Hybrid Computing Architecture for Artificial Intelligence Based on Blackboard Approach

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Abstract: Architecture for hybrid computing, based on blackboard approach, is proposed to solve the problems of artificial intelligence, such as: identification, robot control, information retrieval. The blackboard approach for collaborative computation is being generalised with a dynamical workflow notion. This allows to find solutions for complex problems using different methods applied to sub-problems and generalisation techniques.

Key–Words: Stochastic systems, Nonlinear control, Learning control, Intelligent control

1 Introduction

Many problems of computer science and engineering still do not have a general solution, the method to be used always where the specific problem appears. In this case usually there exist several algorithms solving the problem bad in general, but used in some cases. Sometimes these are not mathematically proven algorithms, but heuristics. For instance, looking for a minimal identification path to find an appropriate class for the object in minimal number of steps requires large computational effort and in general can be solved only by suboptimal algorithms, each working better in some particular case [1].

Hybrid computing is being studied more and more these years because some problems, which are too complicated for usual von Neumann architecture, can be easily solved by hybrid computer (analogous [3], quantum [5], DNA-based nanocumputer [4]). Moreover, in practical applications specific computational device is often preferable than such a general tool as the von Neumann computer. For the problems discussed in this paper, the von Neumann architecture is not required. Talking about a hybrid device notion, the sufficient requirement for it in this paper is that it takes some typeable input, and produces some typeable output.

Blackboard approach to ill-defined and complex problems of artificial intelligence, modeling, integration is being used more than 20 years in different areas [2]. It is very efficient and dynamical; it requires several sufficiently different methods for partial problem solution to collaboratively work in common context developing the solution. However, this approach is not very flexible in contemporary distributed multiagent computational enviroments, such as GRID environment[6].

This paper proposes an additional generalisation to blackboard approach together with workflow notation. We define well-typed description language based on workflow notation and computing architecture for running the algorithms described in this language and propose it for usage in artificial intelligence. The typed problem definitions allow creation of a collection of hybrid computing devices, each solving specific task. They collaborate by one using other for sub-problems solution deriving from it's own problem, and by using each other's experience while solving the same problem. Returning to blackboard approach, we can say that several blackboards are needed for some tasks. The hybrid devices play sometimes a role of controller, sometimes a role of knowledge source, sometimes even contain a blackboard for running other devices as knowledge sources and a controller.

2 Typed Problem and Hybrid Device Definitions

The problem from artificial intelligence class can be formulated in terms of automatic control as optimization task. Several problems of this class were studied using this approach [7, 8, 1], however it is not the only one. We consider a problem of minimization of some cost function depending on the observations. Typed problem consists of definition of the known and unknown parameters in the model, noise if it appears, scheme of observations and the way of controlling the system, i.e. input arguments of the model.

There is ierarchy of problem definitions, with multiple inheritance, from generalisations to particular problems.

Each problem should have a collection of hybrid devices solving it. Description of hybrid device is also typed and contains the types problems to which solution the device could be applied and the rules for definition of the correspondence between input and output values of the device and the problem parameters.

3 Blackboard approach and Collaborative Computing

Let's consider such a scheme of computations to solve some typed problem. There is a blackboard (world model, WM) - it is a collection of known facts, observations, estimates which can be used in problem solution. There are knowledge sources (KSs) - it is a set of different hybrid devices, providing different ways to solve the problem. Each KS finds out facts and puts them into world model, using the facts already contained there. KS is a metaphore for the expert, specialist in some particular method which can solve the problem. KS can use every fact from WM, however if the fact is some prediction then KS can choose how it trusts this fact. Sometimes there are particular problems, for which the answer can be easily checked if it suits or not, but to find the answer is difficult. Such answers are perfect to be put in WM. The last part of blackboard is the controller which chooses the solution from several proposed by KSs. Often when the problem requires real-time action, each KS proposes it's own variant and the controller finds out what variant is the best one. This decision can be based on the quality of the answer provided by each KS and on the quality of the answer which controller computes itself based on the problem definition only. The KS internal work is invisible to the controller.

This computation scheme is called blackboard approach. If there is a problem that contains several ill-defined sub-problems, and each of them should be solved by blackboard, or even if they are quite simple, but we want to build more transparent scheme of computations, the blackboard approach itself is not enough. We propose to generalise the blackboard approach and add sequential, parallel (independent), while, if-then-else constructs to be able to define flows of data from one device to another and the problem decomposition using the present devices.

4 Conclusion

All the problems described can be solved in terms of proposed in the paper hybrid computing architecture. Enabling this architecture in engineering can help in applications. The GRID infrasctructure is proposed to be the infrastructural part of the multi-agent environments, and can be used as a basis for modeling of hybrid computing architecture. Implementation of the architecture in GRID environment is one of the projects in SPRInt Lab of the Saint Petersburg State University.

Several questions arise. Among them are: how to estimate quality of hybrid device, how to control blackboard, how to define workflow. Also, a problem of multi-agent environment, in which each agent solves it's own separate problem, is being kept out of scope of the proposed architecture, but it seems to be somehow wrong.

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