A Virtual MR Scanner for Education

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Purpose

- A realistic simulation of a MR scanner is to be developed
- For the user it should be possible to change all relevant settings of the virtual scanner and to adapt them to the expected pathology
- Students in education and doctors in training are the target group.

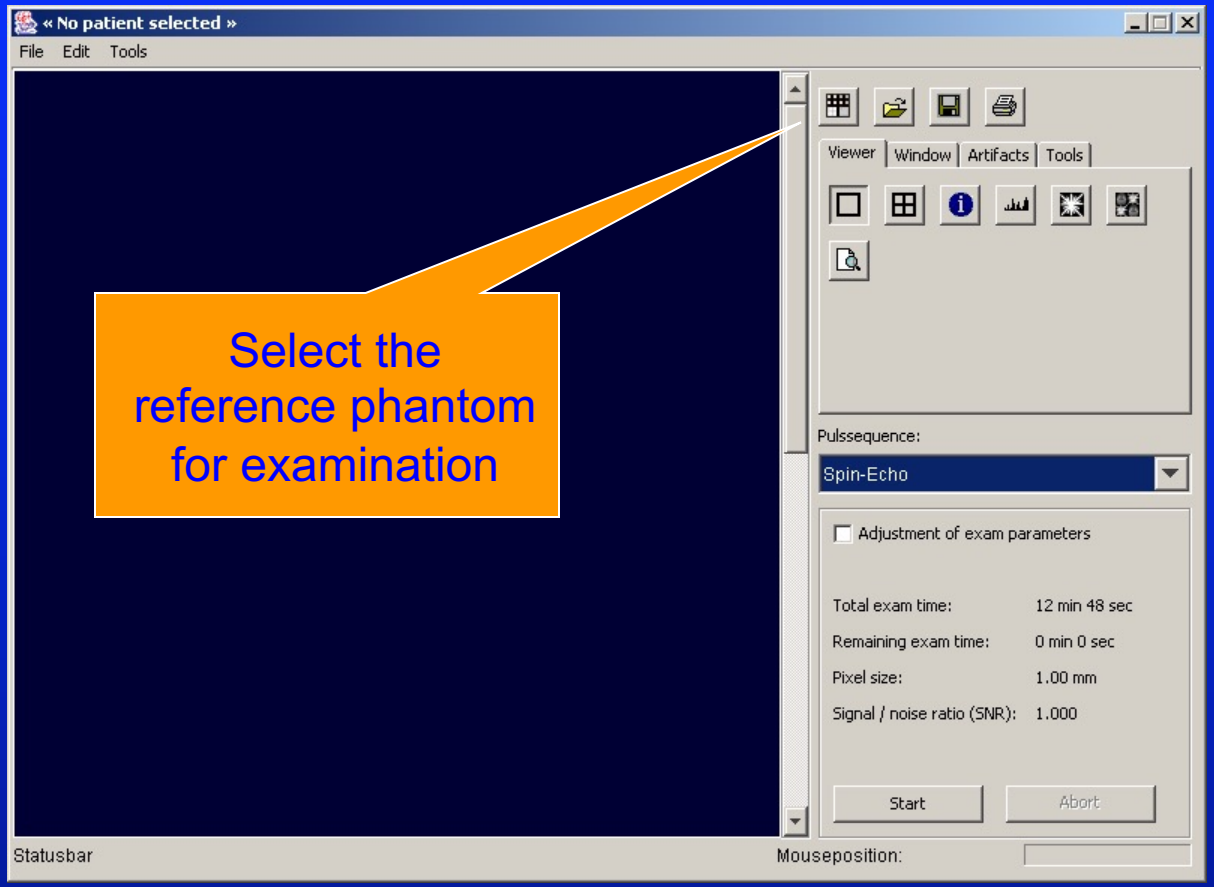
Purpose: Details

- Examination
  - Selection of an adequate pulse sequence
  - Optimization of tissue contrast by adjusting the parameters of the pulse sequence
  - Optimization of the signal to noise ratio (SNR) and the examination time
  - Identification of image artifacts
- Post processing
  - Windowing
  - Differentiation between image space and k-space

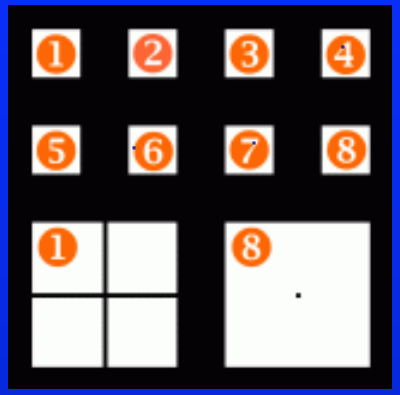
Structure of the Presentation

1. A quick tour across the simulation
2. The technical structure of the software
3. A detailed look at the simulation
4. Parameter images
5. Conclusion

A Quick Tour: Main Program Window



A Quick Tour: Reference Phantom

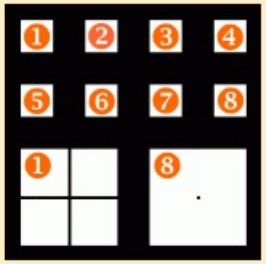


	Content	PD %	T1 ms	T2 ms
1	Fat	80	280	50
2	Methemoglobin	86	460	106
3	White matter	54	510	67
4	Gray matter	62	760	77
5	Edema	77	900	126
6	Cystic Fluid	89	1,080	280
7	CSF	89	2,650	280
8	Water	100	4,000	4000

Relaxation times dependent on magnetic field strength. Given values for 1.5T.

A Quick Tour: Reference Phantom

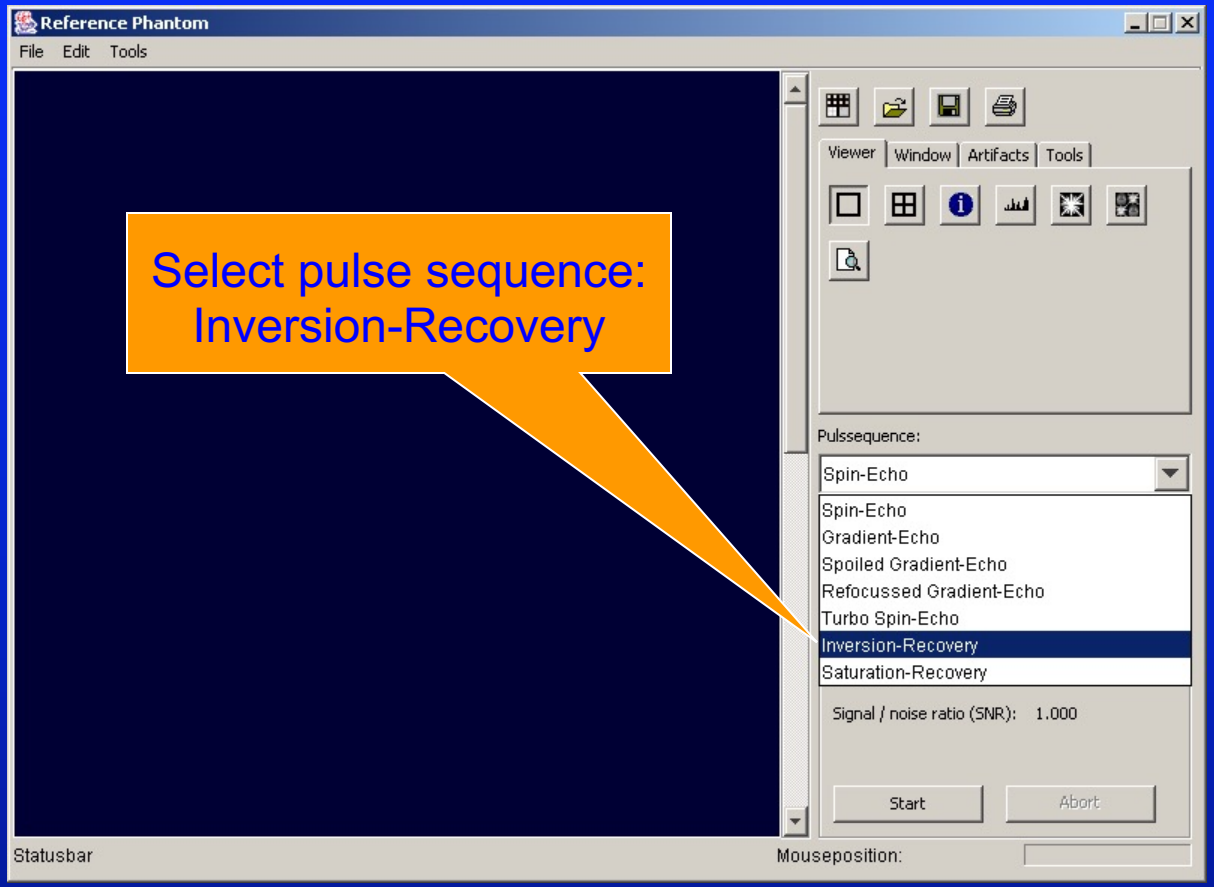
Information about the patient: Reference Phantom



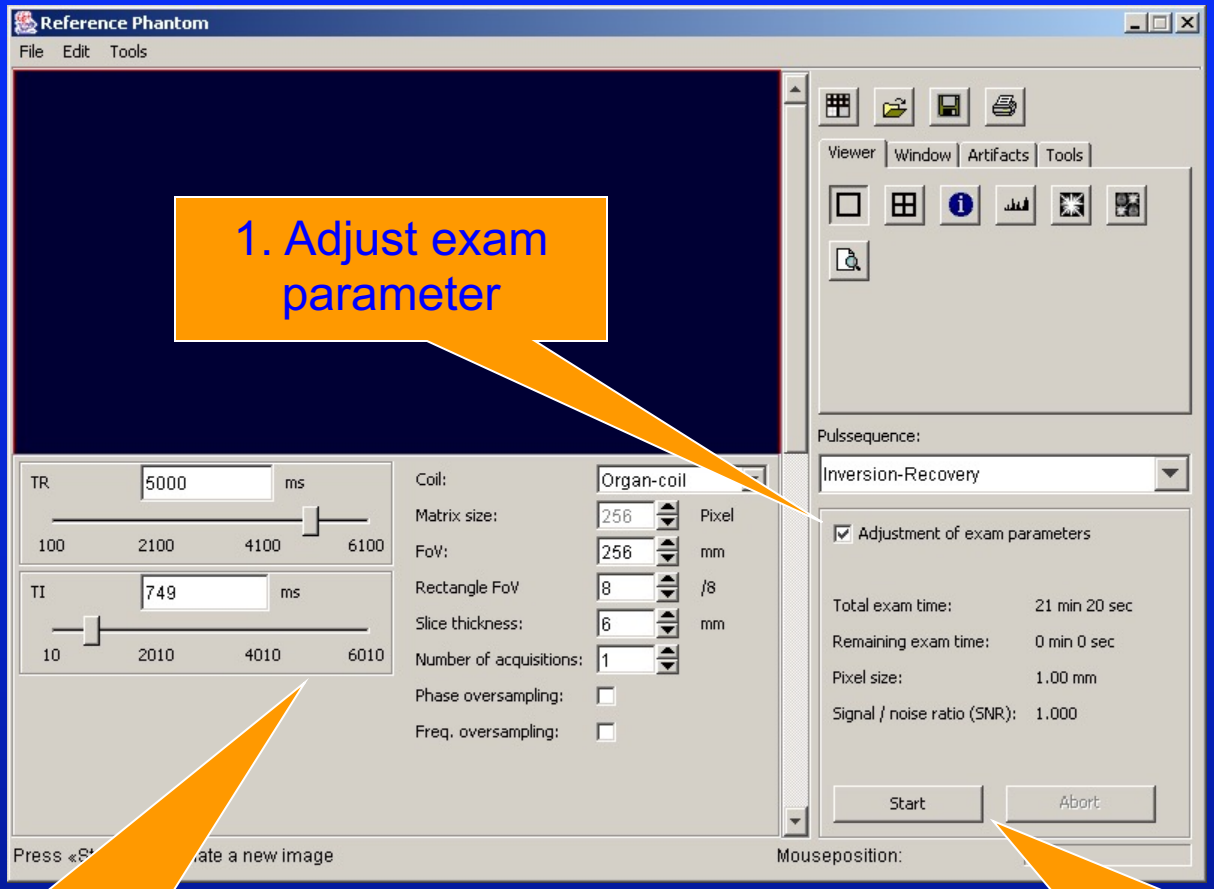
Number	Contents	Proton-density %	T1 relaxation time ms	T2 relaxation time ms
1	Fat	80	280	50
2	Methemoglobin	86	460	106
3	White matter	54	510	67
4	Gray matter	62	760	77
5	Edema	77	900	126
6	Cystic fluid	89	1080	280
7	CSF	89	2650	280
8	Water	100	4000	4000

Close the info window

A Quick Tour: Select Inversion-Recovery



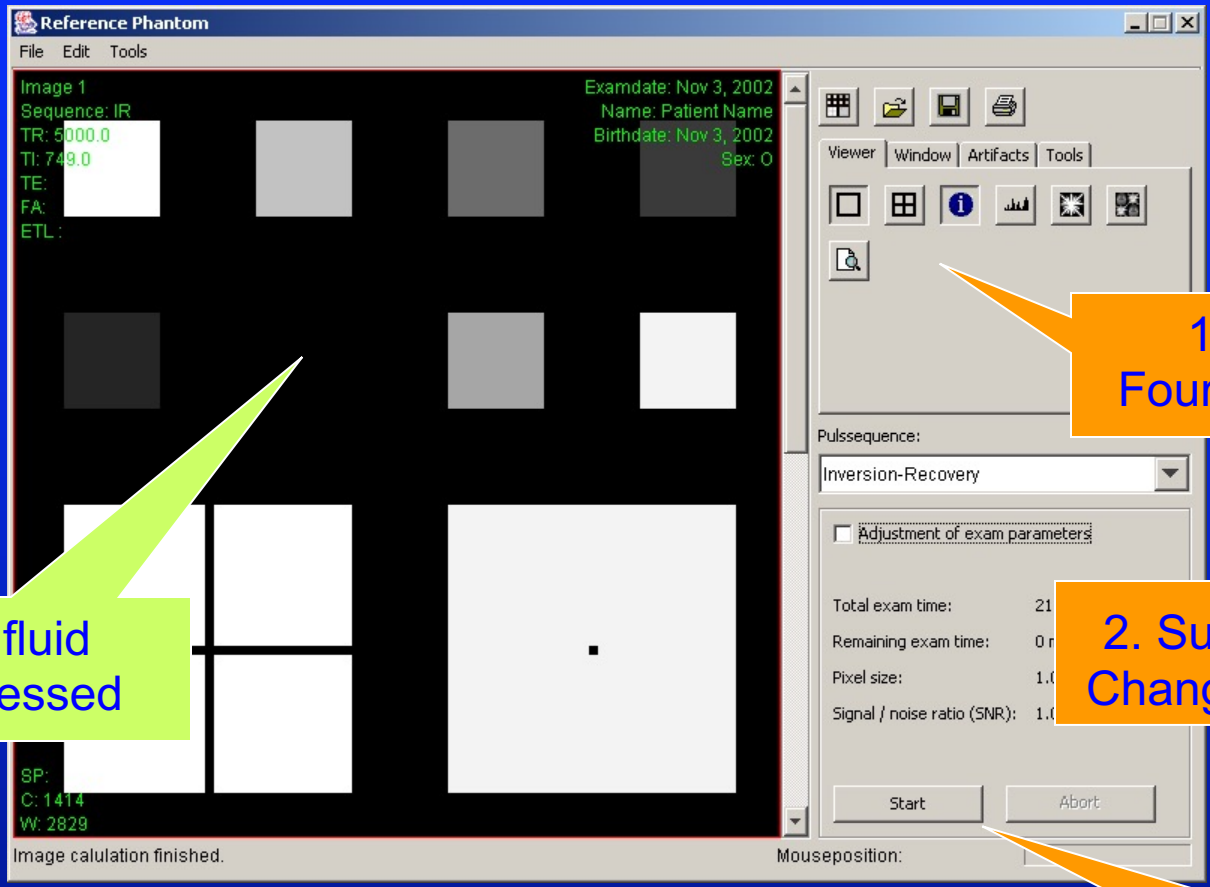
A Quick Tour: Suppress Cystic Fluid



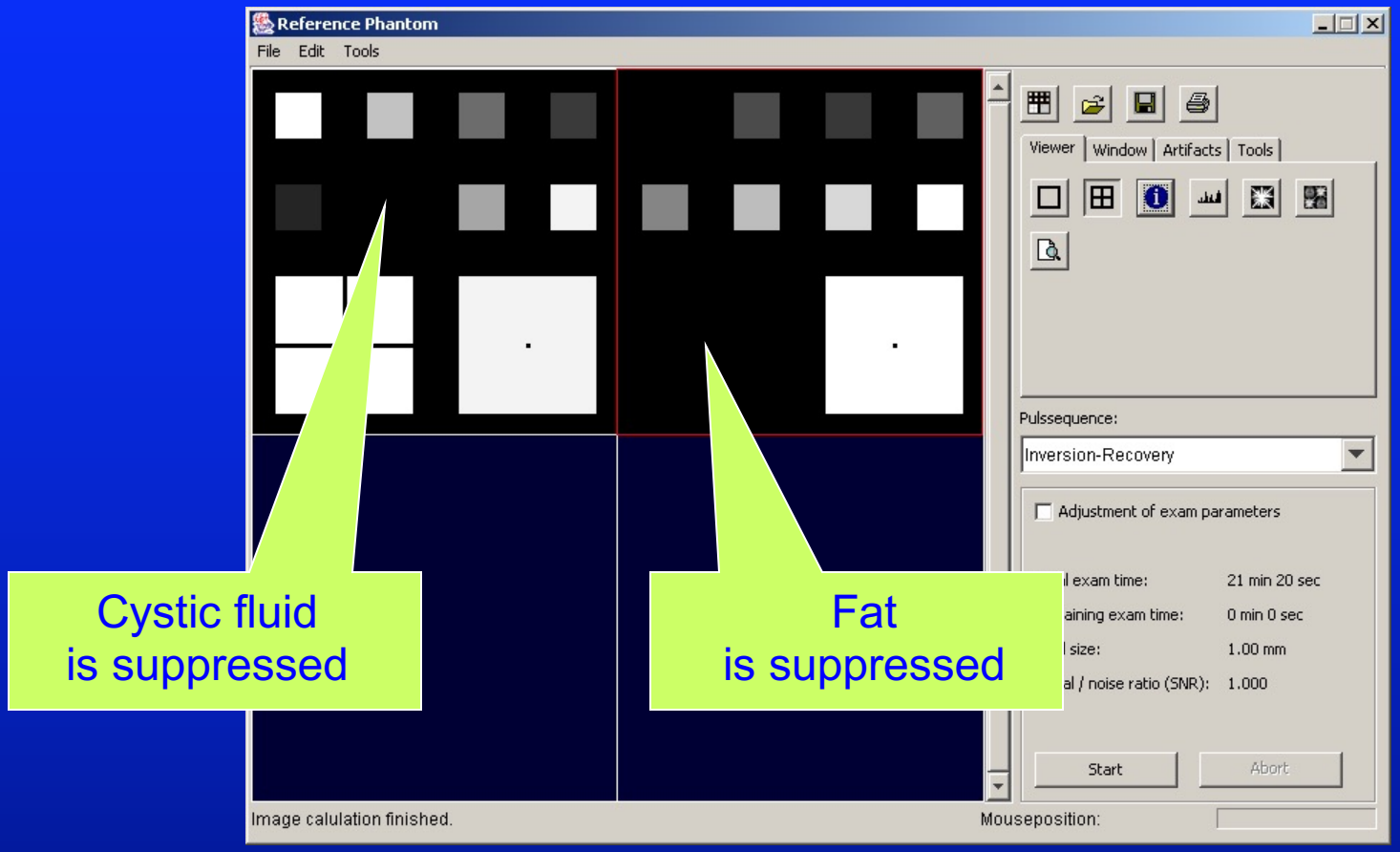
2. Change TI to 749 to suppress cystic fluid

3. Start examination

A Quick Tour: Suppress Fat



A Quick Tour: Comparison of Results



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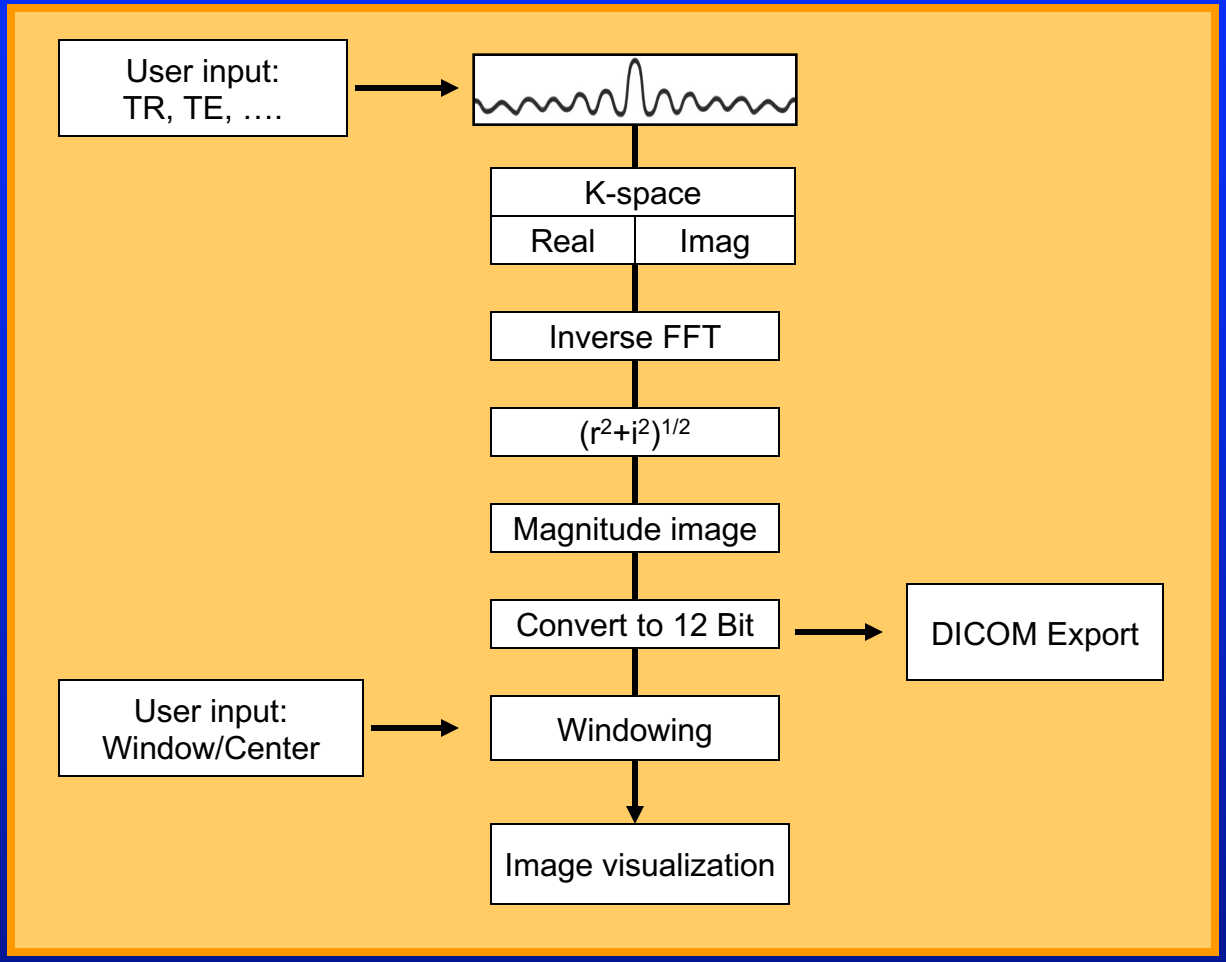
Objectives

- User interface is to correspond to a real world scanner
- Simulation is to be independent of a particular hardware and software platform
- Pulse sequences are to be easily extensible with a plug-in mechanism

Method

- Programming language:
  - Pure Java 1.2
  - Internationalized versions: English, German, Estonian, …
- Hardware requirements:
  - Equivalent to a Pentium II 400MHz, 128 MB, 618k (!!) free hard disk space
- Software requirements:
  - Operating system with a Java JRE 1.2 or higher
- License:
  - GNU General Public License

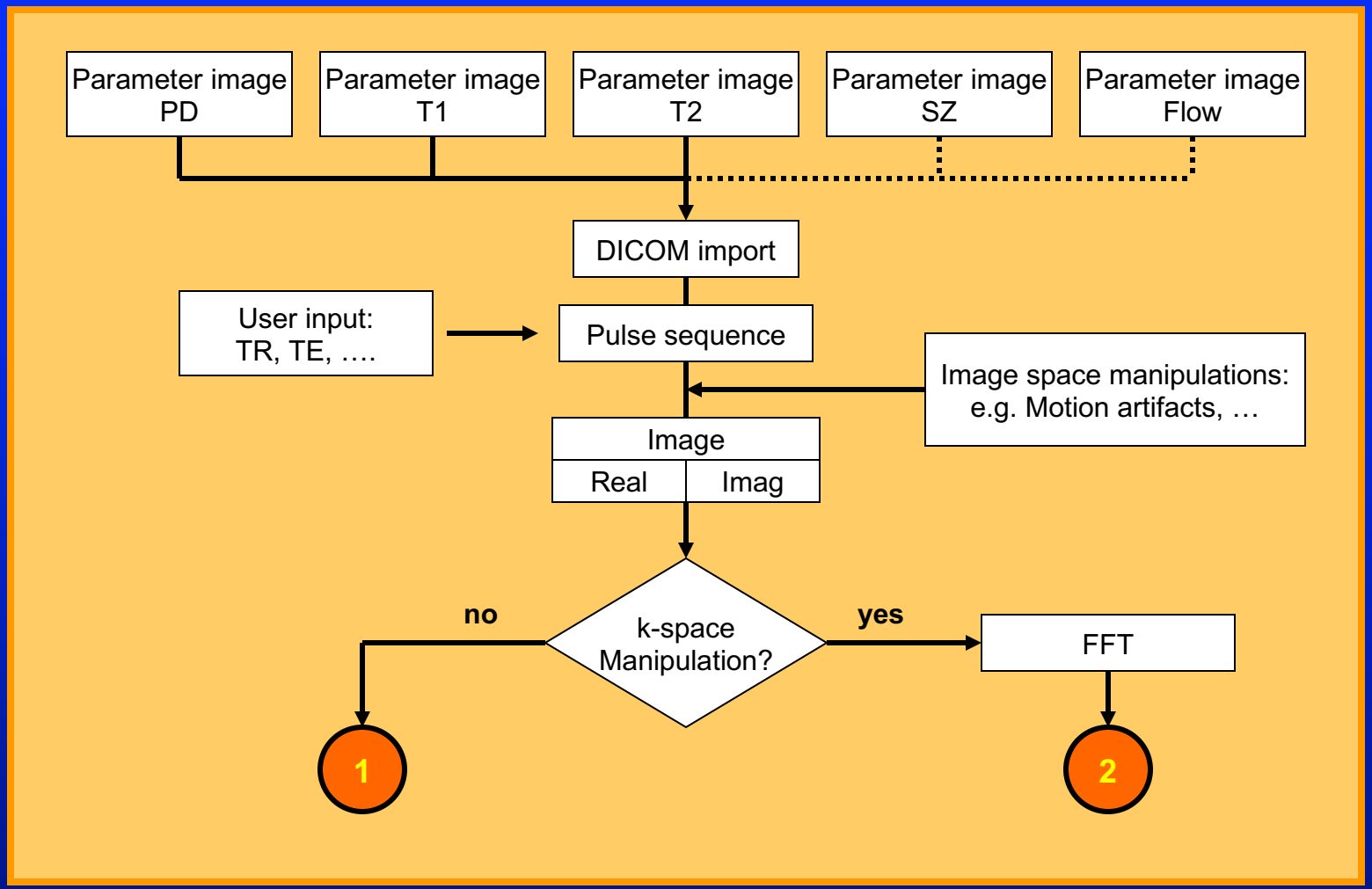
Real MR Scanner



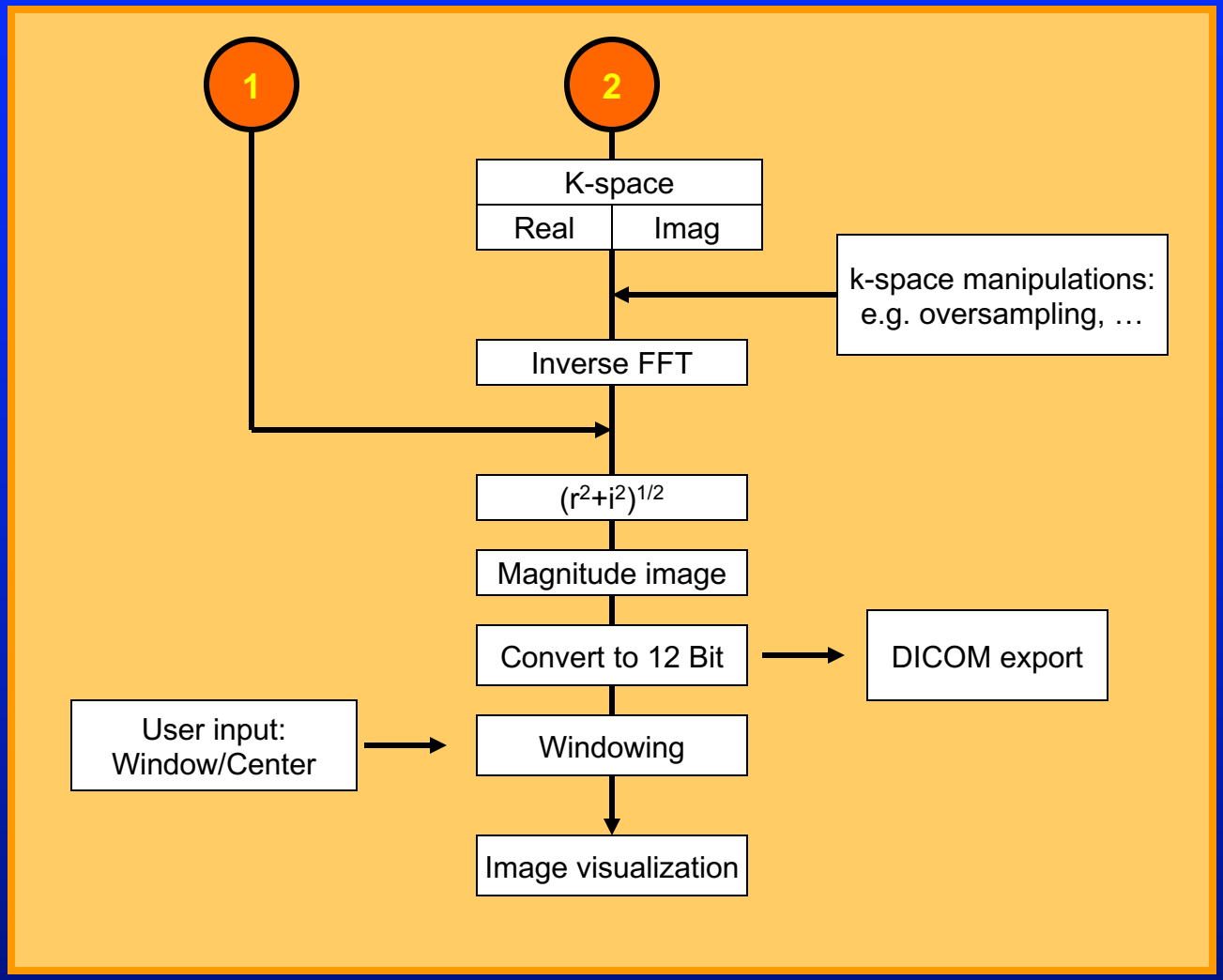
Basics of the Virtual MR Scanner

1. Base of the simulation are parameter images of T1, T2 and PD derived once from a real-world examination
2. Calculation of an intensity image in exchange for the real-world object
3. Superposition of artifacts (e.g. noise) in the image space
4. Transform of the intensity image into the k-space
5. Processing of k-space analog to a real MR scanner

Virtual MR: Part 1



Virtual MR: Part 2



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User Interface

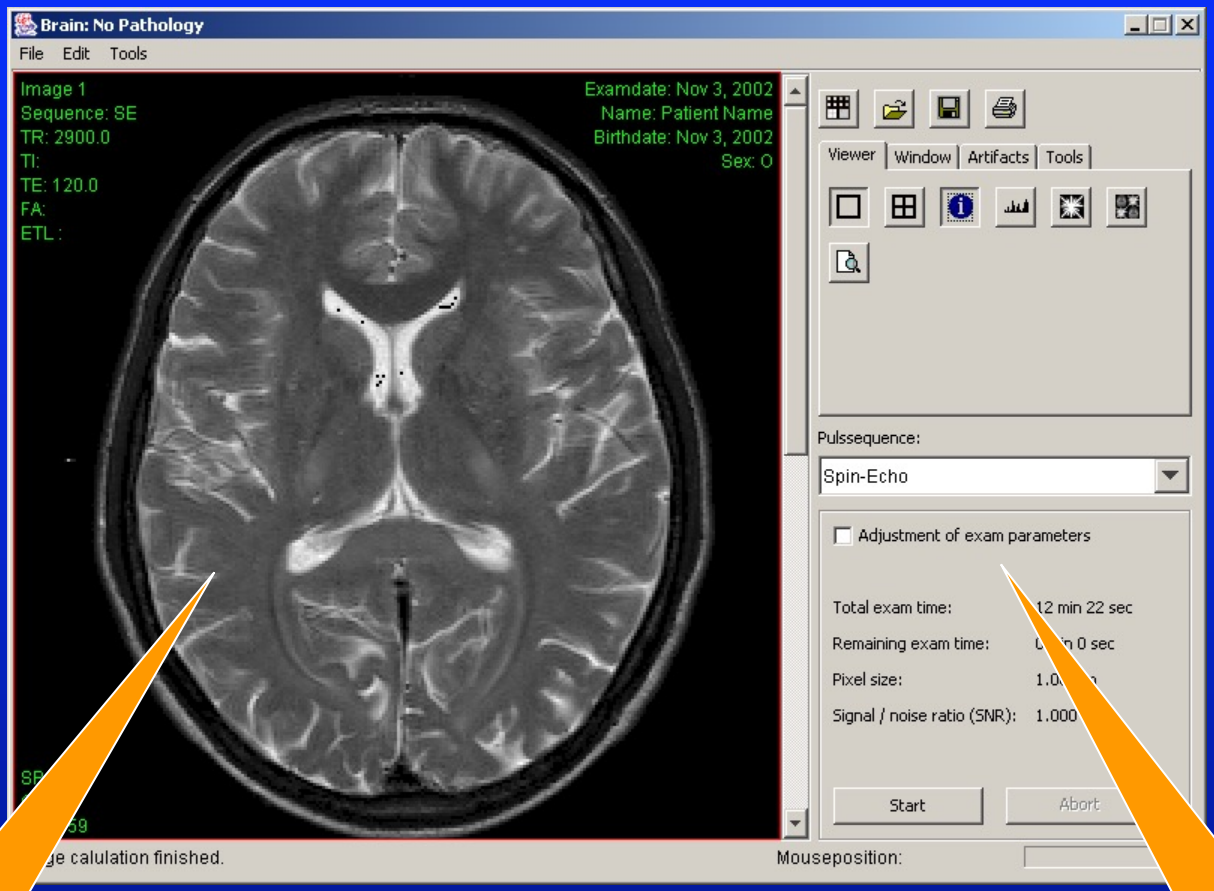
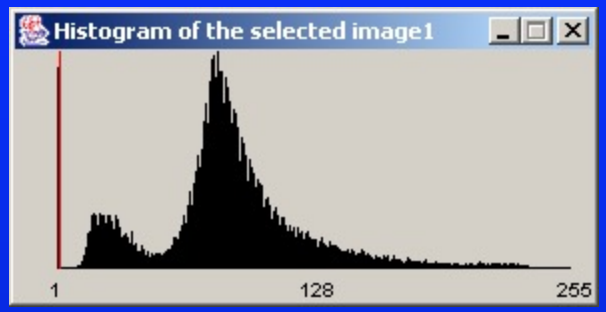
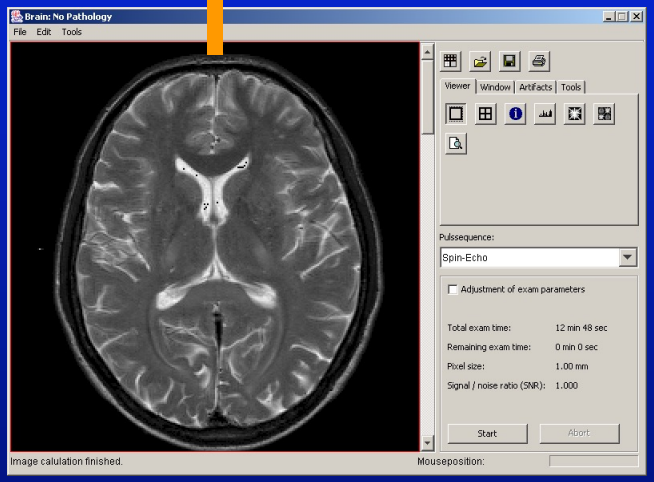


Image area

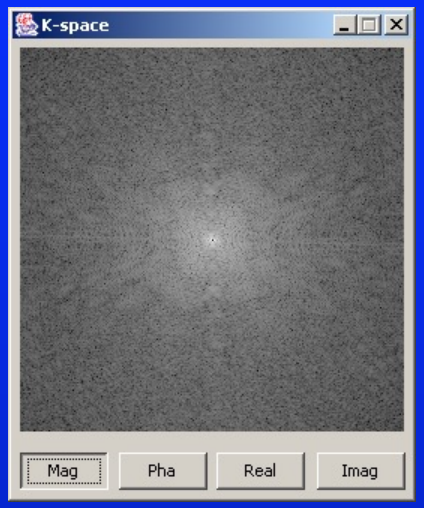
Control area

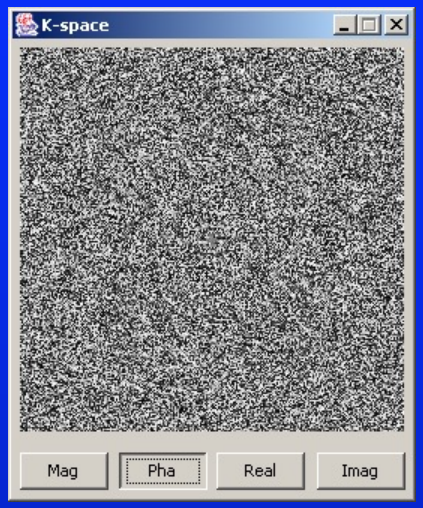
Histogram View

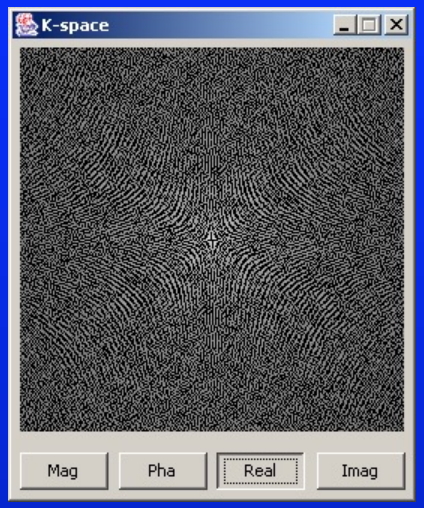


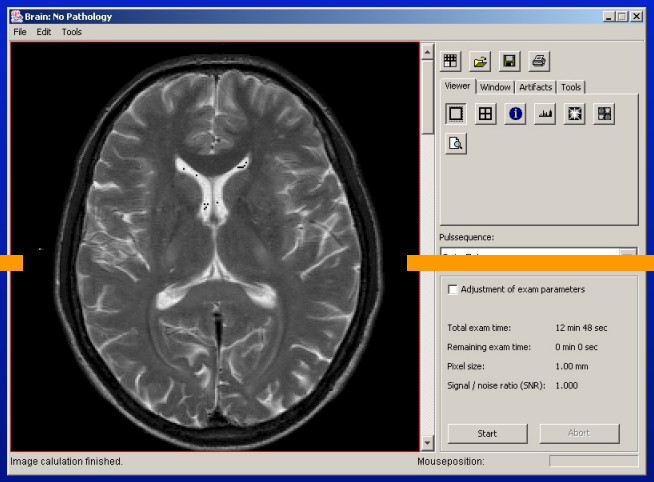


K-Space View

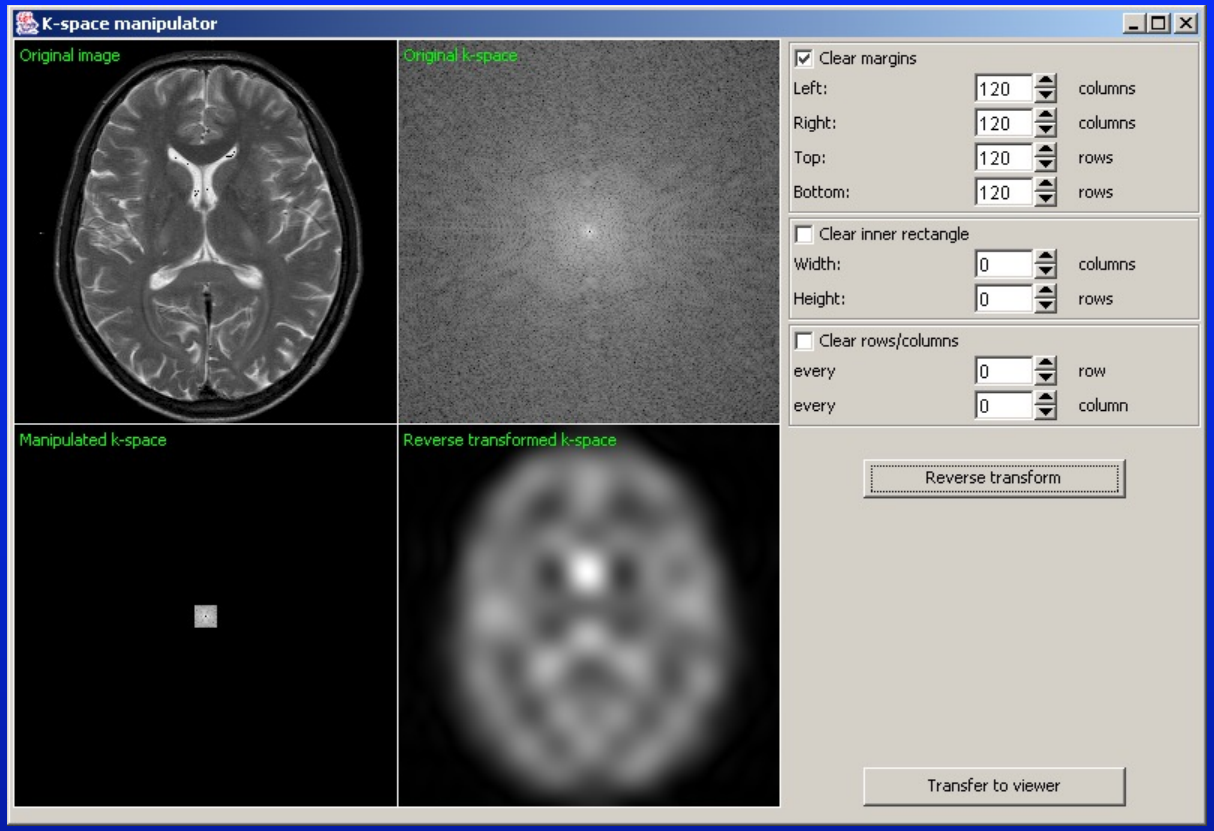

K-space
Mag
Pha
Real
Imag


K-space
Mag
Pha
Real
Imag

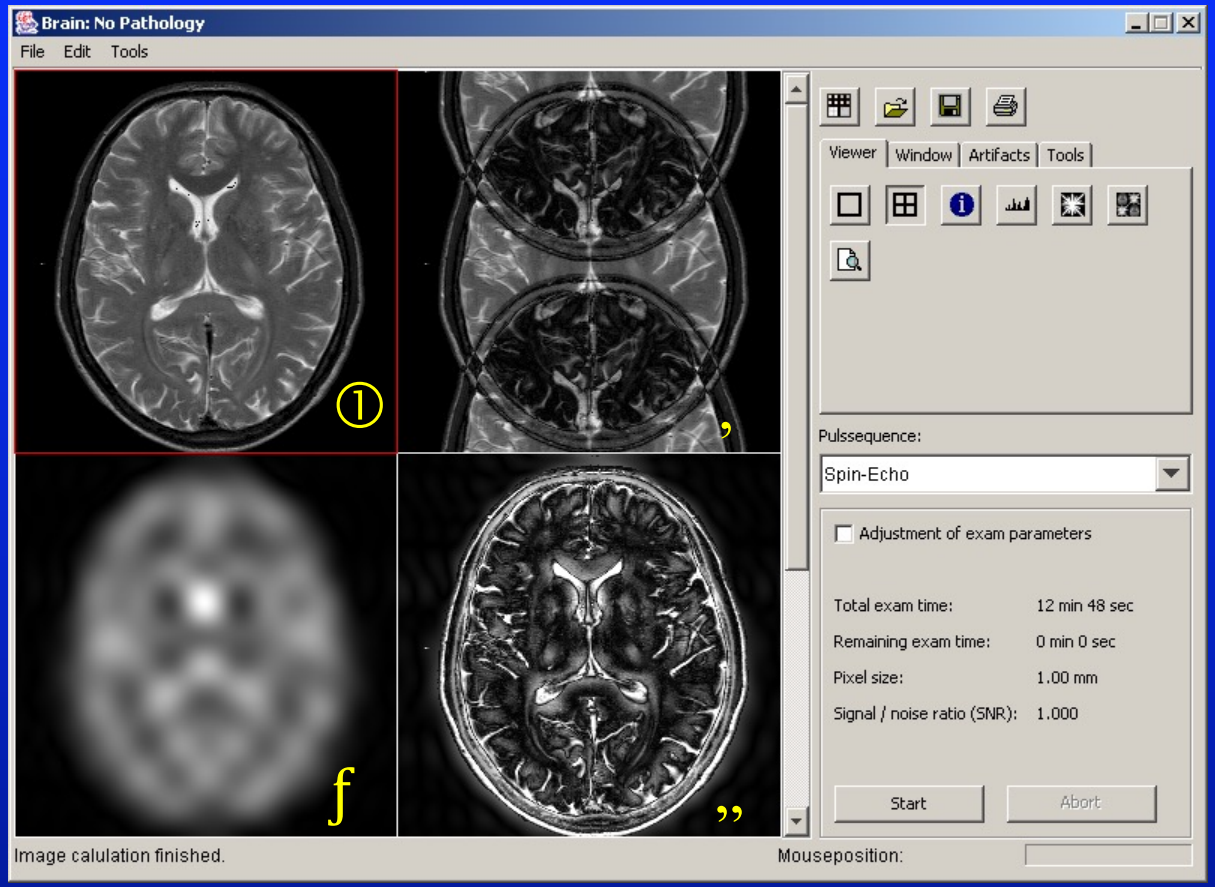

K-space
Mag
Pha
Real
Imag


Brain: No Pathology
File
Edit
Tools
Viewer
Window
ArtiFacts
Tools
Pulssequence:
Adjustment of exam parameters
Total exam time:
12 min 48 sec
Remaining exam time:
0 min 0 sec
Pixel size:
1.00 mm
Signal / noise ratio (SNR):
1.000
Start
Abort
Image calulation finished.
Mouseposition:

K-Space Manipulator

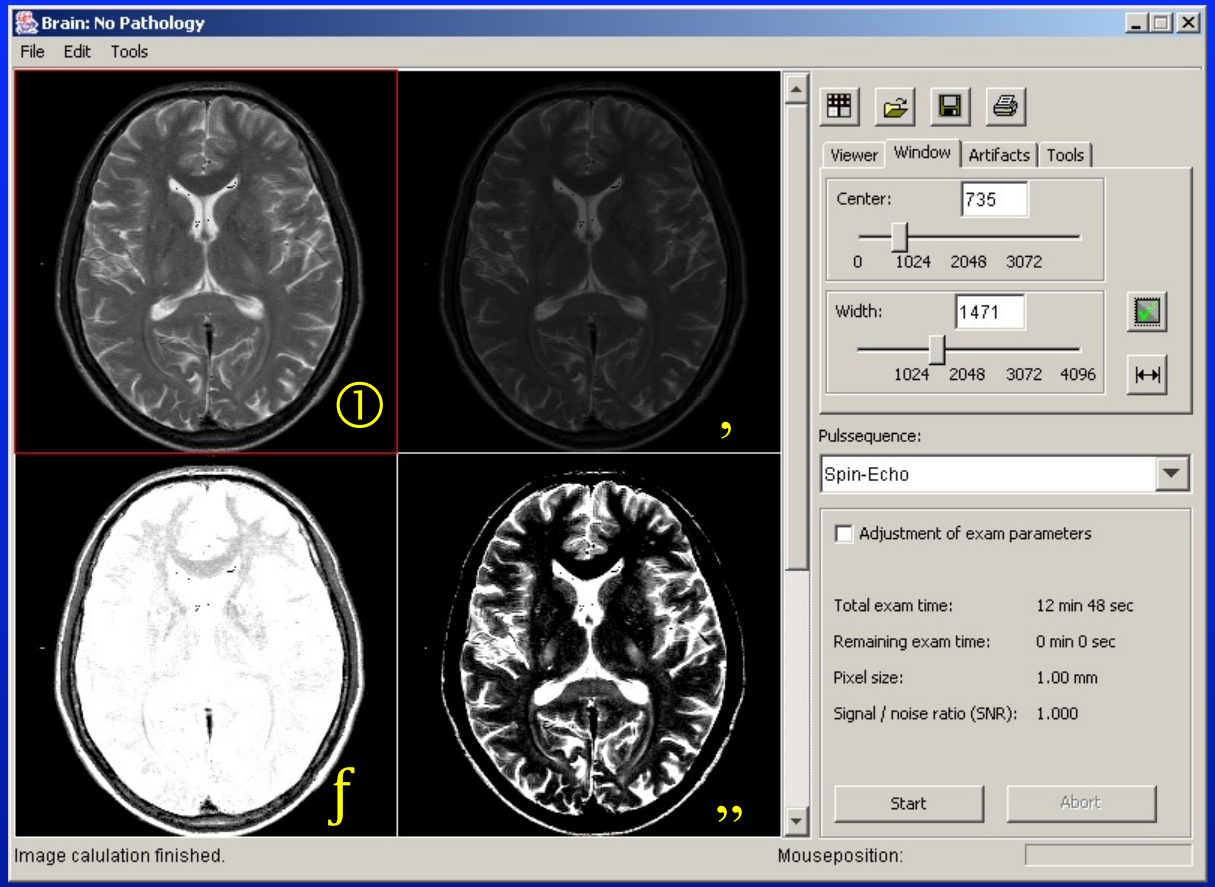


Available K-Space Manipulations



1. Original image
2. Every 2nd column cleared
3. 120 pixels wide margin cleared
4. 16 pixels wide center cleared

Windowing



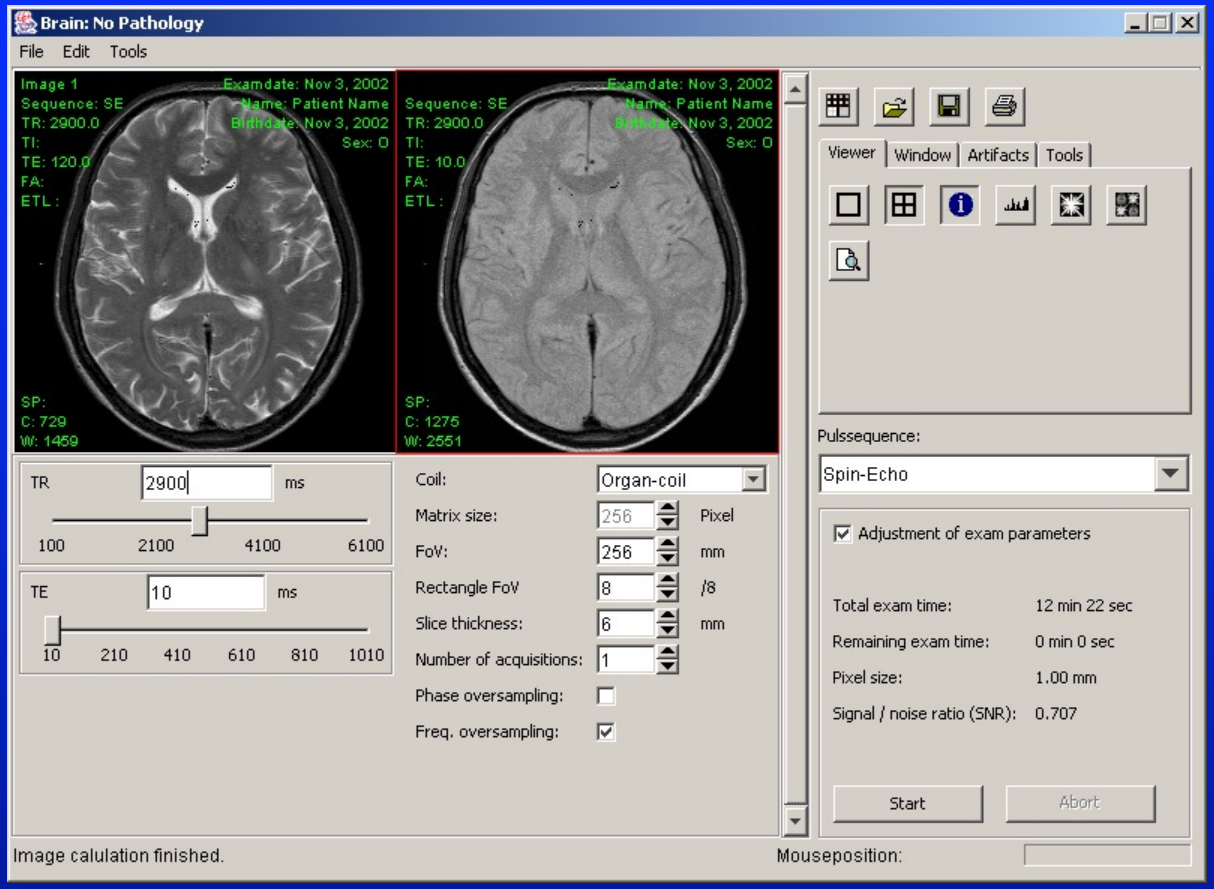
1 Optimum
C= 735
W= 1471

2 Maximum
C= 2048
W= 4096

3 Brightness
C= 0
W= 880

4 Contrast
C= 581
W= 303

Adjusting Parameters of a Pulse Sequence



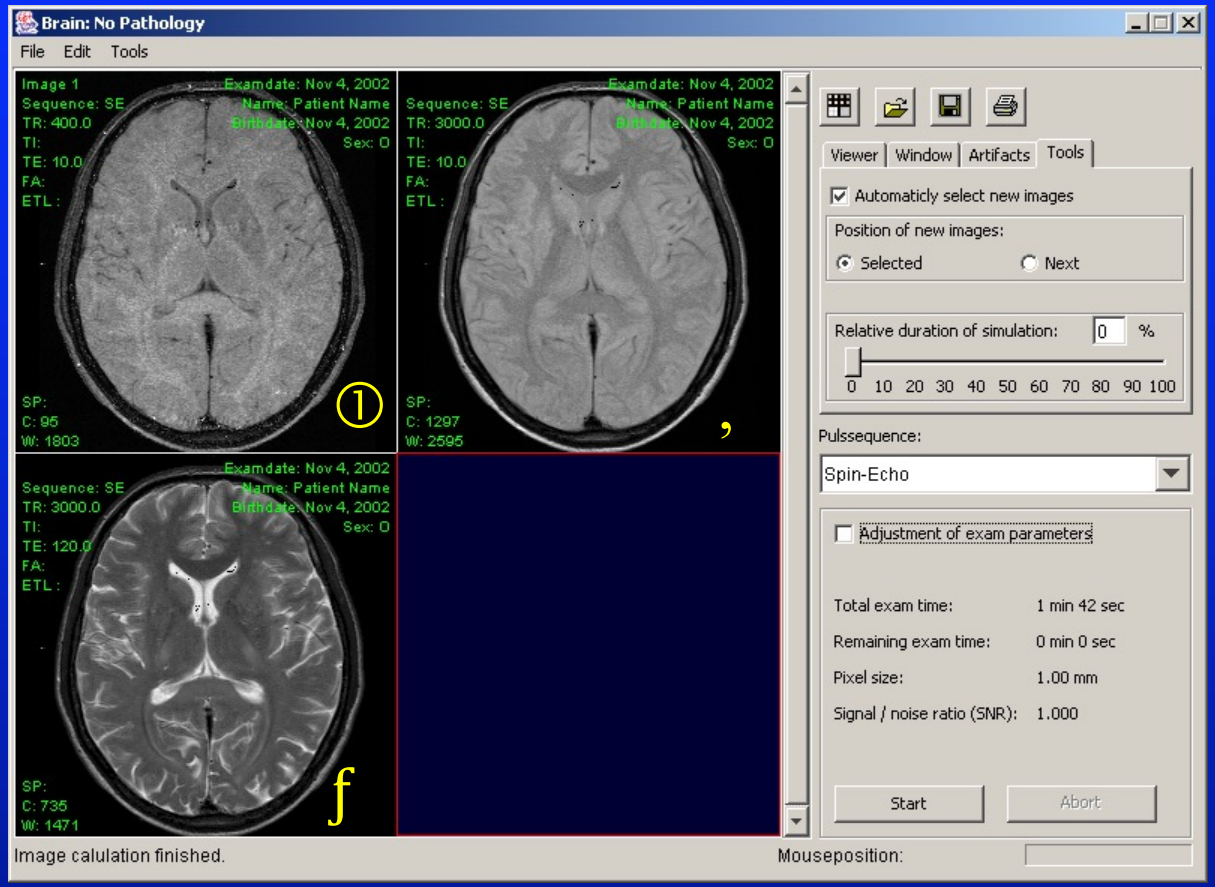
General Parameters

Parameter	Comment
Coil	Organ coil or body coil
Matrix size	Fixed value of 256*256 pixels
Field of View (FoV)	[mm]
Rectangle FoV	Vertical to horizontal ratio of FoV [1/8]
Slice thickness	[mm]
Number of acquisitions	Number of acquisitions/excitations (NEX)
Phase oversampling	Off / On
Frequency oversampling	Off / On

Pulse Sequence dependent Parameters

Pulse-Sequence	TR	TE	TI	Flip.	TEeff	ETL
Spin Echo	+	+				
Turbo Spin Echo	+				+	+
Gradient Echo	+	+		+		
Spoiled Gradient Echo	+	+		+		
Refocussed Gradient Echo	+	+		+		
Saturation Recovery	+					
Inversion Recovery	+	+	+			

Weighting (Spin Echo)

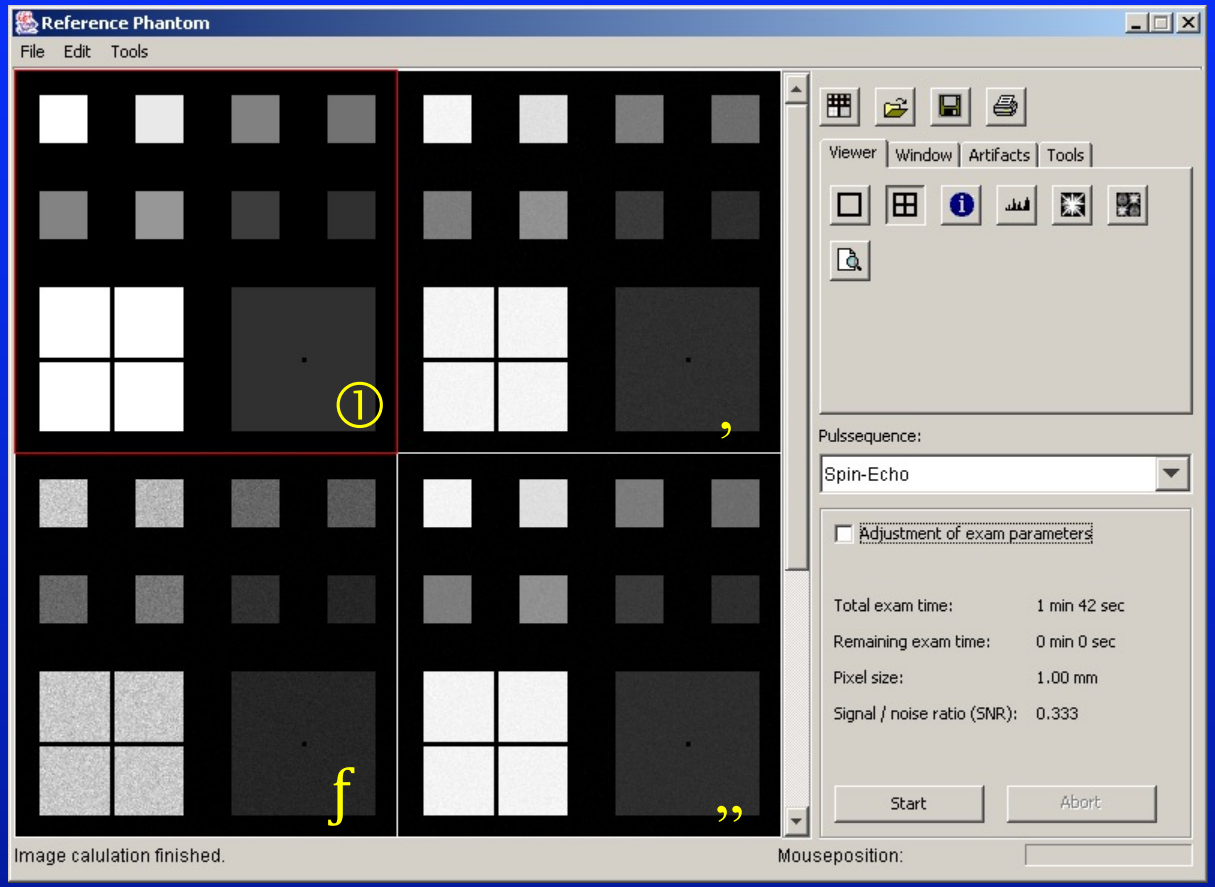


1 T1 Weighting
TR=400, TE=10

2 PD Weighting
TR=3000, TE=10

3 T2 Weighting
TR=3000, TE=120

Signal to Noise Ratio (SNR)



1 SNR = 1,000
Organ coil,
6mm, 1 NEX

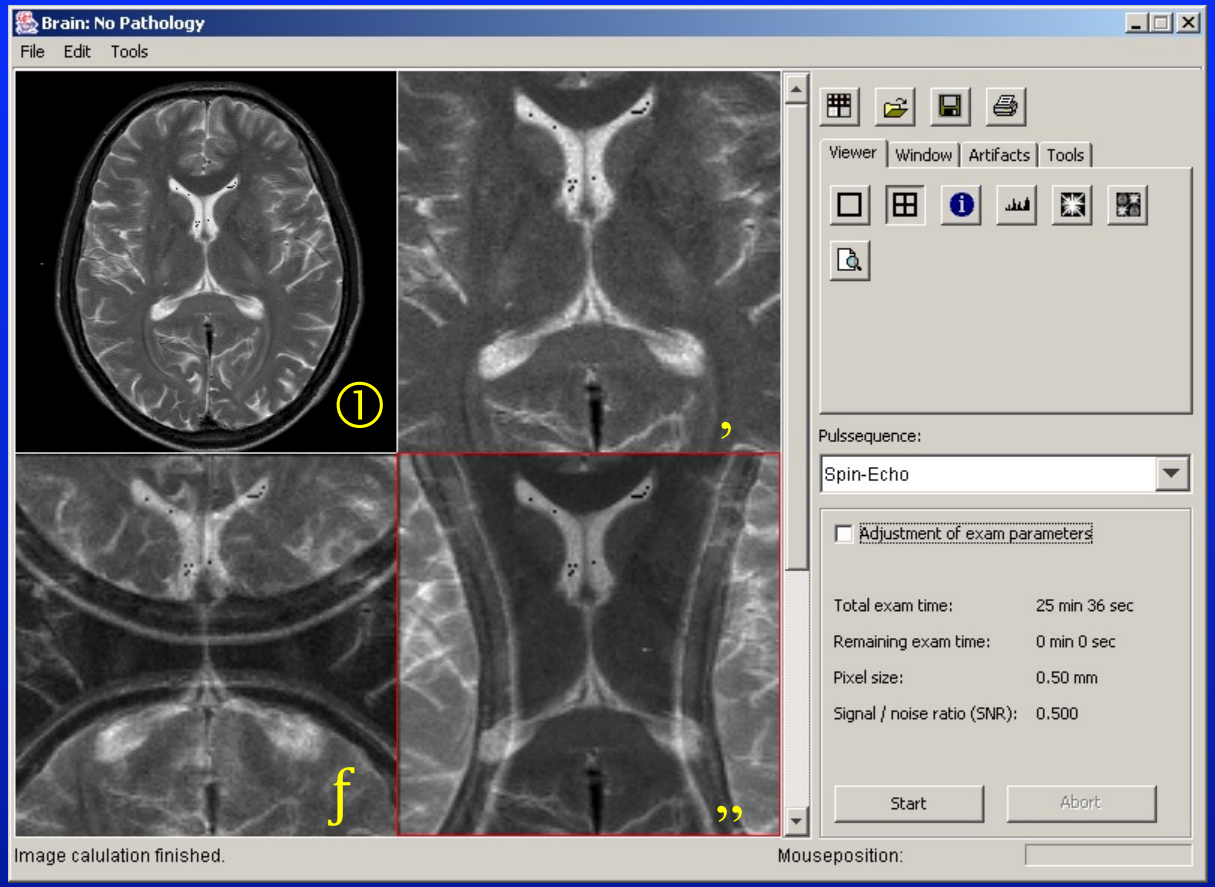
2 SNR = 1.000
Body coil,
6mm, 1 NEX

3 SNR = 0.333
Body coil,
2mm, 1 NEX

4 SNR = 0,943
Body coil,
2mm, 8 NEX

Oversampling

PO=Phase Oversampling FO=Frequency Oversampling



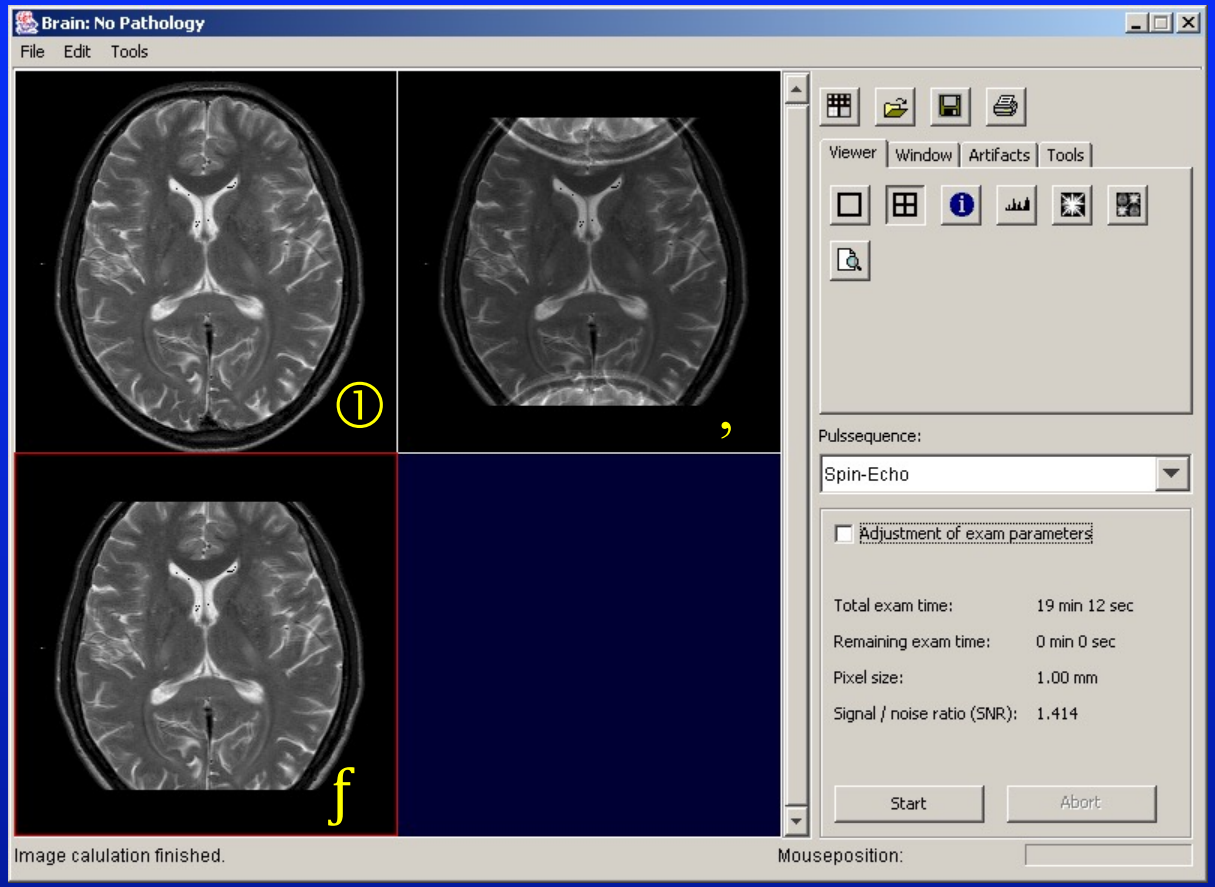
1 FoV = 256
FO = no, PO = no
SNR = 1.000
Exam time 4:16

2 FoV = 192
FO = yes, PO = yes
SNR = 0.354
Exam time 8:32

3 FoV = 192
FO = yes, PO = no
SNR = 0.250
Exam time 4:16

4 FoV = 192
FO = no, PO = yes
SNR = 0.500
Exam time 8:32

Rectangle FoV

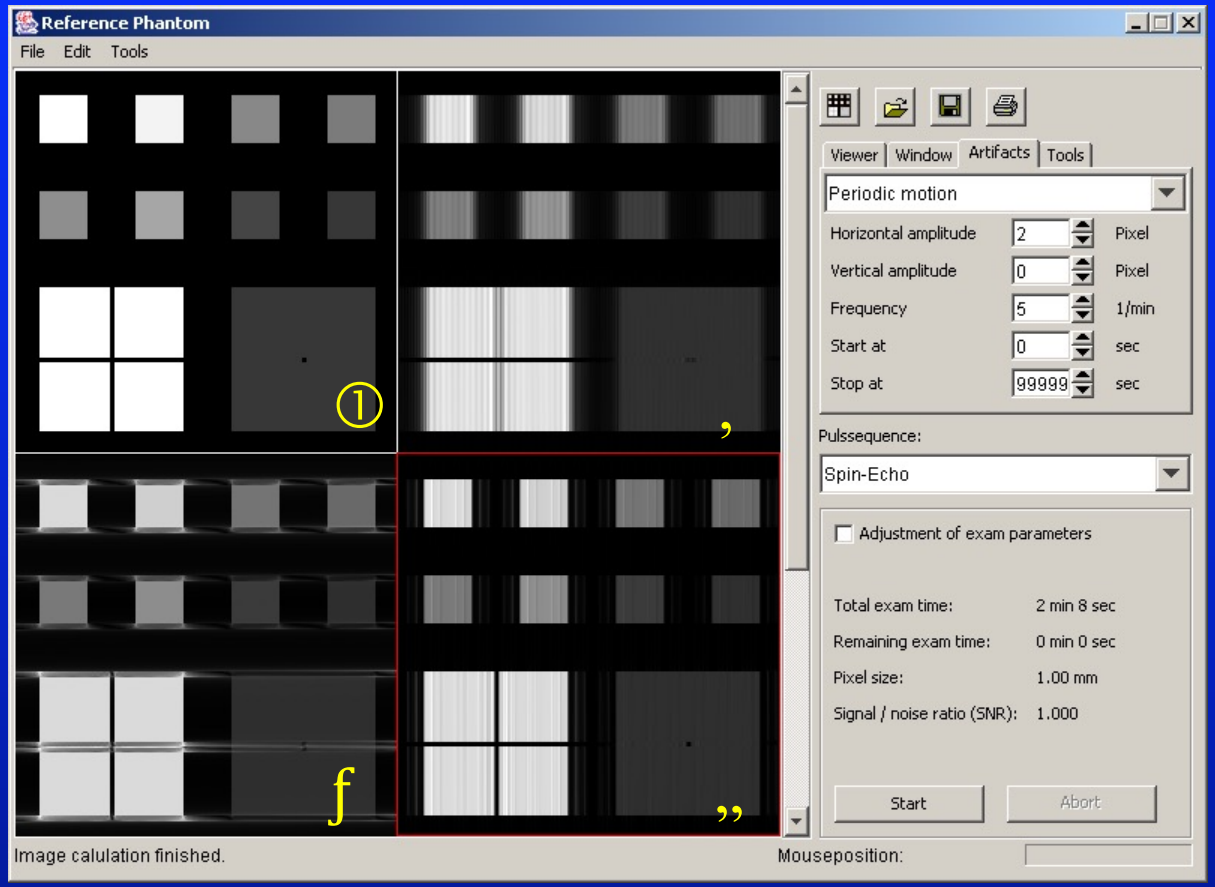


1 FoV = 256
Rec = 8 / 8
PO = no
SNR = 1.000
Exam time 12:48

2 FoV = 256
Rec = 6 / 8
PO = no
SNR = 1.000
Exam time 9:36

3 FoV = 256
Rec = 6 / 8
PO = yes
SNR = 1.414
Exam time 19:12

Motion Artifacts



1. No motion
2. Translational motion horizontal = 2 Pix/min
3. Translational motion vertical = 2 Pix/min
4. Periodic motion horizontal = 2 Pix/min frequency = 5 /min

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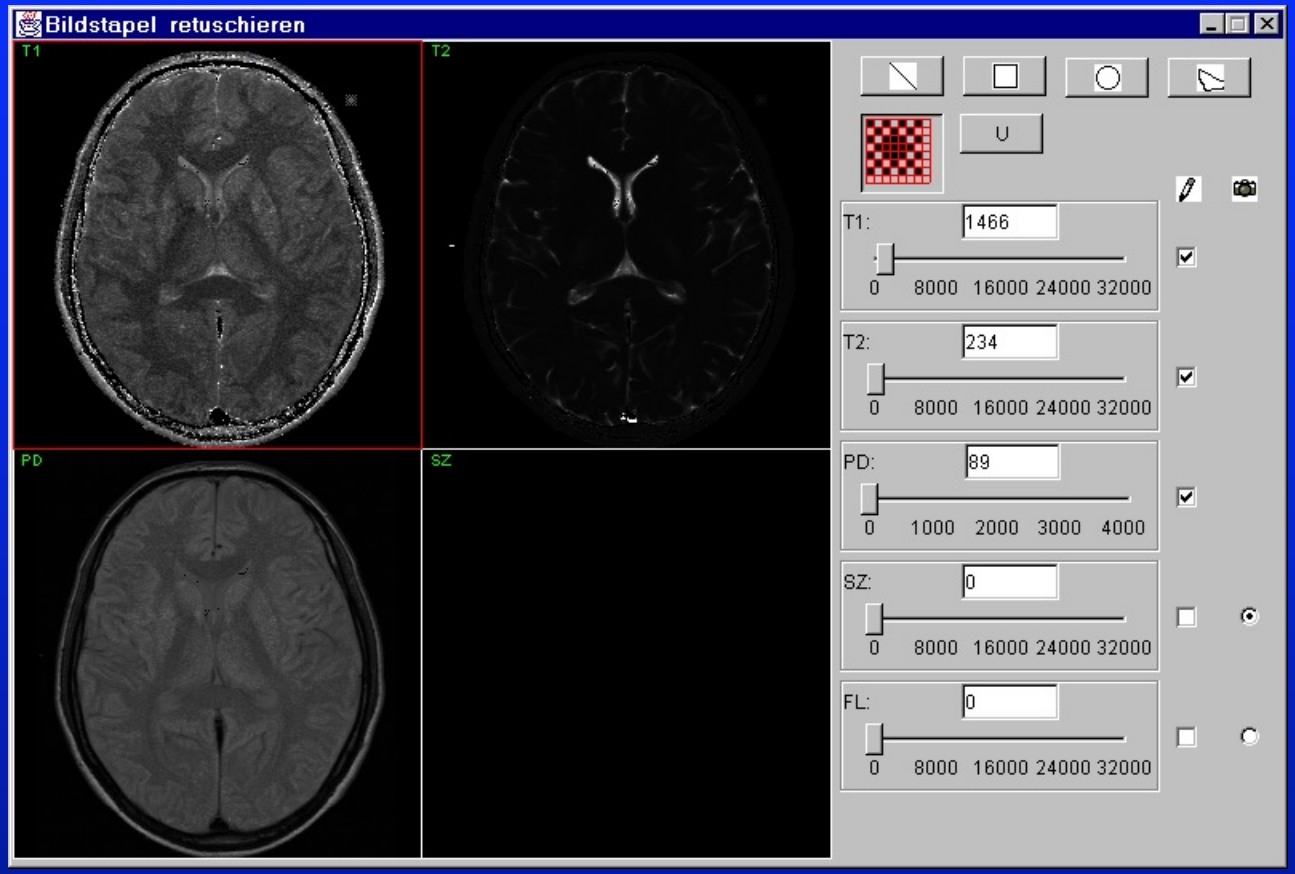
Calculation of the Parameter Images

- Patient examination under clinical conditions
- Spin echo pulse sequences
  - T1: TR=160..520 step 30, TE=5 (9 measurements)
  - T2, PD: TR=2440, TE=50..800 step 50 (16 measurements)
- Calculation of T1,T2 and PD using a weighted least square fit
- Error of the calculated T2 values: ± 5%
- T1 is uncertain! Possible solution: non-linear curve fit (Marquardt-Levenberg algorithm) or simplex method

Editor for Parameter Images

Alpha version



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Results

- On a 500 MHz PC the software calculates an image within 5 to 20 seconds
- Calculation time depends on
  - Pulse sequence
  - Superposition of artifacts

Conclusion

- An interactive simulation of a real world examination is possible on a standard PC
- The users can study the operation of a costly and not everywhere available equipment on their desktop
- Contact:
  - Web: www.iftm.de
  - E-Mail: hacklaender@iftm.de