Closing the "Uncertainty Chain": Enhancing Trust by Communicating Uncertainty Information in Maps

Jochen Schiewe*, Martin K.W. Schweer**

* HafenCity University Hamburg, Lab for Geoinformatics and Geovisualization – jochen.schiewe@hcu-hamburg.de
** University of Vechta, Chair for Pedagogical Psychology, Centre for Trust Research – martin.schweer@uni-vechta.de

Abstract. While usability testing nowadays is a standard procedure in the workflow of map design and production, user experience (UX) issues are hardly treated. This contribution picks out trust as being one of the central UX factors. Trust is always necessary if there are any risks or uncertainties in data, a task, or a decision. With that the interesting question arises whether the communication of uncertainty information to a (map) user leads to the impression of a risk reduction and an increase of trust, respectively. Based on a general framework that summarizes trust cues in the context of map usage, we present previous work as well as results of own preliminary surveys that investigate the relationship of uncertainty and trust in more depth.

Keywords: User Experience, Trust, Uncertainty, Map Design

1. Introduction

It is well known that various geometric, thematic or temporal uncertainties come along with spatial data and information. So far most of the previous work in the domains of GI Science and Cartography has concentrated on modeling and visualization of this type of information. For selective tasks it has already been proved that the actual usage of uncertainty information (i.e., the existence of a closed *uncertainty chain*) leads to qualitatively improved decisions with respect to economic, ecological or other criteria; for instance, for the prediction of flooded areas and derived evacuation measures.

On the other hand, the step of actually using cartographically communicated uncertainty information and its linkage to the previous processing steps has not been investigated very intensively so far. In this context, usability parameters play an important role. Going even further, disciplines like cognition psychology and human-computer-interaction also emphasize aspects of user experience which deals with those perceptions and reactions of persons that might occur prior or during the usage of a product. Of course, a positive user experience is strongly correlated with a good usability. But besides that there are also a couple of "soft" factors like aesthetics, emotionality, anticipation or trust.

In this contribution, the central user experience factor *trust* will be picked out and investigated in a systematic and empirical manner. Trust is always necessary if there are any risks or uncertainties in data, a task or a decision. With the existence and knowledge of uncertainties in the given spatial data the very interesting – and so far not addressed – research question arises whether the visualization of uncertainty information really is a trust improving feature (which corresponds to our working hypothesis), or, alternatively, leads to a reduction in trust and – as a worst case scenario – to no further use of the current map.

2. Fundamentals of Trust

In the face of ever changing environments and globalized processes trust on interpersonal and systemic levels represents a basal resource for the ability to orient oneself and to act. In this context the complexity reducing function of trust is of major importance, because in terms of forward-looking expectations upcoming events can be anticipated or excluded, respectively (e.g., Endreß 2002). Therefore, experienced trust also leads to a gradual abandonment of control, a perceived risk is compensated psychologically, and central needs for safety are met (e.g., Luhmann 2009; Schweer 2008; Schweer & Thies 2008). Thus, the notion of trust is currently omnipresent when it comes to handling and acceptance of uncertainties (e.g., Slovic 2000).

Basically we have to differentiate between (inter-)personal and systemic (subject-related) trust (Earle et al. 2007; Ebert 2007; Schweer 2008). *Personal trust* is referred to concrete interaction between partners while *systemic trust* is directed towards the viability of social systems. However, both trust types cannot be treated independently from each other because their representatives are potential trust objects and carriers of trustworthiness at the same time (Schweer & Thies 2005).

Previous work in the context of *object trust* – for example: trust in maps – is quite rare (Ebert 2007). Quite often trust in objects is referred back to involved persons (*person-like entities*). Although object trust is correlated with personal and systemic trust, it is treated as a distinct type because specific features of the different objects significantly influence the development of trust.

3. Previous Work on Trust in Maps

Since a couple of years trust aspects play an important role in web design and human-computer-interaction. Particularly, in commercial applications like eCommerce or online advertisements trust between customers and vendors is an essential component for the achievement of goals. Development of trust is a long-term process which can be supported by a number of activities like linkage to quality seals, professional design or simple access to conditions of use and fees (Nielsen 1999).

Focusing on the specific case of object trust related to geo data and information only little research has been undertaken. Harvey (2006) deals with the exchange of geo data between administrative offices and follows the hypothesis that trust building is enabled through free access of data; however, empirical evidence for this statement is not given. Bishr & Kuhn (2007) emphasize the importance of trust for the interaction in social networks like for user generated content on platforms like *OpenStreetMap (OSM)*. They postulate a strong correlation between trust in actors on the one hand, and data quality on the other hand. The authors also stress the spatio-temporal component which is introduced by the proved local knowledge of data producers.

Skarlatidou et al. (2011) assume a limited understanding of lay users of a web-based GIS. At the same time the high complexity of geo data and interfaces lead to an increased risk for an inappropriate usage – and with that the increased need for trust. The authors identify a couple of trust attributes which are all focused on the object Web-GIS, for instance,

- perceptual properties (like reputation of source),
- functional properties (like aesthetics, professional navigation, or regular updates), and
- properties that determine the initial contact.

Furthermore, some aspects of “good design“ in terms of trustworthiness are given (such as a large map frame). The authors also state that there is more

trust in paper compared to online maps. However, the empirical evidence for all these statements is based on a rather small sample size (N=25) only.

What is still missing, is a consideration of the object "map" as such (and not in combination with a Web-GIS or similar). Furthermore, the usage for a concrete task has not been taken into consideration. Also personal parameters like demographic variables, media affinity or experiences have not been investigated in depth.

4. Framework

In order to summarize and to structure the trust phenomenon in the context of maps we have developed a general framework that is based on the so-called dynamic-transactional paradigm (Schiewe & Schweer 2013). This framework (see figure 1) contains the above outlined trust components user (person), map (object) and task/context (situation). To these components the various *trust cues* are attached which have been derived mainly from literature (e.g., Egger 2011; Skarlatidou et al. 2011).

In order to understand the importance and interplay of uncertainty and others factors we have already performed an empirical study in form of guideline based interviews (Schiewe & Schweer 2013). Only a small number of participants (N=12) was selected because we did not aim at quantitative but overall and general statements yet. The interviews of 20 to 30 minutes length were recorded, transcribed and finally analyzed. The following core statements could be derived:

- The *source* (the branding, respectively) of a map has a leading influence on the trust assessment.
- The *up-to-datedness* of a map is also relevant; however, very often this is assumed without any reflection (in particular, with online maps).
- There is quite an ambivalent evaluation concerning the relevance of *map design* on trustworthiness. On the one hand, statements like "a map shall appear in a professional manner" are given; on the other hand, concrete design cues are hardly mentioned.
- Surprisingly, *situational aspects* seem to have a minor impact on the trust building process. For example, none of the test persons uses different maps and usage approaches for private or professional cases, respectively. However, in the context of travel planning purposes a usage of manifold maps is preferred.

- With respect to *personal parameters* only the preference of (and probably a larger trust in) different map media could be observed: While people in the age of 20 to 50 years prefer smartphones and internet maps, older people still go with paper maps.

Currently we are setting up selected application scenarios and design quantitative studies using a reasonable number of participants in order to further specify these first results.

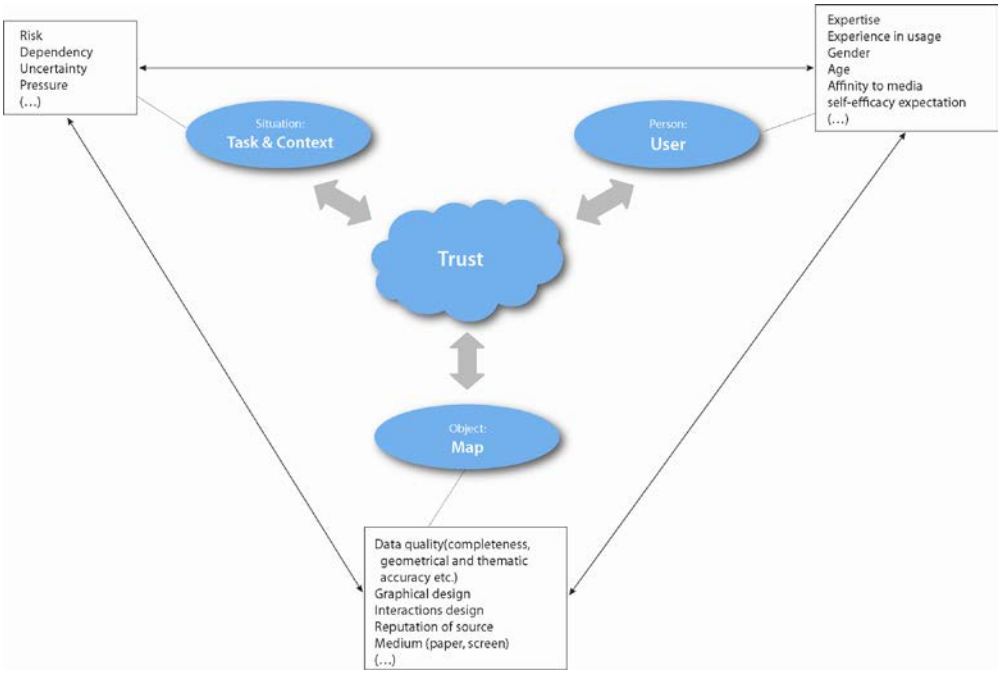

Figure 1. Dynamic-transactional paradigm for describing trust phenomena in the context of map usage.

5. Uncertainty and Trust

Risk is generated through uncertainties of data, information, processes etc. Because uncertainty and trust are reciprocal to each other, the interesting question arises whether the communication of uncertainty information to a

(map) user leads to the impression of a risk reduction and with that to the increase of trust.

Obviously we are dealing with map applications which are not that "risky" (for example, by choosing the shortest route for holiday traveling purposes), but also with those that form the basis for critical decision processes (for example, in the context of a natural disaster management). Obviously, in the latter case a huge trust in displayed information is mandatory. The postulated relationship between uncertainty and trust – stating an increase of trust through the communication of uncertainty – is illustrated in figure 2.

Figure 2. Postulated relationship between uncertainty and trust.

So far most of the work related to uncertainties in geo data and information has been concentrated on modeling and visualization aspects (for example, Pang 2001; Schiewe 2010; Kinkeldey & Schiewe 2012; MacEachren et al. 2012). In these cases the target groups are experts. In contrast, Grira et al. (2006) focus on the process of user generated data (like in *OpenStreetMap*) where users and producers of data are quite often identical (thus, called *prosumers*). Here the modeling and communication of uncertainty handling does not follow pre-defined or default procedures so that respective information are hardly shared. Of course, this interrupts the above mentioned *uncertainty chain* and prevents from an increase in trust.

Few contributions have already stated that the communication of uncertainties can lead to qualitatively improved decisions with respect to economic, ecological and other aspects – for example in predicting flooded areas and follow-up evacuation measures (Aerts et al. 2003; Deitrick & Edsall 2006; Harrower 2004).

From our experiences (Schiewe & Schweer 2013) visualization of uncertainties in connection with the use of maps is generally welcome by map users. On the other hand, there are only few examples in daily experiences which display uncertainty information (with or without maps; rf. to figure 3) so that this type of information is not well-known. With that not only expecta-

tions of users, but also a thorough empirical proof of the actual usage and the proposed improved decision making process become quite difficult.

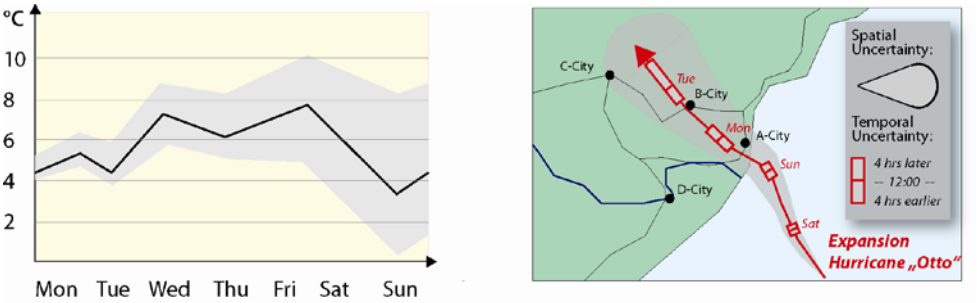

Figure 3. Fictitious examples for visualizing uncertainties in daily applications – left: attribute uncertainties (temperature corridor); right: spatio-temporal uncertainties (expansion phenomena).

In another study (Schiewe 2013) we concentrated on uncertainty processing through *prosumers*, namely those of *OpenStreetMap* data. Obviously, those data are coming from a huge number of different and unknown sources, leading to a heterogeneous distribution of uncertainty which generally leads to a reduced trust impression of potential users. On the other hand it is well accepted that the number of people that actively work with data at certain places improves data quality (also known as *collective intelligence* or *Linus' Law*); however, how and whether this principle actually works for this application has not been proved so far.

In order to overcome this gap we performed an online survey, interviewing 192 *OpenStreetMap* mappers in Germany. This survey revealed that *OSM* mappers show a rather high degree of awareness of uncertainty problems. Important uncertainty items are – not surprisingly – completeness and up-to-datedness, while – mostly due to missing pre-knowledge in the domains of geodesy and GIS – less attention is paid for various aspects of geometrical and thematic accuracies. Currently there is the option to use *OpenStreetBugs*, a separate website where errors in *OSM* can be marked. This option is quite appreciated (90 % of *OSM* mappers know it, 80 % of them have used it already), but 69 % of those mappers that have used it also wish an option that gives even more in-depth information – an indirect indication of importance of uncertainty information which can also lead to an increase in acceptance and trust in *OSM* data.

Of course, a crucial point is the generation and communication of uncertainty information to *prosumers*. Classical metadata catalogues known from official data are not feasible here. Instead, a well-structured and formalized input procedure for uncertainty information is needed due to the heterogeneous understanding of and knowledge about uncertainty. With respect to visualization we did a little experiment where we presented a visualization concept that distinguishes on the hand between uncertainty estimation made by the original producer and follow-up users, and between geometric and attribute accuracies on the other hand. Even considering the fact that we omitted a legend by purpose (in order to indirectly test intuitiveness), the correctness of specific answers in the order of 60 % is definitively too low. This leads to the conclusion that in the next steps of our work we have to develop simple (in particular, iconic), attractive and scalable methods, including the option for free text input.

More generally, this survey showed that trust building measures in the context of user generated content are definitively needed; however, the more technical pre-requisites (i.e., the modeling and visualization steps) are still unsolved problems and lead to an open *uncertainty chain*. This example once more shows the complexity of trust enhancing measures, in particular, the dependency of various personal and systemic factors as expressed in our above outlined framework.

6. Conclusions

In this contribution we stressed the importance of a closed *uncertainty chain* – expressing the whole process of modeling, communicating (mostly, visualizing) and actually using uncertainty information. Because uncertainty and trust are reciprocal to each other, implementing this concept is necessary in order to create the impression of a risk reduction and an increase of trust, respectively.

With respect to different user groups the implementation status of such an *uncertainty chain* is quite different. For expert systems various examples exist; however, a thorough empirical evaluation of the actual usage and the effect on trust is still missing. For *prosumers* (indicating, that producers and users are often the same persons in the context of user generated data) the situation is much more complex: On the one hand, there is a higher need for uncertainty communication in order to generate missing trust, on the other hand the modeling and visualization steps are far away from being mature or standardized.

References

Aerts, JC, Clarke, KC & Keuper, AD (2003) Testing Popular Visualization Techniques for Representing Model Uncertainty. Cartography and Geographic Information Science, 30 (3): 249-261.

Bishr, M & Kuhn, W (2007) Geospatial Information Bottom-Up: A Matter of Trust and Semantics. In: Fabrikant, S.I. & Wachowicz, M. (Eds.): The European Information Society: Leading the Way with Geo-information, Lecture Notes in Geoinformation and Cartography, Springer.

Deitrick, S & Edsall, R (2006) The Influence of Uncertainty Visualization on Decision Making: An Empirical Evaluation. In: Progress in Spatial Data Handling, Springer Berlin Heidelberg: 719-738.

Earle, T , Siegrist, M & Gutscher, H (2007) Trust, risk perception, and the TCC model of cooperation. In M. Siegrist, T. C. Earle & H. Gutscher (Hrsg.), Trust in Cooperative Risk Management. London: Earthscan: 1-49.

Ebert, TAE (2007) Interdisciplinary trust meta-analysis. Online unter http://epub.ub.uni-muenchen.de/1388/1/20070613_LMU_ Disskussionsbeitraege_ Trust.pdf (05.04.2011).

Egger, FN (2001) Affective design of e-commerce user interface: how to maximize perceived trustworthiness. In: M. Helander, H.M. Khalid & M.P. Tham (Eds.), Proceedings of CAHD2001: Conference on Affective Human Factors Design, 27–29 June Singapore. Singapore: ASEAN Press: 317–324.

Endreß, M (2002) Vertrauen. Bielefeld: Transcript.

Grira, J, Bédard, Y & Roche, S (2009) Spatial data uncertainty in the VGI world: Going from consumer to producer. Geomatica, 64(1): 61-71.

Harrower, M (2004) Representing Uncertainty: Does it Help People Make Better Decisions? In: UCGIS Workshop: Geospatial Visualization and Knowledge Discovery Workshop. http://www.geography.wisc.edu/harrower/pdf/ uncertainty.pdf. (20.12.2012)

Harvey, F (2006) Status Functions, Collective Intentionality: Matters of Trust for Geospatial Information Sharing. In: Raubal et al. (Eds.): GIScience 2006, LCNS 4197: 145-152.

Kinkeldey, C & Schiewe, J (2012) Visualisierung thematischer Unsicherheiten mit "Noise Annotation Lines". Kartographische Nachrichten, 62(5): 241-249.

Luhmann, N (2009) Vertrauen: ein Mechanismus zur Reduktion sozialer Komplexität (4th edition). UTB, Stuttgart.

MacEachren, AM, Roth, RE, O'Brien, J, Li, B, Swingley, D & Gahegan, M (2012) Visual Semiotics & Uncertainty Visualization: An Empirical Study. IEEE Transactions on Visualization and Computer Graphics. 18(12): 2496-2505.

Nielsen, J (1999) Trust or Bust: Communicating Trustworthiness in Web Design. useit.com-Alertbox.

Pang, A (2001) Visualizing Uncertainty in Geo-spatial Data. In: Proceedings of the Workshop on the Intersections between Geospatial Information and Information Technology.

Schiewe, J (2010) Einsatz von Methoden zur interaktiven Visualisierung und Analyse von Unsicherheiten bei der Auswertung von Geodaten. GIS.SCIENCE, 23 (1): 26-33.

Schiewe, J (2013) Improving collective intelligence and exploration in a VGI like context through communication of uncertainty information. Presentation at GeoVIz_Hamburg 2013, Marc 6, 2013.

Schiewe, J & Schweer, M (2013): Vertrauen im Rahmen der Nutzung von Karten. Kartographische Nachrichten (accepted, tob e published in 63(2).

Schweer, M (2008) Vertrauen im Klassenzimmer. In: Schweer, M. (Ed.) Lehrer-Schüler-Interaktion. Pädagogisch-psychologische Aspekte des Lehrens und Lernens in der Schule (2nd edition). VS Verlag, Wiesbaden, pp. 547-565.

Schweer, M. & Thies, B. (2005) Vertrauen durch Glaubwürdigkeit - Möglichkeiten zur (Wieder-)Gewinnung von Vertrauen aus psychologischer Sicht. In B. Dernbach & M. Meyer (Hrsg.), Glaubwürdigkeit: eine Frage des Vertrauens. Wiesbaden: VS: 47-63.

Schweer, M & Thies, B (2008) Vertrauen. In: Auhagen, A.E. (Ed.) Positive Psychologie. Anleitung zum „besseren“ Leben (2nd edition). Beltz, Weinheim, pp. 136-149.

Skarlatidou, A, Haklay, M & Cheng, T (2011) Trust in Web GIS: the role of trustee attributes in the design of trustworthy Web GIS applications. International Journal of Geographical Information Science: 1-18.

Slovic, P (Ed.) (2000) The Perception of Risk. Earthscan, London.