Due Date: 17:00, Wed, Feb 4, 2015
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Lab 3 - Least squares optimization

Your name[1]

ABSTRACT

We will look at the normal moveout (NMO) operator and examine its implementation. You will code the forward operator with linear interpolation to create the dataset. You will then code the adjoint operator and run the dot product test. Finally, you will run two least squares optimizations using two different steppers and analyze the results.

NORMAL MOVEOUT OPERATOR

The NMO operator is an example of a summation transform operator. This operator approximates the reflection travel time given the medium velocity above a reflector in a 1D Earth. In this operator, the model space axes are intercept (analagous to traveltime depth) and slowness whereas the data space axes are time and offset. The mapping equation can be written as:

$$t = \sqrt{s^2x^2 + z^2}, \tag{1}$$

where t is time, s is slowness, x is offset and z is intercept. The operator loops over s, x, z and computes t. The computed time often falls between the samples of the time axis. Therefore, interpolating the values can increase the accuracy of the operator.

YOUR ASSIGNMENT

You are provided with modules for the operator, the dot product test, the steppers and the solver. All the modules (except the operator) are complete and do not need to be modified. The operator module is missing both the forward and adjoint which you need to code. Moreover, you are not provided with any programs. You will code a few programs that implement the modules to answer the questions and perform the required operations. Modify the `Makefile` to add rules that generate the

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required tests, results and figures for each question. Make sure to include the correct and complete set of prerequisites for each `Makefile` rule (including the executable programs). Also, do not forget to add the PDF figures to the default target and include the figures in this paper. Try to include multiple figures per page (either by limiting their dimensions or using sideplot) to not waste paper!

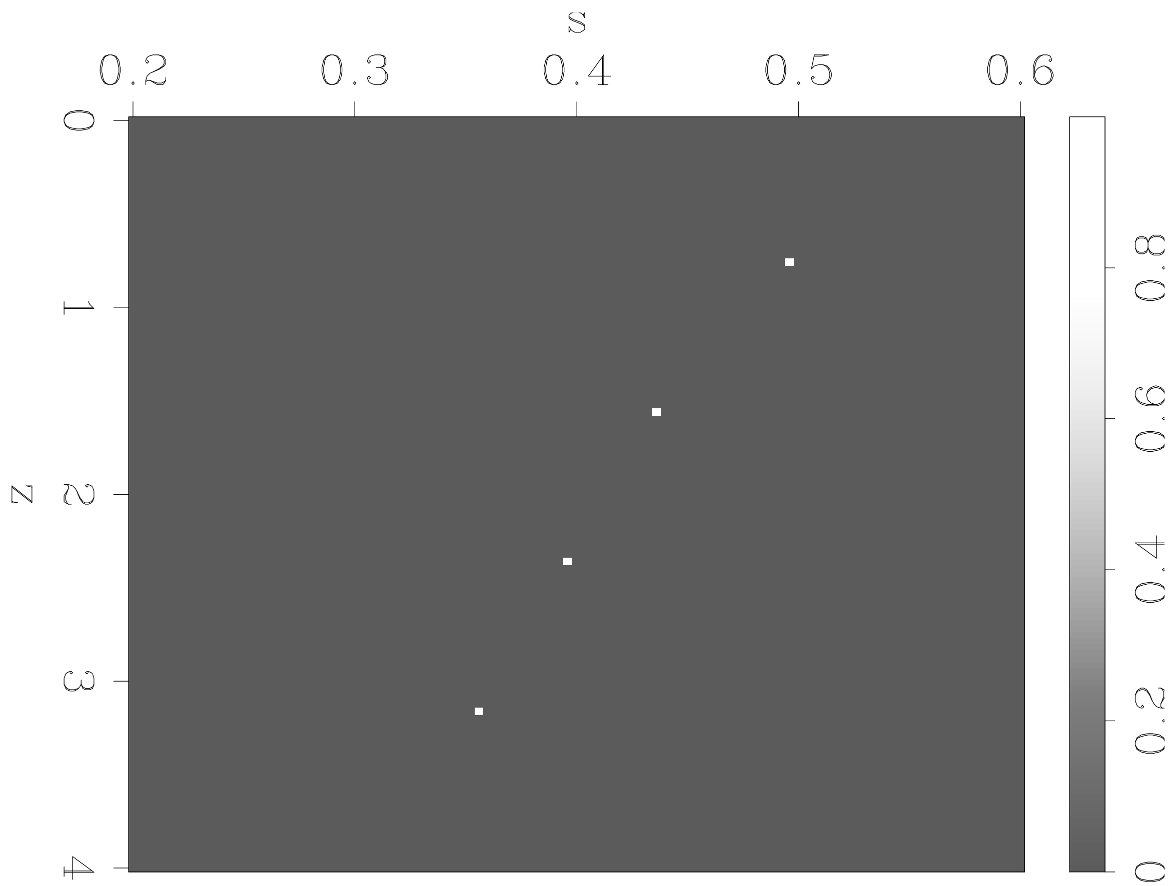

Figure 1: NMO model

Questions

1. Why is the NMO equation parameterized with slowness instead of velocity?

YOUR ANSWER.

2. Code the forward NMO operator and include linear interpolation for the conversion to discrete time. Then, write a program that implements the operator and apply the forward operator on the spike model shown in Figure 1 using the parameters in `Par/nmo.p` to create the "observed" data. Plot the data and describe the effect of the forward operator.

YOUR ANSWER.

3. Code the adjoint of the NMO operator. Then, write a program that runs the dot product test on the operator. What are your test results?

YOUR ANSWER.

4. Apply the adjoint on the observed data and plot the results. Is this adjoint a good approximation to the inverse?

YOUR ANSWER.

5. Although the four spikes were similar in the true model, they are different in the adjoint results. What are the differences? What caused those differences?

YOUR ANSWER.

6. In a real case, we can only measure the accuracy of the results in data space since the true model is unknown. Apply the forward operator on the adjoint model and plot the reconstructed data. How does this data compare to the observed data (be elaborate)?

YOUR ANSWER.

7. Write a program that implements the solver with the steepest descent stepper and run it for 20 iterations. Plot both the inverted model and the reconstructed data. How does this result compare to the adjoint results (be specific about each space)?

YOUR ANSWER.

8. Write a program that implements the solver with the conjugate direction stepper and run it for 20 iterations. Plot both the inverted model and the reconstructed data. How does this result compare to the steepest descent results (be specific about each space)?

YOUR ANSWER.

9. Compute and plot the residual of each optimization by subtracting the reconstructed data from the observed data. Without considering their power, which residual indicates better convergence? Why?

YOUR ANSWER.

Extra Credit

1. What is the difference between conjugate gradient and conjugate direction (hint: SEP-92)?

YOUR ANSWER.

2. Is the gradient power monotonically decreasing? Why?

YOUR ANSWER.

DONE

When you are all finished modifying the source files, `Makefile` and latex file, make sure that will paper will compile correctly from a cleaned directory using the default targets only. In other words, the following sequence of commands should produce your a PDF version of your paper without any problems: `make burn`; `scons -c`; `make`; `scons`.

Once you make sure everything is working properly, clean up your directory by typing `make burn`; `scons -c`. Then, compress the lab directory using the command `tar cvzf Lab3.gzip Lab3` and submit the compressed file to your TA.