GENETIC ALGORITHMS APPLIED TO COURSE-OF-ACTION DEVELOPMENT USING THE MANA AGENT-BASED MODEL

Gregory C. McIntosh and Michael K. Lauren[1]

Abstract. This paper describes a genetic algorithm (GA) tool added to the MANA agent-based model to assist with scenario development. Squads of agents are given chromosomes consisting of genes made up from various personality weightings in the MANA model; the emphasis is on evolving clever tactics and behaviour given the weapons and equipment squads already have. Concepts from evolutionary biology such as gene recombination and mutations are then applied to evolve fittest squads to optimally defeat an enemy in a given MANA scenario. We demonstrate the GA tool using two examples: a simple shooting battle between two massed forces, and a reconnaissance/counter-reconnaissance scenario in which a small Blue squad attempts to locate a high value target within enemy territory. Communications links in the MANA model are utilized for the information sharing, thus highlighting issues of network enabled operations. Generally, the genetic algorithm is seen to be a useful addition to the toolkit of military modelling techniques based on complexity theory.

INTRODUCTION

MANA (Map Aware Non-uniform Automata) is an agent-based distillation model developed by the Operations Analysis group at Defence Technology Agency in New Zealand [1,2]. It has been used by various military colleges and defence science establishments and has become one of the main modelling tools used at the bi-annual Project Albert workshops [3]. MANA has been used in a number of studies: the modelling of civil violence management [4], maritime surveillance [5], investigating modern warfare as a complex adaptive system [6], and a range of studies carried out at the Project Albert workshops [3]. One aspect of MANA which sets it apart from other agent-based models is its ability to model communications links between agents so that aspects of network centric warfare (NCW) may be studied [7].

The agents representing military entities in the MANA model are given a rule set which moves them on a battlefield grid according to their perceived environment and prescribed personality weightings. The environment may include terrain features and other enemy or friendly agents while personality weightings could be the tendency to run towards or way from enemy agents depending on how bold or cautious agents are defined to be for a particular scenario. Information about the environment can come from an agent's own sensors or through communication links to other agents. A characteristic feature of agent-based models is that, although the one-to-one interaction between various agents and their environment may be quite simple, the combined effect of many agents interacting can lead to complicated group dynamics which is both unexpected and interesting. In this regard, agent-based models have the potential to represent the chaotic aspects of warfare quite well [8].

Simple agent-based models purposefully leave out all detailed physical attributes of the military entities being modelled if this is not expected to have any bearing on the study at hand. This allows scenarios to be run relatively fast and over many excursions in order to discover unique situations or tactics where friendly forces can achieve dominance over an enemy. Furthermore, by focusing on the effect of the personality weightings given to the agents, one may study the more intangible aspects of warfare. This is in contrast to conventional military modelling which might focus more on, say, studying the physical effects of weapons fire.

In this paper, we report on a new feature added to the MANA model to assist with scenario development: the genetic algorithm [9,10]. Genetic algorithms have recently found acceptance as a viable tool for solving a variety of problems such as designing electronic circuits [11,12], automated software development, and designing efficient communications networks. More generally, genetic algorithms can be used to solve problems requiring some type of optimization where a large number of parameters is involved and the mathematical structure of the fitness function is not well behaved or is unknown beforehand.

The genetic algorithm derives its inspiration from the way species are thought to evolve in nature. A species' physical and behavioural characteristics are encoded by their genes. The 'solution' for a particular species corresponds to those individuals who are the fittest to survive in their environment. We endeavour to follow a similar strategy for designing military scenarios. Fortunately, the design of the MANA model readily allows us to add chromosomes to agents in order to devise an evolutionary scheme. Essentially, we use the agents' personality weightings as the genes in our scheme. This then places emphasis on evolving clever squad tactics and behaviour for a given scenario. The genes in our scheme are integer valued, in contrast to the genes in evolutionary biology which are of binary nature.

In the following, we describe our genetic algorithm in more detail and give examples of its use. One example involves a straightforward shooting battle between two forces while the other example involves a reconnaissance scenario. These examples serve to highlight the effectiveness of the method. Indeed, research is still ongoing amongst the scientific community into the theoretical underpinnings of the genetic algorithm and understanding how the method works as well as it does [13–16]. We note that agent-based model EINSTein has also had a genetic algorithm added [17]. Also, Lohmeyer has previously investigated the use of a genetic algorithm coded in MATLAB to optimize MANA scenarios [18]. The genetic algorithm presented here is coded into the main MANA distribution and our scheme focuses on evolving clever behaviour and tactics through personality weightings with the military hardware already given.

[1] Both authors with Defence Technology Agency, Naval Base, Private Bag 32901, Devonport, Auckland, New Zealand.

ISSN 1440-5113