SEMI-AUTOMATIC QUANTIFICATION OF LONG-TERM STABILITY AND IMAGE QUALITY OF A PARALLEL TRANSMIT SYSTEM AT 7T

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Target Audience: Researchers working with parallel transmit MRI, QA, and image processing

Introduction:

Parallel transmit (pTx) systems are capable of overcoming limitations of single-channel MR systems with respect to image quality, particularly for high-field MRI where images are commonly impaired by B_1 inhomogeneities. Furthermore, pTx enables application of more sophisticated imaging techniques such as reduced field-of-view imaging, which can be valuable for imaging of small physiological structures. However, care must be taken to characterize and track the image quality of such systems and detect possible errors to ensure long-term stability as there is no standard defined for quality assurance (QA) protocols, yet. This work presents an approach toward quantitative quality tracking based on selective pattern excitation in a phantom and subsequent image processing.

Material and Methods:

As it is possible to design and apply arbitrary excitation patterns with pTx, deviations between a desired target pattern and the resulting MR image may be a way to augment QA protocols. An obvious advantage is that acquisition and evaluation of such images places no special demands regarding hardware requirements and therefore can be applied to any MR system that is equipped with a pTx system, which in return may facilitate comparison of the system performance at different sites. Thus, a standard pTx FLASH sequence (TA = 6.4 s, nominal FA = 10°, TE = 15.8 ms, TR = 100 ms, BW = 260 Hz/px, slice thickness 5 mm, one transversal slice) was incorporated into the default QA protocols on an 8-channel Siemens pTx system at 7T. A homogeneous PDMS phantom was used. The image analysis is based on the calculation of signal differences between reference and newly acquired images as well as further quantities such as homogeneity, signal-to-noise ratio, contrast, reference point displacement, and the mean and variance of signal and noise. The target pattern has a size of 64 by 64 pixels and contains nine triangles (segments) with different orientations, the centers of each triangle being aligned on the perimeter and center of a circle. Triangular shapes were chosen as they are sufficiently simple in geometry for reliable detection in low-resolution images, yet have inherent information that facilitates extraction of the above mentioned properties. The pTx pulses to generate such a selective excitation were calculated only once based on an appropriate B_1 map in the phantom and re-used for later scans of this kind.

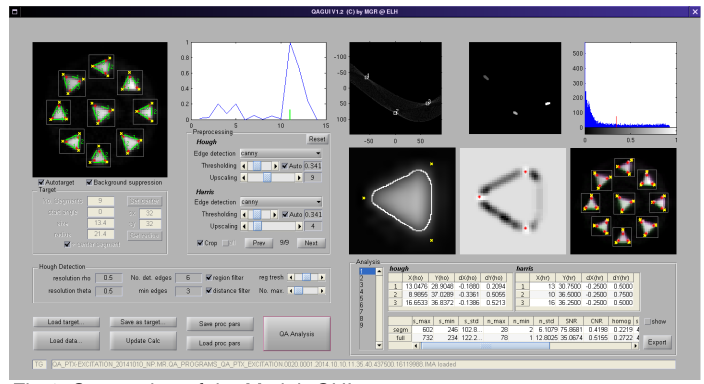

Fig.1: Screenshot of the Matlab GUI

For image processing a customized GUI written in Matlab (Mathworks Inc.) is used (Fig. 1). The processing queue first aims to automatically detect all segments in the image based on signal dilatation and subsequent region labeling to increase reliability of the obtained quantities. After extraction of all regions, upscaling, automatic thresholding, and edge detection are performed on each detected segment. The resulting segments are analyzed by both a Hough transformation [1, 2] and Harris operator [3] independently to extract the position of the corner pixels of each triangle in the image. Since noise can cause ambiguities in this detection, background suppression is used before transformation and group filters are applied to average out multiple detections of corner pixels. All reference points found are assigned and compared to their corresponding points in the reference picture. Further image properties are derived after automated separation of signal and background for each shape and for the entire image, respectively, and subsequently compared to their corresponding values in the reference images.

The QA protocol is acquired once per week for statistics and stability evaluation, and the results were also checked for their significance in the event of an (induced) failure, such as Tx power drifts, phase shifts, or timing errors in the system.

Results:

The images that were acquired for estimation of long-term stability show remarkable stability for all properties. Thus, fluctuation of the signal, noise, and homogeneity were found to be generally less than 4% in both the individual shapes and the overall image. The detected reference points have a mean displacement of half a pixel from their corresponding partner positions in the reference picture independent of their location.

It was found that timing errors of more than 2µs (timing of the RF relative to the gradients) cause a significant rotation in the image that can be reliably detected by the pixel shift, which is commonly greater than one pixel (Fig. 2). Furthermore, the noise variance increases by more than 100%, which might be the result of blurring in the image due to introduced phase errors.

Arbitrary phase shifts of ±10 degrees maximum that were added to the original phase of the transmit channels can be detected for a setup that is kept constant otherwise. Since the resulting variations in the image properties, e.g. homogeneity and pixel shifts, are only on the order of 1.5%, they cannot be used as a reliable measure in a long-term QA setup, as other inherent fluctuations outweigh these small effects.

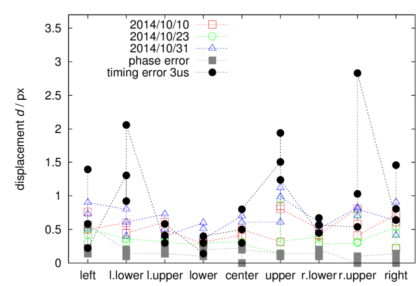

Fig.2: Reference point displacement over time and in the case of an induced hardware error

When introducing variable fluctuations to the transmit power on individual channels, an expected signal drop can be observed, which is highest in the shape adjacent to the affected coil element. In case of a total failure on one channel, a total signal drop of 20-25% is visible in the respective image area. Given a detection threshold of about 5%, deviations of transmit power that exceed 10% may be detected by the presented method.

Discussion and Conclusion:

Although image processing of excited target patterns in a phantom cannot replace default QA protocols, it poses a valuable add-on that may prove useful for characterization and evaluation of long-term behavior of a pTx MR system. Moreover, due to its negligible additional time requirement and lack of need for additional hardware, it can add an interesting aspect to cross-vendor or multi-site performance comparisons.

References:

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