Our ref.: P303NO00

Application no.: 20210133

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Our ref.: P303NO00

Application no.: 20210133

Title: Method of seismic inversion using artificial kinematic constraints

Applicant: PRE STACK SOLUTIONS GEO AS, Vita Kalashnikova

In response to the communication pursuant to Office action dated August 31, 2021

Dear Examiner:

In response to the Office Action mailed on August 31, 2021, the Applicant respectfully requests entry and consideration the following amendments and remarks.

Remarks:

The Applicant thanks the Examiner for the clear direction given in the office action and addresses the Examiner's comments below.

Claim amendments:

The applicant has amended the independent claim 1. The support for the amendments can found on Page 7.

The applicant has further amended the claim 5. No new matter has been added.

Patentability:

Claim 1 discloses a computer implemented method for extracting or estimating rock properties from seismic traces, in particular the method comprises the following steps:

— preparing an initial model with initial functions of velocity and density taking as constants or measured by obtaining seismic trace(s) or measured by obtaining borehole logs,

— generating synthetic trace(s) from the initial functions of velocity and density function(s) with added artificial kinematic constraints and randomly updating the initial functions of velocity and density in random start and length time or depth window(s),

— creating updated synthetic traces, using randomly updated velocity and density functions, wherein for each iteration, artificial wave(s) traveling from a source point to a reflection point and back to any receiver are simulated as a constraint,

— performing a search of a misfit object function of any norm between original/or real trace or traces and the synthetic trace(s) generated in the following iteration, and

— using probabilistic techniques for approximating the global optimum and minimizing the cost function associated with the seismic trace(s) mismatch.

<u>Novelty & Inventive step:</u>

Document D1 discloses a Full Wavefield Inversion (FWI) method to estimate subsurface properties (such as velocity or density). The Full Wavefield Inversion (FWI) requires seismic data (traces) recorded at the different angles and uses a mathematical approach (a Fourier transform, discrete Fourier transform, or a fast Fourier transform) through misfit function. By this method only P-wave velocity (Vp) can be estimated.

According to [0005], the method of D1 relies on the FWI algorithm that uses a starting subsurface physical properties model, synthetic seismic data are generated by solving a wave equation using a numerical scheme (e.g., finite-difference, finite-element etc.). The synthetic seismic data are compared with the field seismic data and using the difference between the two, the value of an objective function is calculated.

According to [0033], the method of D1 relies on obtaining a seismic dataset that is separated into subsets according to predetermined subsurface reflection angle ranges and inverting for density models. Where each of the data subsets generated, acoustic FWI is applied to obtain acoustic impedances. All inversions can start from the same velocity model, and **the kinematics are not updated in this process**. [Emphasis Added in Bold]

According to [0034], the method of D1 relies on a velocity model, density model, or physical property model as used in a cell, where a subsurface region has been conceptually divided into discrete cells for computational purposes.

Concerning the method according to D1, it cannot be pretended that D1 teaches any of the limitation of claim 1. Because D1 does not disclose **preparing an initial model with initial functions of velocity and density taking as constants or measured by obtaining seismic trace(s) or measured by obtaining borehole logs**, generating synthetic trace(s) **from the velocity and density function(s) with added artificial kinematic constraints and randomly updating the initial functions of velocity and density in random start and length time or depth window(s)**, creating **updated synthetic traces**, **using randomly updated velocity and density functions**, wherein for each iteration, **artificial wave(s) traveling from a source point to a reflection point and back to any receiver are simulated as a constraint**, performing a search of **a misfit object function** of any norm between original/or real trace or traces and the synthetic trace(s) generated in the following iteration. [Emphasis Added in Bold]

D2 discloses a method for estimating rock properties from seismic data. According to [0099), the method of D2 relies on the synthetic data that is modelled based on some initial layered elastic model defined in the time domain. According to [0093], the method of D2 relies on the synthetic seismic traces are calculated for a variety of source-receiver azimuths and angle of incidences that represent the seismic data actually recorded.

Concerning the method according to D2, it cannot be pretended that D2 teaches **generating synthetic trace(s) from the velocity and density function(s)** with added artificial kinematic constraints and **randomly updating the initial functions of velocity and density in random start and length time or depth window(s)**. [Emphasis Added in Bold]

According to [0099], the method of D2 discloses the data misfit term or function is the difference between the model (synthetic) and real seismic data.

According to [0099], the method of D2 relies on an algorithm that perturbs the layer P-wave velocity, Vp, S-wave velocity, Vs, and density, ρ and anisotropic parameters such as the normal and tangential weaknesses. As the algorithm perturbs the different parameters, the anisotropic elastic parameters become closer to the actual earth's parameters and the misfit function becomes smaller. These parameters can be perturbed independently or coupled via relationships such as the Gardner's relation linking Vp and ρ.

Concerning the method according to D2, it cannot be pretended that D2 teaches **randomly updating the initial functions of velocity and density in random start and length time or depth window(s).** Further it cannot be pretended that D2 teaches **creating updated synthetic traces**, **using randomly updated velocity and density functions, wherein for each iteration, artificial wave(s) traveling from a source point to a reflection point and back to any receiver are simulated as a constraint.** [Emphasis Added in Bold]

Concerning the method according to D2, it cannot be pretended that D2 teaches the **functions for density and velocity may be independently updated.** [Emphasis Added in Bold]

According to [0011], D3 discloses computer-implemented methods for inversion of seismic data to infer subsurface physical property parameters, including any one of P-wave velocity V_P, S-wave velocity V_S, density, lambda, mu, and combinations thereof.

Concerning the method according to D3, it cannot be pretended that D3 teaches any of the limitation of claim 1. Because D3 does not disclose **preparing an initial model with initial functions of velocity and density taking as constants or measured by obtaining seismic trace(s) or measured by obtaining borehole logs**, generating synthetic trace(s) **from the velocity and density function(s) with added artificial kinematic constraints and randomly updating the initial functions of velocity and density in random start and length time or depth window(s)**, creating **updated synthetic traces**, **using randomly updated velocity and density functions**, wherein for each iteration, **artificial wave(s) traveling from a source point to a reflection point and back to any receiver are simulated as a constraint**, performing a search of **a misfit object function** of any norm between original/or real trace or traces and the synthetic trace(s) generated in the following iteration. [Emphasis Added in Bold]

According to [0010], D4 discloses a computer-implemented method for updating a physical properties model of a subsurface region in an iterative inversion of seismic data using a gradient of a cost function that compares the seismic data to model-simulated data, the method including: obtaining a contrast model of a subsurface physical parameter that is sensitive to data dynamics and a kinematic model of a subsurface physical parameter; determining a gradient of a cost function using the contrast model and the kinematic model, wherein the cost function compares seismic data to simulated data; updating the kinematic model using a search direction derived from the gradient; adapting the contrast model according to an update to the kinematic model performed in the updating step; iteratively repeating the determining, updating, and adapting steps until a predetermined stopping criteria is reached, and generating a subsurface image from a finally updated kinematic model; and using the subsurface image to prospect for hydrocarbons.

According to [0019], D4 discloses the contrast model can be density or impedance and the **kinematic model can velocity and/or anisotropy**. [Emphasis Added in Bold]

Though D4 teaches kinematic model and updating kinematic model, but D4 fails to teach generating synthetic trace(s) **from the velocity and density function(s) and randomly updating the initial functions of velocity and density in random start and length time or depth window(s)**, creating **updated synthetic traces**, **using randomly updated velocity and density functions**, wherein for each iteration, **artificial wave(s) traveling from a source point to a reflection point and back to any receiver are simulated as a constraint**. [Emphasis Added in Bold]

According to [0005], D5 teaches a typical model for estimation of an initial property model and generation of simulation data. A joint penalty function is constructed along the lines of equation based on the measured data and simulated data.

According to Claim 2, D5 disclose each iteration cycle of the joint inversion comprises simulating synthetic geophysical data using current models of the physical properties, and the penalty function measures degree of misfit between the synthetic data and corresponding measured data.

Concerning the method according to D5 fails to teach generating synthetic trace(s) **from the velocity and density function(s) and randomly updating the initial functions of velocity and density in random start and length time or depth window(s)**, creating **updated synthetic traces**, **using randomly updated velocity and density functions**, wherein for each iteration, **artificial wave(s) traveling from a source point to a reflection point and back to any receiver are simulated as a constraint**. [Emphasis Added in Bold]

By combining the teaching of D1- D5 one would never be led to the invention as claimed in the present invention and one would never solve the same problem as the present invention nor would a person skilled in the art reach the same solution.

Further the Applicant submits that D1 alone or in combination with D2-D5 fail to teach/disclose **randomly updating the initial functions of velocity and density in random start and length time or depth window(s).** [Emphasis Added in Bold]

Though, D1 in combination with D2-D5 disclose generating synthetic trace (s), but still D1 alone or in combination with D2-D5 fail to teach/disclose creating **updated synthetic traces, using randomly updated velocity and density functions, wherein for each iteration, artificial wave(s) traveling from a source point to a reflection point and back to any receiver are simulated as a constraint**. [Emphasis Added in Bold]

The Applicant respectfully submits that the amended claims are novel and involve inventive step over the cited documents D1 through D5 and hence allowable.

<u>Certain defects and observations:</u>

The applicant has amended the independent claim 1. The support for the amendments can found on Page 7.

The applicant has further amended the claim 5. No new matter has been added.

Dependent claims:

While the dependent claims incorporate the elements of the independent claims, discussed above, and Applicant believes are allowable for the reasons stated, the dependent claims incorporate additional elements which believes are neither taught nor suggested by any cited references.

As the independent submitted claims are inventive over the cited prior art, also the claims dependent thereupon are inventive over the cited prior art.

With the amendments to the claims and the above explanations, is submitted that Applicant has met the requirements as set forth in the communication.

We hope that the examiner can approve the response and grant the application.

Respectfuly yours,

Angelica Castillo

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