Notes for bathymetry inversion using CNN-based surrogate model for SWEs solvers

Manuscript outline (how you will tell your story):

1. **Introduction**

Introduction section is for literature review, synthesis, critique, and propose. Everything in this section serves one purpose: why you want to do this work, and why your work is new or why yours is better.

* What is the topic? Why is it important? What specific problem to be solved in this work/outcontribution? Importance of bathymetry, difficulty to obtain accurate bathyemtry, inversion is an attractive approach.

List of references to be used here: xxx, xxx

* Previous work: who has done what using which approach? Their strength and weaknesses, which leads to our (better) approach.

List of references to be used here: some specific references that we want to discuss and comment on their strength and weaknesses; why our approach is different and/or better than theirs.

* Short review of commonalities in inversion problem, specialties in bathymetry inversion, such as existence, non-uniqueness, and stability.
* 2D SWEs solvers/models: physics-based models, including SRH-2D.

List of solvers to include and their references: xxx, xxx

* surrogate model to SWEs solvers: who has done what? what is new in this work.

List of previous surrogate model to SWEs solvers: xxx, xxx

* Based on above discussion, describe some specific problems or questions to be solved/answered in this work.

List of specific problems and questions: xxx, xxx

* One paragraph for the structure of this paper: methods, results, discussion, etc.

Use the template, such as: The rest of this paper is organized as follows.

1. **Methods**

Methods section is the place to describe in detail your methods, approaches, data source or methods of generation (tools, equipment, code, algorithm, etc)

* 1. Deep-learning-based surrogate model architecture
  2. Inversion algorithm
  3. Data generation and preprocessing
     1. SWEs solver
     2. Training bathymetry generation

1. **Results and discussions**

Results section should show your results in a logical and organized fashion. The results need to reflect what you promise to solve or answer in the “Introduction” section.

* 1. Performance of surrogate model
  2. Performance of bathymetry inversion
     1. Inversion result evaluation
     2. Inversion process analysis
  3. Effects of inversion regularization
  4. Inversion uncertainty
  5. Effects of CNN surrogate architecture

1. **Conclusion**

Summarize what you have done, your findings, conclusions, future work, etc. Don’t copy from the previous sections (need to re-word or synthesize).

Figures needed

The list of figures or tables that you need to populate the content of the manuscript. This list helps you organize your thoughts and story line.

1. Scheme diagram for CNN surrogate model (using Inkscape; done)
2. Modified ReLU for inversion loss of value and slope (done)
3. Example bathymetries (including one for the surrogate demonstration case, and others in the inversion case; four bathymetries should be enough; done)
4. Example CNN surrogate model result (use case 0145 in test dataset; done)
5. Training loss history (done) and inversion total loss histories (done).
6. Inversion results: general
   1. one plot to show all (individual + mean; done)
   2. error from truth metric (figure to show the band of profiles; done)
   3. inversion process for one case (inverted bed at different iterations; done)
7. Inversion results: effect of regularizations, how to determine the hyperparameters
   1. Compare inverted beds with or without value and slope (smoothness) regularizations (done)
   2. Compare bed profiles with or without regularizations (done)
8. Blocky nature of the initial inverted zb due to feature map size (done)
9. Effect of uncertainties in uv or uvWSE measurement
   1. Add 5% Gaussian error to do multiple inversions to calculate the uncertainty (done)
   2. The uncertainty could also come from the initial zb. Do the two reflect the same or not?
10. Effect of what to include in the loss calculation: uv only vs uvWSE (done)
    1. Does the including of WSE help the inversion in terms of accuracy, and inversion convergence speed?
    2. How about the CNN structure? For uvWSE, we have three outputs (u,v,WSE) vs. two outputs (u,v). Is it equivalent if we only use (u,v) out of the (u,vWSE) to do the inversion? This is relevant in practice because we are more likely to be given a trained surrogate model whose outputs are (u,v,WSE). But we only have (u,v) measurement data? Do we need to re-train the CNN surrogate model so it only outputs (u,v). Mathematically, the weights should be different (can we show this?) for the two CNNs even if we have the same set of training and validation data.
    3. What about CNN surrogate only outputs WSE? Or we only use WSE out of (u,v,WSE)?
11. Effect of subsample uv or uvWSE (seems subsample does not affect too much the inversion results. Could be due to the fact that the dataset is too small).
    1. In reality, no full field measurement data might be available. How do we use incomplete uv data?
12. A figure to show the Python package organization (dl4HM + pyHMT2D) (may be put into Appendix)