Deep learning for seismic data semantic segmentation

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Abstract. Drilling for oil and gas is an expensive and time-consuming process. Companies in the oil and gas industry invest millions of dollars in an effort to improve their understanding of subsurface components, and using traditional workflows for interpreting large volumes of seismic data is an important part of this effort. Manually defining links between geological characteristics and seismic patterns is required by geoscientists. As a result, geologists and oil and gas industry businesses resorted to a seismic survey, in which seismic waves provide a wealth of information about what is inside the earth without the need to dig. The main of this paper concerns the identification of salt layers of a seismic image by a computer which often coexist with gas and oil under the ground by proposing a deep Learning for seismic analysis.We propose U-net architecture to discover seismic data. Moreover, we study the data augmentation with U-net architecture. The result of data augmentation can perform 10 % the U-net architecture model.

Keywords: Deep Learning · seismic · Salt identification · U-net architecture · Data augmentation.

1 Introduction

The seismic survey is an important part of the entire process of petroleum exploration and production, and it can be done either onshore (land) or offshore (marine) by using explosive charges such as airguns for offshore exploration and dynamite or specialized trucks for onshore exploration, which contain a heavy plate vibrated on the ground surface to generate waves that bounce off underground rock formations (hydrophones and geophones).

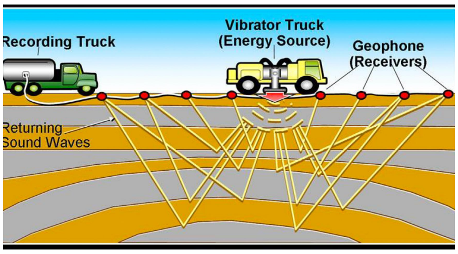

Fig. 1. Vibroseis Research [14]

During maritime seismic acquisition, the hydrophone is a device used to detect seismic energy in the form of pressure changes in water. The geophone is a surface seismic acquisition device. The geophone is a device that detects ground velocity produced by seismic waves and converts the motion into electrical impulses. It is employed in surface seismic acquisition, both onshore and offshore.The amount of time it takes for data to travel from the source to the receivers can reveal information about rock density and the presence of fluids or gases. This can aid in the formation of a subsurface image[1].

1.1 Salt Structures

Salt Structures are a common geological phenomenon that form as a result of the density difference between salt and the layer above it. Because salt is less dense than the layer above it, it pushes toward the top, forming a dome in the sedimentary layers above it. If the salt dome contains oil, it moves to the outer sides of the salt dome and is confined between the sedimentary layers, forming exploitable oil reservoirs. Because of the physical qualities of salt, identifying the salt structure is one of the challenges of seismic imaging, as the density of salt is typically 2.14 g/cc, which is lower than the density of most surrounding rocks.

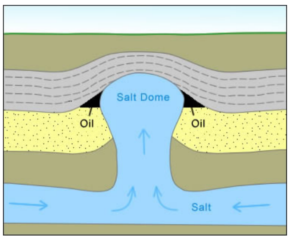

Fig. 2. Salt Dome

Salt has a seismic velocity of 4.5 km/sec [2], which is quicker than the rocks around it. At the salt-sediment interface, this difference causes a strong reflection. Salt is often an amorphous rock with little interior structure. This means that, unless there are sediments trapped inside the salt, there is usually little reflection. Seismic imaging can be hampered by salt's very high seismic velocity.The advantages of salt identification for oil and gas are[2]:

- Because salt is a good sealant, it is used to create the edges of many hydrocarbon traps. Without analyzing the salt contact, these traps cannot be properly mapped.
- Understanding salt geometry and evolution is therefore vital in forecasting reservoir placement in a salt basin. Salt structures can have a significant impact on sediment transport and, as a result, are fundamental influences on reservoir distribution.
- In many basins, salt's distinctive physical qualities make sub-salt and salt-flank imaging difficult. One method for overcoming these difficulties is pre-stack depth migration, which requires an accurate salt model. As a result, a substantial portion of current salt interpretation is focused on developing velocity models for pre-stack depth migration.

The paper is organized as follows, in section 2 we present related works on seismic images. In the section 3, we present our method of seismic image segmentation. In section 4 we present evaluation and results. Finally, conclusion and future work.

2 Related works

Olivier et al.[3] proposed a pre-processing step based on non-linear diffusion filtering, leading to a better detection of seismic faults. The non-linear diffusion approaches are based on the definition of a partial differential equation that allows to simplify the images without blurring relevant details or discontinuities.

Mikhail K et al[4] presents A Deep Learning Approach for Automatic Salt Deposit Segmentation, which shows how various unique deep learning approaches can be combined into a single neural network to achieve an excellent result.Authors proposed U-Net with ResNeXt-50 encoder pre-trained on ImageNet.

Milosavljević et al.[5] proposed a deep learning model. The architecture of the proposed network is inspired by the U-Net model in combination with ResNet and DenseNet architecture.

Yauhen B et al.[6] propose a semi-supervised method for segmentation (delineation) of salt bodies in seismic images which utilizes unlabeled data for multi-round self-training. For the training model, authors used U-ResNet34 and U-ResNeXt50.

3 Proposition

Our proposed method for seismic data analysis is composed by the following steps:

- Data augmentation.
- U-net architecture for train and test data.

Data augmentation To artificially enhance the size of an actual dataset, data augmentation technics generate different versions of it. To deal with data scarcity and insufficient data diversity, computer vision and natural language processing (NLP) models employ data augmentation strategies[7–9]. A data-space solution to the problem of limited data is data augmentation. Data Augmentation is a term that refers to a range of strategies for increasing the size and quality of training datasets so that stronger Deep Learning models may be generated using them[7].There are many strategies for image augmentation such as scaling (zoom in/ zoom out), rotation, reflection, shear.

U-net architecture Olaf Ronneberger et al.[10]created the U-net for Bio Medical Image Segmentation. There are two ways in the architecture. The contraction path (also known as the encoder) is the first path, and it is used to capture the image's context.The encoder is simply a convolutional and maximum pooling layer stack. The symmetric expanding path (also known as the decoder) is the second way, and it is employed to achieve exact localization via transposed convolutions. As a result, it is a fully convolutional network from beginning to end.

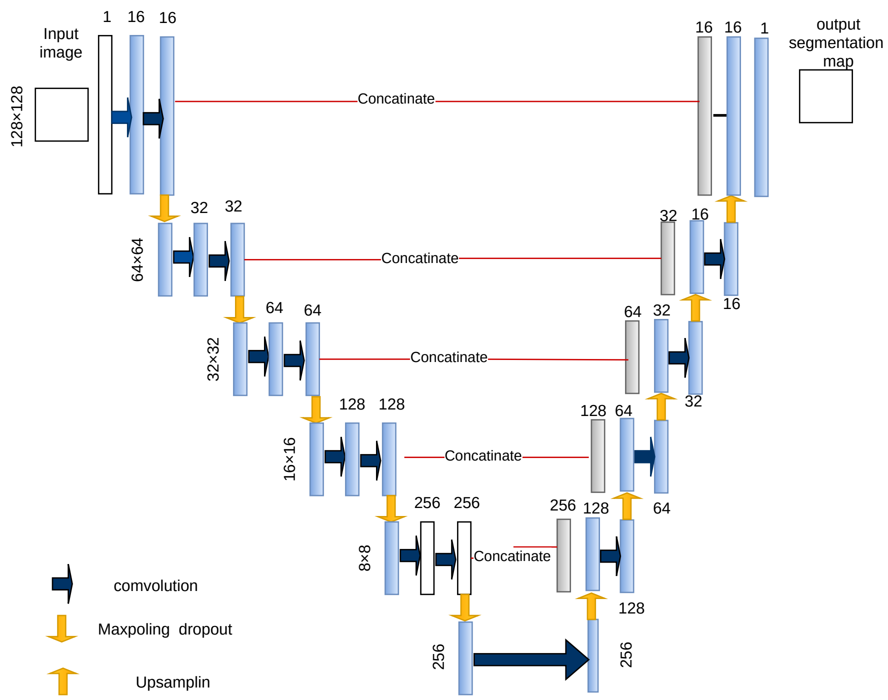

Fig. 3. U-net architecture

4 Evaluation and results

For the evaluation of the proposed model, we used the Data[11] from TGS, a company of energy data and intelligence. The data consists of a collection of photos taken at various subsurface sites chosen at randomly. Images are 101 by 101 pixels in size, with each pixel labeled as salt or sediment. Each image includes the depth of the photographed place in addition to the seismic images. We are compared between U-net with augmented data and U-net without augmented data. The metric of the evaluation is mean average precision at different intersection over union IoU. The overlap between two borders is measured by IoU. It is used to determine the extent to which the anticipated border overlaps the ground truth (the real object boundary fig 4) . In some datasets, IoU uses a predefined threshold to determine whether a prediction is true positive or a false positive [12].

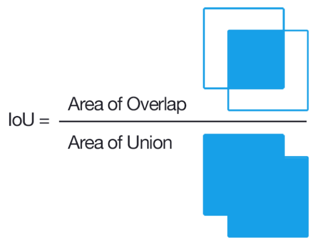

Fig. 4. Intersection over union [12]

For example The IoU is the area of overlap between the predicted and ground-truth bounding boxes B_p and B_gt divided by the area of union between them [12].

$$J(B_p, B_{gt}) = \frac{area(B_p \cap B_{gt})}{area(B_p \cup B_{gt})} \quad (1)$$

Table 1. Results of U-net

Model	IoU
U-net with augmented image	0.70
U-net without augmented image	0.62

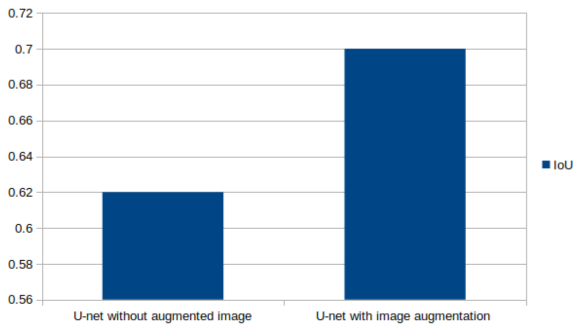

Fig. 5. Results of models

Result discussion We have compared between two method based U-net architecture, in the first we use data augmentation and in the second we used only U-net architecture without data augmentation.The IoU when used data augmentation is 0.70, and for second is 0.60. From the result, we summary the following:

- U-net is an architecture can extract semantic segmentation.
- U-net needs images augmentation to perform the model.

5 conclusion

Gas and oil discovery with artificial neuronal network become an interesting field to understand complex data and help expert decision. We are proposed U-net architecture for seismic data segmentation. Moreover, we studied the performance of data augmentation for U-net architecture. In the first use's case, we used U-net architecture with data augmentation, and in the second we used only U-net architecture for seismic semantic segmentation. The study illustrates the importance of U-net architecture with data augmentation. In the future work, we will propose other data augmentation technics.

References

1. Mondol, Nazmul Haque.:Seismic exploration. Petroleum Geoscience , 375–402 (2010)
2. Jackson, Martin PA and Hudec, Michael R.:Salt tectonics: Principles and practice, tectonics,132–141,(2017)
3. Lavialle, O Pop, S Germain, Ch al.:Seismic fault preserving diffusion Salt,132–141 (2007).
4. Karchevskiy, Mikhail, Insaf Ashrapov, and Leonid Kozinkin.:Automatic salt deposits segmentation: A deep learning approach.arXiv preprint arXiv:1812.01429 (2018).
5. Milosavljević, A. Identification of Salt Deposits on Seismic Images Using Deep Learning Method for Semantic Segmentation. ISPRS Int. J. Geo-Inf,9-24. (2020),https://doi.org/httpshttps://doi.org/10.3390/ijgi9010024
6. Babakhin, Yauhen, Artsiom Sanakoyeu, and Hirotoshi Kitamura.:Semi-supervised segmentation of salt bodies in seismic images using an ensemble of convolutional neural networks. German Conference on Pattern Recognition. Springer, Cham, (2019).
7. Shorten, Connor, and Taghi M. Khoshgoftaar.:A survey on image data augmentation for deep learning. Journal of Big Data 6.1,1-48,(2019).
8. Wong, Sebastien C., et al. Understanding data augmentation for classification: when to warp?.2016 international conference on digital image computing: techniques and applications (DICTA).IEEE,(2016).
9. Mikołajczyk, Agnieszka, and Michał Grochowski. "Data augmentation for improving deep learning in image classification problem." 2018 international interdisciplinary PhD workshop (IIPhDW). IEEE, (2018).
10. Ronneberger, Olaf, Philipp Fischer, and Thomas Brox.:U-net: Convolutional networks for biomedical image segmentation.International Conference on Medical image computing and computer-assisted intervention. Springer, Cham, (2015).
11. TGS Salt Identification Challenge Segment salt deposits beneath the Earth's surface , https://www.kaggle.com/c/tgs-salt-identification-challenge/data. Last accessed 4 Sep 2021.
12. Padilla, Rafael, Sergio L. Netto, and Eduardo AB da Silva.:A survey on performance metrics for object-detection algorithms.2020 International Conference on Systems, Signals and Image Processing (IWSSIP). IEEE, (2020).
13. Vibroseis Research,https://www.cem.utexas.edu/content/vibroseis-research,Last accessed 4 Sep 2021.
14. What is a Salt Dome ,https://geology.com/stories/13/salt-domes/,Last accessed 4 Sep 2021.