A Methodology for Modeling and Representing Expert Knowledge that Supports Teaching-Based Intelligent Agent Development

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The long term research goal of our research group is to change the way a knowledge-based agent is built, from being programmed by a knowledge engineer (based on what he or she has learned from a domain expert) to being directly taught by a domain expert that receives limited or no support from a knowledge engineer. The investigated approach, called Disciple (Tecuci, 1998; Tecuci et al., 1999), relies on developing a very capable learning and reasoning agent that can collaborate with a domain expert to develop its knowledge base consisting of an ontology that defines the terms from the application domain, and a set of general task reduction rules expressed with these terms.

An important component of this research is the development of a general methodology for modeling and representing expert knowledge that supports teaching-based intelligent agent development. This methodology was developed to support the application of the Disciple approach to two very different challenge problems of the DARPA High Performance Knowledge Bases (HPKB) program, the workaround challenge problem (Alphatech, 1998), and the Course Of Action (COA) challenge problem (Alphatech, 1999).

With respect to this methodology we formulate the following claims: 1) it is natural for the expert, 2) it is applicable to a wide variety of domains; 3) it identifies the tasks to be represented in the agent's knowledge base, 4) it identifies the necessary concepts and features to be represented in the ontology, 5) it guides the rule learning process 6) it supports natural language generation of solutions by the agent and their abstract justifications.

We will briefly illustrate this methodology with the COA challenge problem that consists of rapidly developing a knowledge-based critiquer that receives as input the description of a military course of action and assesses various aspects of the COA, such as its strengths and weaknesses with respect to the Principles of War and the Tenets of Army Operations. The domain expert is given a specific problem to solve (such as, to "Assess COA411 with respect to the Principle of Objective") and solves it through task reduction, as illustrated in Figure 1. To perform this assessment, the expert needs a certain amount of information about COA411. This information is obtained through a series of questions and answers that help reduce the initial assessment task to simpler and better defined ones, until the expert has enough information to perform the assessment. Thus, to "Assess COA411 with respect to the Principle of Objective", one has to consider the features that characterize the objective, and these are specified by the expert as being "identification", "attainability", and "decisiveness". Therefore, the current task is reduced to three simpler assessment tasks. Assessing the attainability of the objective is applicable for the main effort and an offensive mission. Therefore, the ontology has to contain a classification of COA missions into offensive missions and defensive missions. To effectively assess the attainability of the objective one would have to determine whether there is a suitable path between the main effort and the objective. This reveals other necessary concepts, such as different types of paths (avenues of approach, mobility corridors, and infiltration lanes), and different types of units. Moreover, each path would need to be characterized by its capacity, and
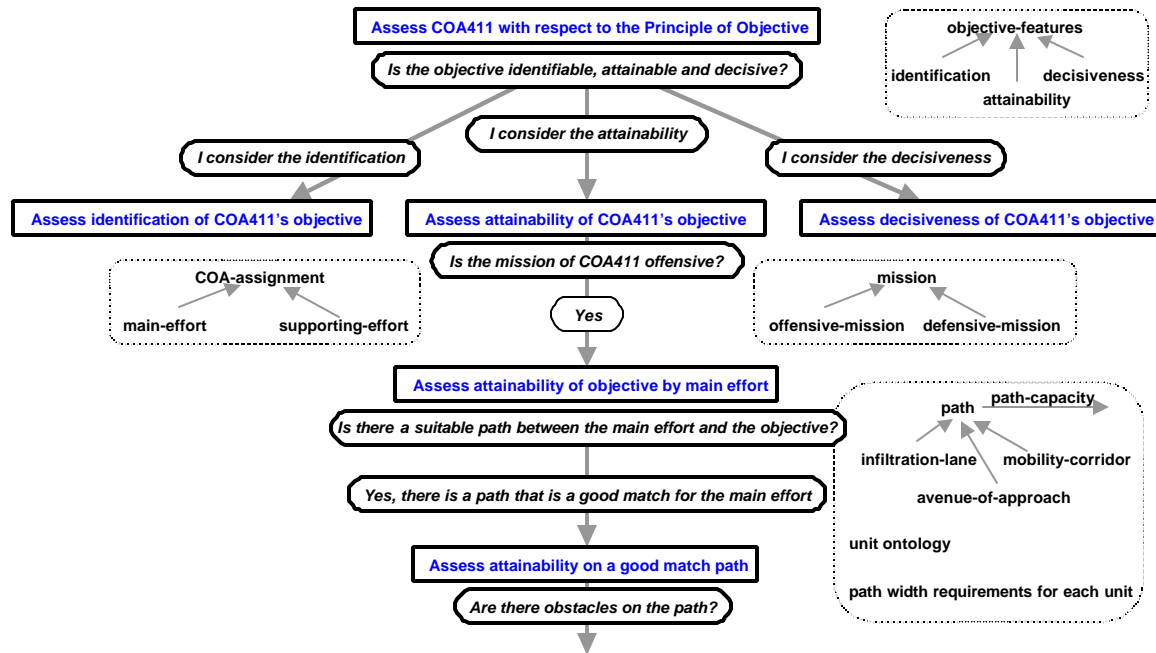
Figure 1: An illustration of the Disciple modeling process in the COA domain.

each unit would need to be described in terms of its path requirements.

There are several important results of this modeling process: 1) Necessary concepts and features are identified - they guide the import of relevant ontological knowledge from external repositories such as CYC (Lenat, 1995), Loom (MacGregor, 1999) or Ontolingua (Farquhar et al. 1996), leading to the definition of the agent's ontology. 2) Each task reduction step represents an example from which the Disciple agent will learn a general rule through the application of a mixed-initiative multistrategy learning method. In particular, the question and the answer from the example reduction guides the agent in generating an explanation of the reduction, which is a central element in rule learning. 3) The learned rules will include generalizations of the natural language phrases from the modeling tree. These phrases are used to generate solutions and justification in natural language. For instance, an abstract justification of an assessment task is generated by simply instantiating the sequence of the questions and answers that led to the assessment.

This methodology was used to build the knowledge bases of Disciple-workaround and Disciple-COA, for solving the two HPKB challenge problems mentioned above. The methodology and the developed Disciple agents were evaluated during intensive DARPA annual evaluations, demonstrating the highest rates of knowledge acquisition and the best performance results out of all the systems developed to solve the same challenge problems (Tecuci et al., 1998; 2000). In August 1999 we conducted a knowledge acquisition experiment with Disciple-COA at the US Army Battle Command Battle Lab where domain experts that did not have any prior knowledge engineering experience found this methodology very natural and easy to use.

In conclusion, we are developing a domain modeling methodology that is tightly integrated with an apprenticeship multistrategy learning approach to knowledge acquisition that allows domain experts to naturally express their expertise in a form that supports many aspects of KB development, including ontology formation, rule learning, and natural language generation.

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