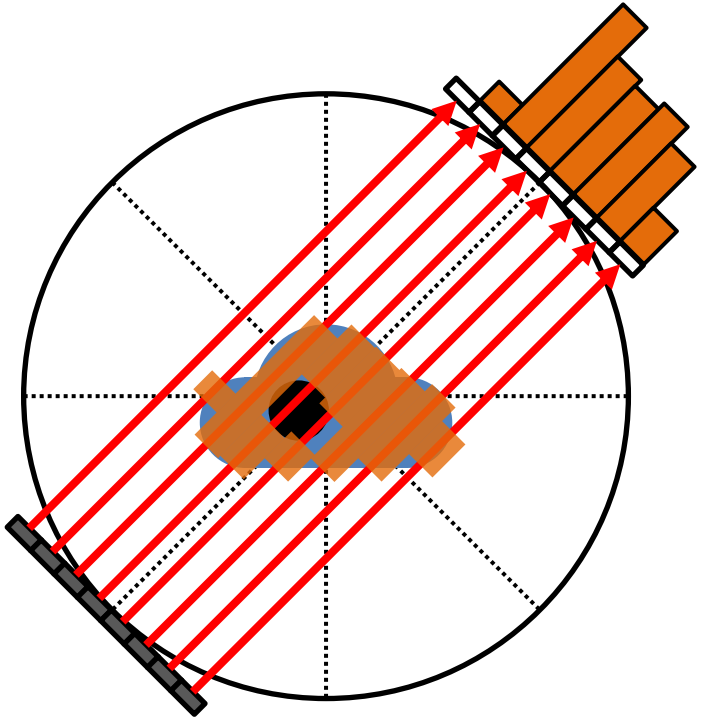
Computer tomography

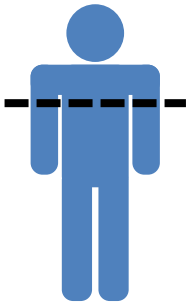


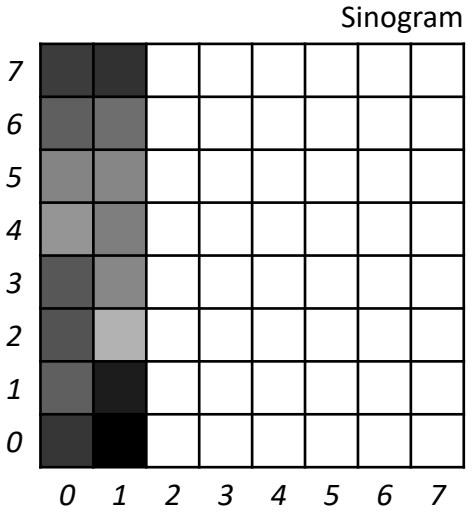




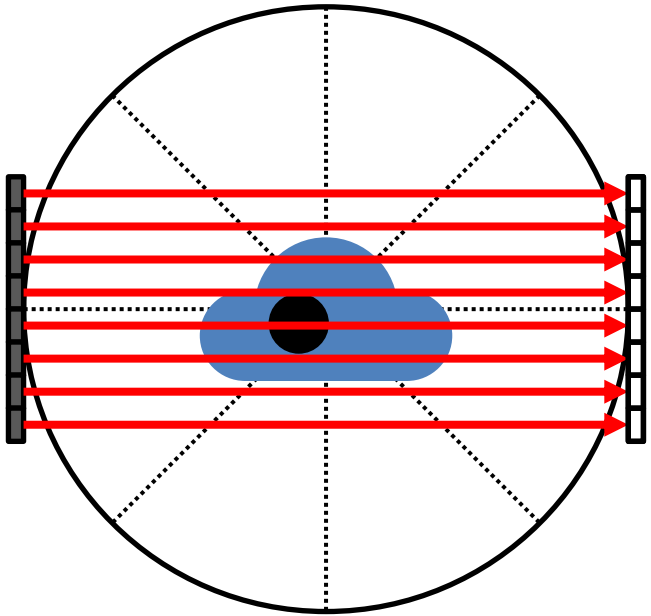
Computer tomography

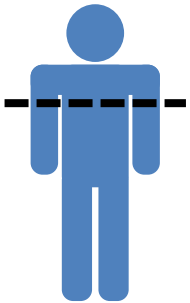


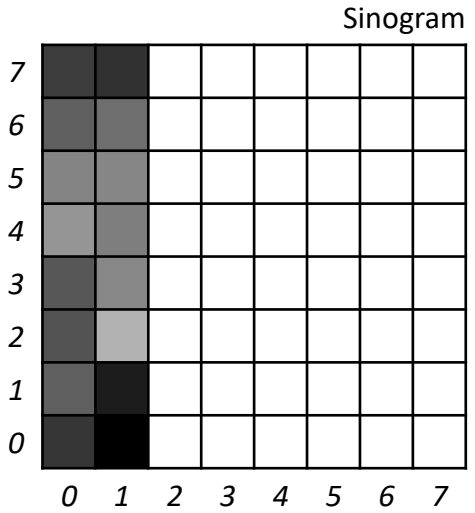




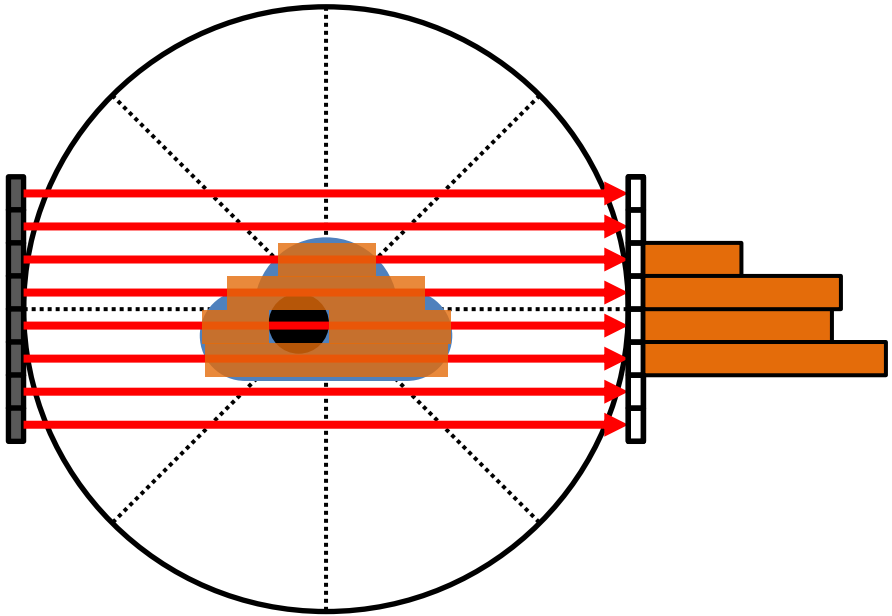
Computer tomography

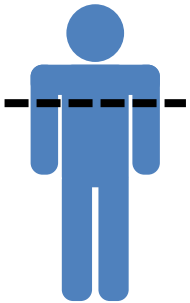


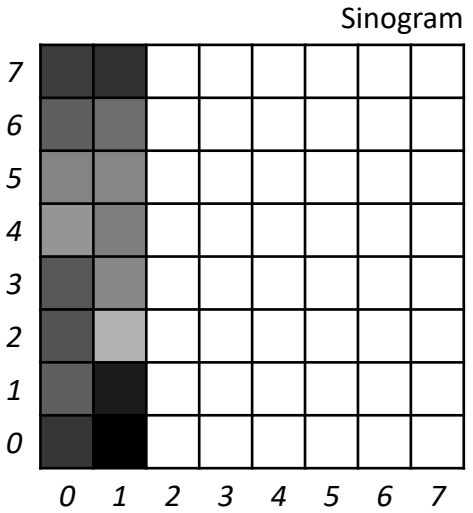




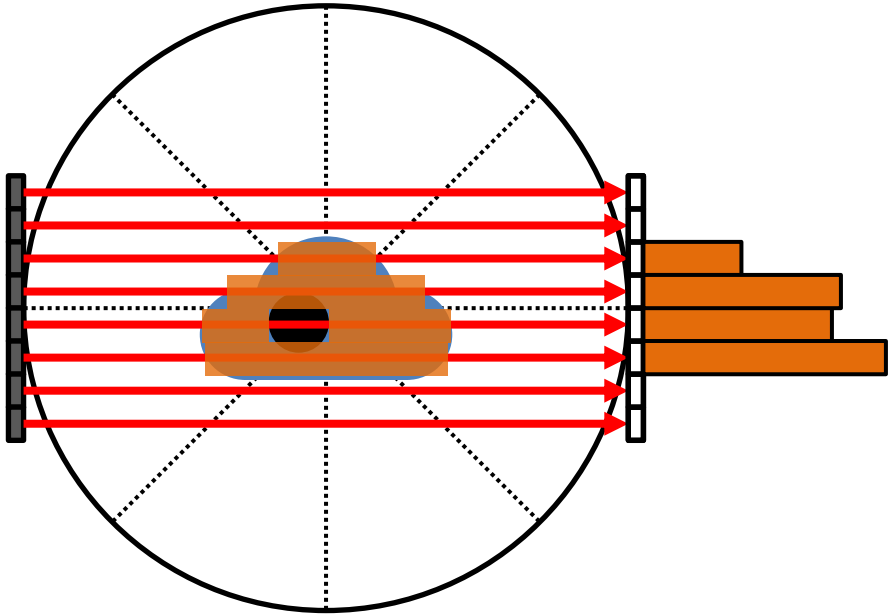
Computer tomography

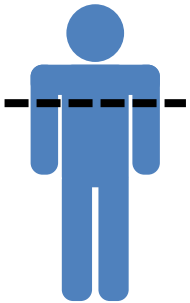


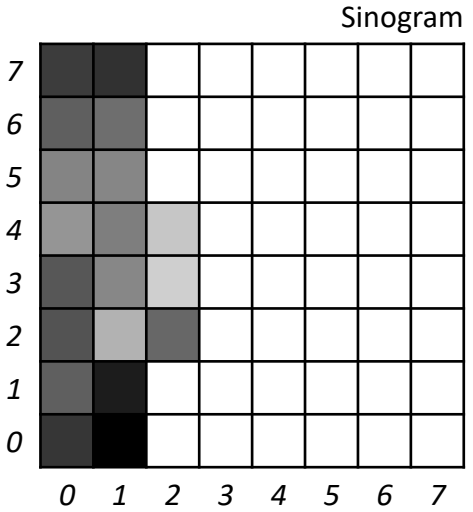




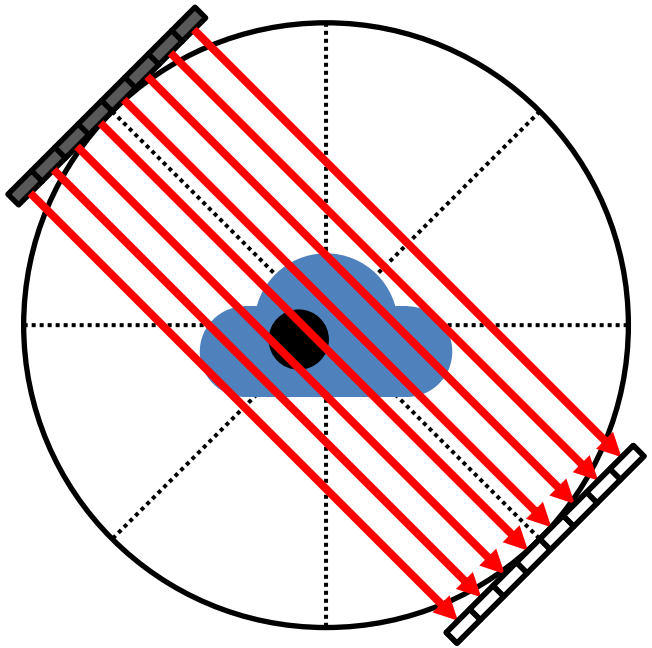
Computer tomography

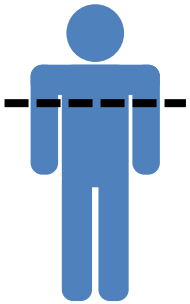


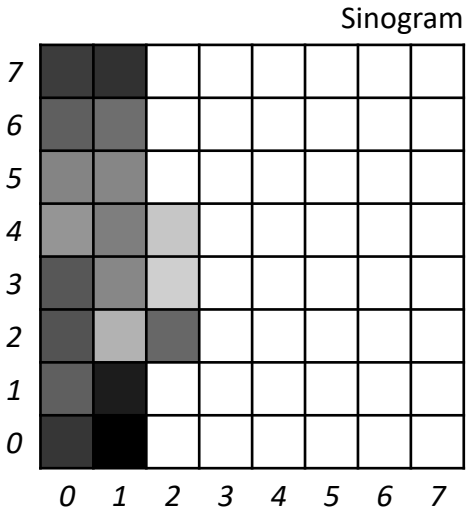




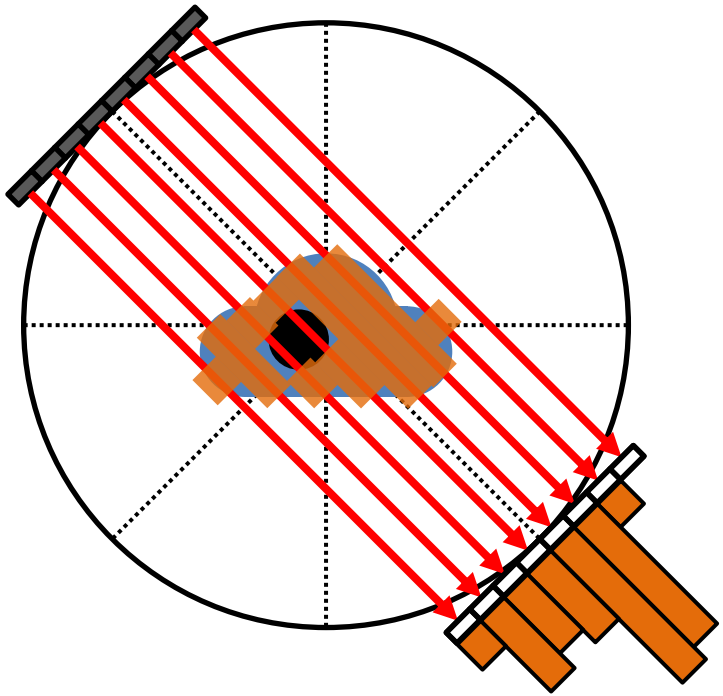
Computer tomography

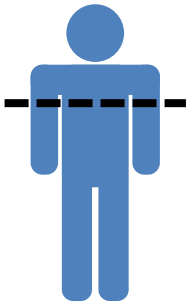


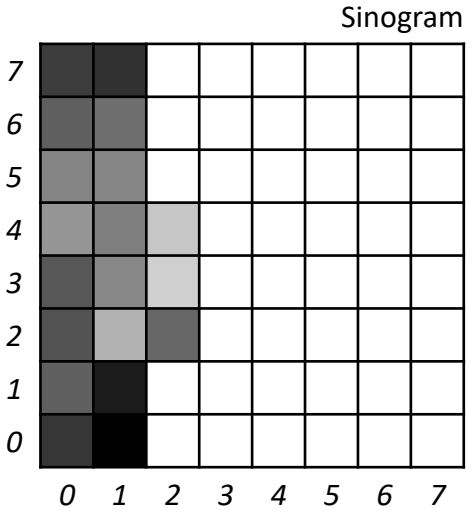




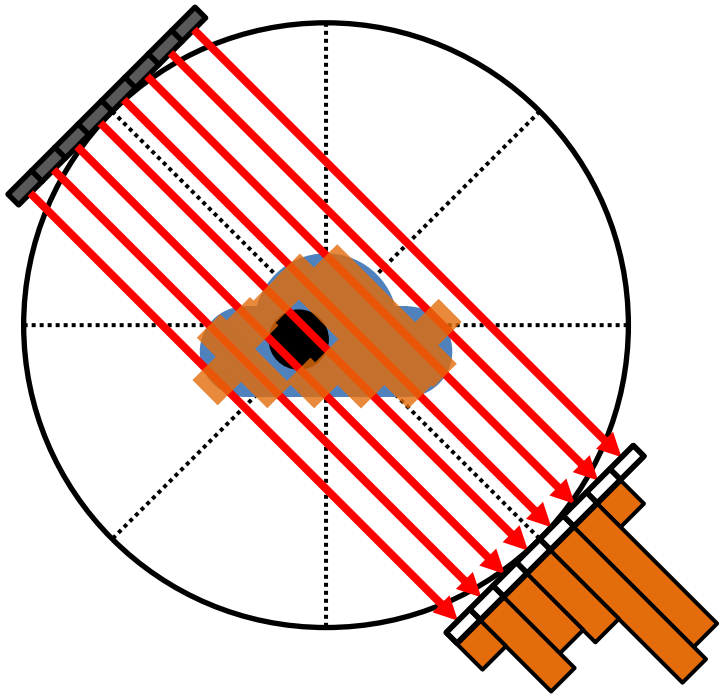
Computer tomography

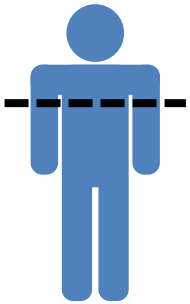


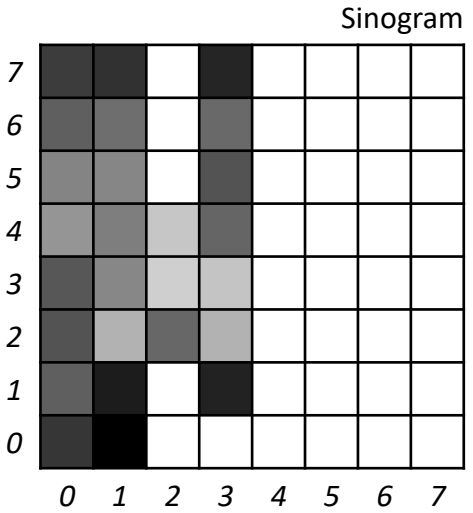




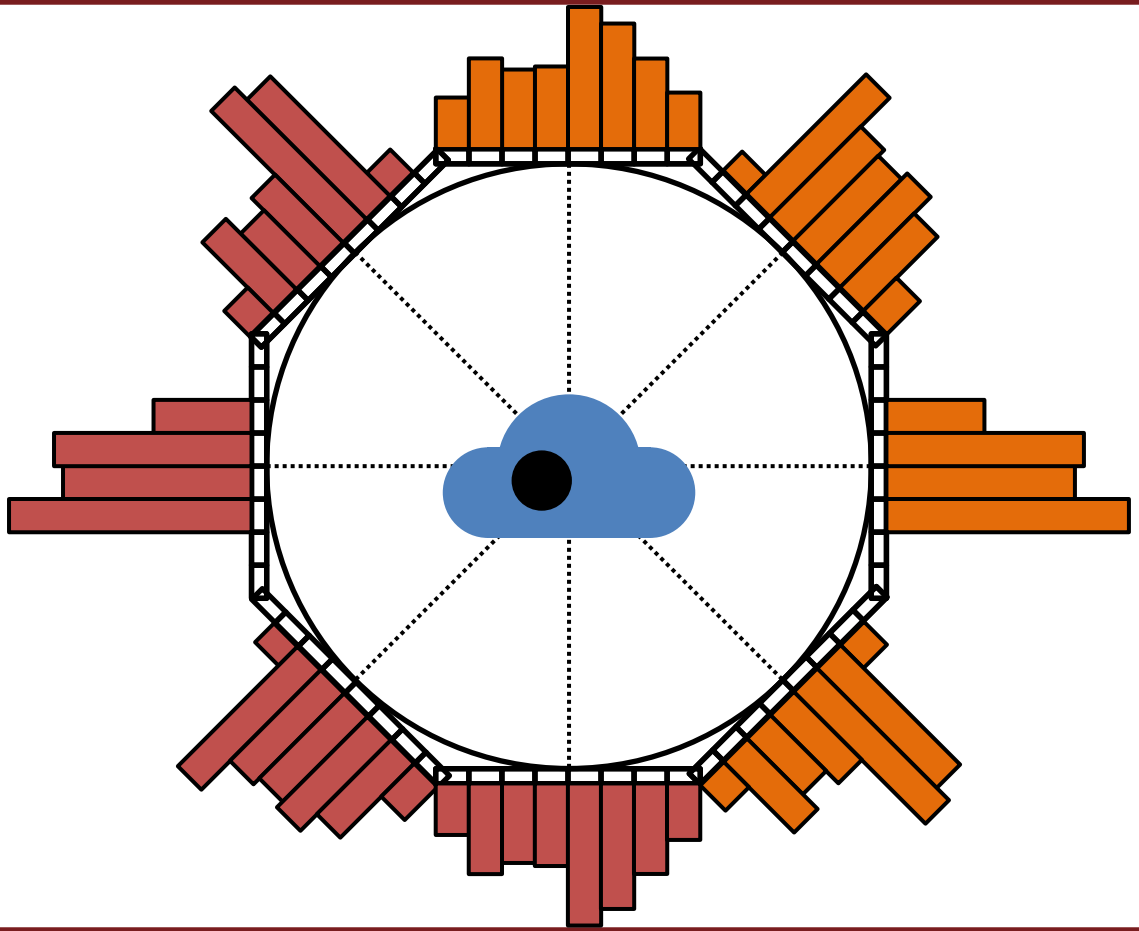
Computer tomography

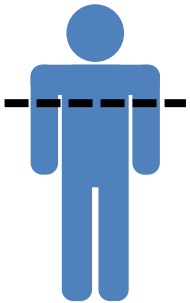


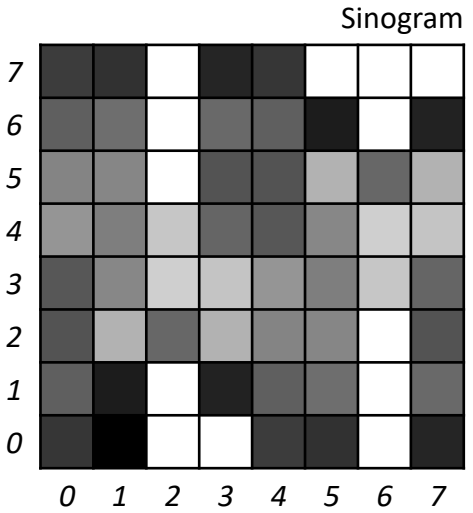




Computer tomography







Bibliography

- GONZALEZ, R.C.; WOODS, R.E. **Digital Image Processing**. 3rd ed. Pearson, 2007.

- MARQUES FILHO, O.; VIEIRA NETO, H. **Processamento digital de imagens**. Brasport, 1999.
  - (*in Brazilian Portuguese*)
  - Available on the author's website (for personal use only)
  - http://dainf.ct.utfpr.edu.br/~hvieir/pub.html

- scikit-image. **Radon transform**.
  - https://scikit-image.org/docs/dev/auto_examples/transform/plot_radon_transform.html

Complementary bibliography

- McFarlane, M. D. **Digital pictures fifty years ago**. in Proceedings of the IEEE, vol. 60, no. 7, pp. 768-770, July 1972, doi: 10.1109/PROC.1972.8775.
  - https://ieeexplore.ieee.org/document/1450705
- Matt NOVAK, M. **How To Send a Photo Around the World (in 1926)**. GIZMODO. July 01, 2018.
  - https://paleofuture.gizmodo.com/how-to-send-a-photo-around-the-world-in-1926-533206646
- NSSDC Image Catalog – Ranger 7
  - https://nssdc.gsfc.nasa.gov/imgcat/html/mission_page/EM_Ranger_7_page1.html
- SHINDELL, M. **Uncovering the Secrets of the Ranger 7**. July 31, 2018
  - https://airandspace.si.edu/stories/editorial/uncovering-secrets-ranger-7
- US: Ranger 7 - 1964
  - https://www.youtube.com/watch?v=QGJbybcXd0c

Complementary bibliography

- KENT, A.; WILLIAMS, J. G. **Computers in Spaceflight: The NASA Experience**. Chapter Nine - Making New Reality: Computers in Simulations and Image Processing - Image processing. NASA
  - https://history.nasa.gov/computers/Ch9-3.html
- Billingsley, F. C. **Digital Video Processing At Jpl**, Proc. SPIE 0003, Electronic Imaging Techniques, (26 September 1965);
  - https://doi.org/10.1117/12.970964
- INPE. **A criação da DPI... como tudo começou.**
  - http://www.dpi.inpe.br/DPI/institucional/pessoal/historico
- Camara G.; Souza R.C.M.; Freitas, U.M.; Garrido, J. **SPRING: Integrating remote sensing and GIS by object-oriented data modelling**. Computers & Graphics, 20: (3) 395-403, May-Jun 1996.

```
@misc{mari_im_proc_2023,
       author = {João Fernando Mari},
       title = {Introduction I},
       year = {2023},
       publisher = {GitHub},
       journal = {Introduction to digital image processing - UFV},
       howpublished = {\url{https://github.com/joaofmari/SIN392_Introduction-to-digital-image-processing_2023}}
}
```

THE END