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Content zooming and exploration for mobile maps

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Abstract

In the context of the development of mobile map applications with capabilities for map generalization and abstraction, we propose a *methodology for content exploration* that uses *content zooming* as a technique to change the degree of abstraction of map content independently of the map scale. We concentrate on „foreground data" (rather than the base map, or map background), and more precisely on POI data and thus on point generalisation. Content zooming provides the user with the capability to change the *amount* and the *granularity* of foreground information presented, while keeping the geometric map scale the same. Content zooming allows overriding the effects of 'standard' map generalisation, focusing on optimised content representation to aid the information seeking task of a mobile user. It is thus complementary to map generalisation. Three cases of content zooming operations are distinguished: two cases apply changes to the amount of foreground data presented, while the third case changes the granularity of the foreground data. The paper defines these cases and proposes technical solutions for each of these, illustrating them with examples from a research prototype.
Keywords: mobile maps, mobile applications, point generalisation, content zooming, LBS, POI, mobile services

1 Introduction

The development of map applications for mobile services, such as location-based services (LBS), provides the context of this research. One of the key challenges in comparison with paper maps stems from the limitation of the screen size, especially for the display of overview information. Following Shneiderman´s 'Visual Information Seeking Mantra' [17] "overview first, zoom and filter, then details-on-demand", the starting point of an orientation and navigation task is typically the overview perspective. Only then is additional and more detailed information displayed for specific areas.

In a mobile map application, the user is confronted with different tasks during the exploration of space related problems. He/she has to get a grasp of *what* can be found on the map and *where* it is located. The question of *where* is primarily answered with the help of the base map (or background map), which provides spatial reference for the foreground objects, such as points of interest (POI), highlighted routes or selected areas. Information on the *what* focuses on the foreground. Conventionally, the assumption in map generalisation is that the level of detail (LOD) of the map background and foreground should always correspond, and thus change in synchronicity across scales. However, depending on the usage scenario, mobile users may want to override the rules of classical map generalisation, adapting the content representation to the given information seeking task.

In this paper, we thus propose a *methodology for content exploration* that allows *decoupling spatial navigation and content navigation* as far as needed. Changes to the map content as a consequence of spatial zooming (called 'standard zooming' here) keep focusing on changes of the LOD, as known from classical map generalisation. Additionally, tools are made available that enable content related zooming and thus support an individual adaptation of foreground data, allowing to override the effects of standard zooming. In this operation termed *content zooming*, the user can decide how much (foreground) content will be shown, and how detailed it is represented, independently of the selected map scale and map extent.

2 State of the Art

Related work that is relevant for this paper has been accomplished in map generalisation, visualisation and interaction techniques, and cognitive research related to LBS.

2.1 Real-time point data generalisation

Operational web and mobile mapping services, such as Google Maps, Bing Maps, or OpenStreetMap (OSM) and associated 'renderers' such as Mapnik and Osmarenderer, provide seemingly 'continuous' zooming and generalisation. Map generalisation, however, does not occur in real-time. Instead, map tiles are styled and pre-generalised offline and cached at many levels of detail; at run-time, map tiles only need to be retrieved from the cache for the proper LOD. Also, these map services focus on the base map, not the foreground data. The foreground data (e.g. POIs), are usually rendered in real-time by a different service. As our focus is on the portrayal of (point) foreground data, we focus our review on real-time, or on-the-fly, point data generalisation.

Detailed reviews of real-time generalisation algorithms can be found, for instance, in [1,12,13,19]. According to these sources, existing real-time methods either rely on precomputation and storage in hierarchical data structures, or on generalisation algorithms that are sufficiently efficient (and often simple) so they can achieve real-time performance. Point data generalisation algorithms of the latter category include ones for selection, simplification, aggregation, typification and displacement of point sets. Of these, algorithms for typification and displacement tend to be more costly and hence are often avoided in a real-time environment. Finally, besides the above generalisation algorithms that manipulate directly the point objects (e.g. by aggregating or displacing points), alternative approaches have been proposed that manipulate and deform the map space (e.g. fisheye transformations), similar to the approach used in focus-plus-context techniques in visualisation [7].

2.2 Visualisation and interaction techniques

In an LBS the portrayal of map content is limited to a small screen. To provide the user with the capability of interacting with the map in spite of restricted screen real estate, different approaches were suggested in the LBS and HCI literature.

Shneiderman [17] proposed a guideline for visual design quoted in the introduction. He states that for a visual design to be successful, the interface should support the following tasks: overview, zoom, filter, details-on-demand, relate, history, and extract. In the case of LBS most of the tasks are incorporated, especially panning and zooming.

Map Content – for the selected map extent – is often too voluminous to be visualised with the desired degree of detail on a single screen, which is especially true for maps on a mobile device. This raises a challenge which cannot solely be solved by providing appropriate generalisation of the map content: How can both context *and* detail be integrated simultaneously into the portrayal of map content? In the literature on 'focus-plus-context' (also known as detail-in-context), this question is addressed and different solutions are provided. The basic idea of focus+context techniques is to show selected regions of interest in greater detail, while preserving the overall context, avoiding occlusion. One of the earliest known focus+context visualisations is the fisheye view proposed by Furnas in 1982 [7].

[21] promoted focus maps for LBS to ease map reading, stating that focus+context representations ease map reading in that they focus a user's attention on the area of a map that is of interest to him/her. Several focus+context visualisation techniques were proposed for LBS, such as [8,20]. [9] present focus+context displays in a different context, for scatter plots. Nevertheless, focusing in on an area of interest, showing it at greater zoom level invariably causes distortion, making the visualization not necessarily easy to interpret.

2.3 Cognitive and user oriented approaches

[5] propose a cognition-based approach, positing that the more zoom levels a map has the more inconvenient and complex map reading becomes. They propose, similarly to [16], to reduce the number of zoom levels for the user to receive the required information. Furthermore, they implemented progressive visualisation that provides asynchronously further details on a specific map scale in an attempt to ease map reading.

Assigning relevance to geographic objects in LBS is addressed by [15], who define geographic relevance (GR) as a quality – the relevance – of an entity in geographic space and a given context that extends beyond location (e.g. user characteristics). As geographic entities are situated in space, they are spatially organised and related to one another. Therefore, [15] argue and demonstrate that users do consider spatial relations between objects such as co-location as being important. Given the limited space available for this paper, we assume relevance to be static and furnished as input for a particular query by an external relevance ranking algorithm.

In summary, what is still missing is the capability for the user to adapt the portrayal of the content to his/her needs, *overriding* the proposed 'standard' generalisation solution to *add or reduce* foreground objects independently of map scale, and thus get better support in solving his/her information seeking task. In the following, we propose *content zooming* and exploration as a methodology providing this desired functionality.

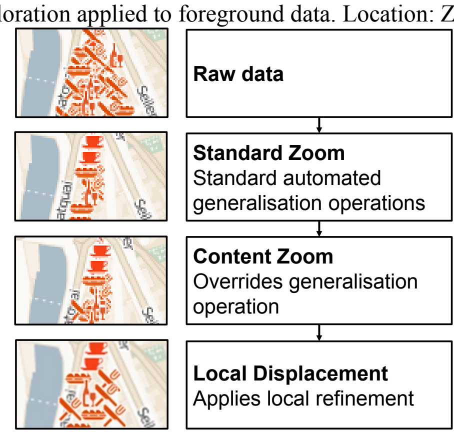
3 Methods

Content zooming and exploration varies the degree of detail on a map without changing the extent. It changes the degree of abstraction on a map of a specific scale and is not meant as the cartographic optimisation of a map such as the application of a displacement operator.

Content zooming implements two aspects: The change of the *amount* of foreground objects, that is, the number of foreground objects displayed for a given LOD; and the change of the *granularity* (see 4.6), referring to how detailed, how dense the represented information is, spatial and thematic terms. This relates to *filtering* and *details on demand* in [17].

The presented methodology consists of three steps, with an increasing degree of sophistication of ***display refinement***. These are: standard zoom (1), content zoom (2) and local displacement (3) (Figure 1).

Figure 1: Schematic flow chart for content zooming and exploration applied to foreground data. Location: Zurich



Source: Base map © 2012 CloudMade – map data CC BY SA 2012 OpenStreetMap.org. Map icons CC BY SA Nicolas Mollet mapicons.nicolasmollet.com.

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The general flow of Figure 1 is as follows:

1. Standard zoom: A user would typically first zoom to the desired location using the selected extent as spatial reference. This step called 'standard zoom' denotes the *traditional generalisation* operations for the current scale at which the map is being represented. Generalisation operations such as selection, simplification and aggregation are mainly applied.

2. Content zoom: In the second step the user adjusts the content of (1) to his/her needs. 'Content zooming' enables the user to override the result of standard zooming, and add more (as in Figure 1) or less foreground objects than recommended by the previous generalisation operations.

3. Local displacement: Finally, the user may request resolution of overlaps resulting from content zooming in (2).

In addition to the above three steps, our methodology also distinguishes between three cases (columns in Figure 2) that differ in the level of sophistication of the ***generalisation strategies*** applied, and thus in how they impact on content zooming and exploration. These cases illustrate how semantic and spatial generalisation are handled in content zooming. The division into three cases does not exclude any combination between them, which is of course possible.

Case A: Is based on predefined scale ranges over which particular feature classes are displayed (such as in the Mapnik renderer of OSM).

Case B: Denotes generalisation operations (selection) based on ranking, making use of a relevance or similarity measure associated with POIs.

Case C: Denotes semantic and spatial hierarchies, based on aggregation or typification operators.

In the following, the three cases are presented and their application in content zooming and exploration is illustrated in combination with the three types of zoom operations.

3.1 Case A – generalisation with predefined LODs

A1. Many mapping applications support the representation of POIs dependent on scale ranges using visibility rules. With the standard zoom the POIs are shown only at large scales, while hidden at smaller scales to prevent cluttering. The definition of scale ranges of visibility per feature class has been proposed [4], and [3].

A2. Content zoom gives the user the flexibility to extend the scale range where POIs are shown. Hence, the number of POIs can be increased, effectively widening the scale range at which a particular class of POIs is shown. Conversely, the number of POIs displayed can be reduced, narrowing the valid scale band (see 4.2).

A3. If the number of foreground objects was reduced in content zoom, then most probably the legibility constraints are satisfied. Conversely, if content zoom was used to increase the amount of information, POIs are likely to overlap. To remove overlaps, local displacement can be applied automatically such as the radial displacement algorithm by [11]. This type of conflict resolution is applicable only for relatively small overlaps. Alternatively, other generalisation operations have to be applied as well (see case B and C).

3.2 Case B – generalisation based on ranking

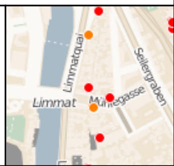
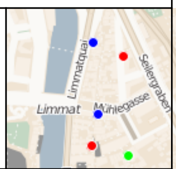
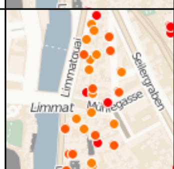
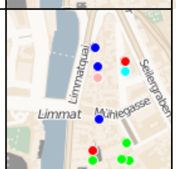
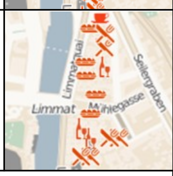
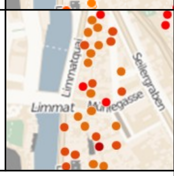
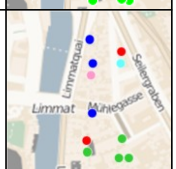
B1. This case considers the generalisation of individual POIs based on semantic ranking criteria such as relevance or similarity measures [14,15]. The amount of information represented can be made dependent on a threshold for the ranking (e.g. show POIs with 80% relevance) or on a fixed number based on the screen size and resolution (e.g. show the 20 most relevant POIs), or based on the 'radical law' of generalisation [18].

We define three types of ranking: *Static semantic ranking*, measures of similarity between different POI elements, ranking based on user communities, or ranking based on

Figure 2: Overview of generalisation approach for content exploration and zooming

Degree of sophistication of generalisation strategies →

Degree of sophistication of display refinement ↓

	A Generalisation based on predefined range of scales		**B** Generalisation based on ranking		**C** Generalisation based on semantic and hierarchical data structures	
1. Standard Zoom	POIs are shown upon a predefined range of scales		Semantic ranking criteria inform the selection operator		Semantic or spatial hierarchy inform aggregation or typification	
2. Content Zoom	Display features on a wider or narrower range of scale than predefined		Display more or less features based on their ranking than predefined		Changes the spatial or semantic granularity of representation	
3. Local Displacement	Check for spatial conflict and apply displacement operator		Check for spatial conflict and use semantically weighted displacement		Check for spatial conflict, applying the spatial data structure for displacement	
	Restaurant Pub	Fast food Cafe	1.0 2.0	3.0 4.0	Regional Mediterranean Japanese	Fast food Asian

simple values such as price. Second, there is *dynamic semantic ranking*, depending on the user and the context. Third, *spatial ranking* considers spatial dependencies and spatial patterns (e.g. co-location of objects, such as an ATM in the vicinity of a restaurant and close to a public transport station). To visualise the ranking of POIs a colour ramp, or changes of saturation work best, displaying the 'most important' as 'most salient' w.r.t. colour and contrast [6].

B2. Content zoom will override these thresholds and allow for a more or less dense portrayal of POIs per LOD. Thus, content zoom provides a simple analysis tool for the identification of POIs according to their ranking (see 4.3).

B3. Spatial conflict that might occur as a consequence of the previously applied step can be resolved by a semantically weighted displacement. Higher ranked POIs retain their position, while lower ranked POIs get displaced. If in the content zoom of B2 the number of POIs was increased, this will have caused lower ranked POIs to become visible, making them candidates for displacement.

3.3 Case C – generalisation based on semantic and spatial hierarchies

C1. While Case A was based on predefined point (sub)sets per LOD, and Case B was based on relatively simple selection operations using precomputed ranking measures, Case C introduces aggregation and typification operations, which are more complex. Generalisation based on aggregation or typification allows aggregating multiple POIs, representing them by one POI (representative) with a modified position. These operations can be aided by hierarchical spatial data structures such as quadtree or k-d tree, or semantic data structures, e.g. dendrogram [2]. Standard zooming will by definition result in a representation without spatial conflicts.

C2. Content zoom may be applied to change the spatial granularity of the foreground data in the map (for details on granularity see 4.6).

C3. In case of conflicts, displacement can be executed based on the existing hierarchical spatial data structures in a fast way, exploiting the inherently stored knowledge on proximity.

4 Prototype / Implementation

4.1 Development environment and data

The prototype was implemented in a development environment using Java and Processing, which is with some changes transferable to the mobile Android Platform.

The foreground data originate from OSM POI data for the City of Zurich, and OSM data for the background layer using a customised soft-toned map style from CloudMade to improve the contrast. The POI dataset features several categories, of which a subset was extracted for the use case shown in the following section.

4.2 User interface

The user interface for the content zooming prototype consists of a background map providing the spatial reference, and POI data displayed as point symbols in the foreground. Map user interaction is implemented with a standard pan and zoom interface. The content zoom is represented as a 'slider' which allows overriding — by adding or removing POIs — the spatial zoom (i.e. generalisation) for the current map extent (Figure 3). The user can choose from a range of generalisation algorithms, depending on the theme and purpose of the map.

4.3 Use case

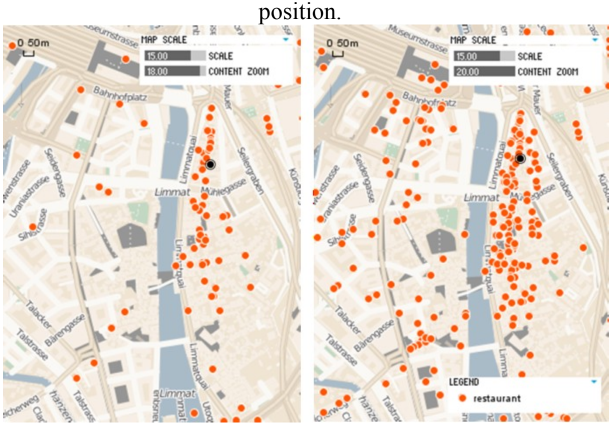
Below, a use case will be employed to illustrate how content zooming and exploration works for the three Cases defined above, and in which application areas it may be usefully applied. The use case envisions a tourist visiting the (unfamiliar) city of Zurich, looking for a place to eat. Note that local displacement (step 3) is not demonstrated in separate illustrations, for the sake of brevity.

4.4 Case A: Implementing generalisation based on predefined LODs

First, we present content zooming based on predefined LODs (Case A). It is the most basic application of content zooming. *The use case pictures a hungry, American tourist named Tom, who looks for an overview of eating places the city of Zurich. His mobile mapping application presents, for the extent and zoom level selected, a predefined set of categories of places to eat (Figure 3 left, A1), which leaves him however clueless about the actual spatial distribution of places to eat. With the content zoom he adjusts the amount of displayed POIs to a smaller scale to see all places to eat available in his area (Figure 3 right, A2), and figures that in Niederdorf his stomach may not be left unsatisfied.*

In Case A, POI data of a certain category (i.e. places to eat) are shown only up to a predefined LOD. Content zooming enables the user to over- or underpopulate the predefined point set, to obtain the information he requires. If spatial zooming (A1) did not include any sort of generalisation, content zooming empowers the user to reduce the amount of information to the desired level. Finally, local displacement helps in both cases to resolve spatial conflicts emerging from the user interaction (A3).

Figure 3: Places to eat in Zurich with and without generalisation of POIs (left vs. right). The black dot denotes Tom's position.



Source: Base map © 2012 CloudMade – map data CC BY SA 2012 OpenStreetMap.org.

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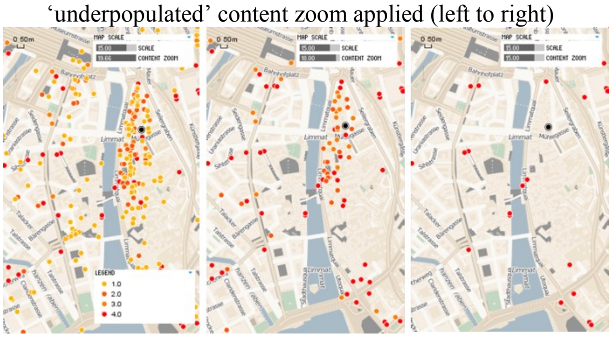
4.5 Case B: Implementing generalisation based on ranking

This case denotes the application of generalisation based on ranking and the resulting potential for the application of content zoom. Tom got overwhelmed by the vast amount of places to eat presented and requests a ranked set of eating places that are recommended. The result for his request (Figure 4 middle, B1) is a ranked generalisation commensurate with the selected zoom level, where the rank is shown in graduated colours.

Tom wants to know where clusters of good places to eat are located in the vicinity of each other. He thus applies content zooming to show more results than originally suggested (Figure 4 left; B2). Conversely, if he only wanted to see some of the best suggestions he simply reduces the amount of POI displayed (Figure 4 right; also B2).

Content zooming maintains the frame of reference and provides the user with the possibility to fine-tune the ranked generalisation results to his needs.

Figure 4: Ranked POIs. 'overpopulated' vs. default vs. 'underpopulated' content zoom applied (left to right)



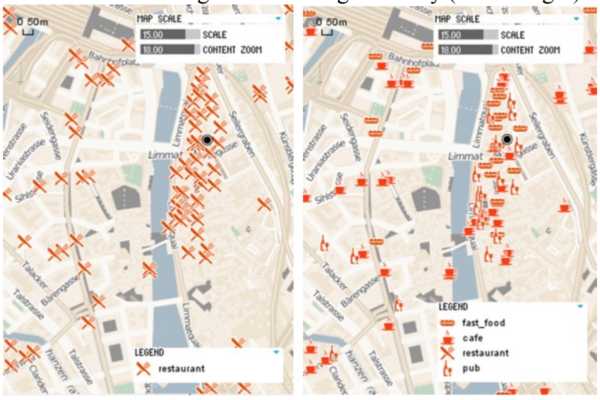
Source: Base map © 2012 CloudMade – map data CC BY SA 2012 OpenStreetMap.org.

4.6 Case C: Implementing generalisation based on semantic and spatial hierarchies

In Case C a distinction is made between two types of hierarchical generalisation, relating to semantic granularity and spatial granularity (i.e. density), respectively, and thus two scenarios are presented. *Semantic granularity* denotes the degree of classification detail of categorical data, for instance, representing a coarse-grained classification of 'places to eat' vs. a fine-grained classification of cafés, pubs, fast food, restaurants etc., or different types of cuisine. Conversely, *spatial granularity* denotes the density of elements displayed and varied by generalisation operators.

While Tom figured out that all highly recommended places to eat are not nearby, he got really terribly hungry, and can't wait longer. The next map he tries shows possible locations (Figure 5 left, case C1), but not of what type of eating place they are. Content zooming allows him to increase the semantic granularity (Figure 5 right, case C2) and provides him with the necessary information to select a place nearby where he can grab some fast food instead of haute cuisine.

Figure 5: Content zooming changes semantic granularity of POIs. Lower vs. higher semantic granularity (left vs. right)

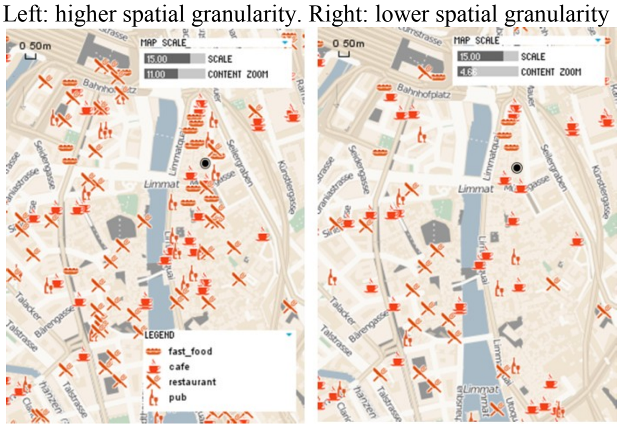


Source: Base map © 2012 CloudMade – map data CC BY SA 2012 OpenStreetMap.org. Map icons CC BY SA Nicolas Mollet mapicons.nicolasmollet.com.

Depending on the applied generalisation parameters and constraint settings employed (set by the user or the system), the foreground POIs may have been spatially aggregated or typified such as in Figure 6 (left, case C1), based on semantic hierarchies or based on density and co-location represented in hierarchical spatial data structures such as quadtrees or k-d trees [4] [2]. In such a case, applying content zooming will provide the user with the capacity to comprehend the underlying generalisation process (Figure 6b left). Furthermore, generalisation algorithms based on spatial distribution, such as aggregation using quadtrees, tend to retain more POIs [2]. So, the user may want to apply content zooming to reduce that load, effectively reducing the spatial granularity, while maintaining the spatial distribution.

Tom, while eating his Kebab and playing with his mobile map, realises that he actually made quite a good choice and that the next pub to have a beer is just around the corner.

Figure 6: Content zooming changes spatial granularity of POI. Left: higher spatial granularity. Right: lower spatial granularity



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5 Conclusions

In this paper a methodology for content exploration in mobile maps was proposed, integrating several generalisation and zooming operations in order to better support mobile users in their information seeking tasks. In particular, *content zooming* was introduced as a technique to decouple spatial navigation and content navigation, to provide the user with the means to adapt map generalisation to his/her needs. Content related zooming thus enables adjusting the *amount* and the *granularity* (see 4.6) of the foreground content (POIs, in our case) and personalise the content to the task at hand.

By providing the capability of flexibly increasing or reducing the spatial density and semantic granularity of a map, the importance and relevance of the content can be better explored than is the case with automated generalisation. Hence, the generalisation functionalities of the mobile system are complemented and extended. Content zooming could also further be combined with focus+context methods, with whom it shares some similarities. Further generalisation strategies, such as highlighting of co-locations following co-location rules of map features [15], are logical extensions. Finally, besides its use in personalised adjustment of mobile maps content zooming can also be seen as a visual analytics tool. In the "map use cube" of [10] content zooming may be positioned as a tool that enables human map interaction for revealing unknowns, driven by an individual user perspective.

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References

[1] P. Bereuter and R. Weibel. Generalisation of point data for mobile devices: A problem-oriented approach. In *13th Workshop on Progress in Generalisation and Multiple Representation*, ICA Commission on Generalisation and Multiple Representation, Zurich, Sep. 2010.

[2] P. Bereuter and R. Weibel. A Diagnostic Toolbox for Assessing Point Data Generalisation Algorithms. In *Proceedings of the 25th International Cartographic Conference*, Paris, France, Jul. 2011.

[3] C.A. Brewer and B.P. Buttenfield. Mastering map scale: balancing workloads using display and geometry change in multi-scale mapping. *GeoInformatica*, 14(2):221-239. 2009.

[4] A. Cecconi, R. Weibel, and M. Barrault. Improving automated generalization for on-demand web mapping by multiscale databases. In D.E. Richardson and P. van Oosterom, editors, *Advances in Spatial Data Handling*, pages 515-531. Springer, Berlin, 2002.

[5] Y.K. Cheung, Z. Li, and W. Chen. Integration of Cognition-based Content Zooming and Progressive Visualization for Mobile-based Navigation. *The Cartographic Journal*, 46(3):268-272. 2009.

[6] P. Crease and T. Reichenbacher. Designing usable cartographic representations of geographic relevance for LBS users. In *Proc. 25th International Cartographic Conference*, Paris, Jul. 2011.

[7] G.W. Furnas. The FISHEYE view: a new look at structured files 17(4): 1982.

[8] L. Harrie, L.T. Sarjakoski, and L. Lehto. A mapping function for variable-scale maps in small-display cartography. *Journal of Geospatial Engineering*, 4(2):111–124. 2002.

[9] D.A. Keim, M.C. Hao, U. Dayal, H. Janetzko, and P. Bak. Generalized scatter plots. *Information Visualization*, 9(4):301-311. 2009.

[10] A.M. MacEachren and M.-J.K. Kraak. Exploratory cartographic visualization: Advancing the agenda. *Computers & Geosciences*, 23(4):335-343. 1997.

[11] W.A. Mackaness and R.S. Purves. Automated Displacement for Large Numbers of Discrete Map Objects. *Algorithmica*, 30(2):302-311. 2001.

[12] P. van Oosterom. Variable-scale Topological Data Structures Suitable for Progressive Data Transfer: The GAP-face Tree and GAP-edge Forest. *Cartography and Geographic Information Science*, 32(4):331-346. 2005.

[13] P. van Oosterom and M. Meijers. Towards a true vario-scale structure supporting smooth-zoom. In *14th ICA/ISPRSWorkshop on Generalisation and Multiple Representation & the ISPRS Commission II/2 WG on Multiscale Representation of Spatial Data*, Paris, Jul. 2011.

[14] T. Reichenbacher. Mobile Cartography: Adaptive Visualisation of Geographic Information on Mobile Devices *Verlag Dr. Hut, München*. 2004.

[15] T. Reichenbacher and S. De Sabbata. Geographic relevance. *SIGSPATIAL Special*, 3(2):67-70. 2011.

[16] D.C. Robbins, E. Cutrell, R. Sarin, and E. Horvitz. ZoneZoom. In *Proceedings of the working conference on Advanced visual interfaces - AVI '04*, ACM Press, Gallipoli, Italy, May 2004.

[17] B. Shneiderman. The eyes have it: a task by data type taxonomy for information visualizations. In *Proceedings 1996 IEEE Symposium on Visual Languages*, IEEE Comput. Soc. Press, Boulder, CO, USA, Sep. 1996.

[18] F. Töpfer and W. Pillewizer. The principles of selection. *Cartographic Journal*, 3(1):10-16. 1966.

[19] R. Weibel and D. Burghardt. Generalization, On-the-Fly. In S. Shekhar and H. Xiong, editors, *Encyclopedia of GIS*, pages 339-344. Springer, New York, 2008.

[20] D. Yamamoto, S. Ozeki, and N. Takahashi. Focus+Glue+Context: an improved fisheye approach for web map services. In *Proceedings of the 17th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems - GIS '09*, ACM Press, Seattle, Washington, 2009.

[21] A. Zipf and K.-F. Richter. Using focus maps to ease map reading. *Künstliche Intelligenz*, 4:35-37. 2002.