AN OVERVIEW OF BLACKBOARD ARCHITECTURE APPLICATION FOR REAL TASKS

D. Rudenko and A. Borisov

Keywords: blackboard architecture, blackboard application, blackboard benefits

1. Introduction

Agents were successfully used in artificial world, but nowadays scientists and researchers are applying agent systems in real tasks. Cooperation between agents can be achieved by means of blackboard architecture. Blackboard architecture is not a new technology, the first famous blackboard architecture Hearsay appeared about 30 years ago. Therefore blackboard architecture applications for real tasks must be overviewed.

The paper is structurized as follows. First, some definitions are listed, then the benefits of the use of blackboard architecture are presented and some examples of blackboard architecture application for real task are given.

2. Blackboard architecture

2.1. Blackboard system definitions

The blackboard methodology is a complicated system task solving strategy using different knowledge sources communicating by means of common information field.

A blackboard is a global accessible database which is used for intermediate, partial results of problem solving. As a rule, various sites of a blackboard allow one to represent hypotheses at various levels of abstraction and provide joint actions of several experts [1].

A blackboard system can be viewed as a group of sitting human specialists next to a large blackboard. They are working cooperatively in order to solve the problem and they use the blackboard as a workplace for solution development.

Problem solving begins with announcement of a problem and writing initial data onto the blackboard. The specialists are watching the blackboard looking for an opportunity in order to make contribution for solution development. When a specialist finds this opportunity, he records the contribution on the blackboard, in hope that others will use his contribution for final problem solving. This process continues until the problem is solved.

A blackboard system consists of three components:

1) Knowledge sources (KSs);
2) Blackboard;
3) Control component.

Knowledge sources are independent modules that contain the knowledge needed for problem solving. They don't need to know about the existence of the others, but they have to understand the state of problem-solving process and the representation of relevant information on the blackboard [2].

Knowledge sources can be represented with different kind of knowledge; they can include rule-based systems, case-based systems, neural networks, fuzzy logic systems, genetic algorithms, legacy software systems (see Figure 1) [3].

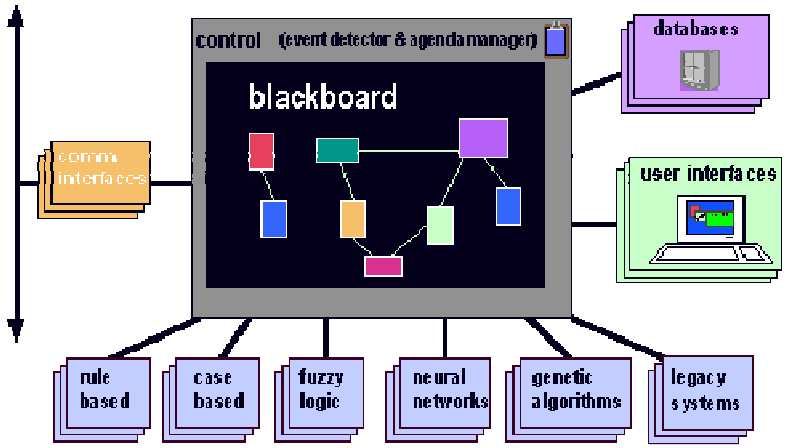

Figure 1. Different kinds of knowledge sources in blackboard system

Blackboard is used as a global database for sharing different information as input data, partial solutions, alternatives and final solutions.

Blackboard applications tend to have complex blackboard structures, with multiple levels of analysis or abstraction.

Control component makes runtime decisions which of knowledge sources to execute next for optimal problem solution [2].

The blackboard was originally designed as a methodology in order to handle complex, ill-defined problems. First famous example is the Hearsay II speech recognition system. More recent example the PLAN component of the mission Control System for RADASAT-1 is a blackboard system. RADARSAT-1 is a sophisticated Earth observation satellite developed by Canada to monitor environmental changes and the planet's natural resources [4, 5].

2.2. Blackboard system benefits

The authors [3, 6] offer the following benefits of blackboard system:

1. Integration of knowledge sources managed by the control system.
2. Modularity - each knowledge source is independent that makes development and maintenance easier.
3. Flexibility - the Blackboard architecture allows blackboard applications to adapt to changing requirements much more flexibly than the traditional procedural software applications.
4. Extensibility - new knowledge sources can be developed and applied to the system not changing the existing system and without having to specify its existence in any other knowledge source.
5. Efficiency and quality - more than one knowledge source is able to perform the same function, therefore the control component can select the one which will provide the most benefit to the emerging solution. This can improve both problem solving efficiency and the quality of the eventual solution.

6. Opportunistic cooperation - cooperation in a blackboard system is explicitly opportunistic; knowledge sources can post partial solutions to the blackboard in hope that some other knowledge source will be able to take these partial solutions and find the final solution.

7. Software reuse - the independence and modularity of knowledge sources means that new applications can easily be constructed using existing knowledge sources, traditional procedural software investments can be preserved because they can be incorporated as knowledge sources, the Blackboard itself is application independent, and is easily applied to new problem domains. [3, 6].

3. Blackboard system application

The blackboard system can be used in different areas, the author [2] offers a list of these areas and they are:

- sensory interpretation;
- design and layout;
- process control;
- planning and scheduling;
- computer vision;
- case-based reasoning;
- knowledge-based simulation;
- knowledge-based instruction;
- command and control;
- symbolic learning;
- data fusion [2].

Mostly blackboard system is used in location-locomotion, data interpretation, and environmental changes monitoring problem solving. Some of the examples are presented below.

3.1. A blackboard system for interpreting agent messages

The main goal of real-time strategy games is the behavior of groups rather than individual behavior, therefore centralized system control is needed. This can reduce overall complexity by allowing individuals to remain simple, while the complexity resides within the centralized control system.

Another aspect of agent coordination is agent communication. The blackboard system is an approach to processing agent communication centrally. The authors describe the use of blackboard system for centralized control and communication through structured messages.

Agents generate messages that contain information about their internal states and surroundings, these messages are sent to the blackboard. These messages provide initial messages for the system. This allows system to be simple and efficient without complex message procedures embedding.

Blackboard has been designed specially in order to cope with complex, ill-structured problem domains, and to allow exploratory programming of knowledge-based systems by integrating heterogeneous knowledge sources. The main difficulties encountered with blackboard are its control strategy and securing real-time performance.

As a result of structuring the working space according to time and the positions of units, the blackboard is well-suited to spatial and temporal reasoning [7].

3.2. A mobile robot for corridor navigation

The authors of this paper focus on building an autonomous vehicle as the test bed for the future development of an intelligent wheelchair for locomotion.

Experimental robot is equipped with four agents (Sensor Handler Agent, Collision Detector Agent, Corridor Recognizer Agent and Drive Controller Agent) and includes the control software, aluminium beams and plastic connectors to build a chassis, two stepper motors, one 360 degree rotating caster wheel, a power module, a battery, a web-camera, nine infrared sensors and extra beams and connectors for reinforcement.

Agents and blackboard form the control system. Agent cooperation is reached by means of the blackboard. Blackboard is used as a central repository for all shared information.

Only two agents have an access to the environment; they are Sensor Handler Agent and Drive Controller Agent (see Figure 2) [8]. The arrows in Figure 2 represent information flow.

There is no global controller for all of these agents, so each of them independently tries to make a contribution to the system during the course of navigation. Basically each of the four agents executes its tasks independently using information on the blackboard and posts any result back to the blackboard.

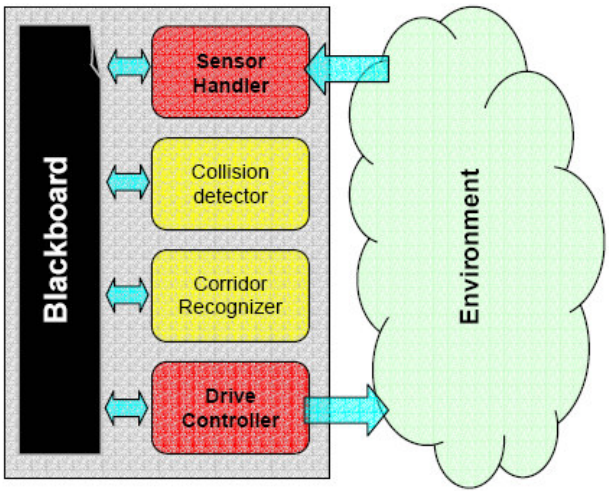

Figure 2. Multi-agent system with blackboard

The Sensor Handler is responsible for all the sensors installed on the robot, and maintains the ability to deal with the sensors without any extensive impact on system modification and configuration. Collision Detector Agent is responsible for the safety of the robot used in this experiment. The agent has 17 fuzzy rules: seven rules for the front sensors, two for the rear sensors, and four for each of the left and right sensors. In the case of collision detection the robot is able to avoid collisions with obstacles and walls. Corridor Recognizer Agent is used to classify the image into three categories: corridor, wall, and obstacle. In the case of collision detection the robot is able to avoid collisions. The Drive Controller monitors the blackboard and uses the navigational information for locomotion.

The robot has shown both desired and problematic behaviors. The Collision Detector Agent maneuvered the vehicle around and navigated it to the end of the hallway without collisions. But there were also some problems; first, the sensor agent was often distracted by ambient light, which caused the retardation in navigating the robot. The second problem is the advisability of the fuzzy rules. The agent sometimes makes magnified conclusions about the turning angle in large amplitude, which results in zigzag locomotion [8].

3.3. A distributed blackboard architecture for interactive data visualization

They applied their distributed blackboard system to an atmospheric transport application [9]. The goal was to accurately forecast the atmospheric transport of the radioactive noble gas radon based on measure wind and emission fields.

The architecture is centered on blackboard and satellite processes that produce and consume data. The satellites implement the simulation, geometry mapping and rendering algorithms, analysis programs. The blackboard manages a database of variables and also it can act as even notification manager:

1. satellites can create, open, close, read and write variables;
2. satellites can subscribe to events that represent state changes in the blackboard.

The distributed architecture consists of six building blocks: a global name manager (GNM), zero or more local blackboards (LBB), zero or more satellites, command, event and data streams. The GNM maintains the bookkeeping information of all LBBs and variables in system. A LBB belongs to each host in the distributed environment. LBB accept connections from satellites executing on the same host and other LBBs. Satellite consists of an operator that transforms input data into output data.

Communication to the LBB is done by sending commands on the command stream. Communication from the LBB is done by receiving events from the event stream. Data streams are used to transport data between LBBs and satellites.

The LBB manages only those variables that are opened by the connected satellites. When a satellite opens a variable, the LBB consults the GNM to check if the same variable exists in other LBBs. If this is the case, the LBB will connect with these LBBs.

When a satellite writes a variable, the LBB will broadcast a mutate event to all connected satellites and LBBs that share the variable. When a satellite reads a variable, the LBB will first check if the data is up to date and, if so, will service the read request. If the data is not up to date, the LBB will first get the latest copy of the data from another LBB before servicing the read request.

They believe that this architecture provides support to fulfil their major requirements – integration, efficiency of data transportation and ease of use.

The Radon forecasting process is shown below. The radon simulation satellite creates a set of three variables containing the wind fields and the simulated scalar radon field. After each step this set is duped into the LBB.

A reader satellite reads the data from the database and writes into the blackboard.

The analysis satellite creates the variable containing the candidate points. It dumps points into the LBB until stop criteria is reached. It also opens the variables created by the simulation.

The visualization satellite reads and displays the data sets and candidate points.

The plotting satellite reads and displays the time series which are put on the blackboard by the reader and analysis satellites.

The authors [9] used a blackboard for effective data transportation. They meant two advantages of the architecture: first, it allows visualization tools to be tightly integrated with simulations, and second, it allows qualitative and quantitative analysis to be combined during the visualization process.

They believe that the blackboard model can be used as a framework for future visualization solutions [9].

3.5. Blackboard system for web application

Unusual enough application of blackboard architecture was found by authors [10].

They discussed the development of a web application to movie chains using the blackboard architecture. The blackboard architecture allows control, communication and cooperation problem solving; therefore they applied a blackboard system in their project.

The requirements for this project were: presentation and collection of user data, validating user input data and performing business processes and storing and retrieving persistent application data.

The goal was to develop an integrated system for movie administration – accounts, ticket selling, movie guides, schedules, reservations etc.

The blackboard system was used for data centralization.

Knowledge sources represented movie information, movie guide, and reservations. The blackboard holds all the data of movie guide and also supports the updating process. The control component monitors blackboard and activates knowledge sources [10].

4. Conclusions

The blackboard architecture can be successfully applied in problem solving in real world. The blackboard architecture has a lot of benefits; therefore it can be widely used.

Blackboard architecture can offer centralized system, and it is known that system centralization means that the system will be robust without complicating system's parts; instead, simple parts will make up robust system.

Cooperation between agents in multi-agent system can be achieved by means of blackboard architecture. They do not cooperate with each other, they use a blackboard as a central depository, they put on it data and look forward the data on it in order to make a contribution.

The agents work consistently; the blackboard is used as a central repository for all shared information. All the partial results made by agents are posted on the blackboard and are used by other agents till the final solution is found.

References

1. http://www.oglibrary.ru/data/demo/0953/09530429.html
2. Corkill D. D., "Blackboard systems", *AI Expert*, 6(9):40–47, September 1991.
3. http://www.nb.net/~javadoug/bb.htm
4. http://en.wikipedia.org/wiki/Blackboard_system, Wikipedia, the free encyclopedia.
5. http://www.space.gc.ca/asc/eng/satellites/radarsat1/default.asp
6. Hunt J., "Blackboard Architectures", *JayDee Technology Ltd 27*, 2002.
7. Cavazza M., Mead S.J., Strachan A.I., Whittaker A., "A Blackboard System for Interpreting Agent Messages", *Proceedings GameOn 2000: International Conference on Intelligent Games &Simulation*, UK, 2001.
8. ONO Y., Uchiyama H., Potter W., "A mobile robot for corridor navigation: a multi-agent approach", *ACM Southeast Regional Conference Proceedings of the 42nd annual Southeast regional conference SESSION: Artificial intelligence #1*, 2004, pp. 379 – 384.
9. van Liere R., Harkes J., de Leeuw W., "A Distributed Blackboard Architecture For Interactive Data Visualization", *Proceedings of the conference on Visualization* '98, 1998, pp. 225 – 231.

10. Metzner C., Cortez L., Chacin D., "Using A Blackboard Architecture In A Web Application", *The Journal of Issues in Informing Science and Information Technology*, Volume 2, 2005, pp. 743-756.

Darya Rudenko, Mg.sc.ing., Ph.D. student, Institute of Information Technology, Riga Technical University, 1 Kalku Str., Riga LV-1658, Latvia, e-mail: to.darya@inbox.lv

Arkady Borisov, Dr.habil.sc.comp., professor, Institute of Information Technology, Riga Technical University, 1 Kalku Str., Riga LV-1658, Latvia, e-mail: Arkadijs.Borisovs@cs.rtu.lv

Rudenko Darja, Borisovs Arkādijs. Blackboard arhitektūras pielietošanas apskats reālajos uzdevumos
Blackboard arhitektūra nav no jaunajām tehnoloģijām, pirmā blackboard arhitektūra – Hearsay parādījusies pirms 30 gadiem. Ar laiku tā izmainījās, kaut gan pamatfunkcijas saglabājušās, blackboard arhitektūra ieguva jaunus uzlabojumus. Tas tika iespējāms pateicoties blackboard arhitektūras pielietošanai dažādās sfērās. Blackboard metodoloģija ir sarežģīto sistēmas uzdevumu risināšānas stratēģija ar dažādu zināšanas avotu piesaistīšanu, kuri iedarbojas ar kopīgo informācijas laukuma palīdzību. Blackboard arhitektūra tika izgudrota kā līdzeklis sarežģīto un slikti noformulēto uzdevumu risināšanai. Dotais raksts prezentē iegūto zināšanu apkopojumu, kuras tika iegūtas zinātnisko avotu pētījumu rezultātā, piemēram rakstā ietilpst šāda informācija kā blackboard arhitektūras pamataspekti, no kā tā sastāv, kādam nolūkam tā tika izgudrota un pirmoreiz pielietota, ka arī tiek piedāvātas blackboard arhitektūras pozitīvas īpatnības, pateicoties kurām šī arhitektūra ir tik plaši izmantojama. Blackboard arhitektūra pirmoreiz tika pielietota mākslīgā intelekta uzdevumu risināšanai – runas atpazīšanas sistēmā Hearsay, bet tagad ir plaši pielietojama arī reālo uzdevumu risināšanai. Šajā rakstā tiek apskatītas blackboard arhitektūras pielietošanas iespējas reālajos uzdevumos.

Rudenko Darya, Borisov Arkady. An overview of blackboard architecture application for real tasks
Blackboard architecture is not a new technology, the first blackboard architecture Hearsay appeared about 30 years ago. Nowadays it has been changed with new additions but the basic features of blackboard remain the same. It became possible because of putting blackboard architecture in different areas. Blackboard methodology is a complicated system task solving strategy using different knowledge sources communicating by means of common information field. The blackboard architecture was developed as a means to handle complex and ill-defined problems. This article presents a generalization of knowledge, which was received as a result of a research of science sources; for example, it contains the basic aspects of blackboard architecture: what it consists of, why it was developed and for what reason it was first applied. The benefits of blackboard architecture are presented as well, thanks to which this architecture is widely used. Blackboard architecture at first was applied for artificial intelligence problem solving – in a speech recognition system Hearsay, but nowadays this architecture is widely used for real problem solving. In this article the blackboard architecture application in real tasks is presented.

Руденко Дарья, Борисов Аркадий. Обзор применений архитектуры классной доски для реальных задач
Архитектура классной доски не является новой технологией, первая архитектура классной доски "Hearsay" появилась около 30 лет назад. Со временем она изменилась - архитектура классной доски приобрела новые дополнения, сохранив свои основные функции. Это стало возможным благодаря использованию архитектуры классной доски в разных сферах. Методология классной доски - это стратегия решения сложных системных задач с привлечением разнородных источников знаний, взаимодействующих через общее информационное поле. Архитектура классной доски была изобретена как средство для решения сложных и плохо сформулированных задач. Данная статья представляет собой обобщение знаний, полученных в результате исследования научных источников, например, в статье представлены: основные аспекты архитектуры классной доски: из чего она состоит, для чего ее создали и для чего впервые применили, а также описаны положительные качества архитектуры классной доски, благодаря которым ее используют. Архитектура классной доски первоначально была использована для решения задач искусственного интеллекта – в системе распознавания речи Hearsay, но сейчас широко используется и для решения реальных задач. В этой статье также представлен обзор применений архитектуры классной доски для решения реальных задач.