Enhancing POSSUM with parallel imaging capabilities

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Overview & Motivation

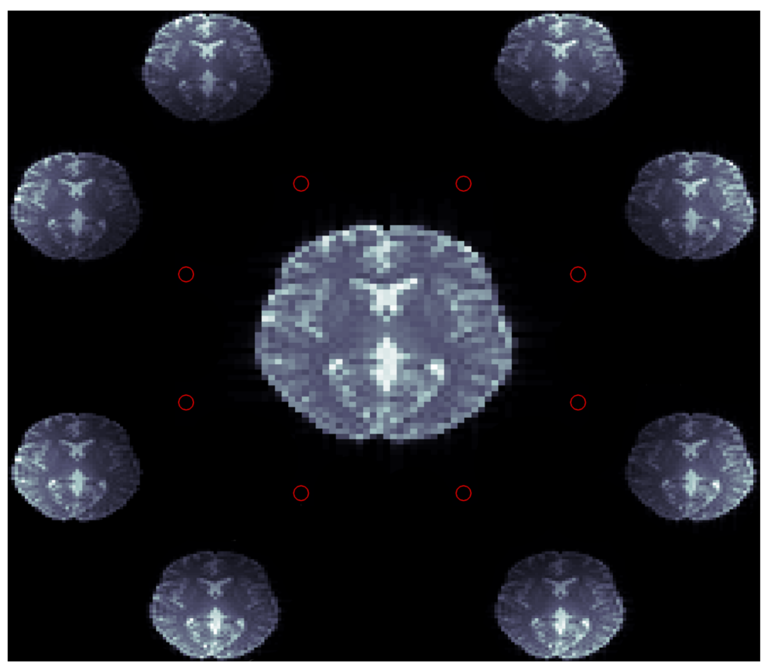
Partially Parallel Magnetic Resonance Imaging (pMRI) is a class of acquisition schemes and reconstruction algorithms used in MRI in order to reduce scan time. This is possible because time consuming phase-encoding steps are skipped during the scan. Unfortunately, this means that the final images will be folded. The purpose of pMRI techniques is, therefore, to resolve the 'folding' and to provide accurate final reconstructions. However, as with any other MRI techniques, these are also prone to a handful of problems which need to be investigated in a controlled and reliable manner. One way of accurately assessing the reconstruction schemes which are used in pMRI is to simulate the parallel imaging acquisition pipeline. As a result, the main aims of this project are:

- **to develop a simulation framework capable of supporting a parallel imaging acquisition pipeline**
- **to assess an image-based reconstruction algorithm under various scenarios such as different coil geometries and increasing acceleration factors.**

This was achieved by enhancing an already existing MRI simulator called POSSUM [3] which represents the current state-of-the-art and which lacked support for pMRI.

RF Sensitivity Profiles

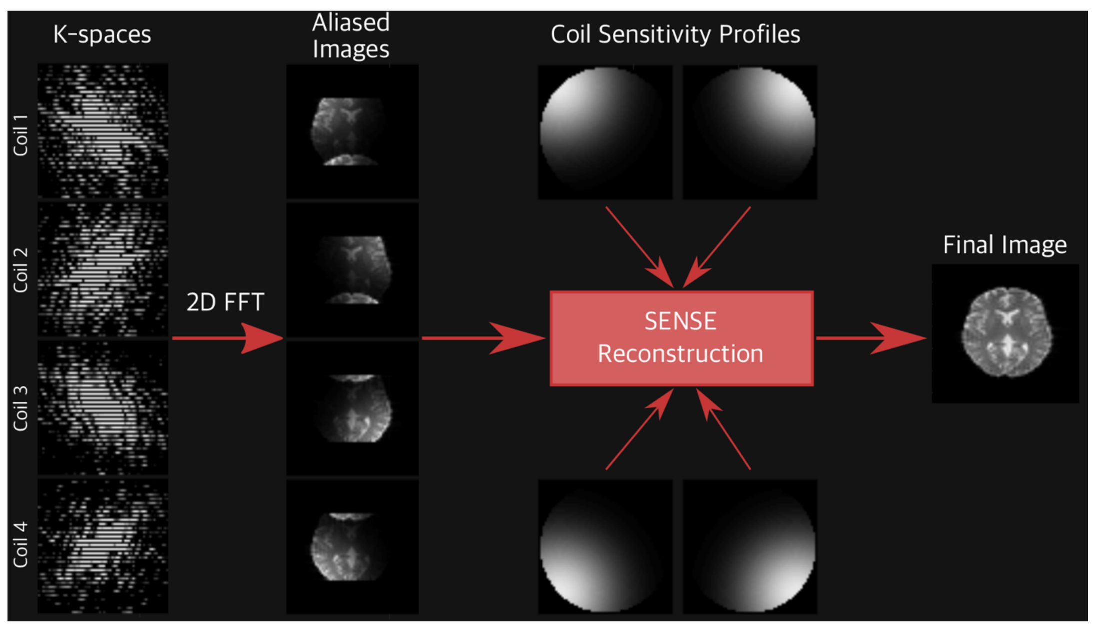
Parallel imaging techniques rely on some knowledge of the multichannel receiver array. Each individual coil from this array has its own **sensitivity profile** which is dependent on the coil's position with respect to the object being imaged. These maps also show how each individual coil is **sensitive to the signal** coming from a different spatial location of the desired field of view [2].



An 8-channel phased-array coil simulation. In this project arrays of 2, 4, 6, 8 and 12 channels have been generated and used in simulations. The channels were placed in a circular fashion around the object of interest, with each individual channel being equally apart from its nearest neighbours. Also, the sensitivity profiles were spatially varied by modelling a 2D normal distribution which is centred on the channel's position and can have various standard deviations.

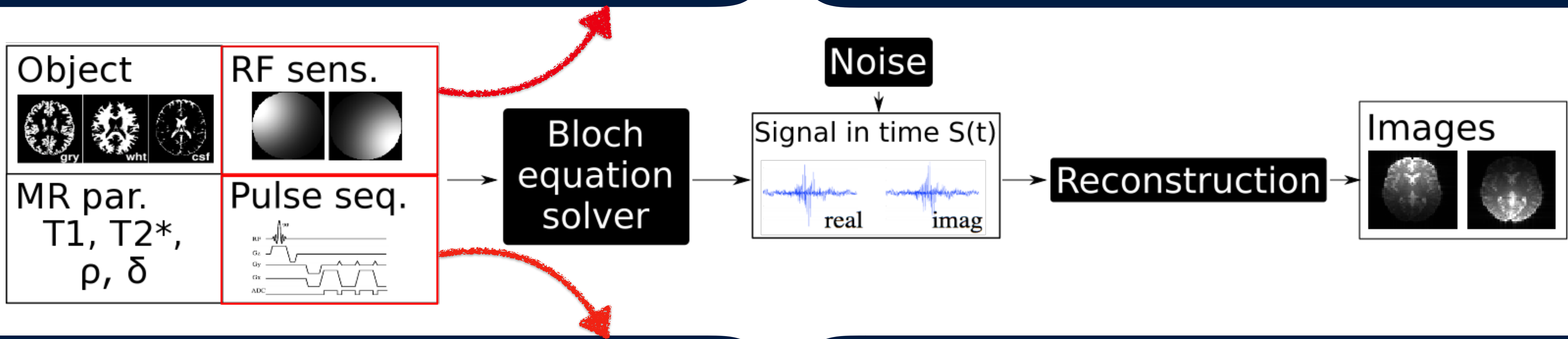
SENSE Reconstruction

Sensitivity Encoding for Fast MRI, or **SENSE**, is a **parallel imaging reconstruction algorithm** which is widely used in the clinics [1]. It relies on **knowledge** of the **sensitivity profiles** of the individual coils which are used to receive the signal. It uses this information and the **aliased images** to 'unfold' the image. A **matrix inversion process (3)** is then used to **unfold** and combine the aliased images from each coil.



$$M = C^{\dagger} I \quad (3)$$

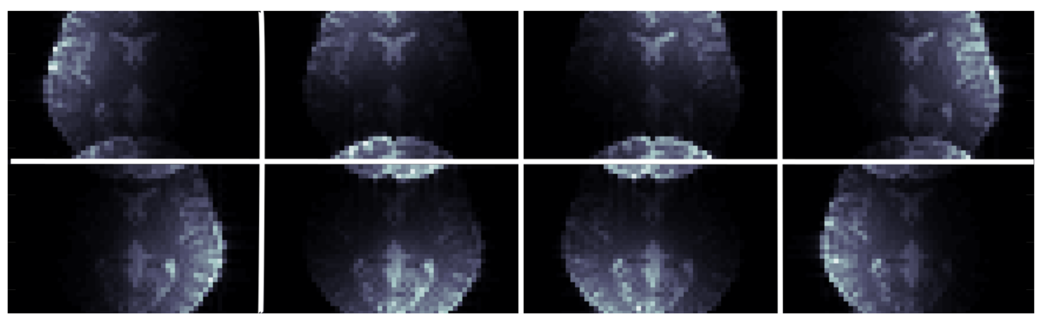
The SENSE reconstruction pipeline example for acceleration factor R = 2 and a 4-channel phased-array coil.



Parallel Imaging in POSSUM

In order to accelerate the image acquisition process, **phase-encoding steps** need to be **skipped**. The k-space sampling interval in the phase-encoding direction is inversely proportional to the field-of-view (1). Also, the image spatial resolution is inversely proportional to the highest spatial frequency sampled in k-space (2). This means that for an acceleration factor $R = 2$, the sampling interval will increase twofold leading to a new FOV which is half of the original one.

$$\Delta k_y = \frac{1}{FOV_y} \quad (1) \qquad \Delta y = \frac{1}{N_y \Delta k_y} = \frac{1}{2k_{y,max}} \quad (2)$$



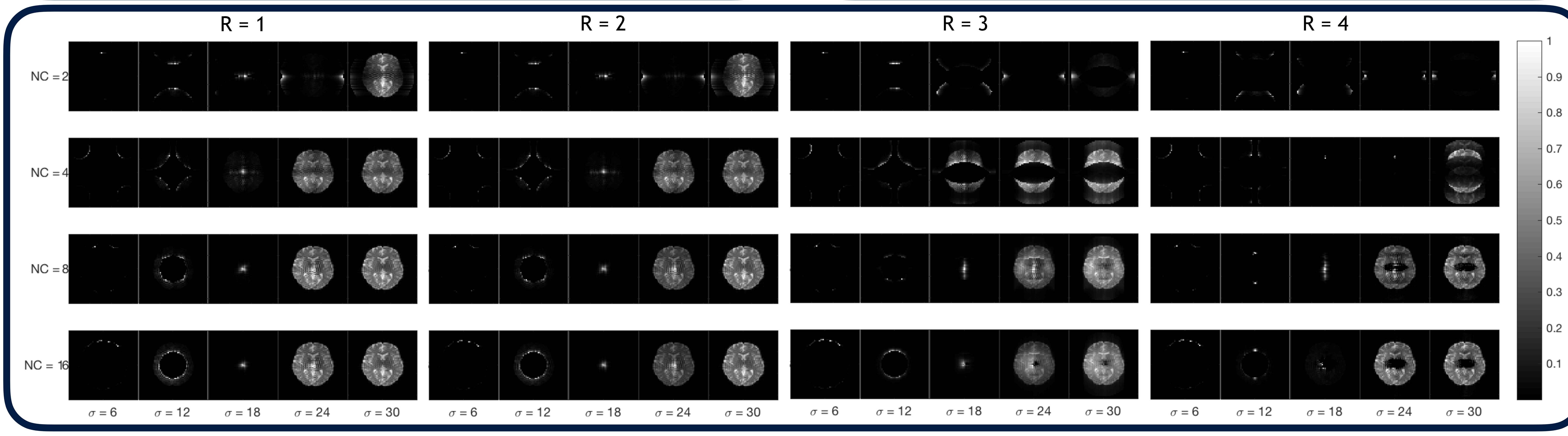
POSSUM simulating aliased images with an 8-coil array and with an acceleration factor R = 2. These folded images are generated by a subsampling on the phase-encoding direction.

SENSE performance and Conclusions

SENSE reconstructions were performed with different **acceleration factors R,** for different **coil combinations** and for different **standard deviations** of the associated coil sensitivity profiles. A good balance between the coil geometry and the acceleration factor needs to be found. Moreover, when high acceleration factors are used in combination with an increased number of coils, the sensitivity encoding matrix becomes ill-conditioned causing poor or impossible reconstructions.

In conclusion,

- The newly enhanced POSSUM can now simulate the **parallel imaging pipeline.**
- Having generated this dataset, an **image based parallel imaging reconstruction algorithm** was then evaluated.



References: [1] Pruessman et al (1999); [2] Deshmane et al (2012); [3] Drobnjak et al (2006)

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