Step 7 Distance calculation.

We cannot calculate the length of the circumference of the object by just using the position of the last marker and subtract the position of the marker because after putting the markers around the object, the position of the last marker will be very close to the first one. To solve this problem, there are a few steps to be done.

1) Calculate distance between markers: we calculate the circumference of the object by calculating the distance of the double markers starting with marker#1 and #2, then #2 and # 3 and so on until the last marker and marker #1. Example of this method is shown in figure 11, and the equation for solving this problem is shown in figure 12.

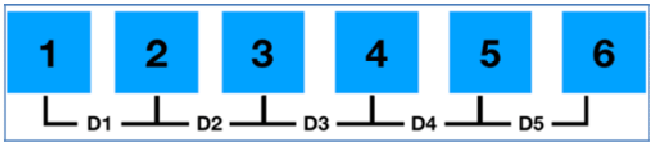

Fig. 11 For example to calculate a distance between markers (blue square is marker)

$$D_i^2 = (x_i - x_{i+1})^2 + (y_i - y_{i+1})^2 + (z_i - z_{i+1})^2$$

Fig. 12 The formula for calculates distances.

D = distance, x = vector x, y = vector y & z = vector z.

2) *Calculate circumference*: Summation of the total distance for the circumference of the object is done using the equation in figure 13.

$$\text{Circumference} = \sum_{i=1}^{n} D_i$$

Fig. 13 Formula for calculate circumference.

D is distance, x is vector x, y is vector y, and z is vector z.

The convert the distance into centimeter, using the equation in figure 14.

$$\text{Cro} = C^* \text{ Marker's size}$$

Fig. 14 Conversion formula for the circumference

Cro = Circumference of the real object and C = Circumference

3) *Calculate the object's height:* To identify the object height by calculating the distance between the top row with the bottom row.

C. Experiment

To prove that our method can identify the object's size and can simulate a shape like real objects. We set up the experiment followed all step above with several objects which have different size and shape shown in figure 15, 16, and 17 as follows:

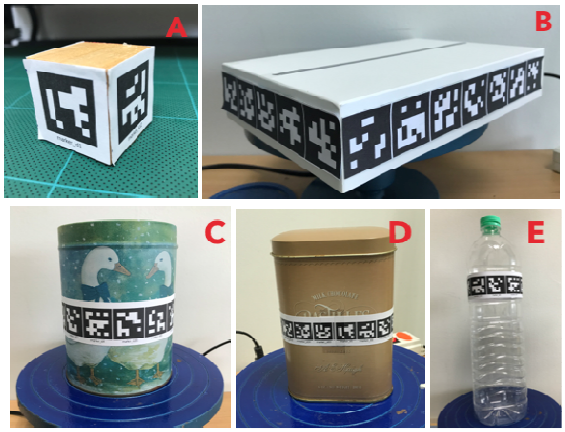

Fig. 15 Group one, Regular shape with one row marker.

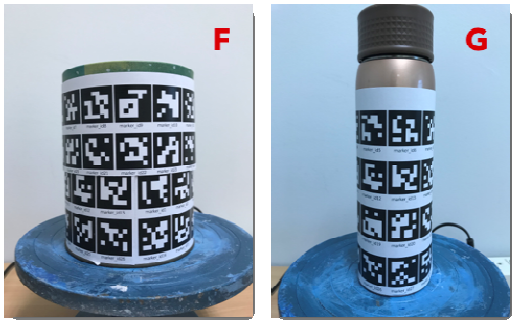

Fig 16 Group two: Cylindrical shape with 4-row markers.

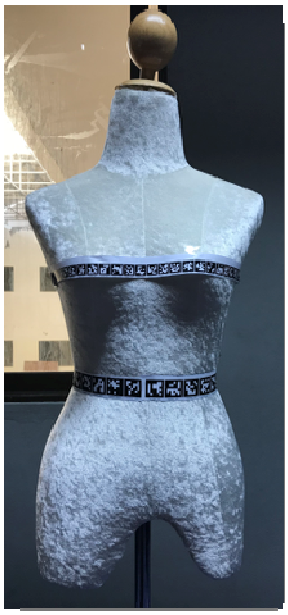

Fig. 17 Group three: body shape

III. Results and Discussion

From the experiment with the objects, the result of the shape that we get is shown in figure 18 to 27. For the size of the objects, we have done the experiment with each object 10 times to prove that our technique can identify an object's size precisely. The results in table 1, 2, and 3 are the average of the sizes of the objects from the measurements.

Fig. 18 An experiment result: Cross-section of the objects A

Fig. 19 experiment result: Cross-section of the objects B

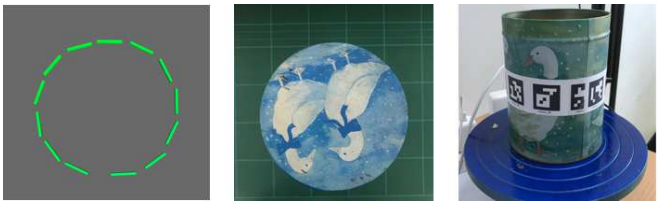

Fig. 20 An experiment result: Cross-section of the objects C

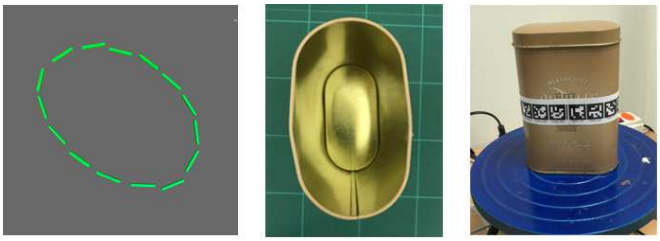

Fig. 21 An experiment result: Cross-section of the objects D

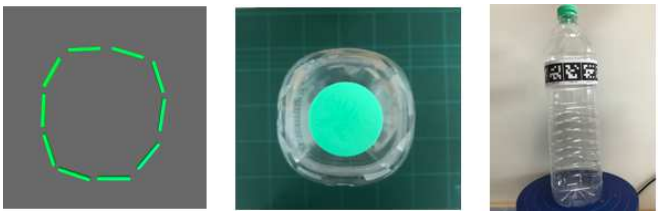

Fig. 22 An experiment result: Cross-section of the objects E

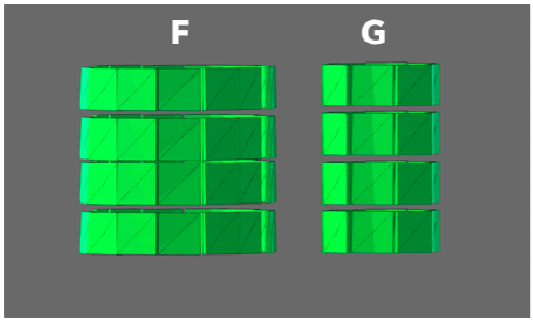

Fig. 23 An experiment result: Shape of the objects F and G on the front view

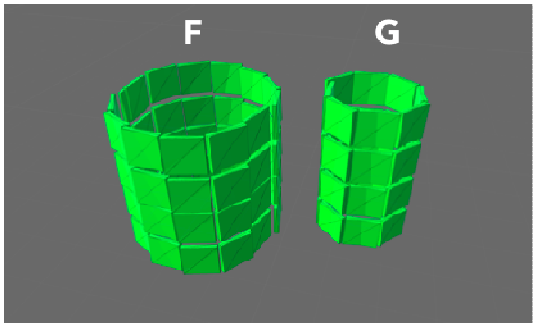

Fig. 23 An experiment result: Shape of the objects F and G on the perspective view

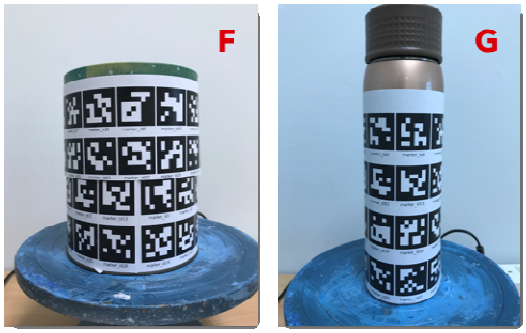

Fig. 24 The real shape of the objects F and G

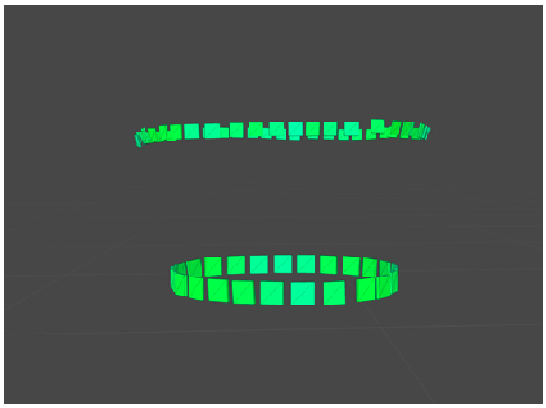

Fig. 25 An experiment result: Shape of the mannequin on the front view.

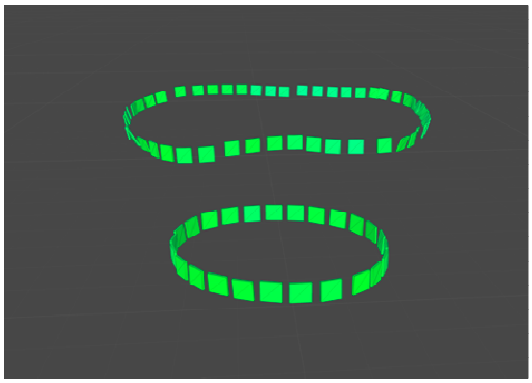

Fig. 26 An experiment result: Shape of the mannequin on the perspective view.

Fig. 27 Real shapes of the mannequin.

TABLE I
GROUP 1, AN AVERAGE VALUE FROM THE CALCULATE EXPERIMENT.

Object	Real size (cm.)	Experiment results (Avg.)	Error
A	14	13.91	0.64%
B	72	72.42	0.58%
C	33.5	33.64	0.42%
D	24	23.8	0.83%
E	27.5	27.02	1.75%

TABLE II
GROUP 2, AN AVERAGE VALUE FROM THE CALCULATE EXPERIMENT.

Object	RH	RC	EH	EC	ErH	ErC
F	10.5	33.5	10	32	4.76%	4.47%
G	16	22	16.3	23.01	1.87%	4.95%

RH is Real size: Height
RC is Real size: Circumference
EH is Experiment results: Height
EC is Experiment results: Circumferences
ErH is Error: Height
ErC is Error: Circumference

TABLE III
GROUP 3, AN AVERAGE VALUE FROM THE CALCULATE EXPERIMENT.

Object : H	Real size: Circumference	Experiment results (Avg.) (cm.)	Error
Chest	65	67.74	4.21%
Waist	87	88.41	1.62%

IV. CONCLUSION

Using our technique with several different types of objects, it can identify the shape and size of objects. From the experiment result, the shape from the system looks similar to the real objects, while the size of the objects from the calculation is very close to the real object with the maximum error of less than 5%. Using our marker-based AR technique takes a much shorter time and did not need sophisticated devices but still get a good result. Moreover, it can be used with the smartphone as well. And can be adapted to support the virtual fitting room for identifying a body's shape without using the measuring tape. Another advantage over measuring tape is that our technique can identify a convex and concave of the human's body while the measuring tape cannot.

ACKNOWLEDGMENT

This research was financially supported by Walailak University, Nakhon si Thammarat, Thailand. In contract no. 05/2561.

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