

Research on Interaction and Collaboration Patterns of Emergency Maps Based on Structured Icons (Postprint)

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Abstract

[Purpose/Significance] By introducing structured icons to improve icon representation in conventional emergency maps, this study aims to coordinate more complex crisis information interaction and collaboration. [Method/Process] Structured icons suitable for crisis contexts are designed, and visualization interaction and collaboration patterns based on structured icons are developed accordingly. [Results/Conclusion] First, the preset base icons of structured icons can visualize crisis event associations and improve information search interaction experience; second, structured icons can dynamically represent the spatiotemporal attributes of crisis information, enhance information cognition, and improve decision-makers' collaborative decision-making capabilities. Theoretically, this study proposes an emergency information interaction pattern based on structured icons, enriching emergency information visualization theory and emergency interaction theory. Practically, it optimizes the design of icon-based emergency collaborative systems, enhances interaction between participants and emergency information, and helps decision-makers conduct efficient and timely emergency collaborative decision-making.

Full Text

Research on Emergency Map Interaction and Collaboration Mode Based on Structured Icons

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Abstract: [Purpose/Significance] This study introduces structured icons to improve icon representation in traditional emergency maps, aiming to

coordinate more complex crisis information interaction and collaboration. [Method/Process] Structured icons suitable for crisis contexts were designed, and a visualization-based interaction and collaboration model was developed based on these icons. [Result/Conclusion] First, the pre-icon base layer of structured icons can visualize crisis event relationships and improve information search interaction experiences. Second, structured icons can dynamically represent the spatiotemporal attributes of crisis information, enhance information cognition, and improve collaborative decision-making capabilities. Theoretically, this study proposes an emergency information interaction model based on structured icons, enriching emergency information visualization theory and emergency interaction theory. Practically, it optimizes the design of icon-based emergency coordination systems, enhances interaction between participants and emergency information, and helps decision-makers conduct efficient and timely collaborative emergency decision-making.

Keywords: human-computer interaction; icon; information structure; emergency collaboration; spatiotemporal analysis; interaction interface

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Information coordination is a key element for achieving efficient and precise emergency interaction and collaboration [1]. How to utilize modern information technology and information management methods to improve information sharing is an important research topic in the crisis information field. Among these, electronic maps supported by geographic information technology have become effective tools in emergency interaction [2], providing emergency personnel with comprehensive, multi-perspective, and wide-scale information query and loca-

tion services [3]. Previous research has demonstrated that reasonable layout of visual elements such as images, text, icons, scales, and colors in electronic maps can meet different information needs in crisis interaction and adapt to variable application environments [4]. However, these visual elements have focused on representing specific physical objects to reduce interaction friction between users and electronic map interfaces, neglecting interaction among crisis users and the visualization of dynamic crisis information. Although most studies have addressed how to express effective crisis information on maps amidst massive and complex information [5], these symbols and annotations mostly represent static information [6] and fail to effectively characterize crisis event changes and inter-event correlations from a dynamic perspective. Therefore, we plan to start by improving representation icons and symbols in electronic maps, designing structured icons and related components suitable for crisis contexts to enrich emergency maps' representation of crisis information, enhance people's cognition of crisis information, and thereby improve collaboration efficiency among emergency rescue personnel. Structured icons consist of two main elements: the pre-icon base layer and pictographic symbols. The pre-icon base layer distinguishes different event themes while strengthening explicit associations among same-theme events, while pictographic symbols represent specific event types. Overall, structured icons can represent multi-level complex crisis information and visualize information structures [7]. Dynamic changes in icon color and size can be used to measure the severity of quantified events, strengthening people's process cognition of event changes. Therefore, this paper focuses on exploring structured icons in emergency maps and their related component designs, analyzing their impact on crisis interaction and collaboration. The research objective is to apply structured icons to crisis maps to enhance people's cognition of crisis information and improve emergency decision-making.

2 Research Status

Emergency information interaction and collaboration involves multiple research fields including public management, information science, and human-computer interaction. This study primarily explores the spatiotemporal dynamic characteristics of emergency information and interaction collaboration based on emergency information, thus involving two main knowledge backgrounds: spatiotemporal visualization of emergency information, and emergency interaction and collaboration.

2.1 Emergency Information Visualization

Information visualization is an interdisciplinary field that studies the visual presentation of large-scale non-numerical information resources. By utilizing graphics and image technologies and methods, it helps people understand and analyze data. Spatiotemporal data refers to spatial data with temporal elements that change over time, representing information about geographic features in the Earth's environment. Due to the inherent characteristics of spatial entities and

phenomena in three aspects—time, space, and attributes—such data exhibits complexity in multidimensional, semantic, and spatiotemporal dynamic associations. Map visualization is the most common means of emergency information visualization. Traditional visualization forms such as text or single symbols can help deepen memory of key information but are not conducive to users' understanding of information content and structure [8]. Structured icons can achieve synchronous visualization of content and structure through their dual characteristics of icons and symbols [9], making them suitable for spatiotemporal data visualization. Spatiotemporal data visualization methods can be divided into static and dynamic visualization. For emergency information visualization applications, one aspect involves representing and simulating disaster situations based on algorithms and data to support decision-making and emergency assessment, including chemical safety evacuation [10], explosion risk assessment [11], flood simulation [12], and virus spread simulation [13] based on maps. The other aspect is data-driven decision-making [14], discovering trends from information classification statistics, such as geographic emergency systems based on tag clouds for public opinion analysis [15] and emergency systems for flood impact area analysis [16].

2.2 Emergency Interaction and Collaboration

Emergency interaction and collaboration has been a hot topic in recent years, such as emergency crowdsourcing and VR emergency training. Regarding interaction, human-computer interaction involves numerous emergency-related directions, with the main research purpose of improving user operation experience, such as touch-screen interactive maps [17], 3D-printed sand table prototype systems [18], 3D maps for enhanced geographic cognition experience [19], and virtual reality-based emergency training systems for enhanced user immersion [20]. Beyond user experience improvements, designing physical templates and graphical simulation interfaces provides another angle for simplifying complex emergency problems [21]. Social networks, collaborative platforms, and open-source communities have become venues for group collaborative behavior, making user information behavior coordination an inevitable trend. In collaborative activities, information coordination is paramount, and such coordination between departments and people is mainly realized through information system platforms. Emergency rescue work involves multiple organizations and actors, necessitating overall layout and research from collaborative concepts, elements, and capabilities [22], analyzing collaborative relationships, building collaborative platforms, and knowledge coordination management models for resource information integration and sharing [23]. In information collaboration activities, the rapidly developing Internet of Things (IoT) in recent years can connect all devices to the network and interconnect these devices when creating networks [24]. Beyond device and hardware connections, developing a built-in information sharing system framework [25] can solve message communication, collaborative perception, and synchronous transmission problems in vehicle monitoring data, achieving integration and exchange of multiple information systems in emer-

gency management.

3 Emergency Interaction and Collaboration Design Based on Structured Icons

Previous research on icon-based maps mainly focused on representing static, simple information. However, due to the complexity of crisis information and constantly changing crisis situations, ordinary pictographic symbols cannot clearly represent crisis information, and people's interaction and collaboration efficiency may be affected. These problems manifest in three aspects: Existing crisis maps based on icons mainly display static information, while dynamic information such as casualties or rescue resource allocation cannot be expressed through images. The traditional visualization method is "ordinary icon + text label," causing real-time crisis information to lack visual links with representative icons, leading to information uncertainty. Representing correlations between crisis information using ordinary icons is difficult. Different symbol representation methods under different information visualization goals make it hard to find implicit connections between different types of emergency information. Icon design limitations result in a lack of icon-based collaborative interaction on maps. Previous icon design focused more on understandability and aesthetics while neglecting interaction between collaborators and icons, further affecting rescue collaboration behavior and decision-making.

Considering the advantages of structured icons for multidimensional visualization, this study plans to apply this icon representation to emergency coordination in crisis maps. On one hand, by introducing structured icons, pictographic symbols are no longer the single source of information representation. The pre-icon base layer and pictographic symbols of structured icons represent relatively independent information: content and structure. Therefore, it can make information structure explicit and represent dynamic information. On the other hand, this study designs extended information search based on structured icons to enhance cognition of correlations between represented events. Overall, this paper plans to redesign structured icons suitable for crisis maps, expand visualization components based on structured icons, and propose an emergency interaction and collaboration mode based on these structured icons according to emergency coordination design processes.

3.1 Preparation of Structured Icons for Emergency Interaction

The purpose of applying structured icons is to illustrate and reach consensus on semantic relationships in tags and implicit connections between tag resources, thereby improving interaction experience based on emergency information and enhancing the ability to apply crisis information for collaborative decision-making and action. The design concept benefits from the classification of beyond-visual-range text labels (based on themes and attribute values). Introducing icon theory into icon design to represent themes and attributes can

better visualize tag content and structure [26]. In structured icon design, a special set of icons called “pre-icon base layer” represents tag categories, such as same viewpoint, same theme branch, or same attribute name. Base icons form a “graphic organizer” called Visual Distinctive Language (VDL), which aims to visually describe information classification and object categorization. VDL helps identify emphasized topics indicated by multi-category tags. For example, “renewable energy” is a multidisciplinary topic tag involving environmental issues when considering energy, but associated with economic themes when considering reducing energy consumption. Therefore, “renewable energy” would appear as unique text formats in both “environment” and “economy” theme groups. VDL-based icons for “renewable energy” might convert it into two related but different image forms with base icons. Structured icons’ advantages lie in graphical tag structures and symbolic signs, meaning VDL-based tag-labeled information resources are strongly connected. These advantages enable VDL-based icons to better represent multidimensional information and relationships. Moreover, VDL-based icons have proven to enhance information search behavior [27]. Previous studies have theoretically discussed the feasibility of applying VDL-based icons to crisis management [28], but without specific implementation plans.

Based on VDL icon theory and related theories, this study divides crisis structured icon design into three steps: Determine pictographic symbols representing events based on crisis event types; Determine base icons representing events based on crisis event themes; Combine both to create structured icons representing each event. To make pictographic symbols simple and understandable, we first extract core and main features that icons should express based on event description keywords. Second, we use standardized symbol design methods to complete crisis symbol design. Static pictographic symbol design refers to existing icons mainly representing various crisis organizations such as police stations, fire departments, and hospitals. Crisis event symbol design refers to common disaster symbols that conform to people’s cognitive intuition, such as “red flame” for “fire” and “blue water drop” for “flood disaster.”

This study introduces the base icon concept to design crisis icons. Base icons have obvious color distinctions, and overlaying crisis event causes or real-time information to be expressed on base icons can represent relationships or more content, effectively eliminating semantic bias. For example, from temporal and spatial perspectives, the icon “fire” may involve multiple themes, but applying base icons can match multiple theme situations to generate “wildfire,” “urban fire,” and “production fire” respectively. This design uses base icons to represent event themes, dividing them into natural disasters, urban public safety, and production safety.

Structured icons are displayed through combinations of symbols and corresponding base icons, with pictographic symbols overlaid on base icons. When marking crisis events with structured icons, users can directly click the corresponding geographic location on the map and input specific information such as event type

and theme in a pop-up box. The event theme and type in the pop-up box correspond to the base icon and pictographic symbol of the structured icon (see Figure 1), enabling multi-angle information description that avoids semantic understanding bias and helps people find information relationships. For example, when people mention “fire,” they usually refer to natural fires while ignoring urban and factory fires, but structured icons can represent the causes behind events. Additionally, text as a supplementary means helps convey information more clearly. When users hover over event-representing icons, they can view detailed event information such as casualties and scope.

3.2 Emergency Interaction and Collaboration Mode Design

Emergency management faces many challenges including personnel coordination difficulties, time constraints, and information reliability issues. These challenges greatly test the effectiveness of collaboration methods. After determining icon resources and representation methods for dynamic crisis information, this study examines the emergency interaction and collaboration mode based on structured icons. From the perspectives of different types of emergency participants and different emergency stages, we explore how the structured icon-based collaboration mode improves the original collaboration mode.

3.2.1 Collaboration with Different User Types From the perspective of different emergency participants, we discuss three main types of user collaboration:

- (1) **Public Participation Collaboration.** The public is the main body in responding to public emergencies. In recent years, in emergency activities centered on the public, they are no longer just passive recipients of emergency information; their ability to provide information is increasingly valued. Non-governmental actors’ participation improves community disaster prevention capabilities. The system allows users to independently submit emergency information through simple registered account operations.
- (2) **Organizational Personnel Collaboration.** Organizational personnel can view response progress and adjust their plans accordingly. As emergency management leaders, they are responsible for formulating emergency plans and undertaking the most important rescue tasks while coordinating human, material, and financial resources.
- (3) **Expert Collaboration.** Experts modify unreasonable map areas based on emergencies and real-time represented information to ensure accurate use of structured icons. As shown in Figure 3, left-clicking an icon allows replacement; after selecting an appropriate icon, clicking save completes the modification. When experts are unsatisfied with system-provided icon libraries, they can create icons to describe events through simple steps.

3.2.2 User Collaboration Across Different Emergency Stages From the perspective of different emergency stages, we mainly discuss collaboration during emergency preparedness and response stages:

- (1) **Collaboration Exploration in Emergency Preparedness Stage.** The main work in emergency preparedness is knowledge base construction and information annotation based on classified information. Using a top-down approach to build knowledge bases, static analysis gradually refines knowledge to specific information. Knowledge base construction not only reclassifies information based on characteristics but also plays a role in information retrieval. In collaborative information annotation based on structured icons, this model applies spatiotemporal crisis information classification on top of original crisis information classification. Original crisis information is divided into dynamic and static categories. This stage mainly involves static information annotation, which is relatively stable and unchanging. Information representation at this stage helps visualize emergency reserves, such as resident population and medical equipment statistics in specific areas. Additionally, text labels generated from information classification need to be symbolized and converted into structured icons. Special attention should be paid to designing corresponding structured icons for most common crisis events. Different icon types are distinguished by map layers that specify which objects should be displayed.
- (2) **Collaboration Exploration in Emergency Response Stage.** In emergency response, this study applies structured icons in two explorations: Data-driven dynamic information representation of structured icons. The dynamic characteristic means icons can describe not only dynamic information states at a time point but also entire continuously changing information states. For example, casualty data is statistically transmitted to the database at regular intervals, with corresponding severity indicators calculated through formulas to update icon size and pre-icon base color accordingly. This more direct visual experience helps improve users' specific cognition of crisis event severity. Dynamic information search based on structured icons. Structured icons can also improve original information search. In traditional historical event searches, icons can filter specific event types, but such searches cannot accurately display spatial distribution and historical event quantity comparisons. By using structured icon base icons to distinguish event themes, users can compare spatial distributions and quantities of different event types on crisis maps. In emergency rescue based on structured icons, structured icons can improve users' cognition of dynamic processes, helping emergency decision-makers make more reasonable overall resource scheduling and allocation arrangements. For actual emergency rescue activity executors, due to the suddenness and unpredictability of crisis events, emergency coordination plans need constant adjustment during implementation. Structured icons express rich hierarchical information in limited map space, facilitating action process and macro-dynamic coordination of resources and cognition.

4 Evaluation of Interaction and Collaboration Mode Based on Structured Icons

Based on the above analysis, this study evaluates the impact of structured icons on information acquisition and representation in emergency contexts through interviews and questionnaires, further exploring their impact on the entire crisis collaboration process. Specifically, the effectiveness of the structured icon-based interaction and collaboration mode is measured by analyzing users' subjective feelings and utility scoring indicators during the collaboration process.

4.1 Evaluation Design

The evaluation recruited 12 participants (4 female, 8 male) aged 21-26, including university students and researchers from different backgrounds, numbered 1-12. The entire interview was conducted in a laboratory, with participants signing informed consent forms beforehand. During the interview, participants first gained a basic understanding of structured icons and the emergency process. After relevant training, participants were grouped into 3-person teams to complete the evaluation process, experiencing the interaction and collaboration tools designed for each emergency stage in the structured icon-based emergency collaboration system. For the four groups, the first two groups used the ordinary system first, then the structured icon-based system, while the other two groups used the systems in reverse order. Before formal evaluation, participants were briefly introduced to the screen interface, various interaction tools, and supported interaction types. Interaction tools included related event search, event dynamic process viewing, and participant-customized icons. Related event search was used for historical event searches, with the system providing event "filters" including event theme, type, and occurrence time. After submitting filter conditions, the map displayed distributions of matching historical events. Event dynamic process viewing was used for dynamic perception of current crisis events, with the system providing a timeline that automatically jumped to time points, which participants could also click to view crisis event severity represented by structured icons at that time. Participant-customized icons allowed participants to replace icons representing current crisis events with other icons from the library when unsatisfied, or create structured icons matching specific crisis events through simple steps. During evaluation, participants first shared information obtained from the interface and interaction tools within their groups, then each group designed the most reasonable and efficient emergency rescue plan based on mastered information, with a time limit of 25 minutes from evaluation start to collaborative decision completion. After decision completion, group interviews were conducted focusing on interaction and collaboration experiences throughout the process and actual system usage feelings, followed by questionnaire completion.

4.2 Results Analysis

Based on interview and questionnaire results, analysis was conducted from three aspects: the impact of structured icons on information interaction, their impact on the entire interaction and collaboration process, and their impact on emergency collaboration information system construction.

4.2.1 Impact of Structured Icons on Information Interaction Experimental observations showed that when participants shared information referring to structured icons, their descriptions were accurate and all groups mentioned distribution characteristics of related event types on maps. As participants 1, 2, 8, and 10 stated: “The base icons of structured icons make it easier for me to find distributions of similar events on the map.” This reveals the essential characteristics of structured icons. Additionally, participants recognized that structured icons clearly convey information value. As participant 5 described: “Structured icons don’t make information messy despite expressing more information, so I can clearly describe events and express more useful information.” Visual similarity between base icons reflects event correlations. In other words, structured icons actually provide structured information in crisis situations, improving information representation accuracy and interaction efficiency.

4.2.2 Impact of Structured Icons on the Entire Crisis Interaction and Collaboration Process After participants used the information system platform for collaborative discussion tasks, they described the task completion process. Participant 8 stated: “We had more interactive experiences and information acquisition tools, which helped us better generate needed solutions. These useful interactive function components ran through the entire process.” Six participants mentioned that discussion solution quality was closely related to information obtained through the information system. Two participants noted that interactive components such as search and custom icons helped them think and analyze. Participants 2 and 7 also mentioned, “Completing collaborative negotiation with the help of the information system was easier.”

4.2.3 Impact of Structured Icons on Emergency Collaboration Information System Construction The study collected questionnaires from participants, first evaluating the differences between the two systems in terms of comfort, intuitiveness, interactivity, ease of use, and learnability on a 1-5 scale. Results are shown in Figure 4(a). The results indicate that the system had small differences from ordinary icon-based emergency systems in intuitiveness, ease of use, comfort, and learnability, but showed obvious advantages in interactivity. Second, factors evaluating emergency system utility included: information representation capability; capability to represent event correlations; user interface interaction experience; inter-user collaborative experience. Participants scored these on a 1-5 scale, with higher scores indicating higher system evaluation. Experimental results are shown in Figure 4(b). The system scored

above 4 on all indicators, meeting all effectiveness criteria. Participants consistently believed that the information system's value lay not only in structured icons' application improving information representation capabilities, but also in the system's ability to provide structured icon-based interface interaction and inter-user collaborative experience.

5 Discussion

This study proposes a structured icon-based collaborative method building on previous research about emergency map interaction and collaboration. Compared with ordinary icon-based methods, introducing structured icons and related visualization components at different emergency stages has significant impacts on emergency information representation, search, and collaboration.

- (1) **Structured icons effectively represent crisis information semantic structure through base icons, thereby strengthening event correlations.** The first task result in the evaluation showed that participants described more information when using structured icons, and subsequent interviews gave structured icons higher ratings than ordinary icons. The average score for event correlation in the questionnaire proved participants' recognition of structured icons' role in strengthening event relationships. Evaluation interviews and questionnaire feedback also confirmed that structured icons help improve participants' cognition of event correlations. Structured icons add a pre-icon base layer as the icon's basic attribute to distinguish different crisis event themes, effectively representing crisis event semantic structure. This multi-layer composite structure corresponds to the complexity and multi-perspective nature of crisis information, helping express and describe crisis event information from different angles. Since structured icons' pre-icon base layer and pictographic symbols describe crisis events from different angles, they broaden participants' perspectives for identifying events related to current events, thereby identifying geographic distributions of similar events on maps.
- (2) **The structured icon-based emergency map interaction mode can form multi-stage visual collaboration with icons as crisis information centers, serving precise emergency decision-making.** Structured icons' improvement in representing information content and structure also affects subsequent collaboration processes such as information search and decision-making. Participants generally gave more positive feedback about collaborative decision-making experience after the second discussion task. The questionnaire showed high average scores for both interaction experience and collaboration experience. In fact, when studying the structured icon-based collaborative interaction mode, the structured icons and their designed components function as a whole in collaboration, with related historical event search components and dynamic information representation components closely integrated with structured icons. Specifically, in historical event search, the system provides struc-

tured icon-based search by event theme and type, increasing users' information acquisition initiative. In collaborative rescue, users obtain continuous cognition of dynamic information by selecting time points on the dynamic timeline. This indicates that the structured icon-based collaborative interaction mode has cumulative cognitive impacts on interaction and collaboration. Throughout the process, structured icons and component designs highlight information such as event correlations and dynamic change characteristics, with their visual components promoting participants' information acquisition and structured cognition. This hierarchical information representation and visual impact improve information search accuracy and communication efficiency, helping decision-makers formulate final decision plans.

This study focuses on the impact of icons in crisis maps on information representation and interaction collaboration processes, designing structured icons suitable for crisis contexts, further exploring structured icon-based emergency collaboration interaction models with users and emergency stages as classification foundations, and analyzing the effectiveness of this collaboration mode from aspects of icon principles and cognitive processes. The main contributions are: First, addressing the problem of lacking representation of crisis event correlations in traditional maps, it explores an innovative structured icon-based emergency information interaction model that improves icon-based crisis information interaction. Second, it summarizes ordinary emergency map information representation methods, practically expands structured icon-based interaction mode applications, and designs a multi-view, role-based collaborative system. The system constructs multiple model-based visualization and interaction tools, facilitating emergency personnel's application of multidimensional, structured information for better interactive collaboration. Future research will further verify this collaboration mode's effectiveness and deeply explore how structured icon-based emergency collaboration modes affect participants' response behaviors when executing complex emergency tasks.

References

- [1] MAREAN J B, GALEW G. A coordinated utility emergency response: addressing information-sharing barriers for utilities and emergency response organizations[J]. *IEEE electrification magazine*, 2018, 6(2): 95-103.
- [2] CAI G, MACEACHREN A M, BREWER I, et al. Map-mediated geocollaborative crisis management[C]//International conference on intelligence and security informatics. Atlanta: Springer, 2005: 429-435.
- [3] DYMON U J. An analysis of emergency map symbology[J]. *International journal of emergency management*, 2003, 1(3): 227-237.
- [4] PACHINGER F, SHEIKH Z, ZAJACZKOWSKI P, et al. Comparison of visualization concepts of map layouts[C]//2016 IEEE 20th international enterprise distributed object computing workshop. Vienna: IEEE, 2016: 1-5.

- [5] LIU S B, PALEN L. The new cartographers: crisis map mashups and the emergence of neogeographic practice[J]. *Cartography and geographic information science*, 2010, 37(1): 69-90.
- [6] KOSTELNICK J C, HOENIGES L C. Map symbols for crisis mapping: challenges and prospects[J]. *The cartographic journal*, 2019, 56(1): 59-72.
- [7] MA X Y, CAHIER J P. An exploratory study on semantic arrangement of VDL-based iconic knowledge tags[J]. *Knowledge organization*, 2014, 41(1): 14-29.
- [8] MA J. The sustainability and stabilization of tag vocabulary in CiteULike[J]. *Online information review*, 2012, 36(5): 655-668.
- [9] MA X Y, CAHIER J P. Collaboratively constructing a VDL-Based icon system for knowledge tagging[C]//International conference on social informatics. Alexandria: Springer, 2012: 309-322.
- [10] ZHAO R, MENG X Y, MIN X F, et al. Emergency evacuation simulation for chemical enterprise personnel based on Pathfinder[J]. *Science technology and engineering*, 2019, 19(28): 417-422.
- [11] SUN M Z, WANG J S. Design and implementation of emergency and evacuation system based on Baidu Map API[C]//2018 26th international conference on geoinformatics. Kunming: IEEE, 2018: 1-5.
- [12] JIANG R G, YANG S Y, XIE J C, et al. Urban waterlogging 3D visualization emergency management information system[J]. *Computer engineering*, 2019, 45(10): 46-51.
- [13] CAO Z, ZHAO P, LIU J, et al. A spatial point pattern analysis of the 2003 SARS epidemic in Beijing[C]//Proceedings of the 3rd ACM SIGSPATIAL workshop on emergency management using. New York: ACM, 2017: 1-8.
- [14] CHEN Z Q, SU X N, YANG J L. Research on emergency decision-making model based on emergency scenario maps[J]. *Journal of the China Society for Scientific and Technical Information*, 2015, 34(8): 845-853.
- [15] DUNN CAVELTY M, GIROUX J. Crisis mapping: a phenomenon and tool in emergencies[J]. *CSS analyses in security policy*, 2011, 103: 1-4.
- [16] GAO Y Q, WU J J, WANG Z Z, et al. Regional flood risk assessment based on fuzzy clustering factor analysis[J]. *Journal of natural disasters*, 2018, 27(2): 141-148.
- [17] AVVENUTI M, CRESCI S, DEL VIGNA F, et al. On the need of opening up crowdsourced emergency management systems[J]. *AI & Society*, 2018, 33(1): 55-60.
- [18] WANG G D, REN G. Design and implementation of emergency deduction sand table system based on virtual reality technology[J]. *Software*, 2012, 33(8): 23-27.

- [19] KANG C X, TANG H L, TIAN Y P. Earthquake emergency 3D thematic map based on ArcGIS and SketchUp modeling[J]. Science technology and engineering, 2019, 19(19): 12-17.
- [20] XU J, TANG Z, YUAN X, et al. A VR-based emergency rescue training system of railway accident[J]. Entertainment computing, 2018, 27: 23-31.
- [21] LI X, PU W, ZHAO X. Agent action diagram: toward a model for emergency management system[J]. Simulation modelling practice and theory, 2019, 94: 66-99.
- [22] GUT J, YANG W N, VILLARREAL D S. Developing an emergency response conceptual framework for network-centric disaster operations[C]//2017 3rd international conference on information management. Chengdu: IEEE, 2017: 252-257.
- [23] LIU W, DUGAR S, MCCALLUM I, et al. Integrated participatory and collaborative risk mapping for enhancing disaster resilience[J]. ISPRS international journal of Geo-Information, 2018, 7(2): 68.
- [24] KODALI R K, MAHESH K S. Smart emergency response system[C]//TENCON 2017-2017 IEEE region 10 conference. Penang: IEEE, 2017: 712-717.
- [25] XIE X J, LU H C, SHI R X. Distributed electric power emergency rescue perception and collaborative information interaction technology system[J]. Journal of system simulation, 2017, 29(12): 3082-3091.
- [26] MA X Y, CAHIER J P. Graphically structured icons for knowledge tagging[J]. Journal of information science, 2014, 40(6): 779-792.
- [27] MA X Y, XUE P Z, ZHANG S Y, et al. Information search by applying VDL-based iconic tags: an experimental study[J]. Journal of information science, 2018, 44(6): 702-715.
- [28] MA X Y, SEDIRI M, MATTAN A, et al. VDL-based iconic co-annotation in crisis management[C]//2014 international conference on collaboration technologies and systems. Minneapolis: IEEE, 2014: 177-198.

Author Contributions

Ma Xiaoyue: Provided research ideas and design proposals, proposed overall research framework, revised the paper.

Cui Kecheng: Designed proposals, implemented verification, analyzed data, wrote the paper.

Zhang Haoqi: Assisted with interface design and implementation.

Chen Qiang: Provided guidance on writing framework and theoretical guidance.

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Abstract: [Purpose/significance] This study aims to coordinate more complex crisis information interaction and collaboration by introducing structured icons to improve icon representation on previous emergency maps. [Method/process] This study designed the structured icon for crisis situations. Then a visual interaction and collaboration model based on the structured icon was designed. [Result/conclusion] Firstly, the pre-icon of structured icon can show the relationship of crisis events and improve the interactive experience of information search. Then, structured icon can dynamically represent the temporal and spatial attributes of crisis information, enhance information cognition and enhance decision makers' collaborative decision-making ability. In theory, this paper proposes an emergency information interaction model based on structured icon. It enriches the theory of emergency information visualization and emergency interaction. In practice, the research optimizes the design of icon-based emergency coordination system. It enhances interaction between participants and emergency information and helps decision makers to make accurate and timely decisions in collaboration.

Keywords: human computer interaction; icon; information structure; emergency collaboration; time-space analysis; interaction interface

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv — Machine translation. Verify with original.