Reconstruction of Turbulence Phenomena Applied 3D Animation Technology

RONG-JYUE FANG
SHIH-FANN CHAO
CHI-TSUNG CHEN
Department of Industrial Technology Educational
National Kaohsiung Normal University
No.116, Heping 1st Rd., Lingya District, Kaohsiung City 802, Taiwan (R.O.C.)
TAIWAN KAOHSIUNG
http://140.127.45.25/3d

Abstract: In recent years, many disciplines have found chaos phenomenon. This study adopted the experiments of turbulence, especially the wake flow behind the bluff body. Air is limpid and observed un-directly. Therefore, the purpose of this study was to reconstruct 3D animation of turbulence to assist instruction. It has been a dramatic change in the development of 3D animation technology. 3D animation technology was the fit tool for evaluation of feasibility.

A CAI method was used to develop this study. Through CAI development procedure will rely on recording data of experiment equipment sensor for turbulence motion. Finally this study applies the formative evaluation in the 3D animation. According to the result of formation evaluation table, teachers towards the turbulence motion animation were positive opinions due to it are suitable for teaching. Consequently, study proposed a successive teaching medium development.

Key-Words: 3D animation technology、Turbulence Phenomena

1 Introduction

In recent years, many disciplines have found chaos phenomenon. This study adopted the experiments of turbulence, especially the wake flow behind the bluff body, to study chaos dynamic.

A low speed flow over a bluff body generates turbulent wake flow because the body always trigs low frequency vortex shedding. Ex Fig.1, Earliest works concerning this topic can be traced back to the studies of Roshko[1], Tritton[2], Bloor[3], Gerrard[4] and Hanson and Richardson[5], etc. Since then, some literatures considered the low-frequency fluctuations to the three-dimensional characteristics of the vortex shedding structures. For example, Roshko[6] attributed the three-dimensional wake flows to the extrinsic and intrinsic effects. Many detailed reviews and related literatures can be found in Miau et al. [7].
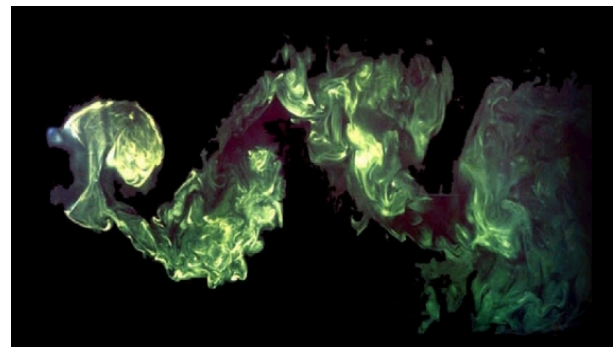

Fig.1 Illustrate of a low speed flow over a bluff body generates turbulent wake flow.

Air is limpid and observed un-directly. The reconstruction of phase space is the fit tool to study this situation. The data X(n),X(n+1),X(n+2) construct a point of coordinate and form an abstraction space named "phase space". The continuous data sets form the trace in the phase space. To study the abstract motion and to reconstruct the phenomena makes the turbulence visualize is the core concept of this paper.

Recent technological developments have led to the availability of powerful environments for the production of a range of electronic material for education [8]. Animation, video, and audio are dynamic building blocks for e-learning, and their

impact on education and training is huge [9]. To apply emerging 3-D computer animation technology has been a dramatic change in the development of computer graphic technique. The purpose of this study was development an animation of three-dimensional animation to help with instruction in abstract concept.

2 Turbulence characteristic

The turbulence of air particles shows some characteristic. Its motion very fast and unable to observe by eyes; another property is difficult to predict its direction and speed. Therefore, engineering application related to turbulence analysis has two methods -- theory construction and experiment. The air is limpid doesn't fit observation directly through bare eyes. This study based on experiments to analyze turbulence. Studies first decide the study processes than setup experimental equipment to measure and recording turbulence motion.

2.1 Numerical record

Second stage set experiment equipment to record turbulence motion. The sensor of experimental equipment records turbulence motion and transform it into digital numbers.

2.2 Reconstruction and Visualization

By third stage, this study modifies the recorded data of turbulence motion and uniform rate to scale up the numbers. The purpose is to analyze turbulence motions by CAD software and make it easier to reconstruct the motion of turbulence and good for 3D animation. This numerical represent motion path of turbulence was a continuous value of air motion.

Within the field of computer graphics, animation is generally considered to be a visual, sufficiently believable visual approximation of motion and collision between and among physical objects in a scene over a specific period of time. In other words, if it looks sufficiently realistic to be believable, then the mission of the animation is accomplished [10]. The reconstruction is different from simulation. Reconstruction relies on the measure and recording of turbulence motion for reality. The data collection was from experiment equipment. Besides the data analysis and computation, how to present numerical data and make it visualize? The CAD and 3D animation tool was fit to create for the turbulence.

It focuses on abstract concept of invisibility to visualization and because through CAD and 3D animation tool making concrete eContent was facilitating to understudied.

3 Methodology

According to the subject of turbulence studied, a series of experimental data was employed. Study first stages decide the research processes and setup experimental equipment to measure and recording turbulence motion.

3.1 Experimental equipment for Turbulence recording

In this section, the experiments briefly introduced the setup. A closed-type low-speed wind tunnel was employed for this study, shown in Fig.2; the test section was in a square cross section of 150mm by 150mm. The turbulence intensity of the wind tunnel was about 0.6% of the mean velocity that was measured at the centerline of the test section (i.e. clearness of empty flow without bluff body).
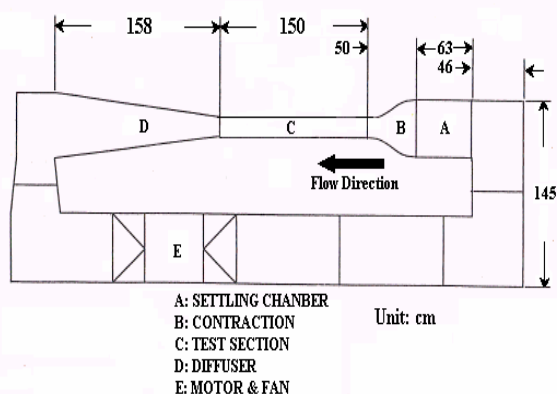

Fig.2 Sketch of wind tunnel.

A trapezoidal cylinder was employed as the bluff body for this study. As shown in Fig.3, the maximum (characteristic) length of the bluff body was 32mm. The blockage ratio based on the front area of the bluff body was about 21%. The bluff body was mounted in the test section between the two sidewalls, where the boundary layer thickness is about 0.4d. The Reynolds number was defined as Re= $\rho U \mathrm{d}/\mu$, where U is the free stream velocity corrected by the blockage effect [11]. In this study, the experimental data of Re=16500 was employed.

The instantaneous velocity in the horizontal component were measured by the split fiber probe (Dantec model 55R55) in the range of x/d=0.5 to 10 which are corresponding point A to point G, respectively, as shown in Fig.3 Simultaneously, the base pressure fluctuations were detected by the PCB piezoelectric sensor when the velocity data was

measured at each point. The A/D converter (Iotech ADC488/8SA) was used to collect and convert the signals to a digital format and its sample rate can be up to 100 kHz with 16 bits resolution. The accuracy of output data is about ± 0.2 % of full range. That was a numerical data. This study gets Pb point position numerical data to reconstruction animation of turbulence.
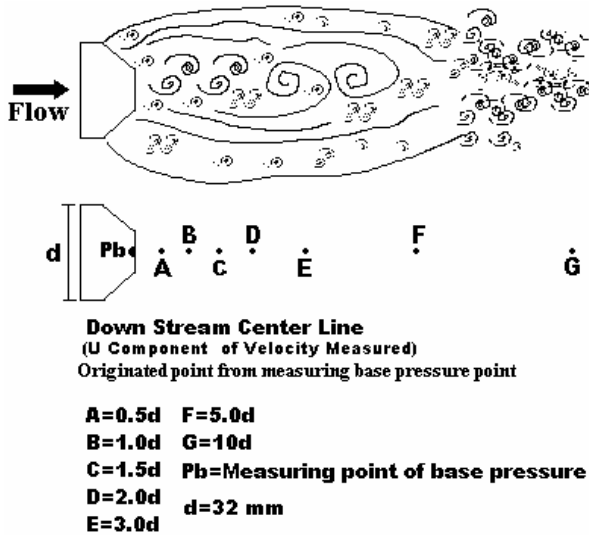

Fig.3 A schematic drawing of wake flow and setup of measuring positions.

3.2 CAI Development
This section utilizes the data of last section for turbulence recording to reconstruction virtual phase space and visualization.

We adopted CAI development method to reconstruct turbulence motion and make it visualization. CAI was a systematic method for many media development and it has exact procedure to expand this study.

CAI developments have following stages as shown in Table 1.

Table 1. CAI developmental method.

Stage for development	Steps
1.The stage of analysis	＊Needs analysis ＊Learning analysis ＊Present resource analysis ＊Specification and tools confirm ＊Teaching subject determination ＊Project guide

2.The stage of design	＊Brain storming ＊Content design ＊Teaching strategies ＊Activities design ＊Situation design ＊Art design ＊Feedback design ＊Interface design ＊Script design ＊System procedure
3.The stage of produce	＊Media produce ＊System integration ＊User Manual ＊System maintain Manual
4.The stage of evaluation	＊Formative evaluation ＊Summarize evaluation ＊Project summarize reports

On the CAI stages, we adopted needs analysis, present resource analysis, content and art design, script design, medium produce, and formative evaluation as shown in Fig.4.
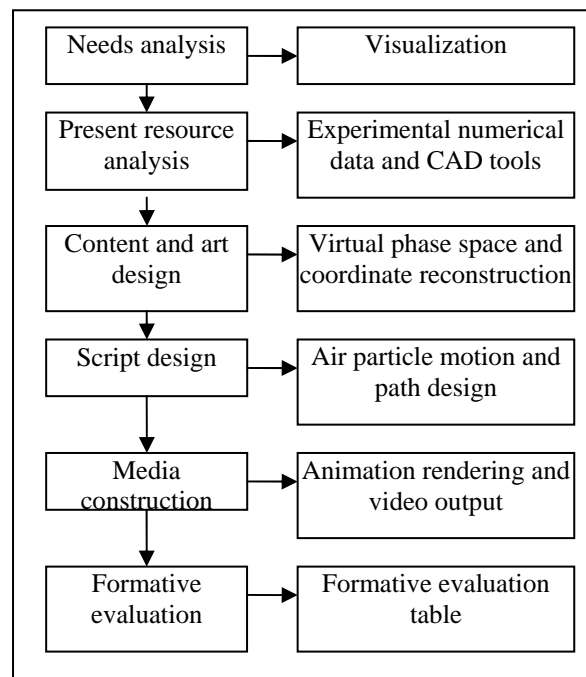

Fig.4 CAI development procedure

CAI development procedure will stepwise to do the works of animation.
※ **Needs analysis**：Air characteristic was motion very fast and unable to observation by eye. When you instruction phenomena of air motion,

3D animation is a perfect visualization medium to assist theory and phenomena explain.

※ **Present resource analysis**：This study was relying on wind tunnel experiment equipment to measure and recording turbulence motion. The 3D animation reconstruction was based on the numerical data of turbulence motion record. Therefore present resources analysis including numerical data of turbulence, computer-aided design software (AutoCAD), 3D animation software (3DMAX) and 3D interactive model web (3DIMW) to access these animations. as shown in Fig.5
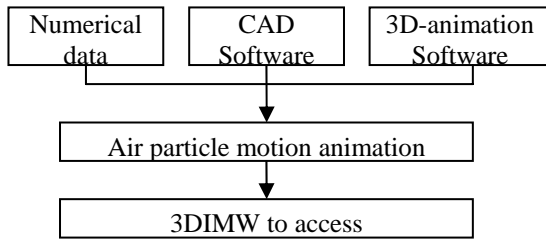
```
┌──────────┐  ┌──────────┐  ┌──────────────┐
│ Numerical│  │   CAD    │  │ 3D-animation │
│   data   │  │ Software │  │   Software   │
└──────────┘  └──────────┘  └──────────────┘
                    │
                    ▼
┌──────────────────────────────────────────┐
│       Air particle motion animation        │
└──────────────────────────────────────────┘
                    │
                    ▼
┌──────────────────────────────────────────┐
│             3DIMW to access                │
└──────────────────────────────────────────┘
```

Fig.5 Diagram of present resource analysis

※ **Content and art design**：To communicate virtual visual model with useful, rely on high-end visualization tools from 3D computer animation technique [12]. The purpose of visualization was to show the air particle motion. Therefore the numerical data of turbulence motion was a continuous value can input to CAD software to reconstruct motion path. The numerical data of turbulence motion path will input to CAD software reconstruct becomes clarity visible path line. The path line can match up virtual phase space of 3D animation as shown in Fig.6. In the 3D animation software, rely on model constructs to virtual phase space and coordinates. Then, combine with AutoCAD path drawing and integrate into 3DMAX virtual scene as shown in Fig.7.
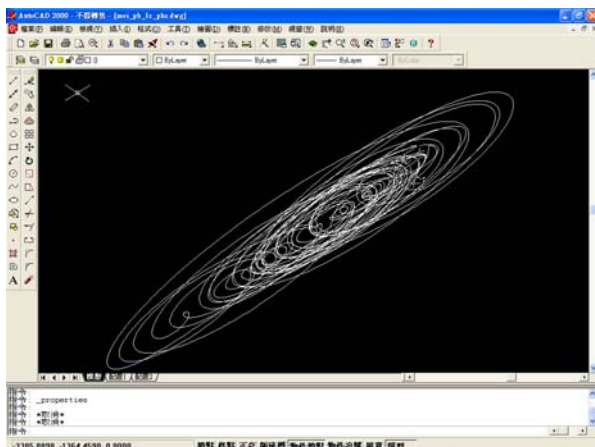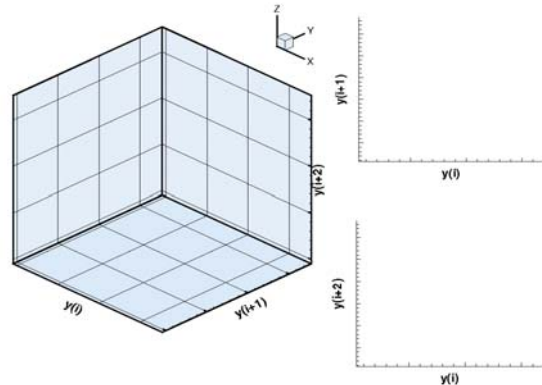

Fig.6 Path drawing from AutoCAD.

Fig.7 Shown construction of Virtual phase space and coordinate.

※ **Script design**：According to the experimental numerical data of , it will employ the CAI development, because the experimental data was non-dimensional numerical and it is a minimum value. For the consideration, the study modifies the experimental numerical data to ten thousand-rate scales as shown in Table 2.

Table 2. Shown numerical data by the PCB piezoelectric sensor from turbulence.

```
-9.9741565E-03 -1.1116979E-02 -1.2231422E-02
-1.1116979E-02 -1.2231422E-02 -1.3187278E-02
-1.2231422E-02 -1.3187278E-02 -1.3867580E-02
-1.3187278E-02 -1.3867580E-02 -1.4184296E-02
-1.3867580E-02 -1.4184296E-02 -1.4090376E-02
-.4184296E-02 -1.4090376E-02 -1.3586549E-02
-1.4090376E-02 -1.3586549E-02 -1.2721992E-02
-1.3586549E-02 -1.2721992E-02 -1.1588776E-02
-1.2721992E-02 -1.1588776E-02 -1.0310813E-02
-1.1588776E-02 -1.0310813E-02 -9.0287672E-03
-1.0310813E-02 -9.0287672E-03 -7.8828465E-03
-9.0287672E-03 -7.8828465E-03 -6.9957972E-03
-7.8828465E-03 -6.9957972E-03 -6.4582396E-03
-6.9957972E-03 -6.4582396E-03 -6.3182791E-03
-6.4582396E-03 -6.3182791E-03 -6.5767346E-03
-6.3182791E-03 -6.5767346E-03 -7.1885195E-03
-6.5767346E-03 -7.1885195E-03 -8.0699762E-03
-7.1885195E-03 -8.0699762E-03 -9.1110924E-03
-8.0699762E-03 -9.1110924E-03 -1.0190929E-02
-9.1110924E-03 -1.0190929E-02 -1.1194116E-02
```

The numerical data have to modify standard coordinate expression by text modifier, e.g. X.Y.Z world coordinate. This way is to align the construction of virtual phase space and coordinate with same position of experimental data. Then, erase the blank space from every numerical data. In additional to utilize AutoCAD software gets the numerical data and write script to drawing path for air particle motion of turbulence as shown in Table 3,

Table 3. Use AutoCAD write script to draw the path of air motion.

```
3dpoly
+358374.125,+424013.594,+459249.844
+424013.594,+459249.844,+466054.469
+459249.844,+466054.469,+448897.031
+466054.469,+448897.031,+413925.781
…
…
-870687.062,-915096.188,-905429.938
-915096.188,-905429.938,-842205.688
-905429.938,-842205.688,-730761.688
-842205.688,-730761.688,-580810.938
-730761.688,-580810.938,-405493.250
-580810.938,-405493.250,-220033.469
-405493.250,-220033.469,-40165.570

zoom
e
scale
+358374.125,+424013.594,+459249.844

+358374.125,+424013.594,+459249.844
0.001
move
+358374.125,+424013.594,+459249.844

+358374.125,+424013.594,+459249.844
0,0,0
zoom
E
```

※ **Medium construction**：Because the wind tunnel base pressure fluctuations were detected by the PCB piezoelectric sensor when the velocity data was measured at each point. The A/D converter (Iotech ADC488/8SA) was used to collect and convert the signals to a digital format and its sample rate can be up to 100 kHz with 16 bits resolution. The 100 kHz is meaning per second pressure fluctuations as one hundred thousand sequences (100 kHz = 100000 HZ). That was very fast motion of air. Therefore 3Danimation construction was to extend the scale of time, by times extend to slow down air motion for facilitating observation. As shown in equation (1).

3Danimation expect play time=33sec.
$100000/(2\times33) = 1515.15$ dataset/sec   (1)

Through numerical data and CAD soft path drawing were employ to the 3Danimation soft for composite to output video. After composite form different viewpoint can to show multi viewpoints of air particle motion on same scene. As shown in Fig.8.9.10. Then render the 3Danimation to output video format as AVI, MPEG and WMV etc. These 3Danimation video was link to the web of 3DIMW as http://140.127.45.25/3d/air/index.htm
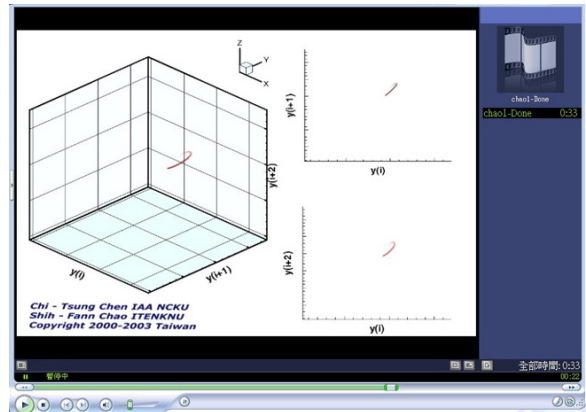

Fig.8 Multi viewpoints show air particle motion on same scene (continuous motion of air particle).
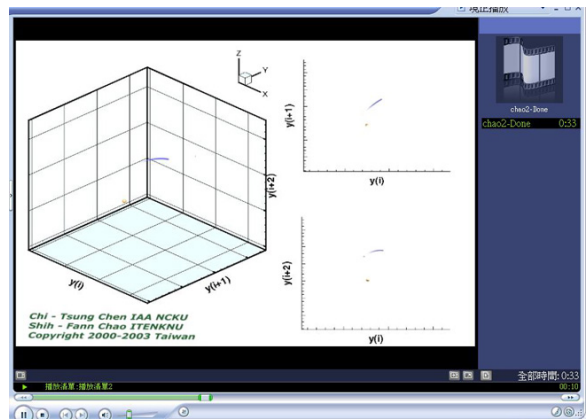

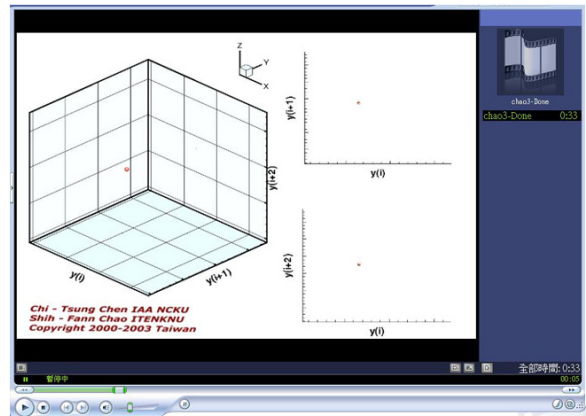Fig.9 Multi viewpoints show air particle motion on same scene (set a reference point).

Fig.10 Multi viewpoints show air particle motion on same scene (point motion of air particle).

※ **Formative evaluation**：Reconstruction of Turbulence Phenomena 3Danimation Evaluate method use formative evaluation; it is a common way to use for CAI development. Formative evaluation includes streaming testing of web and records the result on formative evaluation Table. Formative evaluation Table is likert type 5 point scale with results as shown in Table 4.

Table4. Formative evaluation Table.

Evaluation Classes	Evaluation item	Samples	means
Animation of turbulence motion	Easy to use for operation and interactive.	9	4.4
	Easy to use for observation.	9	4.3
	Animation construction is clarity and suitable.	9	4.5
	Coordinate place is easy to observation.	9	4.2
	Animation streaming on web is stable.	9	4.5
	Animation may improve to understand for turbulence motion.	9	4.9
	Human computer interface for use is kindness.	9	4.4

4 Conclusion

According to the result of formation evaluation table, teachers towards the turbulence motion animation were positive opinions due to it are suitable for teaching. Consequently, study proposed a successive teaching medium development.

The benefit of 3D animation that can provide many video and it is unlimited recycle use in computer. Teachers and students can use the medium on anywhere just access 3DIMW from Internet. So not only provide visual medium for abstract concept instruction but also support it access convenient.

Stimulus of visual and interaction not merely rise to motivation of users or made user exciting, more important is base on review of literature was known the interaction environment to help with learning.

Further research

The 3Danimation has potential for education to development in the future, in addition to this study will construct a platform to management animation and eContent. The animation can adopt many streaming format, MPEG, WMV, RA, MOV, etc. increased circulate of education resource.

Over and above, we except continue expand the 3Danimation application in the future; even more could combine VRML with hardware provide varied use. Further we hope could combine medical science with Magnetic Resonance Imaging to verify visual stimulus with cognitive relation.

References:
[1] A. Roshko, On the Development of Turbulent Wakes from Vortex Streets, NACA Report 1191, 1954.
[2] J. Tritton, Experiments on the Flow Past a Circular Cylinder at Low Reynolds Number, J. Fluid Mech., Vol. 16, pp. 547-567, 1959.
[3] S. Bloor, The Transition to Turbulence in the Wake of a Circular Cylinder, J. Fluid Mech., Vol.19, pp. 290-304, 1964.
[4] J. H. Gerrard, "The Three-Dimensional Structure of the Wake of a Circular Cylinder," J. Fluid Mech., Vol.25, part 1, pp. 143-164,1966.
[5] F. B. Hanson, and P. D. Richardson, The Near-Wake of a Circular Cylinder in Crossflow, J. Basic Eng., Trans. ASME., Vol. 90, pp. 476-484,1968.
[6] A. Roshko, Perspectives on Bluff Body Aerodynamics, J. Wind Eng. Ind. Aerodyn., Vol. 49, pp.79-100, 1993.
[7] J. J. Miau, S. J. Wu, C. C. Hu, and J. H. Chou, Low Frequency Modulations Associated with Vortex Shedding form Flow over Bluff Body, AIAA J., vol.42, no.7, pp.1388-1397, 2004.
[8] Aedo, I., & Landoni, M, Digital Contents for Education. Educational Technology & Society, 6 (4), 6-7, 2003. Available at http://ifets.ieee.org/periodical/6_4/2.pdf
[9] Bijan B. Gillani, Learning Theories and the Design of E-Learning Environment. University Press of America, Inc. p177, 2003.
[10] William A. Ross, Visual 3D Computer Graphic Design-Simulation In Technology Education, Proceedings of the Sixth International Conference on Information Visualisation, IEEE (IV'02) 1093-9547/2002.
[11] C. T. Wang, Investigation of low-frequency variations embedded in vortex shedding process, Ph. D. Dissertation, National Cheng Kung University, June 2000.
[12] Autodesk, 3D Studio Max Reference Volume1-3. AutoDesk, Inc. 1999.