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AN IMAGE DISPLAY DEVICE WITHOUT A CONCRETE AND DEFINITIVE SCREEN

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Key words: image display, 360°-view, surrounding display, nonconcrete screen, smoke vapor.

ABSTRACT

We present a novel and practical hardwareless display system that was developed for the 3-D projection of real objects in the absence of a concrete screen. In this report, the design and experimental results are presented to demonstrate the display of 360°-viewable objects. Images that are projected on an annular stream of aerosol or fluid can penetrate the layer-like aerosols, thereby displaying a 3-D image. Software can be used to normalize the image data to display life-like images of any model, including customers, and various outfits can be added. Moreover, the images can be visualized in full 360°, and the system can be designed to interactively display models performing various poses.

I. INTRODUCTION

A display screen is an essential part of all modern 3C products. Display screens are available in the form of liquid crystal displays, organic light-emitting diodes, field emission displays, 3-D screen displays, holograms, and micro-mirror array systems [2, 3, 7, 8, 12]. Although regular displays and projection displays can be designed to roll up to form a sheet or piece of paper, the final display system still requires concrete elements.

Only a few spatially empty systems are currently available in which a water vapor sheet or a flat aerosol sheet is used as a screen to display the surface images. Heliodisplay products [6] featuring iO2 technology possess a flat aerosol sheet screen for displaying, manipulating, and distorting images. AOSHI™ displays [4] produced by China Au-Su Corp. feature a flat water vapor sheet screen for displaying images. Fogscreen™ [5] and Paraddax™ [9] products display images by using water vapor and flat aerosol sheet screens.

We have developed a nonconcrete and non-definitive type of 3-D display. Considering the appropriate volume of the display space, we have theoretically analyzed and demonstrated the aerodynamics and fluid dynamics of a stream that can function as effectively as projection display screens. Demand is increasing for this type of interactive and addable image display in many presentations and in virtual shows.

In this study, we designed a completely screenless display and quantitatively analyzed the overlapping images produced by the system. Life-like images of any model can be captured using this system, and after normalizing the image data, the model images can be displayed performing various poses, and a diverse range of outfits and accessories can be added to the image. We present the results obtained by using the proposed nonconcrete-type 360°-view 3-D display.

II. HARDWARELESS 360°-VIEW 3D DISPLAY SYSTEM

Fig. 1 shows the conceptual configuration of the proposed display system. The nonconcrete spatially empty 3-D display system includes a steady flow of micrometer-size aerosol or liquid drops that function as the display screen. The physical layout can be designed to display a 360° image of an object by using an optimal number of the projectors.

The display volume can be spontaneously generated using a freely expanding cone or sophisticated rod-type and elliptical shape (Fig. 2).

A generator installed inside a loft and beneath the floor of a room containing the display is used as the source of the smoke or water vapor. The proposed system also includes a compressed air generator that supplies an air stream at a high flow rate to maintain the integrity of the shape of the smoke and water vapor stream. Both the compressed air and smoke (or water vapor) pass through a customized nozzle that is optimized to generate a highly stable stream. Moreover, a platform on the floor houses an accumulator for collecting and recycling the smoke and water. Because all of the hardware

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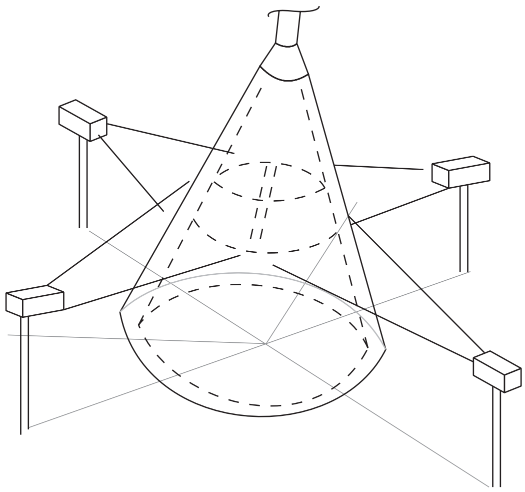


Fig. 1. The conceptual configuration of non-solid type spatially empty display.

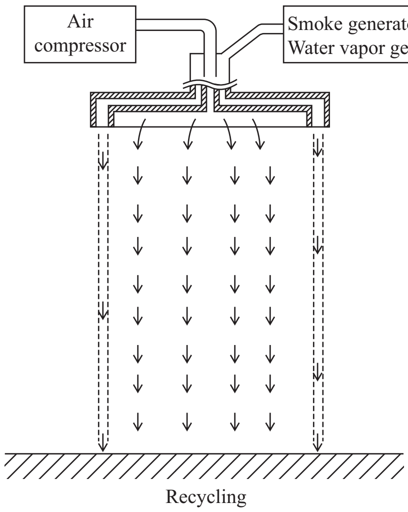


Fig. 2. The complete system configuration of non-concrete-type, 360°-view, 3D displays.

can be installed inside the roof or beneath the floor, the display area is empty and can be used for any purpose.

We have designed a nozzle that generates annular stream of smoke and a shall-like water-vapor stream as shown in Fig. 3. Because the outermost layer has the highest concentration of smoke and water vapor, all of the images generated by the three projectors in the system can collectively form a clear 360°-viewable image. Moreover, because the smoke and water vapor stream allow light to penetrate the stream to an optimized depth, stereoscopic images can also be readily displayed.

We employed Fluent software to simulate the design satisfactorily [1], and we used a compressed air flow under high pressure in the bulky central part of the stream to ensure that the smoke and water vapor layers were concentrated inwardly. Furthermore, a suction device fitted in the floor beneath the display area collects and recycles the smoke and water vapor stream, thus making the proposed system both environmentally friendly and economically attractive.

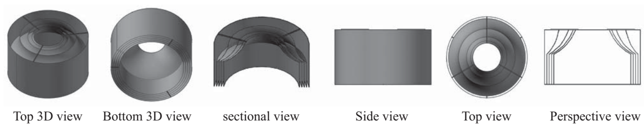


Fig. 3. The nozzle design of this non-concrete and non-definitive display system.

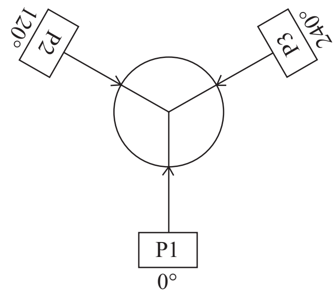


Fig. 4. Three projectors used in this non-concrete and non-definitive display system.

Fig. 4 presents the configuration of the proposed hardware-free spatially empty 360° 3-D display system.

III. SYSTEM ANALYSIS

We analyzed the display of a projected image on the surface of the stream. In a three-projector system, the projected images are separated by 120° intervals. The projection width was set to match the stream diameter, and the outermost surface of the stream was set to display the image optimally in a complete 120° view. Moreover, because the displayed image penetrated the stream, a 3-D image was generated. However, when the penetration depth exceeded δ, the images overlapped, causing a mismatch between images, as shown in Fig. 5.

The pink area at the surface of the 2/3 radius position of Zone I displays the overlapping images generated by projector P1 in Zone III (60°–50°), projector P2 in Zone II' (70°–65°), and projector P2 in Zone III' (65°–60°). Thus, where $r = 2/3$ and $R = 4$ cm, $I = r$ (sin 60°−sin 50°) = 0.399, II' = r (sin 70°−sin 65°) = 0.134, and III' = r (sin 65°−sin 60°) = 0.161.

The image width on a stream surface is typically equal to the product of the radius of the curvature of the stream surface and (sin A−sin B), which can be expressed as

$$I = r\,(\sin 60° - \sin 50°) \qquad (1)$$

where A is the larger angle of the projection at the specified zone, and B is the smaller angle of the projection at the specified zone.

Similarly, the pink area at the surface of the 2/3 radius position of Zone II displays the overlapping images generated

Table 1. All the overlapped numbers.

	Zone I	Zone II	Zone III	Zone I'	Zone II'	Zone III'
C_R	1.047	1.047	1.047	1.047	1.047	1.047
$P1_{2/3R}$	0.399	0.493	0.571	0.399	0.493	0.571
$P2_{2/3R}$	0.399	0.493	0.571	0.399	0.493	0.571
$P3_{2/3R}$	0.399	0.493	0.571	0.399	0.493	0.571
Pink area, 2/3 radius, the overlapped images of P1 and P2	P1, R, zone III, 0.399 P2, R, zone II', 0.134 P2, R zone III', 0.161	P1, R, zone III, 0.235 P1, R, zone IV, 0.257 P2, R, zone II', 0.023	P1, R, zone IV, 0.571 P2, R, zone II', 0.011	P1, R, zone III, 0.399 P2, R, zone II', 0.134 P2, R, zone III', 0.161	P1, R, zone III, 0.235 P1, R, zone IV, 0.257 P2, R, zone II', 0.023	P1, R, zone IV, 0.571 P2, R, zone II', 0.011
Yellow area, 2/3 radius, the overlapped images of P2 and P3	P1, R, zone III, 0.399 P2, R, zone II', 0.134 P2, R, zone III', 0.161	P1, R, zone III, 0.235 P1, R, zone IV, 0.257 P2, R, zone II', 0.023	P1, R, zone IV, 0.571 P2, R, zone II', 0.011	P1, R, zone III, 0.399 P2, R, zone II', 0.134 P2, R, zone III', 0.161	P1, R, zone III, 0.235 P1, R, zone IV, 0.257 P2, R, zone II', 0.023	P1, R, zone IV, 0.571 P2, R, zone II', 0.011
Blue area, 2/3 radius, the overlapped images of P3 and P1	P1, R, zone III, 0.399 P2, R, zone II', 0.134 P2, R, zone III', 0.161	P1, R, zone III, 0.235 P1, R, zone IV, 0.257 P2, R, zone II', 0.023	P1, R, zone IV, 0.571 P2, R, zone II', 0.011	P1, R, zone III, 0.399 P2, R, zone II', 0.134 P2, R, zone III', 0.161	P1, R, zone III, 0.235 P1, R, zone IV, 0.257 P2, R, zone II', 0.023	P1, R, zone IV, 0.571 P2, R, zone II', 0.011

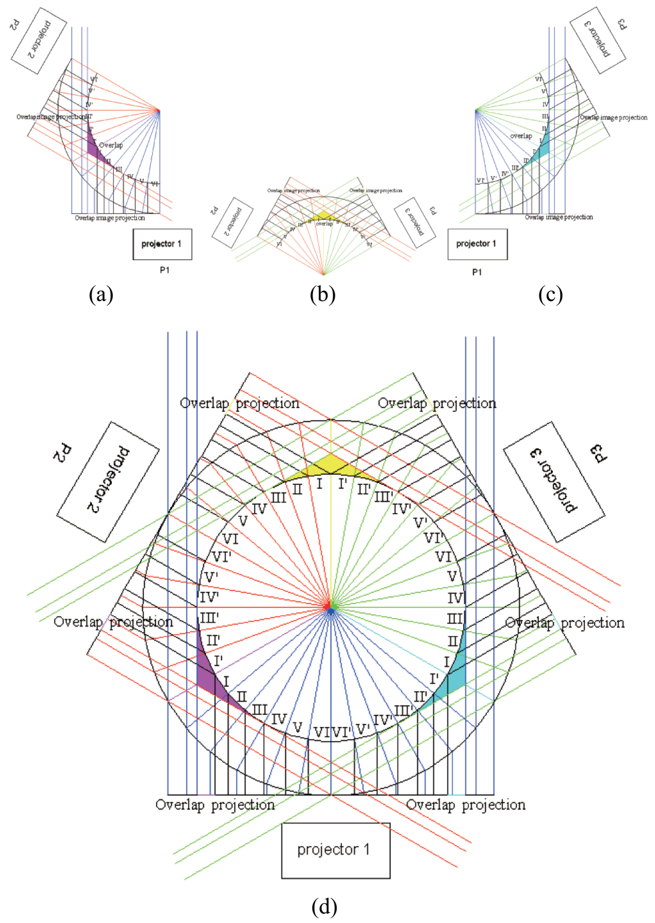


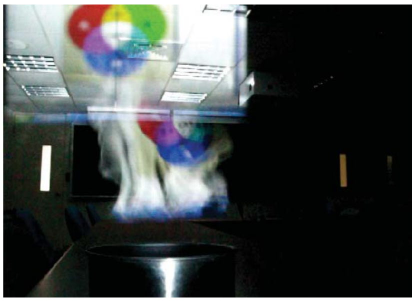
Fig. 5. The actual projection display on the surface of the stream.

by projector P1 in Zone III (50°–45°), projector P1 in Zone IV (45°–40°), and projector P2 in Zone II' (71°–70°). Thus, where r = 2/3 and R = 4 cm, III = r (sin 50°−sin 45°) = 0.235, IV = r (sin 45°−sin 40°) = 0.257, and II' = r (sin 71°−sin 70°) = 0.023. The pink area of Zone III displays the overlapping images generated by projectors P1 in Zone IV (40°–30°) and P2 in Zone II' (81°–80°). Thus, where r = 2/3 and R = 4 cm, IV = r (sin 40°−sin 30°) = 0.571 and II' = r (sin 81°−sin 80°) = 0.011. The pink area at the surface of the 2/3 radius position of Zone I' displays the overlapping images generated by projectors P2 in Zone III' (60°–50°), P1 in Zone II (70°–65°), and P1 in Zone III (65°–60°). Thus, where r = 2/3 and R = 4 cm, III = r (sin 60°−sin 50°) = 0.399, II = r (sin 70°−sin 65°) = 0.134, and III = r (sin 65°−sin 60°) = 0.161. The pink area at the surface of the 2/3 radius position of Zone II' displays the overlapping images generated by projector P2 in Zones III' (50°–45°) and IV' (45°–40°), as well as projector P1 in Zone II (71°–70°). Thus, where r = 2/3 and R = 4 cm, III' = r (sin 50°−sin 45°) = 0.235, IV' = r (sin 45°−sin 40°) = 0.257, and II = r (sin 71°−sin 70°) = 0.023. Finally, the pink area at the surface of the 2/3 radius position in Zone III' displays the overlapping images generated by projectors P2 in Zone IV' (40°–30°) and P1 in Zone II (81°–80°). Thus, where r = 2/3 and R = 4 cm, IV' = r (sin 40°−sin 30°) = 0.571, and II = r (sin 81°−sin 80°) = 0.011.

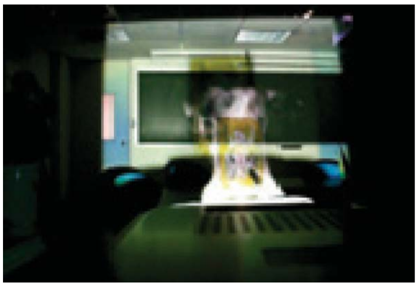
The yellow area at the surface of the 2/3 radius position in Fig. 5(b) shows the overlap of images generated by projectors P2 and P3 in all zones between 120° and 240°. Similarly, the blue area at the surface of the 2/3 radius position in Fig. 5(c) shows the overlap of the images generated by projectors P3 and P1 between 240° and 360°.

We collected all of the overlapping images generated by projectors P1, P2, and P3. Fig. 5(d) depicts the display of a single image at any specified surface in each section as well as the complete 360° image at that surface. The numerical data on the overlapped images are summarized in Table 1.

An analysis and numerical calculations of the data revealed that the images displayed by the projector penetrated the stream, reaching the specified inner surface, and the overall generated image was a superposition of all overlapping images. The display image was not simple and clear, but when we optimized it to a thickness of δ at a small depth, the overlapping images combined to generate a smooth 3D image.



(a)



(b)

Fig. 6. The images displayed on the raw aerosol water stream.

IV. EXPERIMENTAL RESULTS

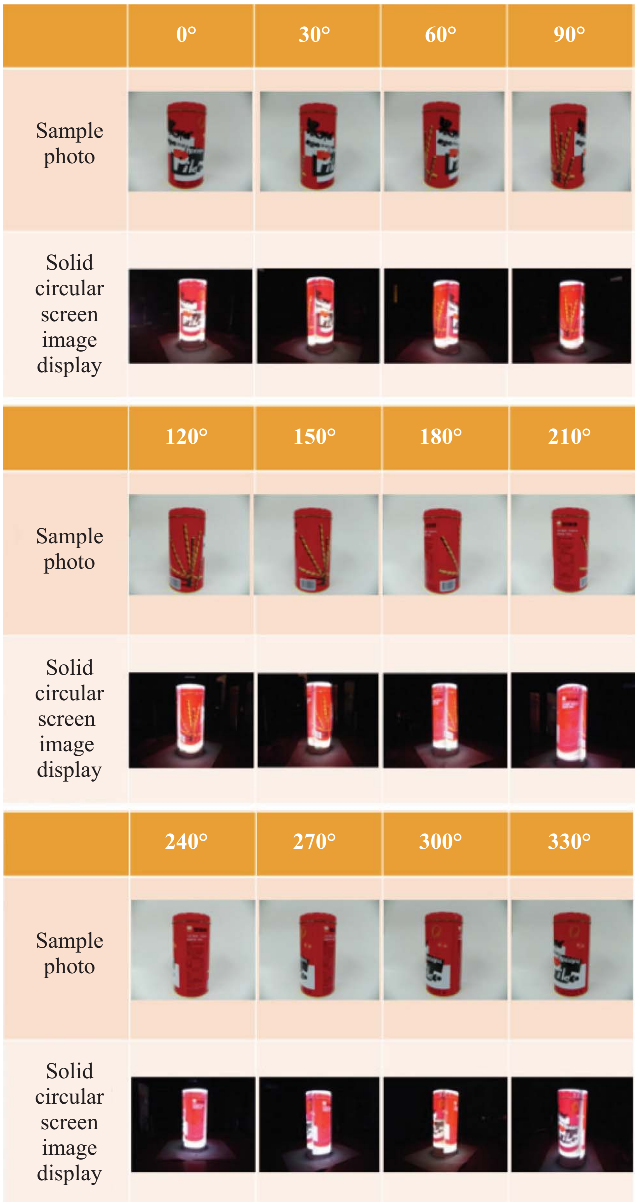
This section describes the results obtained using the non-concrete type of spatially empty 3-D display. Fig. 6 presents the preliminarily images displayed on an aerosol water stream.

Fig. 7 shows a series of photographs of a 3-D object, the original photographs of the actual object, and the image displayed on the water vapor aerosol stream. The images, which were captured using both auto- and manual focus, are shown at four typical display angles.

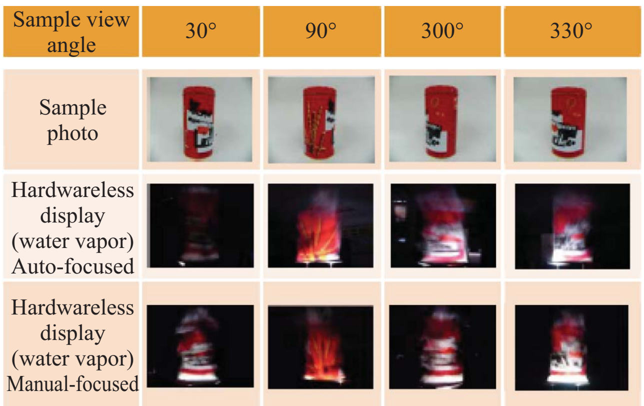
Demand exists for additional generators that can produce micrometer-sized water smoke streams [11]. As shown in Fig. 8, a typical smoke generator generates a stream of unregulated smoke. We have identified numerous suitable smoke-stream generators, including the MPL-I 003 system, which operates at 400 W for 2700 ft^3/min, and can be extended to 3000 W continuous flow. The generators use nontoxic and environmentally friendly materials to produce the smoke stream.

In our complete system, an optimized and steady flow stream of appropriate concentration was generated. The results presented in this section show that the smoke and water vapor streams displayed the images accurately. The widely used vaporized solid CO_2 smoke stream and environmentally friendly smoke generator system can also be used to display images in an empty space. A stream generator and receiver platform can be installed inside the roof and in the floor decorations, and the system fully recycles all materials, and is thus cost-effective.

We employed Fluent software to analyze the fluid dynamics and aerodynamics. Moreover, we optimized the confinement, flow speed, volume, and concentration of the stream.



(a)



(b)

Fig. 7. The images displayed on the paper screen and the water vapor stream.

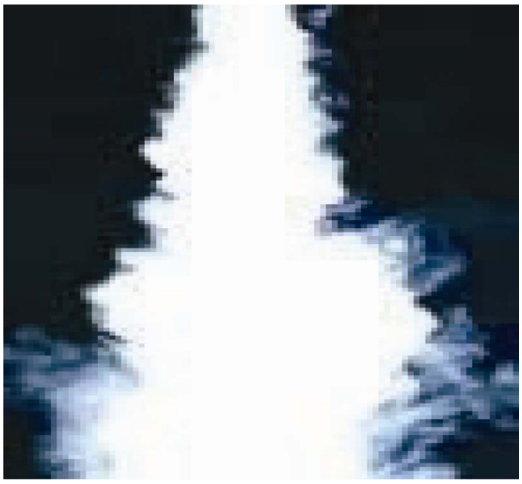
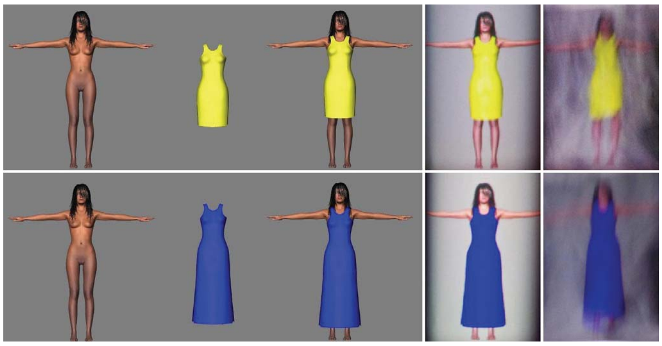


Fig. 8. The smoke stream generated from a typical un-regulated smoke generator.



(a) (b) (c)

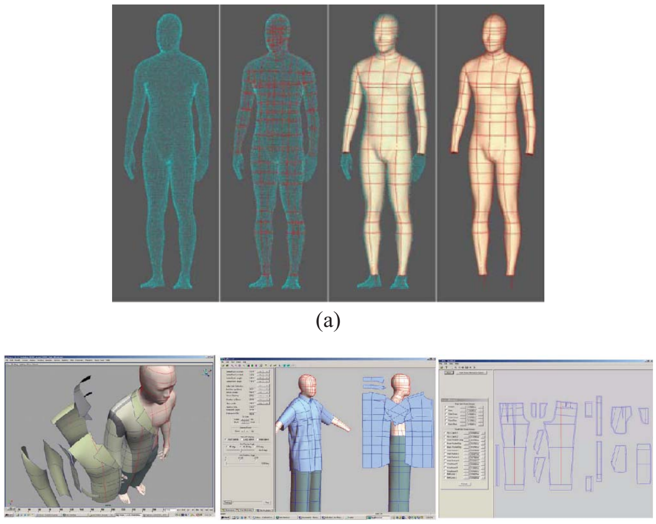
Fig. 9. (a) Model demonstrate with two suits to put on, (b) show the model images display in an ordinary screen, and (c) show the non-concentrate and non-definitive type spatially empty displayed images.

The display volume can also be optimized in circular or elliptical volumes to display 360° views and 3-D images. The photographs presented in the following section demonstrate the satisfactory results obtained using the proposed display system.

V. A DYNAMIC INTERACTIVE DISPLAY SYSTEM

By using the nonsolid spatially empty 3-D display and by performing a matching normalization of the numerical image data, we can display 360° views of a model or a person wearing various outfits and adjust how the model poses.

TPC Corp. [10] developed commercially available technologies in which an innovative 3-D approach was employed to design and construct garments. With the proposed system, we can extend the appropriate interfaces and software to suit our models (or customers) for the purpose of fitting them with fashion or jewelry.



(a)

(b)

Fig. 10. (a) Parametrical human figures generating sub-system, (b) fashion clothing on the individual customer with normalized figure parameters.

We can optimize the parametrical human-figure generating subsystem to suit any customers, and we can fit any item of clothing on the sample model.

Fig. 9(a) presents a model with two dresses that were added to the model, Fig. 9(b) displays images of a model on an ordinary screen, and Fig. 9(c) shows the images generated using our nonsolid-type hardwareless spatially empty 3-D display.

Fig. 10 depicts a typical parametrical human-figure generating subsystem that can be used to suit any customer. Furthermore, the subsystem clothing parameters can be normalized based on the original design to fit models or customers.

Next, we present the sophisticated and interactive 3-D projection displays of objects that were generated using the proposed system. Fig. 11, shows precise computer-generated figures of models and customers, as well as the designed items of clothing, and the clothing added to the models. Fig. 11(a) shows the front 0°, side 90°, and rear 180° views are displayed on a conventional screen and the proposed water vapor stream. Fig. 11(b) shows the front 0°, right side 120°, and left side 240° views displayed on a conventional screen and on the proposed water-vapor stream.

VI. CONCLUSION

We developed a nonsolid-type spatially empty 3-D display. By using the system together with a matched normalization of the numerical image data, any model or person can be displayed fitted with various outfits and then visualized in a 360° view, and the poses of the model can be adjusted interactively. Demand for this type of interactive and customizable image display system is currently growing substantially for use in presentations and remote virtual performances.

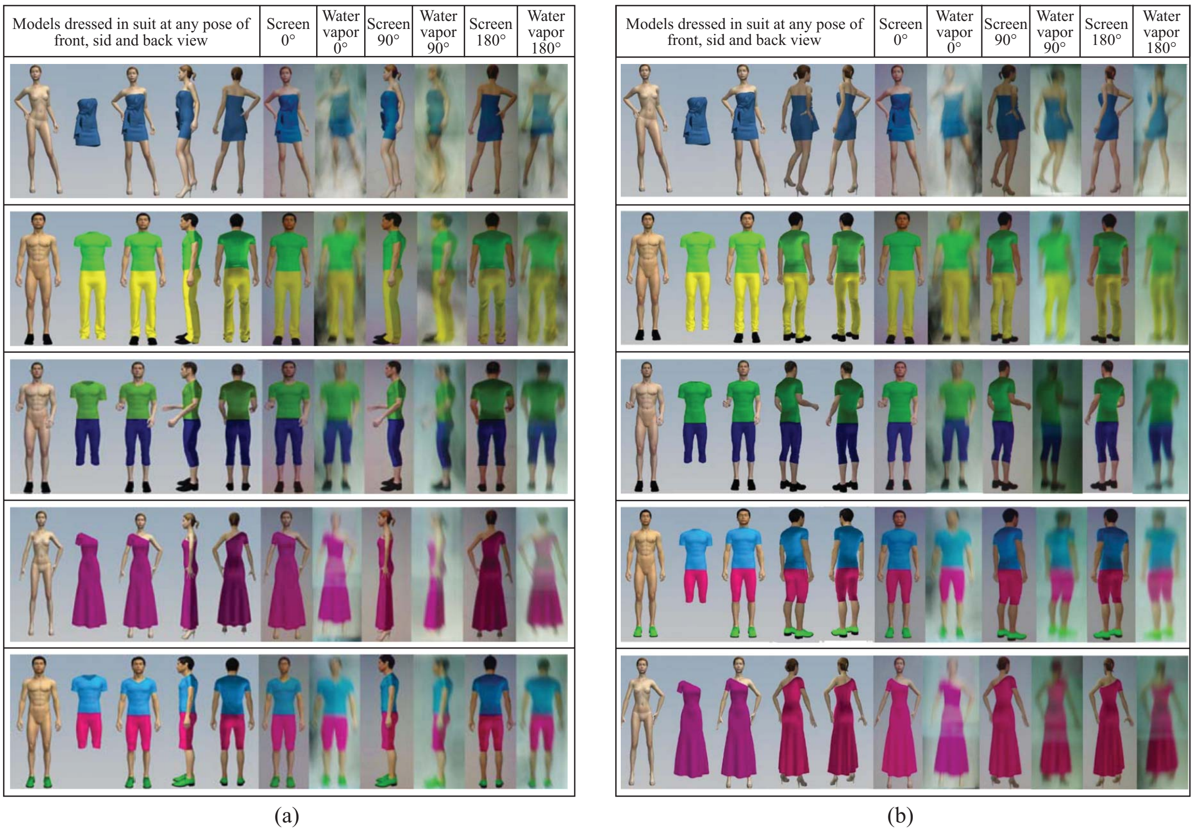


Fig. 11. Interactive non-concrete and non-definitive display results, (a) model of front 0°, side 90° and back 180° views, (b) model of front 0°, right side 120° and left side 240° views.

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