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State-of-the-Art Visual Merchandising Using a Fashionable Social Robot: *RoMa*

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Abstract

Social Robots have the potential to attract people and this capability can be used to develop robots that can come into the retail market and enhance visual merchandising. This paper investigates important criteria to use in the design of a robot that can be utilized to promote customer appeal in the fashion industry. *RoMa* is a novel robotic mannequin that has been developed with the consideration of professional showcase characteristics and a primary feature of interaction with people. Since real and perceptive human–robot interaction relies on the social robot's sensitivity to its environmental information, *RoMa* is able to localize the people around itself. An empirical test was conducted to demonstrate the robot's acceptability and performance. In this test the robot was outfitted and placed in a showcase at an apparel store where prospective customer behavior was studied via a camera, microphone and questionnaire. The results indicate that *RoMa* was able to increase the number of people who looked at the showcase by 280% during the day, which validates the idea of visual merchandising and sales enhancement. In addition, with its design and adequate affinity *RoMa* was able to attract customer attention from the viewpoints of anthropology, movements, and likeability.

Keywords Social robot · Visual merchandising · Robotic Mannequin · Fashion industry · Human–robot interaction

1 Introduction

Since their invention, robots have been developed for various purposes in industries and daily life. With the advancement of technology and resulting reduction of costs many anticipate that in the near future social robots will be one of the cutting-edge technologies used in various social, therapeutic, cultural, and educational areas [1–4].

Visual Merchandising is an amalgamation of ideas, direction, imagination, originality, and a sophisticated business that is considered as the first connection to the customer's opinion. An efficient way to sell merchandise is to interconnect its image to the customer's consciousness. Quality and price are not the only factors in building a popular brand, reputation also relies on the type of interaction the product has with people. As a result, the use of visual trading techniques can help promote and preserve the name of a brand in the customer's mind. Enormous amounts of money have been invested by companies and shops to effectively study the effect of advertising on this issue. But lack of attention to the way products are presented at the retail front and the manner the salespersons communicate with the customer can detrimentally affect the brand image if not handled well [5].

To date, several studies have investigated visual merchandising/commerce and its influence on the consumer. Overall, these studies indicate that there are certain factors which should be considered to attract customers when displaying a product. Khandai et al.'s research showed that the most effective trading technique leading to Impulse Buying is the Window Display [6]. Previous research has revealed that the showcase, which is a combination of products and information, has a powerful impact on customer selection [7, 8].

The appeal, impression, effect, and success of the showcase can be enhanced and strengthened by many elements,

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such as lighting and lighting techniques, which can promote sales by about 107% [9]. Also, according to many investigators, motion and mobility are among the main factors in the desirability of a showcase. Furthermore, a study done by the Point of Purchase Advertising International (POPAI) organization, which analyses the attractiveness and attraction points in a showcase, indicates that no other feature fascinates customer as much as a live and active showcase. Reported statistical data and analysis confirms that the aforementioned feature can improve sales by about 310% [10]. Therefore, an impressive and lively showcase is one that consists of a number of elements in motion to attract people. These elements can change a simple, passive, and boring showcase into a dynamic and eye-catching one. Hence, using a social robot can be an effectual way to supplement moving elements within a showcase in order to attract customers.

Today, social robots have been able to find a suitable place in various facilities and service communities. In the past decade, numerous humanoid and animalistic social robots have been designed not only for educational and training purposes [11], assisting in therapies [12], and social services [13], but also for show business, entertainment, and advertising. Previous research has examined several factors that influence an increase in retail sales. Specifically, factors such as robots, the internet of objects, virtual reality, etc. have a direct impact on this area [14]. Touching customer feelings can lead a person to certain actions. In other words, merchandizing can be used to sell a product by stimulating people's opinion about the product provided [15]. The design of a showcase, especially a smart showcase, can excite the emotions and affect the viewer, which in turn could cause the length of pause and amount of eye contact with the desired item to increase during the period of viewing. In the field of advertising and visual merchandising, interested readers are referred to the research done by Shiomi et al. [16] and Kanda et al. [17]. In each case, a social robot was used to provide information to customers in a store. However, a social robot can be used much more efficiently than to just respond to some questions and provide information. A social robot can also display a product in use. For instance, it can be a mannequin that wears different kinds of clothing for potential customers to see.

One of the best way to showcase a product is to place it in a real situation where it will be used. Therefore, smart mannequins can be an efficient way of showing garments. A study of 150 women in India revealed that most have bought apparel that were presented on a mannequin [18]. Therefore, this issue highlights the impact and significance of using a mannequin, notably from a woman's point of view. Furthermore, social robotics is an emerging field in modern research that examines the social behaviors involved in interaction between humans and robots. In Van Doorn et al. [19], the ability to use technology as an automated social presence in service work is examined. The paper states that technology can be used to add a social factor in services provided to people. Currently, mannequins are generally simplistic stationary models of real human bodies that we have all become used to seeing. However, one wonders how attractive these models would appear to customers if they had the ability to move and perform? If mannequins were available in the form of social robots, what impact would they have on visual trade and retailing?

This paper attempts to describe the design and development process of the social robot mannequin, *RoMa,* which is to be used in an impressive showcase in an apparel store to spark customer attraction. The overall contents of the article are covered in the following eight sections: Sect. 1 presents the introduction and background, followed by significant criteria for a state-of-the-art showcase, position and application of a robotic mannequin, and conceptual design of a social robot acting as a robotic mannequin in Sects. 2, 3 and 4, respectively. Sections 5 and 6 describe *RoMa*'s hardware, software, and the testing of its features and acceptability. Lastly, Sects. 7 and 8 cover the discussions and conclusions.

2 The Characteristics of a Professional Showcase

An eye-catching showcase can be considered as one of the most important factor in building the reputation and smartness of a brand. Consequently, this leads to a demand by reputable stores for a professional showcase in order to attract customers. As previously stated, a live and active showcase can exert influence over customer attention. Moreover, earlier research on showcases as well as customer feedback has shown that a professional showcase design must be in perfect harmony with the brand, product, and customers [19]. This means that a professional showcase should be appropriate for the brand and the store. For example, the colors used in the showcase should be the same colors as in the brand's logo. Also, the layout and components of the showcase should be a close match with the products within it. Furthermore, matching the showcase with the prospective customers of a shop is vital in the design of an efficient showcase. This match relies on the gender, age, and even taste of the consumers [20].

After investigating the more noticeable factors and characteristics of a professional showcase, it was recognized that a professional showcase describes a concept or tells a story [20]. Sometimes we look at a drawing or photo and do not see anything except an image. But once we realize that a painting or photo has a story to tell, we can spend a long period of time looking at it. A showcase is like a painting except we are not limited to only a few colored lines in a 2D design. Thus, a concept or an appealing story should be illustrated in the arrangement of a professional and profitable showcase.

Also, for a sale to occur a professional showcase should influence the shoppers to enter the store to find and look closely at the product. There are many considerations that should be taken into account to achieve this goal. First and foremost, the showcase should be a small scale representative of the entire store. Accordingly, the salesperson should place more attractive and superior products in a comparable position inside the store with those that are displayed in the showcase. This may convince customers that are attracted to the showcase to come inside the store for further exploration and possible purchase. So, the ability to inspire customers to enter the shop is one of the most effective factors of a successful showcase [20].

Furthermore, the occurrence of interaction and communication with customers are highly conducive to an appealing showcase. As social beings, people tend to interact with their surrounding environment. Any object, instrument, tool, etc. that responds properly to their interactions can be attractive to people [21–23]. That is one of the reasons why today's smart systems have so many fans. Hence, smart systems in a shop window would also perform the same function, as shown in Fig. 1 [24].

3 Robotic Mannequin Position and Application

As noted in the previous section, many factors help to achieve a professional showcase, which ultimately boosts sales. These factors, in fact, lead to the promotion of the visual merchandising field. When examining the positioning and application of a robot in this field, the authors believe that the use of a state-of-the-art social robot as a replacement for a mannequin in sales units, especially apparel, can be very valuable because this robot incorporates all the specifications for a professional showcase. As discussed before, one of the most important factors in the existence of a modern showcase is the presence of motion and dynamism. With its degrees of freedom, a robot can create this with different scenarios and gestures. Also, the design of the robot can be done in harmony with the brand and its related products because its outward appearance is independent of its robotic functions, and so can be specifically tailored to fit any brand. Furthermore, after placing the robot the other components of the showcase can be chosen in such a way that they represent a total concept. The attractiveness of the robot draws customers' attention and inspires them to enter the store, and finally, if the robot is able to interact with the customer, it only further adds to its charm. Therefore, the idea of using a fashionable social robot as a new entity in the field of visual merchandising should be introduced.

Of course, the ultimate goal of using this robot is to increase customer attention, which ultimately leads to increased sales. To evaluate this, we examined the empirical test described in Sects. 6 and 7. Also, in addition to this one specific application other purposes could also be introduced for the use of a social robotic mannequin in the field of clothing sales. It should be noted that people do not buy products just because they are products, they pursue certain goals such as tidying up their environment, enjoyment, attracting attention, and so on. The retailer must provide the buyer an incentive to buy their product [18]. The primary priority of clothing and apparel buyers includes factors such as price, clothing material, color, dress style, the way the dress fits the ins and outs of the body, seasonal conditions, clothing comfort, etc. In this paper, these factors are divided into two types. The first type, as mentioned above, includes factors such as price, type of material, color, and comfort of clothing. These factors are not affected by the mannequin type. Additionally, stimulation of customer sentiment has little effect on these factors. The second type, such as the dress style and the way the dress fits the ins and outs of the body, are factors that are shown by mannequins. So, the second goal of using a robotic mannequin is to showcase the clothing in the best possible manner to the customer, and a movable mannequin can perfectly show the different angles and aspects of a dress. It is also expected that the existence of a new element in the showcase of a store will help preserve specific brand names in the minds of the audiences and customers, which is an effective example of visual merchandising.

In order to achieve a successful robotic mannequin, factors need to be taken into consideration to make it more attractive and acceptable to humans. In this regard, important factors regarding design, anthropology, movement quality, design acceptability, affinity, likeability, etc. are considered. In an attempt to test these factors, customers were asked to complete a survey on *RoMa*, the full description of which will be given in Sect. 7. But given the fact that the factors that people inquired about are generally generic and high-level, we need to define these demands as design requirements. Therefore, in the next section, we try to find the appropriate engineering factors to achieve an acceptable design and implement it in the composition of the robot.

4 Conceptual Design of the Robot Mannequin "*RoMa*"

Design constraints, guidelines, and requirements to achieve an appropriate design of the robot mannequin are thoroughly presented and discussed in this section. As noted above, movement in the showcase will increase attention and may eventually increase sales. Consequently, a social robot that will act as a live mannequin should have appropriate movements and the degrees-of-freedom to achieve those movements. In addition, the robot's degrees-of-freedom

Fig. 1 People will pay more attention if a shopper has a deep interaction with the showcase [24]

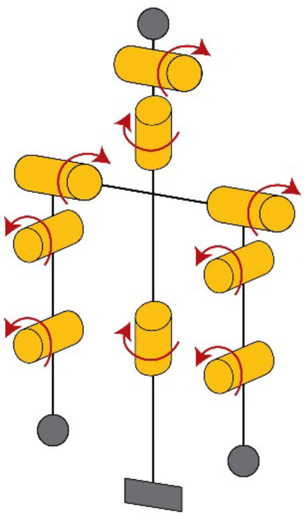

Fig. 2 The *RoMa*'s with 9 Degrees-of-Freedom and its joints motion

should be selected such that the costs of developing such a robot will not be too high. Therefore, selection of the robot joints and its degrees-of-freedom was handled using a number of studies on small-sized mannequins, creating a prototype, and taking many surveys. The results our study indicates that the robot should have at least 9 degrees-of-freedom in order to perform the appropriate gestures. Our results indicated that for each arm there should be three degrees-of-freedom (two joints on the shoulder and one joint on the elbow), for the head there should be two joints, and one joint at the waist (see Fig. 2).

Another significant criteria that needs to be satisfied in the design of *RoMa* is the uncanny valley phenomena. The uncanny valley is a natural unpleasant feeling people experience when a humanoid robot or audio/visual simulation closely resemble a human in many respects but is not quite satisfactorily realistic [25, 26]. Hence, when developing a Social Robot Mannequin one should take into account that while it may generally look like a humanoid, it should move and function like an android/robot. On the other hand, a robotic face and motion is interesting for many people, especially children, because it brings to mind the memories of science-fiction or robotic movies. As a result, in the design of *RoMa*, the joints, motors/actuators, and other parts are partially uncovered to display its robotic appearance. Additionally, the head of *RoMa* was devised to be a mixture of a human and android head.

Moreover, a social robot mannequin must not only have a suitable form to match the brand or product, but it should be able to interact with customers with a collection of various scenarios and movements. This interaction brings a sense of life and intelligence to the customer's perception and is therefore enjoyable which causes the brand name to remain in their mind. To sustain and preserve the appeal of the social robot mannequin, smart interactive features should be well-thought-out in its design. In fact, the intelligence and interoperability of the robot is necessary to gain favorable outcomes from the presence of a robot in the store.

To achieve this sense of life and to engender better interaction, features like the capability to detect a customer and sense their location in the store are observed in *RoMa*. This competence creates an atmosphere of respect for customers who are trying to interact and communicate with the robot. Emulating the customer's gestures could also be an additional ability of the social robot mannequin [2]. Other future possibilities for the robot mannequin could be the capability of responding to the emotional state of the customer's face by means of facial processing methods [1, 27–30]. Also, a social robot that is intended to perform as a mannequin in the clothe stores should be designed and constructed of light-weight materials and components so it can be easily moved around by store personnel. Therefore, *RoMa*'s structure was designed with the least possible components, small and light actuators (i.e. motors), and its body and hands are made of light-weight materials like aluminum and foam.

The skin color of the robot mannequin should be chosen in a way that it beautifies the appearance of the apparel it is modeling and also be compatible with other components of the showcase and the brand. Finally, being user friendly and easy to use is mandatory for robots that are intended to be operate by unskilled people who are not familiar with robotics and/or programming. Thus, *RoMa* comes with an application that is designed to permit the user to readily control and program the robot via a smartphone.

5 "*RoMa*" Software and Hardware Design

Considering the design specifications discussed in Sect. 4, *RoMa*, a social robot mannequin with unique features has been built to be used in a showcase setting in clothing stores. *RoMa* has the ability to move some of its upper body joints similar to humans. Figure 3 shows pictures of *RoMa* in different poses. In addition, some solutions are presented to make it capable of interacting with customers. Since social robots should interact naturally with people, natural and smooth interaction is the most important and challenging factor in their design. When a social robot speaks to a human, sound source localization is a must as it is both an acknowledgment of the opposite speaker and a natural movement to receive better quality sound waves. It is essential for a social robot to have the ability to turn its head toward the speaker in each vocal interaction for better speech recognition [31]. This reaction is also a natural means of interaction which is also a significant goal in Human–Robot Interaction (HRI) studies. The following is a brief description of *RoMa*'s HRI algorithm and also its hardware and software architecture.

5.1 Human–Robot Interaction

Prior to commencing the description of *RoMa*'s HRI algorithm, a brief overview of studies on the topic of human–robot interaction is presented here. In most recent studies, interactive communications are classified as verbal and non-verbal. The detection device system for verbal interaction or the robotic hearing setup may be assigned for speaker identification, speech recognition, or emotion detection [32]. Consequently, these systems have to be able to detect speech segments and localize sound sources for better reception of speech. Thus far, a number of methods have been applied for speaker localization in the field of humanoid robotics. If speech signal localization is desired, especially in a noisy environment, then it is crucial to use a speech activity detection technique.

Binaural robot audition is the subject of a set of methods which try to imitate various features of the human auditory system (ears). This approach is based on the use of only two microphones specially placed inside an artificial ear which has a human-like pinna. Thus, in robotics some acoustic features are extracted and integrated just like in the human brain. Interaural Cues for horizontal direction and Spectral Notches for vertical direction estimation are the most studied features. The methods in binaural approach utilize the time–space relationship between the signal scattered from a sound source and the two signals perceived by the two ears [33]. This correlation is called the Head Related Transfer Function (HRTF) and many solutions are offered to obtain this model. Although various HRTF databases, like CIPIC [34], have been published for human subjects, Nakadai et al. [35–37] extracted three basic models for robotic context from 2000 to 2003. However, the complex structure of most robot heads make it difficult to model the exact HRTFs at each microphone. In addition to the effects of the robot structure on the signal spectrum, problems such as turning toward the speaker and the noise of actuators in the neck mechanism should be considered in the design in robotic applications of sound source localization. Various concepts for designing the neck of an iCub robot have been evaluated and compared with respect to these specifications [38].

In sound source localization methods and especially in the binaural approach, the shape of the robot auditory apparatus plays an important role in HRTFs. Researchers are trying to improve sound source localization in humanoid robots by allowing for a human-like artificial ear inspired by the human ear anatomy. In a different paper by Nakadai and his group [39], two of the main glitches in the sound source localization method are discussed and an artificial pinnae is designed to solve these problems.

We consider that *RoMa* should be able to localize an active speaker in the horizontal plane covering 180 degrees in rotation and in the vertical direction by three levels. Fortunately, the robot is able to turn toward the speaker, which enables it to better recognize speech as well as to interact naturally. In the next section, our method for speaker localization using the binaural approach is explained in more detail.

5.1.1 Speaker Localization Algorithm

Speaker localization is defined as the estimate of the direction of a speech signal in an environment. Commonly, approximating the azimuth and the elevation direction of a sound signal is referred to as sound source localization in which the distance of a sound source from the audition system is taken into account. Hence, a method of sound source localization along with speech activity detection can be utilized to localize the speaker. This implies that: first, a speech activity detection procedure is used to choose the speech segments that can then be employed for feature extraction. Next, thanks to two neural networks, the azimuth direction and elevation level of the speaker are identified. In the final stage, after localizing speech, the robot should turn toward the speaker. Therefore, the relative angle of the speaker to the audition system is sent for path planning to command the motor. Figure 4 displays the flowchart diagram of this algorithm for speaker localization.

Fig. 3 Examples of *RoMa* modeling different styles and poses

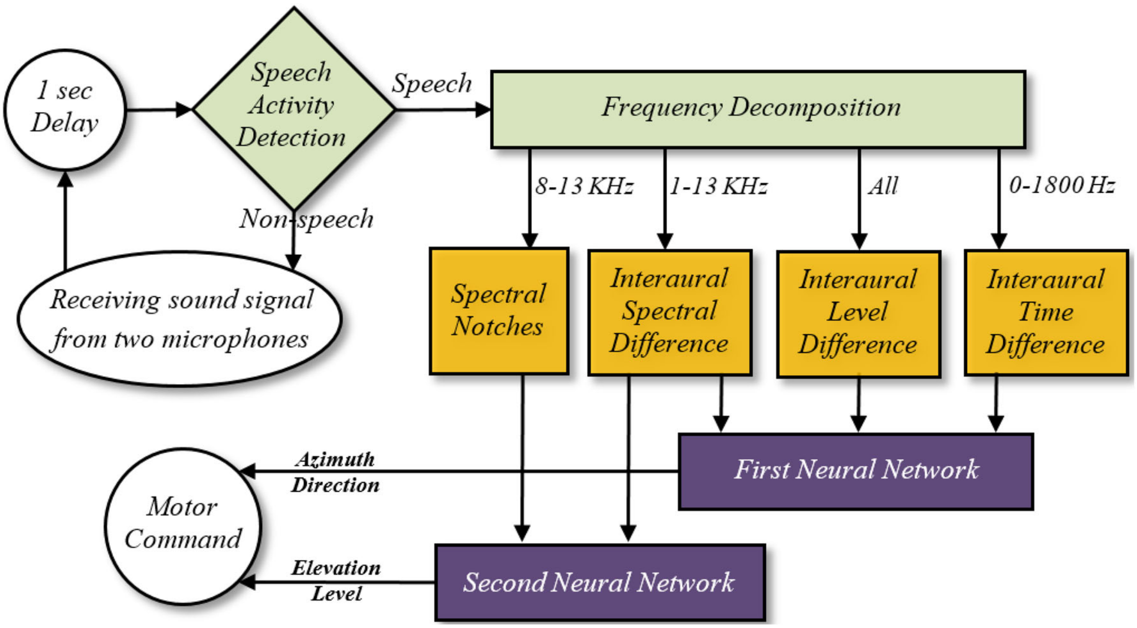

Fig. 4 Schematic flowchart of the algorithm designed for speaker localization in the binaural approach

5.1.2 Signal Processing

Preprocessing is necessary before speech localization for speaker localization in natural environments. Furthermore, speech activity detection should be considered to detect the speech in a sound signal. By using the method proposed in [40], some fractal features of a signal along with auto-correlation, MFCC, time length and energy of each segment were extracted to statistically detect speech segments allowing just the speech segments to be sent for sound source localization. Speech activity detection is done for each 1 s of the signal. Therefore, the system has a 1 s resolution in localization. Speech enhancement techniques cannot be used in preprocessing as phase information will be lost when using such filters, which in turn will deteriorate the performance of whole localization system. Hence, it is an important limitation that should be considered.

As outlined above, interaural cues and spectral notches are among the features that can be extracted in a binaural approach.

The primary cue, namely the Interaural Time Difference (ITD), is the most used. The time to receive a sound signal by the audition setup is different based on the location of each microphone, as indicated in Fig. 5a. This feature is limited to a particular frequency band of signal, bearing in mind the distance between microphones. This means that the signal frequency should be low enough that the period of signal perch would not become less than the distance between the two microphones (see Fig. 5b).

The secondary interaural cue is called the Interaural Level Difference (ILD). The sound signal is damped by air in the environment. Hence, as the location of the microphone is far from the sound source, lower levels of the sound will be received. Consequently, in an audition system the sound level variance of a microphone further from the sound source can be a feature of sound localization. Aside from the distance, an obstacle would have a side effect on the decline of a sound signal level. The body of the audition setup can be an example of an obstacle. This effect is also called the acoustic shadow as shown in Fig. 6a. This feature is more suitable for high

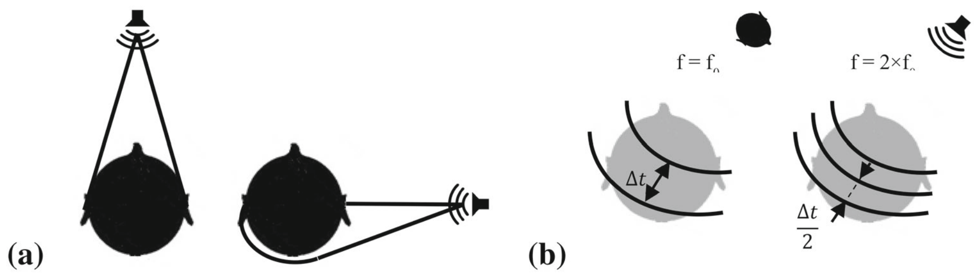

Fig. 5 **a** Using the time delay of sound arrival for sound source localization. **b** The effect of a high frequency signal in the ITD method

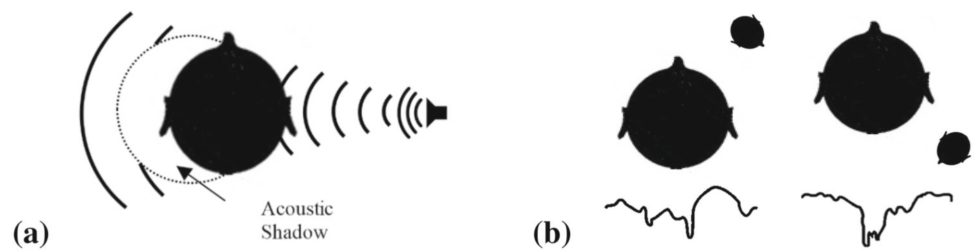

Fig. 6 **a** Decrease in the signal level caused by acoustic shadow. **b** Different spectrums of the same signal recorded by the right ear relative to source locations

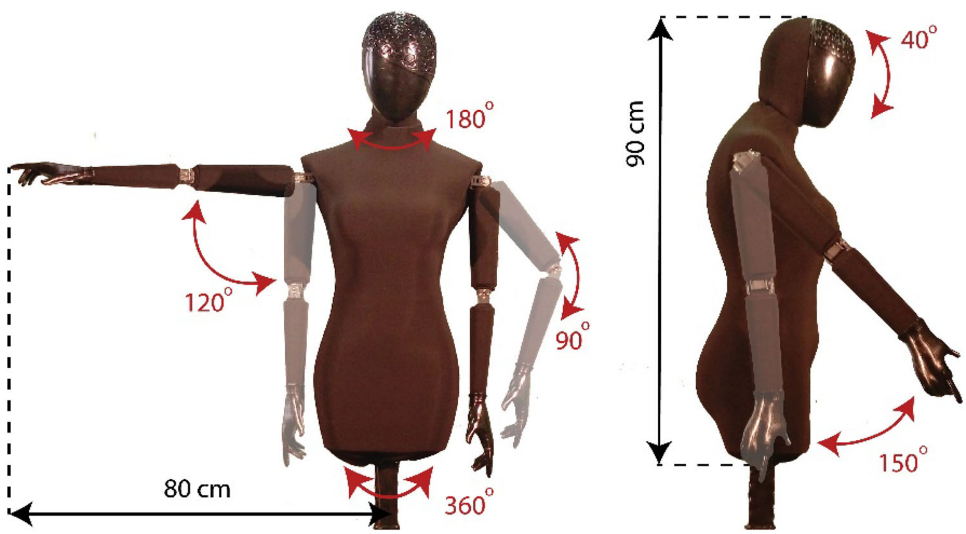

Fig. 7 Dimensions and measurements of *RoMa*

frequency signals as the higher the frequency the more the signal level is reduced.

It should be noted that spectral characteristics that are specific for each sound signal can be altered with the effect of noise, reverberations, etc. Therefore, a feature of sound localization is to detect the spectral difference of signals received by an audition setup; unfortunately, extracting this feature is more sophisticated than the two preceding methods. A head-related transfer function (HRTF) is needed in order to efficiently use this feature.

As the HRTF is hard to model for an unknown auditory system, a MLP[1] neural network is used which has the capacity to learn complex systems. The spectral characteristics of sound signals would be affected by the design and shape of an artificial ear in the auditory setup.

Due to the use of only two microphones on the horizon, the interaural cues cannot be used for elevation estimation of the sound source. Therefore, a feature based on spectral notches should be extracted to solve this issue (see Fig. 6b). In general, extracting the spectral notch feature is not possible for any hearing system. Therefore, the hearing system must be designed in such a way that the features related to these properties can be derived. An artificial ear, head, torso and whole body shape can help to do this. As a result, this acoustic feature along with the interaural spectral difference feature are used for vertical level estimation of the sound sources.

5.1.3 Neural Network

The acoustic specifications of the head and its effect on recorded sounds are hard to learn and model, so we utilized a neural network which has the capacity to learn complex systems. The structure of the neural network is a two-layer

[1] Multi-Layer Perceptron.

perceptron which has ten neurons in its hidden layer. To train the neural network, the same voice signal was recorded in each 10 degrees of the horizontal plane and in three different vertical levels (−20°, 0°, +20°) in an acoustic room. Then, each of the four features discussed above were extracted for each recording. Consequently, we have 114 data for each feature. Training the network used 80% of the data, 10% was used for validation, and the remaining 10% was used for testing. By means of a back-propagation technique, two MLP neural networks were trained to localize the sound sources. Using these two neural network, each with a hidden layer with 10 neurons, the recorded data was classified to three levels of vertical direction. Also, the maximum error of the horizontal direction estimation was less than 8 degrees for the training data. Networks were designed to meet the requirements and accuracy by trial and error and applying the existing general rules.

This section has attempted to provide a brief summary of the sound localization algorithm utilized by *RoMa,* and after conducting experiments and obtaining the results we can discuss the following issues. Due to the fact that we have only employed two microphones in the designed robot, the speaker localization system is able to find the speaker's direction in the azimuth plane covering 180 degrees in rotation and the elevation plane in three levels. With this information the auditory system directed motors to turn toward the speaker in a smooth path. *RoMa* has two built-in microphones inside its ears and simultaneously employs four different binaural features and two neural network for localization. *RoMa* was able to operate in real-time and even update the position during its moving phase. Experiments showed a precision of ± 10 degrees with the presence of white noise which made the SNR to 20 dB. In addition, *RoMa* was able to categorize the elevation levels with a precision of 90%. Utilizing the proposed robotic auditory system, *RoMa* was able to ignore non-speech sounds around itself and act with a good performance in speech localization and natural turning toward the person who is speaking.

5.2 *RoMa's* Hardware

RoMa consists of a light-weight fiberglass body and an aluminum based platform with nine electric actuators. The hands of this social robot model are made of compact foam to insure lightness, and its entire body is covered by Rayon fabric. Figure 7 displays the dimensions and Table 1 provides other design parameters/specifications of *RoMa*.

RoMa's electronic hardware is shown in Fig. 8. The hardware, equipped with an ARM-type microcontroller, is in charge of controlling the robot's joints and movements. *RoMa*'s motors are of servo and DC types. DC motors are utilized in the shoulders for attaining the movements and the rest of the joints move by means of the servomotors. It should be noted that these servomotors are each equipped with a separate microcontroller which is placed on a power board. All motors are connected to each other through the network, and commands are sent from the main microcontroller through a RS232 to each servomotor's controller. Also, with the coding done on the motor's controllers, the motors voltage is adjusted by each individual power board.

Table 1 Overall design parameters/specifications of the *RoMa* social robot mannequin [41]

Specification	Value
Weight	19 kg
Degree-of-freedom	9
Number of motors	
DC Motors	3
Servo motors	6
Material	
Main body	Fiber glass
Arms	Foam
Hands	PLA
Stand	Stainless steel
Processors for	
Movements	ARM controller
Signal Processing	Mini computer
Sound Equipment	
Sound card (two channel)	M-Track (M-AUDIO Co.)
Microphones	QL5 (SAMSON Co.)
Power	
Voltage	12 V
Amperage (Max)	5 A

A potentiometer is used on each motor's shaft to measure the absolute position of the DC motors, this provides analog value feedback to the main controller. To be more user friendly, *RoMa* has a specific application that can transceiver instructions between a smartphone and the main microcontroller via a Bluetooth module integrated in the main controlling board of the robot. It should be noted that the robot's power supply is placed outside its body and 12 volts DC electrical power is connected to the robot to increase the safety of the robot. A number of circuit-breakers are also placed in the system for possible overcurrent motors in order to control current saturation within the control circuit.

A microphone was embedded in each ear of *RoMa* to implement the speaker localization method. Signals received by these microphones were sent to a mini-computer with a two-channel sound card. Once the mini-computer processed the signals, location information was transmitted as the set-point values of motion through the Ethernet connection to each actuator for rotation to occur in both the azimuth and elevation planes. Hence, this social robot mannequin is able

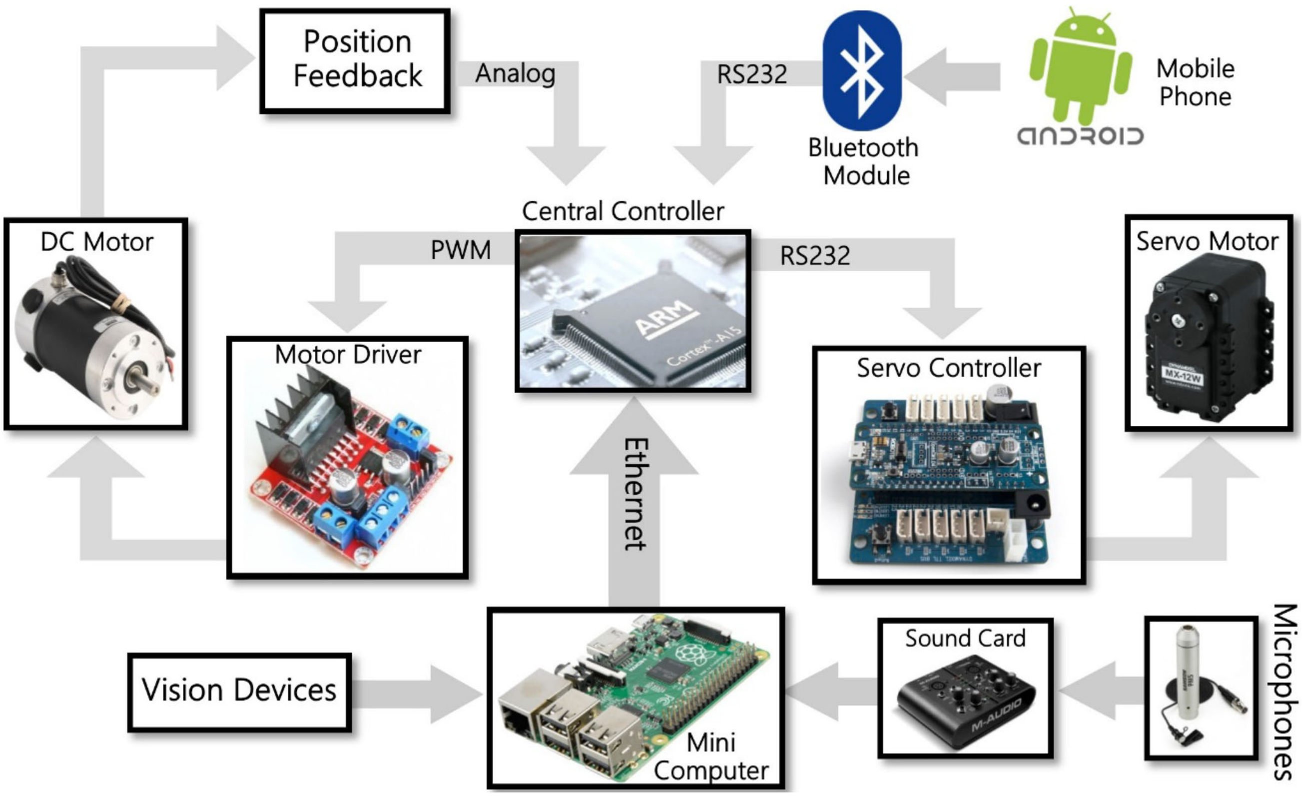

Fig. 8 Architecture of *RoMa*'s electronics and control hardware

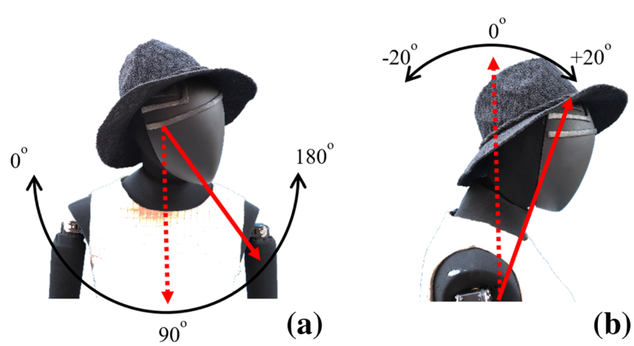

Fig. 9 *RoMa*'s range of rotation: **a** elevation and **b** azimuth

to detect and localize any sound/speech signal and then turn toward the speaker. The range of rotation for each direction is displayed in Fig. 9. *RoMa* is able to record the sound signal with a sampling frequency of 48 kHz and a sample rate of 24 bit/sample. Its condenser microphones have high sensitivity with a 114 dB dynamic range.

5.3 *RoMa*'s Control Loop

Figure 10 shows how *RoMa*'s position control loop operates. In this loop, first the desired motion and position for each joint is determined, and by evaluating the current position of each motor through feedback, the preferred motor speed is calculated. By differentiating the position, the control loop will be closed for the inner-loop that controls the speed. The controller used for this is a PID type, and to prevent possible error, control input saturation is also applied.

6 An Empirical Test of *RoMa*

The robot mannequin is located in the showcase of a women's clothing store in Tehran. This store is one of the best-known clothing brands in Tehran, and is visited by many people daily for purchase. Two robot mannequins wearing women's dresses were placed at the front of the store's showcase. This retailer is located on a crowded street, with lots of customers of various cultural and social levels buying from this store. As shown in Fig. 11, the showcase of the store is striking and slightly above the street, so that the showcase is easily visible to pedestrians.

Inside the store, there are two CCTV cameras to record the reaction of pedestrians and customers who enter the store to the movable mannequins and fixed mannequins. Figure 12 shows a view of the camera position relative to the mannequins. Outside, where passing pedestrians can stand and view the showcase, a microphone was placed to record the verbal responses of the audiences to the robots. Figure 13 shows the location of the microphone.

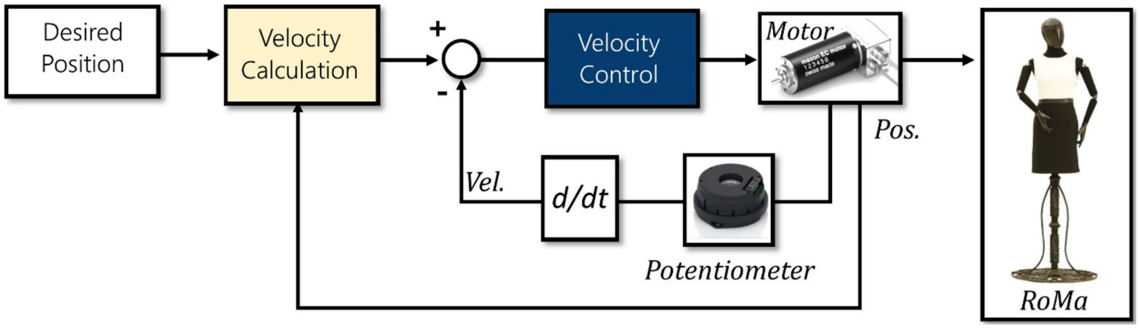

Fig. 10 *RoMa's* position control loop

Fig. 11 Clothing store showcase

To measure important factors from the viewpoint of the audience, a survey was conducted from the potential customers before seeing the robot mannequin. The questions were concerned with the customer's tendency to buy apparel in person or on-line, and the factors important to the customer when purchasing a dress as discussed in Sect. 3. The survey was then used to ask the same people about the characteristics of the robot, i.e., its attractiveness and the measurement of brand-name durability, after seeing the robot.

The questionnaire was completely randomized from 100 female clients aged 17 to 62 with an average age of 30 years and a standard deviation of 9.9. All questions in this questionnaire used a Likert scale with scores by customers from grade 1 (very low), 2 (low), 3 (average), 4 (high) to 5 (very high). The text of this questionnaire can be found in the Appendix.

7 Analysis and Review the Results

In this study, cameras inside the store filmed the behavior of pedestrians in front of the store showcase during two periods before and after running the *RoMa* mannequin in the showcase. The data recorded was examined for different hours of the day. The results recorded before the startup of the *RoMa* showed about 5 people looked at the store's showcase on average per hour. After placing the robot mannequin in the showcase, that number increased to 19. This shows that the creation of a mobility factor in the showcase drew people's attention to the shop windows. Data recorded from the microphone installed in front of the store where pedestrians cross in front of the showcase was also remarkable. Most people were surprised at the presence of a moving object simulating human movements inside the showcase.

After testing the robot and conducting a survey about customers' preferences when buying clothes and about the attractiveness of the features of the robot, the results and analyzes were as follows:

As stated before, the customer's priority in buying clothes is divided into two categories. The first category is factors that are not affected by mannequins, and the second is the factors that can be presented to the customer with mannequins. The dress material was selected from the first group, and the way the dress fits the ins and outs of the body and the dress style were selected from the second group for the customer survey. The survey results are presented in Table 2.

The survey results show that customers' preferences in buying clothes are more focused on the dress style and the way the dress fits the ins and outs of the body. Therefore, it is concluded that when people are buying clothes they are paying attention to how the dress is presented; thus, customer attention can be drawn and stimulated to the appropriate clothing through a smart showcase and movable mannequins.

In another section of the survey, the customer's method of buying was addressed. In the questionnaire, customers were asked to choose between online shopping, seeing clothes on mannequins and buying clothes after trying them on. Table 3 presents customer clothes buying method preferences.

A notable result of this question is that the purchase of clothing after wearing got the highest score. Online shopping got the lowest score, which shows that this choice is not at all a priority for customers when buying a dress. The result of the question is that these customers do not have enough

Fig. 12 View of the camera locations relative to the showcase

Fig. 13 View of the microphone location relative to the showcase

confidence to buy clothes from the internet and they prefer to be able to carefully see the clothes. These results are in agreement with a report from [42], which shows that only 13.5% and 2.1% of sales were online in 2014 in England and Italy, respectively. Customers were also asked if they would buy a dress without trying it on. Answers showed that only 34% of people said they might buy clothes without trying it or seeing it on a body. From the review of comments, it is concluded that people pay much more attention to the way the dress fits the ins and outs of the body. This factor can easily be shown to the customer by the robot mannequin. The advantage of the robot mannequin is that it displays the upper body shapes and movement of the human body, and one can easily imagine the dress on their own body.

Table 2 Results of the customer's priority in buying clothes

	SD	Average (From 5)
The way the dress fits the ins and outs of the body	0.77	4.42
Dress material	1.12	3.35
Dress style	0.82	4.36

As stated above, during the design and construction of *RoMa* the designers considered several factors to increase the robot's attractiveness. The features of the robot were examined from the perspective of anthropology, movement quality, design acceptability, affinity, and likeability. In the

Table 3 Results of the customer clothes buying method preferences

	SD	Average (From 5)
Online shopping	1.02	1.61
Seeing clothes on a mannequin	1.11	2.86
Buying after wearing	0.43	4.82

Table 4 The results from the last part of the questionnaire

	Distribution of each parameter (%)						SD	Average
	5	4	3	2	1			
Natural	7	37	36	15	5	Unnatural	1.06	3.48
Human like	5	33	31	23	8	Machine like	1.18	3.3
Lifelike	21	36	16	19	8	Unlifelike	1.24	3.43
Relaxing	18	65	13	4	0	Anxiety	0.73	4.14
Loveable	45	34	18	2	1	Fearsome	0.91	4.19
Kind	64	22	11	2	1	Unkind	0.85	4.46

first question, the naturalness or unnaturalness of the robot's movements as compared to a human from the perspective of the customers was examined. The results of this question were summarized, and as can be seen in Table 4, a significant number of people believed that the robot's movements are moderately similar to human movements. The standard deviation of this data is 1.06, which indicates that a significant number of people have voted for option 3 (medium) and 4 (high).

Another question was about the robot's operation and movements and its similarity to human. According to the results of Table 4, the majority of survey participants believed the robot movements were human-like. A significant percentage voted for option 3 (medium) and 4 (high). Also, the question about the robot being lifelike or unlifelike was asked from the customers to find out how much they felt like a living creature was in the back of the showcase. The results of this question are also noteworthy and detailed in Table 4. Seventy-three percent of customers believed that robot mannequins are more than 60% similar to a living creature; therefore, they will interact with it as a living creature.

From a likeability and affinity perspective, three important factors have been studied and analyzed. First of all, the creation of a sense of relaxation or anxiety when seeing a robot is studied. This is a very important factor, the customers should not feel distracted after seeing the robot mannequin or be afraid of a moving object inside the showcase. Referring to Table 4, 83% of the customers felt comfortable with the robot mannequin. The standard deviation of this data is also 0.73, which indicates that a significant percentage of customers did not feel afraid of seeing the robot mannequin. Moreover, after seeing the robot, 79% of the customers believed the robot to be an attractive creature mimicking human movements inside the showcase. The magnitude of the standard deviation of this feature examined by the robot mannequin is 0.91, which suggests that the customers overwhelmingly believed that the robot mannequin to be a beautiful entity. These results are presented in Table 4.

In another part of the questionnaire customers were asked about the sense of intimacy they felt with the robot mannequin in their first encounter. In this question, 86% of the customers believed that they experienced a sense of humor and convenience in the first encounter. A number of customers had interesting views on this. Some expressed that this robot mannequin is like a living creature that mimics human movements, and thus a sense of intimacy was formed between them in the first encounter. From the analysis of data from Table 4, and data from the questionnaire, it is concluded that the uncanny valley hypothesis has been well documented in the mannequin design, and humans are not afraid of this human social robot. These parameters are crucial for validation of uncanny valley avoidance.

One of the important effects that the social robot had in dealing with human beings was to preserve the names and locations of the stores as described in Sect. 3. The results from the questionnaire indicates that 65 percent of the people who have observed *RoMa* in operation remember the brand name of the store as shown in Fig. 13. In fact, the use of a dynamic showcase caused people to pay more attention to the brand-name and shop location. This result suggests that the use of a social robot makes advertisement more effective and more durable in the minds of the audience/consumer.

In summary, after observing *RoMa*'s ability to move and act as a social robot mannequin we expect that it will be able to quickly find a good place in the showcase of clothing stores. Primary responses and feedback received from the use of this social robot in Iranian clothing stores clearly indicate a great interest and acceptance from customers as well as the shop owners/managers (Fig. 14). Although *RoMa* was designed and manufactured to display clothing, the robot can also be used for advertising and entertainment in places such as hotels, restaurants, museums, and touristic attractions areas.

8 Conclusion

In this article, initial concepts, hardware, and software description of a novel social robot mannequin designed for state-of-the-art visual merchandising through an active showcase are presented. Our objective to design and manufacture a new robot mannequin based on modern marketing concepts for the Middle Eastern market was achieved. As a result, the design performance characteristics of the Social

Fig. 14 *RoMa* displayed and performing in Iranian clothing stores and exhibitions

Robot Mannequin called *"RoMa"* developed for the dynamically developing fashion industry is demonstrated. *RoMa* is a full-body humanoid social robot platform for visual merchandising to promote customer appeal. The insights gained from this research may assist us in design and characterization of state-of-the-art social robot models for apparel stores. Based on this vision, some of the features and capabilities considered in the design of *RoMa* were: attractive appearance, being interactive, appropriate body movements, avoiding the uncanny valley, light weight, easy maintenance, suitable colour, low-cost, and being user friendly. The use of the robot mannequin in the showcase of a store and the smartness of the showcase caused it to increase the number of people who looked at the showcase by 280% during the day. It was determined that the customer's priority when buying a dress is the way the dress fits the ins and outs of the body and the clothing style. Questionnaire results also indicated that people prefer to buy a dress after wearing it rather than online. In fact, they preferred to see the dresses in person. These results indicate the significance of using a robot mannequin to display apparel to the customer. The results of the survey on the structural features of the robot showed that with this robot design, the uncanny valley hypothesis is met and customers will not experience any discomfort or anxiety when seeing the robot. Considering the above factors, initial surveys, and in-store displays/exhibitions clearly indicate high customer appeal and a favorable response toward creation of an active showcase including a smart social robot mannequin.

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Appendix

The survey questionnaire for *RoMa*

Age: …… Job: …………………..

What are your priority factors when purchasing clothes?

the way the dress fits the ins and outs of the body	1	2	3	4	5
Dress material	1	2	3	4	5
Dress style	1	2	3	4	5

What is your preferred method for purchasing clothes?

Online shopping	1	2	3	4	5
Seeing clothes on a mannequin	1	2	3	4	5
Buying cloth after wearing	1	2	3	4	5

Would you buy clothes without first trying them on? Yes No

What is your idea about the design, movements, and features of the robot mannequin? What is your feeling about it? Do you feel an affinity with it?

Answer the above questions through the following parameters:

Natural	5	4	3	2	1	Unnatural
Human like	5	4	3	2	1	Machine like
Lifelike	5	4	3	2	1	Unlifelike
Relaxing	5	4	3	2	1	Anxiety
Loveable	5	4	3	2	1	Fearsome
Kind	5	4	3	2	1	Unkind

Do you think that the robot mannequin has any effect on you remembering the brand of the cloth store? Yes No

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