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A Collaborative Process for Developing Map Symbol Standards

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Abstract

Geographic information is commonly disseminated and consumed via visual representations of features and their environmental context on maps. Map design inherently involves generalizing reality, and one method by which mapmakers do so is through the use of symbols to represent features. Here we focus on the challenges associated with supporting mapmakers who need to work together to reach consensus on standardizing their map symbols. Based on a needs assessment study with mapmakers at the U.S. Department of Homeland Security, we designed a new, mixed-method symbol standardization process that takes place through a web-based, asynchronous platform. A study to test this new standardization process with mapmakers at DHS revealed that our process allowed participants to identify many issues related to symbol design, meaning, and categorization. The approach elicited sustained, iterative engagement and critical thinking from participants, and results from a post-study survey indicate that participants found it to be useful and usable. Results from our study and user feedback allow us to suggest multiple ways in which our approach and platform can be improved for future applications.

Keywords: symbology; map design; category development; collaboration;

1. Introduction

Consumers of geographic information often develop their understanding of geographic phenomena through the use of visual representations of the phenomena and their surrounding environment on maps. To create maps, cartographic designers wield a wide range of graphical and non-graphical generalization operators to simplify reality and communicate a purpose or afford a particular function [1]. How these decisions are made depends on a few key concerns, including the desired output format, the map audience,

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and the message the map should convey or function it should support [2]. The nature of the problem for cartographic designers is such that there is never a single perfect design solution [3].

One of the key mechanisms by which cartographic designers can communicate geographic knowledge is through the use of graphic symbols to represent features on a map. Symbols use graphic sign-vehicles to stand for their real-world referents, and the way in which sign-vehicles can be manipulated to support map interpretation has been a focus for decades of research in academic cartography [4, 5]. Much of this research has focused on characterizing how changes to sign-vehicles may influence the ways in which users perceive and understand symbols on a map [6]. Somewhat less attention in recent years has focused on the collection, evaluation, and standardization of existing symbols to develop functional symbols sets for application in real-world mapping contexts. This topic is the focus of our present research. Among other things, the development of map symbol standards requires collaboration among multiple cartographers to agree upon symbol sign-vehicles, the definition of referent features, and categories by which symbols may be organized for intuitive application and re-use.

In this paper we present a collaborative, mixed-method approach for tackling these challenges for groups of cartographers who are faced with the need to develop standardized sets of map symbols. We have designed an iterative symbol standardization process that uses a web-based, distributed, and asynchronous collaboration platform. To test our approach, we recruited a group of cartographers from the U.S. Department of Homeland Security (DHS) to iteratively audit, refine, and categorize their map symbols.

The following sections describe common symbol standards and processes for their development, the design and development of our new symbol standardization process, results from our case study application of the process with cartographers at DHS, and what we have learned from this case study to suggest refinements to our collaborative symbol standardization process. We conclude with ideas for future work that emerge from our results.

2. Symbol standards and their development

2.1. Symbol standards

Map symbol standardization received early attention from academic and practicing cartographers over 150 years ago. Funkhouser [7] highlights a series of proceedings from the 1853-1876 meetings of the International Statistical Congress (ISC) as the first printed discussion of map symbol standardization. Proponents argued that the primary advantage of standardization is that the resulting maps can be made directly comparable with one another. Despite these efforts, the standards developed by the ISC were not widely adopted, and practicing cartographers considered them to be impractical.

Interest in map symbol standards was renewed with the rise of the *communication paradigm* in Cartography [8, 9]. This paradigm specifies that the map is a medium through which the cartographer delivers a message to the map user. To ensure this message is delivered effectively, symbols must be selected by the cartographer to represent geographic features. Standardized symbols can improve cartographic communication by establishing a consistent set of sign-vehicles [10].

In subsequent years, some progress on symbol standardization was reported for economic maps [11, 12], topographic reference maps [13, 14], and transportation maps [15]. Robinson [16] also noted existing conventions for geologic, hydrologic, and soils maps that were nearing standardization.

Robinson [16] identified key advantages and disadvantages to implementing symbol standards for thematic maps. Four advantages include: (1) the meaning of a symbol can remain consistent, (2) map users would not need to rely on a legend once a standard has been learned, (3) symbol standards would make map reading easier to teach, and (4) maps are easier to create if symbolization is already prescribed. Today, we would suggest that additional advantages include: (5) the ability to compare multiple maps directly and (6) improved ease in sharing information within and between organizations. Robinson

identified three disadvantages to symbol standardization: (1) resistance from cartographers who are already employing their own symbolization, (2) inability to adapt the symbol standard to a specific objective or task, and (3) the inability to compensate for map user preferences. We also see disadvantages related to: (4) the inability to reconcile competing conceptualizations of the symbolized geographic phenomenon [17], (5) the inability of a single graphical standard to reproduce consistently and clearly on different types of media, and (6) inability to enforce the use of a standard once it has been developed.

Emergency management is one domain in which symbol standards have received a lot of recent attention. Maps quite often provide visual common ground for teams of collaborators who must focus on establishing and maintaining situational awareness in an emergency situation [18]. To be effective, maps for emergency management contexts must be readily interpretable by decision-makers, analysts, first responders, and, in many cases, map users in the general public. Developing standard sets of map symbols is one mechanism by which it is possible for mapmakers and map users alike to engage geographic information from emergency contexts in an effective manner [10, 19].

Multiple symbol standards designed to support emergency management are in use today. Examples include standards for demining [20], military operations [21], and emergency response [22, 23]. The focus of most of these symbol standards is on point symbols, although some recent standardization efforts have also focused attention on symbolizing area features [10].

2.2. Existing processes for developing map symbol standards

Current methods for developing map symbol standards typically feature multiple phases that include collecting existing symbols, defining features that must be symbolized, and evaluating the resulting symbol standard. Here we describe the specific processes used to develop several recent map symbol standards designed to support emergency management activities.

The ANSI 415-2006 INCITS Homeland Security Map Symbol Standard is a point symbol standard designed for use during domestic crisis response efforts. Development of the ANSI standard featured five steps: (1) create definitions for desired feature types, (2) collect existing symbols, (3) classify those symbols by thematic similarity, (4) produce a matrix showing a recommended symbol for each feature, and (5) logically define each symbol in the matrix [24]. The symbols were then evaluated using an online survey by emergency responders. Symbols not meeting a 75% approval rating were either deleted or modified (22 of 214 symbols failed). A recent study of the ANSI symbols conducted with firefighters yielded different results, with only 7 of the 28 fire-related symbols yielding a comprehension rating above 75% [25].

Another symbol standard focused on supporting humanitarian demining operations, the Information Management System for Mine Action (IMSMA), was developed in five steps; (1) survey existing symbols, (2) develop criteria for the design of symbols, (3) design of an initial draft of the symbols, (4) qualitatively evaluate the draft symbol set, and (5) revise the symbols according to expert feedback [10]. 21 domain experts reviewed symbols and their definitions, noting those that should be modified with written comments and suggestions.

The Australian All-Hazards symbol standard extended the Australian Inter-service Incident Management System (AIIMS) standard developed to serve a range of emergency response agencies in the Pacific Rim region. The All-Hazards symbol standard includes for point, line, and area features. Its development was completed in three stages: (1) project planning to define tasks, deliverables, and deadlines, (2) consultation and audits to identify existing symbols and their usage, and (3) creation and evaluation of draft and final symbol sets [26].

3. Characterizing user needs for a new symbol standardization process

Our research focuses specifically on the point symbol needs of the United States Department of Homeland Security (DHS), a domestic security organization that includes twenty-two agencies that focus on a wide range of mission areas, each of which with specialized geographic information requirements.

In preliminary work, we focused attention on the ANSI 415-2006 INCITS Homeland Security Map Symbol Standard [22]. We conducted fourteen interviews with mapmakers at seven DHS agencies to characterize the adoption of the ANSI standard, to identify the other map symbol standards and ad hoc symbol sets, to describe critical incidents related to symbology, to identify technical and organizational constraints on symbol standard development and implementation, and to gather feedback on new and improved processes for developing symbol standards. Here we briefly summarize our findings from this study; full details on this research are available in [27].

Our interview results revealed key issues associated with the adoption of the ANSI standard. The ANSI standard is not used in whole by any of our participants, and is only used in part by a few. Participants state that it does not match their mission-specific needs. The ANSI symbols are also seen as hard to parse, too intricate, and problematic when applied across a range of common map scales. Participants describe no significant technical issues related to symbol standard development and implementation, but they describe significant organizational challenges that suggest new policies are needed to ensure standards are used.

Participants indicate that they currently use ad hoc, informal symbol standards in lieu of the ANSI standard. These symbol collections typically are developed on a one-time basis by a few cartographers at each DHS agency. Furthermore, our participants suggest that formalizing, refining, and sharing these ad hoc map symbol standards is a way forward toward the development of new, useful symbol standards.

4. A mixed-method process and platform for standardizing symbols

Based on our needs assessment research with cartographers at DHS, we designed a new symbol standardization process intended to formalize, refine, and share existing ad hoc standards. The standardization process we developed relies on a distributed, asynchronous platform so that busy cartographers can participate in standard development without being in the same place at the same time. Our approach makes use of flexible open-source web tools to support and capture the process of standard development. This strategy enables repeatability, ensures that we document key decision points and their rationale, and encourages participants to view symbols from a variety of vantage points.

4.1. Mixed-method standardization process

Four rounds comprise our symbol standard development process. The first round focuses on needs assessment to identify and collect current symbols and map examples as well as to discuss problems with existing symbols and symbol categories. An important component of this stage is the identification of ambiguous or misleading symbols as well as symbols that are poorly designed graphically or do not work well for all required mapping contexts.

In the second round, participants begin developing categories for the symbol set by completing a card sorting activity, a knowledge elicitation technique requiring participants to assign individual symbols (i.e., cards) to one in a set of multiple categories [28]. A description of the utility of card sorting method for map symbol design is provided by Roth et al. [29], which includes a discussion of different card sorting variations that may be employed given various stages of map symbol set design. Following these guidelines, participants complete two sets of card sorting, beginning with an 'open' sort, in which they are able to establish their own set of categories (the second sort is completed as part of the third round). Following the open card sort, participants discuss the sorting results and vote on an initial set of categories for structuring the symbol set. Throughout the second round, participants discuss and vote on

how to handle redundant and/or poorly designed symbols identified through the open sort and on ideas for new symbols not included in the sort.

In the third round, participants complete a second, 'closed' card sorting activity in which they assign the revised symbol set to the categories identified and agreed upon in Round #2; while participants are not able to create their own categories during this sort, they can make use of an 'other' category. This activity helps ensure that the final standard reflects an agreed-upon structure that has been iteratively refined. This round also includes discussion and voting on topics related to evaluating the new symbol standard.

In the fourth and final round, the symbols are redesigned according to the feedback collected from the prior rounds. The revised symbol set then goes under an external review of the new standard by cartographers and map users for quality control, as well as an evaluation through a tabletop exercise or other scenario-based approach.

4.2. A web platform for symbol standardization

Our platform, which we call the e-Symbology Portal (Fig. 1.), is a customized Drupal (http://drupal.org/) application that facilitates the creation of asynchronous, round-based activities for interactive refinement and formalization of a map symbol standard. Activities supported by the e-Symbology Portal include threaded discussions and polls, and a wide range of multimedia content can be presented to users in the portal, including text, images, and videos.

Each round has a text-based instruction page that introduces the goals of the round and provides an explanation of and links to the activities included in the round. Each round of participation is opened for a specified timeframe (1-5 days, depending on the activity). Contributions in each round are moderated by a member of our research team to distill feedback into key issues for further discussion and voting. In addition, we have implemented a procedure designed to anonymize participation to promote diversity of opinions—similar to the way in which a Delphi exercise [30, 31] functions.

For the card sorting activities, the process makes use of WebSort (www.websort.net), a web-based application that provides graphic and text card sorts through a straightforward drag-and-drop interface [32, 33]. WebSort features analytical tools to help identify clusters in category assignments for cards, which in turn can be used as feedback to participants to help inform iterative development of symbol categories.

It is important to note that we anticipate different user groups to require somewhat different activities in each round of standard development and we have crafted a configurable process and platform to suit different map symbol needs. While the key goals listed above may remain the same, some groups who already have large symbol sets may not need to spend much time developing *new* symbols, and instead may focus on categorization and definition issues. Other groups with more nascent map symbol sets may require a deeper focus on both types of problems.

Fig. 1: An example of an instruction page and poll for Round #1 in the e-Symbology Portal.

5. Developing standard symbology for U.S. Customs and Border Patrol

To evaluate our process for symbol standard development, we worked with 7 participants at DHS' Customs and Border Patrol (CBP) division to formalize and refine their ad hoc map symbol standard, a collection of 168 point symbols. CBP participants took part in a three week study focused on completing the first three rounds of our symbol standardization process (the final round was omitted because it involves external review and evaluation activities). The following sections describe the results we gathered from each round.

5.1. Round #1 results

Round #1 focused on identifying problems with the current CBP symbol set, suggesting new symbols that should be included in a refined symbol set, and discussing general issues with respect to the categorization of CBP symbology.

A number of symbols were identified that need improvement. These include symbols that appear too similar (16 examples), are graphically complex (8 examples), difficult to interpret (25), or redundant symbols that represent the same feature (1 example). Participants also identified symbols that need to be added to the current symbol set (5 examples).

In terms of symbol categorization, participants suggested that categories should be kept at a relatively high-level rather than too specific. One participant suggested that using an alphabetical matrix was a good idea since this format made it easy to look up symbols.

To prompt further discussion, we asked participants whether symbols in the CBP standard should be categorized at all; 4 voted yes, 1 voted no, 2 did not vote. We also asked participants whether or not the categories they had applied in their ad hoc standard (before starting through our standardization process) should be used in their new standard; 3 voted yes, 1 voted no, 1 voted no categories should be used at all, and 2 did not vote.

5.2. Round #2 results

In Round #2, participants completed an open card sorting exercise to develop a range of possible categories for CBP symbols. Using WebSort, participants were presented with a set of cards, each showing a single symbol. Participants were asked to sort these cards into groups of their choosing based upon their similarity. We did not instruct participants in various definitions of similarity, rather, this round was focused on eliciting the diverse range of individual conceptions of categories in order to stimulate and sustain further iterative refinement in later rounds of the process.

Results from participant card sorting in this round show a wide range of possible category options for the CBP symbol set. As noted above, WebSort provides visual and interactive analysis techniques to

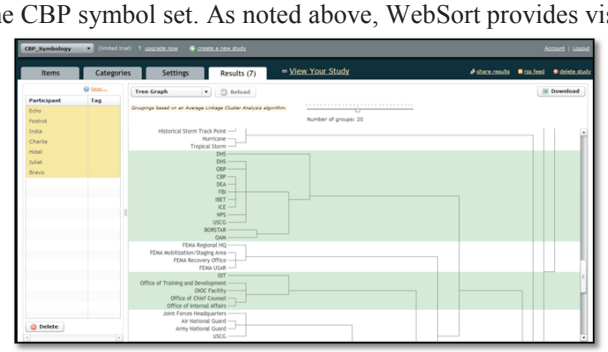

Fig. 2. Interactive exploration of card sorting results using the dendrogram visualization in WebSort.

explore the agreement of symbol groupings across participants. Fig. 2 shows a screenshot of the WebSort dendrogram visualization, which uses hierarchical clustering to order the cards according to how often the y were placed in the same category by participants. Categorization structures can be explored by interactively changing the number of desired groupings using a slider control.

Using these analysis tools, we were able to identify four general categories that had substantial agreement across all participants: Agency Facilities, Infrastructure, Assets, and Events. We presented this information to participants and asked them to discuss these results and reflect on this category structure. In the discussion, participants stated that the four categories were a good starting point, but too broad to be very useful. Based on further discussion, participants suggested nine more possible categories: CBP, Events, Assets, Picture Symbols, DHS, Miscellaneous, General Not Office of Border Protection (OBP) Specific, Intelligence, and Landmark Not OBP Specific. In a subsequent poll, participants voted on which categories to carry over into the next round (Round 3) of symbol standard development. The agreed upon categories for the new standard included: CBP, Events, Assets, DHS, and Miscellaneous and Picture Symbols.

In addition to the card sorting exercise, Round #2 asked participants to continue refining the symbol set based on the issues identified during Round #1. Among the issues addressed in this activity were ambiguity problems with several symbols, the deletion of one symbol from the CBP standard, and the addition of four new symbols. During this discussion, participants also indicated that a general design improvement for event features was necessary to identify the individual event symbols as part of the same higher-level category, such as through the use of a common background color or shape.

5.3. Round #3 results

In the third round, participants completed a closed card sorting activity. Unlike Round #2, where participants created their own categories, this time participants were asked to place symbols (including symbol additions/deletions from Round #2) into the categories chosen in the Round #2. Five of the six categories were included in the closed sorting activity: CBP, Events, Assets, DHS, and Miscellaneous. The Picture Symbols category was not included for logical consistency (i.e., the distinction is based not on the feature type, but on the type of symbol representing the feature type) and after discussions with participants, the Miscellaneous category was included to provide an "other" category for symbols that were not easy to categorize.

The closed card sorting activity was important to the standard development in two ways. First, we were able to identify 19 symbols that were not placed in any of the categories a majority of the time. Discussions on these ambiguous symbols revealed that a sixth category called General Government or External Entities was needed to collect the majority of these symbols; and a follow-up poll determined that the former term was a most appropriate label for this category.

Second, the closed card sorting activity spurred a discussion among participants about the possibility of including a hierarchical categorization for the symbols. Participants generally felt that the category structure they had developed so far, while valid, was still too vague to be maximally useful. Participants suggested creating sub-categories in some instances to provide a hierarchy within the symbol set. Discussion focused on the CBP category in which six sub-categories were identified and adopted.

These Round #3 activities led to multiple rounds of discussion and voting on which new categories/sub-categories to add, what they should include, and general guidelines for what should constitute a reasonable symbol category (e.g., maximum number of symbols, whether or not picture symbols should exist separately as their own category, etc…). Three separate discussion threads and ten polls were used during this round. From these activities, participants reached consensus on a final set of categories on which to vote for adoption in the CBP standard. Six categories were approved: CBP (with sub-categories OBP, OAM, OFO, and Intel), General Government, Events, Miscellaneous, DHS, and Assets. The BP Reference/Waypoint, although receiving a majority of votes, was later determined in

discussions to be a sub-category of CBP. The Picture Symbols category, which did not receive a majority of votes, was included in the final standard because these symbols need to be maintained in a separate ESRI .style sheet.

6. User feedback and process refinement recommendations

In this section we characterize feedback from our study participants as well as the issues we encountered (and recommendations for handling those issues) while conducting and moderating the trial of our standardization process and platform.

6.1. Participant survey results

As outlined above, our study resulted in significant changes and refinements to the CBP symbol standard. To further gauge the effectiveness of our process, and to suggest possible improvements, we created a short online survey for participants to complete. Survey results (survey questions and full results available in Supplement A at www.personal.psu.edu/acr181/Survey.pdf) indicate that most participants were satisfied with the outcome of this study, that the methods we used were helpful toward refining their symbology, that the time commitment required was acceptable, that the materials they received were useful, and that the interactions they had with moderators were positive. This survey also revealed that voting was particularly useful for moving the process beyond back and forth discussions, and that a card sorting activity to begin the study in Round #1 would have helped to suggest symbol problems/issues to kick start the overall standardization process.

6.2. Process issues and recommendations

While executing the case study with CBP, we were able to identify modifications to our approach to improve participation and feedback. First, maintaining consistent participation from busy professional mapmakers remains a challenge. We expected participants to spend roughly 60 minutes over the course of each week-long round to complete the activities. Participants were generally split into two groups: (1) a highly active group that completed all activities and spent a longer than expected time contributing to the message boards and (2) a less active group that missed substantial portions of some activities. Our approach to encouraging participation from the latter group was to send reminder emails once every two days. While this strategy was effective in getting passive participants to complete activities that could be completed in a single sitting (i.e., the card sorting and polling activities), it was not effective in generating continued contributions on the discussion boards. To overcome this issue, we would like to explore the possibility of adding tangible incentives for participation. In addition, we suggest leaving discussion boards open for a longer period than 5 business days to allow for extra time for less active participants to contribute before moving to the next topic.

A second issue, also related to time constraints, was a notable difficulty in transitioning between rounds. A key component of the round-based approach is to have moderators summarize the feedback collected in each round and then use these summaries to use to tailor activities in the following rounds. Because of constraints on participant availability, each round was opened on a Tuesday and closed on the subsequent Monday, meaning that each round needed to be summarized in a single evening with new content posted by early Tuesday morning. This was difficult for moderators to complete. In the future, we suggest building in 2-3 days between rounds for moderators to summarize the prior round and post the next round's content. This would also help to combat participant fatigue, giving them a break between the time-intensive final voting at the end of one round and the equally time-intensive opening exercise at the beginning of the next round.

A third issue we noted was the high reading load given to participants at the start of each round. Part of our strategy to encourage participation was to supply a document at the start of each round that provided instructions for round activities; mirroring the content that was shown on the e-Symbology site. Several of these guides were quite long, particularly in the earlier rounds when participants were less familiar with the e-Symbology interface. In the future, we would recommend alternative media, such as video demonstrations, to assist in communicating the instructions associated with each round. We have already begun developing several videos to use in the next trial of our standardization process.

Finally, we found that concluding the symbol standard process development requires an additional round in which we present a summary of the standardization results to the participants. This helps participants evaluate how successful their efforts were and provides the opportunity to hold a concluding vote to approve the final symbol set and its categories. While we conducted both activities in our test with CBP, we had not anticipated the need for these steps in our original process methodology.

7. Conclusions and future research

In this work we have highlighted the need to support groups of mapmakers in their efforts to standardize map symbols. Previous processes to help define symbol standards have had mixed results. Some standards have been widely adopted, while others have not. Based on prior work and our own needs assessment study with mapmakers at DHS, we designed a new symbol standardization process that blends together multiple methods of knowledge elicitation in a web-based, asynchronous platform.

In the first trial of this new standardization process and platform with mapmakers at CBP, participants identified a large number of issues related to symbol design, symbol meaning, and symbol categorization. Our approach was successful at eliciting sustained, iterative engagement from participants, and feedback from a post-participation survey indicates that participants were pleased with the outcome. In testing our process and evaluating participant experiences with the process we also learned a variety of ways in which we can improve upon our approach and platform.

The results from our research suggest a wide range of possible new directions for subsequent work. An obvious next step is to refine our symbol standardization process further and to apply it with other groups of mapmakers. A long term goal is to generalize our approach to the point at which it can be used by a wide variety of mapmakers engaged in topics beyond emergency management.

Once a standard has been developed, there are not good mechanisms for mapmakers to discover and share symbol sets. One possible solution would be a web-based symbol repository that could allow users to contribute, browse, and share symbols. It is also possible to envision features in such a tool that would allow users to discuss and vote on symbols and symbol categories in much the same way as is done in the standardization process we have outlined here.

Our experiences designing and evaluating a new process for standardizing symbols makes it clear that while the goal of having usable and useful map symbol standards is an important one, the way toward achieving that goal requires substantial effort on the part of mapmakers, even when the process is facilitated in an asynchronous, distributed manner. Even then, our process required manual moderation in order to flexibly tailor each round of activities. A long term goal should be to identify parts of our process and other processes that can be blended into existing mapping tools to make the act of standardizing symbols transparent to the end-user, while still resulting in high quality, refined symbology.

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