Automatic MRI Acquisition Parameters Optimization Using Perceptual Criteria

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INTRODUCTION: The visualization of structures in MRI highly depends on many user defined scan parameters. The selection of them is always done heuristically and requires a vast experience from the operator. Furthermore, sometimes it is not simple to predict the effect on the visibility of the structures of interest when a parameter is modified. We propose a methodology based on an automatic optimization to find the MRI acquisition parameters that maximize the visibility of a desired structure. The objective function of our optimization is computed from Visibility Maps (VM) that are designed to measure the visibility of structures according to two perceptual criteria: sensitivity to contrasts and to spatial frequencies.

METHODS: Since the Human Visual System (HVS) has been adapted to detect specific ranges of contrast and spatial frequencies, we developed Visibility Maps (VM) (Fig. 1d) that mimic these non–linear sensitivities. Our VM give as an output how visible is each voxel of an image, and they are constructed by calculating the pointwise product between two maps: a Contrast Map (Fig. 1b) and a Relevant Spatial Frequency (RSF) Map (Fig. 1c). To model the visibility of a structure according to its local contrast, we propose the creation of Contrast Maps (Fig. 1b), where the intensity of each pixel is the probability of having a given local intensity difference computed from the Contrast Sensitivity Function (CSF) [1]:

$$f_2(bg(x,y)) = f(x) = \begin{cases} T_0\left(1 - \sqrt{\dfrac{bg(x,y)}{127}}\right) + 3, & bg \leq 127 \\ \gamma(bg(x,y) - 127) + 3, & bg > 127 \end{cases}$$

where bg is the background mean luminosity, T_0 is the visibility threshold when bg is cero and γ is the curve slope when the background level is maximum. Relevant Spatial Frequency (RSF) Maps were reconstructed using the discrete cosine transform (DCT) of an 8×8 pixels sliding block in the image. The resultant image is then filtered using the Mannos Contrast Sensitivity Function (CSF) [2]: $H(u,v) = 2{,}6\,(0{,}0192 + 0.114F_r(u,v))\,\exp\left(-(0.114F_r(u,v))^{1.1}\right)$, where $F_r(u,v)$ is the spatial frequency on the image in cycles per degree (cpd). The visibility in each pixel is the DCT coefficient with maximum absolute value in the sliding block (3.5cpd).

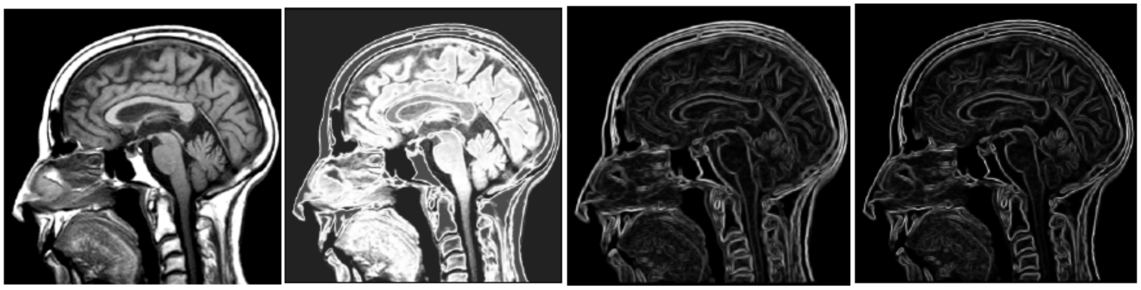

Figure 1: Left: original image. Middle left: Contrast sensitivity map. Middle right: Relevant Spatial frequencies. Right: Visibility Map.

MRI Acquisition Parameters Optimization:

Our methods consist of using the VM of a certain region of interest to optimize the acquisition parameters p. Our cost function will be the standard deviation of the VM in that given region $\mathrm{Max}_p RVI = \sigma(VM(Im,p)|\Omega)$. We tested our method using an Inversion Recovery (IR) sequence of a brain, with Time of Inversion (TI) and Time of Echo (TE) as the optimizing variables. The first step of the optimization is to select a ROI where the structure of interest is located (a region with WM and GM). The second step is to acquire a few MR Images with different TIs and TEs, which should cover roughly the expected optimal range. The exhaustive search of our experiment involved a fixed Repetition Time (TR) of 1000ms, (TE) 10, 20 and 40ms and (TI) 450, 600 and 900ms (yellow dots in Figure 2). In the third step, we computed our index in the selected ROI for every exam. A smooth surface is adjusted to the index values and used to find the optimum. (Fig 2). This process was performed in data obtained from 10 healthy volunteers. Moreover, to validate our method all images were evaluated by 12 radiologists. They scored the images from 1 to 5, where 5 means maximum white matter visibility, and better suppression of grey matter and cerebral spinal fluid. The corresponding TE and TI values of the optimal image found by the radiologists were compared with the optimal values found by our proposed method.

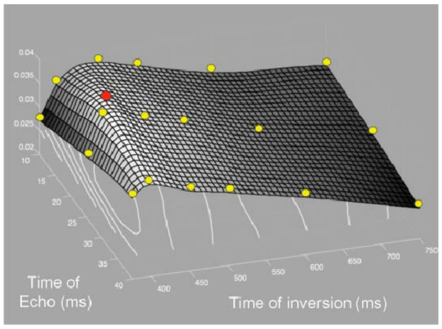

Figure 2

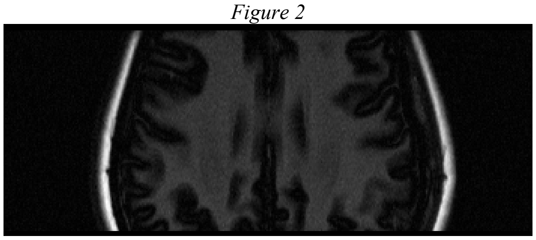

Figure 3

RESULTS: As seen in Figure 2, the objective function is strictly concave and lead to unique set of optimal parameters TE=28ms and TI=450ms. Using those values it is now possible to see a clear distinction between GM and WM, which was the desired visualization effect (Fig 3). Comparison of the optimal TE, TI values found by the radiologist and the proposed method were in excellent agreement with correlations of 81% – 92%.

CONCLUSIONS: A method for optimizing the search for acquisition parameters values has been presented. The method is based in Visibility Maps which can emulate reasonably well the perceptual evaluation of images done by humans. The resulting optimization successfully found an optimal combination of acquisition parameters, which can significantly increase the visibility of structures of interest.

REFERENCES: [1] C.H. Chou, Y.C. Li, *A perceptually tuned subband image coder based on the measure of Just-Noticeable-Distortion profile*, IEEE Trans. Circuits Systems Video Technol. 5 (6) (December 1995) 467-476. [2] J. L. Mannos and D. J. Sakrison, *The effects of visual fidelity criterion on the encoding of images*, IEEE Trans. Inform. Theory, vol. 20, pp. 525-536, 1974.