Medical Image Processing for Diagnostic Applications

MRI – Acquisition Devices

Online Course – Unit 19

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Topics

MR Acquisition Devices

Summary

Take Home Messages

Further Readings

MR Acquisition Devices

MR scanners are huge and heavy systems with strong superconducting magnets:

Figure 1: Examples of 3 Tesla systems: MAGNETOM Verio (left) and Trio Scanner (right) (images courtesy of Siemens Medical Solutions)

Physical and Mathematical Ingredients

For MRI imaging, the following physical and mathematical concepts are required to be understood:

- **nuclei** serve as objects to be imaged,
- **homogeneous magnetic fields** are generated by the scanner to align the nuclear moment vectors,
- the **resonance phenomenon** that results from the interaction of nuclei with the magnetic field enables measurements,
- **Fourier methods** are used for image reconstruction,
- **image enhancement algorithms** are applied to compensate for violations of the required homogeneity of the magnetic field (**bias field correction**).

Note: Details in physics are not in the focus of this course, but the algorithmic aspects.

Components of an MR Scanner

The major four components of an MR Scanner are:

- the main magnet,
- a magnetic field gradient system,
- a radio frequency system (RF system),
- and the imaging system.

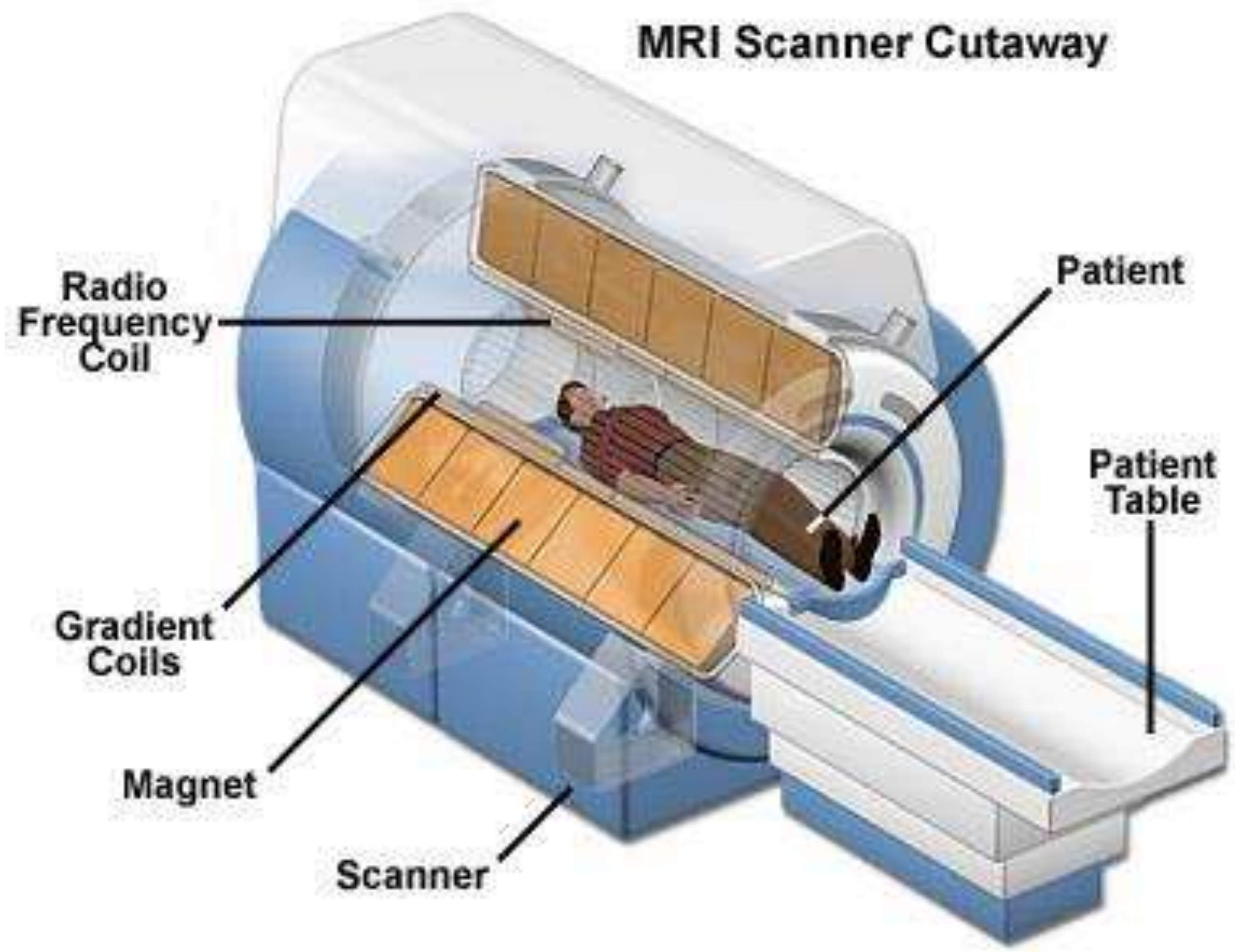

Figure 2: Main components of an MR scanner (image courtesy of the National High Magnetic Field Laboratory, Florida)

Components of an MR Scanner: Main Magnet

The **main magnet** is required to generate a strong uniform static magnetic field for the polarization of nuclear spins.

In practice, there are several options:

- **permanent magnet**: low field applications (< 0.3 T),
- **resistive magnet**: low field applications (< 1.5 T),
- **superconducting magnet**: used for higher magnetic field strengths (high end research scanners, whole-body up to 11.75 T, general research > 20 T).

superconducting -> hoher stromfluss ohne erhitzung

The main magnet of the MAGNETOM Verio scanner is only 6.5 tons!

Necessity of Gradients

To distinguish between the nuclei, the idea is to associate a unique magnetic field with each type of nucleus. This can be achieved by continuous variation of the magnetic field dependent on the 3-D position of the nuclei.

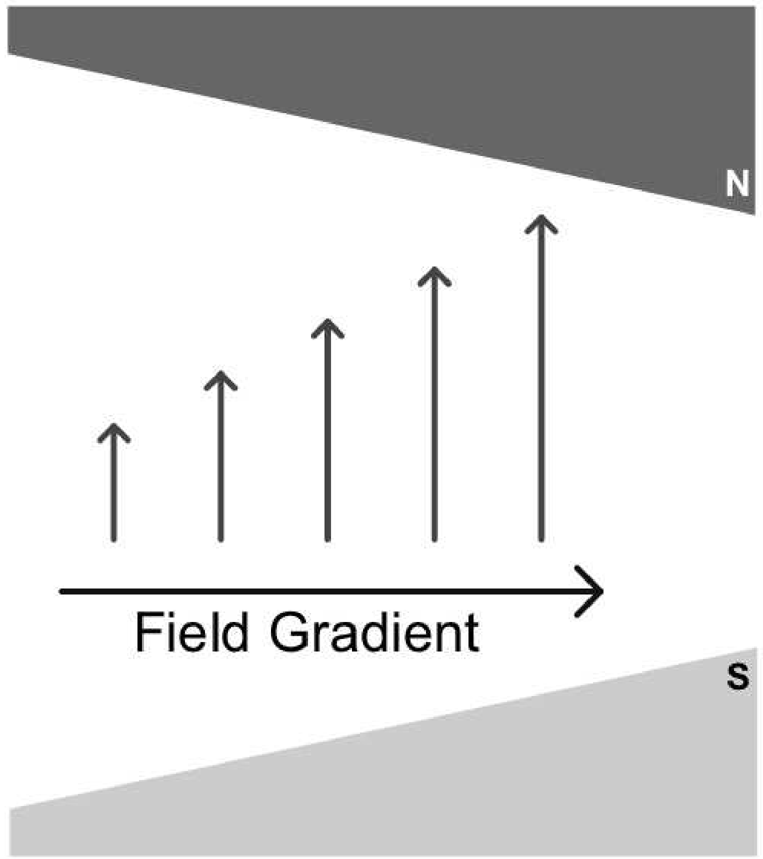

Figure 3: Schematic of continuously changing the magnetic field in 3-D

Note: The gradient strength in 3-D can be used for motion compensation. If the patient motion is known, the gradient field can be adjusted properly!

Components of an MR Scanner: Gradient System

The **magnetic field gradient system** is required to generate magnetic fields of well-defined and controlled spatial inhomogeneity as a function of the particular x-, y- and z-coordinates in space.
The gradient field is needed for signal localization in space.

- Gradient strength: e. g., 45 mT/m (millitesla per meter) in the Tim Trio 3T
- Rise time to ramp up gradient decides on quality of gradient: the smaller the rise time, the better (rise time today < 1.0 ms).

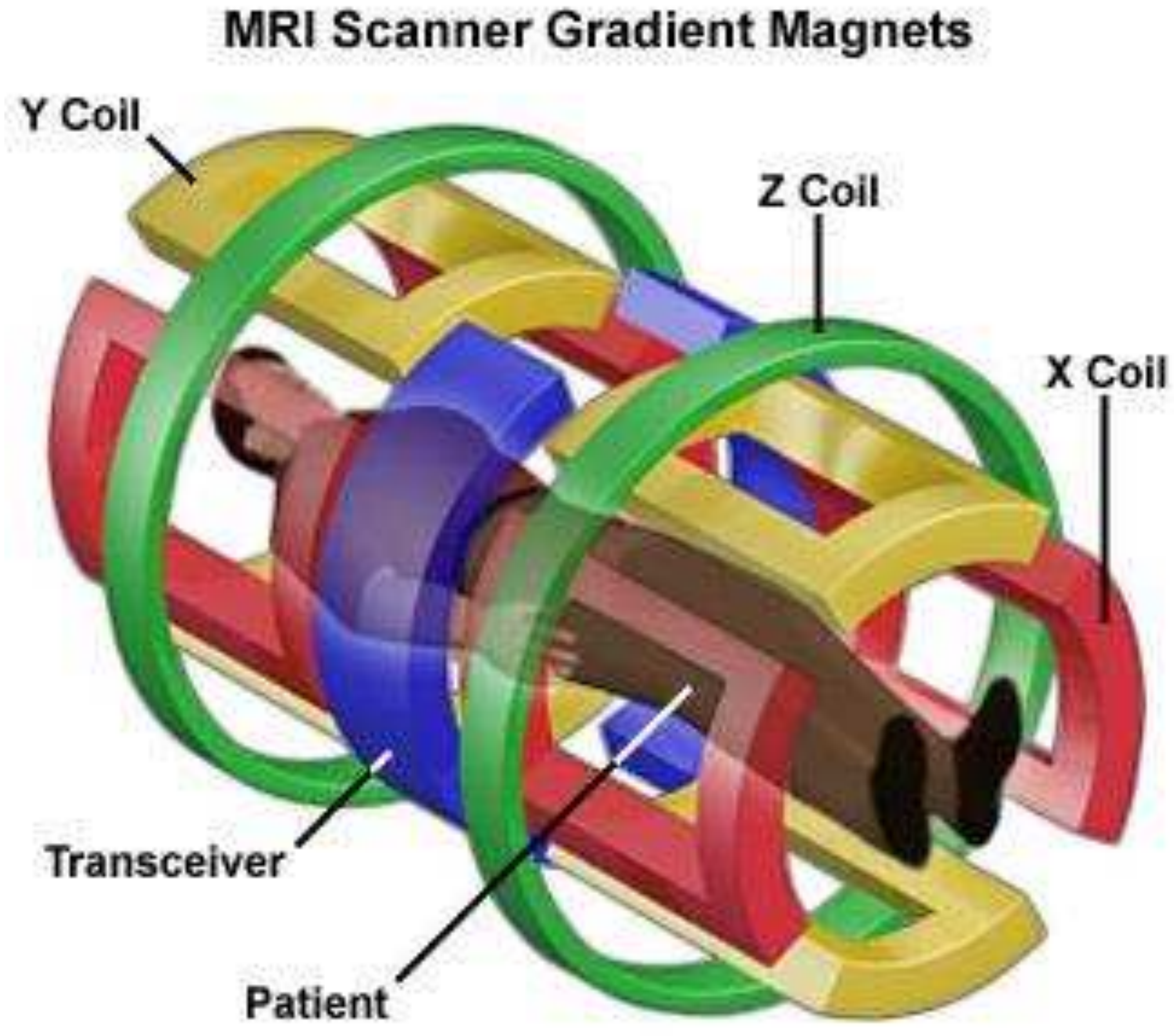

Figure 4: Principle Structure of the gradient system (image courtesy of the National High Magnetic Field Laboratory, Florida)

Components of an MR Scanner: RF System

The **radio frequency system** has two components:

- the **transmitter coil** generates a rotating magnetic field for the excitation of a spin system,
- the **receiver coil** converts magnetic changes into electrical signals.

In some systems transmission and receiver coils are identical which is then called a **transceiver coil**. all in one

Figure 5: Examples of RF head and body matrix coils (image Siemens Medical Solutions)

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- Magnetic resonance imaging (MRI) requires large acquisition devices which consist of a magnet, a gradient system, an RF system, and the imaging system.
- Driven by concepts from quantum physics, a real magnetic field is not perfectly homogeneous which has to be compensated for by image processing.

mag field is not perfect -> artifacts -> image processing

Further Readings

The webpage of the National High Magnetic Field Laboratory can be one starting point for more detailed information regarding MRI. For an initial overview of the technology, the following article is worth reading:

MRI: A Guided Tour by Kristen Coyne.

Another article worth reading is this survey paper on algorithms for intensity correction methods:

Zujun Hou. “A Review on MR Image Intensity Inhomogeneity Correction”. In: *International Journal of Biomedical Imaging* 2006.Article ID 49515 (Feb. 2006), pp. 1–11. DOI: 10.1155/IJBI/2006/49515