Abstract

The employment of Computer Generated Forces (CGFs) within Distributed Virtual Environments (DVEs) dramatically increases the number of entities in a simulated training environment. However, current CGF limitations produce behaviours that can be defeated using methods ineffective against humans. Our research focuses on developing aircraft CGFs. It is necessary to deal with uncertainty, ambiguity, and approximation. The Fuzzy Wingman (FW) relies on fuzzy logic to provide these abilities. In this manner, the FW presents a reasonable approach to effectively populating the simulated training environment with low-cost CGFs while maintaining the realism of training with human-controlled entities.

1. Introduction

With the continuing advances being made in interactive simulation environments, the appeal of low-cost, low-risk training systems is especially important to domains where mistakes during real-world training can be extremely expensive as well as dangerous. In particular, consider the training necessary to adequately prepare individuals for combat. Training in distributed virtual environments (DVEs) [6] holds great potential for providing the level of realism required while increasing safety and minimizing costs. Through distributed interactive simulation (DIS) technology [1, 5], independent manned simulators around the world can be networked to participate in interactive training exercises with the virtual battlefield.

One of the most noted deficiencies with regards to the DVE approach for employment of force training is the lack of adequate numbers of manned simulators to populate the simulation environment. Adequate simulation of even a small scale exercise requires thousands of entities. One approach is to employ computer generated forces (CGFs) to increase the entity count in the simulation environment. A single unit, such as fighter wing or a tank company, could be effectively trained without requiring other units. It is envisioned that CGFs can be programmed with a variety of tactics to simulate any number of different potential foes in a battlefield simulation.

Large numbers of simple CGFs can be quickly constructed. Such entities are often restricted to very basic activities such as point to point straight line traversals. Unfortunately, simple CGFs are readily identified and defeated using methods that are ineffective against humans. In order to preserve the integrity of the training experience, CGFs must be indistinguishable in their behavior from human-controlled entities within the virtual battlespace.

To briefly summarize, a successful CGF entity must (1) approximate human behaviours, (2) be easy to compute, (3) be simple to knowledge engineer, and (4) be scalable in performance. Although this has been the ultimate problem that artificial intelligence has been struggling to solve, the approach taken for DVE training has several advantageous properties. Among the most prominent is that all the information is precise in the simulation environment. For each action taken in the simulation, there is an exact and deterministic reaction.

In this paper, we present a CGF called the Fuzzy Wingman (FW), which provides intelligent wingmen for manned lead aircraft. As its name suggests, the Fuzzy Wingman uses fuzzy logic to guide its behaviour.

2. Rationale for Fuzzy Logic

Why introduce uncertainty in a very certain environment? Actually, we are not introducing uncertainty into the simulation environment itself. The choice of actions taken by the entity directly reflects its external behaviour to the human controlled entities. The Fuzzy Wingman seeks to improve the state of the art for CGFs by using fuzzy logic. Because humans continuously deal with uncertainty, ambiguity, and approximation, we believe that any CGF required to exhibit human behaviors must also be able to deal with uncertainty, ambiguity and approximation. Fuzzy logic provides this ability.
The Fuzzy Wingman is not the first attempt at creating a realistic CGF that exhibits human behaviors. Several others have tried with varying degrees of success such as Tac-Air Soar [4, 7]. Unlike the Fuzzy Wingman, Tac-Air Soar does not handle uncertainty in its decision making process.

3. Requirements and Design of the FW

3.1. The Knowledge-base Hierarchy

An immense amount of specialized knowledge is required to fly and fight a combat aircraft. To make the data management problem tractable, we decomposed it into a hierarchy of knowledge-bases (see Figure 1). The Mission knowledge-base guides the overall action of the Fuzzy Wingman. Threat is part of this knowledge-base because when the Wingman is threatened, it amends its mission in order to evade or suppress the threat. Tactics, Weapons, and Environment compose the next level of the hierarchy. Once the Mission is selected, these knowledge-bases are used to analyze the environment and select the tactics and weapons required to fulfill the mission. The Maneuver knowledge-base is used to select the appropriate aircraft maneuvers for the chosen tactics and weapons. Finally, the Flight Control knowledge-base contains the information required to implement the selected maneuvers. Because of space limitations, we focus only on the Flight Control knowledge-base.

3.2. Linguistic Variables

Currently, the Flight Control knowledge-base consists of the 15 individual linguistic variables, which serve as flight control inputs used in the FW’s decision making process. Space does not permit us to describe all 15 linguistic variables here. We will describe the linguistic variable called CURRENTRELATIVEALTITUDE to illustrate the general procedure used.

There are two linguistic variables used to describe relative altitude. These are CURRENTRELATIVEALTITUDE and PROJECTEDRELATIVEALTITUDE. CURRENTRELATIVEALTITUDE describes the altitude difference between the Fuzzy Wingman’s current altitude and the Fuzzy Wingman’s desired altitude relative to the lead aircraft. This variable describes a portion of the current state of the Wingman with respect to the desired state. The assessment rule for the CURRENTRELATIVEALTITUDE linguistic variable is shown in Table 1.

PROJECTEDRELATIVEALTITUDE describes the anticipated relative altitude differential between the Wingman and lead aircraft at some time in the future, depending on the range, if the current velocities and accelerations remain constant. This linguistic variable describes the expected future state if no action is taken.

3.3. Linguistic Variable Rule Design

There are three independent axes of control for the Flight Control knowledge-base. These are altitude, heading, and thrust. Using the linguistic variables, we developed production rule graphs for each of these axes of control. These rule graphs show how the linguistic variables combine to describe the state of the Fuzzy Wingman along each axis and the correct action that the Wingman should take in response to the state.

Although Flight Control consists of three axes, space limitations permit us to describe only the Altitude axis. Altitude is assessed using the CLIMBRATE linguistic variable and term sets. The CLIMBRATE variable assesses the climb rate of the aircraft that is required to achieve the desired altitude. This variable considers the current altitude relative to the desired altitude and the altitude difference at some time in the future given the current velocities and accelerations. This linguistic variable relies, in turn, on other linguistic variables to determine the appropriate value.

4. Implementation

Each of the linguistic variable designs and production rules used in the Fuzzy Wingman must be transformed into a form that FuzzyCLIPS can use in its expert system engine. FuzzyCLIPS, the expert system shell used by the Fuzzy Wingman,
6. Conclusions and Future Work

To date, the Fuzzy Wingman project has demonstrated the viability and feasibility of a fuzzy logic based CGF. We have a fundamental design that is flexible and ready to serve as the foundation of future efforts on this project. Our implementation has shown that a hierarchy of fuzzy linguistic variables can be used to control a dynamic process in an airplane. Furthermore, such an organization simplifies computations and also promotes ease of scalability and expandability of CGF capabilities.

Future work for the Fuzzy Wingman include augmenting the decision making and knowledge-base to provide complex inter-entity behaviours for cooperative formation flying between multiple FWs. Such a system would use correct tactics and doctrine for multi-aircraft formations including beyond visual range engagements.

Issues regarding transfer from computer to human control of CGFs such as the Fuzzy Wingman will also be addressed. The transition process during critical situations should smoothly increase the human’s situational awareness minimizing potential information overload.

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References