PRE-STACK AND POST-STACK INVERSION USING A PHYSICS GUIDED CONVOLUTIONAL NEURAL NETWORK

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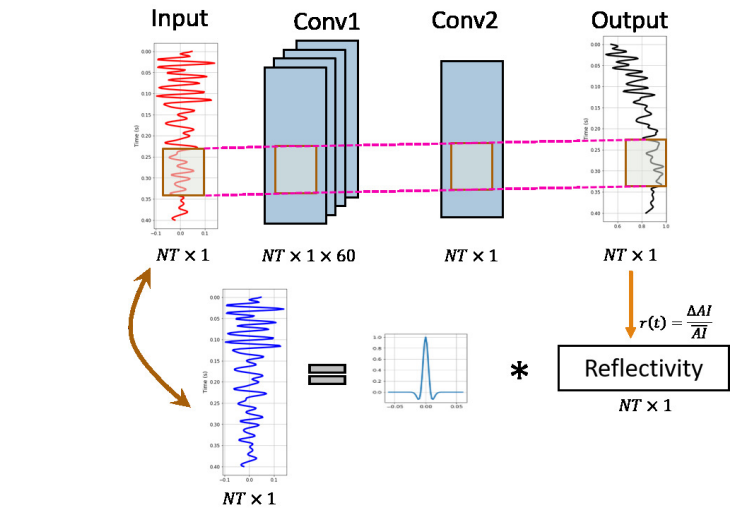
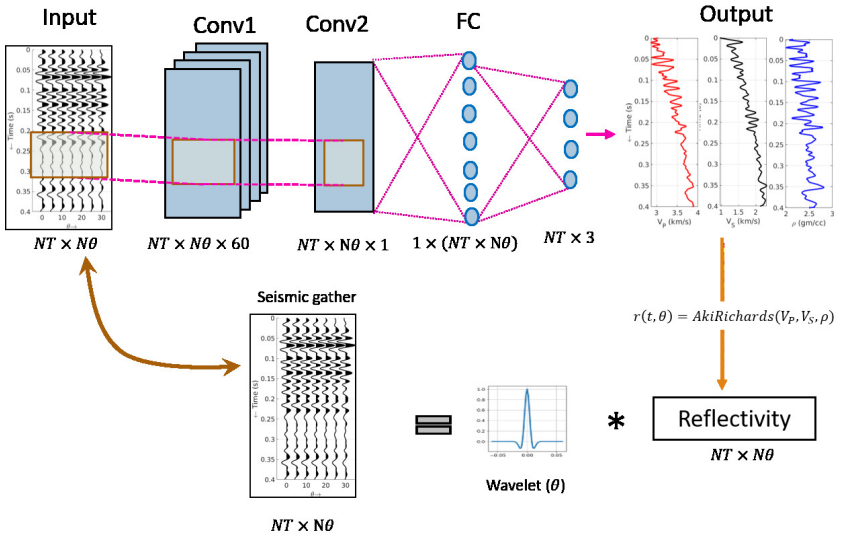
ABSTRACT

An inversion algorithm is commonly used to estimate the elastic properties like V_P, V_S, ρ of the earth's subsurface. Generally, the seismic inversion problem is solved using a traditional optimization algorithm. These algorithms start with a given model and update the model at each iteration, following a rule. It needs to be solved at each CDP separately to estimate the elastic parameters. We develop a novel technique using one of the increasingly popular Machine Learning tools, Convolution Neural Network (CNN), to solve the same problem. There are two critical steps we imposed to make the network work on our problem. Firstly, rather than using CNN as in a classification type of problem, we modify the CNN, to solve a regression problem and estimate the elastic properties. Secondly, unlike conventional CNN, which is trained by supervised learning with pre-determined solutions, we use the physics of our forward problem, to train the weights. The output of the CNN is used to generate the seismic data and then we compare the synthetic data with the actual data and calculate the error. This error between the seismograms is then used to update the weights in the CNN. After the network is trained, it can be used to estimate elastic properties at remaining CDPs directly without solving any forward or inverse propagation. We demonstrated our physics guided CNN on both pre-stack and post-stack inversion problem. To explain its working, we also showed it using a conventional CNN workflow without the physics guidance. We first implemented it on a synthetic data set for both pre-stack and post-stack and finally, applied to a real data set from Cana field. In all the training examples, we used a maximum of 20% of data. Our approach offers a distinct advantage over a conventional machine learning approach in that we circumvent the need for labeled datasets for training



(a)



(b)

Figure 1. Outline of the CNN architecture for physics-based a) post-stack inversion, used to estimate acoustic impedance from a given input seismic and finally the acoustic impedance is used to generate data by convolving the reflectivity with the wavelet; b) pre-stack inversion, used to estimate V_P, V_S, and ρ from a given input seismic angle gather and finally the estimated model is used to generate data by convolving the Aki-Richards reflectivity with the angle dependent wavelet. This calculated data is compared with the input data.