Application of Parallel Processing - A Case Study on MRI

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***Abstract*—MRI is widely used in medical investigation to examine internal body structures of organs, soft tissues, bone, tumours since 1981. It is being used to detect the presence of certain diseases. MRI scanner is one large cylinder-shaped tube surrounded by a circular magnet. Patient will be positioned on the moveable examination table. The computer workstation that processes the imaging information is located in a separate room from the scanner. MRI does not utilize ionizing radiation, instead it uses a powerful magnetic field and pulses of radio waves energy without causing any chemical changes in the tissues. MR scanner will capture the energy and create an image of the body structures scanned based on the information. The computer then processes the signals and generates a series of images, each of which shows a thin slice of the body. Parallel imaging is one of MR techniques to reduce scan time.**

***Keywords:* parallel processing, MRI, medical scanner**

I. Introduction

MRI is an interaction between image gradients specified in pulse sequence, defining trajectory to collect k-space data. Parallel imaging is a technique for fast-tracking the acquisition of MRI data. It works by getting a reduced amount of k-space data with an array of receiver coils. There are two types of parallel imaging, namely image reconstruction, and image that takes place in k-space [1-9].

II. K-SPACE

k-space illustration of MR images is merely an organised assortment of these spatial frequency reflecting images harmonic content. k-space data is gathered line by line in order to fill grid of point. k refers to spatial frequency of waves in various media.

$$k = 1/\lambda$$

k : number of waves

λ : wavelength

k-space is array of numbers representing spatial frequency in MR images. It is a grid of data of form (kx, ky) obtained directly from MR signal. Values are corresponding to spatial frequency of MRI.

III. pMRI

pMRI is a compact data set in phase encoding directions of k-space is developed to shorten acquisition time, merging signal of several coil arrays. Spatial information related to phased array coil elements are used to be utilized for reducing amount of conventional Fourier encoding.

Image resolution is described as line pairs per mm. A pair of lines are like crests and peaks of adjacent waves. All imaginings can be decomposed using Fourier investigation into planar waves with numerous frequencies, phases, amplitudes and orientations.

IV. How MRI works

1. Data are gathered in k-space that contains spatial frequency information and is related to real images through mathematical procedure called Fourier transform
2. k-space data is generated by using spatially changing magnetic field gradients superimposed on main magnetic field of MRI scanner
3. After all data are gathered, the Fourier transform is used to transform k-space data to an image

Table I shows the acronyms for parallel imaging methods and terminologies available.

TABLE I

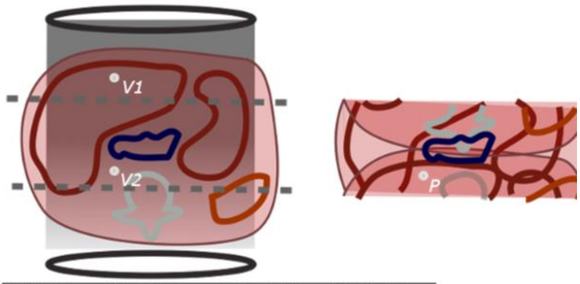
ACRONYMS FOR PARALLEL IMAGING METHODS AND TERMINOLOGY AVAILABLE

Name	Acronym	Method	Manufacturer
SENSitivity Encoding	SENSE	Image-based reference scan	Philips
Array Spatial Sensitivity Encoding Technique	ASSET	Image-based reference scan hybrid (image- and *k*-space based)	General Electric
Auto-calibrating Reconstruction for Cartesian Imaging	ARC	Image-based reference scan hybrid (image- and *k*-space based)	General Electric
integrated Parallel Acquisition Techniques	iPAT	Used by all pMRI	Siemens
GeneRalized Auto-calibrating Partially Parallel Acquisition	GRAPPA	k-space based, auto-calibrated with reference scan option	Siemens
modified SENSitivity Encoding	mSENSE	Image-based, auto-calibrated with reference scan option	Siemens
SPEEDER	--	Image-based, reference scan	Toshiba

V. Types of parallel imaging in MRI

A. SENSE

SENSE involves using the spatial, real space as opposed to k-space, sensitivities of each coil to unwrap aliased images [10]. The simulation above implements the SENSE algorithm, which is described and diagrammed below in Fig. 1.



Spatial aliasing and the SENSE reconstruction (artistic rendition). **Left**, the body part lies in a phased-array of 2 coils, one anterior and the other posterior; the gradient shows that the anterior coil picks up much more signal from anterior tissues than posterior tissues. The dashed lines show the field of view when we do a reduced field-of-view acquisition. **Right**, the reduced field-of-view image. Notice the white circle in the aliased image (point *P*) is a superposition of two points in the body (voxels *V1* and *V2*). The anterior coil receives different strengths of signals from the two points.

Fig. 1. Simulation of SENSE

B. GRAPPA

GRAPPA which stands for Generalized Autocalibrarting Partially Parallel Acquisition, is different from SENSE [11]. It pursues to revive the phase-encoding lines that were left out of the k-space data gaining in order to increase the MRI scan. After the missing lines have been reestablished, the Fourier convert is applied to arrive at the final image. GRAPPA use shares of the attained k-space to calculate the portions that were not acquired.

C. SMASH

SMASH stands for Simultaneous Acquisition of Spatial Harmonics. The concept is almost the same as for SENSE, but the mathematical reconstruction is finished on the k-space images and k-space coil sensitivities, rather than in real space [12-14].

TABLE II
ADVANTAGES AND DISADVANTAGES OF SENSE AND GRAPPA

Types	**SENSE**	**GRAPPA**
Total Imaging Time	Short	Long
Signal-to-noise	Slightly higher SNR and better image	Not preferred
Body Region	Poor	Preferred
Motion	Poorly if motion occurs between the calibration and acquisition scans	Preferred
Field-of-view	More tolerant towards small FOV	Allows smaller FOV to be selected without significant artifact
Use in Single -Shot Echo-Planar Imaging	Less likely to affect the reconstruction process	Not preferred

D. Ways to improve Clinical imaging protocols

1. Reduced attainment time with fixed spatial resolution
2. Improved spatial resolution with fixed acquisition time or temporal resolution
3. Improved spatial and temporal resolution
4. Improved image quality from reduced echo train length

VI. Conclusion

As for the conclusion, spatial resolution of an MRI can be operated by varying the k-space sampling, while the achievement time can be reduced by under-sampling k-space in the phase encoding direction which will show to spatial aliasing in the image domain. Parallel imaging hinges on the use of a group of receiver coils to collect under-sampled k-space data and on particular algorithms to reconstruct full FOV images. SENSE uses acquaintance of the coil sensitivity profile to perform the unfolding and reconstruction steps in the image domain. GRAPPA uses autocalibration signals and a convolution kernel in k-space to achieve reconstruction of the missing lines in k-space.

Objects such as remaining spatial aliasing and noise improvement can be mitigated by choosing an appropriate coil array and reconstruction process and by improving the parallel imaging parameters.

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