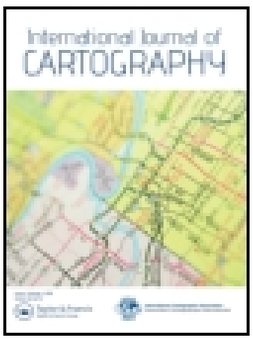

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Gaining overview with transient focus+context maps

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ABSTRACT

Gaining an overview of large spatial data sets presents a challenge common to various domains. 'Overviewing' spatial data involves viewing different areas of focus and context at different scales and requires access to detail from zoomed-out views. Standard pan and zoom interfaces provide limited support with this. Motivated by the application scenario of flood risk monitoring, we extend pan and zoom affordances with a combination of focus+context techniques and multiple maps to support 'overviewing' spatial data with a graph-like information structure. A combination of transient overlays to preview context-on-demand as well as detail-on-demand with the option to decouple additional maps enables fast navigation through the graph-like information space. User-created and -positioned, resizable multiple maps allow for simultaneous exploration of distant regions at flexible scales. The seamless integration of these concepts and the versatility of its components allow for continuously adaptable, user-defined layouts that support various analysis situations. We present a prototype implementation of this interaction model and illustrate its working in application to a hydrometric network, but we believe the model could be transferred to graph-like data in other domains.

Obtenir une vue d'ensemble sur de grands ensembles de données spatiales est un défi dans de nombreux domaines. La vue d'ensemble de données spatiales requiert la visualisation de différentes zones d'intérêt et leur contexte à différentes échelles et nécessite l'accès à des détails à partir de vues dézoomées. Les interfaces de déplacement et de zoom standards n'apportent qu'une aide partielle à ces besoins. Motivé par l'application de scénario de gestion des risques d'inondation, nous étendons les fonctionnalités de déplacement et de zoom grâce à la combinaison d'une technique de focalisation et contextualisation et de cartes multiples pour faciliter la vue d'ensemble de données spatiales avec une structure d'information de type graphe. Une combinaison de superpositions transitoires pour pré-visualiser le contexte à la demande et le détail à la demande, avec l'option de découpler des cartes additionnelles, permet une navigation rapide dans un espace d'information de type graphe. De multiples cartes, créées, centrées et redimensionnées par l'utilisateur permettent une exploration simultanée de régions distantes à des échelles flexibles. L'intégration transparente de

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Geographic visualization; visual analytics support; interaction model; focus +context; multiple linked views

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ces concepts et la polyvalence de ces composants permettent des mises en page définies par l'utilisateur, continuellement adaptables, qui facilitent diverses situations d'analyse. Nous présentons un prototype de ce modèle d'interactions et nous illustrons son fonctionnement sur le cas d'un réseau hydrométrique mais nous pensons que ce modèle peut être appliqué à d'autres données de type graphe dans d'autres domaines.

1. Introduction

'Overviewing' large, complex, potentially dynamic data spaces presents a challenge in various domains (Hornbæk & Hertzum, 2011). In the context of different monitoring tasks, for example, experts need to gain and maintain an overview of changing (information) situations (Jäckle et al., 2015; Lee et al., 2020; Lienert et al., 2009; Mittelstaedt et al., 2013). Hornbæk & Hertzum describe 'overviewing' as the process of (actively) acquiring (situation) awareness, in the meaning of a "*coherent mental picture of what is happening*" (Hornbæk & Hertzum, 2011, p. 519). This process involves capturing relevant information at various scales of the data space and throughout its entire extent (Hornbæk & Hertzum, 2011).

With respect to geospatial data, overviewing poses visualization requirements that are poorly met by standard pan and zoom interfaces. Mainly, three problems arise: Pan and zoom interfaces are limited in conveying small-scale and large-scale information at the same time (Cockburn et al., 2008). Through zooming-in to higher scales, spatial context is lost continuously (Jul & Furnas, 1998). Simultaneous view of distant regions at detail is not possible: Navigation to view distant areas at detail is expensive and the cognitive costs to compare them are high (Plumlee & Ware, 2006). All of this complicates the integration of information that spans several scales into a coherent mental model of a situation.

Motivated by the application scenario of flood risk monitoring, we designed an interaction model that extends the capabilities of a standard pan and zoom interface to support overviewing in the context of flood hazards. Flood risk monitoring involves multivariate geospatial data that is semantically interlinked to form a graph-like information space. We combine distortion-free focus+context techniques with user-decoupled multiple maps to facilitate navigation through the graph-like space and simultaneous exploration of different regions at flexible scales. The semantic links in the data are leveraged to provide context-on-demand as well as detail-on-demand and to give fast access to distant areas of interest. The model is not targeted at the analysis of quantitative attributes directly, but is meant to lay the base for the analysis of various data types. The concepts of the interaction model could be combined with analysis functions for different data types to work as a part of a more complex visual analytics system.

To address the outlined limitations of pan and zoom interfaces, the prototype implementation of the interaction model provides two additional key interaction elements (Figure 1): Firstly, the user can turn on and off dynamic transient (Jakobsen & Hornbæk, 2007) overlays of selected parts of the data. The overlays serve to preview context that exceeds the viewport or to enlarge small-scale areas and access detail.

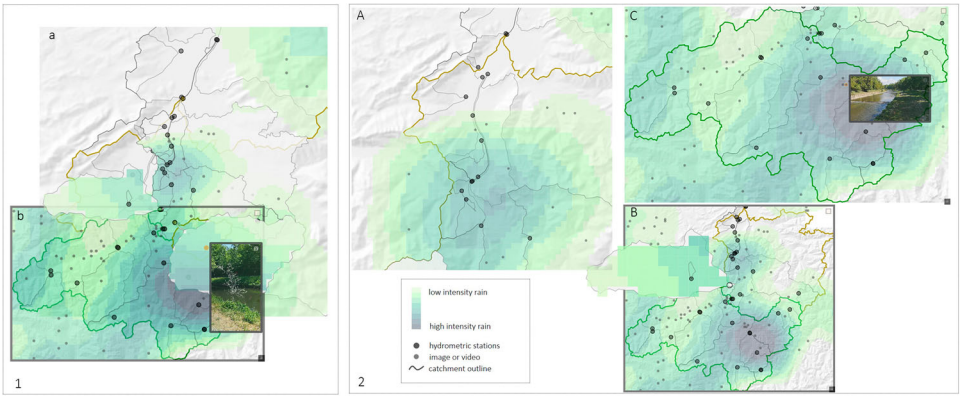

Figure 1. Two screenshots [1,2] of the prototype application illustrating interaction and use of multiple maps for fast navigation and overview of a graph-like information space (a hydrometric network of stations and catchments): [1] shows a map [a] zoomed-in to a downstream area of focus and a downscaled overlay of the main catchment branch that gives access to remote regions of interest. From this, a map [b] of the main upstream catchment is decoupled (active view with grey boarder), in which small catchments are enlarged to access detail that is distant, but relevant to the area at focus in [a]. [2] shows an alternative user-created arrangement of views with a high-scale view of a downstream area of focus [A], a low-scale overview of the river system [B] that was decoupled from [A] (active view, with a transient overlay to inspect a small catchment branch), and a sized-up view of the upstream area [C] that was decoupled from [B]. The order of decoupling is inferred from the linked highlighting of catchment outlines in the parent and child map. (Data sources: hydrometric network (Schwanbeck et al., 2018), relief: swisstopo).

Second, if required, the user decouples a separate, loosely linked map with the context or small-scale area at its focus. Linked maps can be decoupled from overlays or from another map directly. Linked maps appear in topological coherence with their parent view initially. Then, the user decides how to rearrange the view. The user-created and user-positioned multiple maps enable the assembly of flexible layouts that support comparison tasks, multi-focus analysis or other user-defined view arrangements.

We demonstrate the working of the interaction model in a flood risk related application scenario. However, we believe, the model is transferable to similar graph-like geospatial data from other domains, e.g. travel (Brodkorb et al., 2016) or infrastructure networks (Mittelstaedt et al., 2013).

2. Related work

There are three approaches to solve the problems that arise when panning and zooming in large displays: Focus+context techniques, multiple views and contextual views.

Distortion-based focus+context techniques address the problem of lost context when zooming-in to areas of focus (Hauser, 2006). Distortion-based magnifying lenses (Carpendale et al., 2004; Pindat et al., 2012) and space folds (Elmqvist et al., 2008) provide detail views of parts of the map while preserving the context within the same view. While providing the benefit of spatial coherence, the distortions in the drop-off area between focus and context may hamper the process of overviewing because the distortions are hard to

read (Carpendale et al., 1997; Furnas, 2006). Also, these techniques do not provide view of the same data at different scales simultaneously.

Multiple views (Roberts et al., 2019) are used alternatively, to show areas outside of the current view (Ghani et al., 2011; Jakobsen & Hornbæk, 2007) or to show different parts of the display at different scales (Javed et al., 2012; Ware & Lewis, 1995) In the context of spatial data, the main challenge with multiple views is to maintain orientation and achieve mental integration while transitioning from one view to another (Cockburn et al., 2008).

Contextual views are reduced representations of content positioned at the views margin that show and point to off-screen content (Zellweger et al., 2003). Their position is updated dynamically as the user pans and zooms the view. Contextual views (Baudisch & Rosenholtz, 2003; Gustafson et al., 2008) and related approaches (Miau & Feiner, 2018; Moscovich et al., 2009) are aimed at facilitating navigation to off-screen objects mainly in maps and graphs.

Individually, these basic approaches do not solve the problems of panning and zooming in large displays all together. While focus+context techniques and multiple views mainly address the problem of lost context and multiple foci analysis, contextual views and related approaches facilitate navigation to objects of interest. To address the challenges of overviewing in the context of complex analysis tasks more comprehensively, these approaches have to be combined and extended.

Several approaches extend the concept of insets to handle detail of various scales and to improve the visual integration of insets with the parent view (Hadlak et al., 2011; Lekschas et al., 2020; Zhao et al., 2013). Other approaches provide context on-demand (Tominski, 2016) or dynamically (Jäckle et al., 2015) in the sense that they show content that is related to but (far) outside the current focus. Ghani et al. (2011) propose dynamic insets in the function of contextual views to show off-screen objects within their spatial context. Ambient grids (Jäckle et al., 2015) extend the concept of contextual views to a dynamic, topology preserving aggregated projection of the entire off-screen data to the viewport's margin. This approach was designed with the task of monitoring in mind and is aimed at providing a dense overview. However, the context approaches do not support analysis situations that require the view of multiple foci at a time. Many designs limit the displayed content, the level of detail and the functionality of an interface component depending on its dedication to either focus, detail, or context. Brodkorb et al. (2016) relax this confinement to provide detail and context on-demand with the same component. They use dynamic map insets to show off-screen parts of a geospatial graph as well as on-screen detail at higher resolution. The insets are placed on top of the main view and the inset data is connected to the main view via node links. This approach addresses many of the outlined problems, but is limited with respect to comparison tasks (Brodkorb et al., 2016). This is related to a common feature of inset-based approaches: automated disappearance and arrangement of views. These may limit the users control over the analysis process (Hadlak et al., 2011) and may lead to visual disruption (Lekschas et al., 2020). Linked multiple maps that are generated and closed on-demand (Kerpedjiev et al., 2018; Plumlee & Ware, 2003) provide advantages in this respect. The views are independent of each other regarding the section of displayed content and the scale and are thus versatile. They are linked to each other, e.g. through a reference in a low-resolution overview, and optionally coupled in position

or scale (Kerpedjiev et al., 2018; Plumlee & Ware, 2003). Such approaches allow for flexible multi-focus or comparison layouts. However, by itself, this concept does not provide focus +context within a view. Context is inspected either by zooming or in a combination of separate focus views and context views.

With our approach, we strive to preserve the benefits of within-view focus+context techniques (i.e. closeness of the related context to the user's current focus (Jakobsen & Hornbæk, 2007) and topological coherence) as much as possible while providing the flexibility of user-controlled multiple linked maps. To this end, we combine transient visualizations (Jakobsen & Hornbæk, 2007), contextual views and multiple linked maps into a user-controlled interaction model that retains spatial topology initially and lets the user decide at which point to relax these ties. Detail and context is provided on-demand with the same interaction and interface component. In this respect, our approach is closely related to the insets in Brodkorb et al. (2016). However, with the extension of transient visualizations to multiple maps that appear in superposition to the current view first but are drag and resize enabled, our approach supports multi-focus analysis and comparison tasks as well as other user-defined view arrangements.

Some approaches directly apply multi-variate attribute analysis to address the challenges of overviewing spatial data, e.g. by providing alternative view types, such as diagrams and charts, over user-defined subspaces of the map data (Butkiewicz et al., 2008). However, our approach is not targeted at quantitative attribute analysis, but supports navigation and visual tasks involved in overviewing with diverse data types (quantitative, video etc.).

3. Design concept

3.1. Visualization requirements and approach outline

The design of the interaction model was motivated by the application domain of flood-risk monitoring and followed a domain analysis based on a literature survey and interviews with experts. In the context of flood-risk monitoring, overviewing entails acquiring awareness over spatially spread, structurally diverse dynamic processes that are represented over different scales of a multi-dimensional spatio-temporal data space. To attain situation awareness the user needs to maintain a mental model of the spatial context of information across various scales of this space (Poco et al., 2014). In monitoring, the scope and scale of focus and context may change from case to case or during the analysis. Therefore, monitoring requires adaptable displays that show focus and context at flexible scales simultaneously.

Based on the nature of this information space, the tasks associated with overviewing, and information from existing literature that discusses overviewing spatial data, we identify four visualization requirements:

[R1] *Fast access to detail and context on-demand*: Detail information should be accessible from a display at low scale without zooming (c.f. Hornbæk and Hertzum (2011)) and context to an area of focus should be provided on-demand (c.f. Furnas (2006) and Jakobsen & Hornbæk (2007)).

[R2] *Fast navigation to and simultaneous view of distant regions at detail*. A simultaneous inspection of distant regions at detail should be possible with minimal interaction (MacEachren et al., 2004).

[R3] *Simultaneous view of multiple areas of focus and context at arbitrary scales:* The work with multiple focus and context areas at different scales requires multiple, flexibly scalable views (Plumlee & Ware, 2006; Saidi et al., 2016; Wang Baldonado et al., 2000).

[R4] *Flexibly adaptable, user-controlled displays:* This partly follows from R3. The user needs control over the purpose of a view, as well as the combination of multiple views. A high degree of guidance (Ceneda et al., 2019) dismisses the diversity of processes and adaptive visual strategies of the user.

Based on these requirements, we propose a flexible interaction model that is inspired by Linked Data Maps (Valsecchi et al., 2015). On-demand, the design provides dynamic transient overlays of detail or context that seamlessly turn into contextual views at the viewport's border [R1]. On-demand, additional drag and resize enabled views are decoupled to show content at various scales and to let the user arrange layouts with several maps for multiple foci or separate focus and context views [R3, R4]. The combination of transient previews with the decoupling of additional views reduces the need for panning and zooming while navigating the graph-like information space [R2].

3.2. Leveraging the informations semantic links to provide context

A key concept of the interaction model is to make the spatial context provided on-demand the result of a semantically meaningful query (Furnas, 2006). The functioning of this concept is illustrated in application to a geospatial 'network' of outlets or hydrographic stations and their respective catchments along a river system (Figure 2). This 'network' is composed of point data (outlets or hydrometric stations) and polygons (catchments). Outlets/stations and catchments are semantically linked to each other through a rainfall-runoff relationship. Thereby, points and nested polygons form a tree- or forest-like information space, in which downstream catchments may contain several

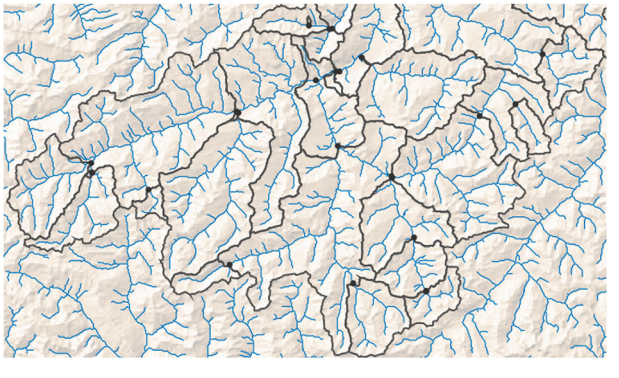

Figure 2. Section of a hydrometric network composed of hydrometric stations [points] and their catchments [dark grey outlines], flow direction roughly south to north. (Data sources: stations and catchments (Schwanbeck et al., 2018), relief: Swisstopo).

smaller catchment branches upstream. Every data point, e.g. cells of gridded precipitation data, integrates through the catchment-outlet relationship into this space. Hence, each catchment-polygon holds the context to the area around its outlet. This is not an artefact of the example data. Another example may be a traveller interested in departures for a particular destination from a specific transportation network node. The departures from that node depend on smooth-running operations in the upstream network and may be delayed by problems there.

3.3. Transient overlays and contextual views

As a starting point to the process of overviewing, an initial map is placed centrally on the screen and scaled to show the extent of the available data (Figure 3). The map supports regular zoom and pan interaction. The context to the current focus is accessible via the links between outlets in the focus and their catchments that may cover a much larger area. Through this link, the user gets quick access to distant regions that are otherwise expensive to navigate to (Furnas 2006). By clicking on any outlet, a slightly translucent overlay of the catchment and the data that is contained within (including catchment branches and their outlets) are turned on and off (Figure 3). This interaction provides context to the user's focus as well as access to detail (Figure 4) [R1]: If a catchment area is small relative to the current focus, the area is enlarged in the overlay, thus providing access to detail. If the catchment is cut-off at the borders of the view, the area is resized to fit the extent of the view, thus providing context to what is currently at focus. To make this principle work independent of a polygons position, overlays exceed the map at its margin.

The transient overlays provide quick previews to decide whether decoupling of a separate linked view is desired for further analysis. This two-step process of preview and optional further inspection meets user behaviour as identified in similar analysis situations

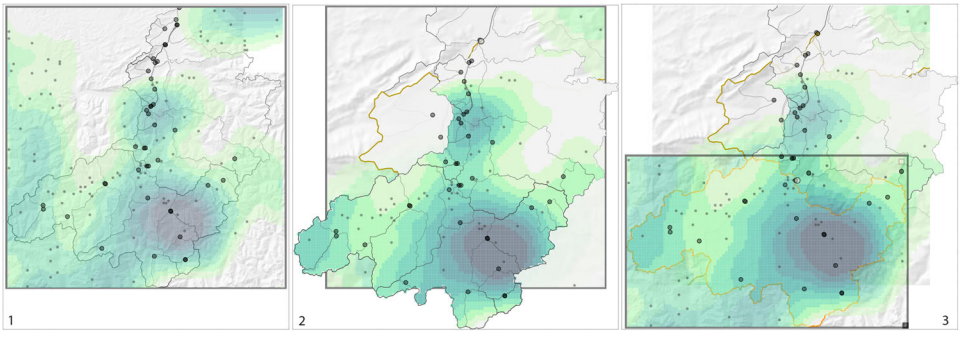

Figure 3. Consecutive screenshots of the prototype application [1–3] showing the step-wise decoupling of an additional linked map of a remote region of interest: [1] Initial map view showing the entire data extent (catchment branches in a river system, flow direction roughly south to north). [2] The user zoomed to a downstream region of interest and turned on a transient, down-scaled overlay of the main catchment branch that stretches far beyond the map extent at the current zoom level (parent shape highlighted in the base map). [3] From this transient overlay, the user decouples an additional map that is zoomed and sized to show the upstream catchment (outline highlighted in orange). The child map appears in alignment with the parent. It can be re-positioned and resized to fit the user's needs. (Data sources: hydrometric network (Schwanbeck et al., 2018), relief: swisstopo).

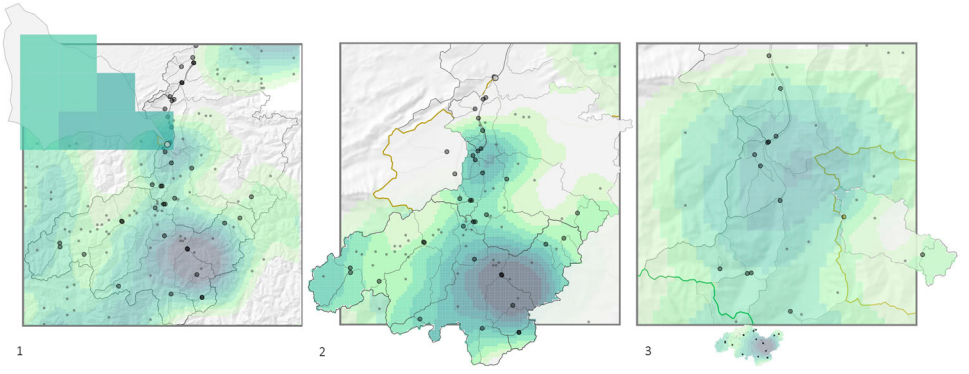

Figure 4. Screenshots of the prototype application [1–3] illustrating the use of dynamically resizing transient overlays to access detail [1] and preview context on-demand [2,3] to the current focus (the scale of maps and overlays is evident from the size of the rain grid cells [km^2]). [1] The user turned on an overlay to enlarge a small catchment (outline highlighted in orange in the base map) to access detail from an overview of the river system. [2] The user zoomed to a downstream region of interest and turned on a scaled-down overlay of the main catchment branch to the area at focus. Overlays of catchments are anchored to the base map at the corresponding outlet location and moved and resized dynamically as the user zooms and pans the map. [3] If an anchoring outlet leaves the view, the overlay remains visible and interactive at the map's margin and re-attaches as the anchoring outlet re-enters the view. (Data sources: hydrometric network (Schwanbeck et al., 2018), relief: swisstopo).

(Lekschas et al., 2020). Jakobsen and Hornbæk (2007) proposed transient visualizations to overlay context on-demand, e.g. in route visualization to aid navigation. The overlays in our design feature all characteristics of transient visualizations, as defined by Jakobsen and Hornbæk (2007): immediacy (i.e. an immediate involvement of the user with the representation), transiency, closeness (i.e. the overlays appear close to the user's focus) and contextuality (i.e. they are related to the information in the user's focus). In a first evaluation of their concept, users preferred transient visualizations over inset overviews (Jakobsen & Hornbæk, 2007). However, the preference for transient visualizations might be dependent on the displayed data (graphs or maps vs. text) and the related tasks (Jakobsen & Hornbæk, 2012). The idea of using translucent overlays for focus+context and detail +overview visualizations was brought up previously (Cox et al., 1998; Lieberman, 1994). Studies to analyse the use of translucent layers or lenses to provide focus in context or overview to detail indicate that in the context of maps, this concept is well adopted by users (Cox et al., 1998; Pietriga & Appert, 2008). These works also point to the importance of designing understandable transitions between overlay and base map. In our design, overlays include a translucent white base layer to improve the readability of information that is displayed on top.

The catchment-overlays are anchored to the map via their outlet. The overlay's position and size is updated dynamically as the user zooms and pans the map. If an anchoring outlet is zoomed or panned out of the viewport, the overlay remains visible within a margin around the map and is positioned dynamically in relation to its off-screen anchor (Figure 4). This prevents unintentional sudden disappearance. The display of off-screen content at the maps margin has similarities to the concept of contextual

views (Zellweger et al., 2003). However, as opposed to abstracted proxies that point to off-screen data, the contextual overlays show all data and retain on-screen functionality: The user can still turn off the overlay in the margin or decouple additional views from it (see 3.4).

3.4. From transient overlays to multiple views

With a right-click on any node in a map or an overlay, a new map is invoked (Figure 3). The child map is pan and zoom enabled and holds the full extent of the original data set. However, upon initialization the map is sized and zoomed to show the triggered outlet's catchment at the scale of the parent map or the overlay. The new map is superimposed in alignment with the parent polygon. For large, cut-off catchments, the new map extends beyond the screen's border. The user can shrink the superimposed view with click+shift to make it fit the screen. Beyond that, child views are flexibly rescalable (on drag in the lower left corner, see 3.5). This allows the creation of focus views or context views at arbitrary scale (Figure 3), from which again detail and context is accessed by turning on overlays (Figure 1). This chain of interactions (accessing small-scale or off-screen content via overlays and decoupling new maps from these overlays, that show either the whole catchment, or any catchment branch contained within) supports fast navigation through the graph-like space with minimal panning and zooming [R2].

3.5. User-controlled placement of multiple views

The initial superposition of additional views and the maintenance of scale is aimed at scaffolding the transition from a single to multiple views (Marai, 2015). After initial superposition, the child views are drag enabled and can be positioned and resized according to the user's needs (Figure 5). Resizing the map does not change the currently displayed extent, but rescales the content at view. With the decoupling of additional views, it is possible to provide context to a parent view at arbitrary scale [R3], to create multiple foci layouts, or to compare distant regions (Figures 1, 5). The view's purpose for itself and relative to other views is not set by the design but is controlled by the user. Also, the arrangement of multiple views is left to the user [R4]. The user may wish to stack several views and fetch them as needed, as in Lekschas et al. (2018). All views provide the same functionality; transient visualizations and additional linked maps can be invoked from any view.

To help the user maintain a mental model of the information space during analysis, the design provides different types of linked highlighting: When the cursor is moved over an outlet, the corresponding outlets and their catchments are highlighted in all views. Also, the outlet as well as the catchment outline are highlighted in the base map, when a transient overlay is turned on and deemphasized again, when the overlay is turned off. When a child view is initialized, the outline of the focal catchment is highlighted in colour in the parent view and in the child view (Figure 1). To help with orientation after zooming and panning in several views and to simplify navigation, a double click on a view's outline centres and scales the map back to the catchment upon which it was initialized.

The need for a custom number of focus or detail views has been recognized and addressed in a number of applications for map-centred visual analysis (Hadlak et al.,

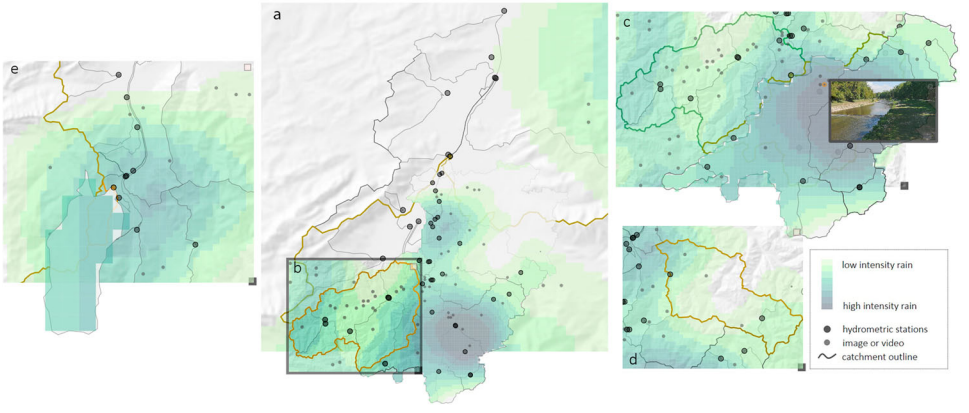

Figure 5. Screenshot of the prototype application showing a state with five user-created and -arranged linked maps [a–e]: [a] Initial map zoomed to a downstream area with a transient overlay of the main catchment branch turned on. From this overlay, the user decoupled a new map [b] (active view with grey boarder) with a particular catchment branch at focus (outline highlighted in orange). The child map appears in alignment with the parent, before it is dragged to a user-defined position and resized according to the users needs. Three more linked maps [c–e] were decoupled; [c] shows the main upstream catchment branch to the focus-area in [a]. An enlarged overlay of a branch of interest is turned on from which a video is accessed. [d] shows a catchment branch adjacent to [c] at a user-defined scale. Both maps [c, d] were initiated from the corresponding outlets in the overlay in [a]. [e] was initialized on the outlet of the main catchment in [a]. [e] was shrunk and zoomed to an area of interest south to the region in [a]. In [e], a small catchment (outline highlighted in orange in the base-map) is inspected in an overlay. (Data sources: hydrometric network (Schwanbeck et al., 2018), relief: swisstopo).

2011; Kerpedjiev et al., 2018; Lekschas et al., 2018). User experiments indicate the importance of multiple detail views for the work with several distant regions of multi-scale data spaces (Plumlee & Ware, 2006; Saidi et al., 2016). Beyond, evaluations of the mentioned applications also underpin the value of user-control in view positioning for visual analysis. In their evaluation of alternative view type insets for large graph exploration, Hadlak et al. (2011) found that users liked to arrange detail views flexibly to bring close together what they had to relate visually. Horak et al. (2019) derive five heuristics from their design space definition to guide the arrangement of multiple views. The user preference heuristic states: "*If user preferences are applicable, they outweigh all other heuristics*" (p. 7). This is supported by the results of a user study (Horak et al., 2019). As exemplified by the subsequent application scenario, we aimed at designing an interaction model that supports a flexible analysis process through initial superposition, possible closing and continuous rearrangement and resizing of views.

4. Application scenario

To illustrate the working of the interaction model, we implemented a front-end prototype with D3.js (Bostock, 2020). We included synthetic rainfall data with a grid structure and synthetic point data that contains mock-up videos of waterway conditions (Figure 1). With the gridded data we exemplify the integration of areal data types, while the point

data is used to exemplify interaction with sparse small-scale information. The gridded data has a km^2 resolution and the grid cells serve as visual scale to the different views.

Next, we describe a short interaction as may be useful in the monitoring of hydrological processes at the river system scale, as addressed e.g. in Lienert et al. (2009). The graph-like information space consists of hydrometric stations and their catchments (Figure 2). The user might focus on a downstream area of interest in a river system (Figure 3). To monitor hydrological processes related to the focus area, the user turns on overlays from hydrometric stations within the area's proximity. Through this, catchments that cover the entire river system upstream are previewed. From these overlays, the user may identify regions of particular interest, e.g. catchment branches that are affected by heavy rainfall, and access detail information on the condition of specific watercourses from videos (Figure 1). To monitor the processes in these regions more closely, separate views of the catchments of interest are decoupled. The views are arranged and resized to show the selected areas in more detail (Figure 5). Alternatively, a separate view of the main part of the river system could be decoupled to serve as a permanent context view to the focus area in the first map (Figure 1).

5. Discussion

We designed an interaction model and presented a prototype implementation to support overviewing graph-like information spaces in the context of flood risk monitoring. Below we discuss the result with respect to limitations, possible extensions and transferability.

Occlusion: The implemented approach to providing context and access to detail within one view tolerates occlusions. Overlays occlude the base map and overlays may occlude each other. Since overlays are meant to serve as transient previews and are turned on and off frequently, this is not necessarily impeding. However, contextual overlays at the map's margin require navigation to be turned on again once they are turned off. In this case, the implemented highlighting helps to visually disentangle overlapping overlays.

Scale: In the provided application scenario, the size of the grid cells (km^2) indicates the scale of a map or an overlay (Figure 4). The integration of information at different scales could be improved by providing additional cues to a map's scale, as in Brodkorb et al. (2016). Likewise, the distance from a contextual overlay at the map's margin to the off-screen location of its anchoring outlet could be indicated as in Tominski (2016). Nevertheless, finding ways to maintain consistency across different displays will be a challenge, once multi-dimensional data is displayed at varying aggregation levels (Poco et al., 2014) or with respect to size-dependent information.

Spatial coherence: Despite the anchoring and the emphasis of the parent polygon in the base map, an overlay might be challenging to read with respect to the extent it spans and with respect to topological connections to other out-of-view regions. Incorporating a topographic base map may relax the challenges of mental integration.

Navigation and Interaction: The context that is provided on clicking an outlet always comprises its entire catchment area. The next selectable subparts within this are the catchment's branches. This provides fast access to remote regions of interest. However, in some cases it might be of interest to view only the part in between the nearest outlet and its next neighbour upstream, or a part between two arbitrary outlets. To this end, the model and its prototype implementation could be extended to support

interaction with polygon parts or the directional selection of a specific tree level as in Brodkorb et al. (2016). In addition, this would facilitate navigation to off-screen content in the downstream network.

Time: The focus of the presented model is on interaction with data in the spatial dimension and the model is aimed at extending the capabilities of a regular pan and zoom interface. However, in the future, interaction with different time states should be addressed in a similar way, since the temporal dimension matters equally in the context of monitoring.

Transferability: To transfer the interaction model to a different application domain, e.g. infrastructure network monitoring (Mittelstaedt et al., 2013), the query that serves the context could be adapted to the analysis' purpose and the given data structure. However, in application to non-hierarchical information structures, occlusions of the base map by overlays may be more problematic.

6. Conclusions

Gaining an overview of a large spatial data display involves overseeing its entire extent, while capturing information at various scales simultaneously (Hornbæk & Hertzum, 2011). Standard pan and zoom interfaces provide limited support with this. Motivated by the task of flood risk monitoring, we designed an interaction model to facilitate navigation in a network-like information space and visual tasks associated with overviewing. With a combination of transient visualizations that merge into contextual views at the map's margin and the decoupling and arrangement of additional linked maps, the model provides context-on-demand as well as detail-on-demand and supports viewing and comparing distant regions at flexible scales. We illustrated how the model could support interaction with different data types. We believe the generic mechanisms of the model are transferable to similar data in other application domains.

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