Analysis of Gender Stereotypes for the Design of Service Robots

Case Study on the Chinese Catering Market

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ABSTRACT

Service robots are entering all kinds of business areas, and the outbreak of COVID-19 speeds up their application. Many studies have shown that robots with matching gender-occupational roles receive larger acceptance. However, this can also enlarge the gender bias in society. In this paper, we identified gender norms embedded in service robots by iteratively coding 67 humanoid robot images collected from the Chinese e-commerce platform Alibaba. We then generated four-step guidance for designers to identify and challenge the gender norms in the robot design. Our research provides both the fundamental grounding and practical guidance for designing catering robots that challenge gender norms and promote social equality.

CCS CONCEPTS

• **Social and professional topics** → **Women**; • **General and reference** → *Surveys and overviews*; • **Human-centered computing** → Systems and tools for interaction design.

KEYWORDS

Gender Stereotype; Design Ethics; Service Robot; Catering Industry; Human-robot Interaction

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1 INTRODUCTION

Service robots are increasingly pervasive in the business area for their potential to reduce labor costs, increase working efficiency and attract customers [27]. Frontline service robots are often designed with an anthropomorphic form since they are interfaces that "interact, communicate and deliver service to an organization's customers" [53]. The COVID-19 pandemic outbreak speeds up frontline service robots' application in catering to limit the virus contamination [54].

However, in China, many robot designers try to take advantage of stereotypes designing humanoid robots [43] and are not aware of their impact on society. The application of gender norms to the robots may perpetuate existing societal gender gaps [37, 52], especially in a gender unbalanced industry like catering [3]. Thus we believe that identifying the existing problems and building a grounding vocabulary to evaluate the gender norms is essential.

This paper presents a code library of gender stereotypes on catering service robots and proposes 4-step guidance to help designers challenge gender norms in robot design. We iteratively coded 67 humanoid robot images from the Chinese e-commerce market in ATLAS.ti. A code library with 8 code families and 42 codes describing the robot gender traits and humanoid degrees had been generated. We further interpreted the results and presented three meta patterns based on mainstream gender norms. Finally, we provided guidance for robot designers to identify, backtrack, reflect and challenge the gender norms in their daily practice.

Our contribution through this work is three fold:

- We detailed our process of analyzing existing gender norms in catering service robots through static images, which contribute to the gender study method and can be adopted by other researchers.
- We generated a code library and three underlying patterns formed on gender norms. These provide other researchers with a basic vocabulary set and exemplary account of how gender stereotypes can be unconsciously embedded in robots.
- We proposed the practical guidance for robot designers to identify and challenge the gender norms in robots, which provides a theoretical grounding and encourages more consideration around gender ethics in robot design.

2 RELATED WORK

Our work builds on prior research on gender norms in human-robot interaction and design ethics in robots' gendering. In the following paragraphs, we present a concise overview of the scholarly work that supports our research.

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2.1 Gender Norms in Human-robot Interaction

Social and moral norms are powerful in human society as they guide people's action selection [22] and enable people's actions to be predictable [12]. Gender is a social category that influences human societies' every aspect in everyday life [28]. The gender division of labor roles in society is closely connected with gender stereotypes [13].

In the field of occupations, the impact of gender stereotypes has been well discussed. Some researchers found that people perceive specific jobs as masculine or feminine [14, 33]. Although these gender preferences in vocation can help predict a successful career's matching personality [2, 21], they can also cause negative impacts on society. For example, the application, recruitment and selection processes of a job match people's gender stereotype perceptions, perpetuating horizontal occupation division[1] [24]. Moreover, in the female-dominating catering industry, the substitution of female workers by robots may lead to unemployment, particularly regarding low qualified women.

If a robot has a human-like body and can act like a human in a human-engineered environment, then it is a humanoid robot [43]. Belanche et al. [4] claim that humanoid robots receive higher degree of customer acceptance, encourage human-robot interaction, and support the application of existing social norms. Due to the need of interacting with customers, frontline service robots are usually humanoid. According to the computer as social actors (CASA) approach [41], people interact with computers in ways comparable to human-human interaction. Thus, users will unconsciously apply gender stereotypes to the robots. Various studies have shown that the robot's gendered features, such as facial cues [18], affect users' perception of the robot's personality and potential functional roles [18, 37, 40].

Much research indicates the benefit of gendering the robot. Eyssel & Hegel [18] and Tay et al. [47] have shown that people prefer gendered robots performing the matching gender-occupational role or tasks. For example, Tay et al. [47] found that participants preferred the female-gendered healthcare robots and male-gendered security robots. Meanwhile, some researchers argue that the gendering of robots may reproduce gender stereotypes restraining social development. The female robot toy Robota is one example. Weber [51] indicated that it might reinforce traditional gender stereotypes partly through her favorite task of dressing up.

Among different cultures, gender stereotypes are not always the same. Nomura [37] suggested focusing on cultural influences to understand gender stereotypes when applying robots in a specific area. For instance, Japanese society believes the guide job is mainly female-dominating. In an experiment conducted in Japan, participants preferred the female guide robot over male guide robot [38]. Thus, the present research focuses on the Chinese culture as China might have unique gender norms and stereotypes.

2.2 Design Ethics in Robots' Gendering

Since robots are likely to impact all aspects of society, research on the ethical matters is important. The existing literature on this topic falls into two directions. One part explores the methods for humans to design, deploy, and treat robots [49], while another part focuses on the capacities that robots should have in order to participate in human society [30]. Our research lies in the former area. Some researchers have put forward a code of ethics for professional robotics engineers addressing the fields related to robotics engineering [26]. Other researchers proposed a code of ethics for practitioners in HRI research, development, and marketing to focus on the impacts of HRI on humans. [42].

Among the various ethical issues in robot design, some scenarios related to the selection of robot morphology and actions arise, especially gender [42]. The unconscious application of societal gender roles to the robots may cause users' abusive behaviors towards robots [15] and reinforce societal gender bias in society in the long run [37, 52]. What is worse, it might shift stereotypes to fragile subgroups in human society and cause similar abusive actions to them. The research on the relationship between conversational agents' gender and verbal sexual harassment is an example [15]. And González-González et al. [23] indicated sex robots' potential relationship to sexual crime on children. However, there is a lack of research on gender ethical issues among frontline service robots. This is especially true in China, as most of the literature is from technical perspectives.

Gendered humanoid robots could both reinforce and subvert original social gender norms [48]. Designers tend to simplify some robots' qualities with stereotyped forms and behaviours to manage the complexity of robotics design [17]. Some of them like to use the "retro-tech" method, which will apply dated gender norms onto the robots [43]. If not well thought out, the embedded gender norms in robots might strengthen the gender stereotypes through influencing users and finally the social culture in a vicious circle [44]. Both robots' physical forms and roles can influence societal gender norms. Humanoid robots' physical characteristics can challenge social norms towards a gendered body, making people feel they are flawed [31]. The gender gap of robots' applications in different occupational roles also reflects and even reinforces gender norms [31]. According to Alesich & Rigby [1], though the female featured robot can free a woman from housework, it also reinforces the assignment of these tasks to females.

Gendering humanoid robots could also challenge the traditional widespread gender norms. For instance, the interchangeable gender of robots could stimulate people to question why human gender is fixed. Furthermore, this might finally challenge the leading social norms [1]. Marchetti-Bowick [31] raised a male robot operating in a kitchen to illustrate that designing male-gendered robots as nurses or home assistants would challenge society's gender stereotypes.

3 OUR APPROACH

3.1 Data Collection

Database. The research aims to collect the most representative catering service robots in the Chinese market and identify the gender stereotypes. Despite the widespread use of service robots in China, there is no authoritative database on the robots currently applied in the market or the research.

[1]Horizontal occupation division refers to the differences in the number of people of each gender presents across occupations. For example, in catering, more cooks are male, while more servers are female [9].

In today's China, e-commerce is a prominent way for both individuals and businesses to purchase products. Alibaba[2] is the largest online business to business (B2B) platform in China. Although not all catering merchants buy robots from this platform, the products can still represent most of the robots available in the market. Based on this reasoning, we conducted our study by searching on this platform.

Search Term. In this research, we focused on service robots in the catering industry. The Chinese terms related to the topic include: "餐饮业(catering industry)", "餐饮(food and beverage)", "餐厅(restaurant)", and "餐饮服务(catering service)". We applied all these terms by combining them with "服务机器人(service robots)" to probe the database.

The query of "餐饮业(catering industry) + 服务机器人(service robots)" and "餐饮服务(catering service) + 服务机器人(service robots)" returned less than ten results. The query of "餐厅(restaurant) + 服务机器人(service robots)" and "餐饮(food and beverage) + 服务机器人(service robots)" both yielded more than 100 results. By browsing the first page of both results, we identified more low-relevance items in the latter query. Thus, we used " 餐厅(restaurant) + 服务机器人(service robots)" as our final search term.

Inclusion Criteria. The query of "餐厅(restaurant) + 服务机器人(service robots)" on the Alibaba website returned 143 items ranked by sales[3]. After excluding the items unrelated to the robots (e.g., restaurant furniture and tableware) and the items referring to robot components, 98 items remained. As our focus is gender stereotypes, we limited our study to humanoid robots. By manually screening the product pictures, 53 non-humanoid items are excluded. This resulted in a total of 45 product items of anthropomorphic catering service robots. A visualization of the process shows in Figure 1.

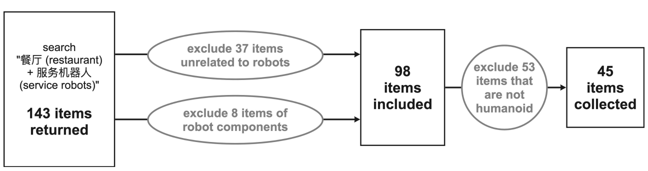

Figure 1: Inclusion / Exclusion Process

3.2 Data Analysis

For the 45 items collected from the Alibaba platform, the main data types we could access were robot pictures and description texts. The texts are often used by the sellers to promote the product. For our study, we don't want to be influenced by the sellers' stereotypes, but to focus on the robot design. Moreover, physical form is a crucial aspect of robot's gendering [1, 43]. A robot's morphology is not merely a functional choice but also communicates its identity, affect, and personality [11]. Thus in this study, we limited our analysis on the static images of the humanoid robots.

[2]https://www.1688.com
[3]The search date is 2020.01.10

Thematic analysis is a widely used qualitative analytic method that searches for themes or patterns in texts like interview transcripts [7]. When it comes to analyzing the images, there is less practice. Chapman et al. [10] highlighted the value of image during research and proposed a five-step photographic data analysis methodology: 1) data organization; 2) code creation; 3) coding photographs; 4) finding relationships; 5) interpretation.

Although the method was originally generated for sociology study, it is also useful for design feature analysis since both are intended to mark different elements in the photos and analyze the relationships among them. We adopted their methodology and coded the robot images iteratively in the computer-assisted qualitative data analysis software: ATLAS.ti[4]. The following paragraphs detail our analysis process.

Data Organization. We used an open-source plugin[5] to download all the display images (n=234) of the 45 product items. However, the original images are not split according to the robots' appearances. In some cases, different robots are shown in one image together. While in some other cases, robots with identical appearances sold by various vendors appear in different images. So we further combined or split the images to keep one robot style an image. Robots in the same style but with different colors are kept as the same style type in one image. In the end, 67 robot images are collected and coded. The coding image collection can be found in the supplementary materials.

Code Creation & Coding Photographs. As suggested by Chapman et al. [10], we first generated a code list based on the literature review, which includes the initial codes like body shape, clothes and functions. One researcher iteratively coded each image and updated the code list (a screenshot of the coding interface is shown in Figure 2). After the 1st round of open-coding, the first researcher reviewed all codes and added definitions to each of them. This resulted in the initial code book. Then another researcher reviewed the coded images with the code book and discussed them with the first researcher until consensus was reached. The final code book and the ATLAS.ti project file can be found in the supplementary materials.

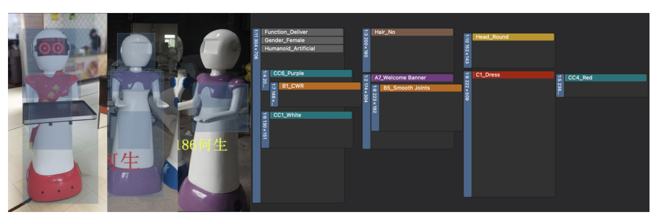

Figure 2: Coding Interface

Finding Relationships & Interpretations. For the analysis of the codes, we first grouped the codes as code families and used the code frequencies and code co-occurrence table to analyze their relationships. Then we compared robots' stereotypes with those regarding real staff in catering to interpret the results. A detailed

[4]https://atlasti.com
[5]https://github.com/keleen/chrome-alibaba

explanation of our coding results and discussions can be found in the following sections.

4 CODING RESULTS

The initial coding results in 8 code families (CF) and 42 codes related to gender and humanoid degree. We further grouped the code families into three categories: appearance & figure, clothes & accessories, and service. A representation of these codes can be seen in Figure 3.

4.1 Overview

Although we excluded the non-humanoid robots during the data collection, the degree of anthropomorphism varied among the included robots. Inspired by McGinn [34] and Chesher & Andreallo's work [11], we categorized the robot's humanoid degrees into three levels from high to low: *realistic*, *artificial*, and *cartoon*. *Realistic* robots are designed to appear lifelike. They have a naturalistic and identifiable android face and wear real clothes. *Artificial* robots also resemble human appearance but abstract them into geometrical features on the smooth surface. *Cartoon* robots are designed with exaggerated features and the comic style of humans. In our analysis, there are 19 *realistic*, 36 *artificial*, and 12 *cartoon* catering service robots.

To avoid the binary categorization of gender, we divided the robots into 3 groups: *male*, *female*, and *neutral*, according to the gendered traits on them. Through our coding, 49 of the 67 robots appear *feminine* in morphology, 9 of them have more *male* features, and 9 remain *neutral*. In line with previous research findings [1], our analysis showed that *female* robots are often in the highest humanoid degree while *male* and *neutral* robots are less humanoid.

4.2 Appearance & Figure

CF1_Hair Length. This code family classifies different hair lengths of the robots into three groups: *long hair* (n=16), *short hair* (n=4), and *no hair* (n=45)[6] . Through our analysis, the majority of the robots have round mechanical heads without hair. Robots with hair are often highly humanoid and lifelike, all belonging to the *realistic* humanoid level.

Hairstyle is a salient facial cue when determining a target's sex [8]. In our research, all the robots with hair have obvious gender orientation, and all the gender *neutral* robots are without hair. Among the robots with hair, all of the *long-haired* robots (n=16) are feminine-looking, while 75% (n=3) of the *short-haired* robots have more male traits. Only one highly humanoid *female-looking* robot has *short* hair.

The experiment of Martin & Macrae [32] showed that isolated hair cues are able to activate stereotypical knowledge structures about male and female. More specific to HRI, Eyssel & Hegel's investigation [18] indicates that the robot with long hair was perceived as more communal and suitable for stereotypical female tasks than the short-haired robot, and vice versa. Based on these reasons, we mark *long hair* as a prominent *female* trait on robots, *short hair* as a *male* trait, *no hair* as *neutral*.

[6]Two cooking robots with hats whose hair length can't be identified from the images are excluded from the results.

CF2_Body Ratio. This code family identifies three different body ratios of the robots: chest-to-waist ratio (*CWR*), waist-to-hip ratio (*WHR*), and shoulder-to-width ratio (*SWR*). In general, the humanoid degree of the robots with *CWR* and *WHR* traits are higher than those with *SWR*.

Our analysis shows that most *female-looking* robots (51%, n=25) have an exaggerated *CWR*. While only 1% (n=5) of them show the *WHR* directly, the big skirts on robots may also indicate the hip curve to some degree. Both the *male-looking* (44%, n=4) and *neutral* (22%, n=2) robots have a strong *SWR* without apparent chest and hip.

The series of experiments conducted by Bernotat et al. [5] have demonstrated that the manipulation of WHR and shoulder width correctly elicited gendered perceptions of the robots. Moreover, participants preferred to use the female robot shape for stereotypical female tasks. In our research, we mark *CWR* and *WHR* as two prominent *female* traits, and *SWR* as a *male* trait.

CF3_Joint Type. This code family identifies robots whose joints show apparent *mechanical* connections and robots whose joints are *smooth* without exposed connections. Through our analysis, most *mechanical* joints appear in less humanoid robots while 93% of the robots with *smooth* joints are in *artificial* or *realistic* humanoid level. All *male-looking* robots analyzed appear to have *mechanical* joints while 80% (n=39) of the *female-looking* robots show *smooth* joints. Thus we mark *mechanical* joints as a *male* trait, *smooth* joints as a *female* trait.

4.3 Clothes & Accessory

CF4_Clothes Type. This code family identifies different robots' clothes types, including *traditional Chinese dresses* (n=7), *maid costumes* (n=12), *other dresses* (n=31), and *pants* (n=3). All the robots with two legs and without a skirt are classified as wearing *pants* for coding clarity. For the humanoid degree, *traditional Chinese dresses* are mainly (71%, n=5) worn by *realistic* robots, and most of them are real clothes. Meanwhile, *maid costumes* are primarily (92%, n=11) worn by *artificial* robots, and the costumes are abstract and made of hard material. *other dresses* are commonly worn by *artificial* and *realistic* robots, while *pants* or legs are never present on *realistic* robots.

Most *female-looking* robots (96%, n=47) wear *dresses* in our analysis, and none wears *pants*. Regarding robots with a masculine morphology, 3 of them wear pants, 3 of them have no obvious legs or dresses, 3 of them are *cooking* robots with only an upper body. Regarding the *gender-neutral* robots, 3 of them (30%) wear an abstract dress with no obvious style. However, considering its relatively small proportion, we still mark all the *dresses* as *female* traits and *pants* as a *male* trait.

CF5_Clothes / Shell Color. This code family identifies the main color of the clothes or overall shell of the robot. The top 3 used colors in robots are *white* (51%, n=34), *red* (49%, n=33), and *blue* (27%, n=18). Regarding the gender preference of color, *gray* is more used in male looking robots, while *white* and *blue* are frequent in neutral robots. Out of our expectation, *red* is the most used color for *female-looking* robots, while *pink* did not appear that frequently.

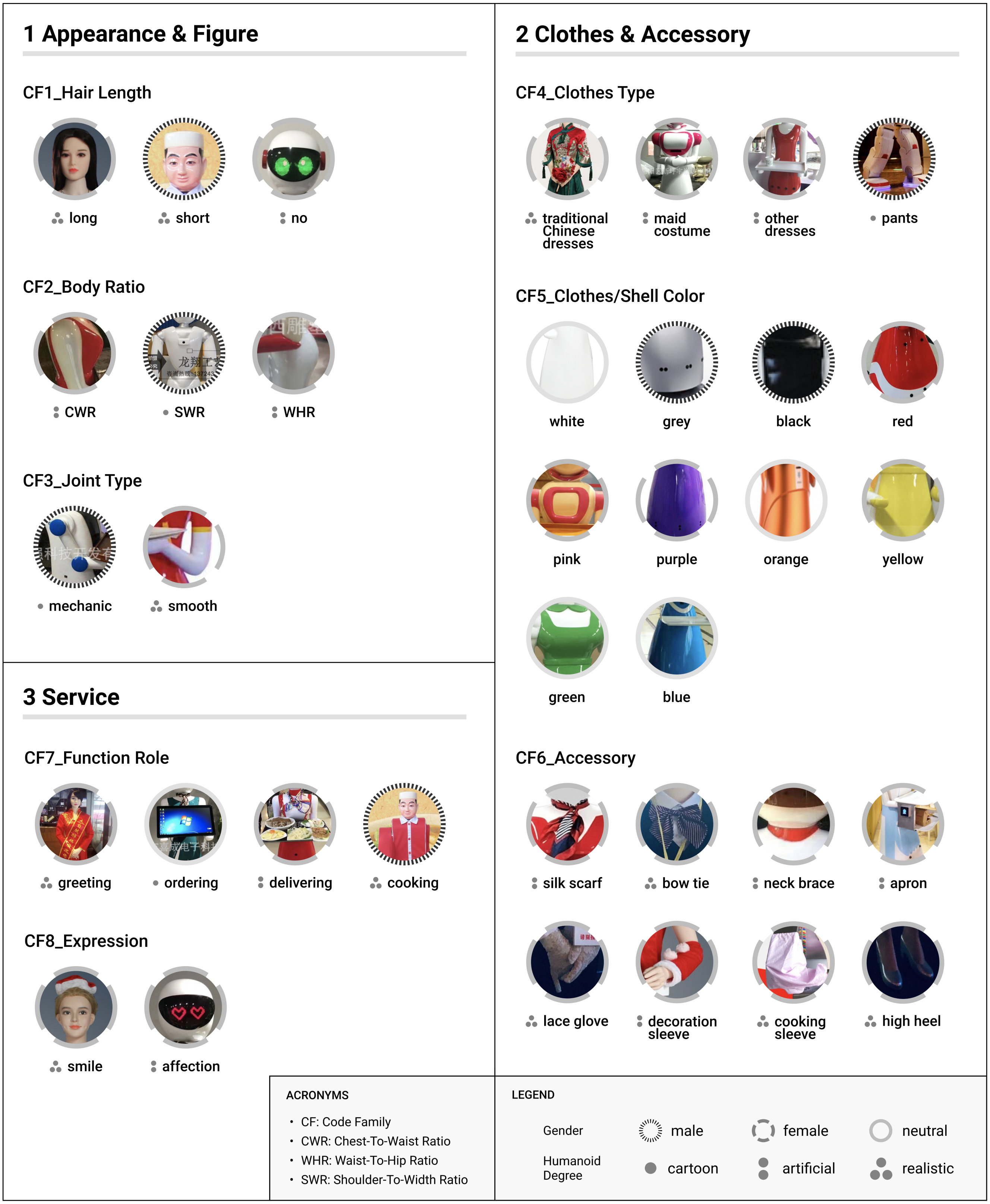

Figure 3: Code Library

Both the *male* and *neutral* gendered robots rarely wear *purple* and *yellow*, which appeared on *female* featured robots.

CF6_Accessory. This code family identifies different accessories that the robots wear: *silk scarf* (n=22), *bow tie* (n=1), *neck brace* (n=8), *apron* (n=12), *lace glove* (n=7), *decoration sleeve* (n=7), *cooking sleeve* (n=3), and *high heel* (n=3). Through our analysis, *silk scarf* and *apron* are the two most frequent accessories, covering 33% (n=22) and 18% (n=12) of the robots. Most of the robots who wear accessories are *artificial* and *realistic* robots. Only 2 of them are in the lowest humanoid level: *cartoon*.

For the gender distribution, the majority (92%, n=56) of the accessories are worn by robots with *feminine* morphology, and only one of them is worn by robots with other *male* features, four by gender *neutral* robots. Thus all the codes in this family are marked as *female* gender traits.

4.4 Service

CF7_Function Role. This code family identifies the designated function roles of robots. Through our research, there are four main function roles of the catering robots: *cooking* (n=5), *delivering* (n=29), *greeting* (n=29), and *ordering* (n=8).

Regarding the humanoid degree, *greeting* robots are the highest ones with 55% (n=16) in *realistic* level. Most of the *cooking* robots (60%, n=3) we analyzed are also highly realistic. However, we need to mention that our selection criteria excluded most non-humanoid ones before coding. 83% of the *delivering* robots (n=24) and 63% of the *ordering* robots (n=5) are in medium humanoid level: *artificial*. *Cartoon* humanoid robots remain a low representation among all functional roles.

The *greeting* (79% are female, n=23) and *delivering* (86% are female, n=25) robots are *female-dominated*, while roles more function-oriented like *cooking* and *ordering* have more than 60% of the robots with *male* or *neutral* morphology.

CF8_Expression. This code family identifies different robot's expressions either through a digital screen or through realistic facial features. All the robots with expression are in medium or highest humanoid level. The dominant expressions are *smile* (n=19) and *affection* (n=6), which convey gratitude and a welcoming servicing attitude. Most of these expressions (96%, n=24) are shown on *female-looking* robots, only one on the *male* featured robot. All the expressions found on robots are positive or neutral; no negative emotions like anger or upset have been spotted.

5 DISCUSSION

We further interpreted the patterns forming gender norms by comparing the robots' gender stereotypes with societal gender norms. Three meta patterns have been generated: gender norms affected by catering industry tradition, gender norms inherited from culture, gender norms exploited for sexual attractiveness.

5.1 Gender Norms Affected by Catering Industry Tradition

Many of the gender norms on service robots are influenced by the traditions in the catering industry. *CF7_Function Role*, *CF6_Accessory*, and *CF8_Expression* are three typical code families that reveal this pattern.

CF7_Function Role. Catering is a female dominated industry and remains great horizontal occupation division [9]. The gender division of robots exacerbates the gender inequality in the industry. Most catering service robots are designed to be feminine, especially in *greeting* and *delivering* roles. While for the *cooking* robots, the male to female ratio is the highest among all function roles.

One possible explanation for this occupation gender preference is the prevailing stereotypes that women are characterized by warmth and commune while men are characterized by agency [20]. This leads to the stereotype that women are good at jobs that involve more interaction with other people like greeting, and men are more good at jobs with high professional requirements like cooking. Although some research showed that customers' reaction was more negative to service providers whose gender was incongruous with norms [29, 35], the dichotomous over-simplifications of robots' occupations based on gender can exacerbate the gender bias during the job application in society [24].

CF6_Accessory. A lot of robots' features are inherited from the real staff's working requirements. However, besides the functional aspects, some of them also convey the gender stereotypes within them. As it is easier to change and clean, waitresses commonly wear aprons to protect clothes from food oil. Although on robots, aprons no longer play their original role, these kinds of traditions remain. With ten female and none male robots wearing an apron, this may reinforce the female housewife image since aprons are also a stereotype in women's domestic work.

CF8_Expression. Smile is an important feature that affects customer satisfaction during the service encounter [45] and their perception of the service provider [46]. Connected with the old saying "customer is god" in the Chinese service sector, employees are often viewed as lower-powered than the customer and need to respond to every customer's request with a smile. It is also revealed in robots' expressions. All the expressions designed for service robots are positive emotions like smile or affection and there are no negative expressions, like anger or upset. Although the fawning attitude may improve service satisfaction, this tradition may set the bad example for real staff when they face harassment or abuse.

5.2 Gender Norms Inherited from Culture

Some robots' gender features are inherited from Chinese traditional culture. *CF6_Accessory*, *CF4_Clothes Type*, and *CF5_Clothes / Shell Color* are three typical code families that reveal this pattern.

CF6_Accessory. One apparent aspect of the cultural influence can be seen in the neck accessories of the robots. Most of the *greeting* and *delivering* robots (n=22) are female-looking, wearing a silk scarf typical in Chinese service etiquette. Meanwhile, western male adornments like ties and bow ties were occasionally seen on the analyzed robots.

CF4_Clothes Type. Cheongsam and hanfu are both iconic traditional Chinese costumes for females and sometimes worn by Chinese restaurants' human workers. The style of cheongsam highlights the curve of the female body and conveys a unique beauty of Asian women. As the restaurant's symbolic staff, the greeter's costume needs to convey the restaurants' characteristic to catch customers' attention. Robots with traditional Chinese clothing may give the customers the impression that the restaurant has traditional Chinese cuisine and a long history. However, this might also reinforce an outdated female's image in China.

CF5_Clothes / Shell Color. : Red is the most used color on robots besides white. The popularity of red may have a cultural reason behind it. In China, red is a symbolized color conveying the meaning of luck, auspiciousness, and fortune [55]. So it is often used for celebrations, like festivals, weddings, and store openings. Using red on robots may convey these positive messages to customers.

5.3 Gender Norms Exploited for Sexual Attractiveness

Emphasized feminine gender traits are used to improve the sexual attractiveness of the service robots. *CF2_Body Ratio* and *CF4_Clothes Type* are two typical code families that reveal this pattern.

CF2_Body Ratio. The design of the female catering robots often highlights their body curves to improve stereotyped attractiveness. Some robots wear tight dresses to highlight the waist-to-hip ratio (WHR), while others wear big skirts to enlarge the "hourglass" shaped figure. Previous studies showed that the secondary sexual traits like breast size and WHR are critical physical features affecting most people's perception of sexual attractiveness both globally and in China [16, 19]. Compared to the real employees in catering, the female service robots' CWR are WHR are exaggerated to some extent. The over gendering of the female robot's body shape may cause improper body pressure for the real female staff.

While highlighting a service robot's sexual physique might increase its appeal to the customers, it can also cause the implicit and explicit sexual attention and lead to potential sexual harassment which already noticed on virtual conversational agents [6]. This could further exacerbate sexual harassment which is a problem reported frequently in catering [3, 36].

CF4_Clothes Type. Some female costumes are designed to improve the waitress's sexual attractiveness and flatter male customers. One typical example is the waitress in maid costumes working in Japanese Maid Cafe. Maid Cafe is a special type of experience restaurant where the good looking waitresses give a caring, tender, and thoughtful maid service. The maid costume originates from the 19th-century Europe and is often styled with the shirt, slightly bulky dress, apron, and lace decorations. In catering robots, many artificial delivering robots are wearing the abstracted version of this type of dress and working in all types of restaurants besides the maid cafe. This might convey the message that the female robots are the customers' maid and strengthen the stereotype of women being born to serve. It could also lead to the objectification of female service workers.

6 DESIGN GUIDANCE

Based on the analysis results and findings, we developed a four-step method (Figure 4) as design guidance to help robot designers identify and challenge gender norms in service robots using our code library. Instead of providing a definite answer in the design guidance, we build space for discussion and encourage designers to take actions.

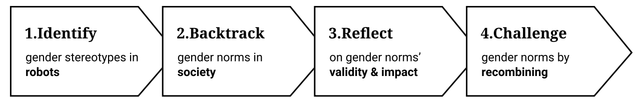

Figure 4: Design Guidance

Step 1: Identify Gender Stereotypes in Robots. The aim of the first step is for designers to reflect on existing gender stereotypes in service robots and get aware of them.

Since designer never works alone, we suggest starting with a user-centred design approach [39] by forming a multidisciplinary gender-balanced team. Women are chronically under-represented in technology and robotics design [25], thus female perspectives are more likely to be neglected or improperly considered [50].

Then, the design team has to define the context boundaries: 1) Market (Chinese or other); 2) Industry (catering or other); 3) Robot's function role (cooking, delivering, greeting, and ordering in the case of catering). After that, resources have to be allocated to review the 8 code families in the code library. The design team can work together to identify the stereotypes related to their working area following our process detailed in Section 3.

Step 2: Backtrack Gender Norms in Society. The second step is for designers to trace back the identified robot gender stereotypes to those in society. From our analysis, there are three main patterns related to the robot gender norms: industrial, cultural, and sexual. The design team can also define others.

To recognize the industrial gender norms, we suggest the designers look into two aspects: 1) the gender distribution and gender-related issues of the real employees in the industry; 2) the traditions of the female and male employees' appearance, clothes, accessories, and behaviors during work.

To recognize cultural gender norms, we suggest the designers look into the industry's history and trace back the influence of culture on business owners, employees, and customer preferences. From our analysis, CF4_Clothes Type, CF5_Clothes / Shell Color, and CF6_Accessory are three positively related code families. Designers can start backtracking from these aspects.

To recognize sexual gender norms, we suggest the designers identify the features used to improve the robots' attractiveness, especially the sexual related ones. CF2_Body Ratio, CF4_Clothes Type, and CF6_Accessory are three highly related code families that designers can look into.

Step 3: Reflect on Gender Norms' Validity & Impact. In the third step, we suggest designers compare the gender norms that exist in robots and the society. Then reflect on their validity and impact.

For the gender norms that exist in the society but is not present in robots, designers should question 1) whether previous designers neglect it due to their unconscious bias and an oversimplified classification (e.g., no trousers designed for female robots); and 2) whether the robots have shown the true diversity of people in the society [50] (e.g., the actual staff's personality and temper can vary, while the robots' expressions are more homogeneous).

For the gender norms already shown in robots, the designers should 1) question the validity of the gender norm and whether its benefit is actually supported by evidence; 2) evaluate the impact the gender norm could have on the society.

Designers can evaluate a gender norm's validity by asking:

- Is this trait an expression of modern society or it's just an outdated stereotype?
- Is the inherited trait from the real staff also effective on robots?
- Does the gender norm have a different meaning in another culture?
- Will the gender norm benefit the interaction between different users and robots?

Designers can evaluate a gender norm's social impact by asking:

- Will the gender norm affect people, especially children's expectation of a specific gender and its occupation?
- Will the gender norm reinforce and enlarge the societal gender gap?
- Will the gender norm reinforce the dark historical gender culture?
- Will the gender norm mislead the customers and cause potential harm to one gender?

Step 4: Challenge Gender Norms by Recombining. In the last step, we suggest the designers challenge the gender norms by designing gender attentive and gender fluid robots.

Designers can first try to use the low humanoid and gender neutral traits. Then, if a certain gender trait is necessary to facilitate human-robot interaction, designers can try to mix it with other counter gender traits to prevent the potential formation of gender stereotypes. They can also consider adding what's existing in society but is neglected in robots to reduce the representative bias in robots.

For example, designing a male greeting robot and a female cooking robot can challenge societal occupational stereotypes. Combining the female gender trait "apron" with the male gender trait "wide shoulder" can avoid the gender assignment by the user. Pepper[7] produced by Softbank is one of the commercially successful examples of gender-neutral robots. This kind of recombination can challenge societal gender norms and help people interacting with the robot to reflect on their gender stereotypes and biases.

7 CONCLUSION

The application of service robots has a broad and profound impact on society. Moreover, human society is not only a starting point of robot design, but also a destination. If not well designed, human-robot interaction and human-human interaction will be in a vicious circle (Figure 5), which reinforces the societal stereotypes among humans.

In response to the vicious circle, Londa Schiebinger [44] proposed a virtuous circle (Figure 5) that robot designers identify the existing gender stereotypes and challenge them in design. By embodying

[7] https://developer.softbankrobotics.com/pepper-qisdk/design/pepper-humanoid-robot

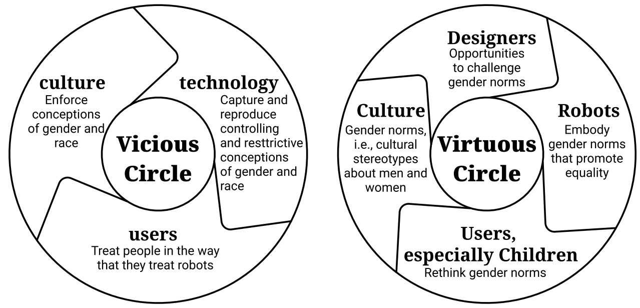

Figure 5: Vicious & Virtuous Circle of Gender Norms, adopted by the authors from Londa Schiebinger [44]

gender norms that promote equality, robots employed in society can help users rethink societal gender norms.

To this purpose, we developed a code library of gender stereotypes on catering service robots by iteratively coding 67 humanoid robot images from the Chinese e-commerce market. We further discussed the results from industrial, societal and sexual perspectives and proposed a practical guidance for designers to challenge these gender norms in robot design.

The limitations and future work of our research are as follow:

- Our research focused on the catering service robots in the Chinese e-commerce market. The results may not be the same to other markets. However, our analysis method and design guidance are still useful to other scenarios and we encourage other researchers expanding our approach to global markets and different applications.
- Due to the data source limitation, we analyzed the robot appearances and functions only based on static pictures. Other aspects like the robots' voice and behavior may also have an impact on the formation of gender stereotypes. Future research can deepen these aspects.
- Although we try to keep objective as possible, all the analyses and interpretations are done by three female researchers and inevitably influenced by their ethical values. Future research can involve male researchers and robot designers to evaluate and improve the result.

Through this work, we envision providing robot designers with a foundation and exemplary account of gender stereotypes in service robots as well as practical guidance to design robots that challenge gender norms and promote social equality.

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