SIMULATION-BASED TRAINING FOR AIRLINE CONTROLLER OPERATIONS

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- Simulation-based training
- Aviation applications
- Simulation software development

ABSTRACT

An appropriate training is a base for any human endeavor. One needs to get a significant hands-on experience to operate properly any complex technological equipment such as an aircraft, a nuclear power station, a ship, an air traffic control station, or a missile launch system. The training must include general familiarization with the system interface and the operating procedures, followed by an extended period of actual working on the system executing various operational scenarios under the supervision of an experienced operator. Unfortunately, such situation for a novice trainee, involving a real system, can be hazard prone, not practical, and very expensive. Replacing the real system by a simulator is a well accepted solution.

The paper presents the background and principles of simulation based training focusing on aviation domain. The issues of training concepts, human interface, level of the simulation system detail and object-oriented software development methodology are discussed. An example of object-oriented development strategy for a simulation program, imitating an airline operation dealing with the equipment and crew assignment to daily routings is presented.

INTRODUCTION

Controllers are employees who are responsible for conducting of normal daily operations. Operations involve monitoring system activity and require that controllers adjust system inputs/parameters to ensure that the system maintains normal operating conditions. Controllers are also responsible for handling irregularities that may occur unpredictably during routine operations, and could potentially disrupt system operations. To handle disruptions, the state of the system and the output must be interpreted, the cause and effect of disruptions must be identified, and techniques should be implemented to return system operations to normal. Controllers should be properly trained to handle any possible irregularities that may occur.

Computer simulation has been frequently used for controller training - in addition to lectures on theory and concepts, classroom-like instruction, case studies and application exercises, task analysis, studying operating procedures and system operational philosophy. When used for training, computer simulations must be realistic, user friendly, verifiable, easy to modify, providing desirable intellectual content, complexity and intensity of experience. Simulation facilitates learning by allowing students to envision dynamic relationships between entities of the system, helping them to grasp the relationship between normal and irregular functioning. Students can also learn from the consequences of their own actions (Pilkington and Grierson 1996). The examples of simulations for controllers' training in non-military applications include disaster management, power plant operations, tugboat service, or air traffic control.

With a highly realistic virtual environment, the students can experience conditions of high pressure and intense competition (Thorne 1992). The interaction that a simulation provides can also help employees build confidence in their decision making skills, try new techniques, implement major process changes and to observe the effects of decisions, before applying them in real-world conditions. Computer simulations can be designed to pack a great deal of learning into a short time period, creating intensive events. As a result, participants are forced to make many more decisions in the simulation than they would in real working conditions. The time required for training can be significantly decreased, thus reducing both training expenses and the impact on operations. However, to be effective for training, participants of a simulation must be willing to use it. Also, the management must be committed to the use of simulation being involved in setting the objectives of the simulation component of training activity.

Simulation developers must maintain a delicate balance so the training simulation would allow the participants to increase their knowledge while enjoying the process. A simulation must be easy to use, with a level of content that will prevent users from getting bored. Simulation systems should be designed not to distract students. In some cases, students might be forced to spend too much time trying to figure out how to manipulate the simulation software, in order to complete tasks. In other cases, students just play with the computers, simply searching for the right buttons to push to "win the game" (Slack 1993). However, if designed properly, a computer simulation that responds like a game could be a valuable technique to create intellectual interest. By combining a game with an education program, simulation developers can create an attractive product creating feeling of being in the virtual world.

AIRLINE OPERATIONS

Airlines vary greatly in size and structure, resulting in large differences in job titles and responsibilities. In each airline, the actual position that has the authority of making operational decisions can be different. The interactions that take place between airline employees when managing airline operations vary among the airlines. As a result, a computer simulation designed to serve as a training tool for operation controllers must be specifically tailored to each airline needs.

Airlines operations can be divided into two phases, strategic and tactical. During the strategic phase, airline flight schedules are developed (Clarke 1995). A schedule consists of a set of flight legs that are to be flown between two airports, along with the flight's planned departure and arrival times. Factors considered when a flight schedule is developed include: market demands, profitability, passenger connections, and airline's fleet characteristics. Each of these factors may influence the airline operating costs and revenues. After a schedule is developed, an aircraft type must be assigned to each flight leg, in a process called fleet assignment, considering such factors as aircraft capacity and passenger demand - in attempt to minimize the total operating cost of the schedule.

The actual aircraft that will be used to cover each leg is determined during daily aircraft routing. One of the main considerations that must be taken when routing aircraft is scheduled maintenance. All aircraft used by airlines must undergo certain maintenance inspections within specific time intervals. As a result, an airline fleet must be rotated so that specific aircraft are strategically routed to end up, at the end of the day, at the airport that has the required maintenance resources.

The tactical phase of airline operations involves the process of scheduling the system resources on a daily basis. Most airlines manage tactical operations from a central organization called the Airline Operational Control Center (AOCC) (Clarke 1995).

Operation Controller (OpC) is an airline employee that has the authority to resolve problems that develop during normal flight operations. The operation controllers are responsible for making decisions that ensure that flights operate as close as possible to the schedule, while minimizing operating costs, in the event of irregularities that cause disruptions (Clarke 1995). In the aftermath of irregular operations, operation controllers must make decisions that attempt to return operations to normal, while minimizing the number of delayed and canceled flights. Due to the number of factors that need to be considered, the time restrictions that are imposed, and the financial consequences of the decisions that will be made, operation controllers should be properly trained to handle these situations.

OpC do interface with other airline employees and manage the airline resources. The examples of entities/objects that the controller interfaces with or manages include: Aircraft, Flight Crew, Station Operation Agents, and Maintenance Controllers.

IRREGULAR OPERATIONS AND RECOVERY

Due to the great number of elements that must work correctly in an airline structure to operate flights on time, it is expected that events may occur that can cause disruptions to the normal schedule. Possible situations that can lead to disruptions include aircraft maintenance and servicing problems, weather deterioration, unavailability of crew, and air traffic control delays. If disruptions do not cause significant problems to the schedule, they can be referred to as time deviations. However, disruptions that lead to the rescheduling of resources are called irregular operations (Clarke 1995). As a result of irregular operations, flights can be delayed, diverted to different destination, or canceled, causing financial losses for the airline.

In the aftermath of disruptions, airlines can end up with crews and aircraft located at unscheduled destinations, preventing them from being used to cover scheduled next flight leg. Some irregularities, especially severe weather conditions, can cause disruptions to scheduled flights in a domino effect that can last for several days. To cope with irregular operations, some airlines have implemented special plans to guide operation controllers when making decisions that attempt to recover the schedule.

A flight crew is a critical resource that must be scheduled for each flight. They must be present at the departure airport when the preflight inspection is to begin. Crew member illness and late (or no) show to work, due to crew scheduling errors or crew irresponsibility, may result in irregularities. Schedules are created so that the crew has enough time on the ground before their departure for the next flight. However, when disruptions occur and a crew is delayed inbound on a flight, it is possible that their next flight will be also delayed.

Even a short period of poor weather can greatly disrupt a flight schedule with a significant impact on airline operations. In order for an aircraft to takeoff or land at an airport, the cloud ceiling and ground visibility at the airport must meet a certain minimum criteria. In addition, taxi and flight operations can be restricted by air traffic control due to strong winds, turbulence, or freezing precipitation. Poor weather can be limited to a single airport, or be widespread throughout an airline' s flight coverage area.

For minor aircraft maintenance problems it is possible that the subsystem can be repaired in time to depart on schedule. If a problem is severe enough, the flight can be delayed to the extent that the operation controller, in a cooperation with maintenance controllers, must determine if the flight should still be operated. While in-flight, the severity of the problem may require that the flight return to its departure airport, or be diverted to an unscheduled destination airport where repairs can be made. Several other sources of problems can cause disruptions to a flight schedule such as airport closures, runway maintenance, airport navigational aid outages, or air traffic delays, but also fuel truck breakdowns, ground power unit failures, or baggage loading equipment problems.

The task of repairing a schedule in real-time is one of the resource management. The operation controller must recognize all disruptive events and identify all the affected components of the flight schedule. Then, a set of possible solutions must be identified, each of which satisfies a set of pre-determined airline procedures and regulations, but heavily relies on the controller experience. Finally, the operation controller selects the best solution for implementation (Thrampuolidis at all 1997). Decisions facing controllers in the wake of irregular operations include: wait for a broken aircraft repair or replace the equipment (if available), cancel one flight in order to use the equipment for another flight, wait for the delayed crew, use a replacement crew (if available), relocate qualified crew to operate another flight, create new flight, merge the flights and/or change the routing, delay or divert the flight to accommodate potential stranded passengers, etc.

AIRLINE OPERATIONS CONTROLLER SIMULATOR DESIGN

A prototype simulator has been designed with an interface that resembles the system that is presently used by the OpC – the controller working in an airline operation control center. The prototype developed in this project limits its scope of functionality to a few common tasks that are routinely performed by airline operation controllers. The main objective of the prototype development has been to learn more about the airline operations system, to identify potential solutions, to determine if a particular simulation software architecture has the potential to meet the system requirement specifications.

The interface contains three main components: (a) rainbow chart, (b) menu bar, and (c) simulated telephone. Flight following information represents the flights in the form of the rainbow chart. The graphic information includes the current state of each flight, scheduled/estimated flight departure and arrival times (ETD, ETA), scheduled departure and destination airports, and aircraft/crew assigned to each flight. Selecting options from the menu bar allows the user to inquire about selected crew flight schedule, selected aircraft list of pending flights, selected flight departure and arrival times, location of each selected crew and aircraft, current weather at each selected airport. The prototype functionality includes: checking selected flight/crew status, assigning an aircraft to a flight, modifying crew schedule, canceling flight, placing flight on (or releasing flight from) operational hold, updating flight's ETD, setting up gate return or diversion, changing the speed of the simulation, or using the telephone to contact other employees or respond to the other party calls.

Various external events are reported to the operation controller by a simulated telephone call. They include such events like unavailability of aircraft, incorrect schedule, lack of assigned or available aircraft. Some randomly generated events include mechanical problems, unavailability of crew, or weather conditions. To simulate these events, in addition to simulating normal airline operations, the prototype randomly generates a subset of disruptions that can cause irregular operations. The simulation input controls the type and frequency of disruptions that will be generated. The input data include probability and severity of a mechanical problem (during a preflight inspection, taxiing, or flight), probability that inspection causes flight delay, minimum and maximum times required to fix mechanical problems, probability of weather changes, variation in flight time, probability of busy phone, etc.

PROTOTYPE DEVELOPMENT METHODOLOGY

To identify the prototype functionality, we depended upon the actual airline operation controller work experience of one of the authors (Vargas 1999). A list of features was identified that would be necessary in order to model normal airline operations, without disruptions. By simulating normal operations, users can perform flight following functions, monitoring flights as they depart, travel and arrive at their destination. Subsequently, we identified the most common disruptions that occur during real airline operations and recorded specific techniques for managing such disruptions.

A list of requirements was created to document the functions that the prototype would allows a user to perform, including the input, processing and output provided by each function. In addition, each function is described by a Use Case, indicating the steps that need to be taken by the user during the simulation. The Use Cases indicate how shall the system respond to each of the user's actions.

The Object-Oriented Analysis and Design (OOA/OOD) method was selected for the development of the prototype (Davis 1993). The domain of this project, airline operations, includes a large number of entities that interact with each other. For each entity its attributes and behavior can be identified. Similar entities belong to a common category or class (aircraft, flight, or crew). As a result, the OOA/OOD method seemed to be an appropriate technique to apply to the problem. When the system was designed, real-world entities in the domain were identified and modeled as objects. The interactions between the entities were modeled as methods of the objects. Object diagrams identify each object in the category including their relationships with each other, and their relationships with objects in other categories. The diagrams were documented using Unified Modeling Language (UML) notation. An example of Airport Category Object Diagram is presented on Fig. 1.

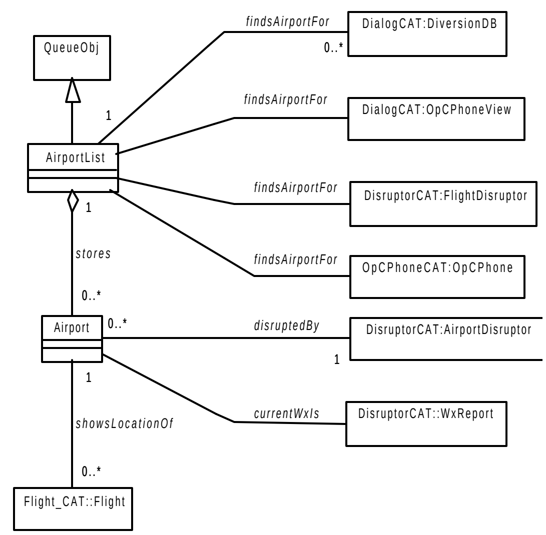

Figure 1: Airport Category Object Diagram

It was desirable that the prototype program be implemented in a language that is easy to use and allows rapid development. As a result, MODSIM was selected as the implementation language. MODSIM (MODSIM 1993), developed by CACI Product Company (currently a part of Compuware) is a modular, object-oriented, discrete event simulation language providing built-in features necessary for implementing a computer simulation. This eliminated the need to design and implement code to manage features such as a simulation clock, event scheduling, interruptions, etc. MODSIM also provides a user friendly graphical user interface that allows created quickly graphical components. The graphics provided by MODSIM are sufficient for the scope of the prototype that was developed during this project.

The prototype was implemented using an evolutionary technique (Kornecki 1994). In the initial version, the program was designed and implemented to simulate only normal operations with no disruptions and using strictly text-based user interface. This version served as the core part of the simulation, and controlled the interactions and dependencies between the main simulation entities, such as flights, aircraft and crew-members. Once the initial version was tested, and its defects removed, the generation of simulated disruptions was added. Subsequently, the graphic user interface was developed and interfaced with the original simulation program. Finally, the simulated telephone was added to the system. The screen shot of the resulting prototype is shown on the Fig.2. In addition to the phone line status and the clock icons in the lower central part of the display, the upper part of the display shows the rainbow chart, and the lower left corner an open telephone communication window. The menu options include: simulation, flights, aircraft, crew, airport, and report. The screen shot was taken about three hours after the simulation started showing five flights in progress and one re-scheduled. The current telephone connection with LAS station is open and the response was received on an inquiry about crew status.

The prototype metrics are listed in the Table 1. The final version of the prototype included total of 55 objects in twelve categories/modules resulting in ~4.5KLOC.

Category	**Num Objects**	**LOC**
Aircraft	4	327
Airport	2	74
CommX	9	630
Crew	4	465
Dialog	9	514
Disruptor	8	618
Flight	5	482
OpCPhone	1	124
SystemData	2	350
Test	1	49
View	9	847
ZTime	1	63
Main program	0	25
Total	**55**	**4568**

Table 1: Airport Operation Controller Prototype Metrics

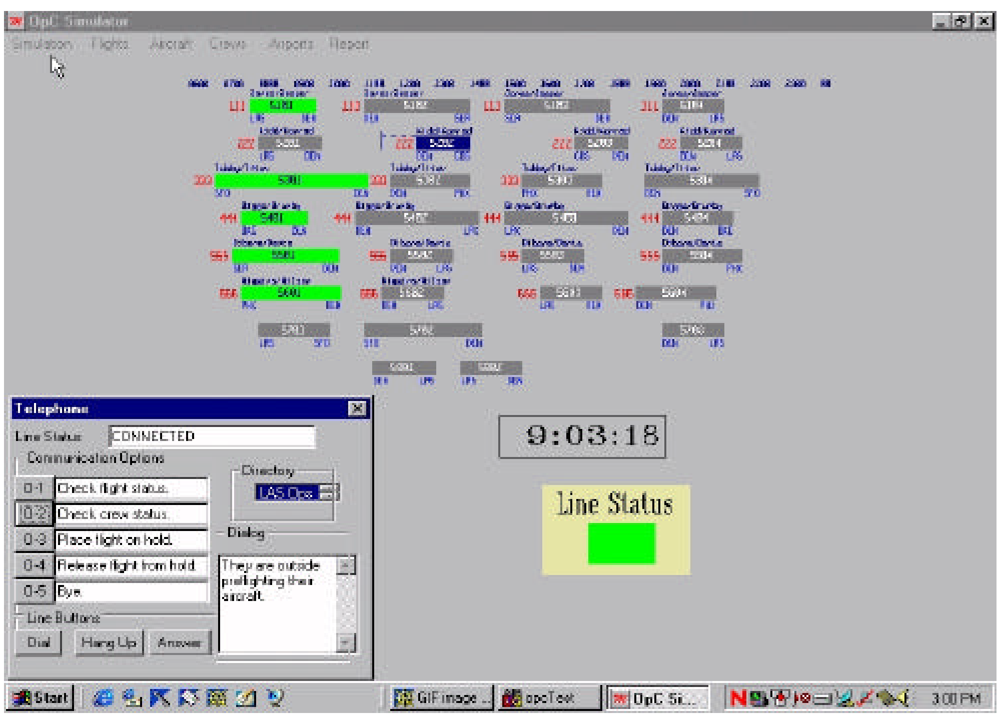

Fig. 2: Airport Operation Controller Prototype Interface

As a result of experimentation with the prototype, several features have been identified that could be added to enhance the system's usability or improve its functionality. With further testing, additional items may be identified that could help improve the service that the system provides. In addition, continued experimentation may allow users to determine if a complete version of the prototype could help enhance the training of operation controllers.

CONCLUSIONS

With the increasing trend in automation in the airlines, and a desire for new techniques for maximizing profits, this could be a good time to introduce to airlines the use of computer simulation to enhance the training of operation controllers. Properly trained employees are more valuable, making decisions that help bring their company increased revenue. Computer simulation is a cost effective and valuable technique that can be incorporated into current training programs. At this time, airlines do not appear to be receiving the benefits of computer simulation as part of a training program for their operation controllers.

The development of the prototype is a valuable step toward the development of an actual operation controllers' training simulator at some point in the future. With the prototype, an actual visual demonstration can be offered to potential customers. The prototype allows users to experiment with the system, increasing their understanding of the system, and helping them identify desired features that should be included in a full application. Additional features not included in the prototype were identified as enhancements that could be beneficial in an actual training tool. It is important to note that the prototype, by itself, was not intended to serve as a training tool. As a result, the functionality that it provides is only enough to demonstrate the potential of a complete system.

The prototype was designed and implemented using the object-oriented development method. During the requirements analysis and design phases, real world entities were identified and modeled as objects. Relationships between entities in the real world were modeled as methods of the objects. As a result, the prototype contains a set of objects that interact with each other in a manner that is similar to the way the real world entities interact. It is possible that developers of a full application decide that they need to begin its development from scratch, considering the current prototype a throwaway prototype. However, it may be possible to evolve the prototype into a full application by reusing the current system design and its components.

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