Preparing Guy Masters' Normal Mode Synthetic Seismogram Code for Delivery to CIG

Dates: 7/1/06 - 10/31/06
PIs: CIG Seismology Working Group (A. Levander, M. Ritzwoller, J. Tromp, M. Wysession)
Budget: See attached.

The following is a proposal from the Seismology Working Group (SWG) of CIG, which requests financial support for a programmer at the University of Colorado at Boulder to prepare a normal mode synthetic seismogram code to be delivered to CIG for subsequent refinement and distribution.

The purpose of the proposed work is to translate Guy Masters' suite of normal mode synthetic seismogram codes into a form that can be delivered to CIG and placed efficiently into the CIG computational framework. The ultimate goal is for the codes and associated information to be organized so that users who are not previously familiar with them can use them simply and productively. This code has been chosen by the SWG to be one of two high priority codes for the first 18 months of operation of CIG. It represents a natural complement to the other code, SPEC/FEM, which is a computationally intensive, high performance code for 3-D wave propagation that remains under significant development. Master's code is a mature 1-D synthetic seismogram code that runs on single-processor machines and represents one of the principal methods to compute 1-D synthetics in radially anisotropic, spherical media (the principal others being reflectivity, WKBJ, and full wave theory).

Although there are several 1-D synthetic seismogram codes in something like general use, well-documented, benchmarked 1-D synthetic seismogram codes remain rare, and the SWG feels it is important to address this shortage at the outset of CIG. The SWG believes that demand for this product is strong within the seismology user community. As evidence of this, there has been considerable discussion of the code within the IRIS community. In particular, the IRIS DMC plans to make synthetics, using this code, available with data orders for FARM (Fast Archive Recovery Method) Products and has resources available to work with the CIG to get this code into routine operations at the DMC. The DMC is developing the capabilities to distribute synthetic seismograms (e.g., a synthetic SEED transfer protocol and methods to request synthetic seismograms). The IRIS DMS Standing Committee voted unanimously in favor of the collaboration between CIG and IRIS and Tim Ahern (Program Manager of the IRIS Data Management System) has stated enthusiasm for this collaboration. The SWG is enthusiastic about collaboration with the IRIS DMC because it will help leverage the CIG investment in the code, getting synthetic seismograms from the code into as many hands as possible and stimulating users to acquire the code for themselves. The SWG believes that the "market penetration" of this code, therefore, could be very high. Before a synthetic seismogram generation capability at the IRIS DMC becomes a reality, much work will be needed in addition to the development of the synthetic seismogram code. The code itself, however, is a necessary condition for the success of this plan. In the long run, the DMC may like to move toward more sophisticated synthetic seismogram production such as that afforded by SPEC/FEM. All parties see the normal mode as a natural and necessary step in this direction. Conversations with NSF

personnel also indicate to the SWG that the collaboration between IRIS and CIG will be very well received.

Master's programs have been chosen to act as the focus for the effort because they are mature, well-benchmarked codes that have been used repeatedly by Masters and his students and ex-students and compared carefully to large volumes of data. The careful benchmarking and inter-comparison with data make this code an excellent candidate for distribution by CIG. Masters has been exceptionally helpful to date and pledges further help in the future as the code nears general distribution. This support from the principal developer is necessary to ensure efficiency in preparing the version for delivery to CIG for later distribution.

In terms of timing, the plan is to deliver the code to CIG for emplacement within the CIG computational framework in time for the upcoming "EarthScope Imaging Science/CIG Seismology Joint Workshop on Computational Seismology", which is to occur Oct 31 - Nov 2, 2006 at Washington University in St. Louis. The intent is to demo the code there. Ideally, it would be provided in a form for distribution so participants can take the code with them after the completion of the workshop.

Our plan is for work to take place in four steps:

(1) technical modification of the code particularly in simplifying I/O,

(2) benchmarking,

(3) documentation, and

(4) preparation of the package for delivery to CIG.

The four steps will be carried out by a programmer (Dr. Misha Barmine) at the University of Colorado at Boulder with oversight by Mike Ritzwoller. Guy Masters has agreed to act as the technical advisor.

The following presents a brief overview of how the work will proceed. Unforeseen technical problems may be discovered that will force the plan to be modified somewhat.

1. Technical Modifications

Master's code is broken into four programs: an eigenfunction code (MINOS_BRAN), an eigenfunction renormalization and reformatting code (EIGCON), a Green function code (GREEN), and the final synthetic seismogram code (SYNDAT). For the sake of simplicity and to retain the existing reliability of the working code, the technical modifications will be as minimal as possible. The plan is for the final deliverable to remain divided into the same four codes. Little change is planned for MINOS_BRAN or EIGCON. The principal modifications will focus on the I/O of GREEN and SYNDAT. At present, I/O is conducted within the framework of a data base package that Masters created called Guy's File System (GFS). We plan to move away from GFS to a simple file structure based largely on ASCII flat files for all parametric information and SAC waveform files. Masters' code currently applies instrument responses. To save time and to simplify the input data formats, we plan that in this phase of the code that the instrument

responses will not be applied. Synthetic seismograms will, therefore, be created in specified units of ground motion. If users are interested in comparing the synthetics to data, they will need to convert their data to ground motion. Future modifications to the code, if desired, could introduce the feature to apply instrument responses to the synthetics.

Information that must be input to MINOS_BRAN and EIGCON includes the model chosen (in a specified format) and choices about which normal modes are desired (frequency band, wavenumber band, normal mode branch or branches). For GREEN and SYNDAT, the I/O format must include information about station locations, component orientation, sampling rate, and earthquake parameters (location, depth, moment tensor, source-rise time).

2. Benchmarking

Masters' code is already well tested. Due to modifications that will be made to the code, however, the revised version must be benchmarked again. Two benchmarks are planned. First, tests will be made against Bob Hermann's eigenfunction and synthetic seismogram codes. Second, it is important to ensure that the code produces the same output as when Masters runs the original code at UCSD. Masters help in this regard is important.

It should be remembered that technical challenges may present themselves during benchmarking -- particularly as it may be desirable to run Masters' code outside the frequency-wavenumber band that the code was designed for and in which he tested it most rigorously. For example, the code should deliver stable results down to periods of at least 5 sec for a wide variety of different structural models and seismic phases. This band probably extends to shorter periods than most of Masters' tests on his code. The recommended use of the final code will reflect the ability to identify and, if possible, overcome any problems that are identified.

3. Documentation

Good documentation is the key to the success of this project. The documentation will cover data (parametric and wavform) and model formats, examples of how to run the code in different circumstances, results of the benchmark tests, and instructions for installing the code.

4. Package for Delivery to CIG

The package that will be delivered to CIG includes:

(1) the four programs (MINOS_BRAN, EIGCON, GREEN, SYNDAT) structured in a way to ensure simplicity of compilation,

(2) example files containing information about station locations, component orientation, sampling rate, and earthquake parameters for use when the code is run,

(3) example 1-D model files from a 3-D global model including tectonic and stable continental models, oceanic models of different ages, and global average models such as PREM, AK135, IASPEI91 and so forth, and

(4) the documentation, which includes a summary of package components (1) - (3), and installation information.

5. Budget Description

The budget contains four months of salary support for a scientific programmer named Dr. Misha Barmine at the University of Colorado at Boulder. Dr. Barmine has a great deal of experience with numerical programming in general and synthetic seismogram codes in particular. He also has experience with documentation and packaging numerical codes for distribution within a commercial setting. He will work on this project from July 1 until the "EarthScope Imaging Science/CIG Seismology Joint Workshop on Computational Seismology", which will occur Oct 31 - Nov 2, 2006 at Washington University in St. Louis. Within CIG, Dr. Barmine will collaborate with Leif Strand, and Michael Gurnis has suggested mutual visits (Barmine to Cal Tech, Strand to CU) prior to the workshop in late October. No funds are budgeted for these trips, as Michael would prefer that they would be paid for directly by CIG.

CU Proposal No.

PROPOSED BUDGET DETAILS

Institution The Regents of the
University of Colorado
Campus Box 572
Boulder, CO 80309-0572

Title: Preparing Guy Masters' Normal Mode Synthetic Seismogram Code for Delivery to CIG

Principal Investigator: Michael Ritzwoller

Duration: 7/1/06-10/31/06

A. Salaries and Wages	**4.0 Months**
Programmer: Misha Barmine	
100% time, 4.0 months	15,901
Total Salaries and Wages	15,901
B. Fringe Benefits	
Professional FT: 21.6%	3,435
Total Fringe Benefits	3,435
C. Total Direct Costs	19,336
D. Indirect Costs	
On Campus: 49% of MTDC, predetermined for 7/1/05 -6/30/06. Per HHS agreement dated 4/21/05. Provisional thereafter.	9,475
E. Total Costs	$28,811
Total requested for 4.0 months:	**$28,811**