Assignment 2

Blackboard Systems

Introduction to Expert Systems

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Blackboard architectures for constraint driven systems

Blackboard architectures are well suited to ill-defined and complex applications. The model of blackboard architecture is a group of individuals, with separate areas of expertise working together to "brainstorm" an optimal solution. The encapsulation of expertise into independent modules allows for diverse problem solving and computational methods to be utilized by the application. It also allows each module its own internal representation. This is beneficial in complex problem domains because it allows the application to use a multitude of approaches to a single problem.

Rule-based architectures also modularize their expertise, but with much smaller granularity. Knowledge is encoded into individual rules. "Unlike the large-grained scope of KSs, the small size of each rule prevents full independence"(Corkill, Blackboard 2). This lack of independence prevents the diversity of tactics that a blackboard system can employ to solve complex problems. Rules exhibit high coupling, meaning that changes to one rule will likely require changes to other rules. Blackboard systems' KSs are loosely coupled; changes to one KS will have no impact on the functioning of the other KSs. This allows for seamless and constant addition, deletion and modification of KSs. This ability to support change is very important feature in constraint driven applications.

The RADARSAT-1 blackboard system is a constraint driven system. It must manage the physical constraints of the spacecraft, the data reception and processing, as well as access policies and priorities of the partners and customers (Corkill, Countdown 53). "There are over 140 constraints that define the limiting conditions of various system resources involved in imaging, recording, transmitting and processing the image product for RADARSAT-1"(Corkill, Countdown 53). KSs allow blackboard systems to represent this wide range of constraints independently as well as providing a framework for integrating these constraints to find an optimal solution. Rules do not allow for such a broad range of representation.

Most of the policies that define the constraints of RADARSAT-1 were not determined until after the system was in place (Corkill, Countdown 53). Thus the systems had to accommodate changes to policy from the very beginning. Again, the modularity of KSs provided the necessary flexibility. The high coupling of rules, in rule-based architectures, would have inhibited this requirement.

All the constraints required in the scheduling of RADARSAT-1 resulted in a very complex problem, with no single solution. "A good schedule may be achieved through many possible combinations"(Corkill, Countdown 53). No single planning software agent could manage a problem of this complexity. Multiple planners were required to work together to create the RADARSAT-1 schedule. Blackboard architectures' ability to separate this task into the actions of individual KSs makes it an appropriate choice.

Blackboard architectures are better suited for constraint driven systems than rule-based architectures because the modularity of knowledge sources provides the flexibility needed to represent and modify the many constraints. It also allows the complexity of the problem to be tackled by multiple approaches. Rule-based architectures do not provide the appropriate granularity in its modularization of expertise.

Application of Blackboard Architecture : Automatic Polyphonic Music Transcription

Blackboard Architectures are particularly suitable for ill-formed problems that require the application of a variety expertise. In his paper "A Blackboard System Automatic Transcription of Simple Polyphonic Music" Keith Martin describes how blackboard architecture has been employed to transcribe the four-voice polyphony of Bach's chorales. Transcription of music is the process of notating a piece of music. In order to do this the individual notes must first be deciphered and then the beat and tempo of the piece must be distinguished. This is a difficult problem, complicated by the different qualities of sound produced by individual instruments, referred to as timbre. Transcriptions of Bach's chorales "embody a very structured domain of musical practice"(Martin, 2). "The importance of a structured domain is that it allows the transcribing agent to exploit the structure, thereby reducing the difficulty of the task"(Martin, 2).

The areas of expertise required to transcribe a piece of music include: "knowledge about human auditory physiology, knowledge about the physics of sound production, and knowledge about the rules and heuristics governing tonal music"(Martin, 2). In Martin's application, a track of music is converted into a discrete representation using Fast Fourier Transfers in a front-end application developed in Matlab. This discrete representation is then passed to a blackboard system, which performs the actual transcription.

Martin's blackboard is subdivided into regions corresponding to Chords, Intervals, Notes, Partials, Tracks and FFT Spectrum. This hierarchical positioning metric allows for efficient storage and retrieval of data from the blackboard. "The knowledge sources in the system fall under three broad areas of knowledge: garbage collection, knowledge from physics, and knowledge from musical practice"(Martin, 5). There are 13 different KSs, each is associated with one of the levels of abstraction defined by the hierarchical positioning metrics of the blackboard. Each which solves a particular part of the overall problem. The KSs associated with the lower levels of abstraction, including FFT Spectrum, Tracks and Partials encapsulate knowledge from physics. In higher levels, the KSs encoded knowledge from musical practice. The KSs that are responsible for garbage collection removes invalid results of previous activities of KSs. The KSs are activated when new data is added to the blackboard. Each KSs has a precondition and an action. If a KS's precondition is met and it has been selected for execution by the control component then it performs its action and produces a result.

The results of KSs are called hypotheses. The hypotheses are associated with a particular level of abstraction defined by the blackboard. Their names reflect this structure, for example: NoteHyps, PartialHyps, IntervalHyps, and ChordHyps. "Hypotheses are implemented in a frame-like manner. All hypotheses share a common set of slots and methods, including a list of supported hypotheses and a list of hypotheses that support the hypothesis object. Each hypothesis has a list of "Sources of Uncertainty""(Martin, 4). The "Sources of Uncertainty" are essentially tags that allow the control component to manage the course of problem solving. "By allowing the KSs to tag hypotheses with SOUs, the KSs may not have to re-evaluate their preconditions on every time step. Additionally, SOUs can be used to keep KSs from operating more than once on the same hypothesis"(Martin, 5).

The transcription of tonal music is a complex problem. It requires the application of many different types of knowledge. It is a problem that benefits from centralized data store and a centralized control component as well as the modularization of the necessary expertise. These characteristics make transcription of tonal music a suitable domain for blackboard architecture.

Centralized and decentralized control systems

"Collaborating software involves the integration and coordination of relatively independent, self-contained software systems that are able to work together on their own"(Corkill, Collaborating 1). There are two types of collaborating software; those with centralized control systems, such as blackboard systems and those that operate with a decentralized structure of control, such as multi-agent systems (MAS). Both control systems operate with a "divide-and-conquer approach to the development and maintenance of large and complex software applications"(Corkill, Collaborating 1). The application is divided into smaller, independent modules that encapsulate specialized knowledge. This model allows for each module to apply its specialized knowledge to the problem when applicable.

The modules in an agent-based system are required to communicate directly with one another. This "promotes the use of *private* communication protocols"(Corkill, Collaborating 2). These individualized communication protocols can be efficient but modification or addition of modules can require changes to many modules. In Blackboard architectures the blackboard allows "*indirect* and *anonymous* communication among modules"(Corkill, 2) because it functions as a communication intermediary. This centralization of communication protocols eases the addition and modification of modules. It also "reduces the number of communication interfaces that must be supported among highly collaborating modules"(Corkill, Collaborating 2).

With centralized control systems general representations are used. This allows all modules to understand, and possibly use, results of any given module, but it also enforces a certain *degree of detail* in the representations. Because all data is stored in a centralized storage the *degree of detail* becomes an issue of performance and efficiency. The *degree of detail* necessary for each module may differ. In decentralized control structures the knowledge representation and *degree of detail* can be tailored to the individual needs of each module.

Blackboard architecture is well suited for the constraint-driven planning required for RADARSAT-1 while MAS provides a good model for the knowledge-driven planning of Ocean Tanker Fleet Scheduling.

RADARSAT-1 uses the blackboard architecture developed by BBtech. This application is required to "allow end users anywhere in the world to connect to the system, prepare and submit requests, and monitor the status and progress of each request as it is planned and executed"(Corkill, Countdown 52). This behavior requires a centralized system in order to manage the complex interaction of the many constraints. The centralized control of blackboard systems allows for opportunistic control, which provides the application the ability to manage the course of problem solving. It also requires efficient retrieval of the operating state of the application at any given time. The blackboard acts as a centralized data store giving the application efficient retrieval of data as well as the ability to integrate the results of the independent modules.

Magneta's MAS Ocean plans ocean tanker fleet scheduling. "The Magenta Ocean i-Scheduler is designed to cope with re-planning in a very effective way – by performing only a localised re-planning. This means that only the agents related to the vessel(s) affected are activated and start negotiations to find all possible options"(Rzevski, 2). With MAS architecture agents only have "local view of problem solving activities" (Corkill, Collaborating 10). Thus a distributed control structure is well suited to this problem domain.

Works Cited

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