

# *Teaching Method Based on BIM Lightweight Visualization—A Case Study of Bridge Engineering Course*

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**Abstract:** In order to improve the teaching effect of engineering-related courses, the Building Information Model (BIM) visualization technology is introduced into the course teaching, and the lightweight of the structural model is realized with the help of the graphics rendering technology on the web page. BIM lightweight visualization technology based on web page provides a 3D model display method with easy to use, high efficiency and rich interactive forms, which not only effectively solves the problems of non-intuitive, lack of detail and less interaction in traditional teaching methods, but also overcomes the disadvantages of using native BIM model directly. This paper introduces the technical route and application scene of applying BIM lightweight visualization technology to the teaching of bridge engineering course, and gives some suggestions to improve the teaching effect based on practical experience.

## 1. Introduction

Building Information Model (BIM) is the product of the development of digitization and informatization of graphic tools. It has been widely used in the engineering construction industry all over the world because of its advantages such as visualization, parameterization, stimulability, optimization and so on. In order to improve the application level of BIM, countries such as the United States, Japan and Singapore pay special attention to the training of BIM talents in higher education, and have integrated BIM into traditional engineering courses as an auxiliary means. In China, BIM has become the main technical means to promote China's construction ability to achieve high-level industrialization, digitalization and informatization. In order to meet the national concept of new engineering training, higher education should conform to the needs of information and digital development and explore the innovation of curriculum teaching mode. The undergraduate course teaching should reform the teaching mode with the help of information technology represented by BIM. BIM in course teaching should achieve interdisciplinary joint application and effective integration. This integration will help to improve the teaching effect of specialized courses, improve students' BIM application level, and promote students to better adapt to the employment needs of the

information age.

Bridge Engineering is one core course of Road and Bridge Engineering and Road, Bridge and River-crossing Engineering. The course involves theoretical analysis and calculation, such as lateral load distribution and internal force calculation of the girder, which is highly theoretical; at the same time, the course is closely related to engineering practice. There are two common contradictions in the teaching of this course: (1) strong practicality of the course, but lack of practical conditions; (2) complex bridge structure, but lack of effective display means. These contradictions can be solved with the help of the three-dimensional visualization of BIM.

However, teaching applications which are directly based on the BIM native model have the following disadvantages: (1) Data redundancy; (2) High requirements of BIM ability; (3) High requirements of softwares and hardwares; (4) The modeling process is time-consuming; (5) Lack of interactions during teaching.

BIM visualization technology based on WebGL technology is a lightweight BIM model display technology<sup>[1]</sup>, which provides a convenient scheme for the visualization of BIM model. WebGL is a graphics library that combines JavaScript and HTML5 technology. It can realize the fast rendering of complex 3D geometric models in web pages by calling the underlying instructions of the GPU and is compatible with computers and mobile browsers, and has good cross-platform portability. Bian Genqing and Chen Weitao<sup>[2]</sup> implemented a network visualization scheme of BIM model based on WebGL technology and industrial foundation class (IFC) standard file format. This method significantly reduces the data amount of the BIM model, improves the detection accuracy of visual components, and achieves better loading efficiency and rendering effect on the Web. Zhang Jianzhong<sup>[3]</sup> realizes the function of scene management and model visualization based on 3D engine through the integration, transformation and lightweight processing of model and attribute information. Liu Jinghao et al<sup>[4]</sup> realized the integration and expansion of lightweight BIM operation and maintenance model on the web side by using Three.js and Cesium engine, and then opened up the whole process of data acquisition, processing and visual management in the process of railway operation and maintenance, and got rid of the dependence on large-scale commercial software.

## **2. The necessity and basic idea of lightweight visualization of BIM model**

The lightweight BIM model can be independently applied to a variety of information platforms without relying on commercial BIM software, which extends the application scenario of BIM visualization technology.

### **2.1. The necessity of lightweight visualization of BIM model**

Parameterized model is the basis of visualization, and "family" is the basis of parameterization. Different types of families contain different properties. The original data format of Building Information Model (BIM) contains rich information, including not only geometric model related information, but also material, physical properties, construction progress and quality management and other related information, resulting in a large volume of data files and slow reading and display speed. Some of the data belong to redundant data for the course teaching with three-dimensional visualization as the main purpose. The goal of BIM model lightweight processing is to reduce hardware system configuration requirements and to compress the volume of model data files.

In order to meet the needs of real-time interaction in course teaching and realize faster loading and rendering of data on the web side, the original BIM data files must be lightweight. This web-based lightweight visualization teaching method also provides an effective alternative for course teaching under the epidemic condition of large-scale infectious diseases.

## 2.2. The lightweight of BIM model and integration with teaching

The lightweight processing of the BIM model reconstructs and compresses the volume of the data file, which can significantly improve the loading and display efficiency of the model on the web page.

The lightweight processing of BIM model is accompanied by the conversion of data format, it is necessary to convert BIM native Rvt format files into industry foundation class (IFC) standard files, then convert IFC files into binary glTF format geometric data files and JSON format attribute information files<sup>[2]</sup>. Finally, these two types of files will be compressed together into lightweight data files by special algorithm (Data layer in Figure 1).

Among these graphic exchange formats, glTF is a 3D graphics format standard for real-time rendering applications; JSON is a lightweight data exchange format, which uses text format to record and store model attribute data, including geometric information, material and texture data.

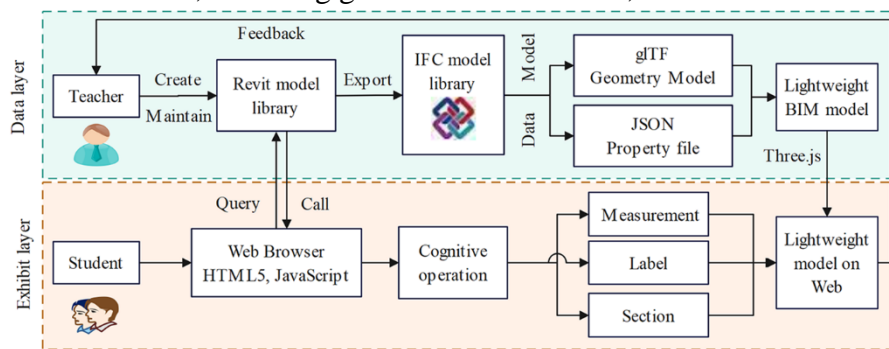


Figure 1: Web-based BIM model lightweight technology application roadmap.

Web graphics rendering can usually be accomplished with the help of WebGL graphics library or its extended graphics library<sup>[1]</sup>. As a 3D graphics library based on JavaScript language, WebGL provides hardware accelerated rendering function for web-side graphics display through JavaScript and OpenGL technology. The WebGL graphics library can provide interactive graphical display for web browsers. However, the application programming interface (API) of WebGL only provides the most basic graphics functions, and complex geometry can only be generated based on the combination of basic graphics. Programming directly based on WebGL requires users to master graphics and mathematical knowledge, so the workload of programming is relatively large and tedious. Three.js is a graphic library with system encapsulation and simplification on the basis of WebGL, using which users can deal with complex applications such as lighting, material, texture, scene, shadow and three-dimensional calculation, with less programming workload and higher usability. Therefore, Three.js can be used to realize the reconstruction and fast rendering of the BIM lightweight model on the webpage.

## 3. Application of BIM lightweight visualization technology in teaching

### 3.1. The basic process of applying BIM lightweight visualization technology

The application processes of BIM lightweight visualization technology in teaching are shown in Figure 1, which mainly include: (1) In the data layer, the teacher is responsible for the creation, maintenance and the lightweight transformation of the BIM model; (2) In the exhibit layer, students retrieve, browse and interact with the BIM model; (3) At the communication layer, communications between teachers and students will be carried out by the BIM model.

In the data layer, the bridge or component models involved in the course are created in advance by the teacher and added to the model library and retrieval list. On the web side, students retrieve the

model in the model library according to their learning needs and issue call instructions. The model is exported and converted to realize lightweight processing, and is displayed on the web page through a set of commands based on Three.js.

In the exhibit layer, students rotate, zoom and translate the model with the help of Three.js to achieve rapid rendering and display.

In Figure 1, the "cognitive operation" in the exhibit layer includes not only simple graphic rotation, scaling and translation, but also functions such as measurements, adding text labels, intercepting sections and walkthrough of the camera.

In the interactions between teachers and students, students' questions about a component can be marked in the corresponding position of the model in the form of question tags, and the questions are summarized into the "answer list" at the same time. When browsing the model after class, the teacher can see the questions left by all the students and the corresponding location index in the answer list. If the positioning of the corresponding structural part is added to the question, you can quickly locate the corresponding structural part by double-clicking the positioning index in order to make a targeted answer.

### **3.2. Application scenario of BIM lightweight visualization technology in teaching**

BIM lightweight visualization technology can be applied to the following teaching scenarios:

#### **3.2.1. Classroom teaching**

BIM lightweight visualization technology provides the function of three-dimensional real-time display of complex structures, which is helpful for students to form an accurate understanding of the details of bridge structure.

Teachers can quickly open the web page and access the associated BIM model by clicking the link in PPT, and show the details of the model to students through the rotation, scaling, measurement, profile and roaming function of setting the first-person perspective.

The long-span bridge has large external size and complex internal structure, so the structural details of the local structure can be displayed through the appropriate section.

For example, the two beam segments are located in segment 0# of the fulcrum section of the continuous beam, but the beam heights of the two segments are different and the internal structure is also different. The segment which is located in the side span fulcrum section has a lower height; while the segment which belongs to a fulcrum section of the main span has a higher height, and it is necessary to set a manhole to facilitate construction.

Through transparency processing, the arrangement of steel bars and embedded parts in concrete members can be displayed, as well as the internal structure of complex steel structures, which can accurately show the relative position relationship between concrete members and steel bars.

These auxiliary functions are very important for students to master the role of steel bars and prestressed steel strands in the structure.

#### **3.2.2. Group discussion**

##### **(1) Discussion at the structural component level**

During the group discussion, topic tags are set on the relevant structural component of BIM models, and students are required to view the components and participate in the discussion within a specified period of time. The final results or conclusions of each group are submitted in written form.

By analysing the content submitted by students, we can understand the degree of students' mastery of relevant knowledge, and also use students' participation and performance as the basis for course grades.

## (2) Discussion of bridge scheme

Since the BIM lightweight model can more intuitively show the details of the model and the construction process, the content of the group discussion is also more diversified. For example, geographic information system (GIS) software can be used to provide students with digital topographic maps, so that students can select and determine reasonable bridge schemes and related technical parameters based on the digital topographic maps. Students query and select the component types and parameters to be used in the BIM model library, and complete the assembly of the model based on the given terrain. Students who have the ability to learn are encouraged to independently create models through BIM software. Teachers can guide and assist students to complete modelling and lightweight conversion, and finally display the bridge scheme on the webpage. This way allows students to spontaneously review the knowledge they have learned systematically, which is conducive to consolidating students' knowledge and forming a knowledge system.

## (3) Construction simulation and collaborative creation

Virtual construction can restore the main construction process of the construction site, and a group of BIM models under time series can be used to show the development of the construction process. The students work out the construction plan of each group, determine the sequence of construction procedures and construction auxiliary measures, determine the state of the structure after the end of each process, and establish the BIM model in this state. The models corresponding to each time node are lightweight processed and uploaded to the database, and these models are displayed in a certain time order to reflect the construction process.

Collaboration is one of the core concepts of BIM technology. In the construction simulation, we should promote the team spirit and encourage the students to participate in the team creation, which can not only improve the teaching effect, but also cultivate the cooperation of the students.

### 3.3. Precautions in teaching applications

To ensure better teaching results in the application of BIM based lightweight visualization technology, it is necessary to pay attention to the followings:

(1) Teachers should collect students' feedback and suggestions on auxiliary tools in a timely manner by providing survey questionnaires or leaving a message book on the course homepage. Teachers should make timely improvements to the model library or operating interface based on feedback information.

(2) After the end of the course, the teacher systematically collates and analyses the usage data obtained from the web page, such as analysing the distribution of knowledge points with intensive difficult problems of students, analysing the solutions so as to make targeted improvements in the subsequent teaching, and analysing the continuous improvement plan in the BIM model database.

(3) Although the use of the BIM lightweight visualization model library significantly reduces the technical threshold and makes the teaching process easier to carry out, teachers should still encourage students who are interested in BIM and have spare time to try modelling themselves. During the modelling process, students can further familiarize themselves with bridge structures and improve the operational skills of BIM software.

(4) Teachers should coordinate the relationship between traditional drawings and lightweight BIM models. As future engineers, students still need to develop the ability to read traditional drawings while in school. Traditional drawings test students' understanding of structural construction, while lightweight BIM models can be seen as a tool to judge whether students' understanding is correct, and it is an expansion of traditional abilities.

## 4. Conclusions

The lightweight visualization technology based on BIM provides a comprehensive, multi detail, dynamic, and interactive digital model display that traditional blackboard writing, images, and videos cannot provide. The BIM lightweight visualization model provides a refined display of the model that runs through both inside and outside the classroom; The lightweight model-based web application platform provides a more effective way of communication between teachers and students, which can serve as a beneficial supplement to classroom teaching. As the main participants in the teaching process, students use the BIM lightweight visualization platform to discover, discuss, and receive answers in a more proactive manner. With the help of this platform, the role of students has shifted from traditional passive acceptance of knowledge to an active acquisition of knowledge, which will significantly improve teaching effectiveness.

The lightweight application of BIM is not a complete replacement for the native BIM model, but a supplement and extension. The advantages of lightweight applications lie in their low entry difficulty, convenience, high speed, and rich interactivity, which can be reflected in professional course teaching. However, the foundation of the lightweight model is still the native BIM model. Besides visualization, other core characteristics of BIM, such as coordination, simulation and optimization, still need to be mastered by students through BIM software and the native model.

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