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(54) SYSTEM AND METHOD FOR PREVENTING WELLBORE INTERACTIONS

SYSTEM UND VERFAHREN ZUR VERHINDERUNG VON BOHRLOCHINTERAKTIONEN

SYSTÈME ET PROCÉDÉ DE PRÉVENTION D’INTERACTIONS DE PUITS DE FORAGE

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EP 4 121 633 B1

Description

[0001] <DELETED>
[0002] <DELETED>

TECHNICAL FIELD

[0003] The disclosed embodiments relate generally to techniques for preventing wellbore interactions and, in particular, to a method of preventing wellbore interactions by using strain/strain-rate measurements.

BACKGROUND

[0004] Completion of wells in the subsurface may include injection of fluids that may cause fracturing in the rock formations surrounding the injection well. Such fracturing may be beneficial for the purpose of extracting (producing) hydrocarbons from the subsurface since the hydrocarbons can flow through the fractures. However, the situation may not be desirable if the fractures from the injection well extend to another well (commonly known as a fracture driven wellbore interaction or a "frack hit"). Conventional methods for preventing wellbore interactions leverage technology such as distributed acoustic sensing (DAS) for strain/strain-rate measurements for a nearby monitoring well during completions. In the conventional methods, the low frequency band of the strain/strain-rate measurement are used for this detection. However, this detection takes too long for real-time intervention to prevent wellbore interactions.
[0005] There exists a need for methods to predict and prevent wellbore interactions.
Reference may be made to:

US 2019/0120047 A1, which relates to low frequency distributed acoustic sensing hydraulic fracture geometry. Examples are given of using the low-frequency band of Distributed Acoustic Sensing (DAS) signal to constrain hydraulic fracture geometry;

WO 2018/0204920 A1, which relates to stimulated rock volume analysis. A data acquisition program, which includes core, image log, microseismic, DAS, DTS, and pressure data, is described. This program can be used in conjunction with a variety of techniques to monitor and conduct well stimulation;

WO2020040829A1, which relates to hybrid physics-based and machine learning models for reservoir simulations; and

HORNE S. ET AL, "Machine Learning For DAS Microseismic Event Detection", 81st EAGE Conference And Exhibition 2019 Workshop Programme, pages 1-5.

SUMMARY

[0006] The present invention is defined by the independent claims, to which reference should now be made.
[0007] Specific embodiments are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Figure 1 illustrates a subsurface with an injection well, fractures, and fiber optics cables in other wells, along with the data recorded by the fiber optics;

Figure 2 illustrates steps of a method for preventing wellbore interactions, in accordance with some embodiments;

Figure 3 illustrates steps and results of a method for preventing wellbore interactions, in accordance with some embodiments;

Figure 4 illustrates steps and results of a method for preventing wellbore interactions, in accordance with some embodiments; and

Figure 5 is a diagram of a system for preventing wellbore interactions, in accordance with some embodiments.

[0009] Like reference numerals refer to corresponding parts throughout the drawings.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] Described below are methods, systems, and computer readable storage media that provide a manner of wellbore interaction prevention by detection of precursor signals and patterns of strain or strain-rate measurements. These embodiments are designed to be of assistance in avoiding causing induced fracturing that reaches wells that are geographically close to the injection well.
[0011] Reference will now be made in detail to various embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure and the embodiments described herein. However, embodiments described herein may be practiced without these specific details. In other instances, well-known methods, procedures, components, and mechanical apparatus have not been described in detail so as not to unnecessarily obscure aspects of the embodiments.
[0012] The present invention uses the idea that the future stress level in a monitor well (and potential fracture propagation to the monitor well) can be predicted by identifying patterns of stress propagation in time for opera-

tional decisions. The system will include pumps that are used to inject the fluids into an injection well that can be stopped when the predicted future stress level indicates that the monitor well may be impacted by an induced fracture.

[0013] The method detects precursor events in data that is recorded by distributed acoustic sensing (DAS) or distributed strain sensing (DSS) in one or more monitor wells near the injection well. The low-frequency DAS or DSS signal contains information that describes the strain field surrounding hydraulic fractures. As shown in Figure 1, simulations show that the DAS or DSS field recordings during hydraulic fracturing capture the strain field around propagating fractures, highlighting heart-shaped like phenomena as precursor events to fracture tips. The present invention provides a method for detection of such events as an indicator for an imminent fracture hit. Early detection of the precursor event (stress build-up) can provide informed decision to shut pumps in time before fracture arriving to the monitoring well. This object detection may be done by template matching, machine-learning, and/or inversion.

[0014] The top panel of Figure 2 shows an example of the fiber optics data recorded during and after a wellbore interaction. The lower panel shows an example of a template for precursor detection. This template example is not meant to be limiting; any shape template that emulates the wellbore interaction precursor event can be used. Additionally, rather than having a user-defined template, a machine-learning method may be used to identify a characteristic pattern like a template.

[0015] The template matching embodiment uses a cross-correlation between the template and the recorded fiber optics data which is continuously applied as the fiber optics data is acquired. In one embodiment, the method may utilize the fast normalized cross-correlation implementation in Scikit-Image, which is known to those of skill in the art. This embodiment uses a user-specified geometrical template for the cross-correlation process. The method aims to continuously match the proposed template against the low-frequency fiber optics data. Since the tensile stress feature is mainly positive, the highest positive value from the cross-correlation process is selected for the cross-correlation.

[0016] In Figure 3, the different panels act as different time intervals of a field recording in real-time. The star denotes the maximum positive correlation using the proposed template for the precursor event. At earlier times, the star location may appear random as the entire image shares the likelihood of the precursor event. As the precursor event reveals itself, the star slowly and steadily converges towards the fracture tip location. An example of early warning criteria is to observe such convergence behavior. In practice, the detection system would flag a potential wellbore interaction as early as time 20 in Figure 3.

[0017] In another embodiment, the method performs object detection with machine-learning. Since this invention performs real-time detection of the precursor events, the machine-learning algorithm must be able to process a large number of frames quickly. For example, the you-only-look-once (YOLO) architecture, a convolutional neural network (CNN)-based object detection algorithm may be used. The CNN may be trained on synthetic data, such as shown in Figures 1 - 4, or field data.

[0018] Figure 4 shows the validation results on synthetic data hidden from the CNN training process. The bounding box together with the confidence score indicates the likely presence of a precursor event. The example of multiple fracture tips is unlikely in practice as first detection would have triggered the warning system. However, this example includes such scenarios to demonstrate the ability to perform multiple detection. Although not applied in the present example, a method of non-max suppression can overcome multiple overlapping boxes on the same detected event.

[0019] In yet another embodiment, the object detection may be done by inversion of the fiber optics data. The fracture hit identification inversion process minimizes the misfit between recorded and modelled DAS or DSS responses. The modelled response from an inverted fracture hit location best simulates the field recording response. The individual frames in Figure 3 simulate field recordings at different snapshots where we invert for a fracture location that best represents the snapshot of interest. In situations where the precursor event is slowly unveiling, the inversion results are given as position along and distance away from the observation well. Once the fracture hit pattern establishes, the inverted spatial distance converges to a static position.

[0020] Figure 5 is a diagram illustrating a hydraulic fracturing system, in accordance with some embodiments. While certain specific features are illustrated, those skilled in the art will appreciate from the present disclosure that various other features have not been illustrated for the sake of brevity and so as not to obscure more pertinent aspects of the embodiments disclosed herein.

[0021] The hydraulic fracturing system includes an injection well 20 with one or more injection pumps 26, at least one monitoring well 21 with seismic sensors deployed in it, and a computer system 23 that receives data from the monitoring well 21 through input line 25 and sends signals to the injection pumps 26 through output line 24. Although injection well 20 and monitoring well(s) 21 appear as vertical wellbores, this is not meant to be limiting. As is know to those of skill in the art, the wellbores may be vertical, deviated, and/or horizontal.

[0022] The computer system 23 includes one or more processing units (CPUs), one or more network interfaces and/or other communications interfaces, memory, and one or more communication buses for interconnecting these and various other components. The computer system 23 also includes a user interface (e.g., a display and an input device). The communication buses may include circuitry (sometimes called a chipset) that interconnects and controls communications between system components. Memory includes high-speed random access memory, such as DRAM, SRAM, DDR RAM or other random access solid state memory devices; and may include non-volatile memory, such as one or more magnetic disk storage devices, optical disk storage devices, flash memory devices, or other non-volatile solid state storage devices. Memory may optionally include one or more storage devices remotely located from the CPUs. Memory, including the non-volatile and volatile memory devices within memory, comprises a non-transitory computer readable storage medium and may store data or data products.

Claims

1. A computer-implemented method for preventing wellbore interactions between wells (20, 21) in the earth's subsurface, comprising:

a. receiving (25), at one or more computer processors (23), fiber optics data from a monitoring well (21) during hydraulic fracturing using a hydraulic fracturing system (26), the fiber optics data comprising distributed acoustic sensing, DAS, data or distributed strain sensing, DSS, data containing information that describes the strain field surrounding hydraulic fractures, the hydraulic fracturing system (26) comprising pumps for injecting fluids into an injection well that can be stopped when a predicted future stress level indicates impaction of the monitor well by an induced fracture;
b. during the hydraulic fracturing, predicting a potential fracture propagation to the monitor well (21) by detecting, via the one or more computer processors (23), heart-shaped like phenomena as precursor events to fracture tips in the DAS or DSS data as indicators for an imminent fracture hit; and
c. on early detection of a precursor event, sending (24) instructions to the hydraulic fracturing system (26) to reduce at least one of injection volume or injection rate or to stop injection before a fracture arrives at the monitoring well (21).

2. The method of claim 1 wherein the detection is performed by template matching.

3. The method of claim 1 wherein the detection is performed by a machine-learning method.

4. The method of claim 3 wherein the machine-learning method uses a convolutional neural network, CNN.

5. The method of claim 4 wherein the CNN is a you-only-look-once CNN.

6. The method of claim 1 wherein the detection is performed by inversion of the fiber optics data.

7. A computer system (23) for preventing wellbore interactions between wells (20, 21) in the earth's subsurface, comprising:

one or more processors (23); and
memory (23),
wherein one or more programs are stored in the memory and configured to be executed by the one or more processors, the one or more programs including instructions that when executed by the one or more processors cause the system to carry out the method of any of the preceding claims.

8. One or more programs which, when executed by one or more processors (23), cause a computer system (23) to carry out the method of any of claims 1 to 6.

9. A non-transitory computer readable medium having the one or more programs of claim 8 stored thereon.

Patentansprüche

1. Computerimplementiertes Verfahren zur Verhinderung von Bohrlochwechselwirkungen zwischen Bohrungen (20, 21) im Erduntergrund, umfassend:

a. Empfangen (25) von Glasfaserdaten aus einer Überwachungsbohrung (21) während einer hydraulischen Frakturierung unter Verwendung eines hydraulischen Frakturierungssystems (26) an einem oder mehreren Computerprozessoren (23), wobei die Glasfaserdaten Distributed Acoustic Sensing-Daten, DAS-Daten, oder Distributed Strain Sensing-Daten, DSS-Daten, umfassen, die Informationen enthalten, die das Dehnungsfeld beschreiben, das hydraulische Frakturen umgibt, und wobei das hydraulische Frakturierungssystem (26) Pumpen zum Injizieren von Flüssigkeiten in eine Injektionsbohrung umfasst, die gestoppt werden können, wenn ein vorhergesagtes zukünftiges Spannungsniveau eine Impaktierung der Überwachungsbohrung durch eine induzierte Fraktur anzeigt;
b. während der hydraulischen Frakturierung Vorhersagen einer möglichen Frakturausbreitung zur Überwachungsbohrung (21), indem über den einen oder die mehreren Computerprozessoren (23) herzförmige Phänomene als Vorläuferereignisse von Frakturspitzen in den DAS-oder DSS-Daten als Indikatoren für einen bevorstehenden Frakturstoß erkannt werden; und
c. bei frühzeitiger Erkennung eines Vorläuferer-

eignisses Senden (24) von Anweisungen an das hydraulische Frakturierungssystem (26), um zumindest eines von einem Injektionsvolumen oder einer Injektionsrate zu verringern oder die Injektion zu stoppen, bevor eine Fraktur die Überwachungsbohrung (21) erreicht.

2. Verfahren nach Anspruch 1, wobei die Erkennung durch Template-Matching erfolgt.

3. Verfahren nach Anspruch 1, wobei die Erkennung durch ein Verfahren maschinellen Lernens erfolgt.

4. Verfahren nach Anspruch 3, wobei das Verfahren maschinellen Lernens ein neuronales Faltungsnetzwerk, CNN, verwendet.

5. Verfahren nach Anspruch 4, wobei das CNN ein You-Only-Look-Once-CNN ist.

6. Verfahren nach Anspruch 1, wobei die Erkennung durch Umkehrung der Glasfaserdaten erfolgt.

7. Computersystem (23) zum Verhindern von Bohrlochwechselwirkungen zwischen Bohrungen (20, 21) im Erduntergrund, umfassend:

einen oder mehrere Prozessoren (23); und
einen Speicher (23),
wobei ein oder mehrere Programme in dem Speicher gespeichert und dazu ausgelegt sind, durch den einen oder die mehreren Prozessoren ausgeführt zu werden, wobei das eine oder die mehreren Programme Anweisungen beinhalten, die bei Ausführung durch den einen oder die mehreren Prozessoren das System zum Durchführen des Verfahrens nach einem der vorhergehenden Ansprüche veranlassen.

8. Ein oder mehrere Programme, die bei Ausführung durch einen oder mehrere Prozessoren (23) ein Computersystem (23) zum Durchführen des Verfahrens nach einem der Ansprüche 1 bis 6 veranlassen.

9. Nichtflüchtiges computerlesbares Medium, das das eine oder die mehreren Programme nach Anspruch 8 darauf gespeichert aufweist.

Revendications

1. Procédé mis en œuvre par ordinateur pour prévenir les interactions de puits de forage entre des puits (20, 21) dans le sous-sol terrestre, comprenant :

a. la réception (25), par un ou plusieurs processeurs informatiques (23), de données de fibres optiques provenant d'un puits de surveillance (21) pendant la fracturation hydraulique à l'aide d'un système de fracturation hydraulique (26), les données de fibres optiques comprenant des données de détection acoustique distribuée, DAS, ou des données de détection de déformation distribuée, DSS, contenant des informations qui décrivent le champ de déformation entourant les fractures hydrauliques, le système de fracturation hydraulique (26) comprenant des pompes pour injecter des fluides dans un puits d'injection qui peuvent être arrêtées lorsqu'un niveau de contrainte futur prédit indique l'impaction du puits de surveillance par une fracture induite ;
b. pendant la fracturation hydraulique, la prédiction d'une propagation potentielle de la fracture vers le puits de surveillance (21) en détectant, par l'intermédiaire du ou des processeurs informatiques (23), des phénomènes en forme de coeur comme événements précurseurs de pointes de fracture dans les données DAS ou DSS comme indicateurs d'un impact imminent de la fracture ; et
c. en cas de détection précoce d'un événement précurseur, l'envoi (24) d'instructions au système de fracturation hydraulique (26) pour réduire au moins l'un du volume d'injection ou du débit d'injection ou pour arrêter l'injection avant qu'une fracture n'atteigne le puits de surveillance (21).

2. Procédé selon la revendication 1 la détection étant réalisée par correspondance de gabarit.

3. Procédé selon la revendication 1 la détection étant réalisée par un procédé d'apprentissage automatique.

4. Procédé selon la revendication 3 le procédé d'apprentissage automatique utilisant un réseau neuronal convolutif, CNN.

5. Procédé selon la revendication 4, le CNN étant un CNN de type « on ne voit qu'une fois ».

6. Procédé selon la revendication 1, la détection étant effectuée par inversion des données de fibres optiques.

7. Système informatique (23) pour prévenir les interactions de puits de forage entre des puits (20, 21) dans le sous-sol terrestre, comprenant :

un ou plusieurs processeurs (23) ; et
une mémoire (23),
un ou plusieurs programmes étant stockés dans la mémoire et configurés pour être exécutés par le ou les processeurs, le ou les programmes

comprenant des instructions qui, lorsqu'elles sont exécutées par le ou les processeurs, amènent le système à mettre en œuvre le procédé selon l'une quelconque des revendications précédentes.

8. Un ou plusieurs programmes qui, lorsqu'ils sont exécutés par un ou plusieurs processeurs (23), amènent un système informatique (23) à mettre en œuvre le procédé selon l'une quelconque des revendications 1 à 6.

9. Support non transitoire lisible par ordinateur sur lequel sont stockés le ou les programmes selon la revendication 8.

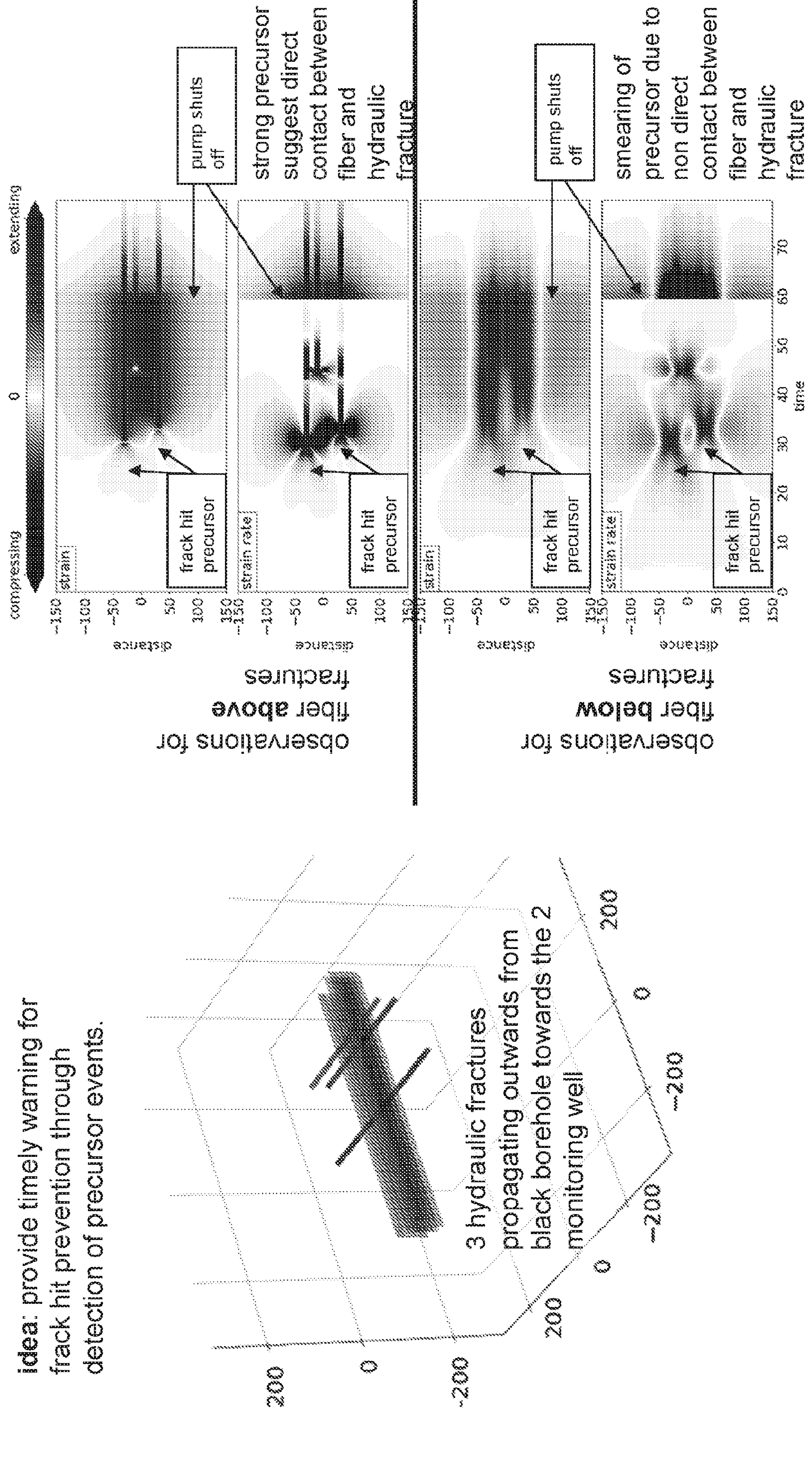
idea: provide timely warning for frack hit prevention through detection of precursor events.
3 hydraulic fractures propagating outwards from black borehole towards the 2 monitoring well
observations for fiber above fractures
observations for fiber below fractures
compressing
0
extending
strain
strain rate
distance
time
frack hit precursor
pump shuts off
strong precursor suggest direct contact between fiber and hydraulic fracture
smearing of precursor due to non direct contact between fiber and hydraulic fracture

FIG. 1

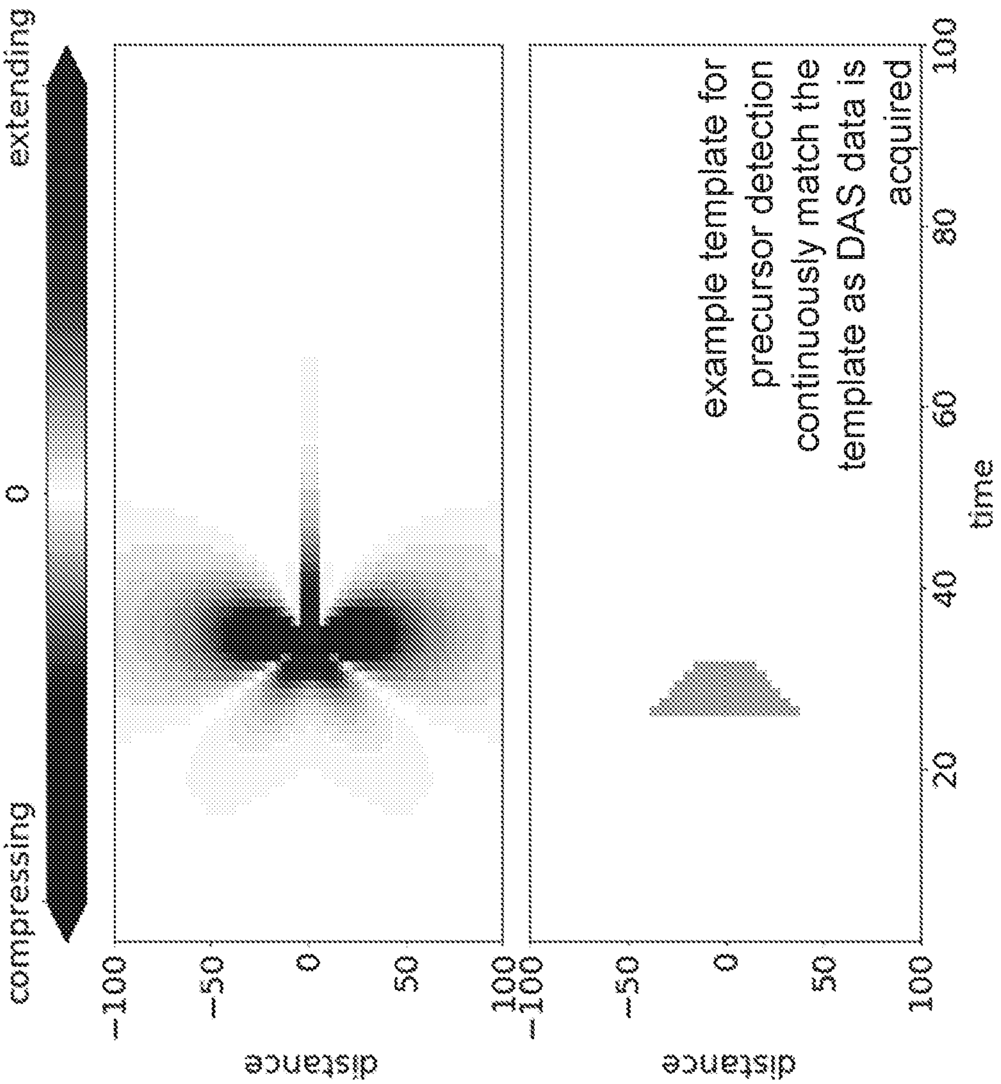
compressing
0
extending
distance
−100
−50
0
50
100
time
20
40
60
80
100
example template for
precursor detection
continuously match the
template as DAS data is
acquired

FIG. 2

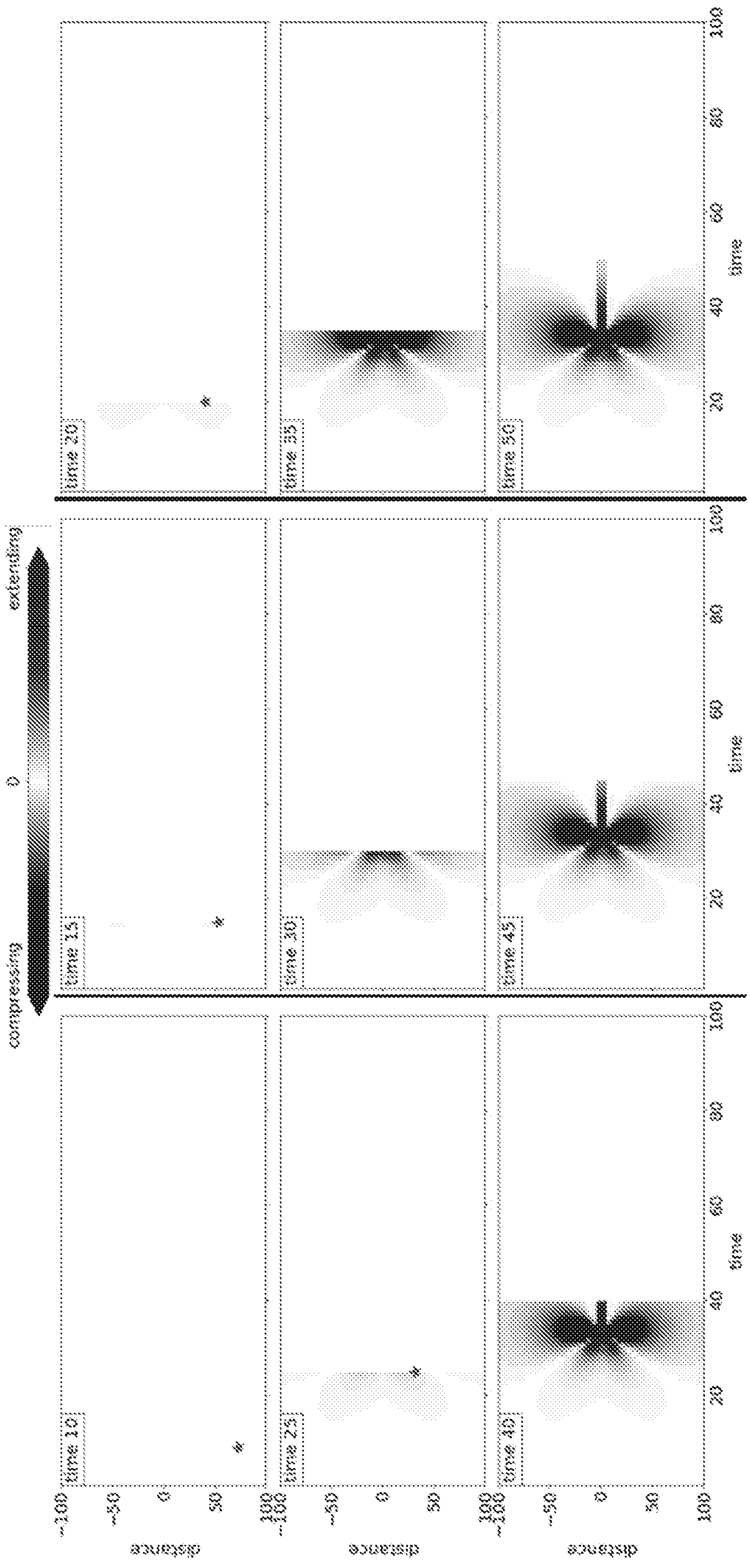
compressing
0
extending
time 10
time 15
time 20
time 25
time 30
time 35
time 40
time 45
time 50
distance
time
−100
−50
0
50
100
20
40
60
80
100

FIG. 3

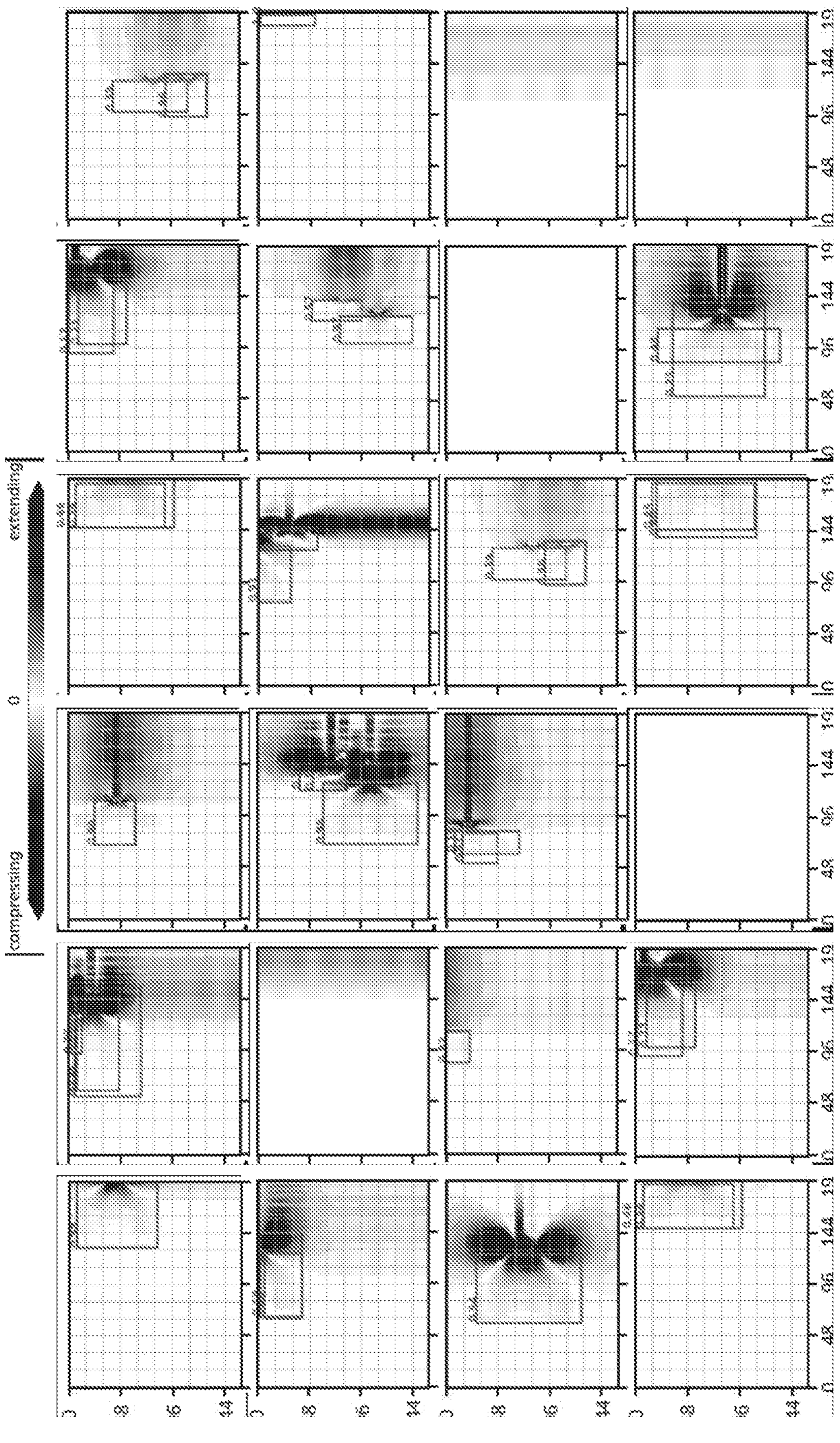

FIG. 4

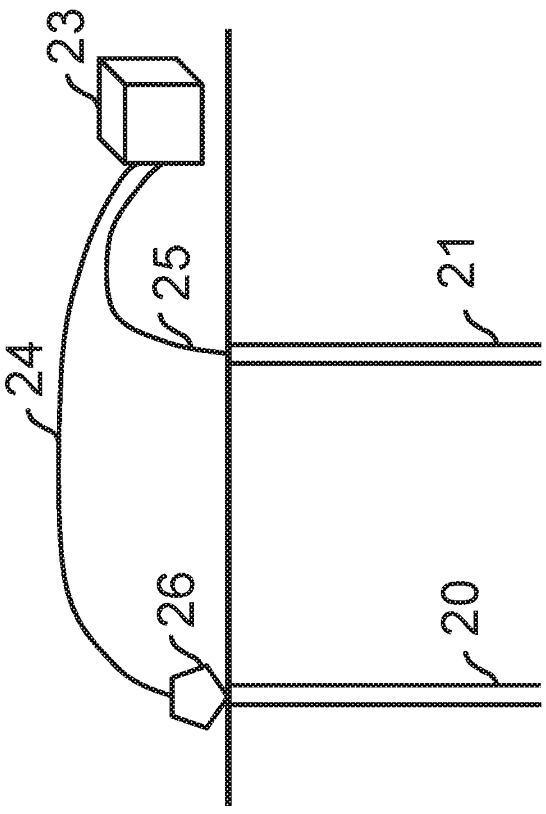

FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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