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Real-time retrieval for case-based reasoning in interactive multiagent-based simulations

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ABSTRACT

The aim of this paper is to present the principles and results about case-based reasoning adapted to real-time interactive simulations, more precisely concerning retrieval mechanisms. The article begins by introducing the constraints involved in interactive multiagent-based simulations. The second section presents a framework stemming from case-based reasoning by autonomous agents. Each agent uses a case base of local situations and, from this base, it can choose an action in order to interact with other autonomous agents or users' avatars. We illustrate this framework with an example dedicated to the study of dynamic situations in football. We then go on to address the difficulties of conducting such simulations in real-time and propose a model for case and for case base. Using generic agents and adequate case base structure associated with a dedicated recall algorithm, we improve retrieval performance under time pressure compared to classic CBR techniques. We present some results relating to the performance of this solution. The article concludes by outlining future development of our project.

1. Introduction

Videogame technologies have recently begun to be used for the purposes of scientific simulation and visualization (Ferey et al., 2008), industrial and military training (Buche, Querrec, De Loor, & Chevaillier, 2004; Gonzalez & Ahlers, 1998), and finally medical and health training and education (Bideau et al., 2003; Volbracht, Domik, Backe-Neuwald, & Rinkens, 1998). Within these simulations, users can interact with autonomous agents and/or human avatars of team members (Raybourn, 2007).

Unlike video games, these simulations tend not to focus on the quality of graphical representations or animation which are not always necessary for optimizing understanding of these situations (Metoyer & Hodgins, 2000). The most important point is to ensure variability and spontaneity within the simulation. The present paper addresses this issue in dynamic and collaborative situations. Unlike procedural activities, dynamic and collaborative situations cannot easily be defined by sequences of rules as there are an infinite number of possible situations. These situations result from local interaction between participants unaware of the overall situation. It is therefore possible to simulate such dynamics using autonomous agents interacting with one or more users. In this case, decision-making is a rapid process largely influenced by context, and therefore partial perception, time limitations, high stakes, uncertainty, unclear goals, and organizational constraints (Argilaga & Jonsson, 2003; Kofod-Petersen & Mikalsen, 2005). Consequently, the outcomes of agents' actions are unpredictable but can be qualified as more or less believable than real-life experience. Moreover, the objective is to simulate adaptive behaviors capable of reacting to many different situations with some variability.

Believability depends on psychological and subjective considerations (Loyall, Reilly, Bates, & Weyhrauch, 2004) and is difficult to quantify. Systematic approaches, such as defining an explicit set of rules (Laird & Duchi, 2000), or automatically learning rules (Sanza, Panatier, & Duthen, 1999), therefore conflict with believability. Even if these latest methods are used to define behaviors in simulating collaborative and dynamic situations (Ros, Veloso, de Màntaras, Sierra, & Arcos, 2006), they are based on the optimization of "simple" criteria (for example, an agent's score, or time taken to complete a task). Consequently, the resulting behavior is efficient, but unnatural and unsuitable for human learning.

Another approach is available to interactively construct dynamic and collaborative situations: the use of case-based reasoning (CBR) (Aamodt & Plaza, 1994) in association with context modeling (Bénard, Aubry, & De Loor, 2006; Brézillon, 1999; Gonzalez & Ahlers, 1998). Case-based reasoning stems from analogous reasoning (Eremeev & Varshavsky, 2006; Kolodner, 1993; Riesbeck & Schank, 1989), which is particularly relevant for

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addressing decision-making in dynamic and collaborative situations (Bossard, Bénard, & Tisseau, 2006). Context relies on all the elements perceived at any one time by a given agent which might influence its decision-making. This concept arises from ecological psychology (Gibson, 1958) and is strongly linked with naturalistic decision making (Klein, 2008). This article mainly addresses the principal difficulty faced when using CBR in this way: maintaining performance in real-time. The time needed to retrieve a case increases with the size of the base multiplied by the number of autonomous agents. For real-time purposes, it is unacceptable for the time taken to make a decision to be linearly dependent on the size of the base (time taken to scan the base), as it is subject to great variation. Depending on the domain in which CBR is applied, the size of the base may increase with experience, or by means of machine learning algorithms executed during experimental sessions. Moreover, the term "dynamic situation" implies that, at any given time, agents must be able to carry out an action even if it is not the best one. Nevertheless, it is important to be aware that, even when these decisions may be inappropriate, they are the result of heuristics and are not merely random. Experts also claim that perceptions guide actions and that not all perceptions are equal, but rather they depend on their implication in the decision (Klein, 2008). It is therefore important to highlight the fact that incorrect or incomplete perceptions may lead to inappropriate actions. Such approximate perception is attributed to a lack of time available to perceive.

These principles can be implemented using the architecture presented here in this paper. This architecture will be able to model (1) that some perceptions are more relevant than others in making decisions (under time pressure, agents will focus on these perceptions first), and (2) that the shorter the time, the worse the perception, and therefore decisions made due to that perception, will be.

This article is divided into three main parts. Section 2 describes CBR and a context model associated to each case. An application, *CoPeFoot*, is used to illustrate this proposal. Section 3 addresses a real-time adaptation of case retrieval. Section 4 shows how this proposition improves recall results and system precision under real-time constraints. These results are also discussed in preparation for the conclusion in Section 5.

2. CBR for decision-making in virtual agents

Case-based reasoning stems from analogous reasoning which states that each situation encountered can be associated with another similar well-known and appropriately-resolved situation. The difficulty is in defining how to associate situations in order to choose the most relevant, and to adapt one situation to fit another. The principles of case-based reasoning are summarized in Fig. 1. When the expert system encounters a problem (*case target*) it searches for a similar case in its base (*case source*) which is associated with a solution (*solution*(*source*)). It then adapts either (*solution*(*source*)) or the resolution derived from case source to (*solution*(*source*)), in order to define the solution (*solution*(*target*)). The main advantage is that it is unnecessary to detail an exhaustive resolution mechanism which can become so complex that it is in fact unknown. The adaptation step concerns either the resolving procedure or the solution directly (Cordier, Fuchs, & Mille, 2006; Lieber, 2007).

An application of CBR to decision-making in autonomous agents in interactive simulations is illustrated in Fig. 2. Each autonomous agent uses CBR to choose its subsequent decisions within the simulation.

The *context box* is the process of abstraction which extracts semantic information from features perceived in the simulated world. More precisely, whereas simulations produce low-level information like changes in the positions of objects, the *context box* gives information such as the qualitative distances between agents (agent *a* is far from agent *b*), or more domain dependent information (see examples in the following section). Each autonomous agent has its own context depending on its position in the virtual world. In CBR, this step is known as elaboration, during which all of the relevant context elements are defined by experts. This context is compared with elements from the case base in order to select one case ("recall step"). Finally, using semantic information, the case is adapted to the current situation and autonomous agents can act within the virtual world ("adaptation step"). Both the elaboration and adaptation steps are part of psychological research linked to the field in which the CBR is implemented.

2.1. Application

The theoretical proposition was implemented in the *CoPeFoot* simulation tool for studying collaborative and dynamic situations in sport (Bossard et al., 2006). This application will be used to illustrate each step of the theoretical model. The practical uses of *CoPeFoot* are described in Bossard et al. (2006). It is designed to be used for training sports coaches and referees. Both the starting conditions and the exercises can be configured in order to immerse a real player in a 3D scene with autonomous players. Users can also study the situations from different points of view by watching the recordings of user's movements. Fig. 3 depicts a user interacting with *CoPeFoot* in an immersive room.

2.2. Context model

Although context is domain dependent, it is possible to formalize its data structure as follows: a context *Ctx* is a set of predicates. Each predicate stands for one possible perception of an agent, and is domain-specific. Examples of such perceptions for football are the fact that a player is marked (followed by an opponent) or that

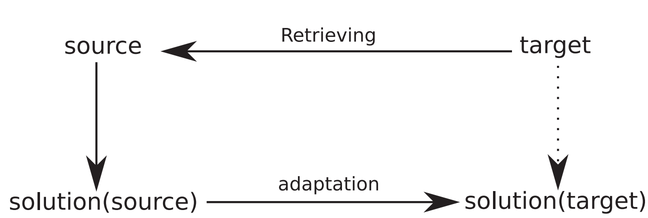

Fig. 1. The Principles of CBR.

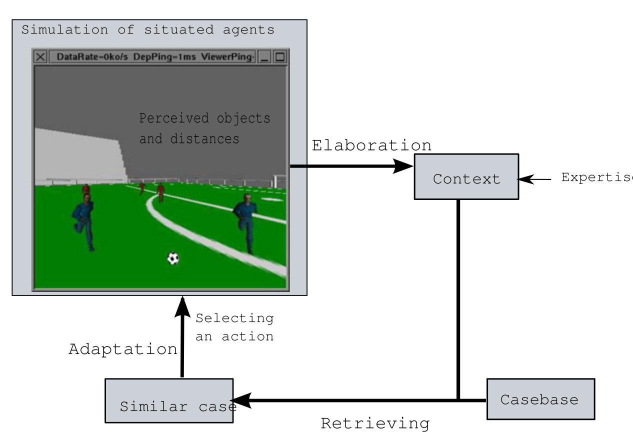

Fig. 2. Case-based reasoning within simulation of interactive dynamic situations.