論 文 の 内 容 の 要 旨

論文題目　　Human-Centered Mapping in Mobile Environments
　　　　　　（モバイル環境における人間中心マッピング）

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In recent years, online web mapping products have become well developed and widely used in mobile environments. Location-based mobile applications also use web mapping services to provide map-based functions. The rapidly growing user-generated geospatial content also primarily uses web mapping for base maps. However, the fast growth of outstanding web mapping products has brought up new issues in the use of maps in mobile environments, one of which is that the diversity of maps is insufficient in mobile environments. Computer-generated maps used by web mapping are accurate and generic for multiple purposes, but the diversity of geoinformation representation is insufficient to satisfy a wide variety of user groups' requirements when used for specific purposes. On the other hand, various well-designed conventional maps are still widely used in the printed media for people's daily uses, such as the maps in guidebooks and leaflets for tourism and city exploration, the maps on newspapers and in magazines for presenting arguments and proposals, and so on. Such maps often have a sense of human-centered design in map communication within a limited medium. However, they are less used in current digital mobile environments. The purpose of this research is to study, design and develop a new mapping platform for introducing human-centered maps to the latest digital mobile devices to combine the advantages of both.

Chapter 2 shows the background and problems in the dissertation, and addresses the necessity of this research. This chapter begins by reviewing both the lexical and functional traditions in conventional mapmaking to reveal that map communication is essential in human-centered mapmaking, while functionality, storytelling, artistry and inconsistency can be important characteristics of such maps. The bird's-eye view maps produced by the great cartographic artist, Hatsusaburo Yoshida (吉田初三郎, 1884-1955), are used as an example of well-designed human-centered maps and significant factors of these maps are addressed. It has been confirmed that quickly developing web mapping services have had an impact on cartography and changed mapmaking and map usage. The shift of map media has brought important new features to maps, including hypermedia, dynamics, interactivity and accessibility, and, therefore, has extended the capability of map communication. However, such potential has not been well explored for human-centered maps. This research also examines the drawbacks of the currently outstanding web mapping services, which include the side effects brought to map users by the dominating products and their lack of human-centered design thinking. It has also been pointed out that the data-driven approach and technology-driven approach will misdirect the ways to achieve effective mobile mapping. Maps should be made for humans and consider the demands and background of the users, employing a human-centered approach. Therefore, it is important to fully involve human's creativity in mobile mapping, because the machine-generated maps should not totally take the place of the human-made maps. Simply stated, human-centered maps should be made for humans and made by humans. A survey

distributed to young users of mobile mapping has been conducted, and the results reveal that current web mapping does not take the place of conventional printed maps when used for specific purposes such as sightseeing. It further indicates that well-designed conventional human-made maps are preferred if the advantages of mobile devices, especially GPS positioning, can be integrated into them. Examples of existing mobile applications using maps other than web mapping have been investigated, and their limitations have been pointed out. The studies and discussions show the necessities of academic research and system development to establish and incorporate human-centered maps in mobile environments.

Chapter 3 suggests a proposal and clarifies key factors to realize a feasible platform for human-centered mobile mapping. This research has analyzed the causes of the limitations in current map applications, which include external sources, such as the deficient functions of human-centered mapmaking tools, as well as internal defects of human-centered maps, especially the difficulties of positioning because of the immeasurable distortions. Usage has been studied from both the author's and the user's viewpoint, to clarify the requirements of the expected approach. A human-centered mobile mapping framework including both authoring tools and user applications has been proposed in this research. This framework is designed for importing conventional human-centered maps to mobile devices, and converting them to interactive and geo-enabled mobile mapping by integrating geo-metadata and multimedia content to originally static maps. Geo-metadata is designed to be the key to geo-enabling the printed human-centered maps. The design of the concept model of geo-metadata is introduced in detail, including the graphic components and their georeference patterns. Frequently used geo-events and geo-interactions for interactive mapping are also enumerated and discussed. In realizing mobile mapping, practical positioning methods for distorted maps used in location-aware devices are key technologies in the proposed framework. This research introduces several different point-based and line-based methods, and discusses their usages, advantages and limitations. Among them, error analyses have been made to two-pointed based similarity transformations, and the results show that errors in this method depend on the stretch rate of the map and the distance to the line of the pair of control points.

Chapter 4 introduces the developments that have implemented the proposal of this dissertation. To implement the proposed framework and test its feasibility, a series of prototypes named **Manpo** (漫步) have been developed on Apple Inc.'s iOS platform as a target application for walking tours. Although the functions are still simple, the prototypes have realized both authoring tools and user applications in the framework. The authoring tools recognize the whole workflow of importing walking route maps, editing geo-metadata for positioning, adding extra multimedia content, and so on, to create geo-enabled interactive mobile maps, such as *Manpo content*. The applications of **Manpo** allow users to appreciate **Manpo content** using geo-interactive map browsing functions, and show the user's current location and moving trajectories on the maps when walking outdoors.

Chapter 5 focuses on experiments and discussions of the results. Algorithms of two-pointed based similarity transformation and line-based linear referencing are realized and implemented in the prototypes. Experiments using simulated and real trajectory data have compared the effects of different combinations of control points and lines used in the realized methods and have demonstrated the effectiveness and limitations of them. Sufficient density and reasonable distribution of control points is important in achieving a reliable positioning. Control lines are effective when they are distributed on the moving path of the users with proper setting of the buffer range. Experiments with the prototype on the mobile devices in the real world have also revealed the feasibility of the realized positioning methods in practical mobile applications. User tests by university students and completed surveys have shown the functionality and usability of **Manpo** for both authors and users. However, they also have revealed one of the limitations of the approach, which is that the quality of content, especially the reliability of positioning, is also strongly dependent upon the authors' experiences and skills. From the examination of student-created **Manpo content**, three types of typical mistakes made by the students in geo-enabling hand-drawn maps are classified and discussed. Among them, the improper placement of control points in distorted maps is the most difficult to

avoid by untrained, ordinary users. In the user tests and surveys, the students, who are used to current web mapping products, have shown their interests in **Manpo** and creativity in making their own mobile mapping. This can be considered as evidence of the potential of **Manpo**'s platform to create practical, useful and welcomed human-centered mobile mapping products.

Chapter 6 concludes by presenting the contributions of the dissertation and suggested future research issues. This research has proposed and realized a pragmatic platform for human-centered mobile mapping by importing and converting printed well-designed conventional human-centered maps to geo-enabled interactive maps based on the current technological conditions. In the future, more research issues, including more accurate and reliable positioning, new tools for interactive human-centered mapmaking, platforms for publishing and sharing human-centered map content, and so on, need to be further studied and developed in order to disseminate human-centered mobile mapping and create more functional products. Finally, a new ecosystem of the human-centered mapmaking industry should be established to fully involve the creativities of cartographers, illustrators and publishers, with the participations of civil organizations, governments, companies and research institutions, to benefit human-centered mapmakers and map users.