Review of

DeepISMNet: Three-Dimensional Implicit Structural Modeling with Convolutional Neural Network

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The manuscript is well-written, but needs additional editing to correct some grammatical errors.

Appropriate figures, but Fig 11 and 12 need to be enlarged. Annotation would help to refer the reader to the specific examples mentioned in text (I elaborate in the comments below)

I attempted to test the github code on a Windows operating system and had a few issues with conflicting dependencies with installed modules. In particular, I received open MPI errors:

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"OMP: Error #15: Initializing libiomp5md.dll, but found libiomp5md.dll already initialized."
```

In attempting to fix this, a number of other dependencies now no longer work.

Most figures appear before being cited in text.

Introduction

Line 26 Calcagno et al 2008 is a more appropriate reference than Guillen et al 2008. Guillen focusses on geophysics, not so much on structural modelling.

Line 28 “interpreting” should be “interpolating”?

Line 33 Please elaborate on what you mean by “empirical rules” – is this the tectonic history or topology (i.e. stratigraphy; fault-fault and fault-stratigraphy relationships)? See Calcagno et al 2008 for one example)

Line 33 “file observation” is “field observation”?

Line 37 – “or regional available” - this part of the sentence doesn’t make sense

Line 47 “DIS” should be “DSI”

Lines 56 – 69
The authors make some valid points. Also worth mentioning is implicit methods suffer with dense and clustered data points, which can be addressed through downsampling. The problem is that downsampling brings its own issues, such as how or whether to aggregate data points and what appropriate algorithms from which to produce representative inputs to implicit methods. I suppose this is what you describe Lines 128-130?
Line 61-62 Also look at Grose et al 2018; 2021 (10.1029/2017JB015177; 10.5194/GMD-14-3915-2021) for implicit methods that incorporate greater number of relevant structural data as constraints.

Line 70 -73
The authors need to explain how "past experiences" are relevant to structural modelling. What is 'example data"? Observations, or other models (in which case, not data). Providing examples would help here.

Line 74 "without defining a physical process". Implicit modelling doesn't require a description of a process, but geometrical and topological constraints. The resulting model geometries can be interpreted to represent some process, but that is not quite what is written here. Process models are an entirely different class to structural ones, at least in the context described earlier in the document.

Line 78 citation "Ioffe and Normalization" is Normalization really the name?

Line 88 You imply that GNNs being not repeatable is a problem… I assume this means that your method is? Perhaps state how your NN architecture is able to ensure repeatability (presumably because the parameters are not randomly initialised?)

Line 99 How is the scalar field produced? Automated model building (how?) Masking why? Many questions about where the rendering happens

Method

Skip connections are an important feature in your NN implementation. You need to explain how they work and why they are necessary so that the reader understands how they allow what appears to be multiscale modelling.

Line 168 What is "MAdds" referring to?

* Line 180. Inverse-distance weighting schemes are well-used in spatial stats, but just because it's consistent with traditional methods, doesn't mean it's appropriate. For example, what about in geological scenarios where there is a large shear zone separates one geological terrane from another? The data on each side of the shear zone may be spatially close, but may be quite distant contextually. So, the assumption of weighting on spatial proximity goes against some of your criticisms of existing methods in the introduction. It's a known drawback of other implicit geomodelling schemes. Justifying this assumption is important, and please provide supporting references. In fairness, this is quite a difficult

problem that I don't believe you're attempting to solve directly with this contribution, Nonetheless, it's worthwhile discussing as a potential limitation.

Line 190 provide references for which methods use MSE/MAE.
Line 204 provide references for SSIM
Line 210 the term G_sigma_g is missing from eq. 2? As is sigma_g
Lines 215 I see that sigma_g is a 'superparameter'. It may help to define this as a 'hyperparameter' to fit with ML semantic conventions, unless there is a specific reason you're using 'super'. If so please explain why 'super' and not 'hyper'.
Line 231 'artifacts' are old and interest physical objects from antiquity, 'artefacts' are unintended side-effects from numerical processes.

Line 231 – what is 'it' in the phrase "such as MAE to the MS-SSIM as *it* is only related to the values on a single point" the artefacts? Or the MAE… ?

Data preparation

Given how important the training data is for your procedure, you need to have at least a two or three sentences explaining the method of Wu et al 2020. Wu et al 2020 generates a training set using a CNN for your CNN… Both methods produce a scalar field from which to render geology – so it would be helpful to make clear how your approach differs.

Line 262. This is a question commonly asked, but needs to be addressed. How do you know 600 models is enough given the uncertainties of a result that you admit cannot be easily validated (L253)?

Implementation

Section 4.1 Training and validation

I understand the need for normalisation, but it's not clear how this is achieved on the entire model. Structural data, at least in most implicit schemes consists of contact observations (X,Y,Z coordinates, or U,V,W and a 'lithology' label with topology, usually a stratigraphic direction or polarity) and orientation data (X,Y,Z, type [contact orientation; fault orientiation; fold hinge; etc] a vector; usually expressed as dip direction/dip and the lithology it represents). How do you simultaneously normalise coordinates and vectors? What is method for normalisation e.g. min-max?

Lines 328-329 You do explain some of these metrics elsewhere in the manuscript, but not all e.g. R2S. You may think to supply these explanations as supplementary material.

Line 339 – 346 This paragraph belongs in the discussion.

Line 348-350. The context of this problem isn't clear. Annotate with what, and do other applications do this, but poorly, or not do it at all? What do you mean horizon values – it would seem that it is the iso-value from the scalar field (or fields, especially if considering faults..). Provide some examples with relevant citations.

Application

Section 5.1 Provide a sentence describing the geological scenario and location of study area #1.

2d case studies are simple and not a great test as the horizons are laterally contiuous being essentially flat. The fault displacements seem to be honoured, which is good. But existing model packages are very effective at producing models with similar simple geometry and topology.

Line 401 – how do you define complex geological settings here? Polydeformed beds? Domains with vastly different tectonic histories? Multiple magmatic intrusion and extrusion events? Overturned bedding?

Figs 11 and 12 have the necessary content, but are too small. Enlarge each panel in the figure, and use more space in the manuscript. Annotations would also help the reader, such as pointing out where the complex parts of the model are (see previous comment), where "the seismic reflections are partially ambiguous and difficult to be continuously tracked" and "results shown in Figure 11c demonstrate that our CNN architecture is beneficial for 3-D structural modeling by predicting a geologically valid model".

Discussion

Section 6.1 and Fig 13. I like the uncertainty analysis. One thing worth pointing out is that you deal with both aleatory uncertainty (uncertainties resulting from measurement error) and epistemic uncertainty (relating to missing knowledge or data) citing Pirot et al 2022 in GMD. You remove/add drill holes in your fig 13, which is a nice test, so it is worth highlight that point here, or at the very least in the figure caption.

Lines 484 – 487. This is good to acknowledge as modelling these types of structures realistically is challenging, however you can elaborate on why your method is unable to replicate them. I would think the type of geological object is arbitrary given the framework you developed. Is it not possible because the synthetic model generation of Wu et al 2020 cannot recreate unconformities and intrusions? A possible solution maybe to expand the training set to a wider range of objects? Another source could be the Noddyverse (Jessell et al .2022) where dykes, plugs and unconformities are represented. Perhaps you can comment in whether this would work of not. It could be that because you're using a scalar field in the tradition of Lajuanie et al 1997, in which intrusions and unconformities (as distinct from onlap relationships) have not yet been solved (at least to my knowledge).