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Review of the paper Egusphere-2024-1326
Consistency-Checking 3D Geological Models
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(Revised Version)

This revised version of the paper « Consistency-Checking 3D Geological Models » is similar to the former version in its broad lines. However, it provides detailed additional explanations about the nature of the « geo-objects » considered for geo-model evaluation, about their internal polarities and about the space, time and polarity relationships that are of interest for consistency checking. Echoing many remarks and questions of the reviewers of the former version (including myself), this new version also corrects several defects or ambiguities of the former text and better explains some of the choices made by the reviewers at the implementation level. Together with the extensive answer that the authors addressed to the reviewers, this new version allows a better understanding of the paper intention. In view of this, I will newly examine some key points of the paper.

1/ The nine "geo-objects" that are considered for consistency evaluation, were selected in view of their frequent presence within geo-models. They can be 3D material objects (geological units), 3D "immaterial objects" (folds) or immaterial objects of lower dimension (erosion or faut surfaces, lineations…). Age and space relationships are commonly considered between geological entities of different natures but the use of a parameter like "polarity" is less evident. The authors provide examples illustrating how "polarities" can be attached to the nine categories of geo-objects that they consider. But they do not provide a unique clear definition of polarity that would be valid in all these cases. For this reason, it had some difficulty in considering that a unique internal polarity parameter could be attached to these heterogeneous objects in order to define a general validation framework. However, when considering the extensive explanations and examples given by the authors, it appears that they call "internal polarity" a vector which indicates the direction in which a geological process has been progressing through time. This direction may be identified in material or immaterial geological objects (sedimentary stack, metamorphic isogrades, folds) or deduced from the very nature of some of these objects (erosion surface). Internal polarities can provide information about the courses of a majority of geological processes: earth material creation, mechanical erosion, matter transformation (metamorphism), geological volume deformation and displacement. This includes folding but possibly also faulting and thrusting since displacement vectors can be associated to the geological volumes separated by a fault or a thrust surface.

Geological surfaces like horizons or faults characterize key instants of the geological history of a given region or site. For this reason, they are considered essential for capturing the essence of geological events (Wellmann & Caumon, 2018). Accordingly, in the classical vision, geo-model consistency mainly relies on a correct interpretation of the age and topological relationships between geological surfaces. By introducing internal polarity as a third parameter, the authors notably extend the spatial and temporal fields available for geo-model evaluation. In the spatial dimension, not only geological surfaces but also volumes can be objects of interest since their local internal structure (stratification, sequential layering, basalt flow fracturing pattern successions etc.) can be used for determining local polarities. In the temporal space, this parameter can help tracing geological evolution continuously and not only at discrete instants. The evaluation methodology involving polarities that is proposed in the paper, can probably be applied to most of the geological entities presented in geo-models, including faults as long as they are not seen as isolated discontinuities but as parts of a dynamic system. In view of this, we may consider that the authors define indeed a novel interpretative framework.

It remains that, even in its new version, the text of the paper doesn't allow the reader to fully catch the full geological dimension of this novel approach. Erosion surfaces, individual elements of planar fabrics like metamorphic isogrades or sedimentary layer interfaces are all linked to some geologic process. An erosion surface materializes the ultimate stage of a rock matter destruction process, metamorphic isogrades materialize stages of rock volume burying process at depth, the ChronoBottom, the layer interfaces and the ChronoTop surfaces of a sedimentary unit materialize the beginning, the intermediate stages and the termination of a deposition process. All this would have deserved to be clearly exposed as well as the links which exist between the internal polarities attached to geological volumes, to geological surfaces and to fabrics, and also with the temporal polarities defined between meeting "geo-objects". All these parameters are related to a consistent geological whole. The paper redaction would be greatly improved if all this was exposed in a few lines together with a clearcut definition of polarity. This would help the reader realizing that what the author define is indeed a novel conceptual framework.

2/ The authors have made the risky choice of presenting in a single paper the broad lines of their geo-model evaluation method both at the theoretical and at the practical level. This choice is challenging for several reasons.

At the theoretical level, you must clearly define the polarity parameter which is at the heart of the proposed method at the geological level and also at the ontological level, since polarity is related both to material and immaterial "objects". At the ontological level, you should make a choice between various possible reference frames like GeoCore or GSO and give enough explanations about these tools to allow full understanding by readers who are not all familiar with the ontological reference that you have chosen.

At the implementation level, you must carefully choose the parts of the method that you will consider. The presented implementation should be kept simple in order to be easily understood but large enough for fully illustrating your approach. Simplifications are unescapable but you should carefully justify each of them for not being accused of oversimplifying the system.

Use cases have to be chosen for fully illustrating how the methodology can be used in practice. The authors have taken the risk of not only presenting synthetic cases but also real ones based on results provided by industrial geo-modelers currently in use. This is another challenge since it is not easy to identify significant industrial examples.

In its present version, the paper tries to fulfill a majority of these requirements. The careful analysis that I made of the theoretical background of the method shows that what is exposed still doesn't cover all the aspects of the subject but this can hardly be the case in a paper that intends to present all the broad aspects of a novel methodology both at the theoretical and at the practical level. The comments made by the of the former reviewers (including some “severe” critics that I made) and the discussion that followed, contributed, I think, to produce a better text. Any new adjustment operated by the authors to still improve this new version will probably be welcome. We could also go on having ping pong exchanges on such or such details of text with the hope of making the text optimal but the added value of such exchanges might be little compared with the interest of quickly presenting a novel approach that defines a new interesting framework for geo-model evaluation. In view of this, I consider, this new version is eligible even as it is, for a publication by the Geosphere Special issue: The Loop 3D stochastic geological modelling platform – development and application.