Entertainment Computing 5 (2014) 347–355

Contents lists available at ScienceDirect

Entertainment Computing

journal homepage: ees.elsevier.com/entcom

Development of a mechanical maintenance training simulator in OpenSimulator for F-16 aircraft engines ☆

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ARTICLE INFO

Article history:
Received 31 May 2013
Revised 2 May 2014
Accepted 15 June 2014
Available online 22 June 2014

Keywords:
Virtual worlds
OpenSimulator
Virtual learning
Cooperation
Task coordination
Aircraft engine maintenance

ABSTRACT

Mechanical maintenance of F-16 engines is carried out as a team effort involving 3–4 skilled engine technicians, but the details of its procedures and requisites change constantly, to improve safety, optimize resources, and respond to knowledge learned from field outcomes. This provides a challenge for development of training simulators, since simulated actions risk becoming obsolete rapidly and require costly reimplementation. This paper presents the development of a 3D mechanical maintenance training simulator for this context, using a low-cost simulation platform and a software architecture that separates simulation control from simulation visualization, in view of enabling more agile adaptation of simulators. This specific simulator aims to enable technician training to be enhanced with cooperation and context prior to the training phase with actual physical engines. We provide data in support of the feasibility of this approach, describing the requirements that were identified with the Portuguese Air Force, the overall software architecture of the system, the current stage of the prototype, and the outcomes of the first field tests with users.

1. Introduction

At the Portuguese Air Force, engine technicians go through an initial training process at the Centre for Military and Technical Training of the Air Force (CFMTFA, Portuguese-language acronym), and are subsequently placed at different air bases, each with different aircraft, and specific engines and requirements. Thus, at each of these bases, they receive further training, focused on the specific engines and aircraft deployed and serviced there. In the case of the F-16 aircraft, this takes place at Air Base Nr. 5, in Serra do Porto de Urso, near Monte Real, Leiria, Portugal. Since technicians may be re-deployed to other bases, training of technical procedures for maintenance of specific engines is a common and frequent process. The training process has an initial theory phase, based on technical documents known as "Technical Orders" or TOs [1] (Fig. 1). Then an on-the-job training phase ensues, with trainees acting directly on an engine, in actual maintenance circumstances.

This final on-the-job training phase is resource-demanding, since it requires engines to be available either specifically for training or for longer servicing allowing for training to take place, and consequently unavailable for operation. Also, procedure errors, whose risk is greater during training, may in some cases produce costly component damage. Further, several of the technical procedures need to be executed by a team, meaning that time allocation of trainees, trainers, and experienced technicians needs to be managed, in order for a full team to be available for on-the-job training to ensue. These various resource requirements place constraints on the availability of on-the-job training opportunities and emphasize the need to optimize it. The development of a serious game for this scenario, a 3D multi-user mechanical training simulator, aims to provide trainees and trainers with more opportunities to conduct training, with the goal of allowing trainees to reach on-the-job training better prepared and thus to optimize the effectiveness of the resource-intensive training occasions with physical engines. This is a joint effort of the Portuguese Air Force and the University of Trás-os-Montes e Alto Douro (UTAD), which subsequently received the cooperation of the INESC TEC research organization.

☆ This paper has been recommended for acceptance by Bellotti.
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http://dx.doi.org/10.1016/j.entcom.2014.06.002
1875-9521/

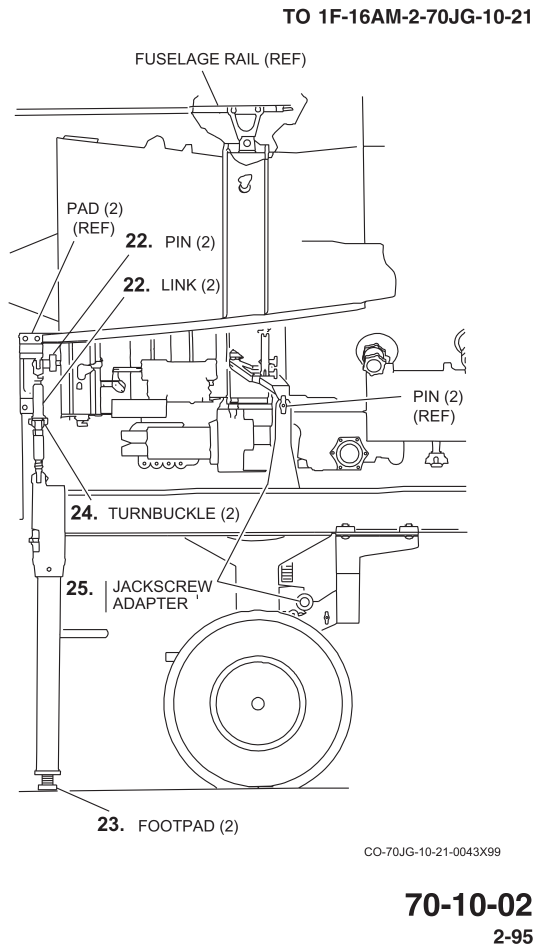

Fig. 1. Sample instructions from a technical order for the Pratt & Whitney F100-PW-220/220E engine from [1].

The development of such a serious game is a complex software engineering project, requiring technical expertise and a careful balance between design principles and pedagogical content, taking time, resources and teamwork. As serious games become more complex, so do the engineering challenges that arise during their development. A particularly significant challenge in this scenario is that mechanical procedures are constantly evolving: as errors are committed and/or insights developed, the recommended practice is changed, in order to optimize resources and lessen risks. At Air Base 5, this evolution effort is executed under the approach known as lean principles [19].

The consequence for software development is that any mechanical procedures implemented in a simulator are likely to become obsolete rather quickly. Any development costs and resources are further increased by the need to update the simulated procedures. This is now somewhat lessened by employing game engines or development platforms rather than developing from scratch, rendering the early-stage selection of the engine or platform for development critical [2]. Following this software engineering perspective, there is a goal of lessening the resource requirements of both simulation development and updating. Thus we present an approach that focus on tuning and perfecting the simulated operations and behaviors, rather than the visuals. For this purpose, we employed a readily available virtual world platform (OpenSimulator) rather than a game engine; and in order to allow the knowledge embedded in behaviors and operations to be independent from this platform, we implemented control code and decision-making logic as an external system, accessed as a Web Service. The rationale for this architectural choice was to enable the visual and interaction platform to change subsequently, if necessary, but keeping the fast-prototyping benefits of a virtual world platform such as OpenSimulator [3]. In this paper, we present this approach and test its feasibility by submitting the prototype to user tests at the air base, with mechanical maintenance trainers.

2. Background

F-16 aircraft of the Portuguese Air Force are at the so-called mid-life update version (known as MLU), and employ Pratt & Whitney F100-PW-220/220E engines, with large number of mechanical maintenance procedures – the manufacturer recommends periodical inspections depending on the number of flight hours. Inspection procedures are conducted before and after each flight, and there is also programmed maintenance that takes place every 300 flight hours, with the overwhelming majority of these procedures taking place at air base Nr. 5. We held meetings with the training team and mechanical experts at air base Nr. 5, to ascertain the most relevant procedures for technicians that are initiating their training with this specific engine. In the course of those meetings, the procedures for installation of the engine inside the F-16 aircraft fuselage were selected as the first simulation target. This involves a series of steps for properly installing and connecting the engine, which need to be done not only effectively but also safely. We have collected data on this process by combining several sources: we reviewed the TOs [1] and taped and photographed the actual current installation process for the engine from various perspectives. We then decoded this data, describing it in terms of a natural-language script, and created UML diagrams of the various procedures, keeping in regular contact with Air Force trainers to clear out doubts and get further details. Briefly, these steps involve preparing the engine for transportation towards the aircraft fuselage, transporting it and preparing it for insertion, raising it and inserting it into the aircraft fuselage, establishing the engine connections to the fuselage, and testing the installation (the full list is provided in Table 1). The level of detail required for simulation of each task was also determined in cooperation with the trainers at Air Base Nr. 5.

For creating the simulation, given that this project was developed with minimal funding, it was be necessary that development could be incremental, in small steps over time, likely involving different people in each academic year. In the meetings with the training team at the air base, context-specific requirements were

Table 1
Procedures involved in the installation of the engine into the aircraft.

Nr.	Task description
1	Installation of the engine mount to raise the engine
2	Engine raise
3	Couple engine to the aircraft
4	Perfect alignment of the upper engine mount with the fuselage rail
5	Fasten and break of the trailer to the fuselage
6	Adjustment of the trailer to transfer engine weight
7	Support the engine on the fuselage rail
8	Enter the engine in perfect alignment with the fuselage
9	Align with the trust pin connections
10	Enter the trust pins using the connection doors
11	Finish the back
12	Check perfect alignment of the trust pin with the clamp half
13	Tighten up the clamp half with a ring (nut) to finish baking
14	Finish installing the trust pin with an inspection
15	Check the SEAL, from the air entrance
16	Remove the trailer
17	Remove the back engine adapter
18	Lighten/download support fuselage
19	Completely remove the trailer