Diagnostic Medical Image Processing

Introduction

WS 2010/11

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Diagnostic Medical Image Processing

X-Ray Imaging

A few historical facts on the classic medical imaging method that started the field of radiology:

- **Nov. 8, 1895:**
  Wilhelm Conrad Röntgen incidentally discovered X-Rays in Würzburg, Germany
- **Dec. 22, 1895:**
  first X-ray image of the hand of his wife (exposure time 57 minutes!!!)
- **1897:**
  introduction of contrast agents (in the USA)
- **Dec. 10, 1901:**
  first Nobel Prize for physics awarded to W. C. Röntgen

X-Ray Imaging

... a few more second row facts:

1903 Impact of X-ray to body cells

1906 Visualization of kidney

1908 Dynamic image acquisition

1912 Anti scatter grid (by Gustav Bucky)

1913 Visualization of mamma carcinoma

1924 Visualization of gall bladder and vessels

1928 Rotating tube anode

1929 Use of catheters for heart diagnosis (by Werner Forssmann)

1935 Tomosynthesis

1938 Tuberculosis screening using X-ray systems

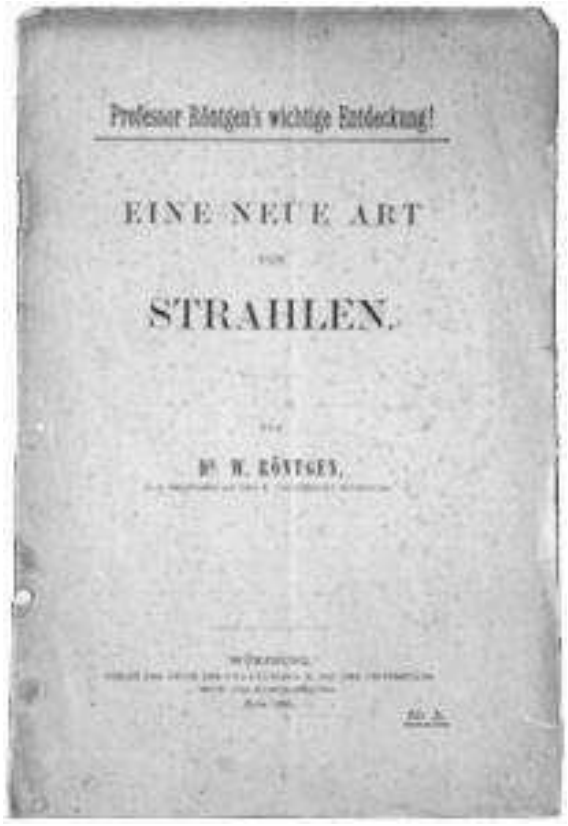
X-Ray Imaging

A few general remarks:

- Röntgen submitted a paper on his results to the Physical-Medical Society of Würzburg
- The discovery of X-ray was like a tornado: within a few days the whole world learnt about X-ray and physicians began to use it right away. The speed was breathtaking and unique in industry.
- It took Edison 4 months to get into the manufacturing of X-ray equipment (the roots of GE Medical Systems).
- It took Max Gebbert a few months to start the production of commercial X-ray systems (the roots of Siemens Medical Solutions).

Figure: Manufacturing generators for X-ray devices in 1939 (image: Siemens Medical Solutions)

X-Ray Imaging


Professor Röntgen's wichtige Entdeckung!

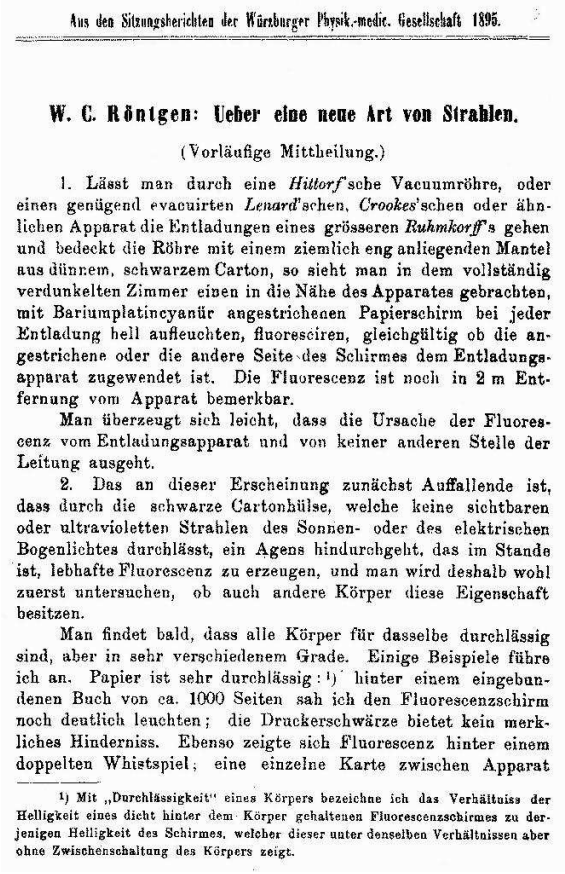
EINE NEUE ART

VON

STRAHLEN.

VON

Dr. W. RÖNTGEN.


Aus den Sitzungsberichten der Würzburger Physik.-medic. Gesellschaft 1895.

W. C. Röntgen: Ueber eine neue Art von Strahlen.

(Vorläufige Mittheilung.)

1. Lässt man durch eine *Hittorf*'sche Vacuumröhre, oder einen genügend evacuirten *Lenard*'schen, *Crookes*'schen oder ähnlichen Apparat die Entladungen eines grösseren *Ruhmkorff*'s gehen und bedeckt die Röhre mit einem ziemlich eng anliegenden Mantel aus dünnem, schwarzem Carton, so sieht man in dem vollständig verdunkelten Zimmer einen in die Nähe des Apparates gebrachten, mit Bariumplatincyanür angestrichenen Papierschirm bei jeder Entladung hell aufleuchten, fluoresciren, gleichgültig ob die angestrichene oder die andere Seite des Schirmes dem Entladungsapparat zugewendet ist. Die Fluorescenz ist noch in 2 m Entfernung vom Apparat bemerkbar.

Man überzeugt sich leicht, dass die Ursache der Fluorescenz vom Entladungsapparat und von keiner anderen Stelle der Leitung ausgeht.

2. Das an dieser Erscheinung zunächst Auffallende ist, dass durch die schwarze Cartonhülse, welche keine sichtbaren oder ultravioletten Strahlen des Sonnen- oder des elektrischen Bogenlichtes durchlässt, ein Agens hindurchgeht, das im Stande ist, lebhafte Fluorescenz zu erzeugen, und man wird deshalb wohl zuerst untersuchen, ob auch andere Körper diese Eigenschaft besitzen.

Man findet bald, dass alle Körper für dasselbe durchlässig sind, aber in sehr verschiedenem Grade. Einige Beispiele führe ich an. Papier ist sehr durchlässig:[1] hinter einem eingebundenen Buch von ca. 1000 Seiten sah ich den Fluorescenzschirm noch deutlich leuchten; die Druckerschwärze bietet kein merkliches Hinderniss. Ebenso zeigte sich Fluorescenz hinter einem doppelten Whistspiel; eine einzelne Karte zwischen Apparat

[1] Mit „Durchlässigkeit" eines Körpers bezeichne ich das Verhältniss der Helligkeit eines dicht hinter dem Körper gehaltenen Fluorescenzschirmes zu derjenigen Helligkeit des Schirmes, welcher dieser unter denselben Verhältnissen aber ohne Zwischenschaltung des Körpers zeigt.

Figure: Cover and first page of Röntgen's publication (image borrowed from the web...)

X-Ray Imaging

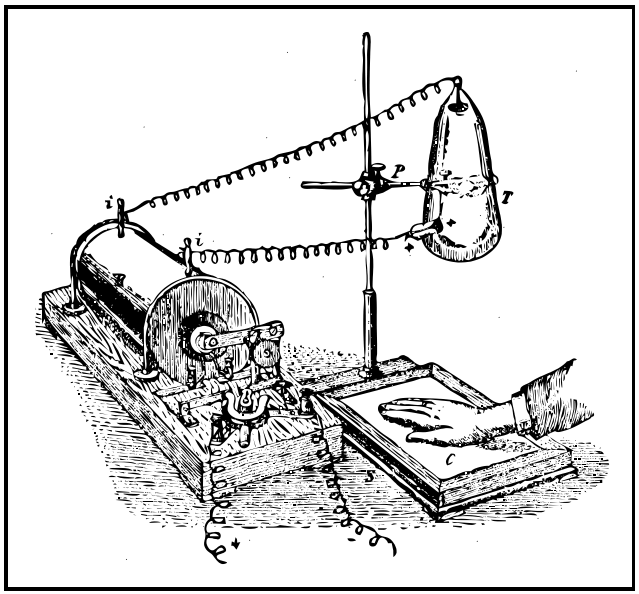


Figure: Conventional Röntgen scheme using photographic paper (image source: Fölsing)

Here we see already the major components of an X-ray system at work:

1. generator
2. X-ray tube
3. detector
4. ... and the patient between source and detector.

X-Ray Imaging

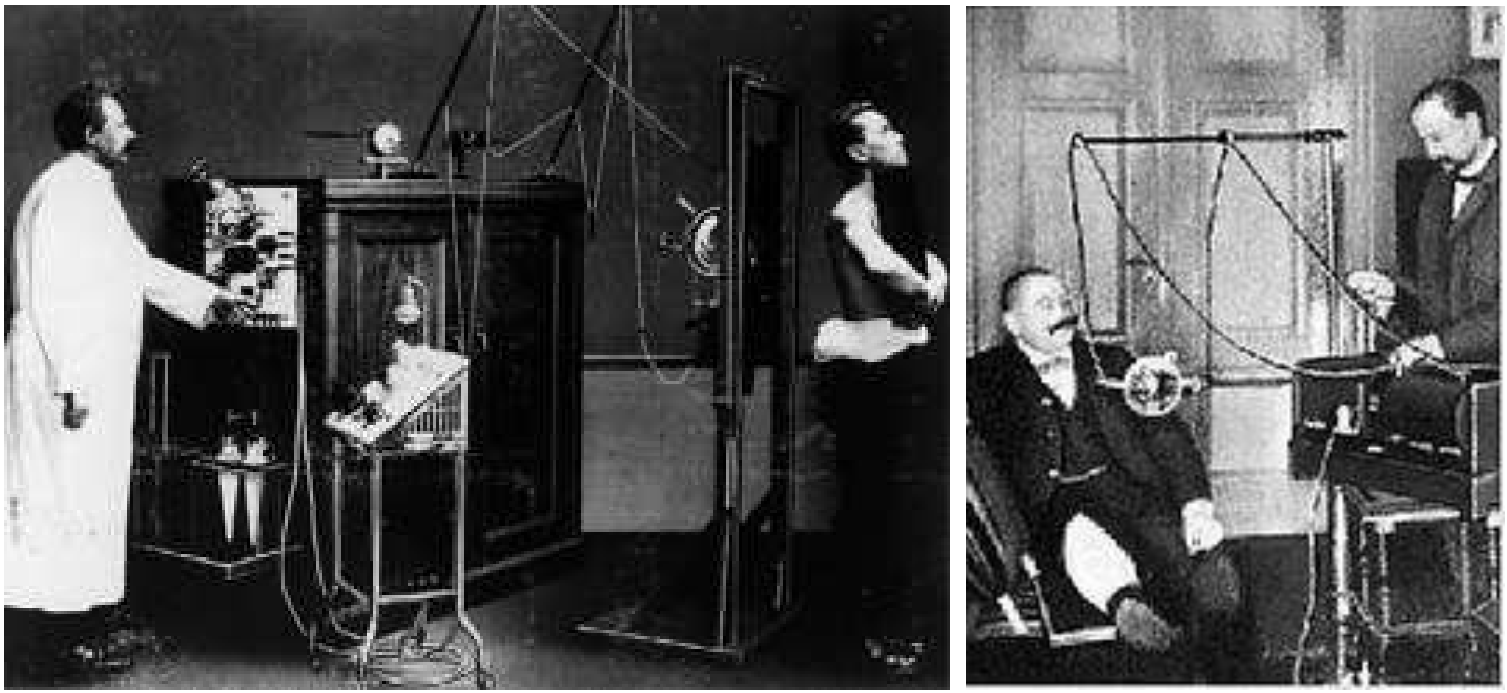


Figure: Historic X-Ray Devices around 1900: thorax (left) and knee (right) imaging (image source: Fölsing)

X-Ray Imaging

X–ray systems are often classified as follows:

1. radiography
2. fluoroscopy
3. angiography



Figure: Modern X-ray systems for radiography, fluoroscopy, and angiography (images: Siemens Medical Solutions)

X-Ray Imaging

Definition

Radiography In **radiography** a single image of a static object is acquired using x-ray.

Definition

Fluoroscopy Fluoroscopy uses X-ray to produce image sequences of dynamic objects.

Definition

Angiography Angiography uses X-ray to visualize blood vessels after injecting radio-opaque contrast agent.

X-ray Imaging

Example

Radiography: Static images can be visualized by film sheets. You won't believe it, X-ray film sheets and lightboxes are still used. Go and visit your orthopedist!

Figure: Lightbox to visualize and analyze X-ray films

X-Ray Imaging

Example

Radiography is mostly applied to acquire images of bones:

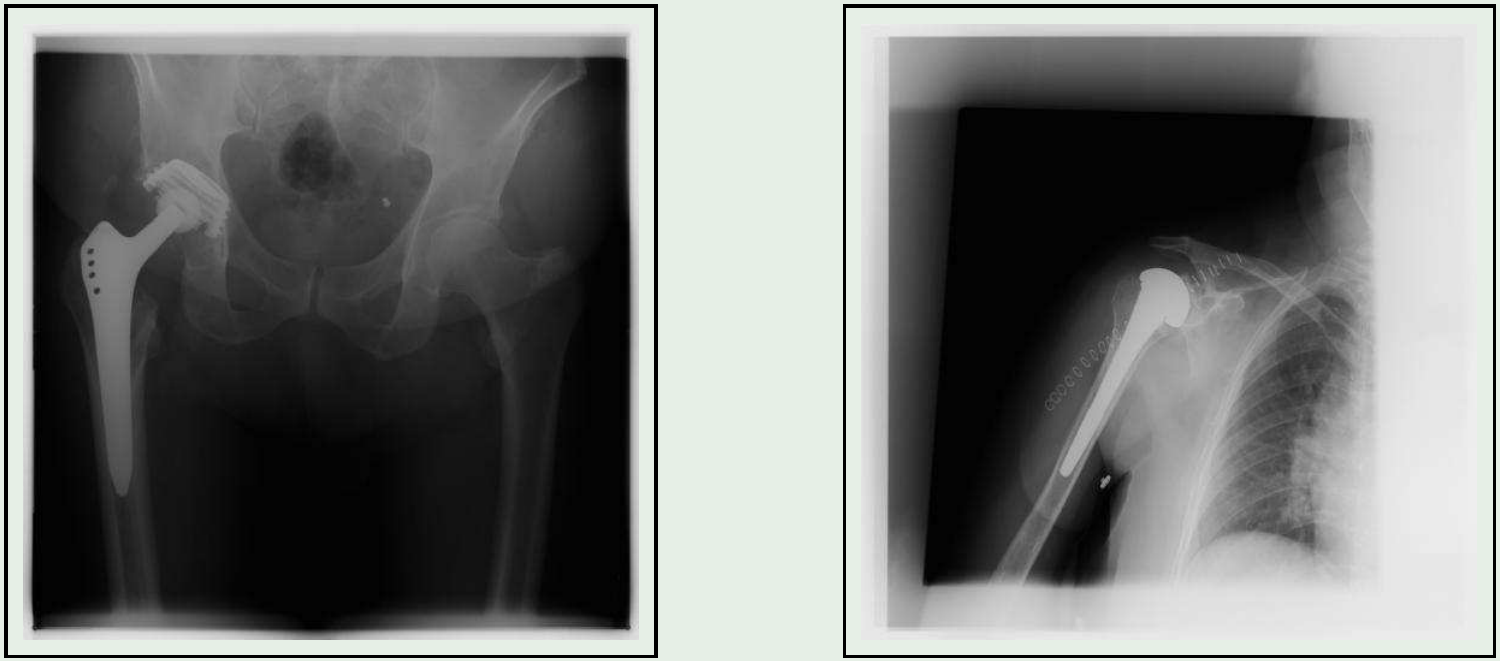


Figure: Hip and Shoulder

X-Ray Imaging

Example

Mammography systems to visualize the mamma are radiography systems, too.

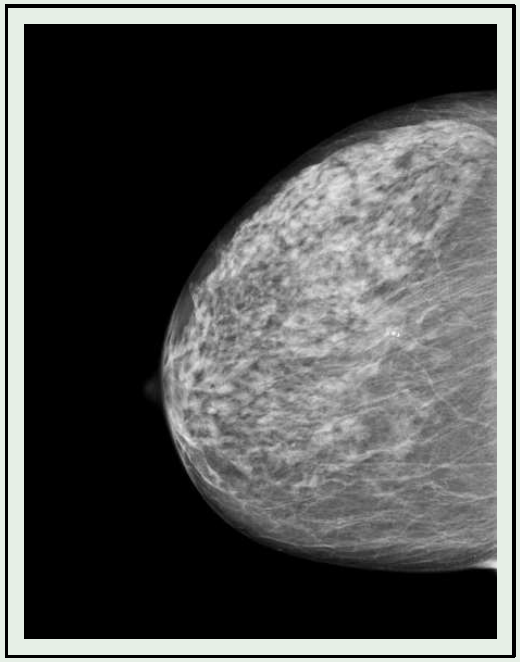
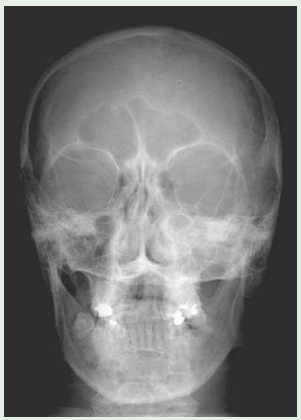


Figure: Mammography System and Mammography Image

X-Ray Imaging

Example

In fluoroscopy image sequences are acquired to visualize, for instance, the colon or the swallowing process.



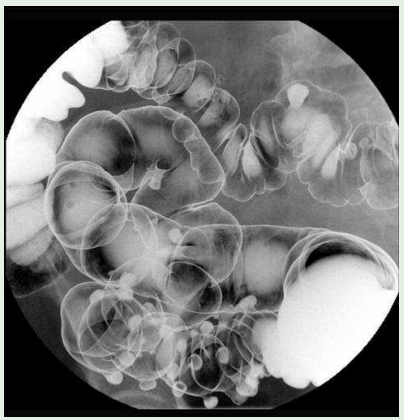


Figure: Head and Colon

Fluoroscopy systems are also used for angiography.

X-Ray Imaging

Angiograms are generated in

- radiology to visualize vessels in general,
- neuroradiology to visualize the cerebral vessel system, and
- cardiology to visualize the coronary arteries.

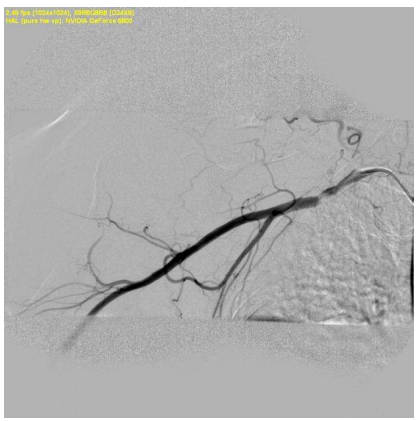
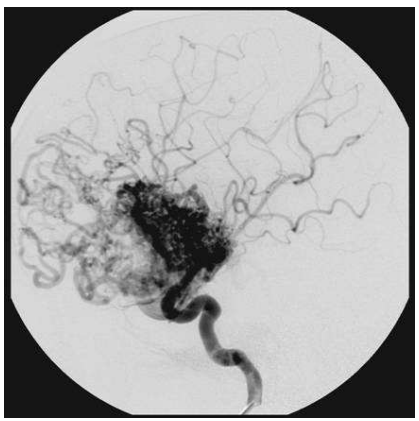




Figure: Arteries in kidney, cerebral vessels, coronary arteries

X-Ray Imaging

In **digital subtraction imaging** two images are mapped into a common coordinate system (we call this process image registration), then the difference image is computed. The final image just includes the image differences.

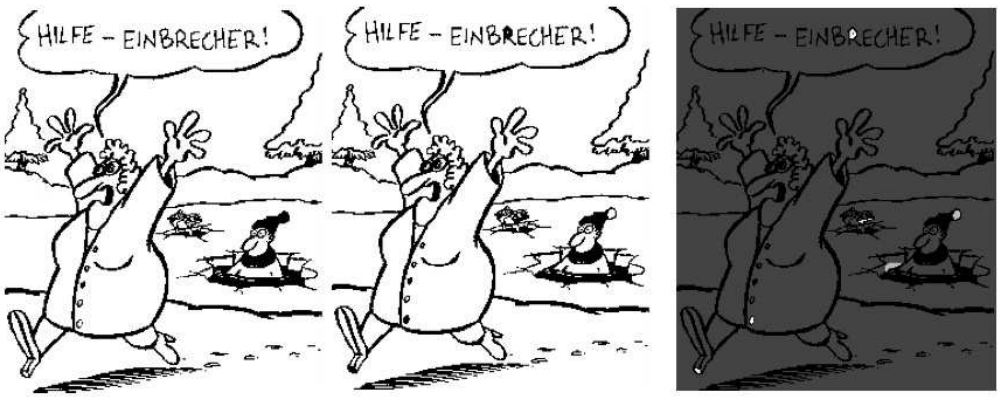


Figure: Automatic detection of image differences

X-Ray Imaging

Definition

In **digital subtraction angiography** (DSA) a X-ray image, where the blood vessels are filled with dye (fill image) is registered with and subtracted from a native X-ray image, called mask image. The resulting difference image is called **DSA image**.

Example

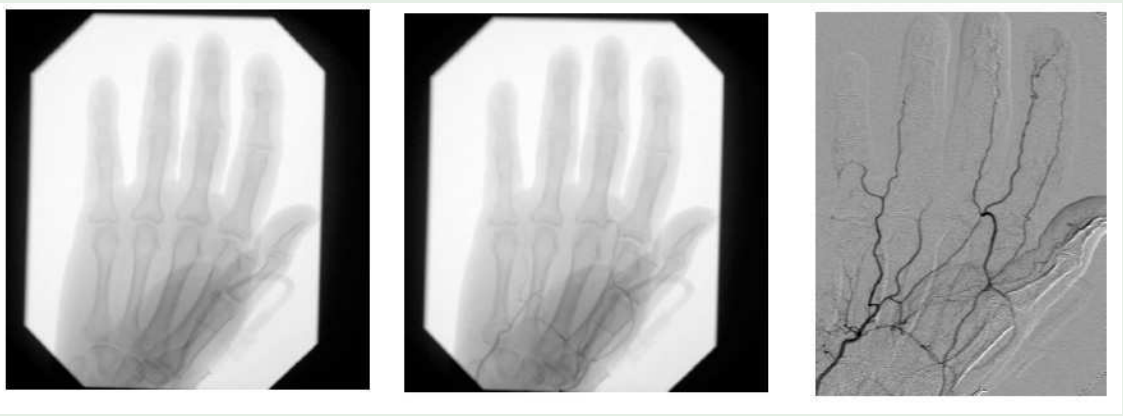


Figure: Hand: mask image (left), fill image (middle), angiogram (right)

X-Ray Imaging

Digital Subtraction Angiography (DSA)

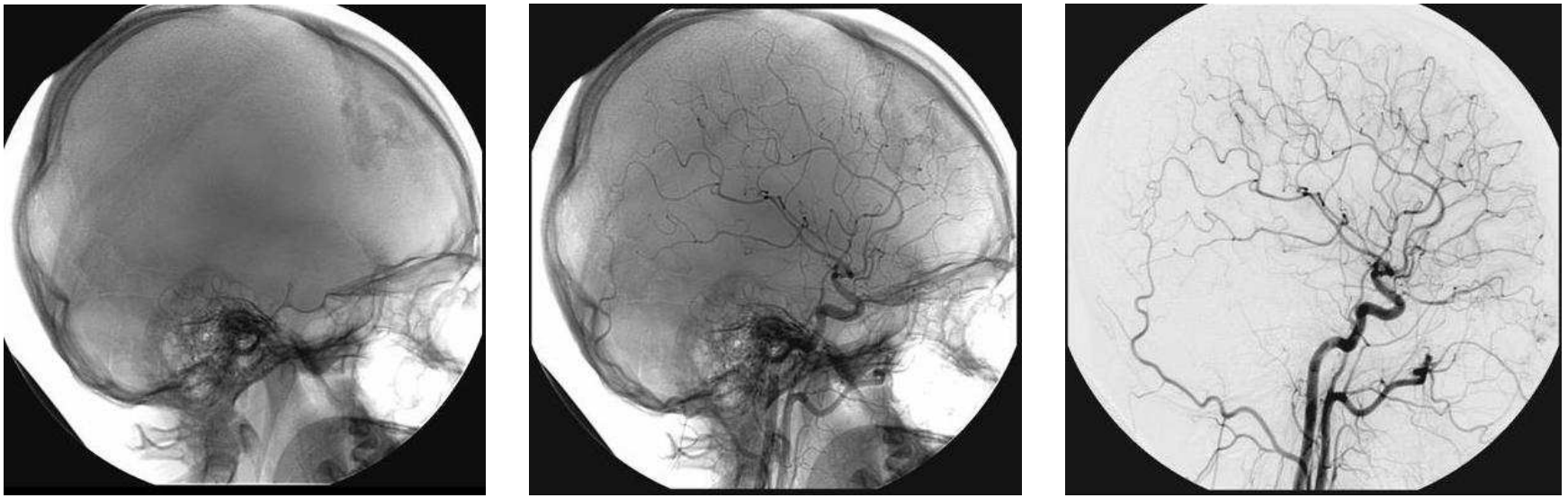


Figure: Cerebral vessels: mask image (left), fill image (middle), angiogram (right)

X–Ray

Image Stitching

- image stitching is a common practice in generating panoramic views
- it allows to generate images that are larger than detectors
- image processing task: find the proper alignment of overlap regions
- current research topic: volume stitching in CT or MR

X-Ray Imaging

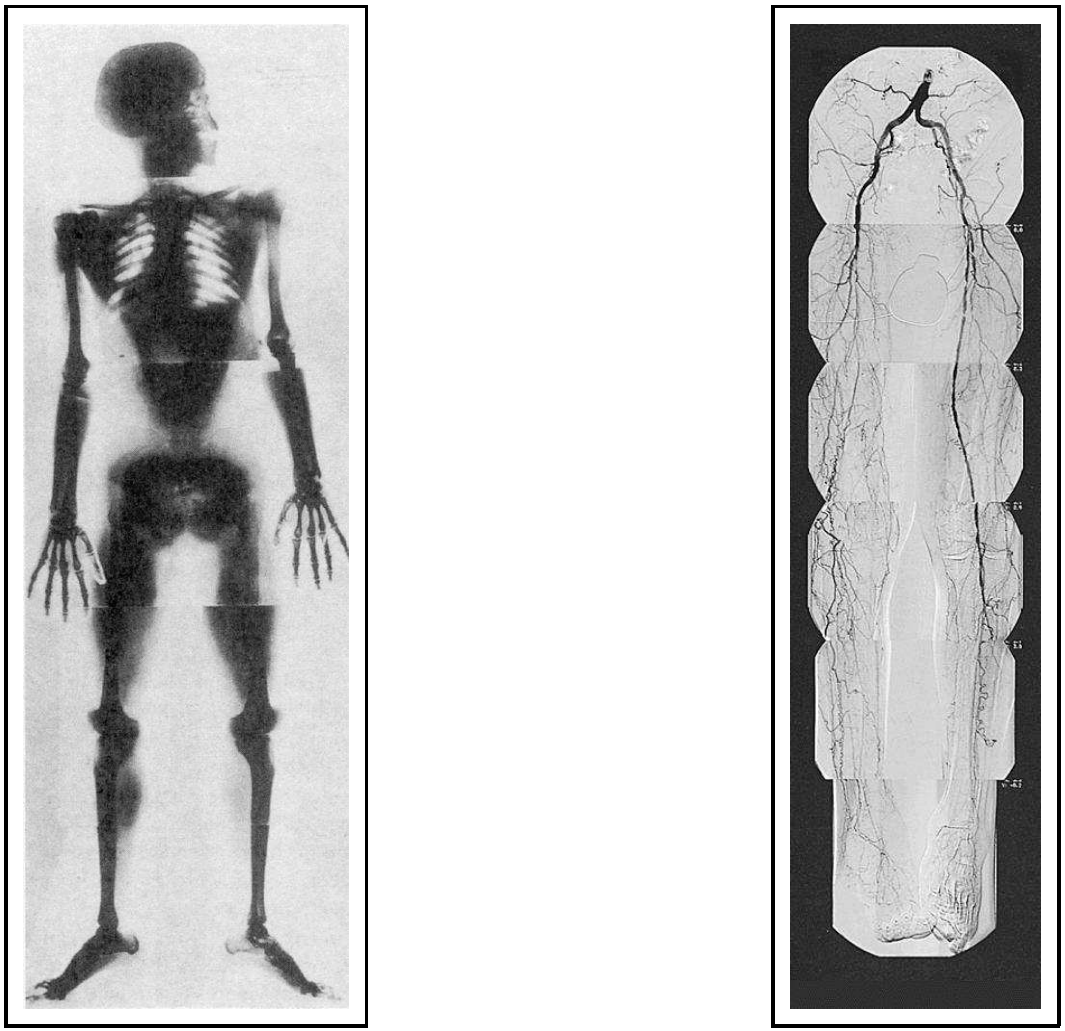


Figure: Two generations of image stitching methods: manually stitched images based on film sheets and a pair of scissors (left), automatic image stitching (right).

Major X-Ray Imaging Research at LME

- hardware accelerated image enhancement, e.g. using standard graphics cards, the Cell processor (Playstation 3), Intel architecture.
- image denoising and artifact reduction
- segmentation and tracking of catheters
- non-rigid X-ray image registration
- estimation of motion vector fields
- 3-D reconstruction from X-ray projections
- calibration of acquisition geometry

Diagnostic Medical Image Processing

Take Home Messages

- X-ray imaging is basically the origin of medical imaging and radiology
- X-ray imaging is old, but a still evolving field
- X-ray imaging has highest demands on computational power
- X-ray imaging is still standard in radiology
- X-ray imaging is good business and leaves many research questions open
- X-rays are ionizing... so be careful!

Diagnostic Medical Image Processing

Further Readings

- If you like to learn more about the life of Prof. Röntgen, you should read the enjoyable biography:
  Albrecht Fölsing: Wilhelm Conrad Röntgen, Carl Hanser, München, 1995. (amazon this book here.)
- More technical details on X-ray imaging can be found in
  Peter Hertrich: Röntgenaufnahmetechnik - Grundlagen und Anwendungen, Publicis Corporate Publishing, Erlangen, 2004. (amazon this book here.)