



An Open-Source Passive Seismic Data Processing and Visualization Package: *Passeis*

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Summary

As an in-house, open-source passive seismic data processing and visualization package, *Passeis* is developed by using Matlab Graphical User Interface (GUI) tools and can be executed by running Matlab 7.5.0 (2007b) or higher versions under both Linux and Windows operating systems. A total of 63 modules have been developed so far, which can be roughly casted into the following 10 module-groups: Input and Output, Traces, Data, Frequency, Correlation, Source, Model, Modeling, Coordinate and Interpretation. Each module has its own GUI(s), and applies a well defined processing step to the given input data before passing the processed data to another chosen module. Although *Passeis* initially has been designed to handle the long-recorded passive seismic data (especially within the low frequency range), it is still applicable for any kind of seismic data. *Passeis* is developed in aim of being applicable for both academic and industry environments due to its ability to be adapted to specific tasks by the end user. However, the key power of *Passeis* is its robust core and open environment which permit the user to easily and quickly build his/her own modules into *Passeis* by using the module template. These features are very important for the developing package applied for Passive seismic data processing and visualization because most of present methods or ideas for handling Passive seismic data are basically immature and the development of publicly acceptable processing procedures for Passive seismic data is still far behind that of conventional seismic data. Thus, whenever new ideas come up, the constantly required program (software) can be written and implanted into *Passeis*.

Introduction

In later years the acquisition of passive seismic data has gaining popularity in at least the following three fields: 1) Low frequency passive seismic data analysis to find the so-called direct hydrocarbon indicator (DHI) (e.g., Walker, 2008; Hanssen and Bussat, 2008). The driving force behind such surveys has been the hypothesis of an increased energy level in the frequency band between 2-6 Hz in case of a hydrocarbon reservoir; 2) Reservoir monitoring (Maxwell and Urbancic, 2001) and 3) Hazard or geothermal reservoir monitoring (Asanuma, et al., 2004). However, to our knowledge, there still no mature processing package focusing on these data sets is available for researchers in either academia or industry. Therefore, in this project, as an integrated processing package focusing on passive seismic data, *Passeis* was developed. Here,

we shortly present this package by only focusing on its four aspects: Installing, Data structure, Module layout and Building/Running processing flow with *Passeis*.

Installing *Passeis*

Installing *Passeis* is very simple. The user only needs to copy the whole package into his/her own directory (for example, myDir), open Matlab, change Matlab's path to the path of 'passeis' (it should be myDir/passeis) and type `passeis_paths` in Matlab Command window. Now, the user may start to use any available module of *Passeis* within the Matlab environment.

Data structure

Unlike the conventional seismic data, passive seismic data generally can have varying recording length as well as trace header from station to station because of the special way a survey is carried out. Even sometimes, the different components of the same station may have different recording length. However, in the actual data processing one does not always process the data in base with a single station, especially when the 2-D or 3-D features need to be investigated. Thus, there is a need for an all-around data representation for a given passive seismic data set allowing for irregular trace length as well as different type of trace header. In *Passeis*, the data representation format is defined by using a $(n+1) \times 6$ (n is total trace number) cell array and named *Passeis*-data (Figure 1). The advantages of this data structure are as follows: 1) Different traces carrying with different lengths can co-exist; 2) All initial trace headers are kept; 3) Data header is a Matlab struct containing such information as the processing history, the log information of a module applied and so on and 4) The same processing approach can be applied to the whole data set by processing it trace by trace and component by component.

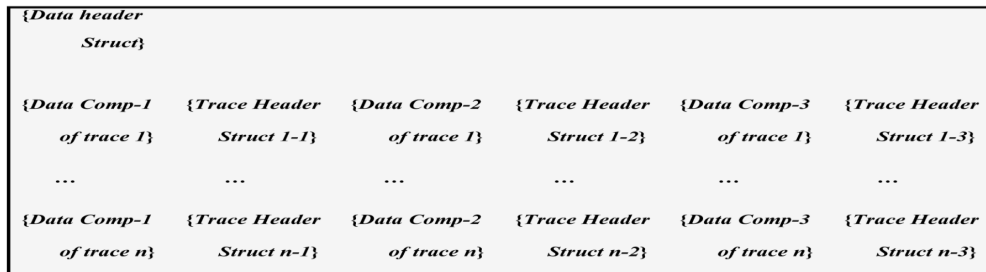


Figure.1: *Passeis*-data structure. Here, 'Data header' is a Matlab struct which carries the general information about the whole data by having such members as 'DataType', 'ModuleName', 'Loginf', 'TracesNumber' and so on. 'Comp-1' and 'Comp-2' represent the horizontal components and 'Comp-3' usually means the vertical component. Their corresponding trace headers are represented by Header trace i-1, -2 and -3 respectively. However, if only single-component data is available, it will always be put in 'Comp-3'.

Layout of the main GUI of a module

A given *Passeis* module has only one main GUI denoted the parent figure, which is actually a Matlab figure. To carry out the designed processing associated with a specific module, its main GUI may also have multiple GUIs as its children. However, only the main GUI can communicate with the other modules. Thus, only the main GUI of each module has the similar layout (Figure 2) which basically consists of three sections: 1) Module description and parameter status; 2) Parameters and 3) Processing.

Building/Running processing flow with *Passeis*

Two ways of using the modules to build a processing flow are available in *Passeis*: Building a flow inside or outside the *Passeis* main platform. To build a processing flow inside the *Passeis* main platform, user only

needs to run 'run_passeis' in Matlab to access the main GUI shown in Figure 3 and then add new modules in the processing flow by one of the following three method: 1) Left click module from menu list; 2) Directly input module name and 3) Input module group and select module from the popup list. Once a processing flow is built, the user can check/run the flow by clicking the corresponding button in Figure 3.

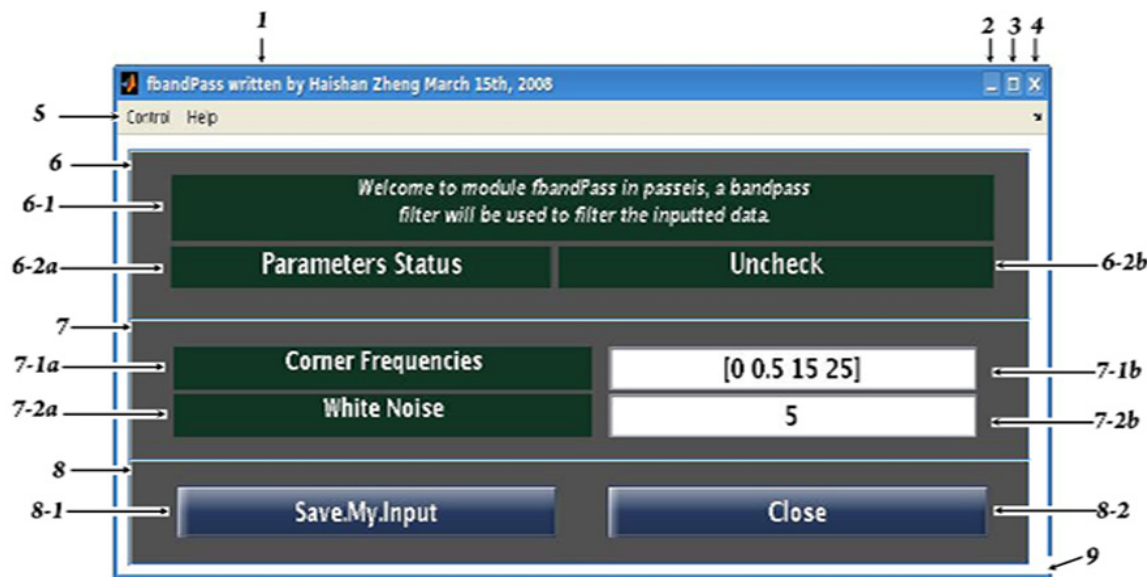


Figure 2: General layout of the main GUI of a *Passeis* module (*fbandPass*). 1) Name of GUI; 2) and 3) Minimize/Maximize window; 4) Close this module; 5) Menu list; 6) Module introduction (6-1) and parameters' status (6-2a, b); 7) Section of parameters (7-1a, b and 7-2a, b); 8) Section of processing and 9) Dragging this frame to resize the window.

On the other hand, building a processing flow outside *Passeis* platform is tailored for the more advanced user of *Passeis*. It offers a more efficient and flexible way of building processing flow. The user may use the following codes as a starting template (see directory myDir/passeis/help/flow_template.m) to write his/her own processing flow in a general .m file in Matlab:

```

passeis_paths;
global PasseisBuffer;      % declare the global variable for Passeis
% First step
H1 = module1('Running');  % Keep this line if module 1 is one of *input modules
H1 = module1(MyData);     % Keep this line if MyData is available and serves as the starting data
Waitfor(H1, 'Visible', 'Off');
% Second step
H2 = module2(get(H1, 'UserData'));
Waitfor(H1, 'Visible', 'Off');
delete(H1);               % Optional code, comment it out if you want to keep the data of module1
% other steps which follows the similar codes as the second step

```

Once the processing flow is written and saved as a general .m file, say MyFlow.m, it can be run directly from Matlab command window.

Conclusions

Passeis is currently a Matlab based (GUI) processing system basically focusing on passive seismic data with special efforts in dealing with the different data formats (e.g., PSEGY, SEGY, Binary and ASCII) and

station coordinate transforms (e.g., From Ellipsoidal coordinates to UTM). The core modules in current *Passeis* package are those related to seismic interferometry and time reverse modeling (2D, 3D acoustic and elastic wave), which is one of the most popular method used to investigate the basic features of passive seismic data (Walker, 2008). *Passeis* also provides with some statistic tools to review the data in a base with station or predict the probability of existing the DHI. However, the biggest strength for *Passeis* is its capability to serve as a concurrent development framework so that any new processing tools carrying with new ideas from user can be freely and rapidly developed by following the guide and using the module template. *Passeis* provides with help documents for each module and the whole package. User can also easily improve the contents for any help documents based on their own experience because of the open-source feature of *Passeis*. With more efforts in improving and upgrading the current version of *Passeis*, we believe that it could be of interest to researchers in both academia and industry.

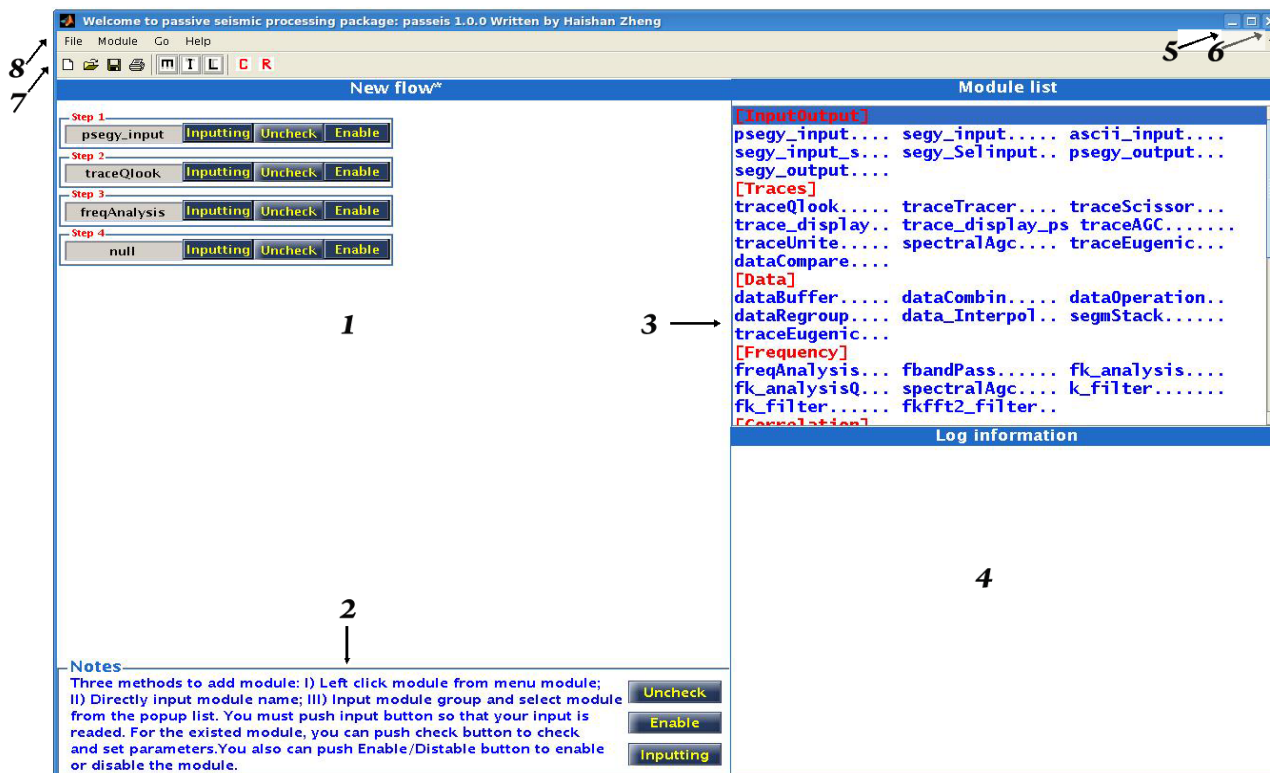


Figure 3: Main platform of *Passeis*. 1) Module flow; 2) Notes for building a new flow; 3) Module list; 4) Log information window for checking and/or running flow; 5) Resizing function; 6) Close function; 7) Toolbars and 8) Menu.

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