Title	Navigation System based on Humane Engineering for Wheelchair Users
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Description	

1 INTRODUCTION

This paper discusses the creative design of a social engineering system. To consider the design of the system, a systemic framework from a trans-disciplinary research viewpoint is necessary. "Humane engineering," which includes media and technology based on human centric design, is applicable to explain such complex and systemic structures of social engineering. We propose engineering for a human centered society, specifically, "humane engineering," and discuss how to integrate determination of quality with design. Humane engineering is not currently widespread, but it has the potential to introduce new concepts in creative design in the future. The concept of human centered design (Cooley 2000; Hodson 2011; Mitsui and Nagai, 2014) or human centric design is included in humane engineering. This paper explains social design by humane engineering, from multiple viewpoints of design domains, including engineering design, information design, product design, and community design; by including cognitive science and social science. In addition, social design by humane engineering must include a value creation process. There is scope for business growth and education promotion through such a system by providing physical and non-physical services to people. There are many such cases that can be developed using a social engineering system (Bohnhoff et al.1992; Taura 2013).

Further, it is important for social design by humane engineering to consider the quality of the human experience. Thus, design by humane engineering, beyond previous ergonomics, is expected to develop. Emotional feelings such as fun, exciting, calm, and comfort, are key criteria for design by humane engineering (McDonagh-Philp and Lebbon, 2000; Graziosi et al. 2013). A methodology is also expected to be developed for knowledge based engineering for creative design, a related area (Boxberger et al. 2012).

Engineering and technology have driven the development of the industrial society. With the growth of the global economy in the 21st century, the social structure of industrial society has changed and the production system has broadened significantly by overcoming geographic limitations. However, the development of engineering and technology has progressed independent of the social needs of people, which are determined by diverse conditions, including the lifestyles of communities in the local areas. There is a large gap between industrial technology and the quality of people's everyday life. To bridge that gap, management of social technology is required with an integrated view of engineering and sociology.

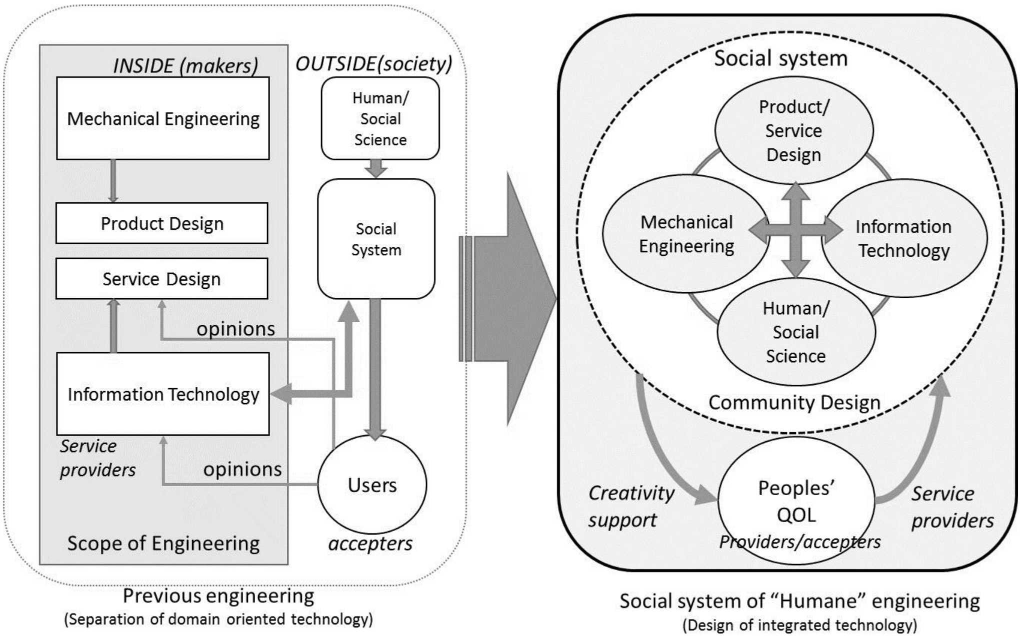

Figure 1. Philosophy of humane engineering

Figure 1 shows the development of a design view for social systems that is changing from the domain oriented view to a social system framework via humane engineering. In comparing them, the "design" of the system including management is important to consider. The management system of each view is different. Management in the previous engineering was systematic. The production process was organized by makers (inside system) separately from society (society). In contrast, the management of humane engineering is systemic. In the whole system, it is impossible to separate production and society (human).

2 DESIGNING A NAVIGATION SYSTEM

In this research, we carried out an experimental study in which we focused on the fun experience to propose a personal navigation system from the viewpoint of humane engineering in order to encourage users to have fun exploring a zoo. We considered two types of user mobility, walk and wheelchair, and conducted an experiment to evaluate the distance to be travelled and the time required to explore a zoo by both mobility methods using our proposed system compared with other navigation systems. The results of the experiment suggest that the proposed system successfully encourages users to fun-explore the zoo not only by walking but also by other modes, such as wheelchairs. Further, the results reveal the importance of emotional experience for creative design and show the feasibility of a community-based support navigation system in a humane engineering framework design. The results of this experimental study indicate that promotion of the formation of a community that will support the independent action of wheelchair users and to encourage creative behavior reflecting the high quality of people’s everyday life is important.

2.1 Creative lifestyle

Before describing our research, in which we propose a navigation system based on humane engineering, we address the reason why engineering requires humanity from the viewpoint of sociology. The overarching key term is “creativity.” Creativity is viewed as a personal ability; however, the social aspect of creativity is considered to be even more important. A notion of “creative society” represents peoples' expectation for increasing quality of everyday life. Creative Societies are gathering attention, and are supported by the UNESCO, which has formed a network of culturally rich cities, thus promoting the creative industry for strengthening the creative industries through employment and trade expansion. It is an example of representation of the peoples’ wish to be creative. The famous historical cities of the world, which are home to world or national heritage sites, are also expected to form creative societies because they have rich resources in terms of cultural properties that attract tourists. Further, the cities in areas that seize the advantage to become developed with valuable services for the well-being of their residents are thought to be potential places for creative societies. The lifestyle of people in creative societies promotes a good, healthy, safe, friendly and happy community, and provides the foundation for wellness and well-being. In the effort to foster such a lifestyle in creative societies, engineering can contribute not only to increase the value of production for creative industries, but also to provide good services; for example, a convenient transportation system in and around old heritage sites for people, including tourists. Even towns without heritage sites can develop as creative societies if they are developed practically for the wellness and well-being of their residents in accordance with the principles of humane engineering. Thus, service design can be viewed as an example of humane engineering to make people more creative.

Alternatively, from the viewpoint of enhancing people’s activities, accessibility is an important issue to be realized for a creative society. A navigation system is expected to encourage people to be more active and communicative. Consequently, we are focusing on humane engineering to produce new media, which include a navigation system to encourage people to go outside and communicate with others.

2.2 Role of navigation systems

When people want to go out alone, they need a navigation system designed to enrich their experience; the navigation system is a dependable tool to support human activity by performing enjoyable and comfortable operations. Since the advent of GPS forty years ago, navigation systems have been growing in sophistication and popularity. At first, automotive navigation systems were established to support driving by guiding the driver with the route, direction, and expected arrival time (Dingus and Hulse, 1993). Initially, navigation devices were either built into or attached to automobiles.

Consequently, with the development of smartphones, navigation systems are now used by applications on personal devices, and people can now use these navigation systems through their smartphones when they go out on foot, by train, by bus, or by car. A navigation system for bicycle riders has also been released recently (Yamamoto 2013). A guide route for bicycle riders is different from a guide for walking, because the former needs to avoid steps. In addition, direction of travel is limited for bicycle riders than walkers, and therefore the time for arrival is different too.

However, a navigation system for wheelchair users has not yet been developed. The navigation system for a wheelchair user should guide the user to routes avoiding steps, and must navigate the safest path for the user.

Recently, navigation systems have also begun to provide diverse kinds of information. Not only the preset information, but the updated information about an area can be meaningful (that is, “smart”) for people. Smart navigation involves various kinds of information; for example, the name of the popular shop on the street, outside views of buildings, memorial event venue, and previous users’ opinions about the venue. These kinds of information enhance the walking experience. The desirable information systems used in navigation systems are considered to be useful and enjoyable. Both usefulness and enjoyability are required to make people become motivated by assisting the navigation system for all users including wheelchair users. Therefore, to build a desirable navigation system, it is important to make it “thoughtful,” even though thoughtfulness is a quality that usually applies to human beings. Providing predictive information about locations/places/venues for wheelchair users is especially effective; for example, the size of a cafeteria, width of a pedestrian path, and usability of a toilet. The value of the information should be evaluated by wheelchair users, and a feedback system for the users should be developed. This study aims to promote the formation of a social support system, which is open access, for smart navigation to enhance the independent action of wheelchair users. We aim to build a smart navigation system that provides predictive information “thoughtfully.” We call it co-creative smart navigation, in this paper.

2.3 Concept of the co-creative smart navigation system based on humane engineering

We built a high-quality navigation system for wheelchair users based on previous navigation systems designed for walkers. We adopted an automatic scales function, which is based on the navigation system for bicycle riders built by us previously (Nagai and Yamamoto, 2014).

Human engineering is the basic concept on which the proposed navigation system is based, in contrast to conventional navigation systems, which are built from the information technology perspective.

On the basis of a social system of humane engineering, we designed a framework for a co-creative smart navigation system for wheelchair users, which will produce well-being and fun experience.

Our proposed navigation system was firstly designed based on location-oriented navigation. Location-oriented navigation is characterized by the richness of the prepared trustful preset information provided by the location site; for example, amusement park, zoo, and museum. The usage characteristics of our proposed system are limited compared with conventional navigation systems because of the restricted set of users. In addition, location-oriented versatility is considered low because of the activities of the users are limited.

3 METHODS

As outlined in the design framework of a co-creative smart navigation system for wheelchair users based on humane engineering, shown in Figure 2, we built a system with a four-stage process (Figure 3). Notably, we decided on a zoo for field trials of the proposed system.

First, we investigated the needs of the wheelchair users, including unconscious needs, and the helpers of the wheelchair users, via a field survey. In addition, we gathered basic data on the locations in the zoo from a geographical map, and decided on what should be implemented.

Second, the basic function of the navigation and database for gathering information were developed at this stage. In addition, an exploitative case study for building a system was conducted.

Third, a series of experiments was performed to test the proposed navigation system, and the results obtained after analysis used to further improve the effectiveness of the navigation system.

Lastly, we experimentally evaluated the revised navigation with a social assistance system.

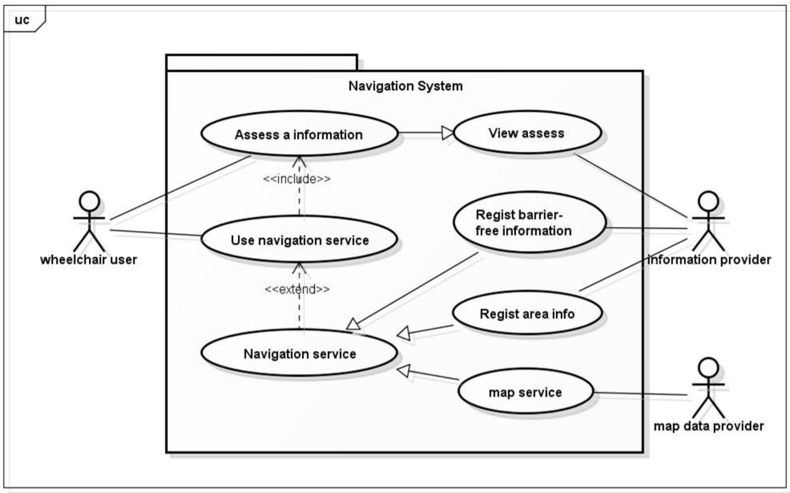

Figure 2. Use case of a Co-creative smart navigation system for wheelchair users.

Figure 3 shows the process and structure of this research on designing a navigation system for wheelchair users.

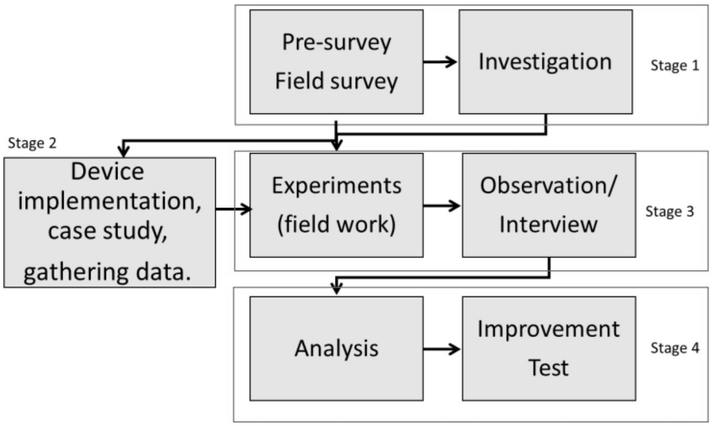

Figure 3. Process and methods of this study

3.1 Purpose of the navigation system design

With the goal of developing a navigation system that can be attentive in order to encourage wheelchair users by providing predictive useful information with good timing and stimulating motivation by emotional experience, while omitting unnecessary information for the user, in this study, we developed a navigation system to help people, primarily wheelchair users, to have fun exploring. Not only families or groups of visitors but also individual persons visit zoos. For these public facilities to be more popular to a wide range of citizens, it is important to make visitors feel free to explore even when they are alone. These places, for example, zoos, are usually safe and designed such that people can freely move and enjoy the area. Therefore, we chose a zoo as our site to develop a smart navigation system. Because zoos are developed on a universally adopted design and provide barrier-free accessibility for wheelchair users, we can pay attention to provide thoughtful information to make exploring fun. In the safe environs of a zoo, we can identify the unconscious requirements of the visitors that will improve their satisfaction levels.

Furthermore, the management of the zoo expected repeat visitors motivated by their own previous satisfaction. Therefore, they allowed us to use a trial version of our navigation system as the experiments.

3.1.1 Investigation

We identified the important functions required of a smart navigation system by contrivances or necessities, throughout the experiments in the field via a survey, and ethnographically observing the wheelchair movements of users. The investigation was performed from April to August 2013 at five places (a park, three zoos, and an aquarium). One of the three zoos was subsequently selected as the main experimental site for this study and we gathered basic data about the zoo such as area size, number of animals present, and number of visitors per month, from the managing organization of the zoo.
Interviewing of wheelchair users was conducted by a wheelchair user.

3.1.2 Detected requirements

Based on the investigation of visitors in the zoo, ethnographical observation, and interviews of wheelchair users and their assistants, we determined the fundamental requirements for the smart navigation system for wheelchair users and classified this information into four categories according to situations: “in moving,” “enhancing comfort,” “enhancing motivation,” and “enhancing learning” while the wheelchair users drifted through the zoo.
In accordance with the classification of requirements, the following goals were determined for the system:

- Detecting movement means of the user (walk or wheelchair) automatically.
- Selecting a suitable map scale by detecting the movement means of the user automatically.
- Displaying suitable content information at the correct time by detecting the movement means of the user automatically.
- Providing educational information based on cognitive modes of behavior. For example, providing a quiz to enlighten exploratory behavior.

3.1.3 Implementation

To implement the specific functions to address the abovementioned requirements, the core mechanism of the smart navigation system was established. We implemented the following functions for a personal device (“Android” smartphone):

- Using the acceleration sensor implemented in smartphones to detect the movement means of the user (walk or wheelchair).
- JAVA application that informs “Sensor-Event”
- An original function for automatic scale change was also programmed.

The two different acceleration sensor patterns detected in the smartphone are shown in Figure 4. One was obtained from walkers and the other from wheelchair users. We used these two patterns as the criteria for identifying whether users were walking or in wheelchairs.

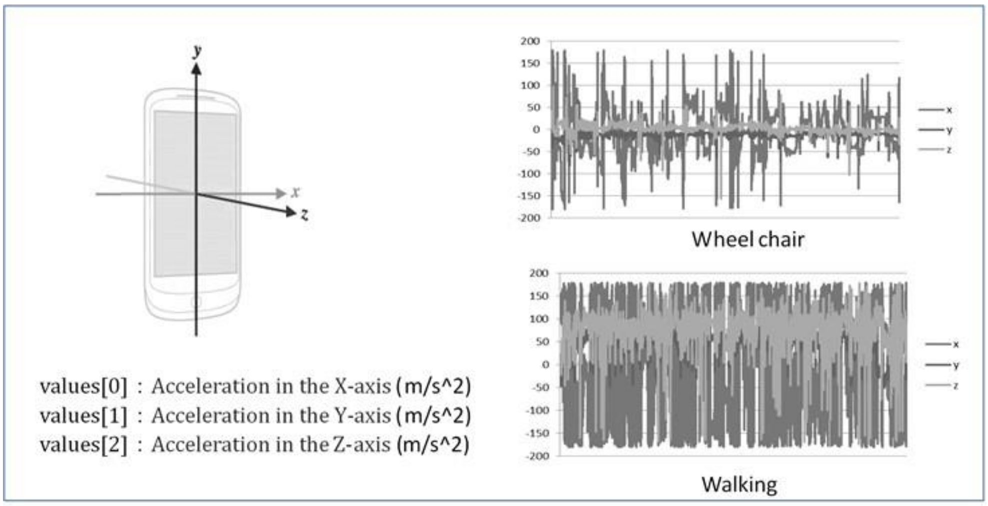

Figure 4. Acceleration sensor patterns.

3.1.4 Contents of the information

For the execution of smart navigation based on investigations, we prepared the following contents:

- Two original types of maps (for walking or moving in a wheelchair) developed by us with the agreement of the zoo.
- Accessibility information in collaboration with NPO (association of barrier-free tourists).
- Quiz of the animals and plants in the zoo in cooperation with the managing organizers of the zoo.

The core structure of the proposed navigation system is shown in Figure 5.

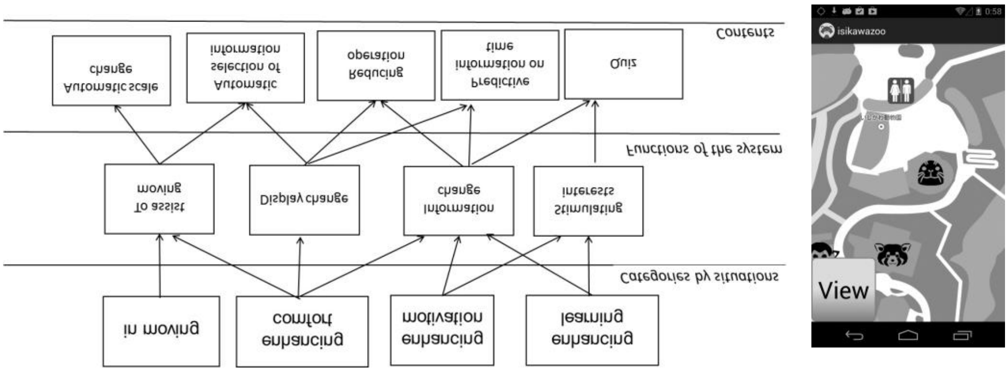

Figure 5. Structure of the proposed navigation system and a sample mobile display.

3.2 Analysis

To test the applicability of the proposed navigation system, we focused on the emotional effects of satisfaction and unconscious cognition of enjoyment of exploration. Behavioral data of a person, such as the "total time for exploring," "the entire distance explored," and "the number of devices operated" by a user are key pieces of data for testing the smartness of a navigation system.

3.2.1 Time and distance of one exploration sequence

A sensor in a device, in combination with video monitoring, automatically records the time and distance of one exploration sequence by walk or wheelchair.

3.2.2 Number of operations

The proposed navigation system is installed in a personal device (Android) and logged. The record of operation is captured and gathered in a server.

3.2.3 Questionnaire

Descriptions or verbal accounts of subjective impressions are representative of the experiences. It is necessary to collect the answers immediately after the experience. Furthermore, scoring with the use of evaluation items is a useful method to analyze the experience.

4 EXPERIMENT

4.1 Experimental environment

The experiment was conducted in the zoo from September to December 2013 (Nagai and Yamamoto, 2014). The zoo was opened in 1999 as a high barrier-free designed zoo, and all paths are at an inclination of less than 4°, even though the zoo is located on a natural hillside. Situated on an area of 23 ha, there are 3831 animals of 184 kinds in the zoo. The zoo itself is supported by the local government of the prefecture.

The participants were 12 adults, ages 20–30 years old (10 males, two females). On days with similar conditions (except weekends and holidays), from 10:30 to 15:30, each participant was requested to independently explore freely until he or she wanted to quit.

The participants were separated into two groups according to the alphabetical order of their names. The odd-number group members were asked to use a wheel chair and the even-number group members were

asked to walk. All participants were required to use either the proposed navigation system or a popular navigation application (based on Google maps). In the first session, they used one of the navigation systems, and after a few days, in the second session of the experiment, they were required to use the other navigation system. The order of usage of the navigation systems was random.
Table 1 compares the functions of the proposed navigation system with those of the existing system (based on Google maps).

Table 1. Functions of navigation system

	Proposed navigation system	Previous navigation system
Map	Original map	Google maps
Scale change	automatic	Manual
Location presentation	On	On
Touch scroll	On	None
Information contents	Specific (About animals in the zoo, quiz, etc.)	General

Two experimenters observed and recorded each participant's behavior in both sessions. The recorded behaviors are classified into four categories; viewing, moving, learning, and others (toilet, rest, phone, etc.). After a session of exploration in the zoo, each participant was interviewed to determine their satisfaction and impressions and handed a questionnaire sheet to independently evaluate the systems.

4.2 Experimental results

The results obtained from the interviews and questionnaires were analyzed in order to determine whether the proposed navigation system is perceived as smart (thoughtful). Further, the data obtained from all sessions of the experiment—the time and distance spent exploring and the number of operations on a device—were analyzed to compare the two navigation systems:
Consequently, the following trends were obtained:

1. Regarding the total time per exploration session, using the proposed navigation system took longer than using the existing system.
2. Regarding the total distance per exploration session, using the proposed navigation system was longer than using the existing system.
3. There is a positive correlation between the total exploration time and the satisfaction rate in the questionnaire for the wheelchair group (Figure 6). The walking group showed similar results.
4. On average, the proposed navigation system had a significantly higher satisfaction rate (Table 2) in the wheelchair group. In addition, the walking group showed similar results.
5. The use of the proposed navigation system resulted in a lower number of operations on the device.

The above trends are present in both the walk and wheelchair groups.

Table 2. Results of evaluation of the proposed navigation system

	Positive	Uncertain	Negative
Usefulness of automatic scale change	33.3%	50.0%	16.7%
In-zoo information	66.7%	16.7%	16.7%
Timing of showing information	83.3%	16.7%	0.0%
Satisfaction	50.0%	0.0%	50.0%

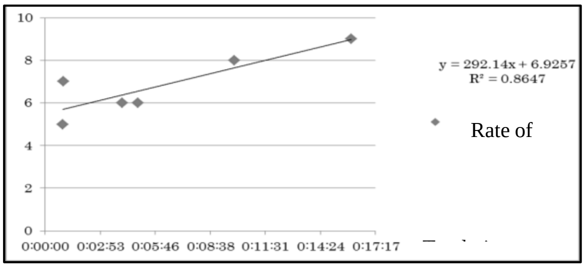

Figure 6. Correlation between rate of satisfaction and total time per exploration session in the zoo.

The results of the evaluation of the proposed navigation system are presented in Table 2. In particular, the timing of the automatic display of the information in the zoo was highly evaluated as positive among the participants.

5. DISCUSSIONS

5.1 Evaluation of the proposed system

From the results of the experiments comparing the proposed navigation system with the existing system, longer time and distance per exploration session were realized when using the proposed navigation system. Further, the number of operations per device was lower when using the proposed navigation system. Moreover, the lower number of operations is possibly correlated with the high satisfaction rate, which is supported by the results of the interviews.

If the long time and distance of an exploration session occurred because the participant had gotten lost, the rate of satisfaction and comfort may have been low. However, in the evaluation result of the experiment, there is no such discomfort trend.

These results suggest that the proposed system successfully provides useful information with good timing. This indicates that the proposed system acts as a smart navigation system and creative assistance for exploring.

Additionally, regarding the high evaluation rate for contents of the information, the quiz was highly evaluated by participants, especially in the wheelchair group. This finding suggests that the exploration time and distance were extended by the motivation to search for answers. For further improvement of the proposed system, the obtained trends suggest enrichment of the contents. On the other hand, an excess of information shown simultaneously may prove troublesome to display. The timing of displayed information will be a key issue to avoid the troublesome presentation of information. However, to verify this assumption, the preset information was limited to a small volume in this experiment. It is necessary to develop the navigation system to be co-creative with a large project in the future.

5.2 Further development of this study

We have obtained significant results and suggestions to improve the proposed smart navigation system. From the viewpoint of social design by humane engineering, the proposed navigation system is a tool that acts as the first step towards developing co-creative social systems. We are continuing the development of the navigation system for wheelchair users beyond the limitation of the experimental area. The next project based on the findings of this study is planned to be executed from July to November 2015 at the central part of the city, and will be supported by the local government of the prefecture. A larger interdisciplinary team will be formed to develop a navigation system through humane engineering. Wheelchair makers have also invited a team, and further collaboration between designers and architects is expected. In addition, personal manufacturing has been changing the industrial production system as well as the social system (Mostert-van der Sar et al. 2013). We are combining the navigation system to develop a wheelchair design within a personal manufacturing network. Because the use of the open navigation system is systemic (Figure 2), social networking is feasible for improving the proposed system aiming at a co-creative smart navigation system. In this open system, additional information is structured to form a database for both wheelchair users and citizens. People can provide tentative information by tweeting or providing opinions as well as by updating the maps. For wheelchair users, critical information such as weather problems, construction, and disasters should be provided by a sufficient number of supporters. Including a large amount of human resource for a social system will be a design challenge from the social viewpoint of engineering by trusting humanity, including morality and ethics (Paul and Elder, 2010).

We addressed the importance of the creative lifestyle in subsection 2.1. Our proposed system is a new example of a personal service movement for changing social systems. The system will contribute towards a creative society focused on the realization of safety and well-being in the forming of a social design by humane engineering. That will be realized from multiple viewpoints of design disciplines; specifically, engineering design, information design, product design, and community design integrated with social science.

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