

# Bare Demo of IEEEtran.cls for IEEE Computer Society Conferences

Isaac Sacramento  
and Mauro Roisenberg  
and Rodrigo Exterkoetter  
*Department of Computer Science  
Federal University of Santa Catarina  
Florianopolis, Santa Catarina  
Email: isaac.sacramento@posgrad.ufsc.br*

Leando P. de Figueiredo  
*Department of Physics  
Federal University of Santa Catarina  
Florianopolis, Santa Catarina  
Email: homer@thesimpsons.com*

**Abstract**—In this paper we will present a new convolution neural network model to deblurr post-inversion acoustic impedance images.

## 1. Introduction

Deblurring is an important problem in image processing. It seeks to remove distortions from a blurry image in order to recover the original image. Recovering the original image is possible if the details of the blurring method are known. In most cases, blurred images lack of enough information to uniquely recover a plausible image, this feature sets deblurring as an ill-posed problem and characterizes as an inversion problem. It is not observed in the literature a general object deblurring algorithm. Thus, as mentioned by [6] exploiting domain-specific knowledge can result in superior deblurring. The focus of this work is post-inversion acoustic impedance deblurring. Specifically, acoustic impedance deblurring must take into account the fact that the resulting image still must to reflect the synthetic seismic data characteristics.

Reservoir characterization consists in determining the multidimensional and quantitative structure and properties of an oil field. To achieve this goal, it is essential to combine in a single model all the information, knowledge and data about the field, in such a way that is possible to make the quantitative predictions about the reservoir behavior [8]. These data are usually geological models, data logs, testimonial data, production summary and 3D seismic data. The seismic amplitude is used in model generation and reservoir characterization, however, the deeper the investigated horizon is, the bigger the limit in using the seismic amplitude data [9]. The seismic data inversion has proved to be an efficient tool to accurately integrate the seismic information in order to generate models that contribute to an effective reservoir characterization [10]. Besides integrating data, seismic inversion is widely used because of its facility and precision in interpreting the acoustic impedance.

According to [7], a good acoustic impedance model contains more information than the seismic data because this model keeps all the seismic data information and additional information originated in the well-logs. Depending on the applied method, the acoustic impedance volume is the result of the integration of data from different sources, such as, the seismic data, well logs and velocity models. Thus, building an acoustic impedance model is the natural process to integrate the available informations to obtain a model accessible to geophysicists, geologists and engineers. The acoustic impedance models allow fast interpretations and an efficient identification of exploratory targets in seismic scale. However, the seismic data are band-limited, in other words, the seismic data are short of high and low frequencies. This is a consequence of seismic acquisition, earth attenuation, high-frequency noise, etc [2]. This phenomenon leads to a misinterpretation of seismic data and, by consequence, the same to the resulting acoustic impedance models, that lacks of high-frequency details, additionally, inversion methods such as MAP (Maximum a posteriori), lead to blurry images [16]. In this sense, we believe that increasing the resolution of the acoustic impedance models through deblurring the model sections, as a post-inversion refining process, can lead to a more accurate interpretation of the impedance models.

We approach the problem of deblurring post-inversion acoustic impedance images through the Convolution Neural Networks (CNN). CNN is a framework of deep learning which has been used in a wide sort of machine learning tasks. The availability of benchmarks [11] and the advances in Graphical Processing Unit (GPU) [3] allowed CNN to outperform the techniques in detection [12], [13], model-free tracking [14], classification [15]. With excellence in feature learning, CNN achieved notorious success in image classification [17], action recognition [18], video classification [19] and speech recognition [20]. Under the post-inversion perspective, we consider acoustic impedance as image and work on it with image processing algorithms.

In this paper we propose a new multilayer convolution network model to perform deblurring in post-inversion

acoustic impedance. Each network layer maps higher level features originated in the previous layers through convolutional filters. To perform this mapping, the filters, also named weights, are adjusted by minimizing a loss function. The trained model enhances the resolution of the impedance image, resulting in an equivalent image with increased high-frequency band and lower noise. The model was tested First, we blur the synthetic acoustic impedance to form the pairs of images of high and low resolution. Then, the dictionary of images is normalized to the real interval  $[0, 1]$  and used to train the convolutional model. Once the model We compare the deblurred images depicted by our model and by two other deblurring methods (). The core concept of our architecture is the combination of the convolution layers with regression layers, thus proceeding a regression solution, instead of classification.

## 2. Related Work

Deblurring plays an important role in computer vision. Methods based on...However these methods lack of ...

Recent researches in geophysics have applied deep learning solutions, such as convolution networks, to solve a wide sort of problems such as lithofacies recognition [4] and calculation [5],

However, there is a lack of researches to investigate methods for improving the resolution of images resulting from inversion processes. Improving the resolution of seismic inversion is possible by adding high frequency in acquisition and processing seismic data. The seismic data is generally short of high and low frequencies and this phenomenon is caused by seismic acquisition, earth attenuation, high-frequency noise, etc., what negatively influence on geologic interpretations of seismic data [2]. Thus, we propose enhancing seismic impedance resolution adding high-frequency post-inversion through a convolutional neural network.

## 3. Data and Method

The experiments described in this paper were performed on a set of synthetic acoustic impedance images. Using synthetic models allows studying the results of the algorithms without external interferences, this leads to efficient interpretations and assessments. According to [21], wedge shaped models is a straight way to analyse the seismic model modeling and inversion processes. It realistically reproduces reservoir contexts such as stratigraphic refinements, *pich-outs* in sand layers, edges and channel structures.

In order to generate a set of training images, we proceed two steps to obtain the wedge images. In the first step we created the a set of random wedges forms, containing two horizontal dimensions represented in images  $32 \times 32$ . The wedges representing the reservoir varied in width and length. The second step filled the lithology with values of petrophysical properties. In order to simplify the assessments and conclusions, the lithology structures are filled with constant reference values of rock densities and compressional

velocity observed in the literature. Fig. ?? illustrate the lithology model with the corresponding values for density and velocity.

With the density and velocity models the acoustic impedance model is calculated. The high resolution final model used to train the model is illustrated in Fig. ?. To proceed the supervised training, the acoustic impedance models were filtered and the high frequencies removed in order to obtain blurred images. To increase the number of examples in the training dataset and allow the model to learn general edges in wedges images, we rotate the impedance models in angles countable multiples of 90 degrees.

### 3.1. Acoustic Impedance Images

### 3.2. Convolutional Neural Network

The work-flow of the proposed method consists of the following steps:

- Generate synthetic impedance images;
- Blur these images through a low-pass filter;
- Train the convolutional model with the pair of images;
- Test the model with different blurry images;
- Assess the result for the testing output.

The approach adopted in this paper consists in training a CNN model to to deblurr synthetic acoustic impedance images. The model is able to solve two important problems related to deblurring physical properties images: (1) learning the spacial patterns in the low resolution training images and (2) predict each pixel intensity value in the new higher resolution image. The CNN is a well established method for patter recognition. Thus, an important breakthrough was developing a model capable to proceed the regression task. To reach these two goals, the structure of the model contains convolutional layers combined with a regression output layer.

The model proceeds a supervised learning through a dictionary of pairs of low and high resolution images. The optimization algorithm adjust the network weights in every layer by minimizing the Mean Squared Error (MSE) in each batch of images. Thus, after the training phase, the model is capable to deblurr any other image not presented in training dataset. The output image must recover higher frequencies and, in advance, be more similar to the high resolution image than the blurred image.

Three metrics assess the performance of the convolution networks: fourier index (IFFT), the Rooted Mean Square Error (RMSE) and the frequencies magnitudes. The IFFT similarity metric is defined as in Eq. 1 and was introduced by []

$$C = \frac{(\sum_{i=1}^N F_{1i}F_{2i} - N\bar{F}_1\bar{F}_2)^2}{(\sum_{i=1}^N |F_{1i}|^2 - N\bar{F}_1^2)(\sum_{i=1}^N |F_{2i}|^2 - N\bar{F}_2^2)}, \quad (1)$$

where, for each frequency, an intensity value is calculated from the real and complex parts of fourier transform.  $F_{1i}$

represents the intensity value of  $i$ -th *pixel* in the first image and  $F_{2i}$  is the intensity value of  $i$ -th *pixel* in the second image.  $\bar{F}_1$  e  $\bar{F}_2$  are the mean frequencies in each image. The closer IFFT is to 1, the higher the similarity between the images. The frequencies spectrum is indeed useful to present the graphic of frequency magnitudes in the images. This approach makes possible distinguishing the frequency spectrum added by the proposed model. Additionally, the Root Mean Squared Error (RMSE), Eq. 2 is calculated in order to measure the global error in each pair of deblurred and high resolution images.

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (x_i - y_i)^2}{N}}, \quad (2)$$

The model architecture consists in two convolution layers, each one followed by one pooling layer and regularization layer. The second regularization layer is followed by a fully connected layer, which maps the convolution layer's output to 1024 neurons. The output model comprises a regression layer to predict the intensity value of each pixel.

## 4. Experiments

The proposed model aims to deblurr image representations of acoustic impedance. In this context, the model was first trained with a synthetic dataset. The dataset is composed by images representing two geological structures, in which one of them is in form of a

## 5. Conclusion

The conclusion goes here.

## Acknowledgments

The authors would like to thank...

## References

- [1] H. Kopka and P. W. Daly, *A Guide to L<sup>A</sup>T<sub>E</sub>X*, 3rd ed. Harlow, England: Addison-Wesley, 1999.
- [2] Xi Xiaoyu, Ling Yun, Sun Desheng, Guo Xiangyu, and Wang Huifeng, "Studying the effect of expanding low or high frequency on post-stack seismic inversion," in SEG Technical Program Expanded Abstracts 2012. September 2012, 1-5.
- [3] Buduma, N., "Fundamentals of Deep Learning," Academic Press, 2015, in O'Reilly Media.
- [4] Qian Feng, Yin Miao, Su Ming-Jun, Wang Yaojun, Hu Guangmin, "Seismic facies recognition based on prestack data using deep convolutional autoencoder,".
- [5] Liu Lihui, Lu Rong, Li Jianhai, Yang Wenkui, "Seismic Lithofacies Computation Method Based on Deep Learning," p. 649-652.
- [6] G. G. Chrysos, S. Zafeiriou, "Deep Face Deblurring," 2017 IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), Honolulu, HI, 2017, pp. 2015-2024.
- [7] Rebecca Buxton Latimer, Rick Davidson, Paul van Riel, "An interpreter's guide to understanding and working with seismic-derived acoustic impedance data," 2017, pp. 242-256, v. 19, num. 3, in The Leading Edge.
- [8] JJM. Buiting, M. Bacon, "Using geophysical, geological, and petrophysical data to characterize reservoirs in the North Sea," in 5th Conference on Petroleum Geology of NW Europe, London. CD-ROM.
- [9] Paul van Riel, "The past, present and future of quantitative reservoir characterization," in The Leading Edge, 19, p. 878881.
- [10] Sergio Sacani Sancevero, Armando Zaupa Remacre, Rodrigo de Souza Portugal, "O papel da inverso para a impedncia no processo de caracterizao ssmica de reservatrios," in Revista Brasileira de Geofísica, 2006, p. 495-512, v. 24.
- [11] O. Russakovsky, J. Deng, H. Su, J. Krause, S. Satheesh, S. Ma, Z. Huang, A. Karpathy, A. Khosla, M. Bernstein, "Imagenet large scale visual recognition challenge," in International Journal of Computer Vision (IJCV), p. 211252, 2015.
- [12] R. Girshick, "Fast r-cnn," In IEEE Proceedings of International Conference on Computer Vision (ICCV), pages 14401448, 2015.
- [13] S. Bell, C. L. Zitnick, K. Bala, and R. Girshick, "Inside-outside net: Detecting objects in context with skip pooling and recurrent neural networks," in arXiv preprint arXiv:1512.04143, 2015.s
- [14] H. Nam and B. Han, "Learning multi-domain convolutional neural networks for visual tracking," In IEEE Proceedings of International Conference on Computer Vision and Pattern Recognition (CVPR). IEEE, 2016.
- [15] K. He, X. Zhang, S. Ren, and J. Sun, "Deep residual learning for image recognition," In IEEE Proceedings of International Conference on Computer Vision and Pattern Recognition (CVPR). IEEE, 2016.
- [16] A. Levin, Y. Weiss, F. Durand, and W. T. Freeman. Understanding and evaluating blind deconvolution algorithms. In IEEE Proceedings of International Conference on Computer Vision and Pattern Recognition (CVPR), p. 19641971.
- [17] A. Krizhevsky, I. Sutskever, G. E. Hinton, "Imagenet classification with deep convolutional neural networks: Advances in neural information processing systems," 2012, p. 10971105.
- [18] S. Ji, W. Xu, M. Yang, K. Yu, 2013, "3d convolutional neural networks for human action recognition," in IEEE transactions on pattern analysis and machine intelligence, n. 35, p. 221231.
- [19] O. Abdel-Hamid, A.-r. Mohamed, H. Jiang, L. Deng, G. Penn, D. Yu, 2014, "Convolutional neural networks for speech recognition," in IEEE/ACM Transactions on audio, speech, and language processing, n. 22, p. 15331545.
- [20] S. S. Farfade, M. J. Saberian, L.-J. Li, 2015, "Multi-view face detection using deep convolutional neural networks," in Proceedings of the 5th ACM on International Conference on Multimedia Retrieval, ACM, p. 643650.
- [21] P. J. Harvey, D. J. MacDONALD, "Seismic modelling of porosity within the jurassic aged carbonate bank, offshore Nova Scotia," in Canadian Journal of Exploration Geophysics, n. 26, p. 5471.