Construction of a Virtual Reality Rail Transit Simulation System

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Abstract: The proposed virtual reality rail transit simulation system integrates 3D modeling with data storage and processing techniques, designed specifically to simulate conveyance environments. This approach improves both the operational realism of training simulations and enhances the development of future transit technologies, conveyance structures, and station scenarios in an effort to raise the calibre of staff training and technical research and development in the rail transit industry. Storing 3D models on cloud-based platforms enhances both data accessibility and the collaborative potential of rail transport simulations. By leveraging cloud infrastructure, simulations can be deployed across various systems, streamlining training and research in the field. This practical and effective tool for creating virtual reality content raises the bar for talent nurturing and R&D standards in the rail transportation industry.

Keywords: Data Set; 3D Modeling; Virtual Reality; Cloud Server

1. Introduction

According to the Ministry of Transport's 2022 Statistical Bulletin, China's railway operating mileage reached 1.55 million kilometers, employing approximately 4 million individuals [1]. The association's data indicates that 84% of the workforce in the sector is skilled, indicating a high number of professional and technical staff as well as a high technological content. The need for new professional and technical workers to be trained in the use of new technologies has increased due to the rail transport industry's fast expansion. The technical bottleneck preventing the sustainable growth of rail transit is caused by the technical training techniques' lag, which leaves both the manner and quality of training inadequate to fulfill talent development expectations. An efficient, high-quality, low-cost talent cultivation mode has become an urgent problem for the industry to solve [2]. In these situations, it is essential to teach new hires and current staff members on new technologies and cross-training using virtual reality rail transit simulation systems.

2. Research Foundation

The research foundation for this project includes the following professional technical capabilities:

1. User experience design, virtual reality hardware, and software technologies: Developing a virtual reality rail transportation simulation system requires a deep comprehension and command of these fields.
2. Familiarity with the rail transit field: In-depth understanding of the rail transit system requires a thorough understanding of its core parts, including its physical structure, signal system, communication system, and power supply system, in order to accurately reproduce them in the virtual simulation system.
3. Utilize computer technology to its fullest: create highly interactive and realistic simulation environments. Programming languages allow developers to create natural and fluid interactions with users while precisely controlling every detail of the virtual world. At the same time, cloud computing systems with high availability and scalability ensure smooth operation even when processing large amounts of data and complex situations.
4. Education and Training Knowledge: Learning content and learning methods should be designed specifically to meet their needs. Interactive teaching methods play a crucial role in enhancing the attractiveness of training. Virtual reality technology provides a completely new interactive teaching method,

which increases the interest and interactivity of learning for trainees while they practice in a virtual environment.

3. Research Methods

First, choose a realistic rail transportation scenario and concentrate on its benefits as the simulation object. Construct a new system, as shown in Figure 1.

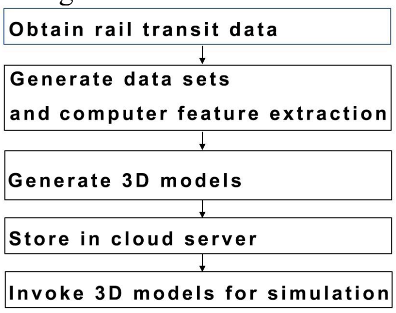

Figure 1. Flowchart of the VR Train Simulation Process

3.1 Rail Transportation Data Collection for Simulation

3.1.1Acquire conveyance operating environment, conveyance structure, and station scene data for rail transportation. This entails doing the following actions to gather conveyance operation environment, conveyance structure, and station scene data sets:

3.1.2 The 3D model creation process involves capturing the operating environment of rail conveyances through multi-perspective imaging. This data is then integrated into a detailed model of the conveyance structure and its environment, forming the basis for realistic simulation scenarios. This process aligns with common practices in 3D modeling for transport simulations;

3.1.3 To collect the conveyance's external structure data set, take pictures or videos of the rail transport conveyance's outside from various perspectives;

3.1.4 Take pictures or videos of the inside of the rail transit conveyance in order to collect the conveyance interior structure data set;

3.1.5 To acquire the conveyance structure data set, integrate the conveyance exterior structure and interior structure data sets;

3.1.6 To create the station's external scene data set, take pictures or videos of the station's outside construction from various perspectives;

3.1.7 Capture pictures or videos of the interior of the station to create the internal scene data set for the station;

3.1.8 To acquire the station scene data set, integrate the exterior and internal scene data sets of the station.

The process involves importing the conveyance operation environment, conveyance structure, and station scene data sets into a computer for feature extraction. This yields the conveyance operation environment model building data set, conveyance structure model building data set, and station scene model building data set.

3.2 Constructing a Convolutional Neural Network Model for Railway Traffic

3.2.1 Gather historical data on the conveyance operation environment, conveyance structure, and station scene for rail transit conveyances. This will yield sets of historical data on the conveyance operation environment, conveyance structure, and station scene; of these, the historical data on the conveyance operation environment, conveyance structure, and station scene are all image or video data.

3.2.2 Create a neural network with convolutions [3]. Typically, deep learning frameworks and programming languages are needed to build a convolutional neural network.

Steps to build a CNN model in TensorFlow:

1. Importing necessary libraries:
```
import tensorflow as tf
from tensorflow.keras import layers, models
```
2. Creating the model:
```
model = models.Sequential()
```
3. Adding the first convolutional layer:
```
model.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(224, 224, 3)))
```
In this step, a convolutional layer is introduced with 32 filters, each of size 3x3. The ReLU function is applied as the activation function, and the input shape is configured for 224x224 pixel images. The parameters like the number of filters and input dimensions can be customized as needed.

4. Inserting a pooling layer:
```
model.add(layers.MaxPooling2D((2, 2)))
```
Pooling layers are used here to reduce the spatial dimensions (height and width) of the feature maps.

5. Adding additional convolution and pooling layers:
Repeat steps 3 and 4 to stack more layers as required by your model.

6. Adding a fully connected layer:
```
model.add(layers.Flatten())
model.add(layers.Dense(64, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))
```
The model is flattened, converting the 2D feature maps into a 1D vector. A dense layer with 64 units is added, followed by the output layer with 10 units, where the `softmax` function is used for multi-class classification.

7. Compiling the model:
```
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
```
The model is compiled using the Adam optimizer, a commonly used choice for efficient training. The loss function, `sparse_categorical_crossentropy`, is suitable for multi-class classification tasks.

8. Training the model:
```
model.fit(train_images, train_labels, epochs=10)
```
The training data, including images (`train_images`) and labels (`train_labels`), is used to train the model over 10 epochs.

Figure 2. Steps to Build A CNN Model in Tensorflow

The implementation of convolutional neural networks (CNNs) follows standard practices, such as importing necessary libraries (tensorflow) and constructing the model sequentially with convolutional layers. For example, a model may begin with a Conv2D layer to capture spatial features from input data. These steps shown in the figure 2 are commonly employed in CNN architectures for feature extraction.

3.2.3 Using the historical conveyance driving environment data in the conveyance driving environment historical data set, the historical conveyance structure data in the conveyance structure historical data set, and the historical station scene data in the station scene historical data set, train and build a convolutional neural network to create a computer feature extraction model.

3.2.4 The conveyance structure data from the conveyance structure data set, the station scene data from the station scene data set, and the conveyance driving environment data from the conveyance driving environment data set must all be entered into the computer feature extraction program in order to extract features. As a result, the corresponding model construction data sets for the station scene, conveyance structure, and driving environment will be produced.

3.3 Creating 3D Models with Integrated Data Sets

Using 3D modeling software, enter the data from the conveyance driving environment model construction data set, the conveyance structure model construction data set, and the station scene model construction data set to create the 3D models of the conveyances, structure, and scene, respectively [4].

3.4 As Indicated in Figure 3, Save the 3D Models of the Conveyance Driving Environment, the Conveyance Structure, and the Station Scene as Virtual Reality Model Data on an Internet Cloud Server. This Involves Doing the Following Actions:

3.4.1 A conveyance driving environment model database, a conveyance structure model database, and a station scene model database are established by the internet cloud server.

3.4.2 The associated databases, referred to as the conveyance driving environment model database, conveyance structure model database, and station scene model database, respectively, house the 3D models of the conveyance driving environment, conveyance structure, and station scene.

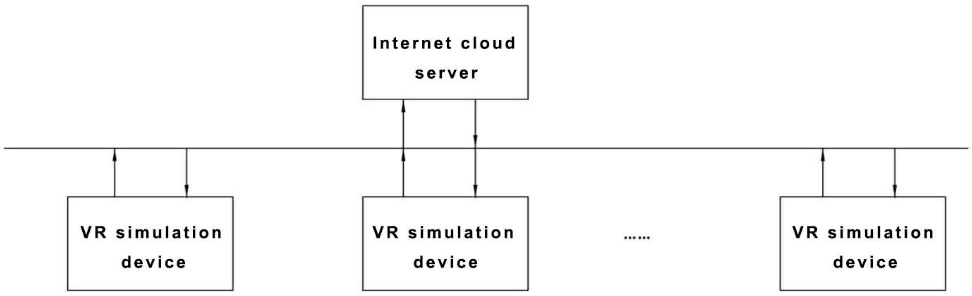

Figure 3. A Schematic Diagram of the Structure of the Virtual Reality Train Simulation System

3.5 The Virtual Reality Simulation Device Uses the JanVR Engine to Summon the 3D Models of the Station Scene, the Conveyance Structure, and the Driving Environment of the Conveyance from the Internet Cloud Server to Simulate the Rail Travel. The Actions Consist of:

3.5.1 The virtual reality simulation device can access the conveyance driving environment model database, the conveyance structure model database, and the station scene model database on the internet cloud server by obtaining the required access authorisation.

3.5.2 The virtual reality simulation device retrieves the conveyance driving environment 3D model, the conveyance structure 3D model, and the station scene 3D model from the corresponding conveyance driving environment model database, conveyance structure model database, and station scene model database.

3.5.3 The 3D models of the station scene, the conveyance structure, and the driving environment are created into numerous model files in the virtual reality simulation device [5].

3.5.4 The scene model is automatically constructed and rendered by updating the model files in the JanVR engine editor utilizing the various model files and exporting the model attributes to the JanVR engine. AI technology may automatically model around text or picture references throughout the modeling process. This is a contemporary way for creating computer vision rendering models that employ deep learning to do 3D rendering jobs [6].

3.5.5 By script editor to write simulation logic can achieve the control of scene model changes and environmental changes in the assembled scene, thereby achieving interactive and dynamic effects. Figure 4 is an example script to illustrate how to achieve such effects: The example code uses relevant libraries and modules of the JanVR engine to create a scene object and a scene model object, and adds the model to the scene [7]. The interactive and dynamic impacts of the model are then realized by looping through the process of updating the scene model's transformation parameters and rendering the scene after each update.

In accordance with their own requirements, users can add additional logic and functionalities to the script, such as the ability to change the model in response to user input and modify the ambient lighting in response to time. By writing simulation logic with the script editor, it is possible to flexibly control models and environments in the scene and achieve rich interactive and dynamic effects [8].

```
# Import necessary modules from janvr_engine and the random library
import janvr_engine
import random

# Initialize a new scene
my_scene = janvr_engine.Scene()

# Load a 3D model into the scene
my_model = janvr_engine.Model("model.obj")

# Add the model to the scene
my_scene.add_model(my_model)

# Main loop to continuously update the scene
while True:
    # Generate random values for the model's translation, rotation, and scale
    random_translation = (random.uniform(-1, 1), random.uniform(-1, 1), random.uniform(-1,
1))
    random_rotation = (random.uniform(-180, 180), random.uniform(-180, 180),
random.uniform(-180, 180))
    random_scale = random.uniform(0.5, 2)

    # Apply the random transformation to the model
    my_model.set_translation(random_translation)
    my_model.set_rotation(random_rotation)
    my_model.set_scale(random_scale)

    # Update the scene to apply the changes
    my_scene.update()

    # Render the scene with the updated model transformations
    my_scene.render()

    # Pause the loop for a short duration before repeating
    janvr_engine.sleep(1)
```

Figure 4 An Example Script

4. Project Application

To simulate the operation of a general freight train using a virtual reality railway simulation system, the specific method is to first obtain the structural data of the general freight train, obtain the railway line, track, station, weather conditions and other driving environment data, obtain the driver's cab, control lever, brake system, speedometer, accelerometer, signal system, communication equipment, train control computer, collision avoidance system, train data recorder, and emergency braking device data related to train operation, and then correspond to obtain the structural data set, environmental data set, and driving scene data set of the general freight train. Then, by feeding the conveyance driving environment, conveyance structure, and train driving data into the computer features for feature extraction, the corresponding conveyance driving environment model building data set, conveyance structure model building data set, and train driving scene model building data set are obtained. The appropriate 3D models of the conveyance driving environment, conveyance structure, and driving scene are then produced by feeding the data sets for the conveyance driving environment model, conveyance structure model, and driving model into 3D modelling software. Subsequently, the virtual reality model data for the driving scene, conveyance structure, and driving environment 3D models is stored on the internet cloud server. To finally access the conveyance driving environment 3D model, conveyance structure 3D model, and driving scene 3D model stored on the internet cloud server, the virtual reality simulation client replicates the operation of a standard goods train.

The virtual reality railway simulation system utilized in this project to model train operation is a safe and effective training approach that helps to develop the driver's abilities, safety awareness, and emergency reaction capacity. This is confirmed after the aforementioned procedure has been verified. It may be utilized for emergency situations, new driver training, and skill maintenance and improvement on a regular basis.

5. Conclusion

Computer feature extraction technology is employed to extract features from images or videos of the conveyance driving environment, conveyance structure images or videos, and station scene images or videos, and use the extracted features to build 3D models, which improves the efficiency of model establishment; and store the 3D model in the Internet cloud server, and use the client to extract the 3D model for railway simulation, which is convenient for providing 3D models for multiple user clients and greatly facilitates the professional learning and training of railway technology R&D personnel, engineers, technicians, and college students in the fields of railway virtual design, virtual operation, virtual driving, and virtual education.

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References

[1] Statistical Bulletin on Development of Transport Industry in 2022, Ministry of Transport. 2023-06.
[2] Li Wen. Qingdao rail transit industry meta universe vision into reality.www.qdcaijing.com.2023-05-08.
[3] Lohr Dillon;Aziz Samantha;Friedman Lee;Komogortsev Oleg V.GazeBaseVR, a large-scale, longitudinal, binocular eye-tracking dataset collected in virtual reality. Journal. Scientific data.Volume10, Issue1.2023.
[4] Zhao Zhengyang, Wu Yanhua, Cheng Zhibo, Wang Yunlong, High-speed rail track quality index prediction method based on 3D convolutional neural network. Railway Computer Application.2020,29(12).
[5] Umbra Software Oy; Patent Issued for Three-Dimensional Modelling With Improved Virtual Reality Experience (USPTO 10,290,144)Journal Information Technology Newsweekly. Volume, Issue . 2019. PP 5445.
[6] Wang Jing. Application research of virtual reality technology in 3D animation production. Digital Technology & Application. 2021,39(02).
[7] Xu Jiangming. The New Development and Deep Application of 3D Realistic Modeling Technology in the Field of Intelligent Transportation. China Security & Protection.2019(10).
[8] Lu Pin, Zhu Genxing. Design and implementation of 3D simulation system. Machinery & Electronics. 2003(02).

