DISPROS - A Distributed Blackboard Architecture

By

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Certificate

This is to certify that the thesis entitled **DISPROS - A Distributed Blackboard Architecture** submitted by Mr. Manoj Kumar Saxena to the Department of Computer Science and Engineering, Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy is a record of the original bonafide research work carried out by him under our guidance and supervision.

The thesis or any part thereof has not been submitted to any other university/institution for award of any degree or diploma.

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Preface

In recent past, there has been an upsurge of interest in Distributed Artificial Intelligence (DAI), with a recognition that the core problems are quite profound and impact many areas interesting to others both in Artificial Intelligence (AI) and its related disciplines. DAI provides a means for interconnecting multiple expert systems that have different but possibly overlapping expertise to enable the solution of problems whose domains are outside that of any one expert system. DAI is the most appropriate solution when the problem itself is inherently distributed, such as in distributed sensors net and specialized medical-diagnosis systems. The approach potentially has the additional advantages of modularity, speed, reliability, knowledge acquisition, and reusability.

When we started our work in 1987 there were few paradigms or models for building distributed intelligent applications. The principal paradigms that had been employed derived from *expert systems, blackboard systems and object-oriented systems.* Each of these approaches to system development consisted of an underlying computational model, a method for organising knowledge and other computational elements and a control regime for determining the sequence of operations. We felt a need to combine features of these paradigms into a unified paradigm for distributed problem solving, which would be *highly modular, flexible and support diverse knowledge representation and reasoning mechanisms.*

In this thesis we describe our research efforts to meet the above mentioned objectives and the proposed **DISPROS - DIS**tributed **PRO**blem **S**olver architecture, which is the result of those efforts. We have described the concepts and terminology used in this thesis in Glossary at the end of the thesis. A list of abbreviations used in the thesis is also included.

Abstract

At the current level of evolution, the computers are increasingly being employed to solve complex problems and exhibit intelligent behaviour. Lately, the blackboard architecture and its variations [Nii 86a, 86b, Engelmore 88] are being explored to achieve efficient and reliable problem solving paradigms. It has been viewed as particularly appropriate for parallel and distributed hardware architectures, as blackboard metaphor entails multiple, independent sources of knowledge trying to solve problem collectively. Yet, most of the blackboard systems have been implemented on conventional hardware and are primarily executed serially. So far very few attempts have been made to exploit the concurrency. This thesis describes our efforts to exploit the inherent concurrency offered by blackboard architecture, by distributing it over a network of heterogeneous computers.

To achieve any degree of success in supporting complex, distributed knowledge based problem solving, the system must address the issues of expressive adequacy and notational efficacy of the knowledge representation scheme. The system should be able to reason with incomplete and not necessarily consistent knowledge. The control mechanism has to be intelligent enough to achieve coherence and consistency among the concurrent problem solving activities of various experts, with distribution of problem solving over a network, there is an additional need to have fault-tolerance mechanism to withstand various faults. It is also desirable to make the system modular, flexible and widely distributable.

To address these issues/ requiremnents, we have proposed **DISPROS - DIS**tributed **PRO**blem Solver, as a framework for the implementation of distributed problem solving systems in loosely coupled, multi computer environment. DISPROS allows a knowledge based system to be described as a collection of cooperating, distributed, intelligent, encapsulated agents called Level Managers (LMs). Each LM is based on blackboard model and is an active structure consisting of the knowledge base, the behaviour part, the local controller, the monitor and communication controller. LMs execute entirely

asynchronously, in parallel and communication by passing messages. In this thesis, we describe the underlying computational and control models to support the problem solving using DISPROS, and the strategy adopted to withstand various system and communication related faults.

DKRL - **D**istributed **K**nowledge **R**epresentation **L**anguage, the knowledge representation paradigm developed for DISPROS considers LM as an object, and allows object-oriented programming techniques to be used for application development. We have proposed **DIAM** - **D**istributed **I**ntelligent **A**gent **M**ethodology, to develop distributed problem solving using DISPROS. It allows a problem solving system to be specified as a collection of intelligent agents. These agents can be directly mapped to LMs in DISPROS and implemented using DKRL.

To demonstrate the applicability of the proposed paradigm two systems were developed. The ASSIGN [Saxena 90b] system was developed to illustrate the expressive power of DKRL and local control component of the LM. The FEP - Field Engineering Planner, system has been developed to establish the viability of collection of LMs as a distributed problem solver. It also demonstrated the global control mechanism and the viablity of message passing as a means of communication and cooperation amongst LMs.

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