

## ***Interactive comment on “Semantic Description and Complete Computer Characterization of Structural Geological Models” by Xianglin Zhan et al.***

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Dear Prof. Wellmann,

On behalf of all the co-authors, I would like to express our sincere appreciation for your comprehensive, detailed, and constructive comments. I will first address main concerns you have and outline how we plan to address all the points. The detailed changes will be included in the revision. To facilitate discussion, I labelled your comments with numbered points.

1. Your comment: "Concerning the first point, many aspects of the included semantic

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description show a lot of similarity with the description in Thiele et al., 2016. Even though this paper is briefly referenced in the introduction, this similarity is not evident in the following own contribution in section 2. It is correct that the work of Thiele et al. focused on the topological analysis, but it also went beyond a pure description of topological relationships and included geological aspects. In the same way as this manuscript, the work in Thiele and al was motivated by the Egenhofer and Hering (1990) paper, and the semantic associations in Fig. 3 of this manuscript are identical to the ones described in Fig. 1 of Thiele et al. To be sure, the more detailed analysis of the 9-intersection model provided here adds interesting aspects, but the relevance of these aspects is not entirely clear (note that Thiele et al. also describe temporal relationships - so, in fact, what is implemented here with the definition of primary and secondary structures on page 13, lines 8 ff.). In the terminology of the authors, the description of Thiele and al. also includes “advanced semantic entities”.

Response: Thank you for your comprehensive and thorough comments. First of all, we highly value the contributions made by Thiele et al., and we strive to push forward with our own work on that basis. We had misunderstood the topology system proposed in Thiele et al. as a mere description of the topological relationships of geological bodies, ignoring the implicit semantic nature. We will correct our conclusion on this. We now realized the structural topology proposed by Thiele et al. can also semantically describe the construction model to a certain extent. However, we would argue that we still improved the completeness of description. For example, we explicitly added description of geometric shapes, included relationships between geometric elements of different dimensions, and our structural model is no longer segmented from a pure geometric perspective. We will definitely clarify the contribution made by Thiele et al. in our revision, and clearly specify both the relevance and differences between our work and Thiele’s work. As for the similarity between Fig. 1 of Thiele et al. and Fig. 3 of our manuscript, in our understanding, Fig. 1 of Thiele et al. emphasizes relative positional relations of two geometric elements of the same dimension, while Fig. 3 of ours emphasize the subordinate relationships between geometric elements

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from different dimensions. So we think these two figures differ in meanings and we will revise to make this clear.

2. Your comment: "Also, the authors only describe "primary" and "secondary" elements, but many geological systems are clearly affected by more than two tectonic events."

Response: "Primary" and "secondary" are derived from the concepts "primary structure" and "secondary structure". The primary tectonic events refer to all tectonic events that directly affect the existence of rock masses, while the secondary tectonic events refer to tectonic events that only deform rock masses. So the fact that elements are divided into primary and secondary does not imply that only two tectonic events have affected the geological system. We will revise to avoid this possible confusion.

3. Your comment: "The semantic description is then applied in a case study to evaluate how adding this information improves model construction. In this application study, it seems that the authors are applying the concepts mainly to overcome problems in the specific interpolation approach they are using. However, there are by now many modeling approaches that include aspects of geological reasoning (e.g. Calcagno et al., 2009; Mallet et al., 2004; see also our recent overview in Wellmann and Caumon, 2018 for more references), as well as "advanced semantic aspects" like unconformities, faults, intrusions, etc. This does not mean that the analysis of topology may not add very important aspects that these methods still do not consider, but it should be mentioned more clearly what exactly the authors aim to add."

Response: We truly appreciate such a detailed list of prior arts. We will study them thoroughly and acknowledge their contributions. We will clarify the improvement of our semantic description comparing to the topological analysis in the revision.

4. Your comment: "In my understanding, the main contribution in the case study is that the authors use semantic entities to quickly evaluate if a generated geological interpolation conforms to the expected setting. If my interpretation is correct, then it would be good to focus the case study on this aspect and to describe more clearly how

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the semantic relations are estimated from (independent?) data."

Response: Our semantic description does have the function of evaluating whether the model is consistent with settings. However, in this article we explain the practical application value of semantic description from the perspective of constraint modeling process. We hope that the structural modeling with semantic description constraints can directly achieve the certain expected result instead of evaluating after modeling is complete. The estimation of the semantic description is basically based on the expert's cognition of the raw data and the computer's estimation of the geometric topological relationships between two interfaces. We will take your suggestion to describe the potential of our semantic description on model check and give a more detailed description on how to estimate the semantic description.

5. Your comment: "In Part 3./ page 21, the authors only describe that this information is taken from seismic data - but if this is the case, then is this based on 2-D or 3-D seismic data? And if 2-D: how many lines, and how is it evaluated if the 2-D analysis is really representative of the 3-D topology?"

Response: Our basic data comes from structural interpretation of 3D seismic data. We will revise to make this clear.

6. Your comment: "In the section on model reconstruction (4.2), the semantic description is then used as a way to check model modifications - but it is not clear on which basis, for example, control points are added (line 22). Maybe a simple example would help here."

Response: Very helpful suggestion. Although the semantic description provides constraints on the wireframes of the structural model, the surface reconstruction algorithm itself is unconstrained. That is to say, the morphological details inside the surface boundaries are not completely constrained. When the surface is reconstructed, there may be cases where the topology and the semantic description becomes inconsistent due to the shape of the surface (e.g. the crossing between stratigraphic planes.), so we

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set this inspection step using the semantic description here. Only when such situation occurs does it become necessary to artificially add control points to correct the error in surface morphology. The control points are set based on the distance between the incorrect interpolation result and the correct interval specified by the semantic description. We will give some simple illustrations in the revision to show when the control points are needed and how to add them.

7. Your comment: " In section 5, the authors then describe their iterative approach of semantic evaluation and model construction. As stated before, this is a very interesting aspect in this paper. However, in the motivation of the approach, it is simply stated that existing modeling methods ignore these semantic aspects (page 31, line 5) - a statement that is (1) given without any references, and (2) not generally correct (see comments above). A clearer description of the own contribution would be helpful here, and a more detailed comparison to existing literature."

Response: As mentioned above, thanks to your comprehensive and detailed comments, we now recognize our lack of acknowledgement to existing geological semantic description researches. We will re-evaluate the contribution of these methods and add references. We also plan to give more simulation experiments to illustrate the innovation of our semantic description.

8. Your comment: "The organisation of the manuscript is overall clear, with the definition of the methods and the application in a case study. One aspect that should be adapted is the mixture between the "Methods" section 4 with the actual case study. It would be better to clearly separate both parts, or completely combine them into a section "Case study"."

Response: The purpose of Section 4 is to clarify how to extract our semantic description from structural models (Section 4.1) and prove the completeness of the semantic description (Section 4.2), while Section 5 focuses on how one can use the semantic description to solve practical modeling problems. The former one theoretically illus-

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trates the feasibility of extracting the semantic description and the completeness of the semantic description. The latter one explains the application value of semantic descriptions in practical applications. Therefore we intend to separate the two sections more thoroughly and clarify their focal points.

9. Your comment: "I personally found the detailed "workflow" descriptions in section 4.1.2 more confusing than valuable. Maybe a graphical representation in a workflow diagram would be better suited here."

Response: We will revise to make it clearer and more succinct, following your suggestion of using flowcharts.

10. Your comment: "Some parts would benefit from a more thorough proof-reading, with several (minor) grammatical mistakes and unclear sentences."

Response: We will make a more careful proofreading of the manuscript in the revision.

11. Your comment: "Some of the terminology in the section on the semantic elements is not consistent with commonly used terms in the field of structural geology - a thorough checking of these terms would be helpful."

Response: Thank you for pointing out our inaccuracy in the use of terms. We plan to correct the confusions of concepts and misuse of terms as you mentioned.

12. Your comment: "The figures are generally clear and helpful, but some information is a bit redundant (e.g. Fig. 17) and several figures could potentially be combined in fewer figures (the manuscript currently contains 20 figures)."

Response: Fig. 17 will be removed or replaced by a more useful and detailed figure to illustrate our idea about structural modeling. We also plan to follow your suggestion to combine unnecessary figures (e.g. Fig. 18 and Fig. 13).

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