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GEOPHYSICAL SOCIETY OF HOUSTON
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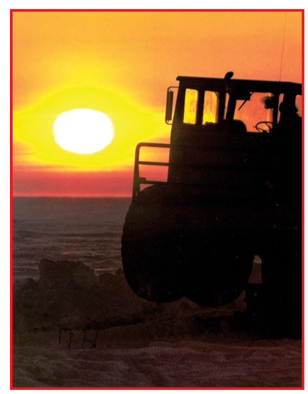
The Epicenter of Geophysical Excellence

TABLE of CONTENTS

On The Cover.

Seismic surveying using vibrators in Alaska.

Photo courtesy of WesternGeco.



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To ensure your information reaches the GSH members in a timely manner, please note the following deadlines and plan accordingly. Please submit your articles and any questions to Alvaro Chaveste, editor, at AlvaroChaveste@hotmail.com

GSH JOURNAL DEADLINES

Apr 2021	**Feb 8**
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A Word from the Board

Your Presence is a Present

By Laurie Geiger, Secretary

Well, here I am, another day of sitting in my small condo with my trusty assistant, Star, lying on my laptop as she does every day all day. She's my four-legged, fluffy, underpaid co-worker. I never thought my cat could be a role model for me. As I lament the loss of the things I once took for granted or even complained about, she seems to think this stay-at-home deal is the best thing since catnip. Every morning, when she realizes it's time to get to work, she runs over to my desk and bolts up onto it, sliding across the papers, to perch herself on my warm laptop. She sets up for the day and stays there until late into the night, just in case she's needed.

Her enthusiasm helps me see that there is good in everything, even great change. Sometimes I must work at seeing the bright side of all that this crazy year has brought us, while Star shows me that it is easy. Just take it as it comes, find your new place and perch there for a while, making yourself useful. Your presence is a present to others, even if you're just keeping them company and putting smiles on their faces.

In this strange time, being present for others might mean showing up in-person, but more likely it means attending online, at least for now. A couple months ago, I was attending an online society workshop, and during the Ice Breaker event, where a couple were playing musical instruments from their home, I realized something. Sure, I was there to enjoy the music, but suddenly I was aware of the symbiotic nature of what was going on.

Online events are a strange thing. It really does matter whether or not other people are there on the other end of the line. We are mirrors and canvases for others, and the contribution of our time, attention, feedback, ideas, opinions, talents and more are some of what our personal and professional lives are about. In 2021, I commit to connecting and participating more, for myself and others.

At times you probably feel the same as I do when I cannot even think about attending one more online event or presentation, after sitting at my desk all day. I'm sure you have come up with ways of keeping up your motivation. I have discovered a few remedies for this myself. During an online event, simply unplugging my laptop from its docking station and moving to another room for a few presentations recharges me. Several years ago I received as a gift a little, easy-to-use device called Chromecast which plugs into my TV and allows me to wirelessly show videos from my phone or laptop. Technical presentations such as those given at GSH lunch meetings show very well on a large TV screen, as the images, such as seismic and velocity models, are beautiful! Also, I get to sit on the couch instead of just staying at my desk. Shaking things up a bit works wonders!

Years ago, my mother and I were riding in the car together, and we saw a fit woman jogging next to the road. My mystified mother said, "Why is she running; she's already fit?" I just laughed. As with our bodies, our minds need regular maintenance to stay fit. Keeping up with our mental maintenance can be especially challenging when most events are online. It's tempting to put off our attendance until in-person events come back.

Yes, regarding the current state of affairs due to the villainous virus, this too shall pass, but we need to stay professionally fit for now and for when things open up. Being present and participating is a way all of us can stay fit and give back to each other at the same time. We'll be ready when the old normal returns. See you there! ▫

From the Other Side

By Lee Lawyer

I have recently received a series of geology textbooks. It is amazing how much earth science has changed since the early years. The "Applied (gag)" geophysics world limits geology to sedimentary rocks. I like the expanded version of geology, i.e., the "Study of the Earth". Maybe that is a little too broad. I recall the first thing I learned about rocks was the definition. A rock is "An aggregate of minerals". I never heard the definition of a mineral. Clearly it is "An aggregate of elements". We learn the names of each mineral and its physical attributes. The same rock (name) can have different colors, different crystal structure and occurrence, i.e., quartz. Let us start with the History of Geology.

From, *Geology, by Emmons, Thiel, Stuffer and Allison.* Copyright, 1932, I learned the following which seems to be a good definition of geology.

> *Geology is the interpretation of the sequence of events from the beginning of the earth as a definite planet in the solar system, through its many changes during the long geologic ages to the present time.*

From, "Geophysics in the Affairs of Mankind", Lawyer, Bates and Rice,

> *Geophysics is that part of observational and experimental physics, which pertains to the planet's atmosphere, hydrosphere, crust, mantle, and core. As a consequence, geophysics is an intriguing scientific and technical field of endeavor.*

I will bet you did not know either definition. Let us be clear. There is a difference between the "History of Geology" and "Historical Geology". Historical Geology is the study of the rocks and how and when they were deposited. The History of Geology is the history of our understanding of geological principals. The history of the "science" of geology does not start until the end of the eighteenth century (much of what I quote is from "A History of Geology", by Gabriel Gohau). Incorrectly, we often use the word geology as the rocks themselves. "Just look at that complex geology!" We do not mean the study of that complex geology. That should clear things up.

Some time ago, we thought the earth was flat. We were confused when we found seashells far from the shore or on top of a mountain. We believed Aristotle who used Earth, Fire, Water to describe everything. I can find amusement in the early efforts of mankind, but they tried to fit their observations into some kind of model. We us the term, flat earth as a derogatory term today. Back then most people believed that the earth was flat. How they explained the fact that could only see to the horizon. If they climbed higher to see farther, they had the data that the earth was a sphere. All they needed was a little geometry.

Coming forward a few thousand years, today we have a geological time scale that spans life as we know it. The construction of that time scale is very interesting. Stratigraphy played a major role, i.e., the study of layered rocks (my definition). We start the time scale for geophysics with our measurements of gravity, magnetics, and seismology as they relate to petroleum geology. That is not fair (and not true). There is more to this life than oil and gas. Really! □

A Live Webinar

Sponsored Jointly by the SEG and GSH

SOCIETY OF EXPLORATION GEOPHYSICISTS

PRACTICAL SEISMIC PETROPHYSICS: THE EFFECTIVE USE OF LOG DATA FOR SEISMIC ANALYSIS

Four Half-days (9 AM - 1 PM Houston Time) March 23-26, 2021

Presented by

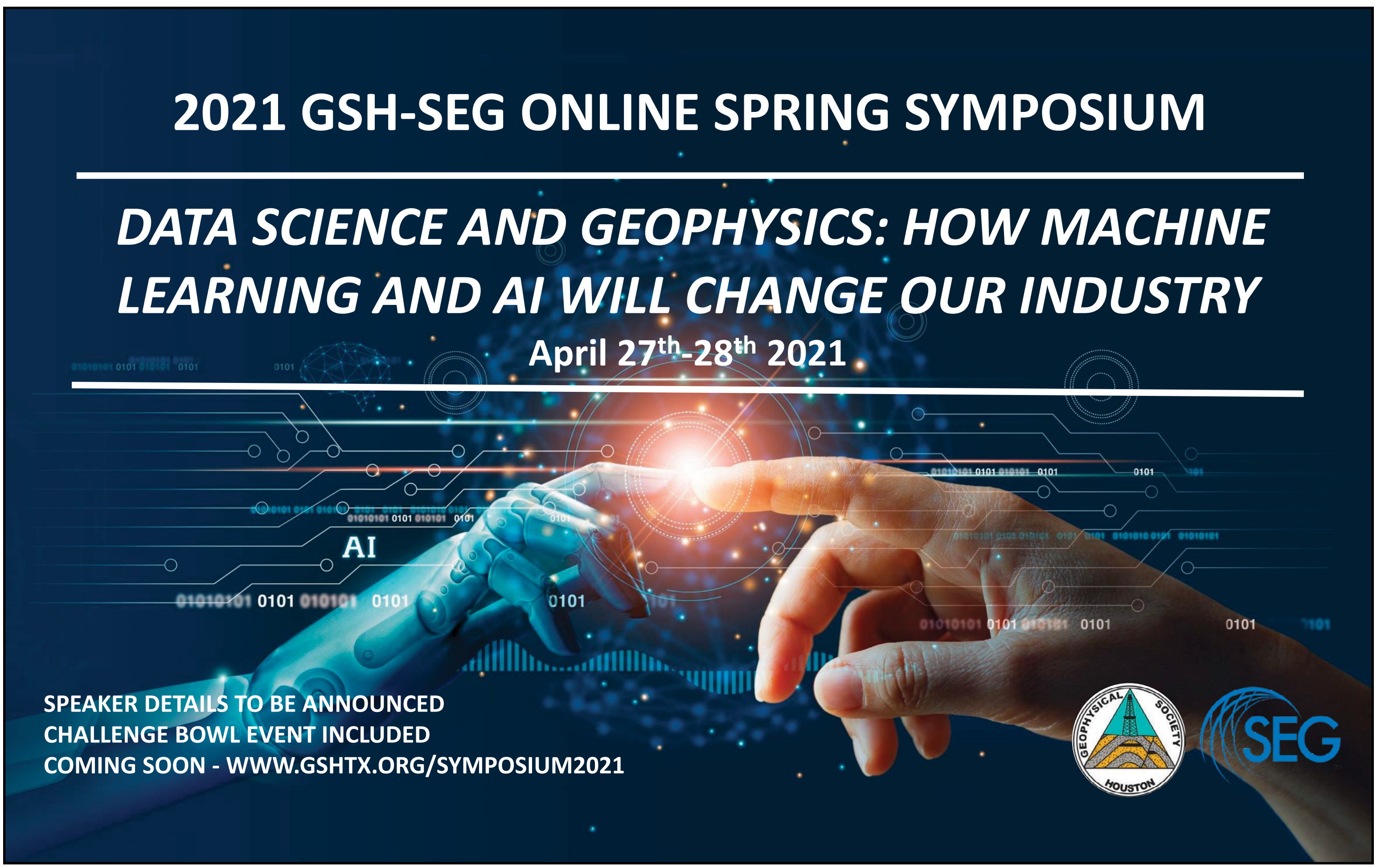
Tad Smith, PhD, Geology

This class will focus on the important role of "seismic petrophysics" in the quest to extract additional information from subtle seismic responses. Some of the topics covered will include important background information, relevant aspects of petrophysical interpretation, various aspects of log editing, and the basics of elasticity and rock physics. We will spend considerable time discussing some common pitfalls associated with the "workhorses" of rock physics, including invasion corrections, problems associated with shear velocity estimation, and some of the challenges and pitfalls associated with Gassmann fluid substitution. It is important to recognize that log data should not simply be recomputed to fit prior expectations as defined by a rock physics model. Instead, rock physics models should be used as templates, which allow the interpreter to better understand the underlying physics of observed log responses and how they are governed by local petrophysical properties. Case studies and hands-on exercises will be used to reinforce critical concepts.

This **16 hour course** can be taken in the comfort of **your office** or even **your own home**. It works on **PC's, iPads, iPhones**, or even two tin cans with a taut string (not recommended). **No travel costs**.
The Course Fee: $390! With major discounts for Groups and Students. 1.6 CEU's are awarded.

All Sessions are recorded for future viewing if you miss a session

Visit gshtx.org, Events Tab to register and see expanded Course and Presenter Information



GSH Technical Events

GSH Gets Down to Business
High Resolution Beam Tomography for Velocity Model Building
Alexander Mihai Popovici, CEO, Z-Terra
Abstract and Bio
Online presentation
February 2, 2021 - 12:00pm-1:00pm CST

Register

Unconventionals SIG
Technology Overview and Future Role of CCUS with Decarbonization in the Electrical Utility Sector
Richard Esposito, Southern Company
Abstract and Bio
Online presentation
February 4, 2021 - 12:00pm-1:00pm CST

Register

Data Processing and Acquisition SIG
Low-frequency Extrapolation using Higher-frequency Multi-channel Prediction Filters
Stephen Chiu, In-Depth Geophysical
Abstract and Bio
Online presentation
February 9, 2021 - 5:00pm-6:00pm CST

Register

Technical Breakfast
DAS VSP Applications to Reservoir Surveillance - Overview of Status
Albena Mateeva, Shell International Exploration & Production
Abstract and Bio
Online presentation
February 10, 2021 - 7:00am-8:00am CST

Register

Data Science and Machine Learning SIG
Machine Learning and Geophysical Inversion-A Numerical Study
Brian Russell, CGG GeoSoftware
Abstract and Bio
Online presentation
February 10, 2021 - 11:00am-12:00pm CST

Register

Technical Lunch
Full Bandwidth FWI
Tatiana Kalinicheva, Fullwave at Imperial College London
Abstract and Bio
Online presentation
February 17, 2021 - 11:00am-12:00pm CST

Register

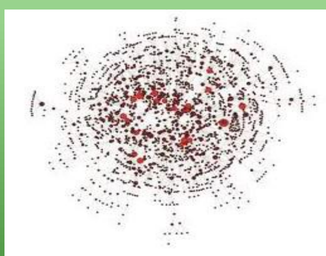
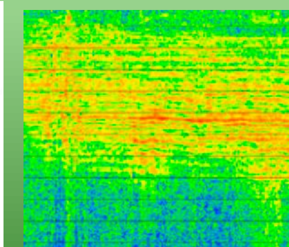
NextGen: Under a Different Rock
Applications of Ground-Penetrating Radar (GPR)
Dr. Daniel Bigman, Bigman Geophysical
Abstract and Bio
Online presentation
February 19, 2021 - 6:00pm-7:00pm CST

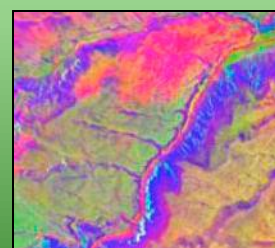
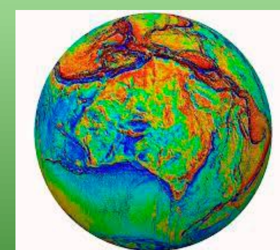
Register

GSH Gets Down to Business: a new business-oriented online series

The traditional technical marketing meeting, whether it is a proprietary client in-house event or a booth presentation at a convention, is another casualty of Covid-19. The GSH has now started a new online presentation series, where geophysical companies are able to deliver information on their latest products and services to GSH members and friends! Key features are:

* A vendor offers their commercial presentation as an online event through GSH.
* The event is announced, promoted and managed by GSH; attendance is free.
* As in a booth presentation, both potential customers and competitors may be attending.
* After the presentation, there will be an interactive Q&A session.
* Attendees contact information will not be shared by GSH, however, vendor contact is available and attendees are free to share their contact information.

Interested vendors please contact the GSH at 281.741.1624 or office@gshtx.org

Automated Well-to-seismic Tie Using Deep Neural Networks

Philippe Nivlet, Robert Smith, Nasher AlBinHassan, Geophysics Technology, EXPEC Advanced Research Center, Saudi Aramco

Summary

One of the first steps toward integration of seismic with the reservoir model is the well-to-seismic tie. This operation can be subdivided into two parts: depth-to-time conversion and wavelet extraction. Here we focus on the former, which is by far the most time-consuming operation using current industry workflows. In this paper, we present a methodology using deep neural networks that can learn the depth-to-time function derived from Vertical Seismic Profiling (VSP) data. Using both synthetic and field data, we demonstrate how a tuned recurrent neural network (RNN) can predict traces in the two-way-time (TWT) domain with acceptable accuracy. Finally, we present an alternative approach using a temporal convolutional network (TCN), which can help overcome some of the limitations of RNNs while producing similar prediction accuracy. Both methods are proven to automate well tie, reducing the needed time to a fraction.

Introduction

Time-depth conversion is one of the first processes performed in the integration of well and seismic data for reservoir characterization. The most direct approach is to use Vertical Seismic Profiling (VSP) or check-shot data, which provide a direct measure of the time-depth function. For most wells, however, this data is missing. Sonic logs, which measure acoustic travel times through formations is also a valuable source of information, but the conversion law resulting from sonic integration typically requires a time drift correction known as sonic log environmental dispersion (SLED) correction. The main reasons for this sonic drift (apart from possible data issues) are (1) dispersion effects caused by seismic and sonic velocities measured at different frequencies, (2) borehole conditions and (3) potentially other field effects (Box and Lowrey, 2003). To correct for the drift, the current industry practice still largely relies on manual time adjustment from wells tops and interpreted horizons, which is a long and tedious process. Alternatively, the drift may be computed either by inverting an attenuation model of the subsurface, or by using dynamic time-warping to match stationary and non-stationary seismograms, the latter integrating the Q effect (Cui and Margrave, 2015). This supposes the prior knowledge of a Q model, which is not necessarily available. Finally, Box and Lowrey (2003) suggested a linear statistical model between sonic drift and depth, after computing the drift from wells with VSP data. They suggest that for larger fields the transformation may be more complex and nonlinear.

In this paper, we use deep neural networks to predict sonic well logs in the TWT domain from the measured well logs in depth, rather than predicting the drift function. We first use a geologically realistic synthetic dataset to demonstrate how a recurrent neural network (RNN), which has achieved widespread success for complex tasks, such as time series prediction (Wiestra et al., 2005), natural language processing (Schmidhuber et al., 2002), or human action recognition (Baccouche et al., 2011), can be used to learn the time-depth conversion based on the integrated sonic. This network architecture is then successfully applied to a real dataset. We end by discussing an alternative network for the seq2seq (sequence-to-sequence) task using a temporal convolutional network (TCN), which overcomes some of the challenges posed by RNNs.

Feasibility study: synthetic example

A realistic 3D synthetic model of a fluvial reservoir (Figure 1a) was used to generate the data for this part of the study. Three stratigraphic units were considered. In the upper and lower units, three facies were simulated using Sequential Gaussian Simulations (Deutsch and Journel, 1998), while in the middle unit, object-based simulations (Haldorsen and Damleth, 1990) were used to distribute channels with random geometric characteristics. Sequential Gaussian Simulations per facies were then used

Technical Article continued on page 10.

Technical Article continued from page 9.

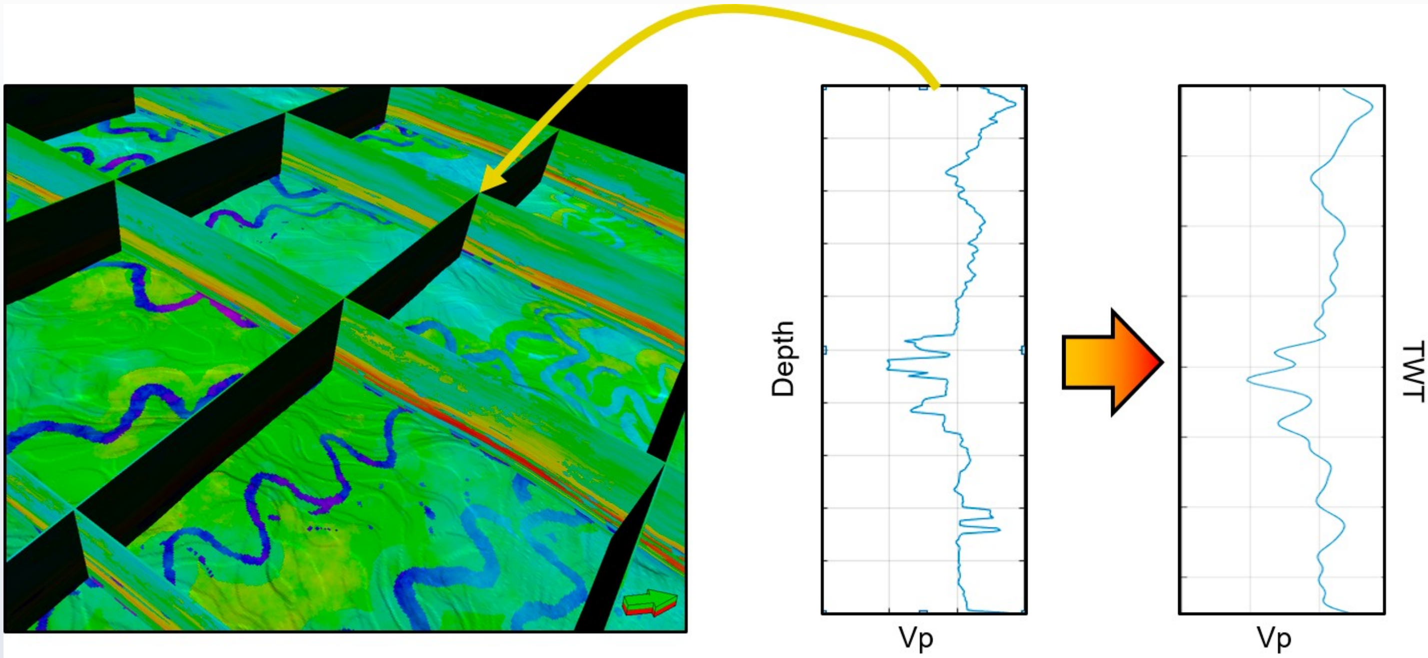


Figure 1: (a) 3D Synthetic Vp model used for calibration/test of the well tie methodology; (b) one trace in its original depth domain; and (c) the same trace in TWT domain

to populate each facies with compressional velocity. Finally, this model was converted to TWT using the simulated 3D velocity field, as illustrated in *Figures 1b and 1c*.

Time-to-depth conversion can be seen as a 1D warping process where the trace is locally stretched or squeezed from one domain to the other. To learn this operation, the network must have access to local and surrounding velocity values. As shown in Tallec and Ollivier (2018), RNNs are a particular type of neural network capable of learning this type of transformation. Basic RNN networks are difficult to train in practice due to the exploding/vanishing gradient problem. To overcome this issue, Hochreiter and Schmidhuber (1997) proposed to use a gated information cell, named the Long-Short Term Memory (LSTM) cell.

Figure 2 shows the complete architecture of our LSTM based network for converting the sonic logs from depth to TWT. While

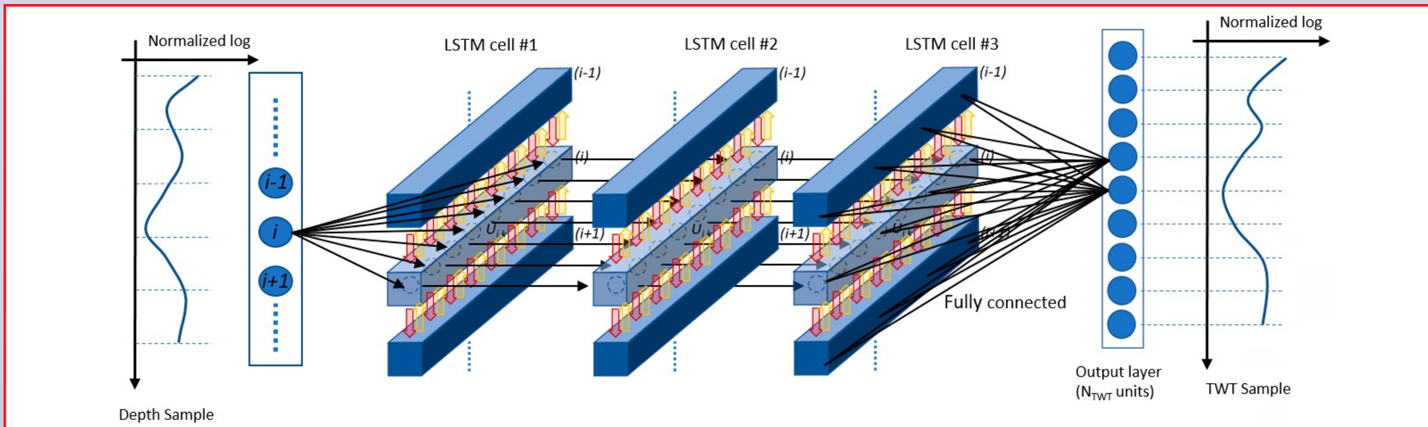


Figure 2: Stacked LSTM cells for converting depth to time

Technical Article continued on page 11.

Technical Article continued from page 10.

more sophisticated encoder-decoder type networks have been widely used for other seq2seq problems (e.g., natural language translation, Cai et al., 2018), we have so far achieved satisfactory performance with the stacked LSTM network in *Figure 2*. The input depth traces are fed into the first hidden layer of the first LSTM cell one depth sample at a time. Each neuron from this layer also receives a signal from the neuron above, corresponding to the memory context of the cell (red arrows). The output of this first hidden layer is then used as input to the second hidden layer, and the process repeats itself until the last hidden layer. Then, the output generated by all the neurons in this first cell are concatenated and fed into the next LSTM cell. Finally, a dense layer connects the output of the last LSTM cell to a constant length output layer representing the output trace in the TWT domain. This type of network can work in both directions (known as a bidirectional LSTM, shown with yellow arrows), which can improve the accuracy of the predictions (Schuster and Paliwal, 1997). Note that since not all time-converted traces have the same length, the network also has to learn the zero-padded values of this output layer, which it effectively does. A mean square error loss function was then minimized during the training process using the Adam optimization algorithm (Kingma and Ba, 2015).

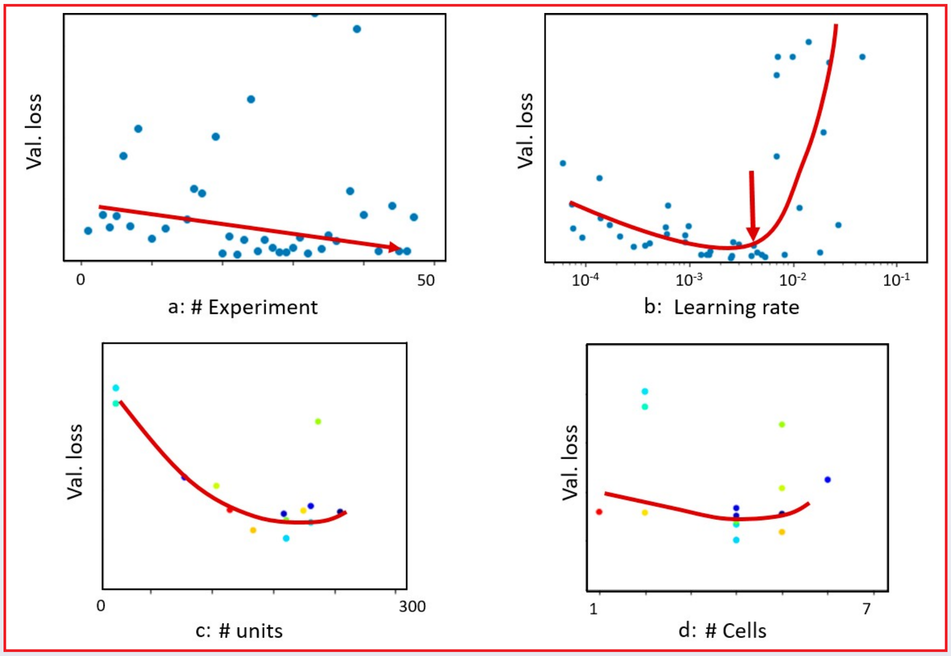


Figure 3: (a) Validation loss vs. trial number (a), learning rate (b), Number of hidden layer per cell (c) and number of cells (d)

To speed up the training phase, the network was trained on limited-size traces of 150 samples in depth (instead of the full 500 sample-long traces available). The network was trained using 60% of the traces, the remaining 40% being divided evenly between validation and test sets. The validation set was used to optimize the network hyper-parameters such as the learning rate, the number of cells and hidden layers per cell, the batch size and also additional regularization parameters to limit data over-fitting (e.g., drop-out proportion, recurrent weight drop-out proportion, weight regularization). Searching such a large hyper-parameter space manually would be very difficult. For this reason, a Bayesian hyper-parameter optimization was performed. Here, 50 training experiments were conducted using a Tree-Structured Parzen Estimator approach (Bardenet et al., 2011). This Bayesian approach modifies the sampling distribution as it gains more knowledge from the loss function behavior by favoring hyper-parameters which have potentially a lower loss. As a result, the validation loss function tends to decrease as shown in *Figure 3a*.

Regularization weights play a dominant role, and were kept to a very small value throughout the experiments. The second most important hyper-parameter is the learning rate: *Figure 3b* suggests the optimal value lies between 10^{-3} and 10^{-2}. *Figures 3c and 3d* show that increasing the complexity of the network globally improves the validation loss until a certain point where the network starts overfitting the data and loses its ability to generalize. We also observed that the network behaves better when bi-directional LSTMs are used. Other parameters like the type of weight initializer or the

Technical Article continued on page 12.

Technical Article continued from page 11.

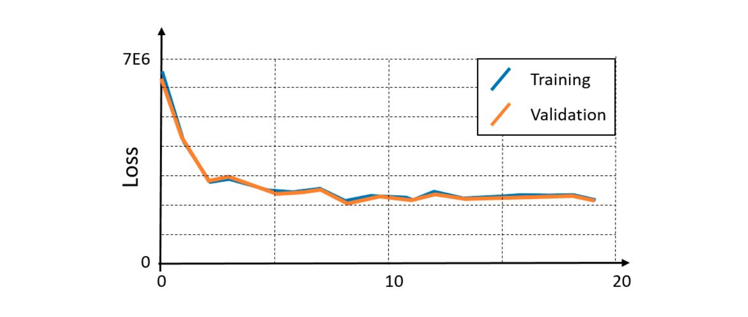


Figure 4: Training and validation loss functions for optimal LSTM]

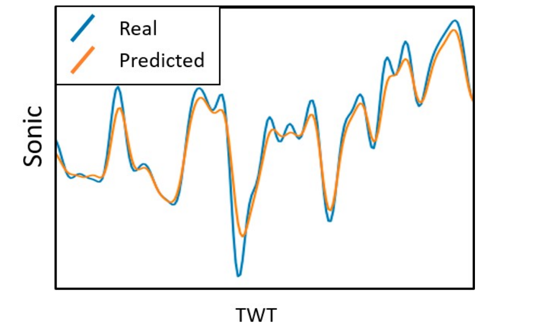


Figure 5: Result of the optimal network on a test trace

dropout rate had a secondary impact on the validation loss.

The network was then retrained from scratch using the optimal set of hyper-parameters. The optimal network converges after 8 epochs *(Figure 4)* and performs equally well on the training and validation set, which shows that the network has not overfit to the training data. Since the complete log for each well has more than 150 depth samples, we convert the trace from each pseudo-well into a list of 150-long sample traces with a stride of 1. Prediction is made independently on each element of the list, keeping only the non-padded values. The predicted TWT trace is reconstructed by estimating the TWT necessary from one element to the next by cross-correlation. *Figure 5* shows an example of the average predicted trace from the test set (orange) compared to the expected one (blue). Globally the prediction is accurate, even though the network does not succeed in predicting accurately the highest frequencies. The trace could be used for building a depth conversion model. Does this approach work when the time-

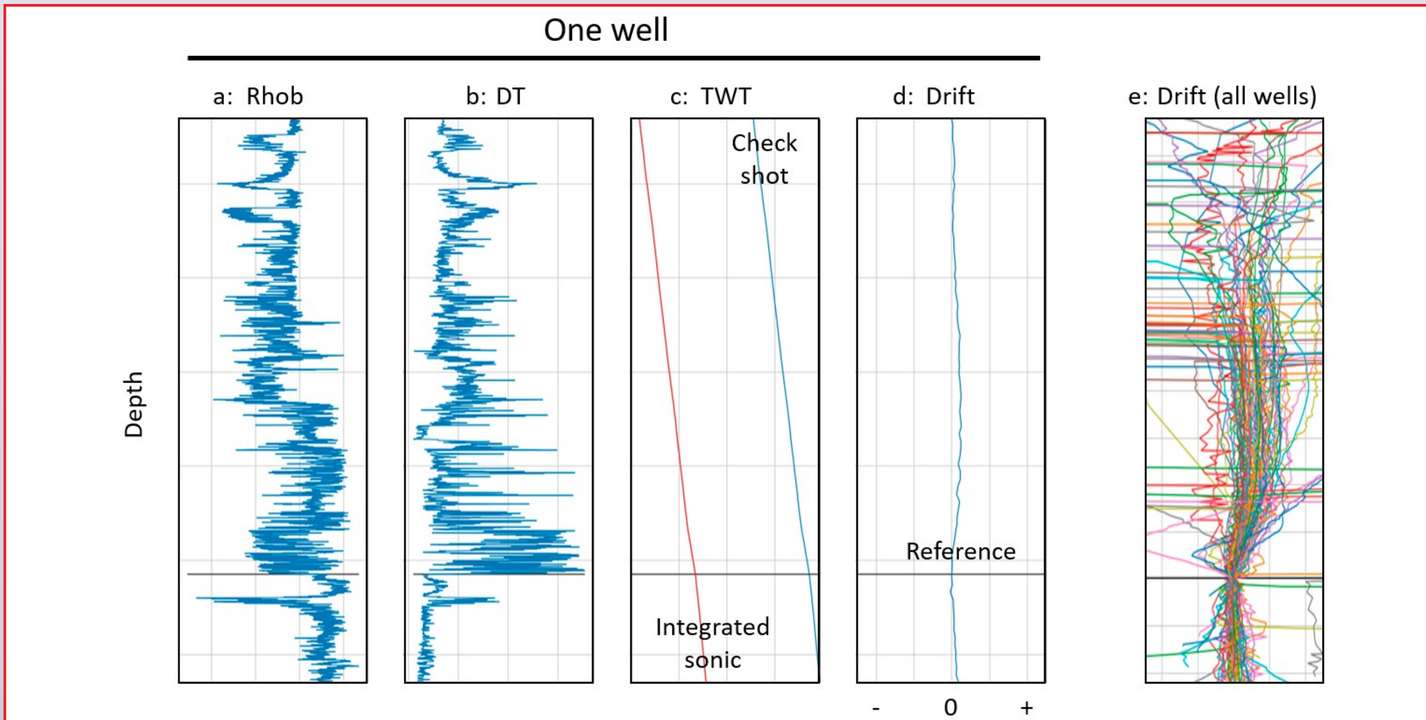


Figure 6: One well with density (a), sonic (b), time-depth curve (c), sonic drift (d); and sonic drift curves for all wells in the field (e)

Technical Article continued on page 13.

Technical Article continued from page 12.

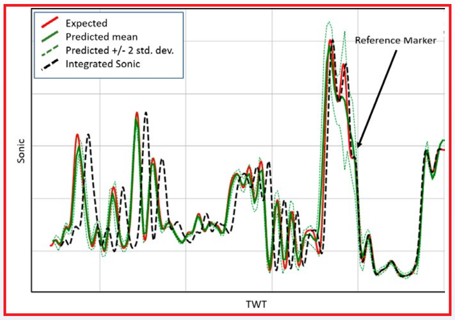


Figure 7: Average predicted TWT sonic for a test well A (green) compared to the expected sonic (red) and the one obtained by using the integrated sonic as a time-depth conversion; dashed green curves correspond to a +/- 2 prediction standard deviation.

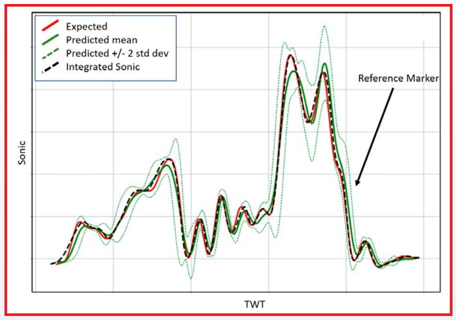


Figure 8: Average predicted TWT sonic for a test well B (green) compared to the expected sonic (red) and the one obtained by using the integrated sonic as a time-depth conversion; dashed green curves correspond to a +/- 2 prediction standard deviations.

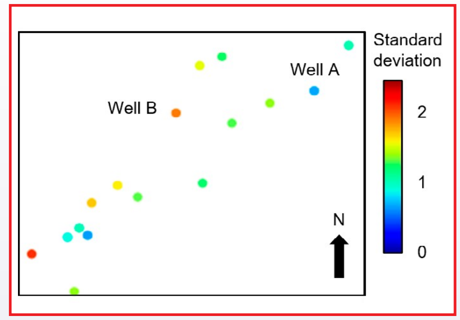


Figure 9: Base map of test wells; color is the prediction standard deviation

depth curve also includes real sonic drift?

Application to field data

We use here data from a field where 98 wells with VSP data are available. The density and sonic logs for one of these wells are shown in *Figures 6a and 6b* respectively, together with the time depth curve *(Fig. 6c)* calculated from integrated sonic or from the VSP. The sonic drift *(Fig. 6d)* was calculated by taking a reference marker, which is also a regional seismic marker, as a reference point where the drift is null. *Figure 6e* shows the drift curves estimated from all 98 wells. In general, drifts are positive as is expected from attenuation theory. While the curves seem to follow a similar vertical pattern, the intensity of the drift varies significantly from one well to another suggesting that the drift is not only influenced by stratigraphy but also by more local factors. These drift curves were cleaned to remove the inconsistent drift curves showing the largest oscillations. Following this process, 78 wells remained from which we used 46 for training using the same network architecture as shown in *Figure 2*. From the other 32 wells, half were used for validation and half for testing.

Figure 7 compares the expected and predicted TWT sonic for test well A. Globally, the average prediction closely follows the expected trace with no time delay. The only places with more significant mismatch between the two curves is where sonic varies rapidly, just above the reference marker. The prediction standard deviation is also highest in this position. In other places, prediction standard deviation remains low. Therefore, the prediction of this particular test well in the shallow part of the well. Well B *(Figure 8)* is more challenging, as demonstrated by the prediction standard deviation in the full well interval. Despite this additional uncertainty, the average prediction still accurately follows the expected curve.

Finally, *Figure 9* shows a map with the average prediction standard deviation for the 16 test wells. All wells are in an intermediate situation between well A and well B and therefore we can conclude that the network generalizes well to data it has not seen during training.

Alternative solution: Temporal convolutional networks

The ability of RNNs to capture long-term dependencies in sequential data resulted in them becoming the default option for a wide range of sequence modelling tasks (such as machine translation and audio synthesis). Despite this, they suffer from a number of issues which may inhibit their use. This includes being notoriously difficult to train as well as being inherently nonparallel, which can result in long training times. Around 2016, a number of papers were published showing that convolutional type networks could surpass RNNs performance on tasks such as audio synthesis (van den Oord et al., 2016) and machine translation. In 2018, Bai et al. introduced the temporal convolutional network

Technical Article continued on page 14.

Technical Article continued from page 13.

(TCN) as an alternative family of architectures for sequential modelling. TCNs (Bai et al. 2018) describes a family of architectures using (causal)1D fully convolutional networks where an input sequence of any length is mapped to an output of the same length. Key to this network architecture is the use of a series of dilated convolutions, which enables the network to look far back in the sequence to make a prediction (as opposed to relying on a memory cell as with LSTMs). They found that TCNs outperformed LSTM networks on a wide range of sequence modelling tasks while also being faster and having longer effective memory. Some of the other advantages over LSTMs include being able to run the convolutions in parallel (resulting in faster training) and the ability to control the receptive field size (by changing the number of dilation layers for instance).

A TCN type network was developed for our well-tie task, the details of which are omitted here. Note that here we modified our network to enable the prediction of outputs with different length to the input, which means it is not a true TCN by the definition given in Bai et al (2018). A simple random search was run to define a set of hyper-parameters suitable for the task. The prediction uncertainty map for the TCN type network is shown in *Figure 10*. This shows comparable accuracy to the results obtained via the LSTM in *Figure 9*, despite the fact that this network has yet to be fully optimized. This network will be investigated further in the next phase of this project.

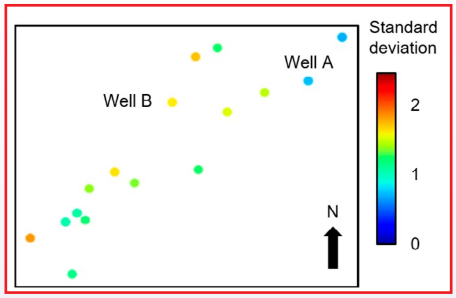


Figure 10: Prediction standard deviation for the results of the temporal convolutional network

Conclusions

We have shown that deep neural networks can be trained and optimized to learn to convert automatically sonic log data from depth to the time domain. The stretch-and-squeeze prediction is accurate even when attenuation causes varying sonic drift. Practically, this means that this type of network can be used on a field basis to integrate well sonic and VSP for velocity model building. We have also seen that dilated neural networks may be used to reach similar prediction accuracy in a fraction of the time. □

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GSH Movie Time

Now Showing

SEEING THE UNSEEN*

GEOPHYSICS AND THE SEARCH FOR ENERGY AND MINERALS

This month's movie, by "The Society of Exploration Geophysicists Education Foundation", was used by GSI as part of its training program in the early 1980's.

John Forsythe introduces the movie which covers, initially, myth and reality of finding oil in the early days. He hosts the movie through exploration's challenges and developments from the 1910's to the early 1980's, in which the movie was created.

Particularly interesting is the idea that oil, a non-renewable resource, would become scarce without the implementation of new technology. We know, today, that technology development has created an oil surplus, and we see now the possibility of having oil replaced by renewable energy long before it is depleted.

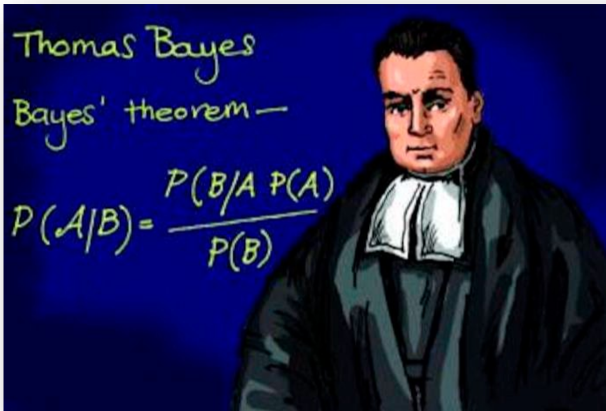
The movie is presented in two parts. Click in the red ticket to see the first part. When finished click on the blue ticket to see the movie's complement.

GSH Part 1

GSH Part 2

* SEG vintage video facilitated by Schlumberger – WesternGeco

Guru Goes Serious in Midst of Pandemic



The Nuggetonian Guru has declared statistical war on disease, the geophysical fallout, and ugly consequence thereof. From now on, we will battle these evil forces with our most powerful weapons aimed at their obliteration.

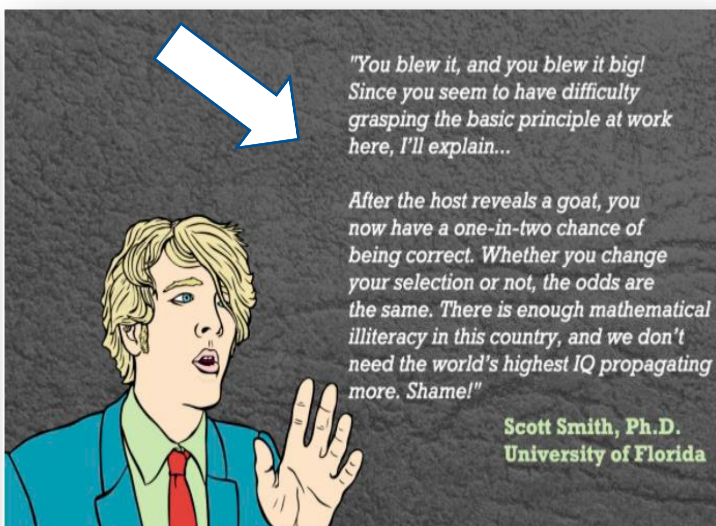
One of these is the **Bayes Theorem**, based on the work of Reverend Thomas Bayes (1701 – 1761) who upset the cozy world of Statistical Frequentists to the point of exasperation. Some still resist.

Bayes innocently suggested that if you really wanted to know the likelihood –or probability - that something meaningful will happen, you had better pay attention to the evidence, even if it comes in inconveniently late and upsets your preconceived notions. This includes the disease testing, seismic inversion, and even fun things like games.

The opposition to Bayes and the relevancy of his theorem (if any) came from the "Frequentists" who believed firmly in their prior findings. ("The science is settled, the evidence shows … is irrefutably true that … causes cancer, DTP, acne, peacock arthritis, peanut allergies, stuttering, halitosis, boils, IBS, pestilence, pandemics, plague, hypertension, plate tectonics, and Trump derangement syndrome."

A Classic Example of the Resistance, some 220 years after Bayes was officially published, posthumously (in 1764 by Roger Price), is the abusive treatment of Marylin Vos Savant, Puzzle Master, who was vilified by one Scott Smith PhD, University of Florida for her answer to the **Monty Hall Problem**:

Unfortunately, for Scott and the University of Florida, **Marilyn was proven correct** (to true scientists), along with Bayesian believers, contrary to most people's intuition,. In the pages that follow, we will show the avid viewer, you, the important, but paradoxical, meaning of Bayesian logic. The Guru is most happy to lead the reader down the path of Enlightenment and Faith. Yes, it may be bumpy, but you are up to it.



Tutorial Nuggets continued on page 17.

Tutorial Nuggets continued from page 16.

What got the ire of Scott was the answer to a quiz show problem in which **Monty Hall** was the long-time host. He would give a "Come-on-down" guest from the audience a chance to win an expensive car of the day – say a Maserati or **Rolls Royce** – by selecting the door behind which the car resided. However, the problem is compounded by the fact that there are **3 doors** and the other two have **Goats** behind them. Cute goats, but a long way from the value of the car which might be in today's market on the order of **$500,000** for the **Rolls Royce Phantom**, which would ruin the weekend for many seeking employment in the geophysical community. While we addressed the Monty Hall problem many years ago, it's worth while to review it again, as the best and most paradoxical **counter-intuitive** puzzle of all.

There are **3 doors, D1, D2, D3**. You are to select one of these which is the one you fervently hope, behind which lies the coveted Phantom. The other two doors have the Cute goats eating the studio rug. Your initial guess is as good as anyone's: P(Car@D1) = P(Car@D2) = P(Car@D3) = **1/3**. Now comes the post selection kicker: to help you and your final decision, Monty shows you what's behind one of the 2 remaining doors, after **you've selected**, say, **D1** , he opens **D2** behind which is a very nice Goat. He then asks if you'd like to **switch**. Should you switch to **D3** or keep your original selection of **D1**? No problem, say the Frequentists, who view previous stats as great and good for all. But Monty has introduced new information that should not be ignored, namely the **$Car** is not behind **D2**. P(Car@D2) = 0. Here we invoke Rev Tom:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

Likelihood B being true given A is true

Prior probability A being True

Posterior probability of A given B true

Probability B being True

Bayes Theorem in a very generalized form and annotated interpretation shown at the left. **P(B)** is critical in that it shows all possible ways in which **B** is true. We'll examine in more detail in **March**. Below is **Puzzle** to show the way.

A Puzzle for March 2021. While we're on Bayes, let's try this one. (One day, in the unlikely occurrence of a pandemic, you may wish to consider problems of this type.)

Suppose a **screening test** for Dermothermoplastosis (**DMP** or the **Tommie Rape disease**) has a false **positive rate = 1%** and a **false negative rate = 1%.** Further, the rate of the disease in the **U.S. population = 0.002.** In the language of Statistical-Speak, the probability that **you,** as a randomly selected **person from the population**, really have **DMP** (this is the Hypothesis), after the screening test says you have it (**tested positive**, the Data). Expressed in Math-Speak:

P(really got a dose | positive test) = P(H | D). H = Hypothesis = A; D = Data = B (above).

Using **Bayes** and your significant other, what is the **probability the Hypothesis is True**, and you'd better get yourself treated – Now – before flaking and fulminating commence.

Tutorial Nuggets continued on page 18.

Tutorial Nuggets continued from page 17.

Puzzle 1 for February 2021

VP1 Matt and VP1-Elect Marianne each have some coins, but Matt has one less than Marianne does. Both toss all their coins simultaneously and count the number of heads each has. What is the probability, in general, that Marianne has more heads than Matt?

As a specific example (not general), Marianne has 5 coins and tosses for **3** heads while Matt with **4** coins tosses 2 heads.

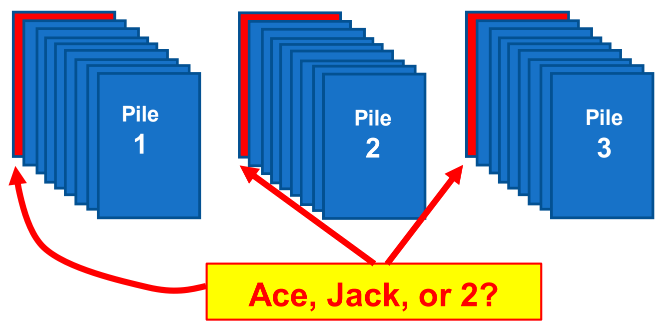
(A) ¼; **(B)** ½; **(C)** ¾; **(D)** Cannot be determined, in general.

Answer. Marianne must either toss **more heads** or **more tails** than Matt. With an extra coin, she can't throw the same number of H or T as Matt. This gives her an **50-50** chance **(1/2)** of getting **more Heads** It also gives her a **1/2 probability** of getting more tails. The answer is **(B).**

Puzzle 2 for February 2021

Which way would you **bet** if a shuffled deck of cards is cut into 3 piles: **(A)** That there is at least **one** of these **3** cards, an **Ace, Jack, or 2**, on the bottom of one **or** more of the the 3 randomly cut piles, respectively or **(B) Probably Not.**

Use your thoughtful analysis of the example given previously in this tutorial to aid you in answering this problem. There is an embedded **Great Truth** here (a common occurrence in these profound writings).



Answer. Your thoughtful analysis will quickly guide you to The **Great Truth** herein embedded, namely that in many probability problems, it is a lot **easier to compute the probability of something NOT happening** than the many ways it could possibly happen. Then, since it either happens or doesn't, so subtract your **P(B = NOT) from [P(A = at least one) + P(B= NOT)] = 1 to arrive at P(A = at least 1)** for the best guidance which way to bet.

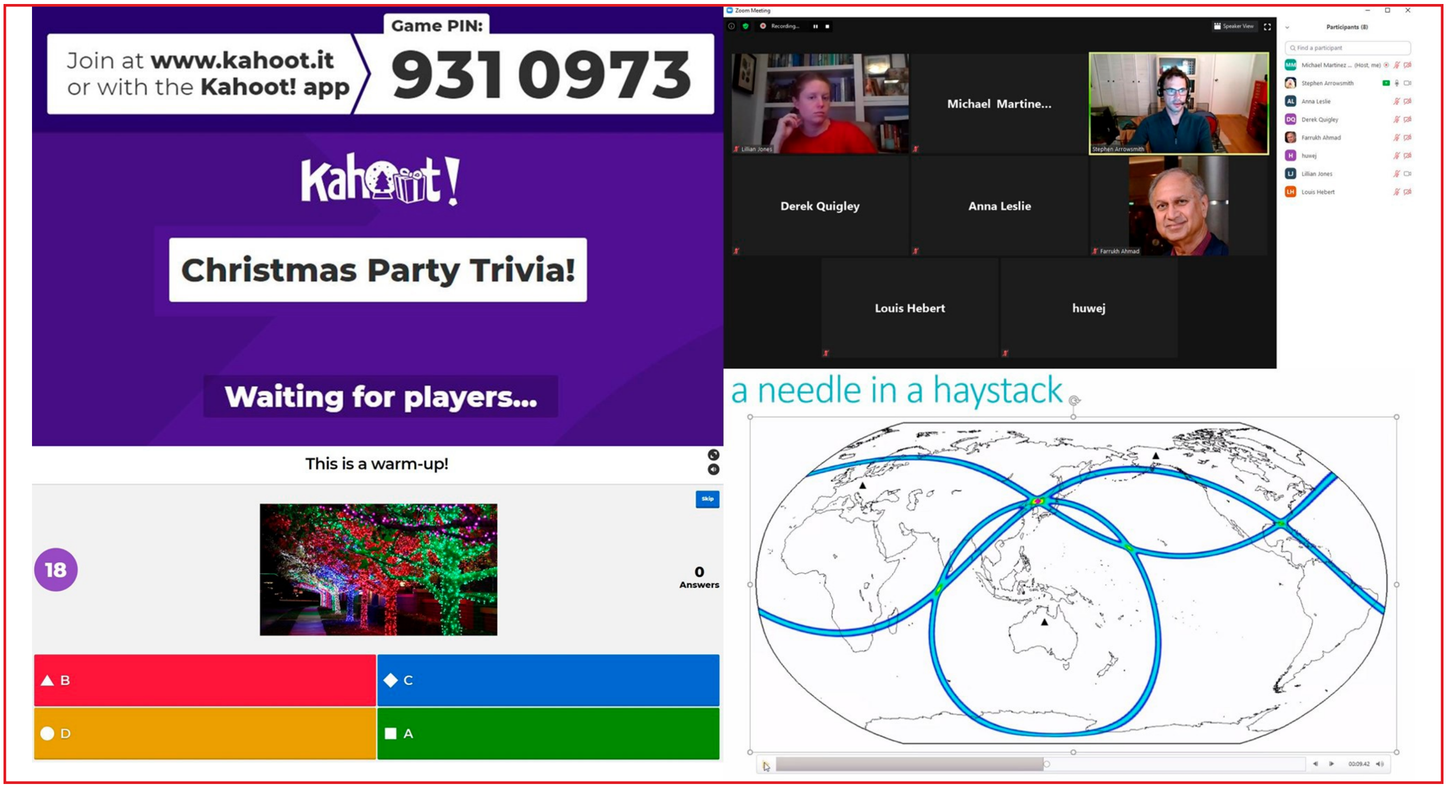
Here we have **P(B = NOT) = (40/52) x (39/51) x (38/50)** respectively, for the 3 piles. The decreasing numerator and denominator in the 3 piles represents the **decreasing** probability of getting **non-A-J-2** since these cards are being used up from the original population. Since the individual probabilities depend on one another, they are a **joint probability** and must be multiplied together, yielding **P(B = NOT) = .447** or about 45% of the realizations will be in the NOT category and **55%** will contain at least one of the 3 card types. **Bet (A)**.

For questions or sponsorship opportunities, please contact:
Scott Sutherland, Scott.Sutherland@CGG.com 346-366-0288

U of H Wavelets

University of Houston Sheriff Lecture Student Poster Competition

By Joe McNease



With finals and the holidays, December was a busy month for the SEG Wavelets. On December 14th, Dr. Stephen Arrowsmith joined us and the NextGen of the Geophysical Society of Houston to discuss the use of seismic and infrasound data to detect and locate explosions. Dr. Arrowsmith worked at Los Alamos and Sandia National Laboratories and is currently an associate professor of geoscience at Southern Methodist University specializing in the use of seismic and low-frequency acoustic signals to study the geosphere and atmosphere.

The AAPG Wildcatters, EAS Graduate Student Committee, UH Geosociety, and the SEG Wavelets hosted the Christmas Holiday Bonanza on December 18th, 2020. This event featured geo-photo, ugly sweater, and raffle contests, along with a trivia event and word clouds. The night of fun games and prizes was a great way to end the fall semester and the Zoom meeting details of similar future events can be found on our Instagram page linked below.

The Geophysical Society of Houston and Houston Geological Society hosted a geoscience trivia night on January 28th, 2021. The University of Houston, Texas A&M, University of Texas, and Rice University battled it out to see who reigns supreme in their knowledge of the geosciences. Registration and Zoom meeting details of these events are posted in advance on our social media accounts, so make sure to subscribe to stay updated. Additionally, the spring semester begins a new series of research presentations as part of the ongoing UH EAS Structure and Tectonics Seminar. The seminar allows graduate and undergraduate students to share their work with faculty and students followed by a Q & A session, allowing the students to refine their ideas with input from their fellow students as well as the faculty. We encourage anyone interested in geoscience to attend the seminar as it is a great way to make connections and learn about exciting new research.

To keep up with the SEG Wavelets, follow our social media profiles on LinkedIn, Facebook , Instagram, and Youtube. Also, you can join SEG at the local level with the Wavelets and the national level by following the instructions on our site! □.

THE HOUSTON GEOLOGICAL SOCIETY PRESENTS

SCHOLARSHIP NIGHT 2021

The HGS Scholarship Night has a long tradition of engaging inspiring, visionary, and entertaining speakers. This year the star presenters will be the student scholarship winners themselves. Each will be given an opportunity to briefly share with us their goals, aspirations, and how they see the future. This talented group of young people will entertain, engage, and inspire us all with their talent and passion for making a difference. All event profits benefit the HGS Scholarship Funds.

FEBRUARY 8, 6:30 PM TO 8:30 PM
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GSH Outreach

Committee Activities *By Lisa Buckner,* **outreach@gshtx.org**

sefh

Science and Engineering Fair of Houston

SCIENCE FAIR JUDGES NEEDED

What: 63rd Annual Science and Engineering Fair of Houston
Where: Online Asynchronous – Laptop or desktop computer and internet connection required (not compatible with smart phones or tablets). **SEFH will provided detailed instructions and training opportunities** for the online judging process during January and early February.
Starting When: Saturday, February 13, 2021 (project abstracts available for review)

Judge Registration Deadline: February 5

Two different types of judges are needed to evaluate the projects by 1,200 Junior and Senior High School students (grades 6-12):

1) GSH needs at least 6 **Special Award Judges** to select winners for GSH Awards. We work in teams and no previous judging experience is necessary. We will be looking specifically for projects related to geophysics starting **February 13** and winners must be certified by **February 27**. Contact outreach@gshtx.org to volunteer so we know who is on the team and then register for the GSH team at https://sefhouston.org/special-awards/#Judging-Procedure.

2) SEFH is also in need of **500** first round **Place Award Judges** working in teams of 3 or 4. Approximately 6 hour commitment **Saturday, February 13 – Thursday, February 18, 2021**(flexible hours). No previous judging experience is required and you will not be expected to judge an unfamiliar category. To learn more and to signup, go to https://sefhouston.org/for-judges/#Start-Here

Information regarding both types of judging (duties, schedules and resources) can be found at http://www.sefhouston.org in the *Judges and Special Awarding Agencies* section.

GSH SCHOLARSHIP RECIPIENTS FOR 2020-2021

GSH / Carlton-Farren scholarship
Julia Astromovich, University of Texas at El Paso

From Michigan
The master's project is part of a research group that focuses on different aspects of salt tectonics with the Onion Creek salt diapir. Julia is approaching it with gravity and magnetic methods. Julia is currently also an intern at BP.

GSH / Hugh Hardy scholarship
Jordan R. Caylor, University of Texas at El Paso

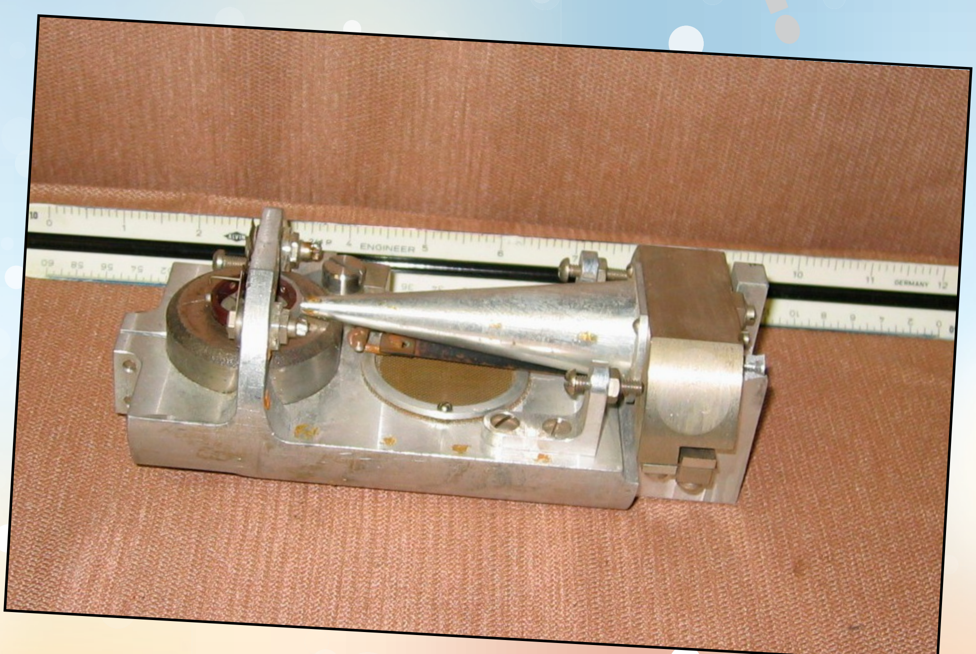
From Bentonville, Arkansas
Studied geology at Southern Illinois University (SIU) then pursued a master's at the University of Texas at El Paso. The master's thesis was focused on investigating the subsurface hydrothermal structure of Old Faithful Geyser by utilizing 2-D refraction tomography and the H/V spectral ratio method. Upon earning a PhD, Jordan plans to either go into research at a laboratory or enter the natural resources (petroleum or mining) industry.

For more about the GSH investing in the future with the Scholarship Program, CLICK HERE.

Mystery Item

This is a geophysical item...

Do you know what it is?



This month's answer on page 25.

The Mystery Item
on page 23
is a
Cut-a-way
of a
Merten cone seismometer
from 1940,
donated by Shell.

Corporate Members

Apache

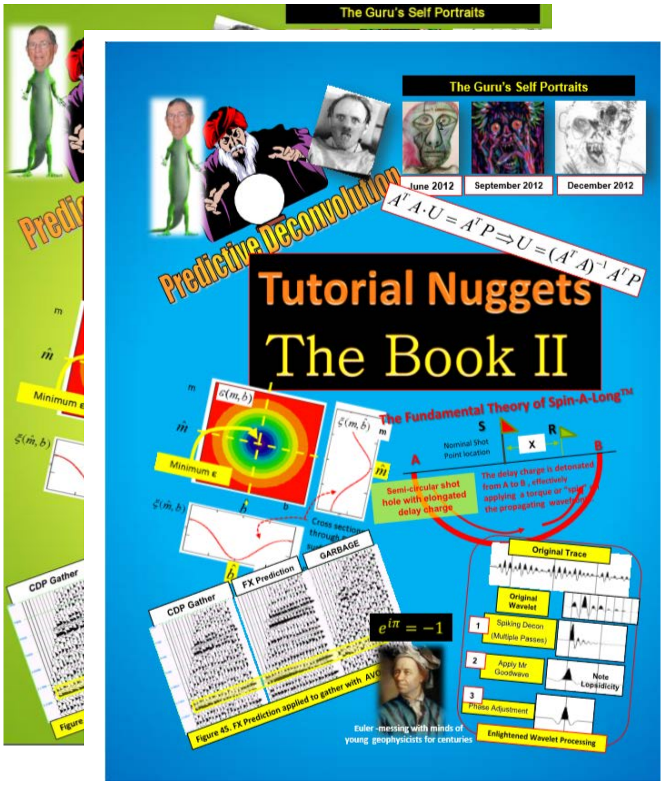
Fairfield Geotechnologies

In-Depth

Seitel

TGS

For more information about becoming a Corporate Member, go to GSHTX.org



These just published, limited printing proof copy of the new industry standard for seismic theory (and other stuff) will surely be a valuable tool as well as a keepsake for your technical library!

$75

Member Price

Per the GURU...

Proceeds will be used to further scholarships, student memberships, educational outreach, and other activities of the Society.

"Cutting advertising to save money is like stopping a clock to save time."
- Henry Ford

For Media Kits, go to: gshtx.org/PUBLICATIONS/Media Kits

Item Of Interest

In 1580, William Gilbert called the earth a gigantic magnet and in 1589, Galilei Galileo established the first principles of dynamics, including the law of free fall and of pendulum motion.

The CGS unit of gravity is called a 'Gal' in honor of Galileo. □

Doodlebugger Diary

My Experiences in The Arctic, 1976

By Russell Cornford

The Doodlebugger Diary recounts the experiences of geophysicists during their working lives. This month we have a guest article from a fellow doodlebugger. Enjoy!

If you have stories of your early career you would like to share, please send them my way (scott.singleton@comcast.net). I will be happy to print them in this segment.

My first foray into the world of seismic was as a drill helper on a GSI crew in the Canadian Arctic in 1976. We were on the ice the whole time and our camp consisted of trailers on skids *(Figure 1)*. The first time I landed in resolute Bay I'll never forget the blast of -60° air that hit me when the plane's hatch opened. That'll wake you up.

As a driller, our main job was dry auger drilling to a depth of 30′ or less, depending on the thickness of the ice. When the ice was flat it was usually about 6′. Our charge was a length of primer cord tied to a 2′ piece of pipe. Initially we made up charges in the evening at camp and in the morning load them into the cab of our Canadair Flextrac CF 10 tracked drill vehicle *(Figure 2)*. I can tell you that several times during the day getting in and out of the cab from hole to hole the door would slam on the primer cord. This was just part of the regular routine and we thought nothing of it. It wasn't until

Figure 1: Basecamp in the arctic. All the vehicles were tracked and the trailers were on skids.

Figure 2: Canadair Flextrac CF 10 tracked drill vehicle. This photo depicts a common occurrence of the track slipping off the wheels. To get it back in place you spread the track with the use of a "Jack All". Once, the jack slipped out of position striking me directly on the knee. Ouch! Fortunately that only happened once.

Doodlebugger continued on page 30.

If you would like to add stories to the Doodlebugger Diary, send them to: Scott Singleton at scott.singleton@comcast.net
or mail them to Box 441449, Houston, TX 77244-1449

Doodlebugger continued from page 29.

after a Canadair Flextrac representative visited the crew and gave us a demonstration on the dangers of handling primer cord that the practice of making up the charges in camp came to an abrupt end. Nice for someone to come out to the field to tell us how to properly handle that stuff before we found out the hard way!

The crew experimented with a variety of charge sizes until deciding on what best to use. We ended up with a lot of unusable primer cord that we were directed to destroy. So one day we made a big pile and moved off a ways. A few fellows had brought hand guns up with them. I recall a .44 magnum Dirty Harry gun and a .357. We took a few pot shots and I know there were some direct hits on some rolls but they wouldn't blow. When we did set it off I was standing near a rig holding a can of soda. The explosion caused a small tsunami in the ice that caused me to jump with the soda splashing all over my face. That was one exciting explosion!

When the ice was flat and 6′ thick, days went by rather quickly. There was no need to add drill-stem segments so all I was required to do was make up charges and load them. If you weren't fast enough the hole could seal up and that would not make the driller happy. On days like this you felt like a cog on a fast spinning wheel, a blur.

There were different ice formations: the 'flat', the 'crunched up craggy' that often surrounded islands, and 'Old Rolly'. 'Old Rolly' were vast areas of rounded hills of what I assume were once the 'crunched up ice' type that were shifted around and worn down by wind. I'll never forget working through an area of 'Old Rolly' when cresting a hill and all of a sudden the hills stopped and there was nothing. Literally I could not see a horizon. It was just this flat, grey nothing, right in your face. I remember thinking something like I was about to float off into nothingness, never to be heard from again. It was kind of eerie.

Often you heard the ice crack and we crossed cracks all the time *(Figure 3)*. We had of course heard stories of people that had fallen into cracks that suddenly widened as they were crossed. Brrr, that's an icy grave. However, just to be clear, we never had any incidents on either of the arctic GSI crews while I was up there. Nonetheless, we all had heightened senses whenever we saw one of these features. We always checked it out and if it was deemed too wide then we drove along it until we found a narrower gap.

Figure 3: An ice crack. One of the real dangers while surveying on ice fields.

Unfortunately our crew gained a reputation for losing drill stem. It got to a point where we were instructed to retrieve what was showing. At the end of one day several of the drills gathered to attempt blasting out a stuck string. Holes were drilled all around the stem and loaded with charges. All that was accomplished was a large crater but we got about 10′ of the stuck string out.

Every rig carried a few days' worth of rations because white outs usually lasted two or three days. You did not lose sight of the rig when having to do your business. Nothing like dropping the trap door at 60° below.

Doodlebugger continued on page 31

Doodlebugger continued from page 30.

One time two of us were assigned to drive a drill vehicle several miles to a new camp location. We were trundling along, on our own, following the bamboo stakes, wind blowing, when all of a sudden, I woke up. We had both fallen asleep. I stopped, looked around, woke my partner, but neither of us could see any stakes. We couldn't see very far because it was windy, it wasn't a "white out" but it was very white. We were unable to raise anybody on the radio so we were faced with a decision, to go left or right. We went right. I don't remember exactly how long it took, maybe an hour or so, but we finally came upon the stakes and ultimately made it to the new camp site. For any readers who have been to the Arctic, I don't mind telling you that although we hadn't yet panicked, we weren't far off. I can assure you it was quite a relief to see those stakes.

My driller went on break once so I was sent to the line crew to pick jugs. I was too slow for the Line Boss so he had me drive the line truck the rest of the week. My one and only assignment to the line crew. You know what they say – you just do what the boss says because he pays your salary.

Of course it was a dry camp, though I think they did bring in some beer once for some occasion. That didn't stop some fellows from concocting some "wine" near the end of work. It was a mixture of fruits, juices, sugar and yeast that "fermented" for a week or two. I don't recall any ill effects. It's amazing what we came up with to break the monotony.

The food was utterly the best. Everything. It was generally like that on all the crews in Alberta. The likes of which I never saw overseas. But this is a general theme on field crews – there isn't much else to do but eat, work and sleep so they really do up the eating part. At least that made mealtimes a fun event.

I was up there for six months from December 1975 to June of '76. Long enough to experience 24 hour darkness to 24 hour light. It was so very interesting to observe the Sun start to peak in the East then West then gradually climb until it was finally all the way over our heads. We also witnessed a phenomenon known as a "Sun Dog" which as I recall was a ring of bright light with a few bright spots emanating outward in a straight line from each side beyond the outer edge of the ring (*Figure 4* for an example of one). Quite spectacular. □

Figure 4: Very bright sun dogs in Fargo, North Dakota. Also visible are parts of the 22° halo (the arcs passing through each sundog), a sun pillar (the vertical line) and the parhelic circle (the horizontal line). (Courtesy Wikepedia, https://en.wikipedia.org/wiki/Sun_dog).