Parallel Implementation of 3D Seismic Imaging via Objective Oriented Procedures

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Abstract. As a rule all oil fields in East Siberia are confined to local heterogeneous lithologic substitution. These areas usually possess higher level of fracturing and besides of reflected waves generate scattered ones with rather high amplitude. Both regularly reflected and diffracted/scattered waves should be used in order to get the proper seismic image of reservoirs structure: reflected waves fix its position while scattered waves are responsible for its internal structure. So, one needs in adaptable seismic imaging procedure to describe the reservoir. This procedure should be able to be tuned to image either regular interface or, vice versa, to destroy their image in order to be focused on imaging of scattering object.

The paper presents parallel implementation of this procedure based on Focusing Transformations. We present results of scalability tests together with results of real data processing and their geological interpretation.

1 Introduction

Currently there is no regular migration procedure which gives foolproof image of scatterers/diffractors in the vicinity of interfaces with more or less considerable contrasts. But, at the same time diffracted/scattered waves as a rule are connected with objects of subseismic structures like faults, cracks, fractures, cavities etc., and so their presence on an image will essentially improve its resolving ability and self-descriptiveness.

In the paper (Pozdniakov and Tcheverda, 2005) an approach to imaging of objects of subseismic scale was proposed, implemented and tested. Its main advantage is possibility to switch from one kind of imaging to another - from reflected to scatterered/diffracted waves. We believe that in order to reveal interior structure of reservoir with highest possible reliability one should use both reflected and scattered/diffracted waves. Really, the first ones are responsible for proper reservoir positioning in space while others bring knowledge about its fine structure. Hence we need in objective oriented or adaptive imaging procedure which provides choice between imaging of regular interfaces and objects of subseismic scales. Below we present some results of application of this procedure based on the Focusing Transformation (Pozdniakov and Tcheverda, 2005). These results are achieved with the help of parallel computations performed on cluster IBM 1350 installed at ZAO "Krasnoyarskgeofizika" (Krasnoyarsk, Russia).

2 Objective Oriented Imaging Procedures (Focusing Transformation)

. For the first of all let us briefly remind main features of Focusing Transformation and in order to do this write down Kirchoff migration procedure in time frequency domain:

$$M(\boldsymbol{r}) = \int d\omega \int\limits_{I} G(\boldsymbol{r}, \boldsymbol{r}_s; \omega) d\boldsymbol{r}_s \int\limits_{J} \left.\frac{\partial \overline{G}}{\partial z_g}\right|_{z_g=0} F\left[D\right]\left(\boldsymbol{r}_g, \boldsymbol{r}_s, \omega\right) d\boldsymbol{r}_g$$

Here $F[D]$ is Fourier transform of input data $D(\boldsymbol{r}_g, \boldsymbol{r}_s, t)$ with respect to time t. Focusing transformation comes if integration/summation is performed not for all sources/receivers, but for their moving constituents $I_{loc}(\boldsymbol{r}) \subset I$ and $J_{loc}(\boldsymbol{r}) \subset J$ only. In order to explain how we choose them let us consider elementary example - imaging of a single point scatterer at some current point $\boldsymbol{R_0}$. After some simplifications (asymptotic representation of Green's function, Born's approximation for scattered wave and summation instead of integration) the leading term of this image in high frequency approximation can be represented as:

$$M(\boldsymbol{r}, \boldsymbol{n}) = \sum_{(i,j)\in I_{loc}\times J_{loc}} f\left[\frac{(\boldsymbol{e}_s^i + \boldsymbol{e}_g^j, \boldsymbol{R}_0 - \boldsymbol{r})}{V}\right] \qquad (1)$$

Vectors $\boldsymbol{e}_s^i$ and $\boldsymbol{e}_g^j$ are unit vectors directed to i-th source and j-th geophone. Function $f(t)$ in (1) is source function and, so, is negligible for $|t > \frac{1}{f_0}|$ where f_0 is the dominant frequency. Therefore in the sum (1) only terms with

$$\left(\boldsymbol{e}_s^i + \boldsymbol{e}_s^j, \boldsymbol{R}_0 - \boldsymbol{r}\right) = O(1/f_0)$$

are not negligible. So, the brightest elements on the image will be elementary reflectors with normal unit vector being orthogonal to scattering vector . But scattering vector is uniquely determined by the choice of moving acquisition system . This means that for different moving acquisition systems one has different scattering vectors and, finally, comes to image of elementary reflectors with different orientations and, finally, to estimation of scattering energy.

3 Real Data Processing

We apply presented in the previous section imaging procedure to 3D real seismic data acquired in East Siberia (see the map on Fig.1)imaging procedure. Due to huge amount of input/output data (areal seismic acquisition system and 3D image) any approach to data processing should be based on parallel computations. As one can see from relation (1) there are few possibilities to perform parallel implementation of this imaging procedure - by source and receivers positions or by moving acquisition system. Currently we choose parallel implementation on the base of regular Kirchoff migration procedure from widely used seismic data processing software Promax - by means of distribution sources/receivers to different processors.

Results of real data processing on the base of Focusing Transformations one can see on Fig.2. There are definitely recognized all of three geologically confirmed faults.

4 Scalability of Focusing TRansformations

For the first of all let us present cluster characteristics:

BladeCenter: 877-2XX Nodes (Blades): 8 x 8832-G1X

Each node: 2 x Intel XEON 3.20GHz CPUs 2-3 GB RAM Internal IDE 40GB (TOSHIBA MK4026GAXB, UDMA 5)

Interconnection: 2 x Cisco Gigabit Ethernet switches (Model No. 13N2281)

Disc memory: 2 x UltraSCSI 320, 15K RPM drives in HW RAID-1 configuration (LSI Fusion 53C1030 controller)

OS: RedHat Enterprise Linux 3 WS Update 2

Data processing was performed by ProMAX: 2003.3.3 + RHEL3 WS patches up to date.

Results of scalability tests are presented on Fig.3

References

1. Pozdniakov V.A., Tcheverda V.A.: Focusing transformation of 3D seismic data for areal stationary acquisition system. Russian geology and geophysics, 5, pp.328 - 338 (2005a).

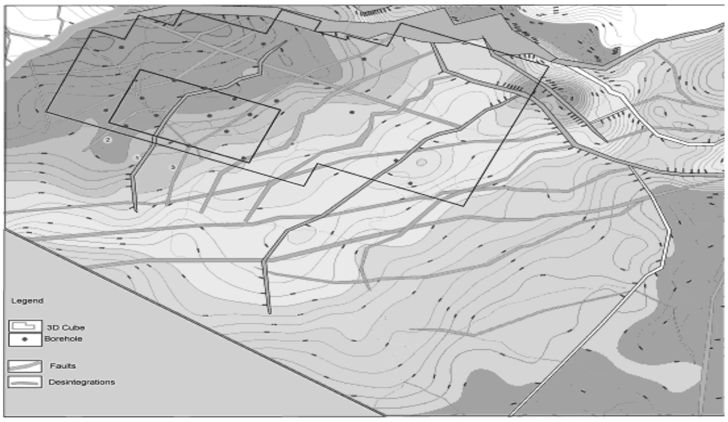

Fig. 1. General geological map of the target area (rectangle). Lines 1, 2 and 3 correspond to faults confirmed by previous studies.

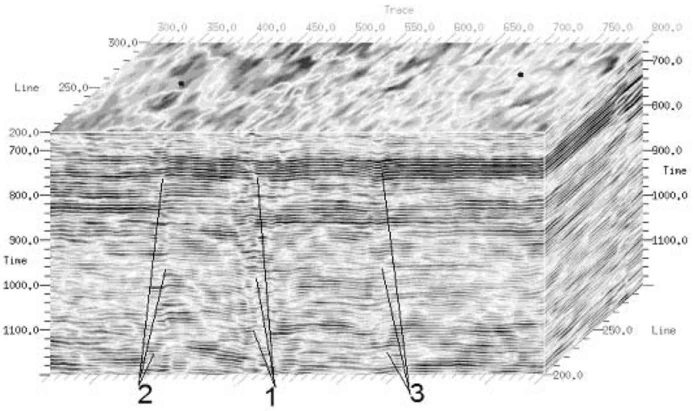

Fig. 2. Result of 3D imaging by means of Focusing Transformation.

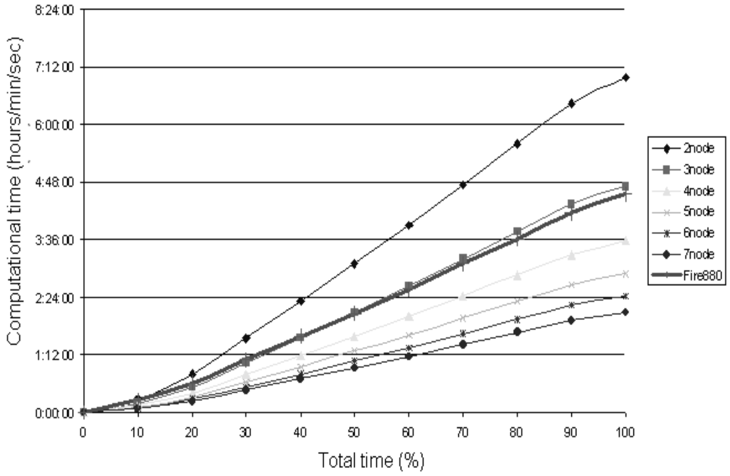

Fig. 3. Scalability tests performed for Focusing Transformation applied for real data processing.