The use of Graphic User Interface for development of a user-friendly CRS-Stack software

Rachmat Sule¹, Dythia Prayudhatama¹, Muhammad D. Perkasa¹, Andri Hendriyana¹, Fatkhan¹, Sardjito², Adriansyah²

¹ Institut Teknologi Bandung, Jalan Ganeca No. 10, Bandung, Indonesia
² (formerly) Upstream Technology Center, PT Pertamina

E-mail: rachmat@gf.itb.ac.id

Abstract. The development of a user-friendly Common Reflection Surface (CRS) Stack software that has been built by implementing Graphical User Interface (GUI) is described in this paper. The original CRS-Stack software developed by WIT Consortium is compiled in the unix/linux environment, which is not a user-friendly software, so that a user must write the commands and parameters manually in a script file. Due to this limitation, the CRS-Stack become a non popular method, although applying this method is actually a promising way in order to obtain better seismic sections, which have better reflector continuity and S/N ratio. After obtaining successful results that have been tested by using several seismic data belong to oil companies in Indonesia, it comes to an idea to develop a user-friendly software in our own laboratory. Graphical User Interface (GUI) is a type of user interface that allows people to interact with computer programs in a better way. Rather than typing commands and module parameters, GUI allows the users to use computer programs in much simple and easy. Thus, GUI can transform the text-based interface into graphical icons and visual indicators. The use of complicated seismic unix shell script can be avoided. The Java Swing GUI library is used to develop this CRS-Stack GUI. Every shell script that represents each seismic process is invoked from Java environment. Besides developing interactive GUI to perform CRS-Stack processing, this CRS-Stack GUI is design to help geophysicists to manage a project with complex seismic processing procedures. The CRS-Stack GUI software is composed by input directory, operators, and output directory, which are defined as a seismic data processing workflow. The CRS-Stack processing workflow involves four steps; i.e. automatic CMP stack, initial CRS-Stack, optimized CRS-Stack, and CRS-Stack Supergather. Those operations are visualized in an informative flowchart with self explanatory system to guide the user inputting the parameter values for each operation. The knowledge of CRS-Stack processing procedure is still preserved in the software, which is easy and efficient to be learned. The software will still be developed in the future. Any new innovative seismic processing workflow will also be added into this GUI software.

1. Introduction

Common Reflection Surface (CRS) Stack method is a new reflection seismic processing method that replaces the sequence processing steps of velocity analysis – NMO/DMO correction – stacking steps,
which are always used in conventional stacking method. The Zero Offset (ZO) CRS-Stack method is introduced for the first time in 1997 by the Wave Inversion Technology (WIT) Consortium in Germany [3]. Since that time, its application to several seismic data that contains complex geological structures is widely used in all over the world, including in Indonesia. The development of CRS-Stack technology still continues until now. Even, a new version of CRS-Stack technique is appeared in 2009, which is then called as Partial CRS-Stack [1].

The original source codes of ZO and Partial CRS-Stack methods can be installed and run in standard computer hardware under Linux OS environment. So far, these versions are widely used for research purposes. For industries needs, it seems that they will be difficult to be accepted, since they are not user-friendly softwares. In October 2007, Institut Teknologi Bandung (ITB) and Pertamina EPTC agreed to conduct a research cooperation in order to develop several geosciences softwares. One of them is to develop a user-friendly reflection seismic data processing software that implement several new processing techniques, including ZO and Partial CRS-Stack methods. Since that time, several faculty staffs and students of Geophysical Engineering Study Program - ITB involve in this research project. This paper will describe the current situation of the developed CRS-Stack based software.

2. The Principle of ZO and Partial CRS-Stack Methods

The successful of CRS-Stack method has been proved by several conducted case studies abroad [5] and in Indonesia [6]. Based on their studies, ZO CRS-Stack method is proved as an alternative method to the existing conventional stack method, which could provide better seismic section that has higher S/N ratio and better continuity of reflections. The ZO CRS-Stack operator is a second-order traveltime approximation of paraxial ray, which is given in terms of central ray coordinate of midpoint-half offset \((x_m, h)\) for segment curved reflector. It can be expressed as follow:

\[
l^2(x_m, h) = l_0 + \left(\frac{2 \sin \alpha}{V_0} \left(x_m - x_0 \right)\right)^2 + \frac{2l_0 \cos^2 \alpha}{V_0} \left(\frac{x_m - x_0}{R_N} + \frac{h^2}{R_{NIP}}\right)
\]

where \(h\) is half source-receiver offset, \(m\) is the midpoint displacement with respect to the considered CMP position, and \(l_0\) corresponds to the zero offset two-way-traveltime (TWT). In this method, stacking is conducted throughout several midpoints and offsets, which is described as green surface (this surface is then called as CRS-Stack surface operator) in Fig. 1 (left), in order to get a stacked trace that is situated in \(x_o\). One needs only to input the near-surface velocity (\(V_0\)), and there is no explicit macro-velocity model is needed. Therefore, this method is sometimes called as a technique that is independent from macro velocity model.

Based on Eq. (1), CRS-Stack depends on three kinematic wavefield attributes, i.e. emergence angle (\(\alpha\)) and radii of curvature of two hypothetical normal incidence point wave and normal wave (\(R_{NIP}\) and \(R_N\)). The main issue in CRS-Stack is how to determine those three CRS attributes for each point \((x_m, t_o)\) in a ZO section. This could be done by executing 3 (three) steps, as proposed by [4] by using the scheme of pragmatic search or by [3] by implementing extended search scheme. Those three steps are:

a) Automatic CMP Stack, i.e. an effort in order to obtain initial ZO stacking section and initial stacking velocity.

b) Linear and hyperbolic CRS-Stack attributes search, i.e. an effort to extract \(\alpha\), \(R_N\), and \(R_{NIP}\) from the initial ZO stack section, which has been obtained from the first step.

c) Local optimization step, i.e. an effort that should be done in order to refine the initial CRS-Stack attributes by using an algorithm that can find the fittest operator to reflection travel-time data. In this step, one must test all possible attributes and choose one that lead to highest coherency value.
Figure 1. Left - ZO CRS-Stack surface (after Mann, 2002), right - Partial CRS-Stack surface. In Partial CRS-Stack method, the stacking process is conducted only along the red line and stored the result in the red dot [1].

The Partial CRS-Stack has similar formulation and tricks to the ZO CRS-Stack. The main difference between both methods is seen on the stacking procedure. In Partial CRS-Stack, the stacking process is carried out only along each half-offset (red line in Fig. 1 right) and the result is a stacked trace that is placed on a particular half-offset (red point in Fig. 1 right). This procedure is repeated for other offsets. As result, one will get a gather with higher fold than that can be provided by the conventional stacking method. This gather is then known as a supergather, which is displayed in Fig. 1 (right) as a purple line. Since the final output of Partial CRS-Stack is a supergather, one should still conduct velocity analysis, NMO/DMO correction and stacking, in order to obtain a stack seismic trace at $x_0$, which is part of a stack section. Detail procedures of Partial CRS-Stack method is described in [2].

By applying this method, the amount of data (traces) in a supergather can be increased. This will make velocity analysis will be easier to do, in which the velocity pattern will be more focused. The application of this method is very useful if seismic dataset consists irregular geometry, e.g. because the seismic lines crossed rivers, villages, complex topography areas, etc. This method could provide additional seismic traces for the gap areas.

3. The Development of CRS Stack GUI

The research was begun with learning process of CRS-Stack method. This could be done by doing literature study of several published papers, Master thesis and Ph.D dissertations, especially originated from Universität Karlsruhe, e.g. [2]; [3]; and [4]. Several B.Sc and M.Sc students of ITB have chosen the topic of CRS-Stack as their research project to pursue degrees from ITB. Since the original source codes from WIT consortium is obtained in March 2008, several ITB students that have good knowledge in information technology (IT) are involved in this research group. Their initial responsibility is to install the original source codes in the available laboratory’s hardware.

To ensure the reliability of this CRS-Stack software, the original source codes are tested in several existing hardware platforms. Several synthetic dataset, which are resulted from elastic waveform modeling by using finite difference method, are produced in order to make synthetic studies and to validate the original programs. The students are asked to make several subsurface models, from a simple model until the complex one, which will be inputted later to the elastic waveform modeling software. Besides that, several real dataset are also provided from several oil companies in Indonesia and abroad for the same purposes. By using those datasets, we reproduce the stack sections by using CRS-Stack method, for different hardware and different operating system. Those results are then compared to the best results obtained from the conventional stacking method.
Up to this stage, several errors have been encountered for different systems. Next important step is to develop a software, since all errors have been fixed. On the same time, optimization of CRS-Stack program for several hardware and operating system must be done, this includes the implementation of CRS-Stack program on 64-bit machine with 64-bit operating system. Besides that, optimization on multi-core CPU to reduce the processing time is also an important issue that must be solved urgently.

The original CRS-Stack code developed by WIT-consortium was written in C++ programming language. Since there is a backward incompatibility in the code to newer C++ syntax, we solved this problem by installing GNU backward-compatibility software library, i.e. an additional library system, which may be different to be implemented for several operating systems. The recent status is that the CRS-Stack code can be compiled and run in 32-bit and 64-bit Linux operating system. Several compatibility tests have been done for several Linux distributors, such as Red Hat Enterprise Linux 5, Fedora Core 8, and open SUSE.

The second phase of the CRS-Stack software development is the development of the Graphical User Interface (GUI), including how automatic installation program can be implemented. The CRS-Stack programs are originally developed in the Seismic Unix (SU) environment, so it requires several SU programs involved in the CRS-Stack processing work-flow. Besides that, the possibility of other software (e.g. SEPlib) to be included must be concerned. Because of facing those challenges, it has been chosen the Java Programming to address those interoperability problems. Besides that, Java Programming consists less efforts to address backward compatibility problem. In the process of CRS-Stack software development, we apply the Agile Development Techniques. These techniques use iterative development as a basis, but advocate a lighter and more people-centric viewpoint than traditional approaches. Agile processes use feedback, rather than planning, as their primary control mechanism. The feedback is driven by regular tests and releases of the evolving software.

The research activities in the laboratory can be divided into 2 groups. There are research members that focus on the understanding and implementing the techniques of CRS-Stack, whereas other group members focus on computation and programming. The first group is composed mostly by the B.Sc and M.Sc students of geophysical engineering study program, who work with CRS-Stack programs for their final projects. As a student finalized his/her research and study at ITB, he/she has to provide a documentation related to his/her methods, programs and scripts, so that his/her experiences and knowledge can be transferred to other laboratory members. This effort is the way of laboratory’s policy in order to preserve knowledge after a student is graduated.

In laboratory, the students are encouraged to use several open sources and commercial seismic processing software, instead of restricting them to use only one commercial seismic processing software. In the development of a new seismic data processing software, the source code of CRS-Stack is integrated with SU programs. The SU data format is adapted in order to perform CRS-Stack procedures. SU, which is developed by Colorado School of Mines (CSM), is a standard available seismic data processing programs and programming library in the laboratory. Moreover, the CRS-Stack procedures provides more possibilities to develop innovative processing procedures incorporating with other seismic imaging tools, in which other programs or seismic programming library may be included, e.g. SEPlib and Madagascar. In our cases, the NIP-wave tomography and PSDM by means of CRS attributes are also parts of interest. Both programs are also developed by WIT-Consortium and incorporating SEPlib inside the processing flow. Thus, the possibility of including other software without major revising in the GUI software is concerned.

During three years of development, three major changes of this software have been occurred, in which the main reason is in order to adapt and fulfill industrial needs. By experiencing other seismic software, such as PROMAX, Vista, and BotoSeis, several concepts are adapted and compiled from their design into our CRS-Stack GUI software. The users’ opinions related to several available seismic processing software are accommodated in order to gain knowledge on how the CRS-Stack software should be designed.
4. Design of CRS-Stack GUI

The developed software is then named as ASPS (Advance Seismic Data Processing Software). The latest version of software interface can be seen in Fig. 2. Several existing features are as follow:

- **A**: The program lists, which are automatically generated. This CRS-Stack GUI Software search a particular folder path ($ASPSROOT$), in order to obtains program headers information. To add a program into this existing GUI software, the developer has only to provide the program header and its corresponding shell script in order to perform program execution. This could be done without recoding and recompiling this GUI software. A program header is a file that describes inputs and program parameters to be displayed on the features E and F. We can add a program to a work-flow window D, by right-clicking the program icon in this display.

- **B & C**: The Area and Line tabs, which are designed to manage a project. This idea is adopted from PROMAX concept, in which each line has its own datasets. The data name in this line are managed and viewed by panel G. Every area tab can have several line tabs, and every line tab can have several work-flow panels. A work-flow panel consists of a combination of panel D, panel E, and panel F, which can be named by a user.

![Figure 2. The latest Graphical User Interfaces](image)

- **D**: Programs flow. A blue colored box represents a program, which can be called by right-clicking program icon in the panel A. A user must set input/output files in the panel E, and sets its program parameters in the panel F. There are two buttons in this icon, i.e. the delete and the run button. The “delete” button is used to remove a program from the work-flow. By right-clicking the “run” button, the user will trigger the shell script program to be executed.

- **E**: Input Output Panel. A user can set input/output file in this panel. This panel consists of two columns, which provide description on input/output file, and a slots ID (number) that corresponds to a Slots number in the datasets Viewer G. Thus, the user can only set input/output files, which have only been described in the panel G.

- **F**: Parameters panel. In this panel, a user can set the values of their parameters for a set of programs in the workflow.

- **G**: Datasets, This facility is adopted from PROMAX’s concept of datasets, in which a user must insert a file into this datasets before the program is processed. By right-clicking this panel, a user can also view file properties and header.

All of those software features are so far working well. This software has been tested to process several datasets belong to some oil companies in Indonesia. A commercial course related to CRS-
Stack has also been conducted by our group in 2009, in which this software is used in the tutorial. So far the feedback from the course participants is very good.

Figure 4 shows an advertisement poster that has been prepared for the launching of ASPS in 2010. Two stack sections are displayed in this poster, the upper stack section is the best section obtained from conventional stacking method, whereas the bottom section is the result of CRS-Stack method.

5. Conclusions
The recent software is the initial achievement that can be given by the team members of ITB - Pertamina EPTC research cooperation, which its members are mostly Indonesian young scientists (ITB students and fresh graduated). The software is already tested and ready to use. Since this software is an Indonesian product and includes CRS-Stack method, we hope that this product can be accepted at least in Indonesian markets for the first stage.

The development of this software will still be continued. In a near future, the new version of this software will include CRS-Stack based of NIP-Wave Tomography and Pre-Stack Depth Migration (PSDM) modules. Any other new application derived from CRS-Stack methodology can always be added, so that this software will be one of the available software in the markets that can include several non-standard processing sequences, in which other commercial software will be difficult to fulfill those facilities. In order to make this plan feasible, special design requirement must be followed; Firstly: There are sustainable research and development activities in order to produce innovative seismic processing sequence; Secondly: The software must also provide high reliability to be
implemented in the industrial business. Those two design requirements are very important to ensure the linkage between research and industry.

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