Heterogeneous Design Features of the Service Robot: A Comparison Case Study by a Socio-Technical Perspective

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Heterogeneous Design Features of the Service Robot: A Comparison Case Study by a Socio-Technical Perspective

Short Paper

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Abstract

In the digital innovation wave, the service robot paid more attentions as a core IT artifact to transform the traditional marketing and service paradigm. On this digital transformation movement, the design features of service robots have been heterogeneous, and the unique design features have been developed by different socio-technical perspectives. Based on this, this study conducted a comparison case study in Chinese and Japanese restaurant business environment. Throughout this case study, we summarized China has more highlighted the AI-empowered service robot, while Japan has more focused on the human-controlled service robot. Consequently, this study makes two contributions. First, it theoretically conceptualizes the current Chinese and Japanese service robot development as the first comparison case study. Second, it practically suggests what design features of service robots have been configured in the different socio-technical context.

Keywords: Service robot, design feature, socio-technical perspective, case study
Introduction

Service Robot has been a core IT artifact in the digital innovation era. Indeed, many service industries have adopted the service robots into their business environments for the customer-centered marketing and service strategies. As a result, the volume of service robot industry has been increased—the global market size from $12.88 billion in 2019 to $41.49 billion by 2027, and it has been recognized as an essential part of digital transformation (Borangiu, Trentesaux et al. 2019).

Engelhardt et al., (1992, pp. 315-346) originally argued that service robot is “systems that function as smart, programmable tools that can sense, think, and act to benefit or enable humans or extend/enhance human productivity.” On this definition, the service robot has transformed the way of working in the service industries, and diverse features of service robot have been released since the last 10 years with a wave of digital transformation (Yoo, Henfridsson et al. 2010; Yoo, Boland Jr et al. 2012; Wirtz, Patterson et al. 2018; Belanche, Casaló et al. 2020).

In the previous studies, scholars represented two perspectives of the design features on the service robot. The first perspective involves "service robot as IT artifact", which replaces with human labors for the better operation and efficient resource management by a traditional management approach (Kiesler and Hinds 2004, Thrun 2004). On the other hand, the second perspective entails “service robot as IT-service platform”, which creates new customer’s experiences with the service robot (Bolton, McColl-Kennedy et al. 2018; Wirtz, Patterson et al. 2018).

On these two perspectives, the design features of the service robot have been heterogenous in the multi-complex service environments. Like this way, different societal, business, and technical environments require heterogeneous design features of service robots to fit their own socio-technical service contexts. The service robot industry is getting more complex, and it calls for more attention to the heterogenous design features of service robot. Nevertheless, it has not adequately documented.

Based on this research problem, in this study, we hypothesize that the design features of service robot are strongly associated with the socio-technical matters (Bostrom and Heinen 1977, Lytinen and Newman 2008, Bockshecker, Hackstein et al. 2018), and the established service robots reflect on the unique values of each society as the outcome of socio-materiality in their socio-technical contexts (Orilikowski 2010; Leonardi 2013; Cecez-Kecmanovic, Galliers et al. 2014).

To address this research problem, we ask the following research question:

**Research Question:** what distinctive socio-technical perspectives could lead to heterogeneous design features of the service robots?

As empirical evidence, this study conducted a comparison case study to analyze characteristic design features of the service robots (Walsham 1995; Butler 1998). In particular, it analyzed two delivery-service robots in the restaurant business environment. The one is service robot Haidilao, Beijing, China, and the other is Orihime Café’s service robot, Tokyo, Japan.

By the analysis of the collected data, it elucidated an interesting finding. The design features of service robot have been heterogenous. Especially, Chinese service robot highlights “AI-operated service robot”, emphasizing the multiple “functionality by design” with the AI technologies. On the other hand, Japanese service robot focuses on “human-operated service robot”, dealing with the “humanity by design” with human interaction technologies. Like this way, the design features of service robots involve the distinctive socio-technical values.

It makes two contributions. First, it seeks to empirically characterize the unique design features of service robots by a comparison case study. Second, it practically suggests a feasible direction about what design features of service robots would be appropriate in a certain service industries, concerning different socio-technical contexts.


**Literature Review**

**Service Robots**

Since Engelhardt et al., (1992), service robot is defined as the smart programmed systems, which can aware contexts like humans and increase the limited human’s productivity. Based on this definition, the meanings of service robot have been widely applied by diverse research domains (Singer, 2009). Some previous scholars argued how new technologies create new features and functions of service robots for individuals, organizations, and societies. For example, the radically developing sensor and data technologies enable service robots to make autonomous decision-making without human’s permission (Miller, Allen et al. 2005; Pagallo 2013). Wirtz, Patterson et al. (2018) maintained that the service robots will replace the human labors in terms of the operational efficiency, and it dramatically changes the traditional resource management. Belanche, Casaló et al. (2020) argued the features of smart service robot that transforms multi-layers of IT artifacts (e.g., camera, mobile devices), IT-service infrastructure (e.g., sensor, speech recognition, and cloud technology), IT-data service (e.g., big data, analytics, artificial intelligence), and other related services (e.g., biotechnology and geographical services).

**Heterogeneous Design Features of Service Robot in IS**

In IS communities, the service robot has become one of the most important subject matters, because it combines diverse ongoing research topics in IS—broader issues in technologies (e.g., machine learning, sensor, AI, IoT technologies), IT artifacts, organizational transformation, and the digital innovation and transformation. With this importance, IS scholars have mainly highlighted the design features of the service robot with the following two perspectives. The one is “service robot as IT artifact” and the other is “service robot as IT-service platform”.

*Service robot as IT artifact* highlights functional and technical features of service robots, dealing with operation issues such as efficient resource management and human productivity. Traditionally, IS scholars argued IT artifacts as the core of IS research (Benbasat and Zmud 2003; Hevner, March et al. 2004), and they interpreted the service robot is as the core part of IT artifacts. On this IS tradition, they believed that developing technologies can identify a variety of functional features of service robots. For example, the RPA-based service robot transformed traditional work routine and functional service tasks (Huang and Vasarhelyi 2019; Ivančić, Suša Vuđec et al. 2019; Madakam; Holmukhe et al. 2019). Also, the machine learning, deep learning, and AI technologies allow service robots to work as independent IT artifacts (Reis, Melão et al. 2020; Zdravković, Panetto et al. 2021).

*Service robot as IT-service platform* accounts for new human experiences and services, focusing on how service robots and could interact with customers. On this perspective, some IS researchers highlighted new customer’s experiences and interactions between humans and the IT artifacts (Brown and Magill 1998, Orlikowski and Iacono 2001). To create smarter digital innovations, some researchers have argued the service robot as a core agent in the service design eco-systems (Yoo, Henfridsson et al. 2010; Yoo, Boland Jr et al. 2012). Davidson et al. (2015) proposed a theoretical framework, demonstrating a design features of service robot in the IT artifacts, infrastructure, and eco-systems. Hinings et al. (2018) maintained digital transformation by an institutional perspective, demonstrating how IT artifacts as a part of service platform to transform the multiple layered organizations.

Like this way, some previous scholars have documented the features and functions of service robot by these two perspectives. Nevertheless, IS research remains in two research limitations. First, the design features of service robot have not been adequately documented empirically. Second, configuring the design features of service robot is a dilemma to determine better service innovation environment. To address these two research limitations, this paper performed a comparison case study to characterize different design features of the service robots in the restaurant business environment by a view of socio-technical perspective (Bostrom and Heinen 1977; Lyyytinen and Newman 2008; Bockshecker, Hackstein et al. 2018).
Methodology: A Comparison Case Study

In this study, we conducted a case study (Walsham 1995; Butler 1998) to compare the characteristics of design features of service robot in China and Japan. As a hermeneutic method for interpretative comparison case study, this study highlights what heterogeneous design features of service robot have been developed in the different socio-technical contexts in China and Japan.

Two Site Selection for the Comparison Case Study

To conduct a comparison case study, this study considered relevant sites and determined “Haidilao” restaurant in Beijing, China, and “Orihime” café in Tokyo, Japan as the two research sites, because these two sites are suitable to address our research question—different characteristics of socio-technical perspectives will lead the heterogenous design features of service robots.

<table>
<thead>
<tr>
<th>Haidilao Restaurant in Beijing, China</th>
<th>OriHime Café in Tokyo, Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Robot</td>
<td>Delivery Robot</td>
</tr>
<tr>
<td>Delivery Robot</td>
<td>Barista Robot</td>
</tr>
<tr>
<td></td>
<td>Delivery Robot</td>
</tr>
</tbody>
</table>

Table 1. Heterogenous Design Features of Service Robot

As Figure 1 presents, Haidilao International Holdings Ltd, one of the largest hot pot restaurant chains in China, was founded by Yong Zhang in Sichuan province in China in 1994. Currently, it operates over 1600 restaurants in the US, UK, Singapore, South Korea, and Japan. On October 28, 2018, it opened its first AI-powered smart restaurant in Beijing's Chaoyang district, using the AI soup-making systems. On the other hand, DAWN Avatar Robot Café Ver. β is located at Nihonbash in Tokyo, Japan. It is an experimental business, where disabled-people such as ALS (amyotrophic lateral sclerosis) are working as staffs via OriHime (a tele-operated robot).

Data Collection & Analysis

As an empirical study, this study collected data by the field observation and preliminary interviews (Kvale and Brinkm 2008; Schultze and Avital 2011; Spradley 1979). First, two authors visited Haidilao, a smart hotpot restaurant, Beijing, China, and the other two authors visited to Orihime café, Tokyo, Japan to conduct two separate field observations. Second, the authors also performed preliminary qualitative interviews to understand the design features of service robots in the restaurant context.

To create the criteria to analyze the collected data, the authors considered Zhang et al. (2010)'s four aspects of service robot: physical appearance, communication, performance, and intelligence. In addition, Belanche et al. (2020)'s six key factors (aesthetics, robot notification, manipulability, proactiveness, affect, and formality) of service robot are configured. Based on this consideration, we justified the following five components as the design features of service robot by a socio-technical perspective. The five components entail 1) navigation (positioning & driving); 2) communication (voice & motion); 3) coordination (scheduling & operation time/speed); 4) control (safety & monitoring); and 5) appearance (look & feel).

Findings of the Comparison Case Study

Table 2 summarizes heterogeneous design features between in Haidilao, China and Orihime, Japan.

<table>
<thead>
<tr>
<th>Design Features</th>
<th>AI-operated Service Robot</th>
<th>Human-operated Service Robot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case of the Haidilao Restaurant, China</td>
<td>Case of the OriHime Café, Japan</td>
</tr>
</tbody>
</table>
### Design Features of Heterogeneous Service Robot

<table>
<thead>
<tr>
<th>Navigation (Positioning &amp; Driving)</th>
<th>The Haidilao service robot navigates in the restaurant spaces by the autonomous positioning and navigation systems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical feature &amp; functions:</td>
<td>The LIDAR (Light Detection and Ranging, a remote sensing method), machine vision, multisensor fusion algorithms as the technical features and functions to support the autonomous navigation.</td>
</tr>
<tr>
<td></td>
<td>The Orihime-D navigates in the café space by the human-robot interaction systems.</td>
</tr>
<tr>
<td>Technical feature &amp; functions:</td>
<td>As technical features, the OriHime-D has two omni wheels with motors for locomotion, where it can go forward, go backward, turn left, and turn right. To reduce the workload of the human operator, the OriHime-D has line tracing function for long distance movement, in which the robot automatically moves to the preset target position.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication (Voice &amp; Motion)</th>
<th>The Haidilao service robot communicate with customers by programmed input/output communication data (e.g., voice and facial expressions).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical feature &amp; functions:</td>
<td>The Haidilao service robot has the voice &amp; facial expression. Vivid bionic expression screen that can express the feelings like joy, anger, sorrow and happiness. It also can speak and interact with customers.</td>
</tr>
<tr>
<td></td>
<td>The Orihime-D communicates with customers by operator’s natural dialogues, using the sound and motion/gesture functions.</td>
</tr>
<tr>
<td>Technical feature &amp; functions:</td>
<td>Sound: the operators can make a voice by using a mouse and the line-of-sight input device. The voice is generated in either natural voice of the operator or in synthesized speech. Also, the ambient sound is transmitted to the operator by the microphone on forehead of the robot. Motion/Gesture: the operator can observe customers and show nonverbal reactions to customers using head and arms.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coordination (Scheduling &amp; Operation time/Speed)</th>
<th>To conduct efficient coordination and operation, the Haidilao service robot coordinate with other multiple stakeholders by intelligent coordination systems, using the multi-machine intelligence technology.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical feature &amp; functions:</td>
<td>It is equipped with intelligent coordination of the self-developed communication system using multi-machine intelligence technology. Managerial features &amp; functions: It can also communicate with other robots to coordinate schedule, time, and speed of the operation. Through such coordination, it can improve delivery efficiency.</td>
</tr>
<tr>
<td></td>
<td>To conduct effective coordination and human-robot interaction, the OriHime-D coordinates with other robots, operators, human employees by socially constructed human-machine interaction systems.</td>
</tr>
<tr>
<td>Technical feature &amp; functions:</td>
<td>To effectively coordinate with other robots, the OriHime-D maintains its speed at the maximum 0.72 km/h and follows line tracing for movement. Managerial features &amp; functions: To coordinate with other operators and human employees, the OriHime-D can communicate with them using sound and motion functions. Also, the café adjusts schedules among operators and their operation time to ensure their physical &amp; psychological well-beings.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control (Safety &amp; Monitoring)</th>
<th>The Haidilao service robot is controlled by AI hardware platform monitoring systems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Orihime-D is controlled by human-robot interaction, concerning the wholistic human-centered quality control systems.</td>
<td></td>
</tr>
</tbody>
</table>
**Technical feature & functions:**
The Haidilao service robot is equipped with AI hardware platform monitoring systems.

**Managerial features & functions:**
In particular, it continuously performs the system maintenance and safety monitoring for the robots, remote OTA upgrade, and one-click OS system update as well.

**Technical feature & functions:**
To ensure safety in the café space, the OriHime-D is technologically designed to control transmission time to shorten the maximum latency time for video communications. This reduces video delays and thus enables safer operations of the OriHime-D even in narrow passages.

**Managerial features & functions:**
To ensure well-being of operators, monitoring is implemented by checking psychophysical and physical conditions of operators. Also, the café conducts customer survey for further improvements of robotic services.

**Appearance (Look & Feel)**

<table>
<thead>
<tr>
<th>Haidilao service robot</th>
<th>OriHime-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the service robot look like in the restaurant/café space?</td>
<td>The OriHime-D is a humanoid robot with a friendly size and look.</td>
</tr>
<tr>
<td>What features and functions of appearance (look &amp; feel) are configured for the service robot?</td>
<td></td>
</tr>
</tbody>
</table>

**Appearance Features:**
The Haidilao service robot is a functional looking service robot.

- Square type of robot design. It has control panel and facial screen with multiple trays.

**Appearance Features:**
OriHime-D has a full-color LED on the eyes, a fisheye camera and microphone on the forehead, and speaker on the chest. These technical features enable OriHime-D. Also, OriHime-D's face is motif of Noh mask which expresses human features. The size of the OriHime-D is average height of a 6-year-old child to give more friendly impressions (500mm in length, 400 mm in width, 1,180 mm in height, 20 kg in weight).

**Table 2. Heterogenous Design Features of Service Robot**

**AI-operated Service Robot: A Case of the Haidilao Restaurant, China**

The service robot of Haidilao restaurant, Beijing, China, entails “AI-operated service robot”, and it has multiple “functionality by design” with AI technologies. With the respect of navigation, it has fully autonomous positioning and navigation systems that have fusion technologies of sensors such as LIDAR (Light Detection and Ranging, a remote sensing method), machine vision, and depth fusion & algorithms sensors. Thus, it can move freely and stably in indoor environments to conduct a series of tasks.

With the respect of communication, the Haidilao service robot communicate with customers by programmed input/output communication data (e.g., voice and facial expressions). It uses audio communication and visual effect using speakers and LED screens. Thus, the service robot can express feeling like joy, anger, sorrow, and happiness using the vivid bionic expression packages with customers.

With the respect of coordination, it has intelligent coordination tasks with a self-developed communication system. To conduct efficient coordination and operation, the Haidilao service robot coordinate with other multiple stakeholders by intelligent coordination systems. With the multi-machine intelligence technology as the technical feature & functions, it can communicate with other robots to coordinate its schedule, time, and speed of operation using multi-machine intelligence technology.

With the respect of control, the Haidilao service robot is controlled by AI hardware platform monitoring systems. With the technical feature & functions, it continuous performs the system maintenance and safety monitoring for the robots, remote OTA upgrade, and one-click OS system update as well.

With the respect of design appearance, the Haidilao service robot is more like a square type to optimize the delivery task. As a functional looking service robot, it has a front screen that shows the facial expression back screen that can show the control menu of the robot. To conduct the role of a delivery service robot, it has multiple trays on the upper part of the body.

All in all, the Haidilao service robot is the “AI-operated service robot”, taking multiple “functionality by design”. The trends of the AI-operated service robot emphasizes service automation for service resource
management. To improve the service automation, the AI-operated service robot highlights more efficient and stable operation by testing interaction with customers and collecting customer’s data.

**Human-operated Service Robot: A Case of the OriHime Café, Japan**

The service robot of Orihime café, Tokyo, Japan, involves “Human-operated service robot”, and it has “humanity by design”, focusing on the human–robot interaction technologies. With the respect of navigation, the OriHime-D’s navigation within the café relies on human operators. Thus, the technical features are simply configured to enable its mechanical movements, using two omni wheels with motors for locomotion, e.g., go forward, go backward, turn left, and turn right (Takeuch et al. 2020).

With the respect of communication, the OriHime-D’s communication with customers is done by human operators’ sound and motion. Specifically, technical features for sound are focused on the usefulness of the human operators in outputting a voice and inputting customers’ voice and the ambient sound. The robot also has functions to choose generating the voice in either the operator’s natural voice or synthesized speech (Takeuch et al. 2020). Since communication with OriHime-D is just like talking with people, nonverbal reactions are important to engage in highly emotional and relational communications with customers. Although the OriHime-D is not designed to freely move its body parts as the operator wishes, the seven head and four arm motions are prepared to show appropriate nonverbal reactions (Takeuch et al. 2020).

With the respect of coordination, the OriHime-D coordinates with other service agents including robots, operators, and human employees within the café. To ensure safe and seamless coordination with other agents, the robot maintains its speed at the maximum 0.72km/h and follows a line tracing for movement (NTT, 2021). Also, the OriHime-D is technically designed to communicate with other agents using sound and motion functions as long as this does not interfere service quality.

With the respect of control, the OriHime-D is technically designed to control transmission time to shorten the maximum latency time for video communications. This allows for the robot’s safer operations even in the narrow passages (NTT, 2021). Furthermore, considering that OriHime-D is operated by people with disabilities, the management puts efforts to continuously monitor the operator’s psychological and physical conditions.

With the respect of design appearance, the OriHime-D is a humanoid robot with a friendly size and look (500mm in length, 400 mm in width, 1,180 mm in height, and 20 kg in weight). Also, the robot’s face is a motif of Noh mask which expresses human features with full-color LED on eyes, and a fisheye camera and microphone are equipped on the forehead (Takeuch et al. 2020). These design features allow the OriHime-D to effectively deliver services and communicate with customers.

In sum, it is noticeable that features and functions of OriHime-D are configured with consideration not only of customers but also of the human operators. The uniqueness of this café is to sell goods characterizing avatar robots (e.g., handkerchief, stationary, etc.) and to have communication partner at each dining table which allows customers can have personal communication with OriHime.

**Conclusions & Implications**

In this study, we explore heterogeneous design features of the service robot by a view of distinctive socio-technical perspective. To address this, our study performed a comparison case study by analyzing the five components service robot design features, incorporating the prior scholars’ design considerations on service robot (Zhang et al., 2010, Belanche et al., 2020). Throughout this case study, we concluded that Chinese and Japanese service robot’s design features represent their own unique socio-technically characteristics. Based on this conclusion, this study takes two implications.

First, it makes heterogeneous design features of service robot as socio-technical meanings. In china case, the AI-empowered service robot design features are associated with “functionality by design” as their socio-technical meaning. Most recently AI-empowered robot is designed to meet customers’ needs to build social closeness and social affiliation with service robot. To do so, AI-empowered robot is rigorously infusing technologies of communication, mobility, sensor, and big data into its systems (Huang and Vasarhelyi 2019). On the other hand, in Japan case, the human-controlled service robot the design features are associated
Design Features of Heterogeneous Service Robot

with “humanity by design”, representing the Japanese Omotenashi culture. The term "Omotenashi" is often used in the sense of expecting added value beyond simply entertaining or providing hospitality to a guest (Nagao and Umemuro, 2012). On this omotenashi culture, the humanoid robots are designed with the Omotenashi feature. The robot embodies hospitality by expressing the operator’s emotions through the robot’s hand movements and facial movements that can be taken as any facial expression.

Second, it will give a positive direction of how the different socio-technical contexts can be configured for identifying the design features of service robot. In China case, the AI-operated service robot is the service outcomes, dealing with the issues of automation by digital transformation by robots. On the other hand, in Japanese case, "Omotenashi" by humans through robots has the following two features—1) the service robot design and technical aspects are geared toward the two targeted customers (human operators and end users) 2) the service robot reflects on the social-technical context (service robot as a service platform/context).

Limitations & Future Study
Like other studies, it has limitations, and they might be the future studies. Whether this study seeks to configure the design features of service robot in China and Japan as the comparison case study. Yet, it is quite challenging to conceptualize the design features of service design. Thus, a series of qualitative and empirical studies are required to elaborate the current propositions as the future studies. Also, the more case studies and diverse interpretations will make more concrete constructs of service robot design features.

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