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Applying Kansei/Affective Engineering Methodologies in the Design of Social and Service Robots: A Systematic Review

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Abstract

This article provides a systematic review of research articles applying *Kansei / Affective Engineering* methodologies for the development of Social and Service Robots. We describe relevant concepts and main types of *Kansei Engineering* methodologies to assist new researchers and practitioners interested in the area. We also summarize the main objectives and findings of eleven peer-reviewed research articles published in relevant conferences and journals. We selected these articles after performing a systematic search in relevant databases for robotics research (Science Direct, Web of Science, IEEE Xplore, ACM digital library, and Springer Link) and *Kansei Engineering* (J-STAGE). This search includes studies published in the English language between 1999 and 2019. Findings from observed articles indicate that *Kansei Engineering* is a suitable paradigm for robot design. Moreover, developers can use *Kansei Engineering* methodologies to identify and better understand the design aspects enabling social and service robots to be accepted and desired by users. Contributions of articles reviewed include (i) the use of novel approaches for grasping emotional reactions in Human–Robot Interaction experiments and (ii) the proposal of guidelines for designing social and service robots. However, the use of *Kansei Engineering* methodologies in robotics is still a poorly explored area. Therefore, we describe possible future directions and open challenges.

Keywords Kansei engineering · Human-centered design · Human–robot interaction · Social robots · Service robots

1 Introduction

Recent advances in perceptual, cognition and control algorithms generate new trends in Human–Robot Interaction (HRI). The objective of applications following these new trends is to reach effective communication between robots and people in dynamic and real-world environments. [14, 15,29,57]. However, robotics is an area presenting many challenges that hinder their successful integration beyond industrial scenarios. Examples supporting this fact are the recent failed attempts at commercializing social robots [22]. As highlighted in [18,22] social and service robots will difficulty reach a successful integration into our society unless manufacturers and researchers become aware of the importance of exploring *human-centered* and emotional design paradigms. In fact, many mature technologies nowadays adopted by the general public have historically switched their design approaches from *machine-centered* to *human-centered* [5,59]. On the one hand, *machine-centered* approaches are often addressed by specific technological communities whose main goals are to generate innovative products or ideas, prove technical performance superiority or simply create new user experiences (in many cases without knowing if these experiences of features will be needed or appreciated by final users) [36,59]. On the other hand, *human-centered* approaches are intrinsically multidisciplinary tasks where the main focus is to develop accessible, desirable, intuitive, friendly, and usable products able to satisfy human needs and expectations [28,59]. Relevant *human-centered* disciplines are *Human Factors*, *Pleasant Design*, *Kansei/Affective Engineering* and *Ergonomics* [61]. Many of these disciplines also focus on the satisfaction of functional and non-functional requirements of products.

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While functional requirements can be seen as those technical and programmable aspects that enable technological devices to perform some specific tasks [59,61], non-functional features are generally tacit and not easily programmable features [65]. The satisfaction of these two types of requirements must be addressed with the same importance as consumers become more informed and the industry becomes more competitive [36,46]. Examples of non-functional features for technological products are reputation, style, consistency, trust, comfort, familiar design, and aesthetic [7,33]. Aspects that influence the acceptance of these non-functional features are emotions, intrinsic desires, and values of users [33]. These aspects are the main focus of *Kansei Engineering*. Therefore, this discipline has become a valuable design tool for the development of commercially successful and appreciated-by-users technological products and services [46].

The main objective of this article is to provide a systematic review of research works and applications found in the literature that use well defined *Kansei Engineering* methodologies for the development of human-friendly robots (i.e, that are easy to use and appreciated by humans) [46]. Unlike other forms of literature review, systematic reviews require the definition of a trustworthy, rigorous, and auditable methodology or *review protocol* [30]. This *review protocol* requires the specification of the research questions guiding the review, the description of the search strategy, and the specification of the inclusion and exclusion criteria used in the selection of the research articles. This type of literature review method can be used to identify gaps and challenges in current research and help to position new research activities [11]. Therefore, performing *systematic reviews* often requires considerably more effort than a traditional literature review [30]. The research question guiding this article are: (i) how relevant has been the attention of the robotics community in the inclusion and understanding of human emotions, implicit values and needs for the design of robotic systems using *Kansei Engineering* methodologies?; (ii) what are the main findings obtained by the application of *Kansei Engineering* methods in Social and Service Robotics?; and (iii) what are the open challenges and possible research directions?. Relevant aspects highlighted in the reviewed articles are: objectives, used or designed robot platforms, application domains, elements to design and outcomes/findings.

The organization of this paper is as follows. Section 2 briefly describes the main concepts and methods underlying *Kansei Engineering*. Section 3 describes the methodology used for the systematic search. Section 4 summarizes relevant approaches and applications presented in the reviewed papers. Section 5 presents open challenges and possible research directions. Discussions and Conclusions follow.

2 Kansei Engineering

Kansei is an ambiguous term coined in Japan [21]. Like some other popular Japanese terms, such as *manga* and *tsunami*, the word *kansei* is nowadays adopted in many languages. However, this term does not have an exact translation in English [21]. Closest meanings include sensitivity, affection, aesthetics, emotion, want, need, and feeling [21,45]. A formal definition is expressed in [45] as *"the feeling felt by the receiver of stimuli contained in the atmosphere of a situation"*. This reaction to stimuli (*kansei*) is highly influenced by the past experiences of users and a combination of sensory modalities (especially eyesight) [45].

The importance of considering human *kansei* in the development of technological and every-day life products is described in [7,45]. These works highlight that products only developed in base of the manufacturer's intuition of what they should be, will probably dissatisfy users if these products: (i) are not able to meet the explicit and implicit expectations and needs of users; (ii) provide many unnecessary functions; (iii) do not support the standards of living of users; (iv) do not provide a reasonable price for its quality; and (v) are not able to adapt to the change of the people's feelings. As suggested in [45] the creation of products able to capture the interest of people can be possible if they are designed to stimulate human *kansei* (emotions); therefore, improving the individual and social values of users.

Kansei Engineering is a consumer-oriented technology [43] and a popular *human-centered* paradigm for designing suitable and accepted products and services. Since its foundation in 1970 by Mitsuo Nagamachi, applications of *Kansei Engineering* have expanded beyond design and manufacturing areas [59]. This research area is mainly prominent in Asian countries such as South Korea, Japan, China, and Malaysia. However, it has recently gained popularity in some occidental countries [46]. The main goal of *Kansei Engineering* is to improve the quality of life, comfort and enjoyment of people [21] by the development of novel emotion-based products using a *human-oriented* (i.e., oriented to the human mind) approach [45]. For this, researchers must grasp and understand the human *kansei* by sensing facial expressions, eyes, spoken works, and other human reactions [46]. This information is then analyzed using psychological, ergonomic and engineering methods for its posterior translation into design specifications. These specifications or design items can be integrated into the final product to (i) stimulate the user's emotions or *kansei* and (ii) to meet the needs and implicit expectations of users [21,45,63].

2.1 Methods in Kansei Engineering

As mentioned in [35], there are at least eight types of *Kansei Engineering* methodologies up to date. However, six are the most commonly referenced in literature [36]. We briefly describe these six types of *Kansei Engineering* methodologies below.

Kansei Engineering Type I (*KE Type I*) was originally used as a method to enable the identification of meaningful design details of products [43]. According to [43,44] the *KE Type I* process starts with the definition of the product (denoted as zero-level concept). Examples of zero-level concepts for robotics can be *home robot*, *robot therapist*, *robot companion* or *robot chef*. However, these high-level concepts often tell few or nothing about the relevant design specifications of products. Therefore, these high-level concepts need to be broken down into more clear sub-concepts. These sub-concepts are organized in numerated classification levels (eg., 1st, 2nd,…) and displayed as a tree structure. These new sub-concepts are iteratively broken down into newer sub-concepts until meaningful design traits of the product are clearly identified [44]. Examples applying this methodology, which is defined as *Category Classification*, are shown in [36,44]. However, a more general and standard definition of *KE Type I* methodology is described in [35,40,47]. Steps generally composing this methodology are shown in Fig. 1. As before, this methodology starts by specifying the concept of the new product to create. Then, it is required to identify a set of relevant *Kansei* words able to describe subjective feelings about the product. Few examples are: *modern*, *elegant*, *old*, *dynamic*, *cute*, *happy* and *angry*. The selection of these words is often done from a survey in state-of-art articles or by consulting experts in the area where the product will be applied. These words are then arranged in a semantic differential (SD) scale [1] to enable data collection in experimental sessions. Then designers must collect samples of each item or category (e.g., color, shape and size) that clearly define the product. These samples come from similar or competing products. Experimental sessions in this type of *Kansei Engineering* basic methodology often imply: (i) to present the product to users; and (ii) to grasp the user's feelings, impressions or reactions about each sample of the products presented. This data is obtained using the corresponding SD scale sheet (where the *Kansei* words previously selected for the experimental session are displayed). Design interpretations are performed by analyzing the results after implementing multivariate analysis methods to the data collected. Multivariate analysis methods often used in *Kansei Engineering* are *Quantification Theory* [38], *Regression Analysis* [24] and *Factor Analysis* [32]. Final results or interpretations can be used to validate the feasibility of some design (as shown in some of the articles reviewed) or create a new emotional product. This type of *Kansei Engineering* methodology is used in all the articles reviewed.

A *Kansei Engineering Computer System* (also denoted *KE Type II*) utilizes Artificial Intelligence technologies such as Neural Networks, Expert Systems, and Genetic Algorithms

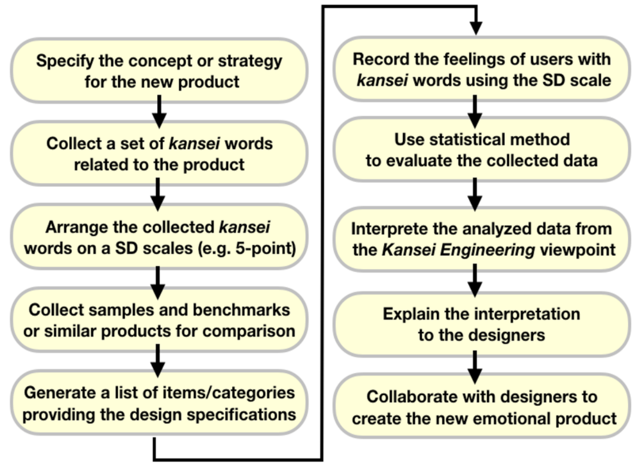

Fig. 1 Type I general methodology (adapted from [47])

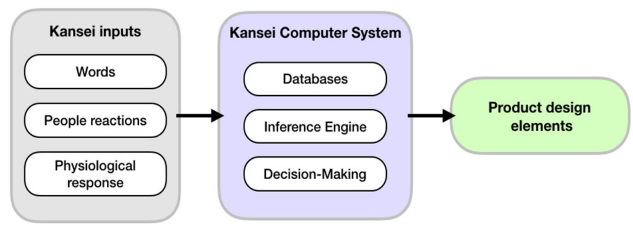

Fig. 2 Forwards Kansei engineering (adapted from [43])

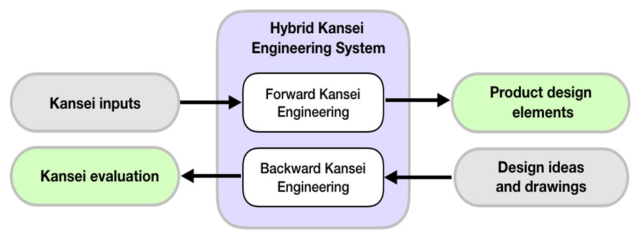

Fig. 3 Hybrid Kansei engineering system (adapted from [44])

to support the process of transferring the *kansei* (feelings) of users to design specifications. Inputs for this type of computer-assisted system are the grasped *Kansei* reactions of the target users. Then, these inputs are processed using databases and inference engines to obtain a possible design candidate [40]. This process is also called *Forward Kansei Engineering* (Fig. 2). Databases in these systems can contain *Kansei* words, images, color, shapes, and information about the relation between these data [19]. More details can be found in [35,43,44].

A *Hybrid Kansei Engineering System* (Fig. 3) or *KE Type III* consists of two *Kansei Engineering* sub-systems. The first sub-system uses *Forward Kansei Engineering* to transform human *Kansei* to design specifications. The second sub-system supports the creativity of designers in product development. For this, the sub-system estimates the level of Kansei value or possible emotional responses of users from the designer's ideas or drawings [43]. This process denoted as *Backward Kansei Engineering* enables designers to evaluate and adapt their designs to fit some desired *Kansei* response in the users [44].

In *Kansei Engineering Modelling* or *KE Type IV* the focus is to build mathematical predictive models to support decision logic in a computerized system [34,58]. For this, fuzzy logic is often used [34,44]. Due the complexity of *KE Type II*, *KE Type III* and *KE Type IV* systems, they are less frequently reported in the literature [36].

Virtual Kansei Engineering or *KE Type V* uses Virtual Reality (VR) methods to present products to users and obtain *Kansei* data using a virtual version of them rather than the real one [34]. Finally, in *Collaborative Kansei Engineering* (*KE Type VI*), databases are shared using internet to enable collaborative tasks remotely [34,36].

2.2 Kansei Robotics

Initially proposed by Shuji Hashimoto in [20], *Kansei Robotics* is a modeling paradigm based on the *Kansei* concept and their use for the creation of robot intelligence, functions or information processing modules. This approach is mainly defined as the use of *"sensitive data processing"* from which robots are enabled to make subjective sense of the environment [20,55]. As mentioned in [55], initial *Kansei Robotics* researchers tried to approach robot intelligence more subjectively by considering both rational elements and emotions. For this, *Kansei* Robotics researchers often define the so-called *Kokoro* or *Virtual Kansei* function. *Kokoro* is a Japanese word involving the oriental conception of mind as an integration of emotion, intelligence and intention [55]. The main aim of this modeling approach is to enable robots to behave like having *Kansei* (i.e, enabling subjective cognition and control of robots). For this, modules of emotion recognition, generation and expression are often required to be integrated into the robot [41].

As highlighted by [55], many initial works in the area of *Kansei Robotics* present "an emphasis on culturally specific concepts of consciousness and agency". This approach served to define and legitimize the efforts of many robotics designers in countries of East Asia that have worked in the development of intelligent robots with human-like emotions. Moreover, many projects using these culturally specific formulations for modeling robotic affection do not reference efforts towards emotional robots developed in the United States and Europe [55]. An example of a very popular work often omitted by initial works on *Kansei Robotics* is [10]. Nowadays, this idea of incorporating emotions as an essential part of the creation of intelligent robots has become an emergent trend often defined in many cognitive and computational emotional models [13]. Few examples of very recent works using emotion-related concepts to adapt the robot expressions and behaviors according to the presented Human–Robot Interaction scenario are [37,53,54]. Works aimed to simulate emotional aspects (*Kansei*) in robots, are beyond the scope of this article, and must be included in literature review studies that focus on the modeling of intelligent robots, such as in [13,48]. Instead, this article focuses on those works using *Kansei Engineering* methodologies (presented in sect. 2) for the design or evaluation of Social and Service Robots.

3 Systematic Search Methodology

The present study considers the guidelines for systematic reviews described in [11,31]. The steps followed are described below.

3.1 Search Process

The main concepts used to compose the search string are *Robot* and *Kansei*. Correlated concepts are *Agent*, and *Affective Engineering* respectively. Then, we define the search string as *('Robot' OR 'Agent') AND ('Kansei' OR 'Affective Engineering)'*. We use this string to search potential articles in relevant digital databases of Robotics research (IEEE Xplore, Science Direct, ACM digital library, Springer Link and Web of Science). Moreover, we also performed a search in J-STAGE, which is a database system often used by Japanese academic societies. Special interests are the International Journals of *Affective Engineering* and *Kansei Engineering*, which are published by the Japan Society of Kansei Engineering. The systematic search performed includes publications between January 1999 (after the creation of the Japan Society of Kansei Engineering) and October 2019.

3.2 Inclusion and Exclusion Criteria

The inclusion criteria we considered for this review is: *The paper presents an application using Social or Service Robots and Kansei concepts*. We excluded those papers that meet the following criteria: (i) *The main objective of the paper is to simulate virtual Kansei or to process sensitive data using robots (Kansei Robotics) and not to use some ergonomic and Kansei Engineering methodology to evaluate interactions or design robots*; and (ii) *the article is not written in English, is a duplicate, or is a short/previous version of another more complete article that expresses the same ideas or results and is written by the same authors.*

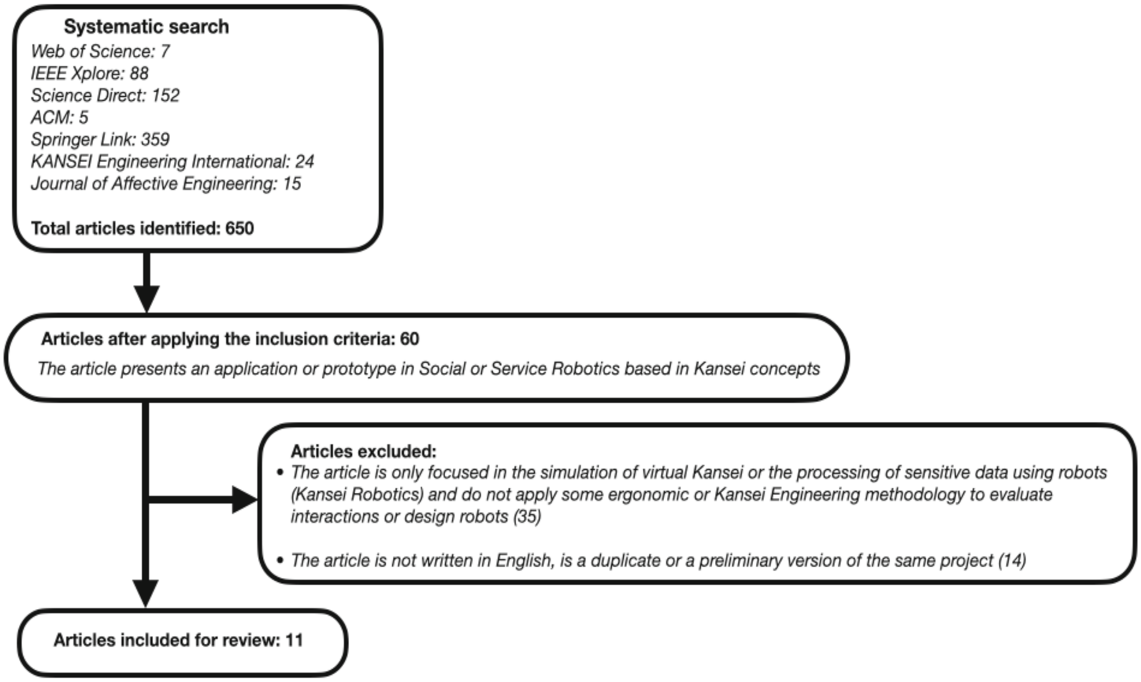

Fig. 4 Flowchart of the search strategy

3.3 Selection of Papers

The selection process of the papers used for this review is shown in Fig. 4. A total of 650 articles were identified after performing a search in the five previously mentioned databases. The following steps clarify how, why and when the defined inclusion and exclusion criteria were applied. *Step 1*. We read the title, keywords, and abstract of all articles obtained in the systematic search. Then, we identify the articles that meet the inclusion criteria described in sect. 3.1. The number of articles that meet these criteria is 60. *Step 2*. We skimmed and applied exclusion criteria. We identify 35 articles whose main focus is the simulation or expression of emotions. Moreover, 14 articles were duplicate versions in Japanese or a preliminary version of the same project. The final number of articles include for review is 11 articles.

4 Applying Kansei Engineering to Robotics

We identify two main types of areas or applications using Kansei Engineering for the development or design of Social and Service Robots. The rest of this section describes these areas. Moreover, we present the objectives and findings of the reviewed articles. Table 1 summarizes this information.

4.1 Capture User's *Kansei*

Three articles reviewed mainly focus on the use of *KE Type 1* surveys to grasp *Kansei* (i.e., the feelings, impressions, emotions or non-functional needs) of users in the initial iterations of product development. Experimental sessions in these applications often imply the exposition of robots to users (e.g. children, students, and elderly people) by either videos showing the capabilities of robots or through real interactions with Social Robots. In this context, Azmin et al. in [4] use *KE Type 1* to prove the suitability of My Keepon robot as a robotic companion platform performing in kindergartens. For this, they grasp *Kansei* information by both direct observations from videos recorded and the application of interviews after the experimental sessions. The authors of [4] claim that the obtained information can be used to better understand which features can make simple and relatively cheap robots attractive to the children. Aziz et al. in [3] use *Kansei Engineering* to extract emotions of both normal and autistic children interacting with a humanoid robot. These emotional states (*Kansei* reactions) are being triggered by the robots through different activities. These *Kansei* reactions are registered by teachers observing the interactive scenario. Findings of [3] suggest that with the application of the right intervention, social robots can ignite and initiate emotions in autistic children. Finally, Bidin et al. in [8] focus on grasping non-functional requirements (emotion values) of social robots in the context of r-learning (assistive learning with social robots) for elderly people, They found that "*interesting*",

Table 1 Summary of recently published works using Kansei engineering methodologies for design robots and its applications organized by publication year

References	Application area	Objectives	Main finding
Mori et al. [42]	Companion robots	Create robots able to maintain interested humans for more time	Animal-like and semi-random movements in a moderate velocity produce positive feeling and maintain interested humans for more time
Sugano et al. [60]	Service robots	Analyse the relationship between physical properties of motion and Kawaii-ness	Kawaii-ness feeling is more probably to be associated with animacy perception
Aziz et al. [3]	Robot-assisted therapy	Capture emotions of children while interacting with a social robot	The right intervention will be able to ignite and initiates emotions in autistic children
Zhu et al. [66]	Home robots	Formulate a method which can be used to quantifies the perceptual cognition of costumers about home service robots	A design patent of a home robot
Azmin et al. [4]	Children-robot interaction	Analyze features of My Keepon robot to better understand which of them are more attractive to children	Prove the suitability of My Keepon as a robot companion performing in kindergartens
Bidin et al. [8]	Robot-assisted learning	Formulate design guidelines for the development of Kansei-spiritual therapeutic robots	Robots embedded with spiritual design elements can be a suitable therapeutic approach for elderly people with Alzheimer's disease
Pakrasi et al. [49]	Mobile robots in a virtual environment	Increase likability, animacy, acceptance, and trust of social robots	A methodology for designing robotic systems using characters archetypes
Ismail et al. [26]	Robot-assisted therapy	Grasping non-functional requirements (emotion values) of social robots in the context of r-learning	Relevant values to average elderly people in Malaysia are *interesting*, *familiar* and *comfortable*
Jafar et al. [27]	Human–robot interaction	To better understand the relationship between emotions and touch senses of an average human	Humans perceive more positive feeling on surfaces with lower roughness
Hsiao et al. [23]	Robot surveillance	Designs and develops a patrol robot	A final mobile robot design
Dou et al. [17]	Robot as receptionists in shops	Examine the relationship between different types of robot's voice and gestures with perceived personalities	Robots with children's voices are more likely to be accepted by users of shops as it is perceived as safe and extroverted.

"*familiar*" and "*comfortable*" are common robotic values often preferred by elderly people in Malaysia. Based on the obtained results, authors [8] also highlight the importance of the cultural aspects for the design of acceptable social robots for elderly people.

4.2 Determine Robot Design Elements

In this type of application, researchers analyze different samples of items or categories composing Social and Service Robots to get suitable designs for the aimed application. Examples of design elements are color, materials, shape, motions and voice. In this context, Mori et al. in [42] use the SD scale and Factor Analysis (tools often used in KE Type I) to examine the impressions of humans about different patterns of motions (eg., linear, circular and random motions) and velocities aimed to performed by a prototype of companion robot denoted as SELF. The result from experiments with 30 subjects suggests that semi-random and animal-like movements, such as following and fleeing at a moderate speed, can create positive feelings and impressions in humans and engage them for a longer time. However, these movements executed at high speed can create negative and boring impressions.

Sugano et al. in [60] perform a survey about the relationship between seven physical properties of motion (position, angle, acceleration, linear velocity, angular velocity, angular acceleration, and time) and the *Kawaii* feeling in a mobile robot. *Kawaii* is also a popular Japanese word used to describe cuteness. Items used in the *Kansei Engineering* process were 24 identifiable motion primitives. They found that the generation of "simple", "regular" and "smooth" motions can influence the perception of the *Kawaii* feeling as well as those movements perceived as biological or intentional. Zhu et al. in [66] address the challenge to design a home service robot using *Kansei Engineering*. They mostly focus on robot aesthetics design requirements. For this, they collect samples of seven existing robots. The outcome becomes a real-world robot design patent. Ismail et al. in [26] use *Kansei Engineering* methodology to formulate a design guide for developing Kansei-Spiritual Therapeutic Robot Interaction (KS-TRI), which is a novel approach used to support elderly people in the performing of spiritual activities. Items used for the *Kansei Engineering* survey are robot voice and movements. Their findings prove the suitability of including spiritual elements in the design of social robots. They claim that spiritual elements can improve the acceptability of these types of robots in elderly people thought to evoke positive emotions [26]. Jafar et al. in [27] performed a *Kansei* survey to find suitable touch surfaces for the design of social robots. For this, 10 samples of different types of fabric surfaces where used in experimental sessions. Their findings suggest that positive emotions can be reached when designing robot surfaces with lower roughness. This type of surfaces can evoke *calm*, *safe* and *comfort* feelings. On the other, negative feelings such as *fear* and *anxiety* can be evoked with rough surfaces. Dou et al. in [17] use *Kansei Engineering* evaluation methods to study the influence of the use of gestures and voice simultaneously in the perceived robot personality. For this, a 3D model of the Pepper humanoid robot was used along with the Wizard of OZ paradigm (i.e., non-autonomous, remote or manual control of robots) in a laboratory setting. Findings of [17] can be used to better design shopping robot receptionists that are more engaging and accepted by costumers. Pakrasi et al. in [49] propose a design methodology aiming to increase the likeability and trust of social robots by abstracting popular characters archetypal and personalities, and use this information to build robotic systems. Unlike other works reviewed in this article, which mainly used *KE Type I*, this work also uses Virtual Reality to present the design elements to the users. The design elements analyzed in this work are color, animated eyes, and motion profiles. Finally, Hsiao et al. in [23] uses *KE Type I* to design and develop a patrol robot. They use security-related emotional words such as *protecting*, *powerful*, *secure* and *reliable* to enable data collection using SD questionnaires. Samples are obtained from competitive products. They use this data to analyze the emotional reactions and current non-functional needs of consumers. The outcome was a real and 3D mobile robot design.

5 Open Challenges and Future Directions

This section describes open challenges and possible future directions based on the findings and observed limitations/disadvantages of the reviewed articles.

5.1 Going to "in the Wild" and Multi-party Interaction

Most articles including Human–Robot Interaction activities are performed in structured settings, such as laboratories [29]. However, we still know little about how people will react to robots when they interact with them in their everyday environment. Even if researchers can still obtain valuable findings from studies in laboratories, the switch to *"in the wild"* (i.e., in situ, natural and outside laboratories) scenarios will be an essential step towards the better understanding of people reactions, feelings and needs of Social and Service Robots [29]. Moreover, robot activities are often designed to deal with single-party interactions (i.e., one robot with one person) [29,56], settings that can differ from many real-world applications where multi-party interaction is also required (e.g. robot receptionist, robots in stores, robot as teachers and robot companions).

5.2 Stimulate Multiple Senses

Cross-modal studies showed that users perceive product qualities through their multiple senses [64]. Moreover, the opinion that users have about a product often switches from one state to another in cyclic interactions through the use of different sensory modalities (e.g., vision, hearing, touch, smell) [64]. Most of the articles reviewed use vision as input to generate *Kansei* responses. An exception that explores touch modality is [27]. However, few have studied the effect of combining different types of stimuli or modalities. Exceptions are [17] and [26] where visual (using gestures) and auditory (from robot voice) are studied together.

5.3 Needs for Long-term Interaction

As mentioned in [9] *Kansei* measurements are often obtained at the moment of the first contact with the product. However, these feelings and values can constantly change in posterior interactions with the product. Therefore, *Kansei* data is "valid only in certain limited contexts and during a limited time" [25]. Crucial aspects that can influence the results on studies in *Kansei Engineering* are: (i) personal interest and competence; (ii) experience of interaction; (iii) fashion and trends; and (iv) time dependency [25]. Therefore, robotics designers must investigate which are the effect of these aspects over long-term interactions with social and service robots as well as analyze differences between *Kansei* information obtained at the moment of the first contact and after interacting with robots in different contexts.

5.4 Use of Machine and Deep Learning Perceptual Approaches

In long-term experiments, the grasping of *Kansei* reactions from direct observations or using recorded videos can be a very time consuming and tedious task. Instead, researchers can take advantage of current state-of-art and new machine learning methods for emotion, gesture, and state recognition. In this context, methods based on Convolutional Neural Networks (CNNs) and Recurrent Neural Network (RNNs) are suitable options. Examples can be seen in [2,16,62]. Most of these approaches use images as input data. Some novel approaches to capture *Kansei* data that researchers can explore are the use of speech and touch modalities as well as the use of novel devices and algorithms able to predict emotions and other human reactions as a hidden biometric. [52].

6 Discussion

Most *Kansei Engineering* projects in the literature focus on the evaluation of forms and colors as the main design elements. According to [9], this is one of the main limitations of *Kansei Engineering*. However, robots are complex machines enabling interaction in many and novel forms. Some of the works reviewed in this paper explore different design alternatives for designing the robot's social capabilities, such as the use of the motion and voice. Moreover, the number of semantic terms that designers can propose to evaluate robots or HRI tasks can be large and application-specific. Therefore, the selection of these *Kansei* words is often a time consuming and error-prone task [9]. The "Goodspeed" questionnaire [6] is an example of an effort toward providing standard measurements for HRI. Research can use this questionnaire to obtain the response about the perceived intelligence, animacy, and safety of Human–Robot Interaction scenarios, how imperfect it is [12]. To evaluate user experience, developers can also use words from well-known psychological and emotional models, such as the Mehrabian dimensional model [39] and the Plutchik's wheel of emotions. [50].

Works reviewed in this article mostly use *Kansei Engineering type I* methodology to evaluate and produce design alternatives based on existing products. However, none of them use a *Hybrid Kansei Engineering* systems for supporting the creativity of designers [46]. The creation of innovative products or designs using *Hybrid Kansei Engineering* systems is an iterative process that follows three steps: (i) use forward *Kansei Engineering* to propose design alternatives as candidates for some optimal design; (ii) modify those alternatives exploiting the creativity of designers to create novel elements; (iii) use backward *Kansei Engineering* to predict the affective response that this new product will produce in the users. The interested reader can consult [51], which uses Deep Learning methods for supporting product innovation.

7 Conclusions

Kansei Engineering is a discipline focused on the design and development of attractive and suitable technological products that are appreciated by people and provides relevant economic benefits. Findings from this article suggest that the interest of researchers to apply *Kansei Engineering* methodologies in robotics design and development is emerging just recently.

Similar to the initial years of computers, researchers in the robotics community mostly focus on proving the novelty and performance superiority of their approaches or algorithms. However, design efforts that only focus on *machine-centered* factors can hardly be enough to capture the interest of people or increase the acceptance of these machines in society. On the one hand, many users could consider some advanced functions as unnecessary, overkill, and undesired. On the other hand, the execution of these advanced algorithms can require powerful hardware; therefore, highly increasing the cost of the final product. Furthermore, approaches only focused on *machine-centered* design approaches could produce undesired feelings towards robots by users and society (e.g., unpleasant aesthetics or threats to the jobs, privacy, safety, or identity of humans). To improve the acceptance and positive attitudes towards robots, they must also be attractive, usable, safe, desired, familiar, cost-effective, and friendly as well as to produce positive emotional values to people. This article showed how *Kansei Engineering* can be used to address many of these issues. To our knowledge, this is the first literature review of research articles applying well-defined *Kansei Engineering* methodologies in the design and evaluation of Social and Service Robots. Moreover, we identify possible directions and open challenges. We hope that the information presented in this article can be useful to new researchers, designers, professionals, and industrial engineers for applying basic *Kansei Engineering* approaches for the design of more suitable and human-friendly Social and Service Robots.

Compliance with Ethical Standards

Conflict of interest The authors declares that they have no conflict of interest.

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