# Bespoke Map Customization Behavior and Its Implications for the Design of Multimedia Cartographic Tools

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**ABSTRACT**
While popular digital maps support an unprecedented number of use cases, new reference map customization tools have been created for purposes for which those maps fall short. With the goal of informing the design of this new class of cartographic tools, we present the first study of naturalistic ("bespoke") map customization behavior. Through a mixed methods and mixed-media approach involving a survey, the analysis of a corpus of customized maps, and an interview with a power user, we find that bespoke map customization is a relatively common activity and identify frequent use cases as well as map customization strategies. We discuss these use cases and strategies in detail, and propose design implications for future customization tools, such as the use of templates for common use cases, adaptability for various customization styles and the support of multimedia interaction.

**Author Keywords**
Digital maps; paper maps; geographic HCI (GeoHCI); multimedia; cartography; design implications.

**ACM Classification Keywords**
H.5.m. Information interfaces and presentation (e.g. HCI): Miscellaneous.

**INTRODUCTION**
While an age-old cartographic precept states that no single map can be optimal for all purposes [27], popular digital map platforms have made incredible strides towards overcoming this barrier. Through innovations in map interactivity and the use of intelligent algorithms, platforms such as Google Maps, Apple Maps, and Bing Maps are now capable of adapting to a large variety of use cases and geographic areas.

The prevalence of a phenomenon that we call bespoke map customization, however, suggests these mapping platforms still do not adequately support certain use cases. In bespoke map customization, end users leverage a variety of external tools to transform a pre-existing map to better suit a particular cartographic need. As we will discuss below, common use cases for bespoke map customization include


**Figure 1: Excerpt of a travel map indicating routes between different points of interest, customized with MS Paint (map corpus, P6).**

constructing maps for planning vacations, inviting visitors to an upcoming event (e.g. a wedding), and supporting the spatial referencing of memories.

We define bespoke map customization more specifically as the act of producing a new, simple spatial dataset with a small number of features and simultaneously visualizing that dataset without the use of programming. As we will discuss below, the mechanisms employed in bespoke map customization are highly diverse and range from the use of MS Paint to complex workflows that span over different media and involve printing maps, annotating them, and then scanning them back into their computer.

To our knowledge, no prior research has been conducted on bespoke map customization behaviors, practices, and use cases. In this paper, we address this gap in the literature, focusing specifically on the most commonly used map type: reference maps (i.e. maps used for navigation and orientation). To gain a broad perspective on bespoke map customization, we adopted a mixed methods and mixed-media approach. Specifically, our study includes an online survey, qualitative analyses of a corpus of customized maps, as well as an interview with a power user.

Our results suggest that bespoke map customization is a common activity—over 70% of the survey respondents reported having customized a map—and provide support for a series of design implications. For instance, our results reveal the importance of designing for mixed-media map support, e.g. treating the possibility to print customized maps as a first-tier feature and supporting the digitization of paper-based annotation done in-situ in a mobile context while engaging in an activity. Moreover, our results reveal the most common use cases for map customization and highlight the importance of customized maps as memory aids and mementos following the completion of an activity.

The importance of our study has increased with the growing number of tools that allow web users to make personalized maps without programming. The most popular tool is Google My Maps (https://www.google.com/mymaps). Others include ZeeMaps (http://zeemaps.com) and Mapmaker (http://mapmaker.education.nationalgeographic.com) by National Geographic. The design implications from our work are largely applicable to these tools. Many of the implications suggest significant new features for the entire class of existing customization tools, and other implications support the design decisions of some tools over others'.

To summarize, the contributions of this paper are as follows: Using a mixed methods and mixed-media approach, we present the first exploration of bespoke map customization behavior. We suggest a series of design implications for reference map customization tools such as templates for common use cases (e.g. travel or meeting maps), adaptation to various customization styles (e.g. free-hand annotation) and support of multimedia interaction.

## RELATED WORK

This paper draws motivation from four research streams in the literature: annotation in information visualization, spatial decision support systems, existing map customization technologies, and the comparison of paper and digital media for cartography. In the following we discuss each stream in turn.

### Annotation in Information Visualization

Reference map customization activities can be considered a subset of annotation in information visualization, although a subset with a number of unique properties. A major focus in recent annotation work has been on asynchronous collaboration around visualization of annotations [4,11] and on the automatic generation of annotations that highlight comparisons made in corresponding text [9,13]. Reference map customization is distinguished from this literature in that it involves maps that are intended for navigation and orientation (the broad use cases for reference maps), rather than thematic maps, which are intended to communicate the geographic distribution of an attribute (e.g. population, or temperature) [29]. Annotations in thematic maps are targeted at highlighting trends rather than supporting navigation, orientation and the diverse use cases of reference maps outlined below.

### Spatial Decision Support Systems

Map customization is also related to spatial decision support systems, which have been heavily studied (e.g. [1]). These systems help decision makers such as disaster relief specialists to quickly analyze scenarios, often by using visualization tools. Bespoke reference map customization is distinct from these systems as it addresses casual users, whereas spatial decision support systems are for professionals and experts. This results in highly divergent use cases and design challenges (as we will see below).

Map building tools for geowikis such as OpenStreetMap (OSM, http://www.openstreetmap.org) present an offshoot of spatial decision support systems that are related to map customization. These tools have been in the focus of recent research at the interface of Geography, Multimedia and HCI (e.g. [10,26]) and the volunteered geographic information research community more broadly (e.g. [7,16,23]). However, like their more expert-oriented analogues, these tools can have different use cases (i.e. disaster mapping) than reference map customization. Geowikis like OSM bear some similarities to reference map customization tools, but their goal is to create a single, uniform reference map rather than to help users in customizing their maps for their own individual use cases (i.e. map creation is different from map customization).

### Existing Map Customization Technologies

A major motivation for this work comes from the recent increase in available reference map customization tools. By far the most popular reference map customization tool is Google My Maps, which was launched in 2007 and has been through a number of iterations since then. Google My Maps is a general reference map customization tool that

supports a number of features such as adding POI "pins" and routes to a Google basemap. National Geographic Mapmaker Interactive and ZeeMaps are competitors, but the latter has a more professional focus (e.g. including specialized tools for journalists), while the former is focused on educational audiences. Tools such as MapBox Studio (https://www.mapbox.com/mapbox-studio/) are also related to map customization. However, these tools require programming skills as they make use of JSON-based styling specifications and thus do not qualify as map customization as defined above. The leading GIS company ESRI also targets this general space with its StoryMaps (http://storymaps.arcgis.com), but like the above-mentioned tools, they require programming skills.

Map customization is also related to the notion of the "map mashup", in which pre-existing datasets are added to an online map through APIs or technologies like Google Fusion Tables. However, mashups often require some programming skills (or at least knowledge of related topics like database joins) and mashups are almost always thematic maps and not reference maps.

### Paper and digital media for cartography

As reported below, people use mixed-media techniques (paper and digital) in bespoke map customization. This is related to the literature on the comparative advantages of paper and digital media for cartographic tasks. While the dynamic displays that digital maps afford are incredibly powerful, paper maps retain certain advantages. For instance, paper maps do not require power; their light weight can make them more portable than digital maps on mobile devices [22], their large display sizes relative to mobile maps support certain activities better [5,15], such as collaboration [2]; they can be cheaper when engaging in foreign travel due to roaming costs [17]; and they can be easier to customize while in the field [22]. Hurst et al. [14] showed that geographic knowledge and the context of use influenced whether users preferred paper or digital media: as geographic skills increase, there is a greater preference for paper maps, while non-experts prefer digital maps.

| |
|---|
| Did you customize digital maps, paper maps or both of them and how many digital or paper maps did you customize? (estimate) |
| What were the reasons for customizing these maps? |
| Please specify the type of the online map service you used. |
| For which purpose did you customize the map? |
| In general, when have you annotated the map relative to the activity you used it for? |
| Describe what you have customized. |
| How have you annotated the map? (using which tools) |
| Have you made the annotation for yourself or to communicate the map to another person? |
| Have you used (are you going to use) the map multiple times? |
| Did you share your map/annotations with somebody else? |
| If available, please upload a picture of the customized map(s). |

**Table 1: Survey questions as presented to participants who had previously customized maps.**

## METHODOLOGY

The primary goal of our research was to understand the design space for bespoke map customization tools and provide design implications for the design of existing and future tools. In order to obtain sufficiently diverse perspectives on map customization activities with respect to this goal, we applied a mixed methods approach involving three separate studies: (1) an online survey, (2) the analysis of a corpus of customized maps, and (3) an interview with a power user. With the survey and analysis of the map corpus, we used an open, bottom-up approach to understand which factors are important. The interview with a power user afforded us a deeper understanding of those map customization factors with Google My Maps, one of the most commonly used map customization tools.

### Online Survey

To design our survey, we drew methodological motivation from Morris et al.'s influential exploratory work on social media question asking (SMQA) [20]. Morris and colleagues performed the first exploration of SMQA through the deployment of a snowball-sample survey. Thanks to the novelty of the SMQA research space at the time, their work has proven to be significant, having identified a number of key characteristics of SMQA behavior that have led researchers to engage in more targeted and robust analyses. Reference map customization in 2017 is in the same position as SMQA in 2009: practiced by users, but not well understood at a high level by researchers. As such, we designed our survey in a similar fashion as [20], trading off robust sampling strategies (which are difficult to define for this novel space) for a practical exploration of a design space and high-level insights, with the aim of supporting more targeted follow-up work.

A link to our online survey was distributed internationally to a mostly non-expert population with respect to mapping tools via professional and student computer science and human-computer interaction mailing lists as well as through social media platforms in our personal and professional network in 2014. We explicitly invited people who customized maps and people who did not customize maps to participate in the survey. The survey was conducted in English using LimeSurvey (https://www.limesurvey.org). In total, we received 108 completed responses (39 female, 69 male; average age 35.2 years, age range: 21-61, SD: 7.61).

The order and type of questions in the questionnaire depended on participants' prior experience with map customization. The survey first asked participants whether they had previously engaged in any bespoke map customizations. In the case of a negative reply, the survey presented a single question inquiring the reasons. On the other hand, if respondents had engaged in map

| ID | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 | P12 | P13 | P14 | P15 | P16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gender | M | M | M | F | M | M | F | F | F | M | F | M | M | M | F | F |
| Age | 28 | 32 | 55 | 26 | 58 | 31 | 44 | 29 | 31 | 27 | 32 | 26 | 35 | 39 | 30 | 44 |
| Nr of Maps | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 4 | 1 | 8 | 1 | 1 | 2 | 1 | 2 |
| Country on Map | DE | IE | FR | RU | DE | LK | FR | FR IE PE US | FR PE UK US | FR | DE IN | DE | JP | FR | South America | UK US |
| Country of Residence | DE | ? | FR | FR | DE | FR | FR | FR | US | FR | DE | DE | JP | FR | CH | ? |

**Table 2: Characteristics of participants and maps from the map corpus.**

| Classification | Location & Country | Category | Purpose | Medium | Orientation & Perspective | YAH Dot | Perimap Elements | Annotations | Basemap | Focus |
|---|---|---|---|---|---|---|---|---|---|---|
| Description | City, region and country | City map, Rural area, Country map, Flight map or others | Goal for which the map was created | Medium of creation and the medium of use (digital or paper) | Viewport of the map (e.g. top-down or bird-eye view) and if the map was north-up or not | "You-are-here dot" presence and style | Presence of elements such as North Arrow, Scale, Legend, Title and others | Type (e.g. Marker, Lines, Numbers), Style (e.g. default, customized, hand drawn) and number of annotated map elements | Basemap Style (e.g. default or customized) | Most prominent layer |

**Table 3: Overall coding scheme for the map corpus.**

customization, they were asked about the character and frequency of their map customization activities (see Table 1). The average time to complete the survey with all questions was around 20 minutes. The gathered data was quantitative (7-point Likert scale) and qualitative (open-ended questions). The quantitative data was analyzed using descriptive statistics; the qualitative data was analyzed using a bottom-up coding scheme as defined below.

## CORPUS ANALYSIS

We asked survey respondents to submit screenshots, scans, and photos of their maps if available. We collected a total of 38 maps from 17 different users (10 male, 7 female; average age 35.7 years, range: 26-58, SD: 9.71). Table 2 presents details about participants and maps. Our final corpus consisted of 37 maps from 16 users. We removed one map that was a map mashup (as defined above) and not a customized map. Our dataset consisted of maps from 12 countries on four continents, with the most maps coming from Germany (8), followed by France (7) and the United States (6). A subset of those maps is depicted in this paper and the maps considered here are available for research purposes upon request.

Our analysis of the corpus utilized a map coding procedure closely following the one proposed by Schöning et al. [27]: two coders started with a single pass through the map using the coding dimensions defined in [27] and identified dimensions to be used in the coding exercise and others that did not apply. Next, the two coders made a single pass on the data set to identify additional dimensions of analysis. Then, they merged their coding scheme. This process resulted in a total of 21 dimensions, a subset of which are described in Table 3. Once this final scheme was established, each map was coded independently by two coders. Then, a third independent coder resolved disagreements (only four cases in total). As recommend in [27], we assured that at least one of the coders was trained in cartography (at least two university-level cartography courses).

## INTERVIEW WITH A POWER USER

Complementary to the survey with casual users, we wanted to learn more about how map customization is done by a "power" user with one specific tool and whether there are similarities or differences with casual users. We invited a woman (29 years) from our personal network who customizes maps more often than average people in their daily lives, but not professionally. As the customization tool we selected Google My Maps as it is among the most commonly used map customization tools. At the time of the interview, the power user had been using Google My Maps for more than six years and had created over 20 maps with Google My Maps. Her maps covered a broad range of use cases, including travel, exploring new neighborhoods or creating maps for her blog. In a one-to-one session that lasted for around an hour and a half, the interviewee walked the interviewer through the different maps she had created, describing for each map when, how and why it has been created, and if the map had been shared with others. This interview also allowed us to access additional examples of customized maps.

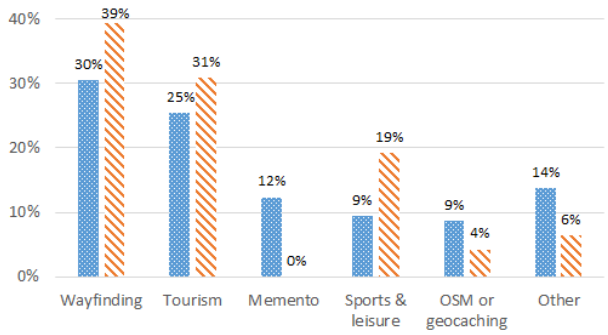


**Figure 2. Most common use cases for map customization for digital maps (dotted blue) and paper maps (orange diagonal stripes). The category "other" includes different uses cases that were each named only once. We do not further discuss "wayfinding" as this is a basic purpose of reference maps and also included in some of the other categories.**

## RESULTS

We report our findings from all three studies together, structured by main themes that we identified in our data sets.

### #Theme 1: Many People Customize Maps, but Most Remain Novices

Like for Morris et al.'s study [20], our survey design allows to give a broad overview of the popularity of bespoke map customization, but not a precise percentage of the population that has engaged in the activity. Yet, the broad picture in our survey results regarding the prevalence of map customization was a clear one: bespoke map customization is far from a niche activity and has been engaged in at least once by a non-trivial swath of the population. More specifically, we found that the majority of the survey participants (71%) had customized at least one reference map. Even adjusting for some bias in recruitment, this is a substantial percentage for a bespoke technological endeavor.

When asked which maps they had customized in the past year, 62 participants (57%) reported having customized online maps, 50 (46%) paper maps, and 33 (36%) online as well as paper maps. When asked for the number of maps customized in the past year, the mean number of digital maps was 6.4 (SD: 5.9) and for paper maps 4.3 (SD 3.7). Among the 29% of participants who had never done any map customization, the majority (57%) reported not feeling the need to do so, 12% did not want to "destroy the map" by writing on it, and 10% did not know it was possible.

With 71% of respondents reporting some map customization activity, these results substantiate the importance of designing for bespoke map customization. However, the results also reveal that, on average, people customize a rather small number of maps per year (6.4 digital and 4.3 paper maps). We can thus assume that map customization is generally not a task at which users become experts. Consequently, designers need to be careful to design map customization systems for primarily novice, inexperienced users.


**Figure 3. Using various marker types to highlight POIs on a travel map (map corpus, P8). Google Maps was used as base map ©Google 2014.**

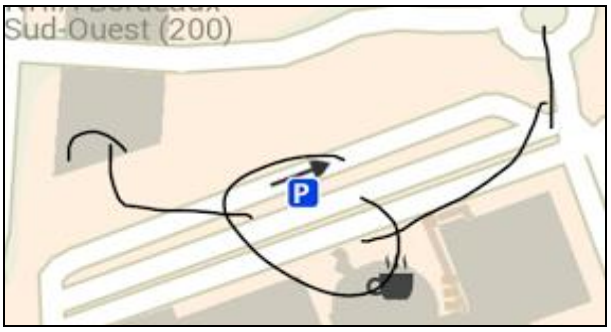


**Figure 4: Example of a meeting map with scribbled annotations using MS Paint (map corpus, P11).**


**Figure 5: Meeting map, based on local public transportation map customized with MS Paint (P12).**

### #Theme 2: Map Customization Has Several Primary Use Cases

We were able to identify several common primary use cases for map customization (see Figure 2). In the map corpus coding schema (Table 3), the "purpose" category served for identifying the use cases. In the survey and interview, we specifically asked participants for which purposes they customized maps.

The most important use case in all three sources was tourism. This was particularly apparent in our map corpus,


**Figure 6: Excerpt of a customized map serving multiple purposes: 1) a wedding invitation, indicating venues with different customized markers, 2) an artifact in a photo album after the event (P8).**

in which 20 maps (54%) were customized to support touristic activities (e.g. Figures 1, 3 and 9). In the survey, 17 participants reported customizing maps for traveling and 8 maps by our power user interviewee had been customized for this purpose. Through the different sources, we could identify that bespoke maps for tourism mainly served to highlight POIs and to support wayfinding (e.g. visualization of travel routes and taking maps along for navigation). The POIs that participants added to maps included their accommodation, landmarks, shops, restaurants, airports and public transportation. Three people added street addresses and phone numbers to their maps.

The second most-common use case for bespoke map customization was spatially-referenced memories in photo albums, diaries or on blogs. A total of 9 survey participants mentioned that they used maps for this purpose. Participants explained that these maps served as mementos for places and locations they had visited and the routes that they took. Within the map corpus, we identified three maps that solely served this purpose. These maps depicted general areas of cities and contained around 20 markers on average. Interestingly, in addition to these three maps, most of the travel maps were used as a memento after the trip. Memory maps also played an important role for our interviewee who has a travel blog and had customized seven maps for this purpose.

Another prominent category in our map corpus was "meeting maps", with a total of seven maps. Meeting maps usually depicted a city and contained a single marker highlighting a specific place as well as directions indicating how to get there from various origins (e.g. text or arrows, see Figures 4 and 5). Five survey participants mentioned that they used bespoke customized maps to explain routes to friends or family and to indicate meeting points. Moreover, our interviewee created one map with the specific purpose of explaining her visitors how to reach her flat from the airport. Very similar to meeting maps are "event maps", which highlight venues that are important for an event, e.g. a wedding or a conference (see Figure 6). The map corpus contained five of these maps and five survey participants mentioned having created them.

The maps in our study also played an important role in supporting sports and leisure activities, including hiking, cycling, cross-country running, hot air ballooning and flying a plane. The map corpus contained four maps of this type, and eight survey participants reported that they used maps for leisure and sports. One survey participant reported that for hiking he annotated maps with lift schedules, potential alternatives routes, the time required to walk along these alternatives, as well as picnic areas next to the trail. These annotations made him feel safer when hiking as he had a variety of options in case he had to diverge from the initial plan.

Fourteen survey participants reported that they developed bespoke maps to help orient themselves in a new geographic environment. Our interviewee created three maps when she moved to a new city to support the familiarization process with the environment.

In all of the above-mentioned use cases, bespoke customized maps for the same use case tend to be quite similar in character. This suggests that designers may be able to better support these use cases by providing templates which users could select based on their needs. For instance, if the user selects to create a meeting map, a template-based system could propose a marker tool for highlighting the meeting point as well as the possibility to add textual descriptions and graphical directions (e.g. arrow symbols) to the map. Similarly, customized travel maps typically contain a specific set of POIs such as accommodation and key public transport locations, as well as routes between these and other POIs. A basic version of the template-based approach we suggest has been implemented for at least one use case: wedding maps (weddingmapper.com). Our results suggest that this approach would likely be effective for most of the popular use cases of bespoke map customization.

It is straightforward to imagine tools that begin creating these maps automatically by mining interesting information. This can be thought of as the spatial equivalent of systems that mine e-mail for hotel reservations and automatically add them to associated calendar systems (e.g. Gmail and Google Calendar). Also, if a certain user generally annotates specific points of interests (e.g. art mu-

seums, public transport or Thai restaurants), the system could automatically annotate the map, suggesting points of interests that match previous annotations using algorithms from machine learning and artificial intelligence. Also, it has been proposed to automatically detect points of interests in geo-referenced photos [30], videos [31] or social media [25]. To our knowledge, no existing map annotation tool so far makes use of machine learning algorithms or artificial intelligence.

**#Theme 3: Maps are Customized Throughout an Activity's Lifecycle**

Our findings suggest that bespoke map customization can take place before, during and/or after the activity to which the map relates. Indeed, our survey results indicate that around 57% of maps were customized before the activity, about 24% of maps during the activity, and 19% of maps after the activity (Figure 7).

Although most maps were customized before the activity, "memory maps" presented an important use case in which customizing maps after the activity needs to be supported. Furthermore, the "travel maps" use case suggests the need to customize maps also during the activity. One survey participant reported that for traveling, he used digital maps created with Osmand (http://osmand.net/), an OSM- and Wikipedia-based map service, which can be used offline on a mobile Android device. This allows him to add POIs both prior to departure and while traveling without any roaming fees for accessing the Internet abroad.

In accordance with our findings, we suggest that map customization tools should provide the possibility to customize the same map during different stages of a map's lifecycle. As devices used for accessing the maps may vary, the map customization tools need to support different devices, media and interaction techniques (paper maps and pen; desktop computer with large screen, keyboard and mouse; smartphone, tablet or other mobile devices with smaller screen and touch display). The possibility to access Google My Maps from a smartphone is quite recent and we believe that further progress could be achieved regarding this interaction scenario (e.g. not all functionalities that Google My Maps provides on a computer are also available on the application for mobile devices).

The use of customized maps on mobile devices might also additionally provide the possibility to highlight a user's current position or log a user's track as already proposed by some mobile applications, but not yet included in map customization tools. This could make it easier to annotate maps in one's surroundings, and facilitate the navigation to places that have previously been annotated.

Beyond that, map customization tools need to support offline map annotation—similar to Osmand as described above—for supporting customization of maps during travel in a foreign country where accessing online maps and services is not affordable due to roaming. We see that this

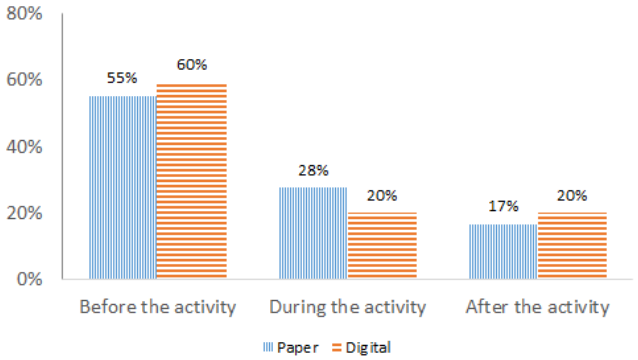


**Figure 7: When survey participants customized papers relative to the activity (marked in vertical blue patterns for paper and in horizontal orange patterns for digital maps).**

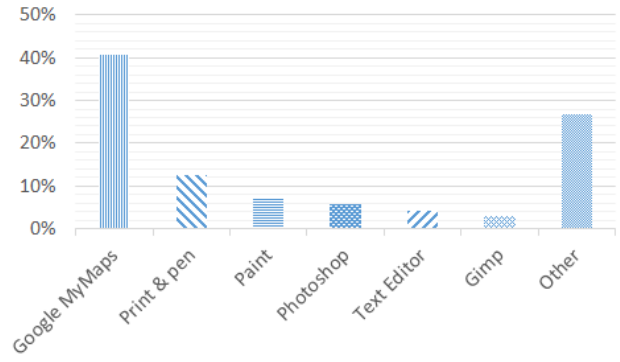


**Figure 8: Most common customization techniques. "Other" includes 19 different techniques that were each named only once.**

feature is currently not well supported by common map customization tools.

**#Theme 4: Map Customization Involves Hybrid Use of Different Media (Paper and Digital)**

Among the survey participants who had previously customized maps, 79% used online maps and 65% used paper maps. Almost half of them (47%) used both. With regard to the latter, a number of participants reported following a hybrid approach in which the same map was customized digitally and on paper. As an example, some users digitally customized a map, then printed it and further annotated the printed map during a city trip. Indeed, while the most popular map customization strategy was to directly annotate on Google My Maps (41%, see Figure 8), the second most popular map customization strategy involved generating a desired map excerpt using a digital map, printing the map, and customizing the printout using a pen (13%). While 12% of all paper maps were digitized at a later stage, one participant applied the opposite process as he traced the original map by hand, scanned it and then worked with it on digital media. We thus observed that map customization is often a hybrid process: people mix analog and digital spatial information and tools.

Interestingly, we observed that only 20% of all survey participants who had customized paper maps had paid for

these maps. Free maps—e.g. from tourist offices—were used by 38% and 40% had printed free maps from the Internet. One survey participant explicitly stated that he did not customize the paper maps included in his travel guide books because it is "bad to write in books". As mentioned above, 12% of the respondents who had never customized maps, stated that they did not want to destroy maps by writing on them.

Our results suggest that future reference map customization tools should not solely focus on the digital production and use of maps, but should also support the integration of paper into the customization workflow. To fully support the types of mixed-media bespoke activities that we observed, this integration needs to go substantially beyond the surface level. As an example, on digital maps, labels can be shown dynamically depending on the user input (e.g. mouse/touch position and movement). However, on a static paper map, significant care must be taken in optimizing label placement. A similar issue exists for the map legend: when zooming and panning is not possible as is the case for paper maps, the legend must be placed in the correct location to avoid occluding key parts of the map [6]. Implementing these features, e.g. through a process prior to printing a map, will likely require some combination of automated approaches (label placement is a challenging algorithmic problem) as well as provision for user customization. Most importantly, the user should not be expected to be an expert in the effects of converting a map from digital to print format (e.g. font size issues, legend occlusion) prior to printing. The possibilities should be highlighted for the user a priori and solutions should be proposed. Knowledge from fields such as machine learning, artificial intelligence and image recognition could provide significant improvements to this regard.

The need for mixed-media support also opens up opportunities for future work in the fields of HCI and augmented reality. For instance, it has previously been studied how to augment paper maps by using Anoto's digital pen technology [21,24,28], or how to project digital maps which can then be annotated using regular pens [3]. Recently, Fedosov et al. have designed a wearable augmented reality system that allows skiers to share content on a printed panoramic resort map using a head-mounted display [8]. However, so far most of these systems remain in the laboratory and have not been transferred to the real world.

#### #Theme 5: Map Customization Tools Should Support Diverse Cartographic Styles

The results of all three data collection methods reveal that, while there are high-level similarities in the cartographic styles of bespoke maps, there is a great deal of diversity with respect to lower-level stylistic decisions. For instance, in the case of the use of map markers, our results suggest that the highlighting of POIs on maps by using markers (e.g. pins, crosses or circles) is an important activity in bespoke map customization. Indeed, almost all maps in our corpus contained some form of markers. Highlighting points with markers was also the most popular answer to the survey question "Describe what you have customized": 31% of all answers regarding the online map and 35% of the answers regarding the paper map referred to this, followed by customization of other map elements such as paths, adding a legend, or manipulating map perspective and orientation.

However, while adding markers is a common bespoke map customization activity, that is where the similarities end. People used a wide variety of marker types, used markers for diverse purposes, and added markers using a diverse set of tools. For instance, our interview participant heavily customized markers and, using Google My Maps, developed a color code to differentiate between "must see", "optional" and "leave out" destinations or different categories (Figure 9). Figure 3 shows a map in which different predefined markers have been used. When annotating by hand, people frequently scribbled markers with various, informal shapes. The same behavior was observed when people annotated maps using MS Paint (Figures 1, 4 and 5), with 7% of survey respondents using Paint as a map customization tool. Existing map customization tools could learn from personalization of menus and options which has been successfully employed in other domains [18].

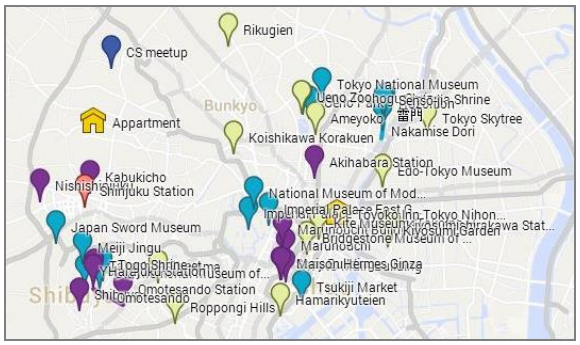


**Figure 9: Travel map created with Google My Maps: modified basemap makes customized POIs more prominent; use of color code for markers to distinguish different categories of sites (power user interview). Google Maps was used as base map ©Google 2014.**

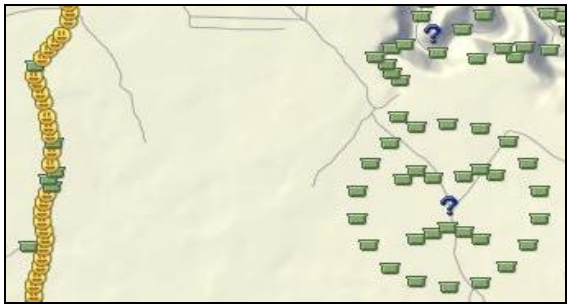

**Figure 10: Using "fun" marker (smileys) and arranging them to form a larger smiley, map created with Bing Maps (P8). ©Microsoft 2014.**

Moreover, we saw examples of participants who employed markers for purposes well outside the typical reference map considerations of navigation and orientation. In particular, we saw evidence of the cooption of traditional map markers for ludic purposes (i.e. "fun"). This can be seen in Figure 10 where, in addition to utilitarian markers, we see that the customizer has also arranged some markers into a "smiley face". To reinforce the ludic aspects of the map, some of the markers were themselves smileys. Existing map customization tools (and mapping platforms) do not support ludic activities like these. While our study suggests that the substantial majority of bespoke maps are primarily utilitarian in nature, providing a set of ludic features may be desirable. For instance, the use of full emoji character sets (pictographs that are popular in text-based communication [19]) as map markers rather than simple smiley faces is one simple way to work towards this.

In addition to the diverse employment of markers, the addition of diverse labels is another important cartographic activity in bespoke map customization. Around 20% of the maps in the corpus contained bespoke labels. These labels were often very informal in nature (e.g. scribbles and sketches), and primarily occurred with maps generated using MS Paint and on printed paper maps annotated using pen and pencil (Figures 1, 3 and 5). While this has been proposed in different contexts, such as for free-hand annotation of endoscopic videos [12], this type of scribbling is not widely supported in map customization tools, even as pen input becomes increasingly democratized (e.g. via Microsoft Surface devices and Apple iPads). Our results suggest that simply adding pen input capability when a hardware device supports it could go a long way towards better facilitating naturalistic map customization activities.

## DISCUSSION AND DESIGN IMPLICATIONS

The purpose of this paper is to provide insight into diverse bespoke map customization activities to support the design of better cartographic tools. To summarize, we propose the following design implications for current and future map customization tools:

**Provide templates and tools for different use cases:**
We observed that map customization has several primary use cases, and each has relatively well-defined cartographic needs. As such, it would be possible to build templates into cartographic tools to better facilitate the creation of specific customized maps.

**Increase the flexibility and personalization of such tools:**
Map customization tools should support various cartographic styles, e.g. handwriting and scribbling, or a large choice of marker types. Support for ludic activities is also suggested as a new feature.

**Support map customization at different moments:**
There is no single fixed time in the course of an activity for the creation of bespoke customized maps. Thus, map customization tools need to provide the possibility to customize maps before, during and after an activity. Therefore, tools need to cater for different devices (e.g., computer, smartphone, paper). Online and offline use should be supported even on mobile devices, as well as the possibility to upload offline annotations later.

**Support multimedia interaction:**
People go back and forth between different media when customizing maps. Digital maps should be convertible into paper maps using printing options that go beyond those that are currently available (e.g. adapting legend style and placement or the amount of displayed text). Advanced interactive devices such as augmented reality systems or Anoto pens could be used to make paper maps interactive.

**Make tools more intelligent:**
We identified opportunities for the integration of machine learning approaches into map customization tools. In particular, information extraction approaches like those taken in modern calendaring systems could be applied to automatically-generated travel and meeting maps, a common use case for bespoke customization.

While we presented the best available data to date about bespoke map customization frequency and behavior, our results have some limitations. First, out of the 37 maps in the map corpus, only three maps were created on paper. We suppose that there was a bias towards submitting digital maps given that the maps were collected through an online survey. In the future, it would be interesting to have a closer look at how paper map customization is done in order to design multimedia tools. Additionally, while our survey sampling approach was appropriate for gaining a first-pass understanding of map customization behavior, a more traditional survey framed by the findings presented here is an obvious next step for further research in this domain.

## CONCLUSION

In this paper, we presented the first exploration of the common activity of bespoke map customization. We applied a mixed methods approach involving a survey, an interview with an expert, and the analysis of a corpus of customized reference maps (which we are making available to the public upon request). We also took first steps towards systematically deriving design implications for current and future map customization tools to better support the use cases for which bespoke map customization is employed. Our design implications suggest a series of new features for mapping tools, such as templates for common customization use cases, more personalization options and deep support for multimedia (paper and digital) map annotation.

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