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A Study on Proactive Methods for Initiating Interaction with Human by Social Robots

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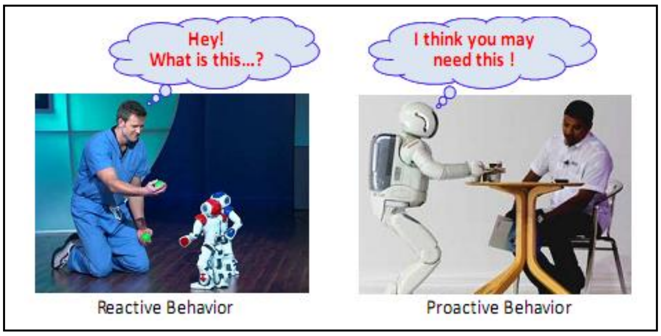
***Abstract*—This paper reports on the trending literature of Human-Robot Interaction (HRI) methods for proactively initiating interaction with human by social robots in social spaces. The discussion explores the state-of-the-art proactive HRI methods and pinpoints the necessity of dedicated attention to initiate successful proactive interaction by social robots with human. The findings suggest that although reactive HRI methods are well established in social spaces but very few proactive methods are implemented. More research should be paid to introduce social robot's proactive HRI approach properly in social spaces. The literature further showed that robust human detection and tracking method is crucial to read human's is interests and intentions from their behaviors before introducing proactive HRI with human in social spaces. Finally, future potential applications of social robots are addressed.**

***Keywords*—human-robot interaction, social robots; interests; proactive services; reactive services.**

I. INTRODUCTION

Traditionally, humans have viewed robots as a "mechanical machines", designed to perform a variety of industrial tasks. However, within the last decades, the reality of robots is quite different from the traditional view and has enabled us to start developing social robots to support humans in their daily activities. The concept of the social robot is rapidly emerging and gradually being introduced as a part of human society where interaction among humans and social robots seems to be important to provide mental, communicational, and physical support to humans in society [1]. Consequently, with the development of HRI systems over the last decades, many robots as social robots have already been

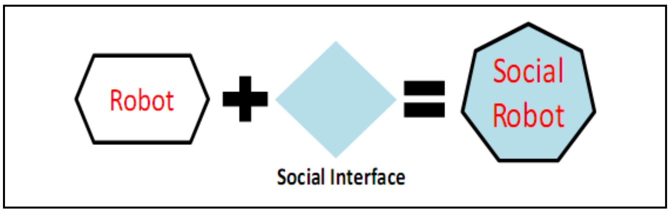


started to move from laboratories to social spaces [2], where a social robot interacts with ordinary people.

Over the last decade, many social robots are developed and many experiments has conducted in real-world environments where social robots are interacted with human beings in different scenarios. For example, social robots have been deployed in public spaces, including day-care service centers [3], hospitals [4], train stations [5], office buildings [6], museums [7], shopping centers [8], child care centers [2], autism therapy centers [9] and in schools [10]. Moreover, many social robots have also been deployed in public spaces with the capability to encourage people to initiate interaction with them [11]. But, in most of these typical HRI systems, the interaction partners (human and social robot) are restricted to controlled Fig. 1. Different modes of interaction among human and social robot.

conditions. In the early stages of HRI, social robots interacted with human reactively. In such typical social robotic systems, people explicitly call the robot for help. There has been a great deal of research to extend the modalities so that we can use voice and gestures in these cases. In addition, Yamazaki et al. proposed that social robots should show their availability and recipiency by it's behaviors so that people could easily start asking for help or assistance [12]. In most cases, social robots wait until people willingly initiate interaction where the robot should only behave reactively, to respond to questions, for example, see Fig. 1(Left).

On the other hand, in actual social interaction, people tend to do things automatically for each other, without being asked for help. In our daily life, for example, if we find a person who is looking around with a map in his/her hand at a shopping mall, we can anticipate on upcoming situations and be proactive. Consequently, we may ask him/her if we can help him/her, but only when the upcoming situations do happen, otherwise it was a waste of time. During the middle of this era, scientist have tried to make the social robots as natural as possible to serve people proactively where social robots should estimate human intentions, and offer help only to those who would need it, for example, see Fig. 1(Right). If it is possible to introduce the proactive behaviors of social robots then it can have several advantages, but if it does not work extremely well, it can be intrusive and disturbing. The advantages of proactive behavior are a more intuitive human-like interaction with robots [13] because the social robot reads human's intentions, s/he does not have to formulate a question (which can be difficult), thus a social robot's proactiveness reduces the human's effort. It is expected that in a more proactive



state the

Fig. 2. A Social Interface creates a social robot (Source: [15]).

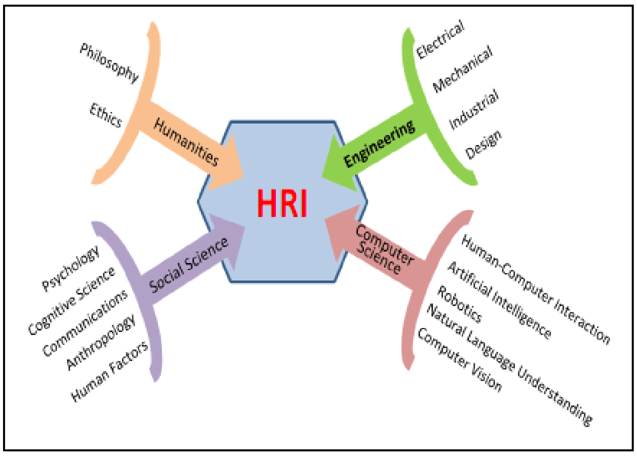
more human-like interaction makes the social robot less machine-like [14].

In this study, interaction among industrial robots and human in industries are excluded, and we focus on interaction among human and social robots in social spaces. Following this introduction, in Section II the HRI taxonomy are defined and categorized, thoroughly. The state-of-the-art progress of the Proactive HRI interaction methods are comprehensively studied in Section III. Additionally, challenges that are faced during implementing this method by the researchers are thoroughly discussed in Section IV. Finally, in Section V, potential future applications of social robots' proactive behaviors are presented.

II. HRI TAXONOMY

a) Social Robots: In comparison with an industrial robot, a social robot combines technical aspects as well as social aspects but the social aspects are the core purpose of social robots. The industrial robot is not a social robot, because it needs specific communicative capabilities to become a social robot. First, it implies the robot behaves (functions) socially within a context and second, it implies the robot to have an appearance (form) that explicitly social with respect to any person. From this point of view, a social robot contains a robot and a social interface (see Figure 2). A social interface encloses all the designed features by which a user judges the robot as having social qualities.

b) Human Robot Interaction (HRI): It is the interdisciplinary study of interaction dynamics between humans and social robots. Mostly, humans express their intentions via speech, gestures, expressions, and sounds. In response, to such types of human behaviors, social robots must be aware and also be able to understand them [16]. Researchers and practitioners specializing in HRI come from a variety of fields, including engineering (electrical, mechanical, industrial, and design), computer science (human-computer interaction, artificial



intelligence, robotics, natural language understanding, and computer vision), social sciences (psychology, cognitive science, communications, anthropology, and human factors), and humanities (ethics and philosophy). HRI differs fundamentally from typical Human-Computer Interaction (HCI) in several dimensions. Yanco et al. state in [17] that HRI can be seen as a subset of HCI. Figure 3 shows the HRI which is placed within the multidisciplinary field of research.

Fig. 3. HRI- a multidisciplinary field of research.

c) Social Robot's Reactive HRI Method: The first introduced interaction method of social robot is reactive method, in which a social robot waits until a user initiates interaction with the robot [18]. By this method, only people who actively try to interact with the robot can be served. However, such people who are hesitating or unsure how to interact would be not served by this reactive approach.

d) Social Robot's Proactive HRI Method: Another interaction method is the proactive one, in which a robot proactively seeks people who potentially need help [19]. During the middle of this era, scientist have tried to make the social robots as natural as possible to serve people proactively where social robots should estimate human intentions, and offer help only to those who would need it. The state-of-the-art development of this methods is discussed in details in the following sections.

III. PROACTIVE HRI INTERACTION METHODS

In the early stage of HRI, social robots are successfully deployed in real social spaces to assist humans reactively (for example, in museum [20], in mall [21], in train station [5]). But, since the last decades, the concept of the HRI is rapidly emerging and gradually being introduced social robots as a part of human society where interaction of social robots seems to be proactive in nature to humans in society [1]. As a consequence, under the improvement of HRI systems over the last decades, very few robots as social robots (see in Table I) have already been started to initiate interaction with ordinary people proactively to serve them in real social spaces. In the following sections, each of the state-of-the-art developed social robot systems are described where social robot interact with human proactively.

Koide et. al [23] presented an approach for an interactive social robots that proactively facilitates a human visitor's experiences in an exhibition environment. Their social robot can provide a visitor with guidance information best suit to the visitor without any question-answering dialog, which is very difficult for human guides. They implemented their social robot system with commercial robot, Robovie to validate its effectiveness.

A series of experiments on developing social robot system has been done in ATR Intelligent Robotics and Communication Laboratory, Kyoto, Japan where social robots are introduced with their proactive activities with human beings in real world fields. In the consequence, an effective social robot is developed by T. Kanda et. al [26], which can provide services to the people in a public space. They presented a series of abstraction techniques for people's trajectories and a service framework for using these techniques in a social robot which enables a designer to make the social robot proactively approach customers by only providing information about target local behavior. They accumulated people's trajectories for a week, applying a clustering technique to the accumulated trajectories to extract information about the use of space and people's typical global behaviors. This information enables the social robot to target its services to people proactively The social robot anticipates both the areas in which people are likely to perform these behaviors as well as the probable local behaviors of individuals a few seconds in the future. In their field experiment in a real shopping mall, they demonstrated that this social robot enables to serve people proactively.

A networked social robot system is developed by M. Shiomi et. al. [27] that coordinates multiple social robots to provide efficient service to customer proactively. The proposed system estimates such human walking behaviors as *stopping* or *idle walking* to direct social robots to provide appropriate tasks to appropriate people proactively. Each robot interacts with people to provide recommendation information and route information about shops. In their field trial in a real shopping mall, four social robots interacted 414 people proactively, and revealed the effectiveness of the network social robot system for guiding people around a shopping mall as well as increasing their interest. Again, they again developed social robot system in [28] to guide people proactively based on the observation of human tour guides. Under their developed system, they designed a guiding behavior in which the social robot walks backward to elicit spontaneous participation. Additionally, the developed a social robot system that applies this behaviors in a real world environment.

D. F. Glass et. al. introduced a social robots [29] that proactively provide services to ordinary people based on their situational context, rather than responding to explicit

requests.
In their experiment in a real shopping mall, a social robot was waiting to offer route guidance, recommending shops, or advertising services to customers. In such cases, the service allocator must identify opportunities for providing services, rather than responding to requests, and allocation logic must be developed to assign robots to services based on anticipation of who will need or want the service . To do this, they uses

TABLE I
RELATED STUDIES IN HRI CONCERNING HUMAN BEHAVIOR TRACKING, INTENTION RECOGNITION, FOLLOWED BY SOCIAL ROBOTS' SERVICES IN DIFFERENT SCENARIOS

	Recognition				Services	
	Local Behavior	Global Behavior	Intention Recognition	Wearable Free?	Proactive ?	Location Scenario
W. Burgard et al. [20]	√	×	×	√	×	Museum
S. Thrun et al. [22]	√	×	×	√	×	Museum
Y. Koide et al. [23]	×	√	√	×	√	Exhibition*
M. Shiomi et al. [24]	√	×	√	×	×	Museum
R. Kelley et al. [25]	√	×	√	√	×	Personal
T. Kanda et al. [21]	×	×	×	×	×	Mall
T. Kanda et al. [26]	√	×	√	√	√	Mall*
M. Shiomi et al. [27]	√	×	√	√	√	Mall*
M. Shiomi et al. [28]	√	×	×	√	√	Mall*
M. Shiomi et al. [5]	√	×	×	√	×	Train Station*
DF. Glas et al. [29]	√	×	√	×	√	Mall*
A. Garrell et al. [30]	√	×	×	√	×	Personal
Y. Kato et al. [18]	√	×	√	√	√	Mall*
D. Brscić et al. [31]	√	×	√	√	×	Mall*
D. Das et al. [32]	√	×	√	√	√	Museum*
G. Rashed et al. [33]	√	×	√	√	√	Museum*
G. Rashed et al. [7]	√	√	√	√	√	Museum*

* Indicates human sensor systems are distributed in environments.

the statistical model of customer behavior provided by the primitive analyzer.

A model of polite approaching behavior of a social robot has been implemented in [18] by Y. Kato et. al. to deploy that social robot in a real-world environment to support ordinary people. Their modeled behaviors are adaptive to pedestrians' intentions, occurred prior to initiation of conversation. They conducted experiment in a real shopping mall and confirmed that their method is less intrusive to pedestrian, and that their social robot successfully initiated interaction proactively.

D. Das et. al. [32] and MG. Rashed et. al. [7], [33] developed museum guide robot systems which can estimate the attention level of the museum visitors in order to read their intentions, interests, and preferences towards the exhibits so that the museum guide robot can proactively guide the museum patrons. In their

research, they have implemented the museum guide robot system with commercial robot (Robovie-R3 [34] in [7], [32] and Naoko [35] in [7]) in a museum scenario
and confirms its effectiveness to make polite and successful
guidance proactively.

IV. Challenges on Implementing Proactive HRI Methods

There are several challenges that has been faced by the researchers and practitioners specializing in HRI on introducing proactive behaviors on social robots to serve ordinary people. The most important challenge is to develop the social robots with the ability to detect and track people's behaviors in social spaces. Besides, another important challenge is to design a social robot which can robustly recognize and estimate people's interests and intentions level from their tracked behaviors. These are discussed in the following sections.

A. Human Detection and Tracking in Social Spaces

In robotics, to implement a successful proactive HRI system, a social robot should have advanced abilities to robustly detect and track people in social spaces. It has been identified as important tool in HRI to provide proactive services by the social robot to the people through observing their behaviors about the surrounding environments. But, most of the state-of-the-art people detection and tracking systems for robots in HRI itself have on-board sensing capability can only track people at short range and are usually operated in controlled environments to provide proactive services. Such types of onboard human sensing systems are insufficient for observing people's behaviors in real world large-scale environments for successful proactive HRI. Thus, it is seen in the Table I that authors in [23] used the ubiquitous sensor (for example, IR-tracker, LED-tags) where some of the humans wore the wearable sensors and stationary sensors instead of on-board sensing system. Again, some authors used environmentally distributed people detection and tracking system supporting to social robot. It is seen in the Table I that rest of the HRI system with social robot's proactive behaviors utilized environmentally distributed human sensing system in social spaces. Among them, authors in [32] utilized environmentally distributed single camera sensors. But, it is sometime difficult to devise a single sensor system to detect and track people in large scale social environment. Thus it is necessary to design a sensor system for HRI which can recognize people's not only in small area but also in large scale area together. For this reason, special sensor system is desirable for social robots. Thus, network sensor system are utilized by [7], [18], [21],[27]–[29], [33], [36] where authors in [33] utilized environmentally distributed multiple camera based human behavior tracking system. Laser Range Finders (LRF) have successfully been applied in [18], [21], [27]–[29], [36] to track humans' behaviors. Authors in [7] used network sensor system where LRF sensor and camera sensor are utilized in combination to track human's behaviors preciously. With this system, a social robot can observe human's behaviors not only in small area but also in larger area of interest to read their intentions and interest.

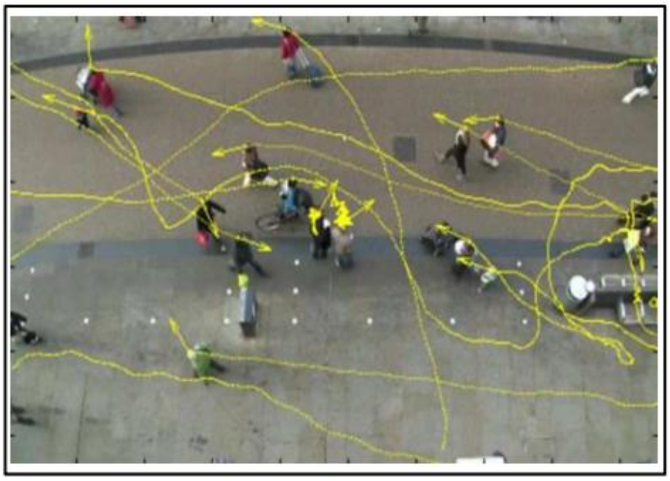


Fig. 4. People's Walking Trajectory Patterns–an example of people's global behavior (Source: [38]).

B. Intentions and Interests Recognition

In order to provide services to human in proactive ways, it
is very important for the social robots to recognize human's.
intentions and interests. Usually, from people's behaviors (for
example, various bodily actions), we can often read their interests and intentions. A social robot also should have advanced abilities to detect and track people's such behaviors in social spaces to read their interest, intentions, and likeness before offer social services. But, in an HRI platform, identifying people's attentions and interests is a challenging task for social robots in real social environments. If robots could deal with such

types of situations in observing people's behaviors, then it would enable the robot to anticipate the future behaviors of individuals thereby estimating people's attentions, intentions, and interests about the surroundings before assist them. Nevertheless, many researchers in HRI research area tracked human behaviors in a large and small area which are defined as *global behavior* and *local behavior*, respectively to read their interest and intentions in social spaces using various types of human sensing systems. People's overall walking trajectory patterns (see Figure 4), such as, "entering through the entrance of an art gallery, walking across all the paintings, stopping in front of a few of the paintings, and finally, leaving the art gallery" can be good examples of people's *global behaviors*, on the other hand, people's basic motion primitives, such as fast walking, idle walking, wandering, stopping [26], various facial expressions (e.g. disgust, anger, fear, sadness, happiness, surprise), visual focus of attention, head movements, eye gaze movements can be considered as their very well-known *local behaviors* (see Figure 5). Both people's *local* and *global behaviors* are highly dependent on the specific environments. To meet the demands, together with the growing acceptance of modern technology sensing technologies can play a crucial role to extracting such valuable information [37] .

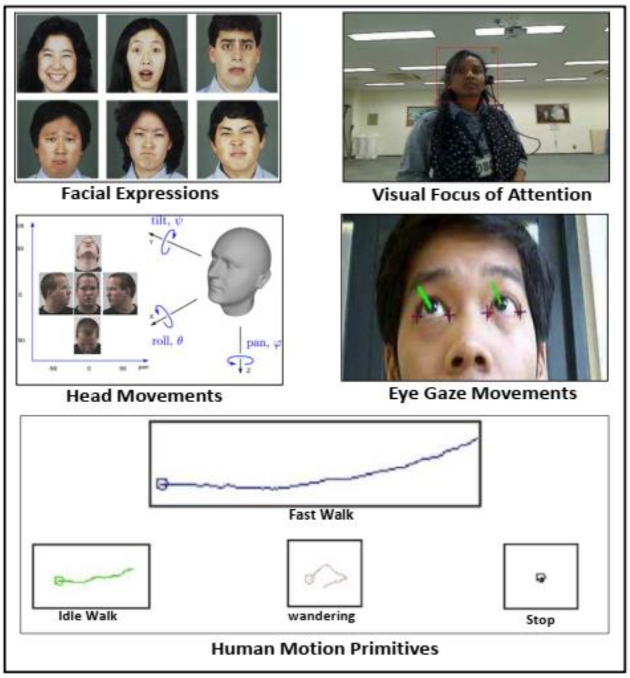


Fig. 5. Illustration of people's various types of behaviors as examples of people's local behavior.

In Table I there are some research works dealing with the issue of recognizing people's interests and intentions on introducing social robots' proactive behavior. In [23], their developed social robot can estimate each user's interest in the exhibition booth from his/her consumption time at the both as global behavior. The environmentally installed ubiquitous sensors provide the social robots with information about each individual's histories of activities in the environment, which allows the social robots to provide them personalized guidance. In [26], [27], sensor network consisting of six laser range finders was utilized in order to track people's"idle-walk" or "stopping" as the target local behavior in order to read people's intentions. They used anticipation and the preapproach function for the "idle-walk" behavior to direct robots to provide appropriate services proactively to appropriate people. In [28], first they studied and analyzed how human-robot interaction changes when the robot moves "forward" or "backward". Later they used a robust and accurate tracking system of walking people. It enables them to control the robot's behavior in a way they defined. Moreover, it records pedestrian behavior around the social robots while they expressed their accompanying behavior. The analysis produced a working hypothesis that the opportunity of looking at the social robot's face, which is offered more by "moving-backward", would increase the chance to let pedestrians overhear a robot's guidance utterances. In [29], "ambient intelligent" (AI) systems was embedded in the environment to help a social robot to provide services in five ways: observation of human behavior using environmental sensor networks, structured knowledge sharing, centralized resource and service allocation, global path planning for coordination between social robots, and support for selected recognition and decision tasks. In [18], pedestrians' behavior are observed in a shopping mall using environmentally distributed LRF sensors. they retrieved the moments when members of the service staff and visitors encountered and initiated interaction (to offer directions and to provide shop information). They found three major pattern of encounter. One of the three pattern of encounter is "staff proactively prepares" for visitors as local behavior. They found that the subtle behavior in this pattern shows how sophisticated humans' politeness is. Based on this observation, they modeled the behavior of the service staff during encountering interaction and impose it to the social robot and tested in a real shopping mall. They found that their method is more efficient than simply-proactive and passive method. But, in HRI, very few research studies have been conducted that considered the cases where robots are expected to observe both people's *local* and *global behaviors* to recognize their intentions before assist them proactively. It is seen from the Table I that most of the authors use single type sensing system to track either *local* or *global behaviors* for from where social robots estimates intentions and interest. But, considering people's *local* and *global behaviors* is highly effective for estimating their intentions. Rashed et. al [7] developed a HRI system where social robot utilized a sensing modalities from where the robot system estimates people's intentions by combining the bits of information from their *local* (VFOA) or *global behaviors* (walking trajectory pattern) in museum scenario.

C. Are Sensing Systems Wearable-Free?

There has been much research on sensing technologies that are employed to detect and track people in the fields of robotics [31], which are usually used to extract knowledge on their interests, intentions and social connections in supporting to proactive HRI development. In ubiquitous computing, positioning devices are often used. These include the use of GPS, or the signal strength of radios (GSM, WiFi, Bluetooth, RFID) [21]. These technologies all used wearable or mobile personal devices, but these approaches have a number of weaknesses for applications in large-scale social environments. For example, in the context of public social spaces, people may enter the space spontaneously, usually pass time based on their own interests, and may not be interested in actively engaging with the technology. Thus, many researchers are interested in making use of people tracking for a wearable-free solution where people do not need to attach markers to themselves or carry special devices so that they may observe them in an unrestricted manner. It is seen in Table I, in implementing social robots proactive behaviors in social spaces, most of the authors utilized wearable-free sensing system to detect and track the ordinary people where they did not wear or carry any devices.

D. Designing the Social Robot's Behaviors

Most of the state-of-the-art social robots do not have any built-in artificial intelligence (AI) to adapt in public spaces to support human activities in real environments. Depending on the environments, the social robots' activities, objectives, and roles will be typically different. Thus social robots are programmed to perform various kinds of functions according in real environments. Since a social robot's presence is novel it can attract people's attention and redirect their interest to the information it provides [39]. Thus, depending on the applications of social robots in real environments, a human designer should define the contents of the services as well as the context in which the social robot should provide the services. Before designing the social robot's behaviors to be able to interact with people, usually, researchers observe the behaviors of the persons who are in conversations in various real environments. Such types of observations are executed in very few HRI studies (for example, [18], [29], [36], [40]) before modeling the social robot's behaviors. Based on their findings, the behaviors of social robot were modelled so that it could play the role of the human in the real world environments. In most of their designed behaviors for social robots, the robots proactively approach humans by exhibiting verbal, gaze movements, gestural (head shaking, hand waving and body movement in between the target person and the objects) actions to draw attention and offer services. In the case of the reactive approach, social robots show their availability and recipiency by their behaviors so that people can easily start asking for help or assistance. It is seen in the Table I, social robots are deployed in many real world environments where most of the social robot's are programmed to perform various kinds of functions accordingly.

V. Potential Future Applications of Social Robots' Proactive Behaviors

Applications for social robots would include services that are typically provided by people. There are a lot of research works where social robots provide services to the ordinary people. Among them, very few social robots are introduced that can provide proactive services to the people in real world environments. For example, as shown in Table I, exhibitor robots [23], customer guiding robots in mall [21], [27], [28], museum guide robots [7], [32], [33] are successfully deployed in social space scenario to serve people proactively. We think there are many other directions to utilize social robots to serve people proactively. Thus, some potential future proactive applications of social robots are explained below.

a) Guidance and Informational Services: Social robots can provide public service announcements in public spaces, directing people in emergency situations such as the evacuation of a building, and providing guided tours. Sometimes people get lost in large social spaces and ask for directions. Even though all public spaces have maps, many people still prefer to ask for help. In such situations, social robots can play important roles, providing proactive route guidance to direct them according to their preferences.

b) Assistance: Social robots could provide physical, mental, or social assistance to persons who could benefit fro it such as the elderly or disabled. Social robots may help them to carry bags or groceries while shopping, or help to carry heavy luggage at an airport. They can also be used to carry people in and out of bed in hospitals. For a closer-to-home example, if we can request that the robot take out the trash and it could find the garbage can, remove the bag, and place it in the right location on the curb, that would be seen as very helpful to have around our home.

c) Entertainment Services and Companionship: Social robots can provide service in the form of entertainment. In such situations, the value of the service primarily lies in the content of the information provided by the social robot. These sorts of services have been demonstrated in the form of a robot playing with children at an elementary school and day care centers. On the other hand, robots are also considered as companions of humans in the public spaces where the main goal is to know the feelings of the person when interacting with the social robot.

d) Peer, Tool, Tutorship in Education: It has been shown through years in the HRI research that social robots are more crucial for children and teenagers, where robots can be used for their development and intellectual growth. As a consequence, greater attention has already been paid to use social robots in education to provide language, science or technology education and that a robot can take on the role of a tutor, tools, or peer in the learning activity. It has been shown in that young children performed better on post-learning examinations and generated more interest when language learning took place with the help of robots as compared to audiotapes and books [41]. Nowadays, education robots are a subset of educational technology, where they are used to facilitate learning and improve the academic performance of students.

e) Autism Therapy: It has been seen from a significant amount of robotics research over the last decade that many children with autism spectrum disorder (ASD) have a strong interest in robots, and further, robots are considered as a potential tools for the therapy of ASD. Robotics research has demonstrated that many individuals with ASD express elevated enthusiasm while interacting with robots.

VI. Discussion

Practically, deploying social robots in social spaces has been considered difficult. But HRI research community try to deploy it in social spaces only on research purposes. Although social robots reactive services are well accepted to the ordinary people in social spaces, few proactive services are tested in social spaces get satisfactory results. But it is revealed that more robust human sensing system is very important to detect and track people's behaviors precisely in social spaces. The robust human sensing system helps the social robots to analyze the detected and tracked behaviors to ultimately read their interests, intentions in any social environments. Without proper reading interests and intentions, a social robot is not able to recognize the necessity of the people in social spaces thereby it is not possible for them to offer proactive services. Much research and field trail should be conducted with social robots in real world environment before deploying them instead of human in social spaces to offer proactive services to human.

VII. CONCLUSION

This study provided a comprehensive overview of state of-the-art proactive methods of HRI system. It is revealed that social robot have the ability to serve ordinary people proactively if the social robots is incorporated with the modern human sensing technologies. This human sensing technologies help the social robots to detect and track people's behaviors in social spaces in order to read their interests, intentions. We can finally say that if social robots could deal with observing people's behaviors robustly, then it would enable the social robot to anticipate the future behaviors of individuals thereby estimating people's attentions, intentions, and interests about the surroundings thereby enabling the social robots to serve
people proactively as same as a human do.

REFERENCES

[1] M. G. Rashed, "Observing people's behaviors in public spaces for initiating proactive human-robot interaction by social robots," Ph.D. dissertation, Sept.2016.

[2] F. Tanaka et al., "Socialization between toddlers and robots at an early childhood education center," Proceedings of the National Academy of Sciences, vol. 104, no. 46, pp. 17 954–17 958, 2007.

[3] [3] M. Gyoda, et al., "Mobile care robot accepting requests through nonverbal interaction," in 17th Korea-Japan Joint Workshop on FCV, Feb 2011, pp. 1–5.

[4] J. F. Engelberger, "Health-care robotics goes commercial: the elpmateexperience," Robotica, vol. 11, pp. 517–523, 11 1993.

[5] M. Shiomi and otehrs, "Field trial of a networked robot at a train station," Intr.Jr. of Social Robotics, vol. 3, no. 1, pp. 27–40, 2011.

[6] K. Arras and S. Vestli, "Hybrid, high-precision localisation for the mail distributing mobile robot system mops," in Robotics and Automation, 1998. Proceedings. 1998 IEEE International Conference on, vol. 4, May 1998, pp. 3129–3134.

[7] M. Rashed, R. Suzuki, T. Kikugawa, A. Lam, Y. Kobayashi, and Y. Kuno, "Network guide robot system proactively initiating interaction with humans based on their local and global behaviors," ser. LNCS, 2015, vol. 9226, pp. 283–294.

[8] H. Kozima et al., "Interactive robots for communication-care: a casestudy in autism therapy," in IEEE International Workshop on ROMAN, Aug 2005, pp. 341–346.

[9] M. Begum et al., "Measuring the efficacy of robots in autism therapy: How informative are standard hri metrics'," in Proceedings of the Tenth Annual ACM/IEEE International Conference on HRI, 2015, pp. 335–342.

[10] I. Leite et al., "Emotional storytelling in the classroom: Individual versus group interaction between children and robots," in Proceedings of the Tenth Annual ACM/IEEE International Conference on HRI, 2015, pp.75–82.

[11] N. Bergstrom et al., "Modeling of natural human-robot encounters," in Intelligent Robots and Systems, 2008. IROS 2008. IEEE/RSJ International Conference on, Sept 2008, pp. 2623–2629.

[12] K. Yamazaki et al., Proceedings of the 10th ECSCW, 2007, ch. Priorto-request and request behaviors within elderly day care: Implications for developing service robots for use in multiparty settings, pp. 61–78.

[13] O. C. Schrempf et al., "A novel approach to proactive human-robot cooperation," in ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005., Aug 2005, pp. 555–560.

[14] N. Kemper, "Effects of proactive behavior and physical interaction with a social robot," Master's thesis, Faculty of Natural Sciences, Mathematics and Computing, University of Amsterdam, 2009.

[15] F. Hegel et al., "Understanding social robots," in Second International Conferences on ACHI, Feb 2009, pp. 169–174.

[16] I. G. Alonso, Ed., International Technology Robotics ApplicationsProceedings of the 2nd INTERA Conference, 2014, vol. 70.

[17] H. A. Yanco and J. Drury, "A taxonomy for human-robot interaction," in AAAI Technical Report FS-02-03, Oct 2002.

[18] Y. Kato et al., "May i help you?: Design of human-like polite approaching behavior," in Proceedings of the Tenth Annual ACM/IEEE International Conference on HRI, 2015, pp. 35–42.

[19] S. Satake and Others, "How to approach humans?-strategies for social robots to initiate interaction," in 4th ACM/IEEE International Conference on HRI, March 2009, pp. 109–116.

[20] W. Burgard et al., "The Interactive Museum Tour-Guide Robot," in Proc. of the Fifteenth National Conference on AAAI, 1998.

[21] T. Kanda et al., "An affective guide robot in a shopping mall," in Proceedings of the 4th ACM/IEEE International Conference on HRI, ser. HRI '09, 2009, pp. 173–180.

[22] S. Thrun and Others, "Minerva: a second-generation museum tour-guide robot," in Robotics and Automation, 1999. Proceedings. 1999 IEEE International Conference on, vol. 3, 1999, pp. 1999–2005.

[23] Y. Koide and Others, "An approach to integrating an interactive guide robot with ubiquitous sensors," in ProceedingsIEEE/RSJ International Conference on IROS, vol. 3, Sept 2004, pp. 2500–2505 .

[24] M. Shiomi et al., "Interactive humanoid robots for a science museum," Intelligent Systems, IEEE, vol. 22, no. 2, pp. 25–32, March 2007.

[25] R. Kelley and Others, "Understanding human intentions via hidden markov models in autonomous mobile robots," in 3rd ACM/IEEE International Conference on HRI, March 2008, pp. 367–374.

[26] T. Kanda, D. Glas, M. Shiomi, and N. Hagita, "Abstracting people's trajectories for social robots to proactively approach customers," IEEE Transactions on Robotics, vol. 25, no. 6, pp. 1382–1396, Dec 2009.

[27] M. Shiomi and Others, "Field trial of networked social robots in a shopping mall," in 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems, Oct 2009, pp. 2846–2853.

[28] ——, "A larger audience, please!: Encouraging people to listen to a guide robot," in Proceedings of the 5th ACM/IEEE International Conference on HRI, 2010, pp. 31–38.

[29] D. F. Glas et al., "The network robot system: Enabling social humanrobot interaction in public spaces," Journal of HRI, vol. 1, no. 2, pp. 5–32, 2012.

[30] A. Garrell et al., "Proactive behavior of an autonomous mobile robot for human-assisted learning," in ROMAN, Aug 2013, pp. 107–113.

[31] D. Brscic´ et al., "Escaping from children's abuse of social robots," in Proceedings of the Tenth Annual ACM/IEEE International Conference on HRI, ser. HRI '15, 2015, pp. 59–66.

[32] D. Das et al., "Supporting human-robot interaction based on the level of visual focus of attention," IEEE THMS, vol. 45, no. 6, pp. 664–675, Dec 2015.

[33] M. G. Rashed and Others, "A vision based guide robot system: Initiating proactive social human robot interaction in museum scenarios," in ICCIE, Nov 2015, pp. 5–8.

[34] ..., "Robovie-r3, available: http://www.robotshop.com/blog/en/robovier3-479," 2010.

[35] ——, "Naoko x robot, available: http://www.naoko-robot.net," 2013.

[36] T. Kanda, D. F. Glas, M. Shiomi, H. Ishiguro, and N. Hagita, "Who will be the customer?: A social robot that anticipates people's behavior from their trajectories," in Proceedings of the 10th UbiComp, 2008, pp. 380–389.

[37] M. Rashed et al., "Robustly tracking people with lidars in a crowded museum for behavioral analysis," in IEICE Transaction on Fundamentals of Electronics, Communications and Computer Sciences , vol. E100-A(11):2458-2469, 2017.

[38] E. Yong, "What are you looking at? people follow each other's gazes, but without a tipping point, available: http://blogs.discovermagazine.com/notrocketscience/2012/04/23/whatare-you-looking-at-people-follow-each-others-gazes-but-without-atipping-point/.v611n9j95ph," 2012.

[39] T. Kanda, T. Hirano, D. Eaton, and H. Ishiguro, "Interactive robots as social partners and peer tutors for children: A field trial," Hum.-Comput. Interact., vol. 19, no. 1, pp. 61–84, 6 2004.

[40] Y. Kobayashi, Y. Hoshi, G. Hoshino, T. Kasuya, M. Fueki, and Y. Kuno, "Museum guide robot with three communication modes," in 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems, Sept 2008, pp. 3224–3229.

[41] H. Jeonghye, J. Miheon, J. Vicki, and H. J. Jun, "Comparative study on the educational use of home robots for children," Journal of Information Processing Systems, vol. 4, no. 4, pp. 159–168, 2008.