Design a media art installation based on fuzzy controlling system

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Abstract

As an art installation showed at Houtan station of Shanghai Metro Line7 and 2010 Shanghai World Expo Museum, "smart suspension ball" system displayed the rational sense of form and order of the controlling. The article focused on how to use appropriate fuzzy strategy to make the movements of the art installation more accurate under detailed experimental data. Another point of the article is to consider how to make this art installation to be a product with network, being combined and modular after upgrading the hardware and software of the installation. The performance of this upgraded product will bring more beautiful visual effects of controlling and technique. It will also be a successful case of integrating of science and technology into product designing for development of creative industries in China.

Keywords: Digital Media Art, Fuzzy Controlling, Installation Design, Arduino

1 Introduction

In recent years, a number of digital art works more or less related with “controlling” theory showing in many international or domestic art exhibitions attracted much attention. The visual presentation of the works in common is to control a large number of simple geometry objects moved regularly and performed in a real space. Audiences may feel a strong sense of order spatial transformation from the work. The performed form of the art works implies a particular technology beauty. This kind of visual effect gives audiences an extremely rational aesthetic enjoy.

From a technical analysis, most of these art works used stepper motors to control objects in space for precise displacement. Special computer programs were also used to control multiple real objects shaping different visual effects. After recently years developing, this kind of "controlling" art works gradually becomes a popular trend in the creating of digital art. It not only subverts the concept that only monitor, projectors could belong to the final output media, but also enriches the ways of digital art works showing. Therefore, more and more digital interactive artists prefer to use such means of expression in their art works.

2 Creative idea and system components

As one of the representatives of digital art works showing rational aesthetics and order of controlling, "smart suspension ball" was originally designed for participating the 2009 Liverpool Biennial. The art installation was planned to place in the Mersey (a canal in Liverpool) side. When audiences went into the display area, the spherical objects in the glass tubes were triggered to move up and down by computer-controlled fans. The shapes made up by spherical objects symbolize waves of the ancient canal and cargo ships shipping in the busy waterway. The idea of the art work makes the residents left abandoned riverside gradually to replant recalls a better life when they lived in the Mersey surrounded communities.

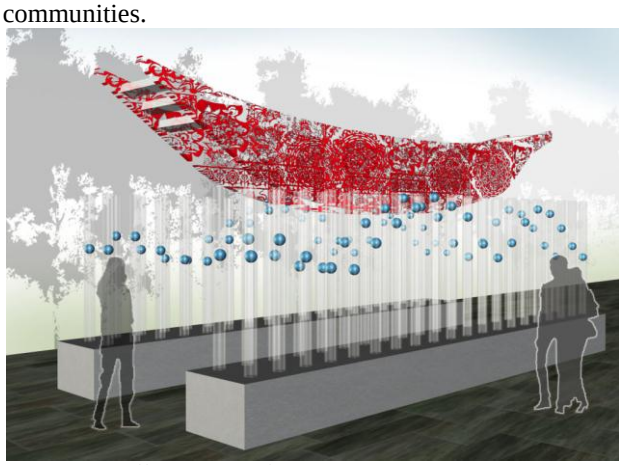

FIGURE 1 Effect drawing of "Smart Suspension Ball" placed in the Mersey side of Liverpool

For some reasons, finally this art installation didn't be showed in Liverpool. The creative idea was selected by Shanghai Shentong Metro Corporation Limited in 2010. The size of the art installation was re-adjusted to fit the metro station. It was also renamed to "Bright Wave" because the dancing spherical objects symbolize

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Shanghai's "urban pulse." The total length of this digital art installation was more than 15meters and the height of each transparent tube was up to 2.5 meters. It was placed in the hall of main station of 2010 Shanghai World Expo metro Line7 (Houtan Station of Shanghai Metro Line 7).

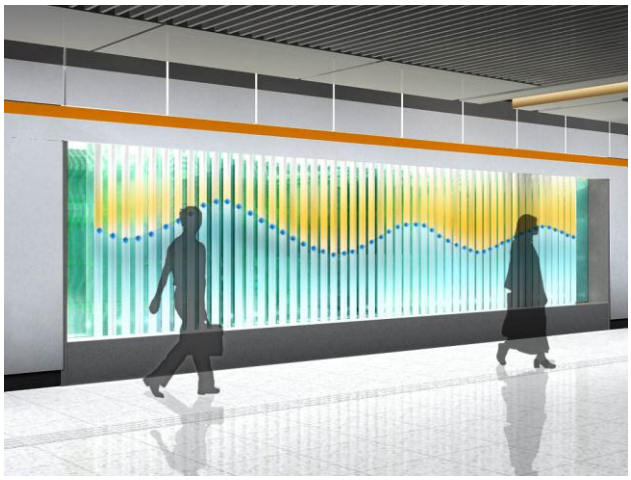


FIGURE 2 Effect drawing of "City Wave" at metro station

FIGURE 3 "City Wave", at Houtan station of Metro Line 7 in Shanghai

After making a number of successful shows, "Smart suspension ball" digital installation received some feedbacks from users and audiences. This year it was redesigned for meeting more and higher technical requirements:

1) Suspended position accuracy of the spherical objects. Accuracy means that the control hardware and software upgrades to using height sensors to get feedback to form a closed loop control.
2) Showing a variety of shapes. Improved the accuracy of the suspension height, so that the style is not just showing linear variation array of three-dimensional graphics rendering possible.
3) Miniaturization of the device. Miniaturization means that in the more space you can show this type of work, but also the recreation of industrial design.

In response to above ideas, the optimal display space for this creative product should be interior environments such as bars, cafes, clubhouse and other semi-public space. So, the product will be upgraded in several important aspects as follows:

1) The overall height of the glass tube in product is controlled in about 80cm. The sphere diameter will be no more than 4cm.
2) Unitization and modular design. Each spherical object in the tube of product is like a display pixel. User can set up a different number of units to constitute entities of varying resolution display system.
3) Limits the noise of industrial fans built inside the product under 35db or less.
4) Using an ultrasonic distance sensor (Sharp) to get the height data of each spherical object, which forms a closed loop control system. The new controlling system makes it possible to control the height of the spherical object more precisely and form them to be a shape.

3 Model of system

In a prototype of the product design, accuracy of experimental data depends on the level of craftsmanship in making. Different batches of materials such as the thickness of the wall of tube, the weight of the spherical objects or the voltage level of digital port on Arduino panel will have a direct impact on the movements of spherical objects. Therefore, it will be unavoidable to have some errors in the data of the system. Followed the laws of mechanics and based on fuzzy control theory under, we proposed a suspension control model.

First of all under physical laws, we will derive the relationship between the height of the spherical object and the wind force.

The cross-sectional area of the spherical object is

$$S_{ball} = \pi R_{ball}^2 = 3.14 \times 0.02^2 = 0.001256\ m^2, \quad (1)$$

As for the tube diameter is 0.04m, the wall is 0.0025m; as for the spherical object sphere diameter is 0.04m and a radius of 0.02m.

Thus, a formula of wind force the spherical object suffered can be derivate by Bernoulli equation:

$$F_{fan} = W_p \times S_{ball} = \frac{v_{fan}^2}{1600} \times 0.00125(kN) = \frac{v_{fan}^2}{1600} \times 1.256(N), \quad (2)$$

where v_{fan} means industrial fan wind speed, velocity near fans approximately v_{fan} = 2.2m / s, while another outlet of tube (about 0.8 meters away from the fan) winds v_{fan} = 1.8m / s, show wind speed and the distance from the outlet on.

$$v_{fan} = f(D_{ball}) = kD_{ball} + C, \quad (3)$$

Here D_{ball} represents the distance from the bottom of the tube to the bottom of the spherical object. By the

$$\left.\begin{array}{l}2.2 = k \times 0.1 + C\\ 1.8 = k \times 2.2 + C\end{array}\right\} \Rightarrow k = -0.1905, C = 2.219,$$

$$v_{fan} = f(D_{ball}) = k - 0.1905 D_{ball} + 2.219. \quad (4)$$

Therefore, by the formula (1) to (3) can be obtained

$$F_{fan} = \frac{(-0.1905 D_{ball} + 2.219)^2}{1600} \times 1.256 = 0.000028 D_{ball}^2 - 0.00066 D_{ball} + 0.0039 (N). \quad (5)$$

On this basis, the experimental observation will focus on the relationship between the height of the spherical object and the speed of the wind.

3.1 DETECTION OF SUSPENDED HEIGHT

According to the product used in the sphere diameter, tube diameter sizes, the actual height of the sphere from the target height is divided into nine levels: -0.3 m, -0.2 m, -0.1 m, -0.04 m, 0 m, 0.04 m, 0.1 m, 0.2 m, 0.3 m and the distance fuzzy language to describe size: ultra low(HN4), very low(HN3), lower(HN2), slightly lower(HN1), middle(H0), slightly higher(HP1), higher(HP2), very high(HP3), ultra high(HP4), as shown below.

TABLE 1 Fuzzy language of distance

	-0.3	-0.2	-0.1	-0.04	0	0.04	0.1	0.2	0.3
HN4	1	0.4	0	0	0	0	0	0	0
HN3	0.4	1	0.4	0	0	0	0	0	0
HN2	0	0.4	1	0.1	0	0	0	0	0
HN1	0	0	0.1	1	0.2	0	0	0	0
H0	0	0	0	0.2	1	0.2	0	0	0
HP1	0	0	0	0	0.2	1	0.2	0	0
HP2	0	0	0	0	0	0.1	1	0.4	0
HP3	0	0	0	0	0	0	0.4	1	0.4
HP4	0	0	0	0	0	0	0	0.4	1

3.2 FUNCTION OF CONTROL

This controllable value of the issue refers to the value of the speed of a industrial fan as a variable F_{fan}. The product can be transformed into the following proposition: the level of wind speed of fans is controlled by the voltage U_{fan}. The level of voltage, U_{fan} is up to the voltage from the Arduino board's analogue output ports. It can output PWM data which range is [0 255]. The fuzzy language to describe PWM data: ultra weak(FN4), very weak(FN3), weak(FN2), slightly weak(FN1), middle(F0), slightly strong(FP1), strong(FP2), very strong(FP3), ultra strong(FP4). The control function is as follows:

TABLE 2 Fuzzy function of fans speed

	255	196	189	188	187	186	185	184	183	181	179	177
FN4	0	0	0	0	0	0	0	0	0	0.2	0.5	1
FN3	0	0	0	0	0	0	0.5	1	0.5	0	0	0
FN2	0	0	0	0	0	0.5	1	0.5	0	0	0	0
FN1	0	0	0	0	0.2	1	0.5	0.2	0	0	0	0
F0	0	0	0	0.5	1	0.5	0.2	0	0	0	0	0
FP1	0	0	0.5	1	0.2	0	0	0	0	0	0	0
FP2	0	0	1	0.2	0	0	0	0	0	0	0	0
FP3	0.5	1	0.2	0	0	0	0	0	0	0	0	0
FP4	1	0.5	0.2	0	0	0	0	0	0	0	0	0

3.3 FUZZY CONTROL STRATEGY

1) If the ball is close to the target position “ultra low” (HN4), the wind should be “ultra strong” (FP4).
2) If the ball is close to the target position is “very low” (HN3), the wind should be “very strong” (FP3).
3) If the ball is close to the target position is “lower” (HN2), the wind should be “strong” (FP2).
4) If the ball is close to the target position “slightly lower” (HN1), the wind should be “slightly stronger” (FP1).
5) If the ball from the middle of the target location (H0), the wind should be in middle (F0).
6) If the ball is close to the target position “slightly higher” (HP1), the wind should be “slightly weak” (FN1).
7) If the ball is close to the target position “higher” (HP2), the wind should be “weak”(FN2).
8) If the ball is close to the target position “very high” (HP3), the wind should be “very weak” (FN3).
9) If the ball is close to the target position “ultra high” (HP4), the wind should be “ultra weak” (FN4).

3.4 FUZZY MATRIX

$$\begin{aligned} R = {} & (HN4 \to FP4) \cup (HN3 \to FP3) \cup (HN3 \to FP3) \cup \\ & (HN2 \to FP2) \cup (HN1 \to FP1) \cup (H0 \to F0) \cup \\ & (HP1 \to FN1) \cup (HP2 \to FN2) \cup \\ & (HP3 \to FN3) \cup (HP4 \to FN4) = \\ & \left(HN_4^T \wedge FP4\right) \vee \left(HN_3^T \wedge FP3\right) \vee \left(HN_2^T \wedge FP2\right) \vee \\ & \left(HN_1^T \wedge FP1\right) \vee \left(H0^T \wedge F0\right) \vee \left(HP_1^T \wedge FN1\right) \vee \\ & \left(HP_2^T \wedge FN2\right) \vee \left(HP_3^T \wedge FN3\right) \vee \left(HP_4^T \wedge FN4\right). \end{aligned} \quad (6)$$

By the (6) finally get fuzzy control strategy matrix,

$$R = \begin{bmatrix} 1 & 0.5 & 0.2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.5 & 1 & 0.4 & 0.2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.4 & 0.4 & 1 & 0.2 & 0.1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.5 & 1 & 0.2 & 0.2 & 0.2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.2 & 0.5 & 1 & 0.5 & 0.2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.2 & 1 & 0.5 & 0.2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.2 & 0.5 & 1 & 0.5 & 0.4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.4 & 0.5 & 1 & 0.5 & 0.2 & 0.4 & 0.4 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.4 & 0.4 & 0.4 & 0.2 & 0.5 & 1 \end{bmatrix}. \quad (7)$$

3 Software Design
4

Programming language of System Control module of the software uses Java-core Processing language. The flow chart is as follows.

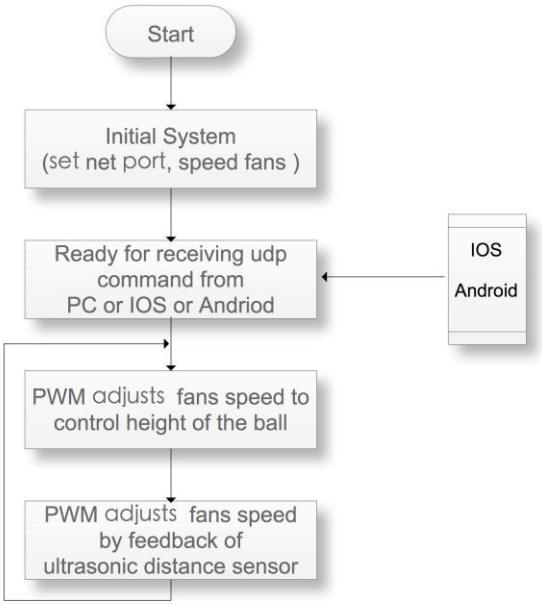
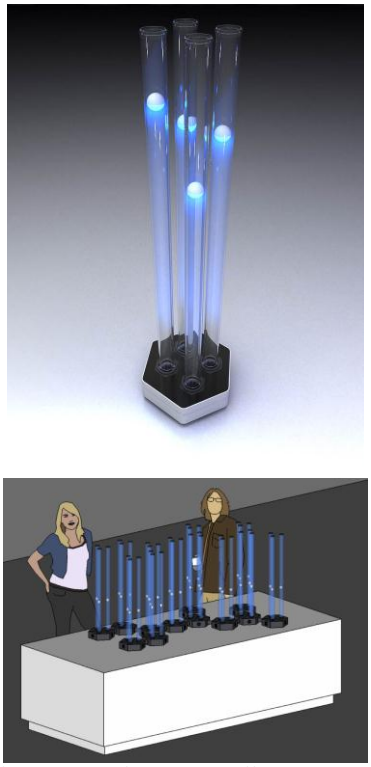


FIGURE 4 Flow chart of software design

The WiFi module is built in units' hardware to communicate with each other and the other intelligent terminals such as IOS, Android system. Transferring signals and commands in UDP protocol. The format of controlling command will be open for developers in different systems to develop different shape display mode individuation.

5 Industrial Design

"Smart suspension ball" unit consists of four transparent tubes with a hexagonal base composition. Each height of the sphere object can be controlled independently, when a user uses a plurality of unit combination, the spherical objects in the tubes formed by program control in different spatial pattern. Here is some ideas using bionic to design the figure of the base part: on the one hand the base need a large enough area to enhance the stability of the monomer product; on the other hands, analogue cellular shape achieved by the combined overall shape of a plurality of units coordinated.



FIGUE 5 Effect drawing of a unit(up); Effect drawing of a group of units in exhibition(down)

6 Conclusions

First of all, "smart suspension ball" is an innovative product with creative art and humanities works. In the second, the product combined the fuzzy control system design for the technical means. Finally, it also represents domestic design and creation of art works changing from the traditional manual way to the mode of workshop in a modern high-tech means. Meanwhile, making the physical objects as an interactive elements into interaction, means that not only tech disciplines but the visual communication, industrial modelling, sculpture, landscape and even construction and other visual arts, public art are also incorporated into the interactive art. More materials inclusiveness, diversity and technical means manifestation makes digital interactive art goes toward to a comprehensive direction.

FIGURE 6 Groups of units showed in Himalayas art gallery, Shanghai, China

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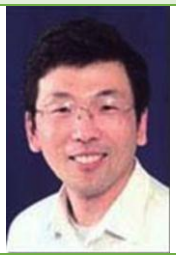

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