Earth Surface Dynamics Discussions

Earth Surf. Dynam. Discuss., referee comment RC1
https://doi.org/10.5194/esurf-2021-103-RC1, 2022

Comment on esurf-2021-103

Roderik Lindenbergh (Referee)

Referee comment on "Full four-dimensional change analysis of topographic point cloud time series using Kalman filtering" by Lukas Winiwarter et al., Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2021-103-RC1, 2022

Review comments by Roderik Lindenbergh and Mieke Kuschnerus for

Full 4D Change Analysis of Topographic Point Cloud Time Series using Kalman Filtering

Short summary

This manuscript considers how changes can be extracted from near-continuous time series of laser scan data. To overcome the problem of missing epochs, and to incorporate measurement uncertainty, time series at each of many so-called core points are approximated using a Kalman filter approach. This approach has the advantage that it provides a way to interpolate the time series to moments when no data is available, and that error propagation is well defined. Given the full time series at many core points, different features, like moment of first significant or maximal change can be extracted. Time series can now also be clustered by grouping points with similar features. The developed approaches are demonstrated on a time series of ~70 consecutive point cloud of an area affected by rockfall undergoing earth moving work.

Major remarks

Our advice is: Major Revision

The presented work contains a lot of interesting ideas and visualizations and is definitely pushing information extraction from time series of 3D data a good step forward. Especially the processing steps of spatial smoothing (M3C2-EP) in combination with temporal smoothing (Kalman filter) to generate regularly sampled, smooth time series are very innovative. These smoothed time series could be used for a variety of applications and in combination with many other methods. Here the authors choose to use feature extraction and clustering to find regions of similar deformation behavior. The explanation of these last two steps lacks focus and should be concentrated on one (maximal two) sets of features and one clustering method. A separate section of the results should then deal with the comparison to other methods.

Some major comments:

- The Kalman filter is one way of interpolating a time series. Directly related is Kriging, which aims at assessing and exploiting spatial and/or temporal correlation. Kriging also enables error propagation. Time series could also be approximated using Fourier or B-Spline polynomials. This could be better discussed in the Intro (as it is related work).
- In your Kalman filter implementation you use three parameters, location, velocity and acceleration. First it should be clearly stated somewhere that you use these parameters to model change in the vertical direction (right?). That said, using velocity and acceleration to model change at a location that changes due to digging is not directly intuitive to me, as such change would better modeled as a step function, please comment. Or more general, how should instantaneous change be incorporated in your setup? And do you really need acceleration as a third parameter, would location and velocity not provide similar results in an easier way?
- I find Figure 1 difficult to understand at first sight, would be good to also include a photo or point cloud colored by height as a fist impression of the site.
- Sect. 2.5, from line 263 onwards and Sect. 2.6: Looks like you are trying many different methods at once. Why not choose one clear method of (1) pre-processing (2) uncertainties with M3C2-EP (3) smoothed time series with Kalman filter (4) feature extraction (5) clustering. Where you choose one set of (most relevant) features for the clustering. In my understanding the main goal of this paper is not to compare different features and/or clustering algorithms but to introduce the two previous steps and highlight the improvements that they yield during clustering. Possibly also add the workflow chart as shown in the readme file that comes with your code on Github. The comparison with clustering on unfiltered time series and without feature detection can then be part of the discussion
- It would be good if some or all of the features in Tables 1 to 4 could be illustrated on 2 two 3 example time series (e.g. RTS-SE-0.5) of representative locations, one in the excavation area, one in a rockfall gully and some third one.
- Results section and Figures 4-8: some subsections are needed here to make it more accessible. The first part deals with the results of processing steps 1-4. From line 300 it goes into feature extraction and comparison/visualization of different features. As mentioned above: better focus on one set of features. Then a subsection called 'comparison' is needed. Here it should be clear, what is 'your own presented method' and what other methods do you compare with. I would suggest to only compare end results and not different steps in between. Make a selection out of Figures 4 to 8 and show the most relevant results.
- P14, Fig 7 is hardly discussed, discuss if relevant, or omit the figure.

Minor remarks

- The testing framework you mention in the 3rd paragraph of Ch.1 we applied to two-epoch TLS data iDeformation Analysis of a bored tunnel by means of Terrestrial Laser Scanning, Rinske van Gosliga, Roderik Lindenbergh and Norbert Pfeifer, IASPRS Volume XXXVI, Part 5, Dresden 25-27 September 2006
- For significant change extraction, also the terrain roughness could be incorporated as a variance value, compare *Kraus, K., Karel, W., Briese, C., & Mandlburger, G. (2006). Local accuracy measures for digital terrain models. The Photogrammetric Record, 21(116), 342-354*
- In Figure 2, the velocity and accelaration could also be omitted, (or shown once, in a separate image) as the graphs have a lot of details now.
- Line 90: data set from 2020
- *Line 97: not clear what kind of comparison is meant here. Comparison of uncertainty estimation, clustering approach or change detection in general?*
- Figure 1: caption discusses II and III, but these are not in the figure. No reference to Fig. 1b in the text, suggested to add to section 2.3
- Line 124: 'methods […] are based on a part of recorded data […]' -> Methods are applied to the data, tested on the data, or similar.
- Line 133 – 139: part of 2.3? not clear why it is mentioned here before M3C2-EP has been introduced.
- Sect. 2.4: not explicitly mentioned in the text what are t and x_t
- p8, r205: what exactly is the "uncertainty in point cloud distance obtained by M3C2-EP?
- P8r227: no variance of position in null epoch: would it not be more realistic to involve a measurement error?
- Figure 2: where is the example core point located in the area? You could mark the location in Figure 1, so it is visible what kind of change to expect.
- From Section 2.4 it was no clear to me why RTS was discussed, later I found out that this was actually used to obtain (additional) results, this could be better announced.
- Is the last series of features (last paragraph of Section 2.5) necessary for this paper? In my opinion these could be omitted and focus could be on the features in Tables 1 to 4.
- Figure 3b: red points (only bitemporal change) are difficult to see and it is a bit confusing that the borders of the area have the same color.
- Caption Fig.4: -> "At grey points no significant change could be detected'
- Caption Fig. 5: 'residuals: between what and what?
- P16: "Fig 8 depicts a bird's eye view": this is the same view as all the other figures, and is not focusing on the lower part of the slope: wrong figure?
- P16: there is no 'II' in Fig.1.
- P16: I could not find Fig. 8c unfortunately
- P19: "Recovered velocities and accelerations": I would use the word "estimated"
- P19: what do you mean by "manually extracted features"? I though all work was automated?