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Interactive comment on "Rapid, semi-automatic fracture and contact mapping for point clouds, images and geophysical data" *by* Samuel T. Thiele et al.

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In this article, Thiele and others present a newly-developed semi-automatic method to trace fractures and lithological contacts, which is demonstrated using a range of remote-sensed data. The article is well written, the methodological approach well-described and the case studies are presented in high-quality figures. However, fundamental concerns arose during reading the manuscript and testing the new GeoTrace plugin on a DEM. These major issues are presented in the following. I still think, though, that this is a good piece of methodological work and I can see the potential and advantage of this method which merits publication in Solid Earth provided major revisions of

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the manuscript are made in line with the comments and the suggested changes below.

With best regards, Thomas Scheiber

General comments

(I) Missing description of the manual extraction method

While the semi-automatic method is well-documented and is proven to be scale-dependent, the manual method is not explained at all. There is the need for a description on how the manual mapping was performed, since it is widely known that results obtained by manual extraction are strongly dependent on various factors (cf. e.g., Scheiber et al., 2015). Especially the scale during mapping and the fractal dimension of the dataset is of great importance for this study. The larger the scale, the more details will be recognized by the mapper and, as a consequence, the more turns/curves will a structural trace have. Larger scales would thus probably lead to more similar results of the manual extraction method compared to the new semi-automatic method. In this respect, a comparison of the data by closest-point difference calculation is problematic, unless it is clearly specified under which conditions (especially the fixed scale) the manual mapping was conducted.

(II) Comparison of data

A large part of the paper, especially the result section deals with the comparison of manually-extracted data and data derived from the new semi-automatic approach. The data are compared on the basis of digitization time, number of traces, mouse-clicks (Tab. 1) and by pixel distances between constructed lines (closest-point difference, cf. Figs.2, 4,5). In the case studies the authors state that the results obtained by the two different methods are "visually similar" , "broadly consistent", "very similar" and show "similar accuracies". These phrases are way too qualitative - what is "very similar", and what would "less similar" be then? Having a closer look, however, the results of the two methods appear "not similar" to me: traces in one interpretation are longer than in

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the other (i.e., they have different start and end points), there are traces drawn in one interpretation and are missing in the other, and there are traces which consist of two segments in one interpretation and appear as one trace in the other, and vice versa (see Figs. 2-5). It is not clear how the authors handled these mismatches, especially when applying a closest-point difference calculation (a description of this comparison technique is missing). The only sound comparison presented in the manuscript would be the one shown in Fig. 5f, where start- and endpoints of a previous manual interpretation are used to recalculate the structural traces using the new tool. However, in this example the authors chose to use a different (updated) base map [Sandwell and Smith (2009) in Fig. 5c versus Sandwell (2014) in Fig. 5d; p. 6, lines 27-31]. This complicates a comparison, because the resulting differences stem from both the different basemaps and the different extraction methods, and the influence of each of these variables cannot be quantified.

A proper comparison of manually- and semi-automatically produced datasets needs to fulfill the following requirements: (1) Different methods have to be tested on similar basemaps. (2) A thorough description of the fully manual method, especially by indicating the scale used while mapping is necessary. (3) The exactly same start and end point have to be used for each constructed trace. This is because the start- and end-point of the semi-automatic approach are defined manually as well! Thus it makes only sense to compare the actual traces (having the same start- to an endpoints) to figure out the differences of the fully-manual and your new method. As a consequence, the number of traces of the two opposing interpretations has to be the same. These requirements are not fulfilled in the presented case studies and should be considered when revising the manuscript. Digitization time and number mouse clicks will vary significantly between users, as correctly stated by the authors (p. 7, 30/31). So if a comparison based on these numbers is presented, it has to be clearly stated that the exercises were conducted by one and the same user.

(III) Practical application of the GeoTrace plugin

When installing the plugin (MS Windows), it would be much more user-friendly, if the installation would run automatically. Up to now users need to install and run several codes and files in python in order to make the plugin work (see detailed instructions for MS Windows users on https://github.com/lachlangrose/GeoTrace). There must be an easier, more user-friendly solution. I have tried to run the method on a .dem file and an ovr file. While it worked out well with the .dem file, I got error messages and couldn't use the plugin with the .ovr file.

"Fit planes", "Stereonet" and "Rose": I tested the tool by tracing straight and sharp bedrock lineaments, which correspond to subvertical fault and fracture zones. In case the "fit planes" box is activated, the columns called DIP and DIP_DIR in the attribute table are filled with calculated values for each trace. The values in these columns, however, appear to be incorrect: In the column DIP_DIR occur numbers which do not represent dip direction (they even include negative values), but these values appear to be arbitrary. For the dip (column DIP), I got values between 0 and 10 degrees, which is obviously wrong as well. This issue needs to be fixed and the methods used for the calculation of dip and dip direction need to be explained in the manuscript (or in the appendix). The tabs called "Stereoplot" and "Rose" allows for directly plotting the structural data. To make the tool more user-friendly, I suggest to predefine and fix the fields "Direction" and "Dip" to the columns DIP_DIR and DIP in both tabs. In both these tabs, it is not clear what the checkbox "Dip Direction" means and does. For the stereonet it needs to be indicated if the plot corresponds to lower/upper hemisphere and equal area/angle. And for the "Rose" tab, it has to be stated if the plot is number/area-weighted. In the manuscript, as it is now, no stereoplots and no rose diagrams produced by the GeoTrace tool are shown. The authors need to provide orientation data plotted in stereoplots and rose diagrams (produced by GeoTrace) for at least one case study to show the functionality and the full output spectrum of their tool.

Specific comments

page 1

Abstract

7-9: The first sentence of the abstract is far-fetched, especially when regarding the fact that mapping at this time concentrated on lithologies and lithological boundaries, not specifically structures. I therefore suggest to delete this sentence.

12: "...extract..." There is the need to add a sentence describing how your new extraction method practically works - you manually add a start and end point between which a connecting line is calculated, which can be manually tuned by adding additional points in between.

21: "The approach improves the objectivity and consistency..." Since start and end points are set manually, I don't really see how this method then improves objectivity

21: change "expert" to "user". This accounts for all places where "expert" is used in the manuscript. Not every user can be considered an expert.

23-24: "it... can quantify the agreement between datasets and interpretation." Unclear. What interpretation (manual or semi-automatic)? How is this practically done? - In the GeoTrace plugin, I couldn't find any tool to compare data - ?

Introduction

33: add e.g., to the references; refer only once to Bemis et al., 2014

35 and following: rephrase this sentence

page 2

1: something is missing between easy and to

11: remove "and contacts". Contacts are geological structures.

13: in brackets: name only the sort of data you used in your case studies.

Existing Methods

Add a short description of the fully manual method here as well and refer to its drawbacks regarding objectivity. Refer to Scheiber et al. (2015). Scheiber, T., O. Fredin, G. Viola, A. Jarna, D. Gasser, and R. Łapińska-Viola (2015):Manual extraction of bedrock lineaments from high-resolution LiDAR data: methodological bias and human perception, GFF, 137, 362-372, doi: 10.1080/11035897.2015.1085434.

16: write more specific: "outcrop structures" instead of "outcrops"

18/19: refer to more recent papers as well

33 onwards: explain the dimensions 3D versus 2.5D

35/36: what do you consider a simple topography? Be more precise.

page 3

2: refrain from using phrases such as "such as described above". Follow this suggestion throughout the manuscript.

4: use the more general term "fractures" instead of "joints"

Method

page 4

14: "DEM based plane fitting and orientation analysis" didn't work (see general comment III)

16: To demonstrate the capability of our new computer-assisted trace detection approach, ...

18: "established manual methods" - A thorough description of the manual method is of great importance as well: Who mapped? At which scale was the mapping performed (see general comment I)?

21: "plutonic diorites and tonalites" - either "plutonic rocks" or "diorites and dolerites" instead

28: use "fractures" instead of "joints" throughout

33: "Several sets of systematic and non-systematic joints..." if a joint/fracture is non-systematic, it doesn't belong to any set.

34: "cooling of the intrusion, subsequent deformation and recent unloading." Are these guesses? If not add references, otherwise remove it. What does "recent" mean in geological time scale? Be more precise.

page 5

1: "...accurate orientation measurement" - of what?

Results

14: "manual workflows" - the manual extraction method needs to be described for each case study.

18: "...compare and contrast the results of both manual and assisted interpretations..." The result sections dealing with comparison of the data have to be rephrased in line with newly obtained results (see general comment II). And the closest-point difference calculation needs to be explained in the method section.

29: remove "previously mentioned"

31-33: "The results are visually similar..." - see general comment II

page 6

1: "As in the previous example,..." Name it.

3: What does this difference in numbers of traces reflect? (see also comment to table 1 and general comment I and II)

8: "as a post processing step..." shorter: "after processing"

15: "fault scarps" In the LiDAR DEM (Fig. 4a) the interpreted fault scarps (Figs. 4b and

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c) are not visible at all. The slope map which was used for doing the interpretation has to be provided in Fig. 4.

27: Replace "described in" by "interpreted by"

33 onwards: Here it is unclear whether the errors refer to the 21% pixels located >5 pixels away. "the computed shortest-path ... would "detour" through..." Does this mean that you reduced these errors by adding control points to "guide" the trace? Clarify

36 "correct fracture zone" A fracture zone cannot be correct or incorrect. Change to for example "desired structural trace"

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Discussion

3: DEM: use plural: DEMs

6: "operates in co-operation" Rephrase

6/7: change to "user guidance"

8: if there is a firstly, there has to be somewhere a secondly as well

12: "improved consistency" Yes there is improved consistency, but it doesn't necessarily mean that it increases precision and that it is closer to reality. This remains a bit abstract unless a reference to the true (nature) pattern of the fractures is given.

30 "...manually interpret datasets using GeoTrace or Compass..." this is confusing. GeoTrace and Compass are semi-automatic tools. I suggest to use "manual" for the fully-manual extraction method and "semi-automatic" or "computer-assisted" for your new extraction tool consistently throughout the manuscript.

34/35 cf. general comment II

page 8

6: add "fully" to "automated"

Tables and Figures

Table 1:

Why do you get different numbers of traces for the manual and the assisted method? Is this due to different operators for each method? Or does this reflect different perception states of the same operator? What does the comparison in numbers tell us here? Cf. general comment II.

Figures 2-5 should be considered to get redrawn/rearranged according to the general comment II and the comments below.

Figure 2: North arrow is missing in both (a) and (b). Here you could add stereoplots and rosediagrams produced by GeoTrace (cf. general comment III).

Figure 3: North arrow is missing in both (a) and (b). What is the reason for the more consistent orientation estimates using the computer-assisted approach (Fig. 3f)? Is this an artefact of the computer-assisted approach? Is the larger spread in orientations in the manual-extracted dataset more realistic? What is closer to reality? See also comment to page 7, line 12. Discuss.

caption: get rid of the "similar results" (see general comment II).

Figure 4: North arrow is missing. Scale bar: show it from 0 to 1000m only, don't go to -250. What are the straight lines across the DEM? Roads or tractor tracks? Indicate. Show the map you used for extraction of structural traces. In the un-interpreted hillshaded DEM (Fig. 4a) I would not dare drawing any of the interpreted traces. Show the slope map, which was used to extract the traces.

Figure 5: Legend for 5a/b (bathymetry?) and for 5c/d (vertical gravity gradient) is missing. The original/uninterpreted data (basemap) needs to be shown for 5a/b. You did the mapping probably at larger scales? If yes, provide zoom-in maps showing

exemplary oceanic fracture zone and their interpretation. Indicate location of Fig. 6 in Fig. 5c or 5d.

caption: remove the last sentence (see general comment II)

Figure 5: Add scale and north arrow.

Technical corrections

page 6

1: "sea-stacks" - in other places written without hyphen. Be consistent.

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