Microrobots

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***Abstract*— MY ABSTRACT GOES HERE**

I. Overview

II. Engineered Particles that can be individually detected

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$x = \sin(3) + \int_{-9}^{\inf} \cos(3)$

A. Micro-engineered particles for multi-spectral MRI

Zabow et al. [6] designed labels that frequency shift water by discrete amounts. The phase shift can be designed to make multiple distinguishable markers. The markers must be aligned with the MRI B_0 field, but were designed anisotropically so they passively align. They presented a design using two nickel disks of radius R separated by distance S.

Their Figure 3 showed 1.24mm discs designed for three different frequencies. Each was distinguishable, Resolution was 500 x 750 μmeter. Figure 5 resolution was 100 x 100 $|mu$meter with much smaller particles 5μmeter disks separated by 2μmeters. Each voxel contained 10 to 20 particles.

They claim that their design with an open interior have a 10^4 greater signal-to-noise ratio than enclosed designs.

Competing methods: labeling cells with superparamagnetic iron oxide (SPIO) nanoparticles or dentrimers[7], or micrometer-sized particles of iron oxide (MPIOs). These methods magnetically dephase the signal from water surrounding these particles.

Specially engineered micro coils can be used for high resolution MRI imaging, but this requires the coils to be placed close to the target [8]. This paper referred to tests with 5 nano-liter samples for NMR spectroscopy. THe coils used surrounded the capillary containing the liquid under interrogation. The coils were 1mm long, with an OD of 0.5mm. Since these are not for imaging, they could instead be used to indicate whether a compound was present or not.

B. Magnetodendrimers

[7]

membrane adsorption process with subsequent localization in endosomes. Visible in MR with doses as low as 1 μg iron/ml culture mdeium.Labelled cells were detected with 9-14 pg/cell for up to 6 weeks after transplant.

C. mangetic micro robots

Diller did some amazing things with hysteresis [9].

D. Stainless steel microparticles in capillaries

This work by Olamaeni et al. [1] is inspired by therapeutic magnetic micro carriers – $\approx 50\mu$m diameter drug capsules that can be steered and tracked by an MRI scanner.

Magnetic bodies create susceptibility artifacs in the MRI image. The paper[1] includes equations describing how the particle distorts the MRI image. Testing used 0.4mm diameter chrome steel spheres with Gradient-Echo imaging. Pairs of particles are distinguishable when their distance is $\approx$ 40diameters apart. The imaging used 0.5 mm pixels on a 1.5 T Magnetom Siemens scanner. The authors demonstrate a 15μm sphere is be detectable in a clinical scanner [10]. Such a particle can navigate in large capillaries, which are 20μm in diameter, but cannot reach small capillaries, which are 4-5μm in diameter.

Later they demonstrated tracking 50μm diameter droplets of ferrofluid using a 1.5T scanner [11]. The droplets moved along a 50μm capillary and were tracked with Gradient-Echo imaging with 0.6mm voxels. The droplets contained 10% MNP (Fe_3O_4).

III. Contrast agents and MRI fiducials

A. nano particle MRI contrast agents

These typically use iron-oxide nanoparticles as MRI contrast agents. Often the particles are collected by cells in the body, e.g. macrophages, and show are dark pixels in an MRI image.

B. Commercial MRI fiducial Markers

There are many products available today for MRI fiducials, used for image registration to link current scanned data with previous scans and targets. MRI fiducials used in routine care range from large 20 mm markers designed to be stuck on the skin, or ≈20mm gold markers inserted via needle into the skin. These have a variety of forms, but are centimeter-scale large objects.

MRI fiducials inserted by a 17-Gauge needle, made of 99.95% gold construction with a snake-like design. , 1.15mm x 1 cm, to 0.85mm x 3cm[1]

Skin markers: [2], 1.75 cm Radiance™filled flexible packets, 1.5cm Radiance™filled tubes, to 3cm Radiance™-filled tubes.

Multi-modality Center-hole markers: [3], a flat disc with 2mm center hole, 15 mm outer diameter, 3.5mm thick, bright in MRI image.

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