Applications of Sparse Modeling to Geophysical Surveys in Engineering Geology

*Shigeru Miki[1], Takeshi Yoshikawa[1]

1. Kiso-Jiban Consultants Co., Ltd.

Sparse modeling is the numerical method of data processing and optimization, and it has begun to attract notice in many engineering and research fields. In ill-posed inverse problem, sparse modeling can obtain optimum result by using the sparsity in the solution, where the number of unknowns, which have 0(zero) solution, are decreased. However, it is difficult to obtain the sparse solution via L0-norm in the real applications because the prior information of the number and location of 0 solution are unknown. Therefore, in sparse modeling, the optimum result is obtained by minimizing L1-norm, and the minimization of L1-norm has a function of choosing 0 solution.

In many sparse applications, observation data have noise and the problem is ill-posed. Therefore, the solution are obtained to minimize the cost function added L1-norm term to the cost function in ordinary least squares method. The regression contained L1-norm term as a regularizer is called LASSO (Least Absolute Shrinkage and Selection Operator). Many algorithms to solve LASSO have been proposed, and FISTA (Fast Iterative Shrinkage Thresholding Algorithm) and ADMM (Alternating Direction Method of Multipliers) are well-known. ADMM are widely used as a powerful and general purpose method.

In the inverse problem in geophysical surveys, it is obvious that physical properties of geomaterial do not show sparsity. However, the sparsity can be expected for the variations of physical properties in spatial distribution and time series. For example, the difference of velocity between adjacent 2 points in same velocity layer will show sparsity, and the difference of velocity between 2 points across velocity boundary shows none-zero value. The velocity will vary by the soil improvement. However, the velocity in out of the improvement area will be unchanged and the sparsity can be expected.

For another example in astronomy, sparse modeling have been introduced into the frequency spectral analysis for the intermittent and irregular observation data. It has been powerful method to distinguish between true signal spectra and artificial spectra due to the irregular observation. Sparse modeling succeed because many spectra are noise and a few spectra has value in the frequency domain. This technique can be applied to the measurement of geophysical surveys. The signal of specific frequency can be derived from noisy measurement data by using sparse modeling.
We have introduced sparse modeling to seismic tomography and the simulation of soil improvement were attempted. The frequency spectral analysis using sparse modeling was also attempted. In this report, we will show the formulations of ADMM in seismic tomography and frequency spectral analysis, and the results of the simulations will be presented.

Keywords: sparse modeling, geophysical survey, inverse problem

