Expert interviews about the use of visually depicted uncertainty for analysis of remotely sensed land cover change

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Abstract. Change analysis based on remote sensing data typically involves a high degree of uncertainty. Past research has shown that ignoring this fact can lead to questionable or unusable results. Although methods exist to describe and communicate geodata uncertainty the incorporation of uncertainty into analyses remains a challenge. We developed a concept to facilitate the use of uncertainty in change analyses including a change uncertainty measure, a technique to visualize uncertainty, and a software prototype for change analysis following a geovisual analytics approach. To discuss the practical use of the concept and identify its benefits and limitations we conducted semi-structured interviews with three expert groups conducting change analysis in different application fields: climate research, urban development, and vegetation monitoring. This paper discusses the methodology, summarizes preliminary results, and highlights first lessons learned from the interviews.

Keywords: uncertainty visualization; change analysis; reasoning; interview

1 Background

Analyses based on remote sensing (RS) data typically deal with a high degree of uncertainty and past research has shown that ignoring this fact can lead to questionable or unusable results (Zhang and Goodchild 2002). Especially in the field of land cover change analysis the high degree of uncertainty often makes it difficult to derive reliable information (Pontius Jr and Lippitt 2008). Although methods exist to describe and communicate geodata uncertainty the incorporation of uncertainty into change analysis remains a challenge.

That is why we developed a concept to facilitate the use of uncertainty in change analyses including a measure for uncertainty in change, a technique to visualize uncertainty (Kinkeldey et al. 2013), and a software prototype for change analysis following a geovisual analytics approach (Kinkeldey 2014). Although the concept has already been discussed with experts during development we saw the need for final discussions about its potential. The overall goal was to make the concept more tangi-
ble by exploring uncertainty in specific change scenarios with the software prototype as a fundament for discussion. In the remainder of the paper we report on the methodology we used for the interview, followed by a summary of preliminary results. The last chapter provides lessons learned and concludes the findings.

2 Methodology

The goal of this research was to discuss the concept for uncertainty-aware change analysis with experts, in particular if they would be able to use it in their work and what they think the benefits and limitations were. For this, we conducted three semi-structured interviews with different expert groups dealing with remote sensing change analysis. The core ideas were to use a working software prototype during discussion to explore uncertainty in land cover change and, instead of using example data, implementing change datasets the interviewees had already worked on. To recruit participants we contacted a number of groups dealing with change analysis (German institutions only to keep travel costs low). In the end we found three groups with two to four experts who were interested and willing to take part in the interview. The groups’ main fields of expertise were climate research, urban earth observation, and vegetation monitoring.

2.1 Software prototype and data

We developed a software prototype for change analysis (ICchange) as proof of concept and as vehicle for discussions (Kinkeldey 2014). It provides two views, a map view and an abstract overview on occurring changes (“info view”), to support land cover change analysis through visual feedback and filtering functionality (Figure 1). Uncertainty is displayed in the map using noise annotation lines, an extrinsic technique to portray uncertainty in maps with complex geometry (Kinkeldey et al. 2013).

We did not let the participants operate the software but told them to give us instructions what to do with the software. This idea is adapted from pair analytics that involves a visual analytics expert operating the tool and a subject matter expert posing the questions (Arias-Hernandez et al. 2011). The plan was to ensure that the discussion stays focused on the contents and does not evoke discussions about the usability of the prototype which had already been assessed before.

Instead of using a uniform sample dataset we integrated change data provided by each expert group into the prototype. Our hypothesis was that it would be easier for the participants to discuss the concept based on data they know without the risk of the data being unrealistic and/or idealized. Together with the fact that they did not have to operate the software themselves we did not see the need for a training phase. The change scenarios we used were the following:

- Change scenario 1 (climate research group, Potsdam Institute for climate impact research, Potsdam, Germany): Change of informal settlements in Hyderabad, India
between 2003 and 2010 from high-resolution optical satellite imagery (Quickbird, WorldView).

- **Change scenario 2** (urban earth observation group, German Aerospace Center, Munich, Germany): Urban development (change in urban areas) for Shanghai, China, in 1987, 1995, and 2004 from low resolution optical satellite data (Landsat TM).

- **Change scenario 3** (vegetation monitoring group, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany): Vegetation change in a post-mining area in central Germany from high-resolution hyperspectral data (HyMap).

![Fig. 1. Software prototype ICchange. Map view (left) representing change by green color and uncertainty by noise annotation lines and info view (right) with supplementary information on occurring changes and slider for filtering by uncertainty.](image)

## 2.2 Interviews

The interviews were conducted as group interviews and had five parts: an introduction clarified the concept and the software prototype, showing a different change dataset (and not yet the data for the discussion) to focus on the functionality of the tool first. The actual discussion was started with questions about the role of uncertainty in the specific dataset. We asked them about insights they had gained from the data and if and how the uncertainty display could help to confirm, reject or modify these insights. After that we wanted to know their opinion on the use of uncertainty in change analysis from a more general view, i.e., not connected to the presented dataset but also thinking about other data and scenarios they are dealing with. Subsequently, we
discussed the software prototype and noise annotation lines, the technique we used to display uncertainty in the map, because at this point they had already gained experience with both during the discussion. In the last section the interviewees could provide free comments. The division of the discussion into sections was not strict but served as a rough guideline. We recorded the discussion with two separate voice recorders (notebook and smartphone) and transcribed the recordings in a written form. The transcriptions did not include every detail because in this case it was more important what the participants expressed and not so much how they made their statements and how they interacted.

3 Preliminary results

The aspect that all groups agreed to was that generally, uncertainty shown in the map can help find interesting regions of change and no-change, e.g., areas where the detection of informal settlements was uncertain and thus manual correction of the classification may be necessary. All participants found the abstract overview of mean uncertainty in the change info view helpful to get an overview on what change types were more reliable than others. The spatially varying depiction of uncertainty in the map was seen as a clear advantage to commonly used class-specific quality measures that only provide one quality value per change type and do not show its spatial distribution. An application that all groups were interested in was to use uncertainty for the optimization of change detection parameters to improve change data quality.

Regarding reasoning with uncertainty two of the three groups were convinced that uncertainty portrayal can be of great help in the way that knowledge about uncertainty can make better informed reasoning possible. For instance, they could imagine that when reporting insights from the data they may express higher confidence with changes that are deemed more certain and express doubts they may have with interpretations of more uncertain changes.

All experts agreed that generally, visualization is a powerful means to communicate change uncertainty. But the question if uncertainty should be communicated to users, e.g., decision makers, was seen in different ways. The members of the climate research group were convinced that people who make decisions based on the data should see the uncertainty (“they need the information what is certain and what is uncertain”). The other two groups were skeptical how this information would be received by users. On the one hand they doubted that decision makers would be able to effectively use “soft” information and on the other hand they were concerned their data could be seen as inferior. However, all groups agreed that this question depends on the role and expertise of the users.

Most experts were interested in using the prototype to try out what we discussed. However, for their daily work they suggested to integrate it as a plugin into standard GIS (ArcGIS, QGIS). Some participants suggested minor improvements to the tool.

Regarding the noise annotation lines technique all participants expressed a positive opinion and found it very useful. Most experts quickly identified the advantages of the technique, e.g., that maps still could be shown using colors that are familiar to
them. At the same time some participants recognized possible limitations, e.g., low readability with a bright background.

4 Lessons learned and conclusion

The first lesson we learned is that semi-structured interviews were a good choice for our purpose. Since uncertainty is a fuzzy concept and includes various aspects (modeling, quantification, communication, etc.) discussions can digress very easily. The method helped focusing the discussion on the utility of uncertainty in change analysis without too much digression towards other topics such as issues with the software tool. At the same time the loose structure did not prevent people from discussing freely and expressing their opinions and ideas.

Using existing change scenarios resulted in additional effort because the groups had to provide us with suitable data and questions such as legal issues had to be clarified. But the fact that the interviewees already had worked on the data and could analyze the uncertainty of the data in the software tool prevented the discussion from becoming too theoretical and made it easier for them to imagine how they could use uncertainty for their work. However, in some cases it could still make sense to conduct a training session before the interview to brush up the knowledge about the data set.

The fact that we operated the software prototype and not the interviewees themselves helped keeping the focus of the discussion on the subject and away from details of the usability of the tool. We can recommend this strategy to avoid that topics such as the usability of the tool become the main focus.

We noticed that it was easier for most participants to imagine the use of uncertainty for technical purposes, e.g., for calibration of change detection algorithms or quality assessment of the data. Making suggestions how to use uncertainty for reasoning with the data seemed more difficult for them. For the future we recommend to develop a strategy to support them regarding this issue, e.g., in preparing a list of insights they had gained about the data before the interview and not during discussion.

All in all, we can state that the methodology we used here met our requirements and, for our purpose, was more suitable than focus groups or pair analytics that have different goals. For the future, further studies of this kind are recommended to understand what analysts really need to integrate information on geodata uncertainty into their work.

References
