User Interface and User Experience (UI/UX) Design

Cite as: Roth, R. E. (2017). User Interface and User Experience (UI/UX) Design. The Geographic Information Science & Technology Body of Knowledge (2nd Quarter 2017 Edition), John P. Wilson (ed.). doi: 10.22224/gistbok/2017.2.5.

Abstract

Advances in personal computing and information technologies have fundamentally transformed how maps are produced and consumed, as many maps today are highly interactive and delivered online or through mobile devices. Accordingly, we need to consider interaction as a fundamental complement to representation in cartography and visualization. *UI* (user interface) */ UX* (user experience) describes a set of concepts, guidelines, and workflows for critically thinking about the design and use of an interactive product, map-based or otherwise. This entry introduces core concepts from UI/UX design important to cartography and visualization, focusing on issues related to visual design. First, a fundamental distinction is made between the use of an interface as a tool and the broader experience of an interaction, a distinction that separates UI design and UX design. Norman's stages of interaction framework then is summarized as a guiding model for understanding the user experience with interactive maps, noting how different UX design solutions can be applied to breakdowns at different stages of the interaction. Finally, three dimensions of UI design are described: the fundamental interaction operators that form the basic building blocks of an interface, interface styles that implement these operator primitives, and recommendations for visual design of an interface.

Definitions

- ***affordance:*** a signal to the user about how to interact with the interface
- ***feedback:*** a signal to the user about what happened as a result of the interaction
- ***interaction:*** the two-way question-answer or request-result dialogue between a human user and a digital object mediated through a computing device
- ***interaction primitive:*** the fundamental components of interaction that can be combined to form an interaction strategy
- ***interaction operator:*** a generic function implemented in an interactive tool that enables the user to manipulate the display
- ***interface:*** a tool enabling a user to manipulate a digital object
- ***interface complexity:*** the total number of unique representations that can be created through the interface (scope multiplied by freedom)
- ***interface flexibility:*** ability to complete the same objective with an interface through different interaction strategies
- ***interface freedom:*** the precision by which each operator can be executed
- ***interface scope:*** the baseline number of operators implemented in an interactive tool
- ***interface style/mode:*** the manner by which user input is submitted to perform the operator

- ***user experience (UX) design:*** iterative set of decisions leading to a successful outcome with an interactive tool, as well as a productive and satisfying process while arriving at this outcome
- ***user interface (UI) design:*** the iterative set of decisions leading to a successful implementation of an interactive tool

Description

1. Introducing UI/UX

1.1 The User Interface versus the User Experience

Advances in personal computing and information technologies have fundamentally transformed how maps are produced and consumed, as many maps today are highly interactive and delivered online or through mobile devices. *UI* (user interface) */ UX* (user experience) describes a set of concepts, guidelines, and workflows for critically thinking about the design and use of an interactive product (Garrett, 2010), map or otherwise. UI/UX is a growing profession in the geospatial industry and broader technology sector (Haklay, 2010), with UI/UX designers needed to engage with stakeholders and target users throughout large software engineering and web design projects (see **Additional Resources**). This entry reviews the conceptual principles behind UI/UX, emphasizing visual design following other entries in the **Cartography & Visualization** section and complementing the technologically-oriented **User Interfaces** entry spanning GIScience in the **Programming & Development** section.

UI and UX are not the same, separated in their focus on interfaces versus interactions. An ***interface*** is a tool, and for digital mapping this tool enables the user to manipulate maps and their underlying geographic information. An ***interaction*** is broader than the interface, describing the two-way question-answer or request-result dialogue between a human user and a digital object mediated through a computing device (Roth, 2012). Therefore, an interaction is both *contingent*—as the response is based on the request, creating loops of interactivity—and *empowering*—giving the user agency in the mapping process with changes contingent on his or her interests and needs (Sundar et al. 2014).

Therefore, humans *use* interfaces, but they *experience* interactions, and it is the experience that determines the success of an interactive product (Norman, 1988). ***UI design*** describes the iterative set of decisions leading to a successful *implementation* of an interactive tool while ***UX design*** describes the iterative set of decisions leading to a successful *outcome* with the interactive, as well as a productive and satisfying process while arriving at this outcome. Accordingly, UI/UX often is reversed as UX/UI to emphasize the importance of designing the overall experience rather than just the interface.

1.2 Scholarly Influences on UI/UX Design in Cartography and Visualization

Within GIScience, interaction most commonly is treated by the research thrust of geographic visualization (see **Geovisualization**). Interactivity supports visual thinking, enabling users to externalize their reasoning by requesting a wide range of unique map representations (DiBiase, 1990), thus overcoming the limitations of any single map design. Geovisualization encourages this interactive reasoning for the purpose of exploration rather than communication (see **Cartography & Science**), with the goal of generating new hypotheses and spontaneous insights about unknown geographic phenomena and processes (MacEachren & Ganter, 1990; MacEachren, 1994). As a result, much of the early research on interaction in cartography and visualization is specific to scientific discovery, considering expert specialists as the target user groups.

Today, UI/UX design requires consideration of use cases beyond exploratory geovisualization and users beyond expert researchers. Interaction allows users to view multiple (sometimes all) locations and map scales as well as customize the representation to their interests and needs. Interaction also empowers users in the cartographic design process, improving accessibility to geographic information and dissolving traditional boundaries between mapmaker and map user (see **Cartography & Power**). Increasingly, interaction enables geographic analysis, linking computing to cognition in order to scale the human mind to the complexity of the mapped phenomenon or process (see **Geovisual Analytics**). Accordingly, interaction has been suggested as a fundamental complement to representation in cartography, together organizing contemporary cartographic scholarship and practice (Roth, 2013a; Figure 1). For discussion of additional influences on UI/UX design in cartography and visualization, see **Geocollaboration**, **Usability Engineering**, and **Web Mapping**.

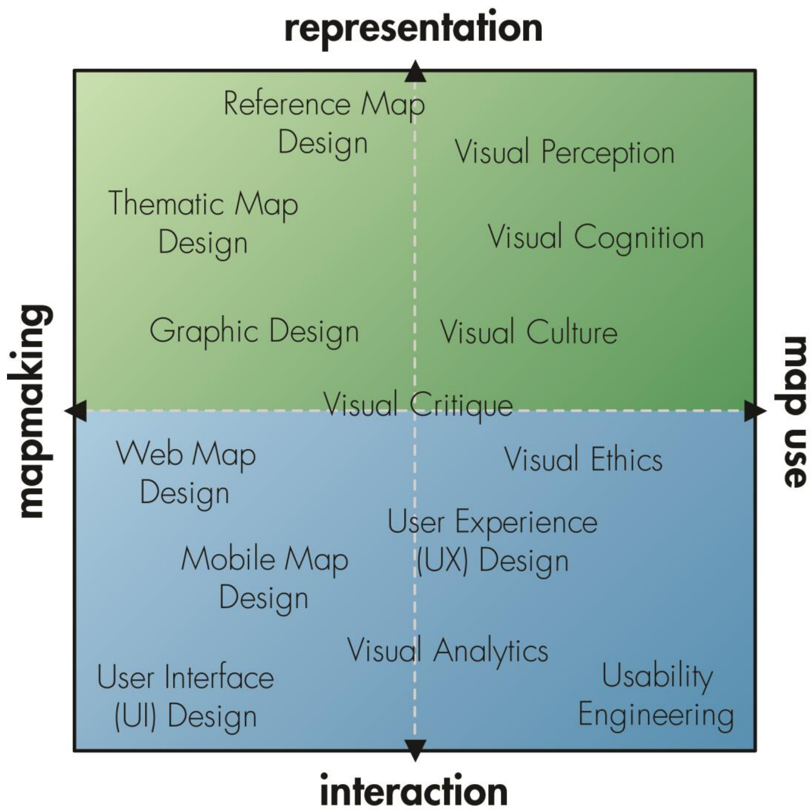

Figure 1. Cartography traditionally has been divided by topics on mapmaking (see the **Map Design Fundamentals** topics) versus map use (see **Map Use**). Advances in digital mapping technology require consideration of a second distinction: representation versus interaction (separated in the Body of Knowledge under **Map Design Techniques** versus **Interactive Design Techniques**). Research and design now draws from a blending of both dimensions. *(adapted with permission from Roth, 2013a)*

2. Designing the User Experience

2.1 Stages of Interaction

An interaction requires the user to employ perceptual, motor, and cognitive abilities as they view, manipulate, and interpret an interactive map. Norman (1988) offers a useful framework for conceptualizing a map interaction as a two-way dialogue or conversation, decomposing a single interaction exchange into seven discrete and observable stages:

1. Forming the goal: The goal is what the user is trying to achieve with the interface and therefore represents the user's motivation for using the interface (a need, interest, curiosity, etc.). Goals are described as "high-level" tasks, and may include exploration, analysis, synthesis, and presentation (see **Geovisualization**).

2. Forming the intention: The intention is the specific map reading objective that the user completes in support of the goal. Accordingly, intentions are described as "low-level" tasks. Intentions include identification of a map feature, comparison of two map features, ranking of a set of map features, etc. Therefore, an intention yields a specific geographic insight, such as detection of a difference, change, outlier, anomaly, correlation, trend, cluster, or spike.

3. Specifying an action: The user then must translate their intention to the functions (described below as operators) implemented in the interface. The interface needs strong ***affordances*****—**or signals to the user about how to interact with the interface**—**for the user to specify which operator best supports the intention before executing the action.

4. Executing an action: The user then must execute the specified action using input computing devices, such as a pointing device (e.g., mouse, touchscreen), keying device (e.g., keyboard, keypad), or other mode (e.g., gesture or speech recognition). Once the action is executed, the computing device processes the request and, if successful, returns a new map representation to the user.

5. Perceiving the system state: Once returned, the user then views the new representation. Here, strong ***feedback*****—**or signals to the user about what happened as a result of the interaction**—**is needed to clarify how the map changed after the request. It is through this provision of feedback that the map participates in the two-way interaction dialogue.

6. Interpreting the system state: After perceiving the change to the map representation through feedback, the user then must make sense of the update. One way to describe this stage is completion of the intention: once a new map is returned, it can be used to carry out the user's low-level task and, if successful, generate a new geographic insight.

7. Evaluating the outcome: The evaluation compares the insight with the expected result to determine if the goal has been achieved. This includes critical evaluation of the insight ("does this seem right?") and meta-evaluation of the overarching goal ("do I have my answer?"). Following this evaluation, the user may revise their goal and initialize a new interaction exchange, restarting the seven stage sequence.

Norman described breakdowns between the user and the map (Stages #1-4) as the "gulf of execution", or the mismatch between user tasks and supported operators, and breakdowns between the map and the user as the "gulf of evaluation", or the mismatch between the result of the operator and the user's expected result. Table 1 works through Norman's seven stages of interaction and lists UX design solutions available when a breakdown at a given stage is observed (adapted from Roth, 2013a).

Table 1. Norman (1988) reduced an interaction into seven discrete, observable stages. An observed breakdown at a given stage suggests a specific set of UX solutions. *(adapted from Roth, 2013a)*

Stage	Ex.1: Analog Door	Ex.2: Digital Map	Observe a Breakdown?	Some UX Solutions?
Forming the Goal	"I want to get out of here."	"I want to explore long-term patterns in tornado activity."	The user's goal is not supported by the interactive (Type I error), or the user does not think that the interactive supports his or her goal (Type II error).	• Complete a needs assessment to define user goals. • Implement strategies to improve user expertise and motivation.
Forming the Intention	"I will identify the door I will use to leave."	"I will start by determining if the frequency of tornadoes has changed since the 1950s."	The user cannot complete one or several low-level tasks or relies on map reading alone to complete low-level tasks without interacting.	• Develop use case scenarios based on low-level tasks. • Evaluate the interactive using benchmark tasks.
Specifying an Action	"I will use the door handle to open the door."	"I will use the sequencing controls to advance the timeline by decade from the 1950s to present."	The user does not understand how the provided interface functionality supports their goals and intentions.	• Improve visual affordances. • Implement startup and tooltip help. • Configure the map with a smart default to show how the UI and map relate.
Executing the Action	"I pull the door handle."	"I use the mouse to move the slider widget from beginning to end."	The user does not understand how to submit information to the interface through the input devices or incorrectly used the input devices.	• Improve flexibility to support multiple input devices. • Reduce point mileage and workload to avoid errors. • Use accelerators to speed interaction. • Use visual metaphors drawn from real-world interactions.
Perceiving the System State	"I feel that the door did not open."	"I see that the map now has more tornado tracks on it."	The user does not notice how the map changed due to the interaction.	• Improve visual feedback through highlighting. • Provide summary information to compare before and after interacting. • Use breadcrumbs to remind the user how they interacted.
Interpreting the System State	"I think this means that I need to push the handle instead of pull it."	"I think this means there are more tornadoes today than there were in the 1950s."	The user does not understand what the change in the map means.	• Combine visualization with statistical computation to highlight significant insights (see **Geovisual Analytics**).
Evaluating the Outcome	"This is a stupid door, but at least I know how to get out now. Good thing there wasn't a fire!"	"I now will modify my goal from a broad exploration of long-term patterns across tornado activity to analysis of specific causes of the increase."	The user does not receive information from the interaction that helped them achieve their goal.	• Provide visual provenance to track interactions across exchanges. • Support enabling operators (e.g., save, annotate, export) to collect insights during interaction. • Support collaboration to share insights.

2.2 Additional UX Frameworks

A number of disciplines, professions, and knowledge areas contribute to UI/UX design, including ergonomics, graphic design, human-computer interaction, information visualization, psychology, usability engineering, and web design. Additional frameworks for understanding UX design have been offered as UX becomes formalized conceptually and professionally (see Roth, 2013a, for a review). For instance, Fitts' (1954) law providing an early understanding of pointing interactions was based on psychology studies about human bodily movement, Further, Foley et al.'s (1990; 2014) three design levels (the conceptual, operational, and implementational levels, as discussed for mapping by Howard & MacEachren, 1996) were derived from research on human-computer interaction while Garrett's (2010) five planes of design (the surface, skeleton, structure, scope, and strategy planes, as discussed for mapping by Tsou, 2011) are offered from web design experience. Finally, most recommendations describe UI/UX as a design process that includes multiple, user-centered evaluations, making use of methods and measures established in Usability Engineering (see **Usability Engineering**).

3. Designing the User Interface

3.1 Interaction Operators

As with representation design and the visual variables (see **Symbolization & the Visual Variables**), an interaction can be deconstructed into its basic building blocks (Figure 2). ***Interaction primitives*** describe the fundamental components of interaction that can be combined to form an interaction strategy (Roth, 2012). Scholars in cartography (e.g., Cartwright et al., 2001) and related fields (e.g., Thomas & Cook, 2005) identify development of a taxonomy of interaction primitives as the most pressing need for the understanding of interaction, as such a taxonomy articulates the complete solution space for UI/UX design. Accordingly, there are now a range of taxonomies offered in the UI/UX literature, including taxonomies specific to cartography and visualization (e.g., Dykes, 1997; MacEachren et al., 1999; Crampton, 2002; Andrienko et al., 2003; Edsall et al., 2008).

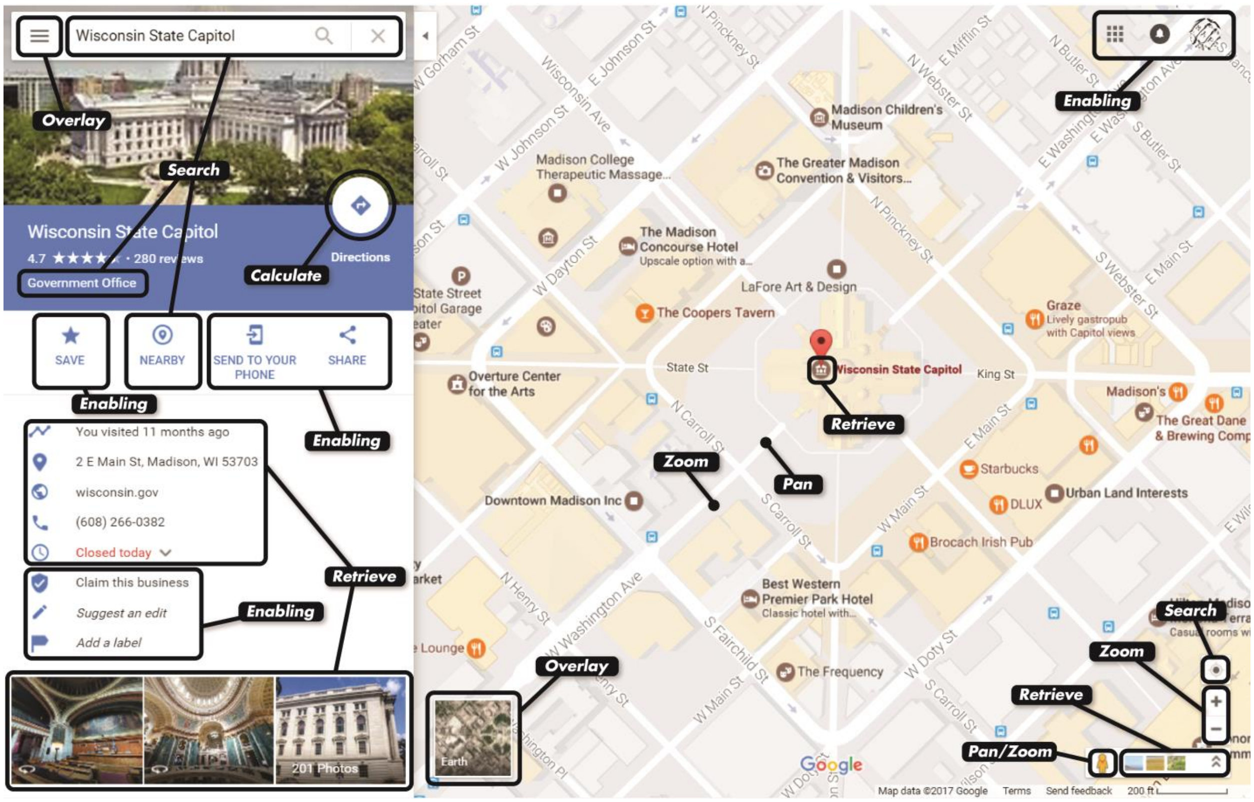

Figure 2. Every interactive map can be deconstructed to its basic interaction primitives. Here, Google Maps is annotated according to the supported interaction operators, with each click, tap, etc., related to its functional purpose. *(image captured and annotated from http://maps.google.com; February 2017)*

Table 2. UI design relies upon interaction operator primitives. UI design recommendations specific to cartography and visualization are beginning to emerge for each operator. *(adapted from Roth, 2013b)*

Operator	Definition	Interactive Map Example	Some UI Design Recommendations?
Reexpress	Set or change the displayed map representation without changing the information.	"Reexpress from a choropleth map to a proportional symbol map."	• Reexpress to a proportional symbol map type on web maps to overcome issues with normalization and Web Mercator. • Reexpress cartograms as choropleth maps to support identification tasks. • Reexpress temporal sequences when interested in linear and cyclical time. • Reexpress between maps and non-map representations to reveal anomalies present in different visual structures.
Sequence	Generate and advance through an ordered set of related maps, each with different information.	"Sequence by decade from 1950 to present."	• Constrain the binning unit to intervals in space, time, or attributes that make sense for the use case scenario. • Sequence all animations (temporal or otherwise) to give users controls over the playback.
Overlay	Change the feature types included in the map for additional context.	"Overlay bike lanes atop the map." (Also underlay: "Turn on the imagery basemap beneath the linework.")	• Overlay only a small subset of context layers for general users to avoid meaningless overplotting. • Overlay custom layers (via import) for expert users to support association tasks (e.g., correlations, cause-effect relationships). • Overlay visual benchmarks providing summary context (e.g., average, max-min) to support comparison and ranking tasks.
Resymbolize	Set or change the design parameters of a map without changing the map type.	"Resymbolize the choropleth map from five classes/colors to an unclassed color ramp."	• Constrain resymbolization for general users to avoid misleading representations. • Resymbolize all design parameters for expert users to manage visual hierarchy while interacting. • Resymbolize class breaks to support ranking and delineation (e.g., clusters, spikes) tasks. • Resymbolize through direct manipulation of the legend. • Dynamically update the legend when resymbolizing.
Zoom	Change the map scale.	"Zoom from a city overview into a local neighborhood."	• Increase the level of detail in the map when zooming into the map (i.e., "semantic" zoom). • Consider conventional tileset zoom level map scales when generalizing linework for mapping on the web. • Zoom only to a subset of relevant map scales appropriate for the level of detail of the linework. • Include a widget to zoom out to the smallest/default map scale. • Support flexibility given the ubiquity of zooming on slippy web maps (e.g., double-click, mousewheel, pinch-and-zoom, zoom slider)
Pan	Change the geographic center of the map.	"Pan the map from the origin to the destination of the route."	• Limit the mouse/pointer mileage needed to pan between map features for the goal of presentation and general users. • Support flexibility given the ubiquity of panning on slippy web maps (e.g., click-and-drag, direction keys, grab-and-drag)
Reproject	Set or change the map projection (beyond map scale and centering)	"Reproject to show north as up on the map."	• Reproject when panning and zooming if not computationally restrictive. • Rotate away from north-up for egocentric mobile applications supporting navigation.
Filter	Remove/highlight map features within a feature type that do not meet one or a set of user-defined conditions.	"Filter the map to show top-rated restaurants only."	• Support filtering over searching for the goal of exploration and expert users. • Use slider widget to filter by numerical facets and checkboxes/radio buttons to filter by categorical facets. • Filter to complete complex ranking and delineation tasks. • Require the user to click a "submit" button for complex filtering taking longer than 100 milliseconds to avoid perceived lags in interaction.
Search	Add/highlight a map feature of interest.	"Search for the destination by address."	• Support searching over filtering for the goal of presentation and general users. • Search to complete simple identification tasks. • Support spatial search by the user's location on mobile devices.
Retrieve	Request details on demand about a map feature of interest.	"Retrieve details about the State of Wisconsin."	• Retrieve details to complete simple identification tasks. • Layout the UI controls so that detail retrieval occurs after other interactions that reduce the candidate map features to a subset of interest (following Shneiderman's mantra). • Move from an information window that activates atop the map to a docked information panel as the f information complexity about the map features increases.
Arrange	Manipulate the layout of maps, coordinated views, and map elements.	"Rearrange the legend atop the map to interpret the symbol."	• Constrain arrangement for the goal of presentation and general users to avoid misleading representations. • Separate coordinated views into dialog windows for mobile.
Calculate	Derive new information about a map feature of interest.	"Calculate the distance to the next city."	• Use persistent interfaces over nested interfaces when supporting complex calculations. • Make visual as many components of calculations and models through the interface.

Interaction primitive taxonomies differ by the stages of interaction they include. While UX design considers primitives at all stages, UI design primarily focuses upon ***interaction operator*** primitives (Stage #3: Specifying the Action), or the generic functions implemented in the interactive that enable the user to manipulate the display. Operators include panning, zooming, and detail retrieval—functions common to "slippy" web maps using tilesets (see **Web Mapping**)–as well as reexpression to different visual overviews, overlay of context information, and filtering across multiple facets of the mapped dataset–functions essential to Shneiderman's (1996) information seeking mantra in big data visualizations (see **Big Data Visualization**). Table 2 describes common operator primitives in cartography and visualization, synthesizing UI/UX recommendations (adapted from Roth, 2013b).

Not all maps need to be interactive, and not all interactive maps require the same UI design. ***Interface scope*** describes the baseline number of operators implemented in an interactive product (e.g., just panning and zooming versus panning and zooming plus searching, filtering), while ***interface freedom*** describes the precision by which each operator can be executed (e.g., zooming any map scale versus only ~20 pre-processed scales). Together, scope and freedom determine the ***interface complexity***, or the total number of unique representations that can be created through the interface. Much like managing information complexity in cartographic design (see **Generalization**), managing interface complexity is essential for good UI/UX design. The appropriate balance of flexibility versus constraint in the UI/UX design ultimately should be determined through user input and evaluation (see **Usability Engineering**).

3.2 Interface Styles

An operator is implemented in one of several ***interface styles***, also called *modes*, or the manner by which user input is submitted to perform the operator (Shneiderman & Plaisant, 2010 as discussed for mapping by Howard & MacEachren, 1996). The same operator can be implemented multiple times through different interface styles, allowing users to complete the same objective with an interface through different interaction strategies, a design concept described as ***interface flexibility***. In *graphic* user interfaces (i.e., GUIs), the interface style is the widget, menu, or form that triggers an event when input is received; the operator is the business logic that is executed after the event is handled.

Interface styles are defined by their level of directness in submitting input (Figure 3). Fully direct manipulation enables probing, dragging, and other adjustments to graphic elements of the UI. For cartography and visualization, direct manipulation can be applied to individual map features (common for detail retrieval), the entire map (common for panning, zooming, and reprojection), map elements like a legend (common for filtering and resymbolizing), a linked information graphic or visualization (common for reexpression of overviews, filtering, and detail retrieval in a coordinated visualization), or simply a custom widget such as buttons or slider bars (common for filtering, toggling overlays, and sequencing through a map series or animation) (Roth, 2013a).

Less direct interface styles include menus, or the selection of one or more items from a list (common for filtering), and forms, or the keying of characters into a blank textbox (common for searching). The move towards mobile-first or post-WIMP (Windows, Icons, Menus, and Pointers) design in cartography has substantially changed how direct interface styles are designed in order to support imprecise (finger-based) touch interactions (see **Mobile Mapping & Responsive Design**). Command language and natural language styles are indirect and non-graphic styles for implementing operators. Shneiderman & Plaisant (2010) provide a comprehensive summary of the relative advantages and disadvantages of interface styles for UI design.

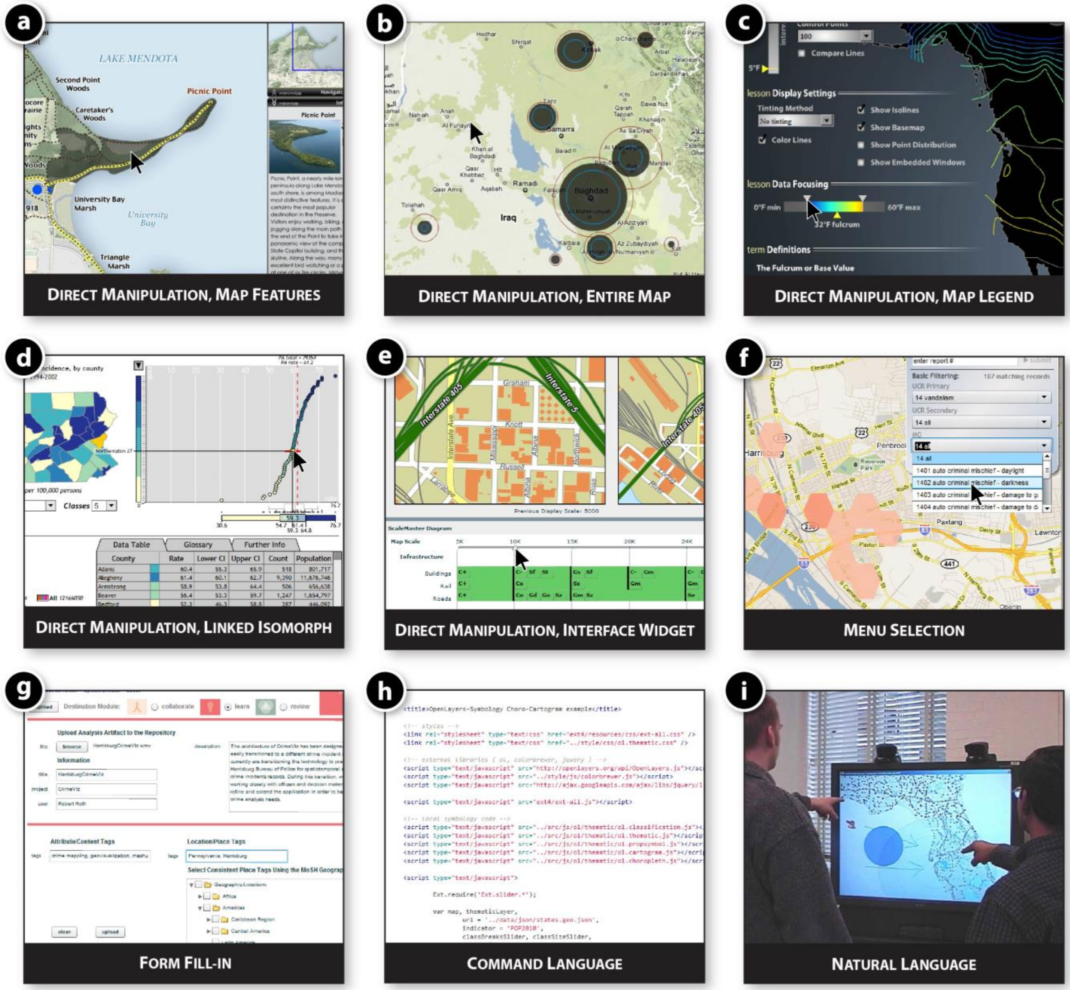

Figure 3. Every interaction operator can be implementing using one of many interface styles or modes. For example: (a) detail retrieval through direct manipulation of a map feature, (b) panning through direct manipulation of the entire map, (c) filtering through direction manipulation of the map legend, (d) coordinated detail retrieval through direct manipulation of a linked isomorph, (e) sequencing through direct manipulation of a slider interface widget, (f) filtering by indirect menu selection, (g) annotating metadata through indirect form fill-in, (h) reexpression of a new map through indirect command line, and (i) detail retrieval through natural language and gesture recognition, Additional details about the depicting interactive maps and visualizations are included in Roth (2013a). *(reproduced from Roth, 2013a, p88)*

3.3 Visual Interface Design

As with paper or static cartographic design (see **Aesthetics and Design**), the visual look and feel of the UI design is "more than just icing on the cake": it sets the tone for the entire user experience, from setting the mood and evoking an appropriate emotional response through improving usability and subjective satisfaction. UI design is a highly creative process, and creation of a coherent and unique visual brand relies on iterative refinement of global design decisions (e.g., interface layout and responsiveness, application navigation, visual affordances and feedback, color scheme, typefaces) and local design decisions (e.g., visual metaphors for direct manipulation interface widgets, specific text phrasing for icons, tooltips, and information windows). Nielsen (1994) provides a useful set of usability heuristics for guiding visual interface design.

Bibliography

Andrienko, N., Andrienko, G., & Gatalsky, P. (2003). Exploratory spatio-temporal visualization: an analytical review. *Journal of Visual Languages & Computing*, *14*(6), 503-541.

Cartwright, W., Crampton, J., Gartner, G., Miller, S., Mitchell, K., Siekierska, E., & Wood, J. (2001). Geospatial information visualization user interface issues. *Cartography and Geographic Information Science*, *28*(1), 45-60.

Crampton, J. W. (2002). Interactivity types in geographic visualization. *Cartography and geographic information science*, *29*(2), 85-98.

DiBiase, D. (1990). Visualization in the earth sciences. *Earth and Mineral Sciences*, *59*(2), 13-18.

Dykes, J. A. (1997). Exploring spatial data representation with dynamic graphics. *Computers & Geosciences*, *23*(4), 345-370.

Edsall, R., Andrienko, G., Andrienko, N., & Buttenfield, B. (2008). Interactive maps for exploring spatial data. *ASPRS Manual of GIS*.

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*. *47*(6): 381-391.

Garrett, J. J. (2010). *The elements of user experience: user-centered design for the web and beyond*. Pearson Education.

Haklay, M. M. (Ed.). (2010). *Interacting with geospatial technologies*. John Wiley & Sons.

Howard, D., & MacEachren, A. M. (1996). Interface design for geographic visualization: Tools for representing reliability. *Cartography and Geographic Information Systems*, *23*(2), 59-77.

Hughes, J. F., Van Dam, A., Foley, J. D., & Feiner, S. K. (original edition 1990; latest edition 2014). *Computer graphics: principles and practice*. Pearson Education.

MacEachren, A. M. (1994). Visualization in modern cartography: setting the agenda. *Visualization in modern cartography*, *28*(1), 1-12.

MacEachren, A. M., & Kraak, M.-J. (1997). Exploratory cartographic visualization: advancing the agenda. *Computers & Geosciences*, *23*(4), 335-343.

MacEachren, A. M., Wachowicz, M., Edsall, R., Haug, D., & Masters, R. (1999). Constructing knowledge from multivariate spatiotemporal data: integrating geographical visualization with knowledge discovery in database methods. *International Journal of Geographical Information Science*, *13*(4), 311-334.

Nielsen, J. (1994, April). Usability inspection methods. In *Conference companion on Human factors in computing systems* (pp. 413-414). ACM.

Norman, D. A. (2013). *The design of everyday things: Revised and expanded edition*. Basic books.

Roth, R. E. (2012). Cartographic interaction primitives: Framework and synthesis. *The Cartographic Journal*, *49*(4), 376-395.

Roth, R. E. (2013a). Interactive maps: What we know and what we need to know. *Journal of Spatial Information Science*, *2013*(6), 59-115.

Roth, R. E. (2013b). An empirically-derived taxonomy of interaction primitives for interactive cartography and geovisualization. *IEEE transactions on visualization and computer graphics*, *19*(12), 2356-2365.

Shneiderman, B. (1996). The eyes have it: A task by data type taxonomy for information visualizations. In *Visual Languages*, *1996. Proceedings., IEEE Symposium on* (pp. 336-343). IEEE.

Shneiderman, B. (2010). *Designing the user interface: strategies for effective human-computer interaction*. Pearson Education India.

Sundar, S. S., S. Bellur, J., Oh, H., Jia, H., & H. S Kim. (2016). Theoretical importance of contingency in human-computer interaction: effects of message interactivity on user engagement. *Communication Research*, *43*(5), 595-625

Thomas, J. J., & Cook, K. A. (2005). *Illuminating the path: the research and development agenda for visual analytics*. IEEE Computer Society.

Tsou, M.-H. (2011). Revisiting web cartography in the United States: The rise of user-centered design. *Cartography and Geographic Information Science*, *38*(3), 250-257.

Learning Objectives

- **Understand:** Describe traditional and emerging use cases for interactivity in cartography and visualization (e.g., exploration, analytics, presentation)
- **Understand:** Describe a user need for the following interaction operators: panning, zooming, overview reexpression, filtering, detail retrieval, etc.
- **Apply:** Walkthrough the stages of interaction using different interface controls in an interactive map and identify potential breakdowns and solutions.
- **Analyze:** Deconstruct an interactive map into its basic interaction primitives.
- **Evaluate:** Evaluate an interactive map design by UI/UX design recommendations (e.g., affordances/feedback, interface complexity, interface styles, design heuristics).
- **Create:** Design an interactive map suitable for a given set of user needs.

Instructional Questions

- Perhaps the two most common kinds of mapping interfaces that geospatial professionals experience today are simple web maps (e.g., Apple Maps, Google Maps) and fully-featured GIS (e.g., ArcGIS, QGIS). These UX design contexts could not be more different! Compare and contrast these two UX contexts according to user needs, potential breakdowns in the user experience, recommended UI controls, etc., arguing why these two kinds of mapping interfaces necessarily should be different.
- In lab ___, you created an interactive map depicting ___. Use the stages of interaction framework to walkthrough how you envisioned a first time user to interact with your map (i.e., work through multiple loops of the framework). Identify potential breakdowns in your design and discuss UX design solutions to enhance your interactive map in the future.
- Navigate to your online campus map:
    - *If interactive:* Critique the campus map according UI/UX design recommendations (e.g., which interaction operators should be added to / removed from the map? how could your university develop a better visual brand through the campus map?). Present your critique as a series of recommendations for improving the campus map.

    - *If static:* Assess how the campus map should take advantage of interactivity according to UI/UX design recommendations (e.g., which interaction operators should be added to the map? how could your university develop a better visual brand through the campus map?). Present your assessment as a series of recommendations for making the campus map interactive.
- You have been given a description of unmet user needs and target user personas for a proposed interactive map (*derive from class readings/discussion*). Develop a requirements document outlining the functional scope of the proposed interactive map. Include notes about the recommend interface freedom and flexibility for each interaction operator included in the requirements document.
- You have been given a description of a use case scenario for an interactive map and a requirements document proposing the functional scope of the interface to support this use case (*derive from class readings/discussion*). Sketch a prototype of the interface based on UI/UX design recommendations, including an example map representation. Annotate the sketch with notes justifying the interface styles used to implement each operator, the layout of interface controls, and aspects of the visual design that produce a coherent look and feel.

Additional Resources

- (2017) The 100 Best Jobs: Cartographer. *U.S. News and World Report*. Retrieved from: http://money.usnews.com/careers/best-jobs/cartographer
- Nielsen, J., & D. Norman. (1998-2017). *The Nielsen Norman Group: Evidence-based user experience research, training, and consulting*. Retrieved from: https://www.nngroup.com/
- Roth, R. E. (2016). Rethinking cartography curriculum to train the contemporary cartographer. In: *6th International Conference on Cartography and GIS*. Retrieved from: https://cartography-gis.com/docsbca/iccgis2016/ICCGIS2016-16.pdf
- Szukalski, B. (2013, August 1). Transforming essential GIS skills. *Esri Insider*. Retrieved from https://blogs.esri.com/esri/esri-insider/2013/08/01/transforming-essential-gis-skills/
- Tolochko, R.C. (2016). *Contemporary professional practices in interactive web map design*. Retrieved from: http://tolomaps.github.io/assets/Tolochko_Thesis.pdf
- Underwood, E. (2013, March 8). The New Cartographers. *Science Magazine*. Retrieved from http://www.sciencemag.org/careers/2013/03/new-cartographers

Keywords

user experience design, user interface design, interactive maps, interaction primitives, interaction operators