Title of Proposal: **Quantitative MRI: A 3D Resolution Phantom**

Nature of Proposal: Innovative Student

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Position: Professor of Chemistry and Imaging Science

**Abstract**

Quantitative magnetic resonance imaging (MRI) is a new form of MRI where disease biomarkers are calculated from magnetic resonance images. We recently completed a successful project with a local company to determine the tolerable error in image acquisition parameters. The next step in this project is to develop and test an MRI phantom capable of expeditiously measuring these errors. We are requesting funds to facilitate the construction and testing of a working three-dimensional resolution phantom for measuring homogeneity of the magnetic field, the linearity of the gradients in the magnetic field, and the point spread function of an MRI system.

**Dollar Request:** $5,000

**Desired Funding Dates:** Winter Quarter 2007-2
Scientific justification

During the period of September 2006 to June 2007, the RIT Magnetic resonance Laboratory undertook a research project with VirtualScopics to develop system performance testing metrics for quantitative magnetic resonance imaging (MRI). The objective of this project was to develop a set of quantifiable specifications for certifying and checking monthly the performance of an MRI site. This objective would remove the requirement to scan a human volunteer as well as use an expert to examine images. The project was successful in that it identified the relationship between the uncertainty in a measurable volume with MRI and errors in static magnetic field (B₀), magnetic field gradient (G), and the resonance frequency (f). To achieve a volume uncertainty of less than 2%, errors in the frequency were found to be negligible. The magnetic field gradients need to have a linearity of less than 1.155%. The B₀ homogeneity across the field of view (FOV) of the image needs to be better than 0.01155·G·FOV/B₀. The next logical step in the project is to determine if these specifications are achievable in a heavily used clinical scanner. To accomplish this, an MRI resolution phantom is needed. Since the NYSTAR funding for the project expired in June of 2007, VirtualScopics is evaluating where to go with the results and is not ready to commit to a continuation.

An MRI phantom is an anthropogenic object used to test the performance of an MRI system. An MRI resolution phantom is a phantom that can test the accuracy, linearity, and orthogonality of the (x,y,z) spatial dimensions in the output of the imaging system. In the problem posed by VirtualScopics, the resolution phantom must also be able to determine the point spread function (PSF) of multiple points in the imaged volume. For time savings and ease of use, we proposed a single three-dimensional (3D) resolution phantom. Imaging this phantom with tomographic slices in any xy, xz, or yz plane and depending on the slice thickness produce: 1.) a matrix of points for determining the PSF, 2) a series of parallel lines for determining linearity, and 3.) a grid for determining homogeneity. Imaging the phantom with a single volume acquisition sequence will obtain all the image information necessary to make these determinations.

We have designed a prototype of this 3D resolution phantom. It consists of a three dimensional lattice of flexible polyvinyl chloride (PVC) tubing supported in a PVC block. The block keeps the tubing at fixed locations forming a grid of tubing lines parallel to the x, y, and z axes and at precise locations. The tubing holds an NMR signal containing substance and because
of its continuous nature, allows easy filling. The narrow inside diameter of the tubing allows
determination of the PSF. The accurate position of the tubing allows calculation of homogeneity
and linearity.

Although a prototype has been designed, there are several engineering aspects of the
resolution phantom which need to be addressed. The phantom filler material must have a short
spin-lattice relaxation time ($T_1$) to allow rapid acquisitions of the magnetic resonance images.
Paramagnetic ion doped water does not work well due to either water permeability of the tubing
or out-gassing of the tubing. For this reason we are proposing to fill the material with low
molecular weight silicone oil doped with a gadolinium complex to control $T_1$. We believe we
have identified the specific complex and oil, but need to formulate the mixture and measure and
optimize its $T_1$.

Once the filler material is optimixed, the phantom will be assembled, filled, and imaged.
Assembly and filling should be straightforward. We will arrange to have the 3D resolution
phantom imaged on one of the 1.5 T MRI scanners at the University of Rochester’s Strong
Memorial Hospital Magnetic Resonance Center. We will use a 3D volume acquisition sequence
with a short repetition time.

The volume set of images will be transferred to RIT and input into IDL where they will be
analyzed. We propose to generate a simple program to analyze the images. This program will
first perform a coordinate transformation so that the data planes are perpendicular to the tubing
lines. The Program will then determine the PSF at each of the 64 locations in a slice, for each of
the approximately 100 slices along an axis, for each of the three axes. Linearity of the lines will
be determined. From this image information and knowledge of the acquisition parameters, we
will calculate the $B_0$ homogeneity, gradient linearity, and PSF throughout the imaged volume.

Once we have demonstrated the utility of the 3D resolution phantom, we will be in a
position to submit an invention disclosure form, assess VirtualScopic’s interest in the IP, and
present the material at an international MRI conference, and publish the results.
Budget Request

We request a budget of $5000 for the proposed project. All of this money will be use to pay Sangyun Moon’s stipend for one academic quarter. We will rely on good will to obtain the approximately one hour of operator assisted MRI scanner time at the University of Rochester, valued at approximately $1000. Monies for the silicone oil, gadolinium complex, and other incidental phantom supplies will come from the RIT Magnetic Resonance Lab’s discretionary funds.

Project Plan

The following timeline is proposed for completing the project during an academic quarter. Because of the uncertainty in scheduling the imaging session, we have listed the imaging session as any time during week 3 through week 6.

<table>
<thead>
<tr>
<th>Week</th>
<th>Tasks</th>
<th>Imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Formulate filler material &amp; measure $T_1$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Assemble and fill phantom</td>
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<tr>
<td>3</td>
<td>Write IDL Code</td>
<td>*</td>
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<tr>
<td>4</td>
<td>Write IDL Code</td>
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<tr>
<td>5</td>
<td>Write IDL Code</td>
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<tr>
<td>6</td>
<td>Optimize Code</td>
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<tr>
<td>7</td>
<td>Transfer Images from UR to RIT</td>
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<tr>
<td>8</td>
<td>Analyze Volume Images</td>
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<tr>
<td>9</td>
<td>Analyze Volume Images</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Summarize results</td>
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</tbody>
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At the end of the project, we hope to have a working 3D resolution phantom with a short $T_1$ value that can be used to measure PSF, $B_0$ homogeneity, and linearity in three dimensions through a $10\times10\times10$ cm volume in 30 minutes.