

Delft Internet-based introduction course on reflection processing with Matlab

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Introduction

In earth sciences nowadays, interdisciplinary teaching has become a common theme. Reflection seismology is an important course in such a curriculum, since it is such a powerful tool to unravel the mysteries in the Earth. From a multi-disciplinary earth scientist's point of view, an introductory course on reflection seismology should convey the concept of the method. To support this, exercises on the computer are very much needed, if not indispensable.

When choosing a certain computer environment for the supporting exercises, the main goal should be that the student (often *not* a geophysicist!) has to stay focused on trying to understand the seismic method, rather than understanding the software or its environment. Combined with the fact that many students do not have a sound basis in Unix (any more), Matlab becomes a very good option as the environment for an introduction on reflection seismology.

In this article, we will first elaborate on the specific advantages and drawbacks when working with Matlab as a processing environment, with the aim of introducing reflection seismics to the multi-disciplinary earth science student. Then, we will describe what is offered by the Delft Internet-based course. To give insight also into the student's perspective, we have inserted in several places in the article reactions from our students to the course, for example, '*instructive experience for the clarification of the objectives of geophysics*', and '*nice to see theory in practice*'.

Matlab as environment for seismic reflection processing

From the point of view of a university student following a course in seismic reflection processing, it is important that he or she gets to understand the concepts of the method. The professional industry packages have many capabilities and the knowledge of these packages may be useful when starting to work for a geophysically engaged employer. For a student starting to learn about reflection processing for the first time, however, he/she is confronted with the special way seismic data are treated in those packages. Furthermore, since the professional packages offer so many options in the processing, they are not likely to have a fast learning curve for seismic reflection processing: initially, time is mostly spent on learning the software rather than learning the concepts of seismic reflection processing. Especially in introductory courses, this is a significant disadvantage.

In this respect, Seismic Unix (SU) from the Center for Wave Phenomena, Colorado School of Mines, has done the educational community a great favour. Since it was designed as a seismic extension to the Unix operating system, the student only needs to have some knowledge of Unix and scripting-languages, and can focus directly on learning seismic processing, rather than learning how to operate software. However, the knowledge base of the students regarding computer skills has changed over the last decade from Unix- and DOS-based systems, to more user-friendly systems with a Graphical User Interface (GUI). Nowadays students, especially multi-discipli-



Figure 1 Starting point of the course on the Internet.



Figure 2 Students following the course.

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nary earth science students, do not know anything about Unix. At such a point it is not a good decision to start working with SU (although GUIs have been built, like TKSU, and the specialized geophysics student will need knowledge about Unix later on to master the many Unix-based industry packages).

Matlab thus seems the obvious computer environment to choose. It is user-friendly thanks to its GUI, and links up to the modern common knowledge base of any science student, so the student can focus directly on the seismic concepts. It is available to the students for a reduced price via a university licence; freely available open-source programs like Octave or SciLab are able to run many codes written for Matlab as well, though not currently our codes. The student has directly available the other well-known tools from Matlab for visualization and numerical computations, and even the tools developed by our non-geophysical earth science colleagues can be linked directly to facilitate integration.

In Matlab, seismic data are represented by a matrix and are therefore not treated differently from any other dataset. This offers insight to the student that, for example, a trace is nothing more than a collection of time samples ('elements') recorded at a specific receiver position ('column') and that time and space sampling information is needed to make a plot on correct scales. In dedicated seismic software, aspects like these are not so explicit since the meta-data ('the data about the data') are hidden away in SEG-Y-headers and/or automatically taken into account, while the student should sometimes know about these.

The current limitations of Matlab are also well recognized. One disadvantage is that meta-data are not dealt with in a standard way, like the quasi-SEG-Y standard used in SU. Also, un-compiled Matlab routines do not offer the fastest performance, since an interpreter is needed to execute the routines from source form. Matlab has difficulties dealing with large datasets because of memory constraints, even in 2D; using Matlab for 3D pre-stack data is more something for the future. However, all these points become less and less important nowadays, when computers are getting faster and faster, with abundant amounts of RAM, for a competitive price.

When one is browsing the Internet, one sees that a fair amount of free seismic software is offered, e.g., via the SEG website. However, not many Matlab seismic toolbox packages exist: the outstanding exception is the package from the educational resources of CREWES, the Consortium for Research in Elastic Wave Exploration Seismology. Some of the tools developed in their research are part of this for educational purposes freely downloadable package.

Delft course for earth science students

The main objective for the seismic-reflection course taught at Delft is to introduce BSc students in applied earth sciences to processing of seismic reflection data to obtain a seismic image, approached from a purely physical point of view. In our experience, it always takes some time for the students to realize what seismic reflection surveying is all about, especially to realize what the CMP is about and what migration is about. This

realization really takes place when the students play with the seismic data themselves, so this practical is a crucial part of the course. (*'You have to really understand what you are doing and how seismic works in order to carry out the practical.'*)

Before the students start the practical, some of the lectures are given and the students buy lecture notes. In these lecture notes, simple modelling and good field examples are given on the different issues in seismic reflection surveying. Also, before the practical, the students shoot some seismic data themselves during fieldwork so that they can play with their own data (just some shots). The students have the exercises, lecture notes, and slides on-line available during the practical, next to their introductory manual of Matlab. The students have only six afternoons for the practical. In the practical, the students work in groups of two. (*'Very nice that the website for the practical was so clear, with all the needed info gathered there'*) (*'In this way the material is less dry and abstract than it would have been with lectures only.'*)

In the practical the students process some records or small datasets. First, the students start with a small Matlab exercise in order to freshen up their skills in that language. In the second part of this first exercise, they start using Matlab for seismic purposes, using the CREWES software. Usually, the first exercise takes up one afternoon. Then, from Exercise 2 onwards, they really start with the seismic processing. The seismic processes they encounter in these exercises are:

- Reading SEG-Y and retrieving geometric information
- Setting geometries
- Analyzing raw data, including a dynamite record shot by themselves
- Sorting seismic data (common-shot, -receiver, -offset, and -midpoint)
- Velocity analysis on CMP-sorted data
- NMO correction
- Analyzing stretch and mute
- Stacking trace-gathers
- Time-migration

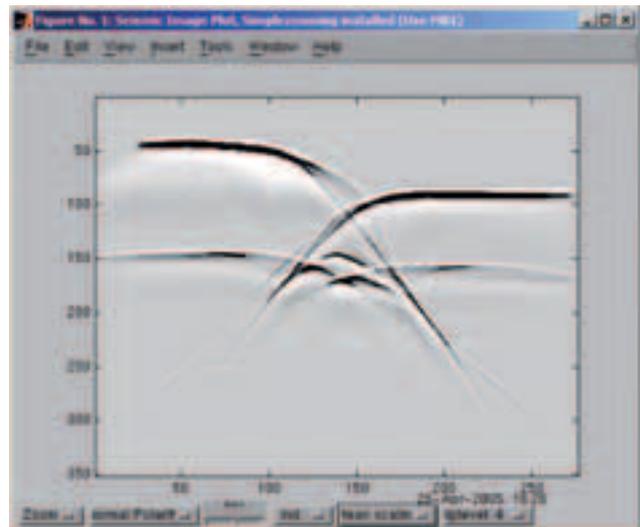


Figure 3 Stacked section produced by one of the students.

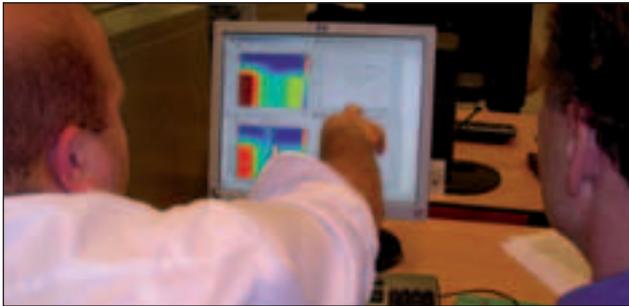


Figure 4 Explanations during the practical.

Although this seems a very basic processing sequence, it does illustrate how to make a seismic image from raw shot data, and how to build the first estimate of the velocity model. The practical is finalized with the processing of a 2D synthetic seismic dataset, starting from reading SEG Y data to delivering a migrated image with a 2D velocity model. The synthetic seismic data are generated with finite-difference code and shot over a syncline model, with another reflector underneath. Because of the syncline, the students really see the effects of migration. Usually, the last exercise takes up two afternoons. (*Some of the datasets look too good to be true, but they give beautiful results.*)

Time in the existing course is too restricted to go into other items such as deconvolution, DMO, or velocity-model building for depth migration. However, some time

is made available for pure signal analysis to appreciate certain aspects of single-trace processing like zero-phase and minimum-phase filtering, but then applied on seismic data, including the seismic data they shot themselves. (*You are working with real data.*)

Course on Internet

The practical can be done at home since the seismic modules in Matlab code are freely available on the Net; the course can be found at the URL listed below. Only a Matlab licence on your own computer is needed and you can start! (*It is nice to see that you are really processing something*) (*Nice practical with, for the first time during my education, real results that are also a little bit right, I hope*) (*Nice and useful site.*)

Web References

- Delft Matlab course: 'Introduction to Reflection Seismology': http://www.ta.tudelft.nl/intro_seismology/
- CREWES Educational Software Release in Matlab: <http://www.crewes.org/Samples/EduSoftware/>
- Seismic Unix (SU): <http://www.cwp.mines.edu/cwpcodes/>
- Graphical User Interface for SU (TKSU): <http://www.henrythorson.com/interface.htm>
- Free seismic software on the SEG-website: <http://software.seg.org>

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