Low Cost Helicopter Training Simulator
A Case Study from the Brazilian Military Police

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Abstract—This work describes a computer based training system to assist the crewmembers to learn the ground school of helicopter AS350-B2, manufactured from HELIBRAS, a brazilian helicopter company and widely used by the Armed Forces, Civil and Military Policies and beyond companies of executives transport and load transport. The training system consists of a 1:1 scale aircraft cabin simulator, a tutoring system software and a MS Flight Simulator interface. The project is in advanced phase of development and already it possess positive depositions of responsible interested parties for the sectors of training of the companies and institutions that operate the aircraft. A case study from brazilian Military Police is presented.

Keywords-simulator; computer based training; hipermedia training system; pilot training

I. INTRODUCTION

This paper reports studies involving the integration of hardware and software simulation to analyze and demonstrate the true AS350-B2 helicopter movement behavior, as fig. 1.0, during normal flight situations using computer algorithms so that they can faithful portray the helicopter instruments together with the external environment where it passes through.

![The AS350-B2 helicopter.](image)

Figure 1. The AS350-B2 helicopter.

There are many flight simulator programs in the market, MSFlight Simulator perhaps is the the most common, although to be considered a game, simulates the helicopter flight and the traffic environment very well. However in computer based training flight simulators, there are more important requirements, for example, to supply specific training and to represent faithful the behavior of a special helicopter to be used in the instructions and training of new pilots.

Thus, the study of the control attitude and behavior equations of the helicopter flight, become basic for the project of a helicopter simulator.

II. THE NECESSITY

The necessity of an helicopter flight simulator, for groundschool training, depends on human factors and economics, since the more time the pilot pass in the aircraft systems training that it goes to work, better the training quality.

The economy it is possible to obtain with the use of computer in the training from tutorials, exercises, tests and simulations of the behavior of the aircraft.

Generally the govern, companies and institutions that use helicopters train its pilots, initially, in simpler aircrafts and, after an amount of flight hours, they start to flight as copilots in the aircraft where they will go to work.

The Military Police of São Paulo - PMSP, for example, trains its future pilots in this manner, and it takes to one high cost with the formation of pilots and high time so that they can be completely apt to the command of the helicopter.

As much the government as the private companies, there are the search for economic and safer forms to train and to form pilots. The training in simulators can diminish the expense to teach a pilot, since that the best schools of helicopter pilot training, charges R$ 75,000.00 for training a pilot. This value could be diminished with the use of simulators optimizing the time expense in its training.

Beyond the civil use in the transport of executives and professionals and cargo, in Brazil it has a great necessity in defending oil reserves in sea and its borders in the Amazonian forest. Having this in sight, the government has planned a great program to bring up to date and to improve its Armed Forces, planning to buy and to construct equipment.

The Helicopter Simulator will be able at the same time to bring little expense and more time of training to the pilot and in diverse situations of training in all environments and with all risk that it can find during this work.
III. DEVELOPMENT

To represent the helicopter behavior mathematically, a research work in articles, books and manuals was carried through and some of the results are presented in the next sections [1 and 2].

A. The helicopter

To understand the helicopter behavior, it is necessary to know its structure in order to analyze the main decisive external and internal factors for the success of its movement, such as drag, aerodynamic pressure, relation referring weight-power and other characteristics that will be cited later.

Based on these knowledge, to detail the mathematical equations for its sustentation in flight. In fig. 2.0 a notion of the main components of a helicopter can be had [3].

The “Rotor” is the responsible mechanism for keeping the sustentation of the helicopter and is composed for the rotating set connected to the engine. Its control, together with the “swash plate” allows the change of the angle of attack of the rotor blades, this change in the angle makes possible the movement of the helicopter for front, backwards, for the sides and top, as figure 3.0.

As well as in the airplanes, the “Synchronized Elevators” are capable to keep the aerodynamic stability of the flight, being hindered that the helicopter if inclines for front or stops backwards.

B. Control equations

There are so many factors to influence the movement of the helicopter, between them: lateral wind, weight, sustentation force and reached maximum speed, can faithful be calculated by some mathematical equations, as it can be observed in fig. 4.0.

\[
\begin{align*}
X_E &= \frac{F_n}{2} \rho \pi R^2 \cos \theta_p \cos \psi_h \\
Y_E &= \frac{F_n}{2} \rho \pi R^2 \sin \theta_p \\
Z_E &= \frac{F_n}{2} \rho \pi R^2 \cos \theta_p \sin (\psi_h)
\end{align*}
\]

When \(X_E, Y_E, Z_E\) represents the speed in the axis X, Y and Z.

\(F_n\) is the sustentation force generated by the rotor \(\beta\) in the air density,

\(A\) is the disc total area = \(\pi R^2\)

\(V\) is the disc speed

\(\theta_p \epsilon \psi_h\) are the attack angle of the rotor blades and tail rotor respectively.

Using the characteristic data of aircraft AS350-B2 it is being possible to adapt the equations to this specific model of helicopter and to set into the SDK of the MSFlight Simulator to supply a feeling very next to the real behavior of the aircraft in diverse situations of flight.

C. The computer based system software modeling

According to recent research literature and, despite being a universal concept, the adoption of systems for computer-based training is still often inadequate and inappropriate. However, there are already work in this field [4-5], directed the training of the various sciences of knowledge.

One of the most recent is the work of students from the Federal University of Itajubá in conjunction with Ecole Nationale d l'Aviation Civile - ENAC in France, who developed and implemented a system for interactive helicopter simulation based on computer [6].

The Computer Based Systems have been designed under the basic guidelines to provide students an equipment for training based on computers, advanced, allowing the practice of the learning activities effectively, and enabling them to carry out their activities in real time, this through familiarity with the various integral components of the matter, whereas under normal conditions and disorders with possibilities of occurrence.
The software developed with the tutorial is to serve as a tool for support and guidance to students in the process of training through the training system, and is related to the occurrence of events that include drawings, graphics and animation when necessary.

The subjects dealt with in tutorials are in accordance with the manuals provided by the company, and address various issues.

Figure 5.0 presents the use cases, which explain the interactions of the student and instructor with the training, including evaluations and simulations. The tutorial has several interactions with the student, the guardian and administrator.

In modeling the system was used UML (Unified Modeling Language), a language completely extensible, adaptable and easy to understand, which uses a graphical notation with a widespread pattern and with different levels of abstraction [6].

The tool used to make the modeling is JUDE (Java and UML Developers Environment), created with Java. With it is possible to model complex, but it is easy and intuitive to use and present data to the user a clear [7].

The process for conducting software development tutorial, oriented to objects is complex and is formed by a series of activities for various repetitive elements [8].

In general the analysis of the system based on a high level of abstraction, is designed as follows:

- The planning and specification of requirements, which were detected in cases of use, enabling the achievement of the requirements of the system and creation of scenarios and

Construction, which includes two phases: the analysis of the problem and design. In the analysis, identify concepts, associations and attributes, and with them, the diagrams are constructed of activities, sequence and state of the system.

They define the dynamic behavior of the system. Already in the design, it produces the diagram of classes, which defines the static structure of the system.

UML uses activity diagrams to the modeling of dynamic aspects of software, which involves the modeling of sequential steps and/or competitors in each of the subsystems.

In the activity diagram shown in Figure 6 is made to model the flow of the system, as it passes from one state to another at different points of the flow of control.

The sequence diagrams of models for the software, is for the interactions that emphasize the structural organization of the various objects involved in it. Figure 7.0 represents the interaction of a user "Student" with the tutorials.

The class diagram modeled in this paper gives a static view of the software tutorial. The training system, the main class has four classes depending on it (for which you create a relationship of dependency): "Tutorial", "Register", "assessment" and "Simulation".
For Class "Tutorial", have the relationship of generalization with the types of tutorials, which means that each subclass is a kind of tutorial class, which is shown in Figure 8.

![Class diagram](image)

**Figure 8. Class diagram.**

### D. The simulator

Taking in consideration the knowledge acquired with the analysis of the structure of the helicopter as well as the mathematical study made on the basis of the relative data to the instrumentation of flight, a three modules Pilot Training System was developed:

- **Simulator Module**, represents the cabin of the helicopter in scale 1:1 and represents the existing instruments in the AS350-B2 control panel as well as the commands of flight (cyclical, collective, throttle and anti-torque pedals) beyond allowing the pilot, the visualization of the external scene to the aircraft, as fig. 6.0.
- **Interface Module**, using the FSUIPC.DLL extension allows that external programs can communicate e, of form limited until, to control the MS Flight Simulator [4].
- **Tutorial Module**, that presents, in hypermedia format and JAVA language, all the related theory the pilotage and functioning of the electrical systems, fuel and hydraulics of the aircraft beyond exercises, tests of knowledge and simulation of normal and abnormal situations that can occur in flight.

The integration of the developed instruments of components in Java language developed previously [9,10], with the MS Flight Simulator supplies the necessary degree of authenticity to the correct representation of the flight [11,12,13] of AS350-B2, allowing the perfect representation, virtual, of the existing instruments of the cabin displays in the panel as well as the representation of the external scene from a multimedia projection.

The flight control of the helicopter is made from two joysticks, especially developed and adapted, the cyclical command and the collective command and of the anti-torque pedals for the control of the tail rotor.

The Tutorial Module, as fig. 7.0, was developed from existing information in the pilots and maintenance manuals, beyond information supplied for the proper pilots [14,15], having also used resources of text and presentation of figures of languages JAVA, HTML and representation of animations supplied for the tool Adobe Flash.

![Screen of tutorial on the fuel system](image)

**Figure 10. Screen of tutorial on the fuel system.**

In the direction to make with the information are easily assimilated, the tutorial account with specific areas for texts with theory and figures regarding what it is in study, areas with locutions to strengthen the focusing the studied object, as well as animations being represented the functioning and/or known imperfections that occur in the helicopter subsystems in study.

The Tutorial Module must be the first one to be used by the pilot during the training process, and presents the following functionalities:

- Tutorials on the electrical systems, hydraulical and fuel of the helicopter;
- Exercises turning on the subjects studied to the end of each chapter of the tutorial;
- Simulations of emergency situations in some of the described systems previously and that they modify the flight conditions of the helicopter; and
Evaluation and control of the pilot interaction with the simulator, controlling time and instruments used to solve the situations.

Figure 11. Administration of the tutorial one.

All interaction of the student with the tutorial is stored in data base and controlled for a system administrator, as fig. 8.0, whose main easinesses are:

- Register of users who can be: the proper administrator, a professor (pilot or engineer of flight) or a student (pilot in formation or mechanic);
- Information management, being able to be: tutorial, simulation or animation of flight instruments;
- Monitoring the evaluations, supplying information on the strong and weak points of each student in relation what it was studied.

IV. CONCLUSION

This article presented a simplified study of the helicopter movement equations, the use of these equations to simulate a specific helicopter behavior, the analysis and modeling of low cost Computer Based Training System using UML programming language, using the tool JUDE (Java and UML Developer Environment) and the system implementation and tests.

The methodology adopted in developing the software tutorial was based on the modeling of the training system, and was presented the case software developed for the AS350-B2, taking into account the planning and specification of requirements, analysis and design of the system.

That was considered the diagrams to build the model of the system, both with the interaction of the actors found in the analysis, as to their responsibilities and duties.

In the current state, the Computer Based System has showed the interest of some pilot training, beyond the interest of governmental bodies (Military Policy, DETRAN, Armed Forces etc.) that they need to carry through the training and recycling their pilots.

In accordance with the results already gotten and the referring research to the project that is being carried through currently, joining knowledge of the mechanics area, mathematics and programming, that are walking for a satisfactory final result, aiming to supply the lack of simulators of this kind, in view of that this simulator has a high cost-benefit, since the pilot can optimize the number of flight hours with real helicopters, running little risks and having an inferior final cost.

REFERENCES


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