

Knowledge Techniques for Advanced Conceptual Modeling

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ABSTRACT: *This paper describes several new techniques which are being developed and used jointly by BRC and UAH to address the large scale knowledge engineering problems of today's simulations. The first of these is called Tracked Repertory Grids which acquires highly detailed knowledge from relatively unskilled sources. This knowledge is collected so as to be clearly traceable. The approach is based on the original work by Wolff[1]. The knowledge is then represented as dynamic conceptual graphs based on the work of Sowa[2]. These graphs control the behavior of individual entities in a realistic manner consistent with the knowledge obtained with the Tracked Grids. This paper will describe the techniques and the tools developed by BRC and UAH to implement this approach in simulation systems.*

1. Introduction

Recent advances in detailed conceptual modeling offer the means to produce more realistic behavior in computer generated forces. While this can provide significantly improved realism in the training experience, there are also significant difficulties involved. These difficulties can be divided into two types, knowledge acquisition and knowledge utilization.

When the model's behavior becomes more realistic, the model requires more specific, detailed knowledge of the underlying behavior. In spite of the increase in detail, a trace must be maintained between the initial source and the final representation. Otherwise, the behavioral models, and the simulations, cannot be validated. Finally, the required volume of knowledge becomes cost limited unless a larger number of less-skilled knowledge engineers are used for the collection effort. Clearly, this will require automated or semi-automated acquisition techniques that easily transform into the final representation. These techniques must

also to identify conflicts and normalize the knowledge between sources.

Once collected, the knowledge must be represented in a clear form that supports utilization. That form should be compact, explicit and traceable. Traditional rule-based representations often obscure the overall knowledge by the serial one-dimensional nature of rules. This linear nature can impede understanding, maintenance, and robustness of large knowledge bases.

In recognition that fully automated collection and representation will not be immediately forthcoming, there is a remaining issue, collaboration. Not only is collaboration crucial in large acquisition efforts, but collaboration and knowledge exchange during utilization must be supported by standard interchange formats. Standards support large numbers of knowledge acquisition specialist in large scale knowledge engineering efforts, and they open the way to further collaborative knowledge development, knowledge reuse and knowledge libraries of realistic behaviors in tomorrow's simulations. Even more

importantly, standard formats encourage standard tool development, knowledge analysis, and knowledge comparisons.

This paper describes several new techniques to address the previous problem areas. These are techniques being developed jointly by BRC and UAH to support large-scale collaborative knowledge engineering tasks. The approach is based on Tracked Repertory Grids that acquire highly detailed knowledge using direct interaction with unskilled sources. The resulting knowledge set is both clear and traceable, as well as amenable to automated de-confliction and analysis. The approach is based on original work by Wolf and Delugach [1, 3, 4]. The knowledge is then represented as variation of dynamic conceptual graphs that are based on the work of Sowa [2]. These graphs control the behavior of individual entities in a realistic manner consistent with the knowledge obtained with the Tracked Grids. This paper will describe the techniques and the tools developed by BRC and UAH to implement this approach in simulation systems.

2. Semi-automated Knowledge Acquisition

In order to automatically generate simulated forces, we must first obtain a reasonably accurate representation for the knowledge of the real-world domain in which the forces are to be operating. Such knowledge must be machine-readable and in an understandable form. We employ a technique known as repertory grids for acquiring the necessary knowledge. Repertory grids allow us to query human experts in a relatively unbiased and efficient way to capture knowledge so that it can be represented in conceptual graphs, our knowledge representation (which is described later in the paper).

Repertory grids are employed as follows. A grid such as in Figure 2 represents the result of a well-defined acquisition process, that is described elsewhere (e.g., [5]). We have adapted and extended repertory grids from those in [5]. These extensions by Wolf called "tracked repertory grids" are described in [1, 3]. A *track* is simply a general relationship defined among a set of grids that corresponds roughly to conceptual relations between the concepts that the grids represent; for other illustrations, see [6]. For example, suppose we have the concept of a *ground vehicle* and the *activity* for which it is used. The conceptual graph in Figure 1 illustrates this relationship.

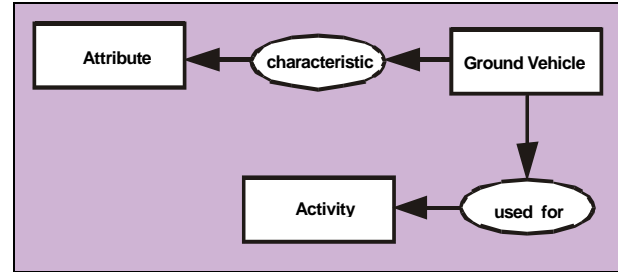


Figure 1. Conceptual Graph Schema For Ground Vehicle.

To acquire this knowledge, a well-defined acquisition process proceeds as follows. First, the concept "ground vehicle" is acquired, in terms of its attributes.

What are characteristics of ground vehicle? 1 = does not apply 6 = strongly applies							
Tank	APC	HMMWV	Truck	Halftrack	Launcher		
6	6	1	1	3	1	Has tracks	
6	1	1	1	3	1	Has turret	
1	1	1	6	3	5	Travels only on roads	
1	6	6	6	6	1	Crew < 3	

Figure 2. Repertory Grid For Ground Vehicle Characteristics.

The meaning of the grid is as follows. The labels represent particular ground vehicles, e.g., **Tank, APC,** etc. In repertory grid parlance, they are called *elements*. The phrases on the right represent the answers to the question: *What are characteristics of ground vehicles?* The phrases are called *constructs*. The scale used in answering the question is a 1 to 6 scale, where 1 indicates "does not apply" and 6 indicates "strongly applies". Thus, the entry under **Tank** indicates that it has tracks, has a turret, does not travel only on roads and does not have a crew less than three.

Our knowledge acquisition procedures are driven by the general conceptual graph schema shown in Figure 1 that will associate a concept with additional grids (e.g., a "used for" grid) based on the concept's purpose, location, user personnel, etc. The tracking of grids allow us to form related blank grids, so that a domain expert can fill in the new grids representing additional knowledge.

For example, an additional grid can be "tracked" to the grid in Figure 2. This new grid is based on the "used for" relationship.

What is ground vehicle used for?						
1 = does not apply 6 = strongly applies						
Tank	APC	HMMWV	Truck	Halftrack	Launcher	
1	6	6	6	6	1	Carry troops
1	1	1	6	6	1	Supply
6	3	1	1	1	6	Attack
1	6	6	1	1	1	Recon

Figure 3. Repertory Grid For Ground Vehicle Uses.

Once the knowledge has been acquired, we organize it and translate it into conceptual graphs to support the capture of database semantics. Each instance in the repertory grid can be expressed in conceptual graph form. For example, the tank instance can be expressed as in Figure 4.

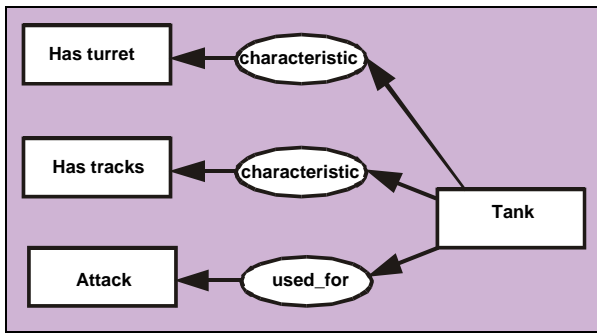


Figure 4. Conceptual Graph From Tracked Repertory Grids.

Once knowledge is acquired from one or more experts, that knowledge is represented in a conceptual graph database, which allows us not only to capture relationships between knowledge, it also gives us the capability to model that knowledge so that we may perform automatic reasoning with it. This is the principal purpose for using conceptual graphs as our representation.

3. Behavior Modeling with Conceptual Graphs

It is implicit in behavior modeling that human-like behavior can be modeled as a set of mappings between sets of concepts. For example, in a rule-based system, the initial set of facts is acted upon by the rules to transform the initial set to a final set of facts. Thus the rules represent a mapping between the beginning facts (concepts) and the ending facts (concepts). Similarly,

neural networks clearly map the inputs by some transformation to the outputs. Philosophers and psychologist may debate the existence of intelligent behavior without the input-transform-output (or observe-assess-act) model of behavior, but simulations deal with what entities observe, how they react and how they plan activities. Therefore, this view of intelligent behavior appears suitable for the immediate problems. This emphasis led to an examination of hybrids of multiple transforms and concepts collected together with clear, flexible representations. The result was a focus on conceptual graph techniques.

3.1 Conceptual Graphs Overview

Conceptual graphs are a knowledge representation and reasoning formalism introduced by Sowa in 1984 [2]. Since then, a number of international workshops and conferences have dealt with conceptual graphs in such diverse areas as logic programming, natural language understanding, enterprise modeling, battle damage assessment, image processing and software requirements. An ANSI standard interchange format, called CGIF, is in the process of being finalized; this will greatly enhance the interoperability of conceptual graph tools and allow sharing of knowledge bases between systems.

A conceptual graph consists of concepts and relations; concepts denoted by a box and relations denoted by a circle or oval. Relations are connected to concepts via directed links; the direction of the arrow is decided arbitrarily but usually follows a linguistic convention; e.g., in Figure 5, we read the "used for" relationship is "The used-for of Tank 9847 is attack". A concept contains a type identifier (e.g., Tank) with an optional referent which indicates a particular individual (or set of individuals) of that type (e.g., #9847).

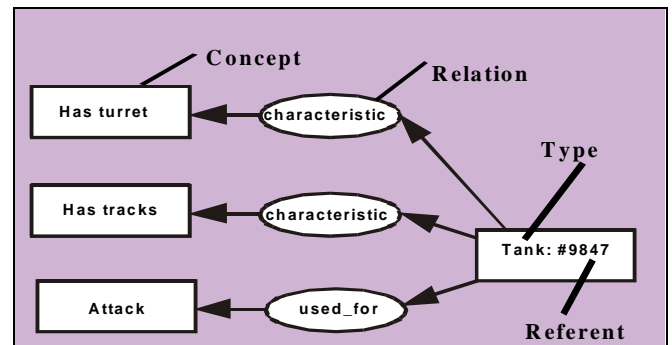
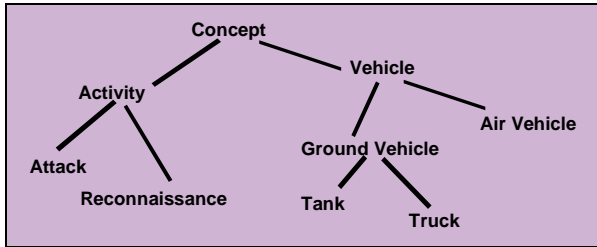


Figure 5. Parts Of A Conceptual Graph.

Associated with one or more conceptual graphs is a type hierarchy showing subtype/supertype relationships with multiple supertypes allowed, and a set of definitions (not shown).



Space does not allow us to fully describe all the useful features of conceptual graphs; for a more complete description, refer to [2, 7, 8].

3.2 Knowledge Model Development

Extracting from Section 2.0, Tracked Repertory Grids provide an approach that identifies the concepts and essential relations within a set of knowledge. From the section 3.1, these form a starting conceptual graph of the knowledge set. Because the Tracked Grid technique is directly traceable to the source of the knowledge, the starting conceptual graph is directly traceable to the source. However, meaningful knowledge sets require extending the details of the initial conceptual graphs. The source of the extension may be multiple Tracked Grids from differing experts, direct interaction with experts, or expert level material, and knowledge components. Experience has shown that automated graph editors, such as found in the CORE tool set [9], are invaluable at this point.

Knowledge components may be previously developed doctrinal templates or idiomatic graphs, which are representational templates. The graphical nature of conceptual graphs, combined with an appropriate hierarchy of concepts and relationships permits forming larger more complex knowledge sets through standard graph operations such as joins and splits. At the end of this phase a static representation of the knowledge base is available for discussion by members of the development team.

3.3 Dynamic Graph Techniques

Simulations require that the conceptual graphs make a decision. Decisions are obtained either by following the logic pattern in the graph or observing the graph states. It is desirable that the graphs behave as

independent entities that respond to changing conditions with new decisions. Numerous papers such as Delugach [10] have discussed animating conceptual graphs by various techniques. The basis for all of these methods has been the employment of actors in conceptual graphs. Actors maintain dynamic relationships within a graph by performing transformations between components. They also provide a mechanism for connection of the graphs to external sensors and to evolving databases. Finally, actors provide the means to dynamically monitor and understand the current behavior of the graph. This provides an additional mechanism for decision making and for communicating between graphs in separate planes or sheets of assertions [11]. An interesting side benefit of the graphical nature is the ease of altering the emotional behavior of a graph by altering the relationships between the concepts. This also provides a ready mechanism for simple adaptation.

4. Collaborative Model Development

Ultimately, single individuals are insufficient for the knowledge collection, knowledge modeling and the knowledge maintenance for highly realistic entities in future simulations. The volume of knowledge required presents a significant problem. Three approaches to resolving this problem are readily apparent. The first is the development of libraries of knowledge. The second is improved collaboration methods in knowledge modeling. The third is machine learning. This third solution is beyond the scope of this paper. Focusing on the first two solutions, it is clear that knowledge interchange between users and machines and between users and users is fundamental to this solution. Initially conceptual graphs utilized a notation developed and described by Sowa [2] that was called the linear format. Initial work on the CORE tool set utilized the linear form to provide a ready means to distribute the conceptual graphs and to store representations. Recently, the Proposed Draft ANSI Standard on Conceptual Graph Interchange Format has emerged as an alternative method to represent graphs with a machine-readable character set. This will simplify the problem of graph exchange when the standard is finally adopted as a means of storing and exchanging knowledge bases. BRC is currently working to adopt the CGIF standard as the standard is finalized. At that time, CGIF output will be incorporated into tracked grid tools to enhance exchange and automated analysis of the graph structures from individual and sets of experts.

5. Summary and Future Directions

BRC and UAH are working jointly extend generated force behavior modeling by focusing on three major development areas. The first area is End-to-End Automated Knowledge Base development. Key elements of this effort are tools for direct elicitation and acquisition, standard utilization, and automated knowledge analysis and evaluation. The Tracked Repertory Grid tools mark the initial efforts in this effort.

The second major development area is collaborative knowledge base development. Again this is supported by standard utilization, which is being implemented in the CORE tool set. The other essential element in this area is knowledge base libraries, hosted on knowledge servers, and supported by knowledge browsing tools, which will be based on the CORE technology.

The final major area of development is enhanced representation of knowledge. Past simulations have relied upon proprietary rule based implementations that inhibited both using another decision mechanism or interchange of knowledge with other systems. While developing experiments in alternative decision methods, BRC and UAH have bypassed internal decision components in both ITEMS and MODSAF to permit use of conceptual graphs for decision purposes. Future simulations should provide this capability from the start. Unfortunately, the lack of standards in knowledge base representation makes direct comparisons extremely difficult and very limited. Simulation developers should provide the mechanisms for plug-in decision components and the use of ANSI standard knowledge base representations to permit meaningful experimentation. BRC is currently planning the migration of the CORE tool set to utilize the CGIF standard. When a standard intelligent behavior interface for simulations is developed, BRC and UAH look forward to incorporating that standard into on-going tool developments.

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