Inverse Problem applied to detection of magnetic particles in imuno-essays

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Introduction

The use of magnetic imuno-essays is a relatively new area of research. With these we can track some disease (e.g.: cancer) using the measurement of the magnetic signal produced by such magnetic particles attached to molecules (antigen). The idea is that such particles would accumulate in the area of the problem, and therefore the problem could be detected by the measurement of an anomalous magnetic field near this region. In this work we studied a prototype of such imaging making use of 1mm-sized magnets. We studied the feasibility of using downward continuation to improve the signal of the magnetic particles for further analysis of the number of particles responsible for the signal measured.

Main features of our method

We set out to solve the mathematical and experimental problem associated to the focusing of a magnetic image and further counting of the number of particles present in the essay. So we were interested in the recovering of a perfect image everywhere, in being able to count the number of magnetic particles from the peaks in the magnetic field in the recovered map. This way we had to ally the technique of Downward Continuation (a kind of inverse problem) to image processing in a coherent manner.

In the mathematical effort to solve the above problem we developed some mathematical tools. First, we studied the behavior of a new class of filters to stabilize our method. These functions have the good quality of being infinitely differentiable in a compact set. Secondly, in an effort to systematize our procedures (keep it the less state-of-art as possible), we developed some validating methods for deciding the range and sampling rate in the measurements to be done. We called these methods "energy validation" for it estimates the L^2 norm of the field of a magnetic dipole in a finite region, which we could find analytically in the continuous measurement case, both in space and in Fourier space. Thirdly, as above mentioned we have an unusual inverse problem in hands, in which we are actually interested in estimating the number of particles that caused the measured magnetic field, which gives us a new complication, since beyond finding a recovered image we want to process it to find the required information. So, we had to choose adequate cost functions, which matched our objectives of counting particles, to measure the success of simulated image recoveries. Furthermore, we had to ally another area of research in this project, which consists in the image processing, to be able to from a magnetic map calculate the number of estimated particles that were there, based in the peaks of the signal.

Experimentally, we are looking forward to get the closest possible to the biomedical application conditions, i.e., we are in the means of miniaturizing our sensors and actuators to be able to identify with enough resolution the nano-magnetic articles used in imuno-essays.

Results

We intend to show the methodological developments of the current work by presenting the simulated results achieved by means of the latter. The simulated results were partially computational and partially experimental since we took our data mainly from an experimental set, consisting in 3 dimensional actuators, gauss meter, and Lab view routine to control the hardware and make data acquisition.

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