Intelligent Tutor of Helicopter Flight Simulator

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Abstract
At present, helicopter flight training through helicopter flight simulator has become a necessary means, but most helicopter flight simulator does not have any automatic evaluation and tutoring facilities, which makes the students' learning efficiency low. In this paper, a general-purpose intelligent tutor for helicopter flight simulator is designed, and the key technologies of the relevant functional modules of the intelligent tutor are analyzed, and the results of facial expression, speech emotion and posture emotion recognition are fused by the quadrature rule algorithm to recognize the students' emotional learning state, and based on the Recurrent Neural Network (RNN), The answer confidence calculation model of Long Short-Term Memory (LSTM) realizes intelligent question and answer function. The intelligent tutor can help the helicopter flight teaching training and improve the helicopter flight training effect effectively.

Keywords: *Helicopter; Intelligent Tutor; Simulator; Affective recognition*

1 INTRODUCTION

Helicopter flight simulator is a kind of auxiliary simulator which can provide high efficiency, safety, economy and repeatability without the influence of natural environment, weather condition and time. It is a kind of complex ground simulation equipment, which is mainly used for helicopter pilot's flight driving training. The simulator can reappear the air flight environment, and is used for training pilots in such subjects as vertical takeoff and landing, hovering, climbing, turning, maneuvering flight and special flight, especially some dangerous training subjects which are difficult to realize by real-time aircraft. Difficult to deal with the special situation of the fault, etc. can be implemented in the simulator. Helicopter flight simulator has greatly reduced the cost of flight training by providing a cheaper and more effective alternative to training on live aircraft. It is a necessary means for pilot flight training, especially for beginners to improve their flight skills [1].

The results show that the teaching ability of the flight instructor is a very important factor affecting the flight training of the flight cadets. The traditional helicopter flight simulator usually uses the auxiliary analysis and evaluation ability, less has the specialized collection flight student study state and carries on the analysis and the quantification appraisal function. In view of the above question, we have designed a kind of general helicopter flight training intelligent tutor module, it can be embedded in the helicopter flight simulator each kind of whole mission, Collect the flight movements, facial expressions and attention focus of the flight trainees in some flight subjects, and combine with the scene of the flight training, analyze and evaluate the long-term and short-term flight skill growth of the flight trainees.

2 HELICOPTER FLIGHT TRAINING SIMULATOR ARCHITECTURE

The traditional helicopter flight training simulator consists of nine parts: helicopter flight performance simulation sub-system, cockpit simulation sub-system, scene sub-system, teacher control sub-system, computer and network sub-system, dynamic simulation sub-system, avionics sub-system, communication and sound simulation sub-system, auxiliary sub-system, etc. The helicopter flight simulator schematic diagram is shown in Figure 1. In the traditional simulator, we add a helicopter flight intelligent tutor sub-system, which is used to collect all kinds of data of the above sub-system function, and provide support for improving the flight skill of the flight trainees. The helicopter flight simulator system composition is shown in Figure 2.

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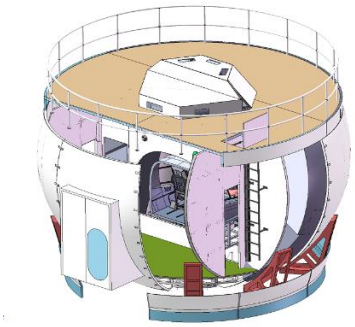

Figure 1: Chart of Helicopter Flight Simulator.

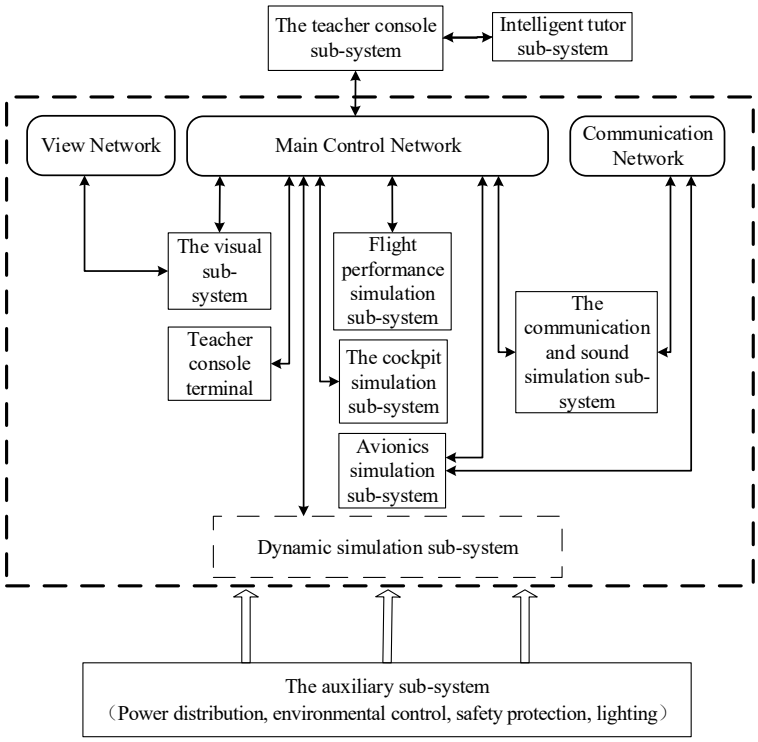

Figure 2: Composition of Helicopter Flight Simulator System.

The helicopter flight performance simulation sub-system mainly simulates the helicopter's flight dynamics through the real mathematical modeling of the simulated object, the algorithm of real-time calculation and the perfect communication interface of the periphery, and provides the realistic flight simulation for the simulator.

The cockpit simulation sub-system provides a realistic training environment for the flight cadets, including the simulation of the control components such as the cockpit cabin body, the cycle rod in the cockpit, the total range bar and the pedal, as well as various airborne equipment and data acquisition units, etc. The data acquisition unit provides dynamic control signals for the helicopter flight performance simulation sub-system and related sub-systems.

The visual sub-system is mainly used to provide realistic visual environment for flight trainees, including graphics computer, screen, image splicing unit, projector and terrain database, etc. It is used to provide realistic out-of-cabin simulated scene for pilots, to generate and display visual information needed for flight hover, takeoff and landing, low-altitude flight, weapon launch, attack and so on.

The teacher console sub-system has the functions of system operation monitoring, training setting, training process control, training process monitoring, training evaluation and information management. It can set up flight account, initial condition and fault state, real-time monitor, display and record flight process and result, so that the simulation flight can be carried out conveniently, quickly and orderly.

Computer and network sub-system is to connect the computer of each sub-system through the network, meet the real-time computer network communication requirement of the whole system of helicopter simulator, and realize the real-time and reliable data acquisition,

drive and exchange of all kinds of information data inside the simulator.

Dynamic simulation sub-system mainly simulates all kinds of low-frequency and intermediate-frequency motion of helicopter, such as simulation of atmospheric disturbance, landing gear/ wheel touchdown and ground effect. It provides the dynamic information of helicopter movement and the instantaneous acceleration and rotation feeling of the pilot's body to improve the fidelity of helicopter flight simulation.

Avionics simulation sub-system is mainly the simulation and real helicopter in the avionics architecture function consistent, can perform the same flight operation and control procedures, and maintain with the actual helicopter avionics system operation, logic, display information and other functional state.

The communication and sound simulation sub-system provides environmental sound simulation, alarm sound simulation and radio communication simulation. Simulates the helicopter's various sounds on the ground and in the air to give the pilot a sense of presence and help the pilot correctly judge the helicopter's flight status and working conditions.

The auxiliary sub-system mainly includes power distribution system, environmental control system, safety protection measures, lighting, boarding ladder, etc., which provides reliable power guarantee and system assistance for the operation of the simulator system, and environmental monitoring and so on.

Helicopter flight training intelligent tutor sub-system embedded in the teacher management and control sub-system and other corresponding functional systems, is a kind of realistic performance, strong perception, real-time operation, real-time response, rich emotion, high intelligence, can simulate the real flight teacher image and teaching function, can carry on language with the students, an agent model in which actions and so on interact. All the basic data information of trainees can be read from the collected basic database, and the relevant data can be analyzed and evaluated comprehensively for the trainees' flight training [2].

3 THE DESIGN OF HELICOPTER FLIGHT TRAINING INTELLIGENT TUTOR

The helicopter flight training intelligent tutor system designs the parameter acquisition module, the data reading module, the data analysis module, the learning module, the training guidance demonstration module, the subject evaluation module, the structural design schematic diagram as shown in Figure 3. Under the environment of intelligent tutor flight teaching and training, the teaching interaction based on "man and machine" has the advantages of big data, cloud computing and artificial intelligence, which can present more vivid pictures, mobilize students' vision and hearing, and the teaching and training system based on intelligent simulation can find a better learning path for students through continuous learning and iteration. Make its flight training effect become better, improve the student's learning efficiency. According to the characteristics of different trainees in the course of simulated flight training, the trainees will automatically complete the collection and setting of flight training subjects, individualize the guidance of flight training process, flight training operation assistance and evaluation of flight training results, and complete all the trainees' learning record and feedback of learning effect [3].

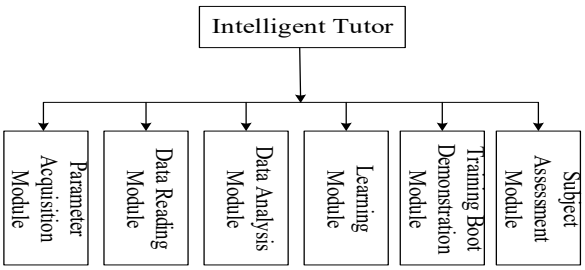

Figure 3: Structure design schematic diagram of intelligent tutor for helicopter flight training.

3.1 Parameter Acquisition Module

Through the signal sensor and signal conditioning module deployed in each sub-system of the helicopter flight simulator, real-time acquisition and collection of the flight trainees' facial expressions, flight movements, eye focal length, attention distribution, speech information and various performance data and environment equipment in flight training; real-time recording and collection of statistics trainees' training status (whether or not to master, Whether qualified or not, there is no doubt) and improper actions in the course of flight training; after filtering, isolating and protecting the data signal acquisition quantity, it enters the data acquisition card and automatically uploads it to the database of the main control network through the bus (DDS) acquisition system, forming the basic information database, which provides the data support for other functions of the intelligent tutor. Realize real-time, reliable data acquisition, drive, simulator inside all kinds of information data transmission and exchange.

The process of voice acquisition for students is as follows:

1.The voice signal of the trainee is collected by the audio acquisition equipment, and the speech signal is re-sampled, divided into frames and windows, and mute. The short-time single frame signal is obtained, and the n frame signal is x(n);

2.The frequency domain data are obtained by fast Fourier transform of x(n), the power spectrum of the

frequency domain data is obtained, and the Mel spectrum of the frame is obtained by using Mel filter bank.

3.The obtained Mel spectrum features are input into the constructed convolution neural network, the convolution operation and the pool operation are carried out, and the matrix vectors of the last layer are input into the full connection layer to form a vector output feature.

4.The output feature of the convolution neural network is compressed into one-dimensional eigenvector, and the one-dimensional eigenvector is used as input and input into the constructed two-way long short-term memory neural network for feature learning.

5.The output characteristics of the two-way long short-term memory neural network are input into the support vector machine for classification, in which the support vector machine selects the RBF Gaussian kernel function as the kernel, uses the grid optimization algorithm of grid search to find the optimal parameters, and outputs the final classification results.

6.Feedback the classification results to the teacher's console sub-system and use the participants in the simulated flight training as an application object to interact with the virtual learning environment.

7.Students' learning state-driven learning module, which uses the feedback of classification results, adjusts the teaching strategy in real-time to promote the improvement of learners' learning state.

8. The convolution operation includes that each filter of the convolution layer acts on a Mel spectrum graph, and uses the shared weight and bias characteristics of the convolution neural network to extract the local features of the spectrum graph, which is output after the convolution:

$$x_j^1 = f_c(x_i^{l-1} \otimes k_{i,j}^l + \theta_j^l) \tag{1}$$

x_j^1 represents the j-mapping set in the first convolution l, x_i^{l-1} represents the i-feature set in the l-1 convolution layer, $k_{i,j}^l$ represents the convolution kernel between the i-feature set in the l-layer and the j-mapping set, θ_j^l is the weighted offset, $f_c(.)$ is the activation function, $\otimes$ represents the two-dimensional convolution.

3.2 Data Reading Module

Data reading module uses B/ S mode structure to realize multi-path information reading, including speech recognition and feature extraction module, face image recognition and feature extraction module, action recognition and feature extraction module, emotion recognition and feature extraction module, prompt and alarm module, etc. The speech recognition and feature extraction module extracts the corresponding features through the deployed trained speech recognition model, real-time recognition of the students and teachers' voice information, and the face image recognition and feature extraction module recognizes the students' face information in real-time through the deployment of the face recognition model, and extracts the corresponding features to determine whether the students are training and learning status. The action recognition and feature extraction module can identify the students and teachers' action information in real time and extract the corresponding features through the well-trained action recognition model, and the emotion recognition and feature extraction module can recognize the students and teachers' facial expression information in real-time and extract the corresponding features through the well-trained emotion recognition model. The prompt and alarm module sends the corresponding prompt and warning information to the teachers and students, and the prompt is processed in time. The data reading module can extract all kinds of state characteristic data recorded in the whole process of flight training in real-time, and send them to each function sub-system through the teacher's console.

The core of this module is the recognition of students' facial expression, voice emotion, posture and so on. The results of facial expression recognition, speech emotion recognition and posture emotion recognition are fused by quadrature rule algorithm, and the final recognition results are identified emotion state, face expression recognition result P(Mj|S), speech emotion recognition result P(Mj|I), and posture recognition result P(Mj|W), quadrature rule algorithm:

$$\begin{cases} P_j = P(M_j \mid S) * P(M_j \mid I) * P(M_j \mid W) \\ 1 \le j \le 7 \end{cases} \tag{2}$$

For each emotional state, the result of facial expression, speech emotion recognition and posture recognition are multiplied, and the result Pj, the probability that the fusion result will belong to j emotion state, P1 and P2 are selected. The maximum of the results in P7 is the result of multi-modal recognition of facial expression, speech emotion recognition and posture recognition.

3.3 Data Analysis Module

The data analysis module can be used for automatic diagnosis, improvement of training subject formulation, re-test, progress monitoring, examination results and report evaluation through comprehensive analysis of the extracted data information. We can analyze and judge the theoretical knowledge and skill level of each trainee, adjust the difficulty level of the flight training task in time to provide teaching help, automatically feedback to the teachers and trainees, and provide the corresponding training content customized according to the students' learning needs. The module is used to analyze all kinds

of data of simulated flight training, to distinguish the difficulty degree of flight training task, to adjust and modify according to the behavior of analyzing the effectiveness of the trainees, to provide the basis for the teachers to master the learning situation and flying skills of the trainees, to evaluate and analyze the teaching quality of the instructors according to the optimization theory, to improve the teaching design, to assign the flying practice, To improve the quality of flight training for trainees.

The core of this module is to adjust the teaching parameters of virtual tutor according to the result of multi-modal identification, which includes that if the actual learning state is determined to be qualified learning state, the teaching parameters of virtual tutor will remain unchanged, if the actual learning state is determined to be unqualified learning state, According to the body movement information and facial features information in the course of the target learner's response to the course's explanation of the action and/or the course's questioning action, the value of the target learner's learning concentration evaluation Z is determined, as shown in the formula (3). Then according to the value Z of learning concentration, adjust the teaching parameters of virtual tutor.

$$Z = \frac{\alpha(\frac{1}{5}\sqrt{(Y(j)(1-\overline{Y})^{n-j})^2} + \frac{3}{5}\sqrt{(K(j)(1-\overline{K})^{n-j})^2})}{T} * e^{-n\frac{Y}{MSE(Y)} - n\frac{K}{MSE(K)}} \quad (3)$$

In the above formula (3), T represents the preset time period, n represents the total number of selected time points in the preset time period T, Y(j) represents the target learner's corresponding body gesture value at the first time point j, $\overline{Y}$ represents the target learner's average body gesture value at the preset time point T,and K(j) represents the target learner's corresponding facial quintuple displacement value at the first time point (j). $\overline{K}$ represents the average face-to-face displacement value of the target learner in the preset period T, α represents the cumulative value of the target learner's history learning, MSE(Y) represents the mean square difference corresponding to the body posture value, MSE(K) represents the mean square difference corresponding to the face-to-face displacement value, and j = 1,2,3, etc. According to the interactive action information, interactive sound information n learning concentration value Z, adjust the virtual tutor's teaching content, teaching method, language and other parameters, and carry out intelligent learning to optimize the output results.

3.4 Learning Module

Students begin with a very easy-to-fly course and evolve into a near-real complex aerodynamics model. For example, junior cadets may be able to control the helicopter by making larger, impulsive movements, while skilled cadets are better able to control the helicopter's posture. The learning module automatically adjusts the control state of the training program and allocates the flight training time and the energy needed by the trainees in different task subjects. The instructor can upload the theory, text, demonstration, animation and other teaching resources of the flight subject into the system database, the trainee can master the flight action essentials and basic theory knowledge of the flight training task in advance through the intelligent terminal before the flight preparation; there is no difficulty and key content in the simulation flight training. Aiming at the individualized difference of students' learning ability, intelligent push needs to strengthen and improve the training content and provide differentiated learning service [4].

The core of this module is to realize VR/MR display control. Students interact with flight simulator by using VR/MR display equipment. VR/MR display control module is also used to set up virtual hand model according to students' real hand model trigger, and project virtual hand model into VR/ MR display device, including: infrared sensor module, which is used to sense gesture information of real hand model, and judge the execution action of virtual hand model according to gesture information; gesture synchronization module, It is used to recognize gestures performed by real teachers on 3D virtual teaching aids and to synchronize gestures to other VR/MR display devices; the voice synchronization module is used to collect speech information from real teachers and synchronize voice information to other VR/MR display devices.

3.5 Training Boot Demonstration Module

The training guidance demonstration module makes it easier for junior trainees to fly a helicopter, just like a bicycle's auxiliary wheel, to dynamically adjust the flight model and guide the trainees to complete actions consistent with the helicopter's condition. Before the trainee carries on the independent operation, may carry on the demonstration guidance to the current training subject, in the key node enters the key prompt, for example, in the flat flight mode needs to turn, the prompt where turns, the deflection how many degrees and so on; In the trainee training process, the real-time monitoring helicopter performance status, when the trainee flies out the specified flight parameter range, for example, the tilt angle is too big, the speed is too fast, Highly advanced, the intelligent tutor will remind the trainees in the form of words, pictures or sounds, and provide real-time feedback to the trainees' operational control activities to help them complete their flight training tasks. In the process of flight training encountered difficulties, real-time communication and communication with intelligent tutor, timely realization of such functions as answering questions and correcting errors, collect and automatically

prompt and correct errors, break the traditional mechanical boring simulated flight training mode.

The core of the training guidance demonstration module is to be able to realize intelligent Q&A, which is mainly based on the RNN and LSTM answer confidence calculation model, input the Q&A to the eigenvector, measure the matching degree of the Q&A pairs by the model, convert the highest score to output, or construct the expert Q&A data by manual collection. The specific steps are as follows:

1.Collect and construct the data set of question-and-answer in specific field, and preprocess the question-and-answer pairs.

2.Construct a two-way long-term short-term memory condition with BI-LSTM-CRF model to carry out semantic analysis and feature extraction of question-and-answer pairs, and realize word segmentation and sequence tagging of statements;

3.Construct an answer confidence calculation model based on long short-term memory LSTM network, input the question-and-answer pair eigenvector, measure the matching degree of the question-and-answer pair by the model, and convert the answer eigenvector with the highest score into output;

4.Build virtual learning environment based on virtual reality technology, build intelligent Q&A engine, introduce training deep learning Q&A model, and construct virtual learning environment based on intelligent Q&A;

5.Get the question-and-answer data through the network artificial collection way, construct the question-and-answer data set of specific field teaching;

6.The pre-processing of question-and-answer pairs is first to re-emphasize the collected question-and-answer pairs, and then to eliminate the random and unanswered data, and finally to get the standard question-and-answer data, then to use the shallow neural network Word2Vec to calculate the conditional probability of the sentence sequence, and to embed it and train and calculate the word vector model.

7.Semantic analysis and feature extraction of question-and-answer pairs, including the following steps:

(1) The BI-LSTM-CRF model is tested by using the standard question and answer data and word vector model obtained from step 1 above;

(2) The problem text sequence X=(x1, x2,...xn) that will be quantized. Input to the trained network model, BI-LSTM synthesizes the relevant information of the words before and after, CRF considers the relationship between the output tags, and after the model participle tagging, the text sequence X corresponds to the tagged sequence y = (y1, y2, ...yn) The predicted output is:

$$s(X,y)=\sum_{i=1}^{n}(A_{y_i,y_{i+1}}+P_{i,y_i}) \tag{4}$$

Among them, A is the state transition matrix, P is the output matrix of BILSTM network, $A_{i,j}$ represents the probability of transition from the i-state to the j-state in time series, $P_{i,j}$ represents the probability that the i-word in the input observation sequence is the j-mark.

8.By using the LSTM network-based answer confidence calculation model, the candidate answers are ranked with confidence, and the answers with low confidence are deleted, and the optimal answers are selected.

9.Using the confidence calculation method of harmonic cosine similarity and CosEuclid distance to calculate the matching degree of the answer, the confidence cosine and harmonic cosine similarity of the answer and Euclidean distance are respectively:

$$Score_{\cos ine}(V_Q,V_A)=\frac{V_Q\cdot V_A}{|V_Q||V_A|} \tag{5}$$

$$Score_{\cos ine}(V_Q,V_A)=0.5(V_Q,V_A)+0.5 \tag{6}$$

$$Score_{\cos ine}(V_Q,V_A)=\frac{2Score(V_Q,V_A)\cdot Score_{Euclidean}(V_Q,V_A)}{Score_{\cos ine}(V_Q,V_A)+Score_{Euclidean}(V_Q,V_A)} \tag{7}$$

V_Q and V_A correspond to the text vector sequence of the answer respectively, and the formula (6) normalizes the cosine similarity to the [0,1] interval.

10.According to the specific actual teaching situation, create the virtual tutor and trainee who can carry on the human-computer interaction, configure the corresponding question-and-answer script program and function for different roles in the simulation flight training; and connect the constructed model with the corresponding specific teaching training content through the intelligent question-and-answer engine, and realize the intelligent question-and-answer function.

3.6 Subject Assessment Module

After the training is completed, the intelligent tutor will provide evaluation feedback and review. There are two main ways of this feedback: the performance summary evaluation report of the training subject and the playback of the training process. Training results summary evaluation report, show the following results: First, the training subjects the best five content; Second, in the flight training process to do the worst five things; Third, the need for students to improve the flight skills of the key content. The replay of the training process allows the trainees to look back at all the movements of the helicopter during the flight training process and visually see the changes that have taken place. The module can also be used to carry out the test of the simulated flight subject, and the evaluation module can make statistical

analysis according to the large data of all the flight training information and the main features extracted, and form the summary report of the flight training for each cadet, and give some suggestions for the improvement of the follow-up training, and evaluate each cadet's learning status and flight skills intelligently [5].

4 CONCLUSIONS

Intelligent tutor is an important application of artificial intelligence technology in the field of computer-aided helicopter flight teaching and training. The results show that the intelligent tutor of helicopter flight training can be used in the program training of helicopter junior students. The intelligent tutor realizes one-to-one teaching guidance, which makes the students master the time of teaching program training obviously.

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