

Research Article

DynaView: General Dynamic Visualization Model for SHM

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We present a general dynamic visualization model named DynaView to construct virtual scenes of structural health monitoring (SHM) process. This model consists of static, dynamic, and interaction submodels. It makes the visualization process dynamic and interactive. By taking an example of a simplified reinforced concrete beam structure model, we obtain raw data through the examination. We conduct the effective general and practicable assessment of structural damage conditions based on fuzzy pattern recognition to compute the assessment results. We construct the DynaView model of the sample structure and visualize it. The instance indicates that DynaView model is efficient and practically applicable.

1. Introduction

The process of damage detection and identification for civil structure is called structural health monitoring (SHM). SHM is the process of observing and collecting periodic sampling data. Firstly, the SHM system analyzes those damage features that are abstracted from those sampling data. Then it evaluates current structure's health state. SHM technology is a powerful tool [1] to help ensure the safety of large and complicated civil infrastructures.

SHM of large structures has become a leading edge of civil engineering. It is very vital for damage condition assessment to judge the structure's working state and health state with those sampling data. It is also important for engineers to recognize the damaged parts and degree to assess the damage condition [2].

Besides the front-end intelligent monitoring and diagnosing function, the back-end visualization function plays an important role within the whole SHM system. Visualization

output not only can reflect the monitoring and diagnostic technology but also can connect the user and the system. Visualization allows one to display the structure state, safety alert, intelligent assessment, and user feedback [3].

SHM visualization which is one of the most important components of SHM can visualize the sampling data. It preprocess the data (including abstracting, filtering, and analyzing), assesses the damage state, constructs the visualization model, and completes the visual scene. It shows the damage conditions to users in a direct way.

SHM visualization is a critical bridge which connects the system and the user. On one hand, SHM results can be displayed in the scene by visualization technology and alert user directly. On the other hand, the visual scenes help users to confirm the correctness and effectiveness of an SHM system.

At present, there are mainly three classes in the terms of visualization environment: visual application environment, visual development environment, and visual software environment. The first class is the visual application environment supported by application software. It is always integrated into the system which can provide necessary data, model, and visual method. The second class is the visual development environment supported by some certain operating systems and development platforms. It takes good use of graphics toolkits which are provided by some famous software, such as MATLAB, OpenGL, and Open Inventor. The last class is visual software environment supported directly by some visualization software just like AutoCAD, 3DMax, and Maya.

We present a dynamic and interactive visualization model named DynaView which consists of static submodel, dynamic submodel, and interactive submodel. The static submodel describes static features of structure. It is the visual mapping of the structure. The dynamic submodel describes those constant changing dimensions or variables during the whole SHM process. It is the kernel technology of dynamic visualization modeling. The Interactive submodel provides the ability to interact with visual scenes which can respond to time elapsing events, mouse and keyboard interaction. We preprocess the sampling data and then assess the structure health state by using the effective and practicable assessment of structural damage condition based on fuzzy pattern recognition. Lastly, we construct the DynaView model to visualize the dynamic and interactive scenes by using VC6.0 and Open Inventor. Users can directly perceive and master the instance structure's health situation through the visual scenes which can promote the safety of the structure.

2. Key Technologies in SHM Visual Modeling

2.1. VRML

Virtual reality modeling language (VRML) is a file format which can describe interactive 3D objects. In 1997, VRML was released as international standard by International Standard Organization(ISO). Now it is called VRML97 which is authorized formally by ISO in 1998. VRML files include space models and its nodes. The nodes describe model, color, light, viewpoint, timer sensor, touch sensor, and interpolator and can locate the model's position and orientation. VRML describes 3D space using Scene Graph. Scene Graph is the inner presentation of VRML 3D spaces. The nodes construct the Scene Graph according to some certain rules. Scene Graph looks like a reversed tree which has lots of root nodes. It is comprised of node-attribute value. All the nodes are hierarchical and form a directed acyclic graph.

VRML provides Event-Route mechanism which is separated from hierarchical structure. Event-Route mechanism can build a dynamic 3D virtual scene. Users can interact

with 3D scenes or change the state and attributes of 3D scenes. VRML ROUTE statement is a special rule which provides the ability to change 3D scenes. It spreads the event from the occurred node to the target node in order to change the latter's state and attributes. Once the event happens, it is immediately transmitted from the sending node to the receiving node according to the ROUTE rule. The target node handles the event by updating state and attributes, triggering another event or by changing the scene's structure. ROUTE statements always construct from EventOut to EventIn, while the type of both points must accurately match each other.

2.2. Open Inventor

Open Inventor is a 3D interactive graphical toolkit developed by SGI. It uses OpenGL toolkit as base platform and can precisely and quickly render VRML scenes. Open Inventor becomes both a foundation and a superset of VRML. VRML is a subset of modified and enlarged Open Inventor 3D graphic file format. Open Inventor is now the only 3D interactive graphical toolkit which can support VRML nodes perfectly. The most important thing is that Open Inventor supports ROUTE as well as the other nodes in VRML97. It provides attribute-to-attribute method to save ROUTE statement with no information loss. The applications developed based on Open Inventor can make good use of ROUTE statement to build dynamic and interactive 3D virtual scene.

3. Dynamic Visual Modeling for SHM

In the engineering project, SHM system obtains the periodic sampling data through sensors. In order to understand and analyze the computing results, we must display those important data in a visual scene for better observation and interaction. The dynamic visualization technology helps to describe continuous monitoring. The dynamic feature also helps users to understand how the changing data have great influence on the whole structure [4]. Due to more and more complicated civil structure, the dynamic characters need to be analyzed by finite element and dynamic scene. It is very useful to dynamic analyzing the civil structures by using modern graphic development environment and visualization technologies [5]. Therefore, it is of great importance and necessary to build a dynamic visual model to be displayed in a visual scene.

SHM system is a kind of overall monitoring. Both static feature such as permanent load and dynamic feature such as variable load are all monitored in time. Some abnormal conditions at certain critical points of the civil structure are monitored by SHM system. Those abnormal states are indicated by sampling feature data [2]. SHM dynamic visual modeling is a complicated process: firstly, it abstracts, filters, and analyzes the periodic sampling data; secondly, it assesses those computed data by using the assessment method of structural damage condition; lastly, it maps those information into graphic elements by using the static and dynamic models. The implied civil structure's state information is shown by directly perceived visual scenes.

3.1. Architecture of SHM System

The architecture of SHM system is shown as Figure 1 which is composed of Data Collection Module, Data Preprocess Module, Structural Assessment Module, and Data Visualization

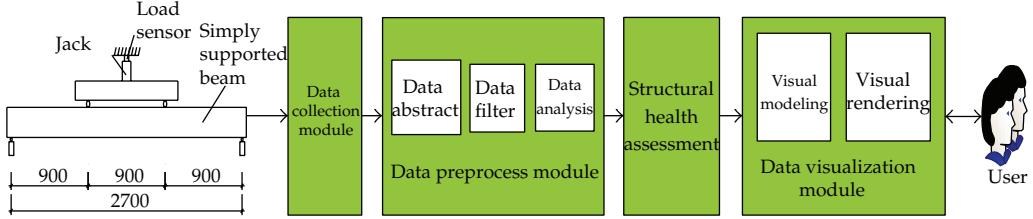


Figure 1: Architecture of SHM system.

Module. The working flow of SHM system is as follows. As a first step, we obtain sampling raw data through those sensors distributed on the structural key points. In the second step, we save the sampling raw data and input them into the Data Preprocess Module to abstract, filter, analyze, and process. Then, we standardize and output them to the Structural Assessment Module. In the third step, we handle the standardized data and acquire the structural health state by using the assessment of structural damage condition based on fuzzy pattern recognition. After that, we output the state information to the Data Visualization Module. For the last step, we build dynamic model and map it to visual scenes by using the visualization engine. Users can observe and understand the civil structure's health state information and interact with the scene.

3.2. Structural Assessment Module of SHM System

The assessment of structural damage condition is used to solve four questions [1]. Firstly, the module indicates whether the warning appears or not. Secondly, the module locates where the damage appears. Thirdly, the module makes sure of the degree of the structural damage. Lastly, the module gives the rest usable time of the damaged structure. Giraldo divides the damage monitor and recognition into three classes [1]: method based on vibratory, method based on static force, and method based on directly monitor. The Structural Assessment Module gets the assessment attributes and results through valid and practicable computing. The results are very important for the Data Visualization Module.

We use an effective general and practicable assessment of structural damage condition based on fuzzy pattern recognition to change the structural state fuzzy variables into a certainty question. The fuzzy variables are not limited by the state feature types. The assessment method is based on both structural characters and prediction by fuzzy professionals. It constructs structural fuzzy sets with overlap features. Without assuming the probability distribution and density function of structural damage features, we can entirely assess the damage state. When the civil structure is damaged, it causes the structural attributes such as quality, rigidity, and damp coefficient changing constantly which leads to the variation of the structural natural frequency of vibration, mode of vibration and impedance [1]. We assess the structural damage state by the approximation principle. We also use fuzzy pattern recognition method to identify the coherence of similar objects and to assure the attributes of the structural damage state fuzzy sets, state similarity matrix, and the membership grade function.

The certification of attributes needs two steps as follows.

The first step is that we obtain the structural damage state fuzzy sets and state similarity matrix. Assuming that λ is the eigenvalue of structural state, the membership grade

function of structural damage state fuzzy sets using normal membership grade construction function is as follows:

healthy state:

$$\mu_H(\lambda) = \begin{cases} 1 & \lambda \leq \lambda_H, \\ e^{-(\lambda-\lambda_H)/\sigma_H^2} & \lambda > \lambda_H, \end{cases} \quad (3.1)$$

little damage state:

$$\mu_L(\lambda) = e^{-(\lambda-\lambda_L)/\sigma_L^2} \quad \lambda \in R, \quad (3.2)$$

moderate damage state:

$$\mu_M(\lambda) = e^{-(\lambda-\lambda_M)/\sigma_M^2} \quad \lambda \in R, \quad (3.3)$$

severe damage state:

$$\mu_S(\lambda) = \begin{cases} e^{-(\lambda-\lambda_S)/\sigma_S^2} & \lambda \leq \lambda_S, \\ 1 & \lambda > \lambda_S. \end{cases} \quad (3.4)$$

$\lambda_H, \lambda_L, \lambda_M, \lambda_S$ is the arithmetic mean value of four structural states' eigenvalues. $\sigma_H, \sigma_L, \sigma_M, \sigma_S$ is the standard deviation of four eigen values. Based on the conception of structural state overlap and damage accumulating, constructing the state similarity matrix SM is used to reflect the degree of overlapping of the random two structural states. It is defined as follows:

$$SM = \begin{bmatrix} SM_{HH} & SM_{HL} & SM_{HM} & SM_{HS} \\ SM_{LH} & SM_{LL} & SM_{LM} & SM_{LS} \\ SM_{MH} & SM_{ML} & SM_{MM} & SM_{MS} \\ SM_{SH} & SM_{SL} & SM_{SM} & SM_{SS} \end{bmatrix}. \quad (3.5)$$

As for the matrix element SM_{IJ} is the lattice degrees of nearness of two random state fuzzy sets I and J . Its value varies from 0 to 1. The lattice degrees nearness of the same fuzzy sets is 1.0. So, SM is a real symmetric matrix whose main diagonal elements are all 1.0. If SM is assigned by the professionals, the value is decided by their experiences.

As for the second step, we obtain the attributes of the membership grade function.

λ_H and σ_H of the structural state can be calculated from the undamaged sampling data. Their values can be substituted into formula (3.1) and can confirm the function $\mu_H(\lambda)$. Before we confirm the other three structural damage state fuzzy sets and the membership grade functions, we must get the values of $\lambda_L, \lambda_M, \lambda_S, \sigma_L, \sigma_M$ and σ_S .

Assuming the discussing domain $U = U_1(\text{overlap level of } H \text{ and } L), U_2(\text{overlap level of } H \text{ and } M), U_3(\text{overlap level of } H \text{ and } S), U_4(\text{overlap level of } L \text{ and } S), U_5(\text{overlap level of } L \text{ and } M), U_6(\text{overlap Level of } M \text{ and } S)\}$, we get the value of the fuzzy subsets A from

the six elements of state similarity matrix. The professionals predict by experiments the fuzzy subsets A' , A , and A' are as follows:

$$A = \frac{SM_{HL}}{u_1} + \frac{SM_{HM}}{u_2} + \frac{SM_{HS}}{u_3} + \frac{SM_{LM}}{u_4} + \frac{SM_{LS}}{u_5} + \frac{SM_{MS}}{u_6}, \quad (3.6)$$

$$A' = \frac{\mu_1}{u_1} + \frac{\mu_2}{u_2} + \frac{\mu_3}{u_3} + \frac{\mu_4}{u_4} + \frac{\mu_5}{u_5} + \frac{\mu_6}{u_6} \quad (\mu_i = [0, 1]). \quad (3.7)$$

In the two formula, the sign SM_{IL}/u_i is not a concept of "fraction," but a sign which means a degree of element A being a member of element u_i . The sign "+" is not a concept of "addition," but a sign which subs a kind of connection.

Assuming f is the European measurement of close degree of A and A' , we can solve the formula (3.6) and formula (3.7) and get the solution of the six unknown attributes:

$$\text{Max } f = 1 - \left(\frac{1}{6} \sum_{i=1}^6 (A - A')^2 \right)^{1/2}, \quad (3.8)$$

$$\text{s.t. } \begin{cases} \lambda_H \leq \lambda_L \leq \lambda_M \leq \lambda_S, \\ \sigma_L, \sigma_M, \sigma_S \geq 0. \end{cases} \quad (3.9)$$

The larger the value of the target function is, the closer A and A' are. Inputting the solution into formula (3.2), formula (3.3), and formula (3.4), we can obtain the other three structural damage state fuzzy sets.

3.3. Data Visualization Module of SHM System

3.3.1. Framework of Data Visualization Module and Visual Workflow

The Data Visualization Module is as shown in Figure 2. Among the Data Visualization Modules of SHM system, OpenGL graphic toolkit is at the lowest level. OpenGL is a 3D interactive graphic toolkit developed by SGI Inc. It provides basic drawing graphic elements and has the ability to parameterize the attributes. Above this level it is the Open Inventor graphic toolkit. Open Inventor is also a 3D interactive graphic toolkit developed by SGI Inc. It uses OpenGL as the bottom rendering platform. Open Inventor is special in accurately and quickly rendering the visual scene, especially the VRML scene. Between the user and the toolkit, it is the dynamic interactive visualization model which is comprised of static submodel, dynamic submodel, and interactive submodel. The static submodel describes static features of structure. It is the visual mapping of the structure. The dynamic submodel describes those constant changing dimensions or variables during the whole SHM process. It is the kernel technology of dynamic visualization modeling. The Interactive submodel provides the ability for users to interact with visual scenes which can response time elapse, interactive mouse and interactive keyboard events. The user is on the top level of the visualization model. The user can directly perceive and master the instant structure's health situation through the visual scene which can promote the safety of the structure. Moreover, the user can deeply observe and judge the state by interacting with mouse and keyboard.

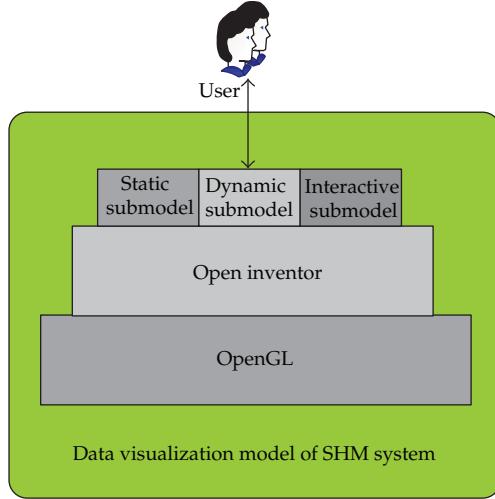


Figure 2: Data Visualization Module of SHM System.

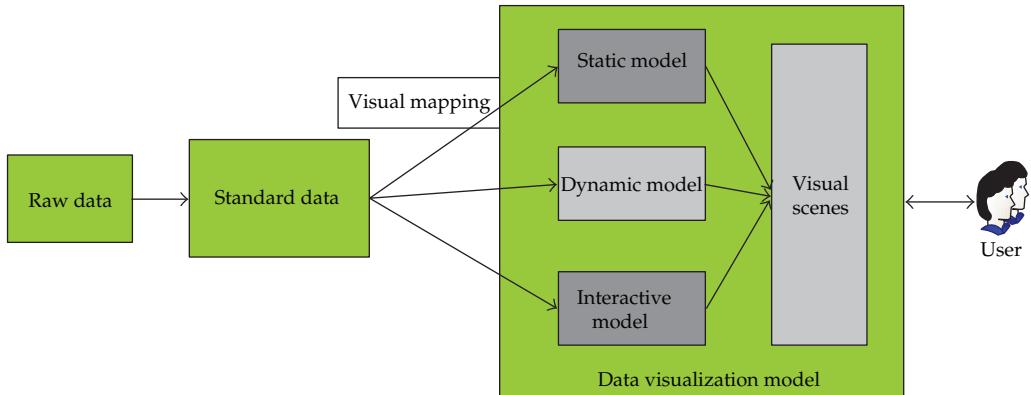


Figure 3: Visual workflow of SHM System.

The kernel of Visual Workflow in SHM system is visual mapping, as shown in Figure 3. There are three steps to complete the flow. In the first step, we input the preprocessed, standardized, and assessed data into the visual model DynaView. The visual model can map those data dimensions into the visual dimension. The critical step can produce the static submodel and dynamic submodel. In the second step, the visual model can also map the interactive information such as time lapse and interaction with mouse or keyboard into the interaction submodel. In the third step, all of the information of the three submodels is displayed in the visual scenes for users to examine and interact.

3.3.2. *DynaView: Data Visualization Model of SHM System*

OpenGL and Open Inventor is a real kind of mathematics state machine which can control the basic graphical programming. They can handle lots of mathematics computing in graphical problems. The developer and designer concentrate on how to build those visual scenes.

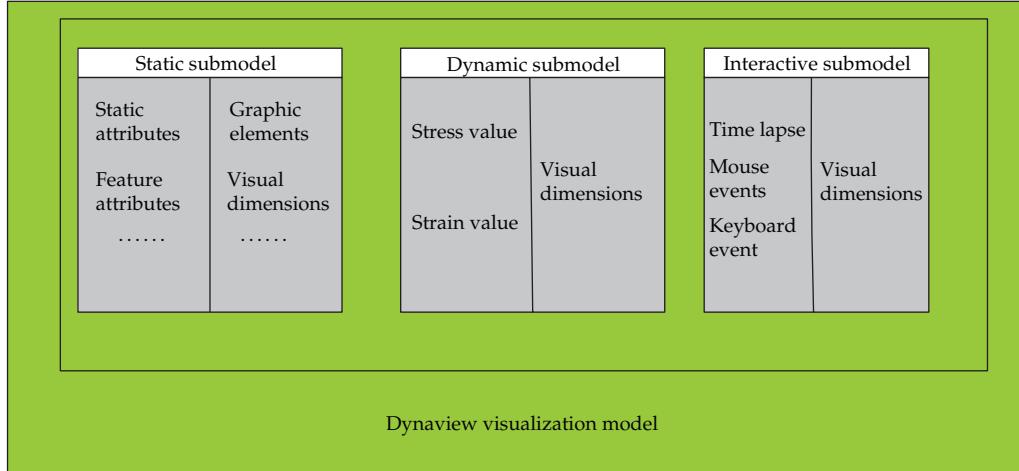


Figure 4: DynaView Visualization Model.

Although both OpenGL and Open Inventor provide the ability to produce lots of complicated dynamic and interactive visual scenes, those toolkits themselves can only provide the method or function of building and rendering the visual scenes. They do not provide the visualization models in special domain. It is necessary for the SHM professionals to build a sophisticated dynamic visual model to be fit for the SHM system.

DynaView, the Data Visualization Model of SHM System, is presented to solve the problem we met. It is shown in Figure 4. Firstly, DynaView model maps the static data dimensions to the basic elements of visual graphics such as cylinder, sphere, point, line, and surface. The DynaView model also maps the data dimensions to the elements' visual dimensions such as material, color, brightness, angle, transparency, and height. All the basic elements and their visual dimensions construct the static submodel. Secondly, DynaView model connects the motoring and computing data with those basic elements and their visual dimensions. The sampling data is changing with time lapse. All the assessed data derived from the sampling data are also dynamic changing. All those data construct the dynamic submodel. Lastly, DynaView model maps the user interactions into interactive model which provides the ability to receive and handle the user's interactive needs.

- (1) **Static submodel:** input data of this model is preprocessed sampling data. The submodel translates them into standardized modeling attributes. It abstracts the geometrical characteristics and maps them into the basic visual elements. It also builds the static visual scenes using visual dimensions such as points, lines and surface. At the same time, the submodel maps the structural attributes into the basic graphical elements' visual dimensions with detailed information. The static visual scenes are the visual mapping of the civil structures.
- (2) **Dynamic submodel:** input data of this model is the preprocessed and assessed changing data which can reflect the changing civil structures such as stress and strain. In order to construct visual scenes, those data are changed into standardized modeling attributes which can be mapped into basic visual elements and their visual dimensions. Because the sampling data is constantly changing, the standardized modeling attributes are dynamic data too. The DynaView model

Table 1: Load-deflection experiment data.

Number	Load (KN)	Test 1 (mm)	Test 2 (mm)	Test 3 (mm)	Test 4 (mm)	Test 5 (mm)
0	0	0	0	0	0	0
1	3.673	-0.0909	0.601	0.696	0.430	-0.0301
2	8.440	-0.1118	0.611	2.121	1.380	-0.0668
3	13.210	-0.1241	1.939	4.151	2.703	-0.1011
4	17.966	-0.1444	3.338	5.883	3.842	-0.1323
5	22.737	-0.1842	4.292	7.747	5.103	-0.1570
6	25.121	-0.2203	5.027	8.835	5.860	-0.1913
7	27.505	-0.2504	5.619	9.761	6.472	-0.2213
8	29.889	-0.2734	6.241	10.7	7.084	-0.2530
9	32.273	-0.3005	7.061	11.967	7.903	-0.2910
10	34.657	-0.3351	7.731	12.977	8.630	-0.3243

maps the dynamic data to the TimeSensor nodes which is provided by the toolkit. Those changing data make the scenes dynamic.

- (3) Interactive submodel: input data of this model is the interactive event information from mouse or keyboard. The model transmits the interactive event to the TouchSensor nodes and ProximitySensor nodes which are provided by the toolkit.

The user interactivity can be responded in the visual scenes.

When the DynaView model is built, it also needs Open Inventor toolkit to render visual scenes in the computer. The user can observe, translate, rotate, examine, and interact with the visual scenes in the ExamineViewer which is provided by the toolkit. The user can also watch the dynamic scenes on a regular Web Browser such as IE if the proper plugins are installed. The user can directly realize current health state of the civil structure and can interact with the visual scenes to get more information about the structure.

4. Experiments

4.1. Preprocess the Sampling Data

The experiment simulates that the reinforced concrete beam is pressed to concentrated load on the center of beam during the course of pressing. The experiment is completed in the Key Laboratory of Structural Engineering and Earthquake Resistance. As Figure 5 shows, Figure 5(a) is the structure of beam. Figure 5(b) is the load of the beam. Figure 5(c) is the distribution of testing point. The input parameters are as follows: f_c is compressive strength of concrete; f_y is the vertical steel area in the area of tensile; A_s is the steel in the area of tensile; f_y' is the vertical steel in the area of compression; $A_{s'}$ is the steel area in the area of compression. b and h are the broad and height cross-section.

The experiment simulates load on the center of beam's changing when every test point is pressed. The value of deflection and strain is concerned. All the experimental data are listed in Tables 1 and 2. Under the condition, the warning value of deflection and stain is 13.5 mm the former and $1550\mu\epsilon$ the latter. When the load is changing from zero to 34.657 KN, the values from 5 test point are recorded into the two tables. From the data, it is concluded that the value of deflection never exceeds the warning value, though the value of strain starts to over the warning value when the load is bigger than 29.889 KN.

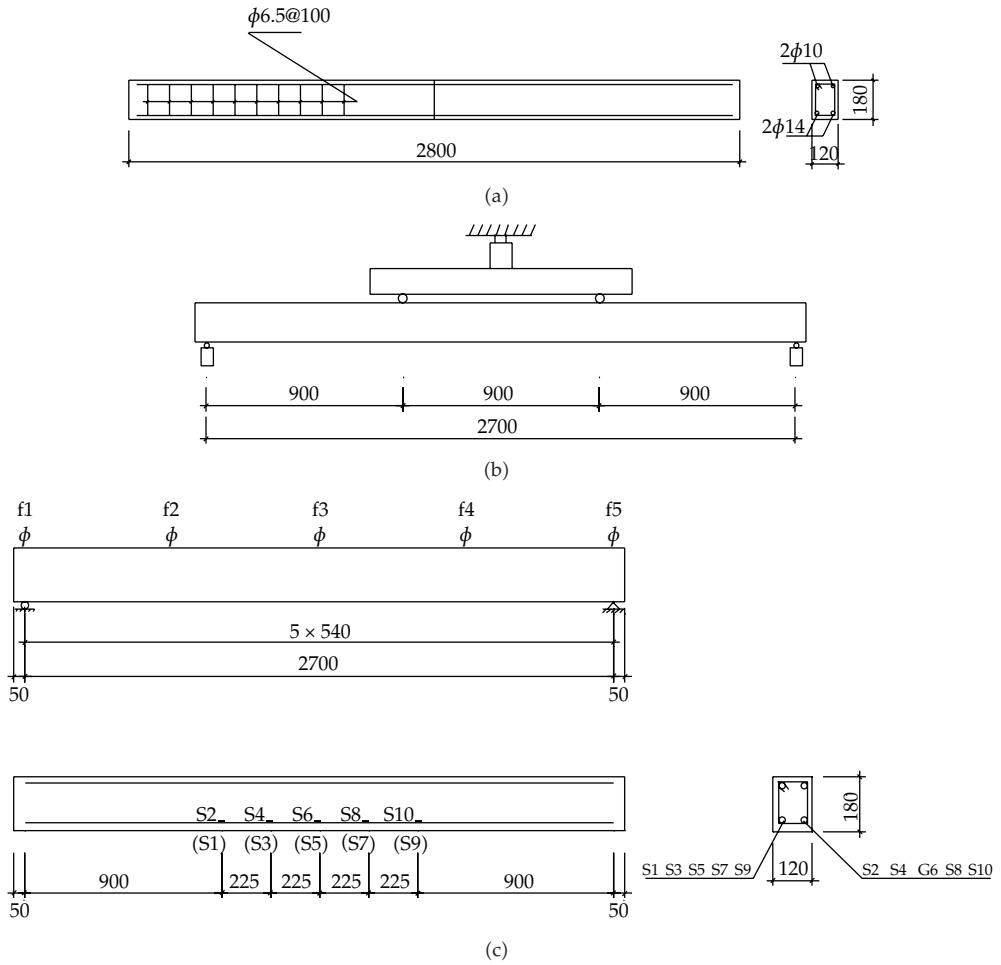


Figure 5: The experiment model of reinforced concrete beam.

Table 2: Load-strain experiment data.

Number	Load (KN)	Test 1 ($\mu\epsilon$)	Test 2 ($\mu\epsilon$)	Test 3 ($\mu\epsilon$)	Test 4 ($\mu\epsilon$)	Test 5 ($\mu\epsilon$)
0	0	0	0	0	0	0
1	3.673	60	94	55	72	62
2	8.440	272	327	304	332	251
3	13.210	562	653	613	653	558
4	17.966	767	895	850	883	817
5	22.737	990	1136	1122	1145	1082
6	25.121	1137	1298	1290	1310	1273
7	27.505	1260	1434	1431	1460	1399
8	29.889	1380	1571	1565	1595	1551
9	32.273	1542	1754	1785	1789	1738
10	34.657	1699	1925	1935	1956	1888

Table 3: Arithmetic mean value and standard deviation of four damage states.

	Health state	Little damage state	Moderate damage state	Severe damage state
Arithmetic mean value	22.6	46.8	64.5	73.9
Standard deviation	22.8	26.2	19.5	3.8

Table 4: Eigen values of three recognizing damage states.

	Arithmetic mean value	Standard deviation
Recognizing state 1	24.7	21.4
Recognizing state 2	36.1	24.6
Recognizing state 3	25.1	22.1

Table 5: The lattice degrees of nearness of three recognizing damage states.

	S_{HU}	S_{LU}	S_{MU}	S_{su}	Max
Recognizing state 1	0.9668	0.7703	0.2014	0.0864	0.9685
Recognizing state 2	0.9455	0.9388	0.7899	0.5011	0.9855
Recognizing state 3	0.9455	0.7211	0.2217	0.0744	0.9642

The formula $\sigma = E\varepsilon < f_y$ can compute the section's reinforcement stress value. E in the formula is a constant, and $E = 2.1 \times 10^5$ (Unit: N/mm²), while f_y is a constant too, and $f_y = 310$ KN. The sampling data such as deflection and stress are obtained in the experiment. Substituting both the two constants' value into the formula, we can get the value of the stress σ . Comparing the value with yield strength f_y , it is concluded that if the compared value is between 30% and 40%, the values are normal. The users must pay great attention to the abnormal values in case of the unexpected accidents.

4.2. Assessment of Structural Damage State

The experimental structure is shown in Figure 5. There are the arithmetic mean value and standard deviation of four structural states' eigen values in Table 3. The eigen values of three recognizing damage states are shown in Table 4. The lattice degrees of nearness with random state fuzzy sets of three recognizing damage states are shown in Table 5. All the data indicate that the assessment of structural damage condition based on fuzzy pattern recognition is effective and practicable.

4.3. Dynamic Visualization of the Experimental Structure

The experimental structure is shown in Figure 5. According to the experiment's structure, the preprocessing data, and the assessment information, we can build the dynamic model for the example structure.

- (1) The example static submodel: the experimental structure is a simplified reinforced concrete beam. We map the beam's structure into the graphical elements with Open Inventor hierarchical nodes to create the static submodel. As shown in Figure 6, a simple virtual beam is in the visual scene which is organized as a tree inside.

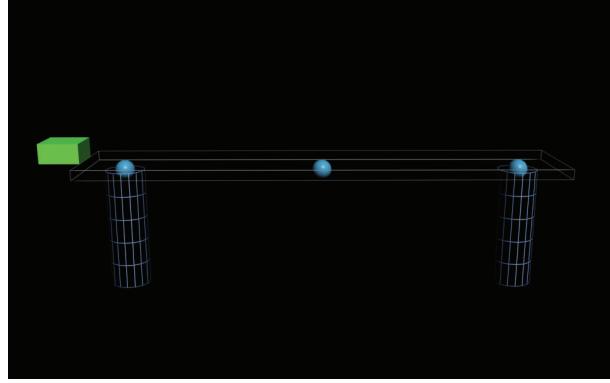


Figure 6: Static model of the experimental structure.

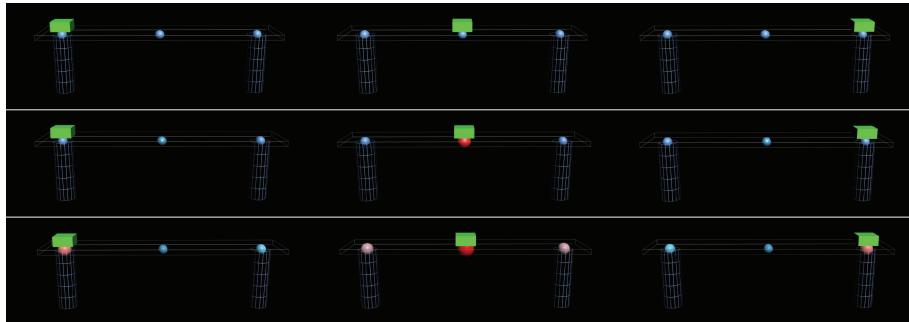


Figure 7: Dynamic model of the experimental structure.

- (2) The example dynamic submodel: according to the assessed information and damage state, we build the dynamic submodel. The various information and the changing state can also be mapped into the graphical elements with Open Inventor hierarchical nodes. Especially, the midspan load of the experimental structure is from one side to another. Its values change consciously with the characteristic of instantaneity. So we map the time lapse event into the TimeSensor node and complete the scene with ROUTE statement to get the dynamic scenes. As shown in Figure 7, a simple virtual dynamic visual scene which is organized as a tree inside is properly built.
- (3) The example interactive submodel: the experiment considers some simple user interaction such as dragging the load object (e.g., a car or something) from one side to the other side. Dragging interaction can be a direct and subjective operation for the users to get more information about the health state. The interactive submodel obtain the user's interactive event and handle it. After the interaction, the next scene is built. The events are mapped into the TouchSensor node or another sensor node with Open Inventor toolkit and ROUTE statement. As shown in Figure 8, a simple interactive visual scene which is organized as a tree inside is properly built.

We build DynaView model of the experimental structure, including the static submodel, the dynamic submodel, and the interactive submodel with the development environment VC++6.0 and Open Inventor toolkit. In fact, DynaView Model is a visual scene

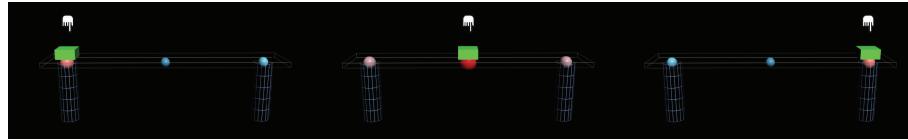


Figure 8: Interactive model of the experimental structure.

tree constructed by Open Inventor nodes. Users can observe the visual scenes in the inbuilt browser provided by Open Inventor. Users can directly examine and interact with the scenes, paying more attention to the structural damage state at any time.

5. Conclusion

A general and dynamic visualization model named DynaView is proposed. This model consists of static submodel, dynamic submodel, and interaction submodel. The raw data is from sampling monitoring data. The assessment method is an effective general and practicable assessment of structural damage condition based on fuzzy pattern recognition. We built virtual scenes with DynaView model and Open Inventor toolkit in VC++6.0. We implement the dynamic and interactive visual display in SHM system. Using the DynaView Model, users can directly examine and interact with the virtual scenes. User also can reconstruct the dynamic process of inner or outside changing on the structure. Although the experimental structure is a simplified reinforced concrete beam, the DynaView model is the base of handling complicated and large structure such as large bridge and large building. In the future, DynaView model also can provide more and more interactive ability for users to analyze the health states.

Acknowledgments

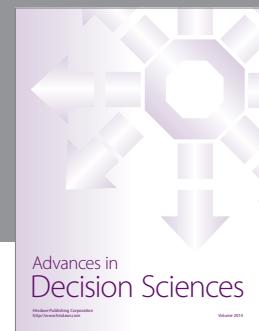
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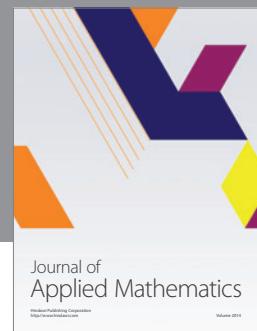
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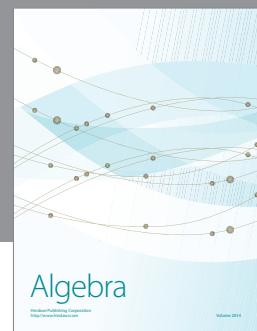
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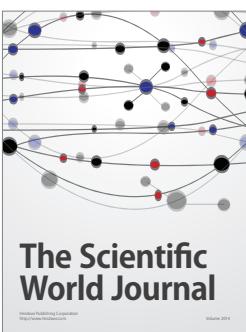
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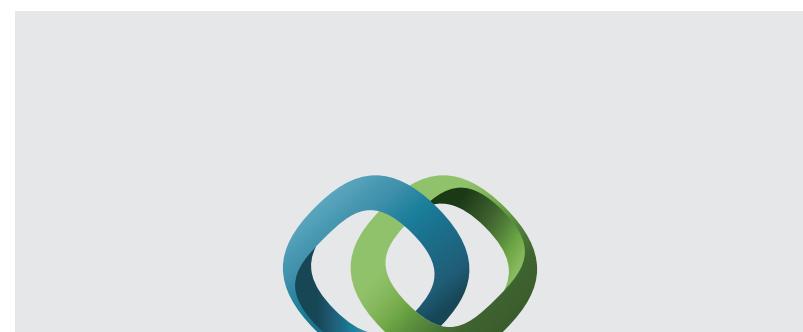
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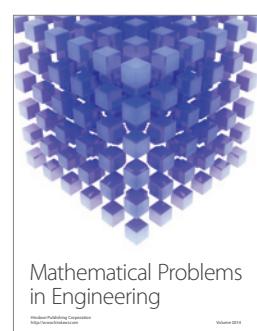
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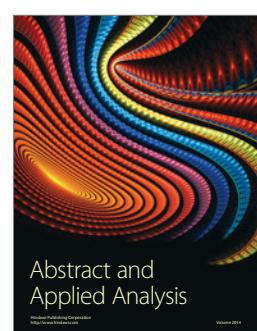
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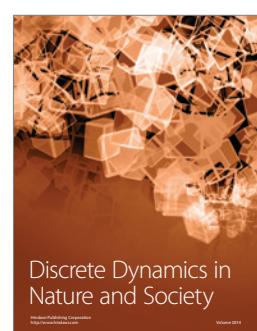
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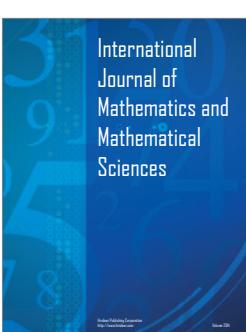
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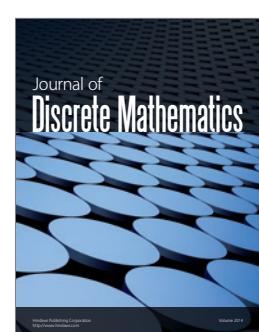
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