

The Efficiency of Intelligent Distributed Collaborative Agents in the Knowledge Based Society

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Abstract: *Defining elements of the information society are presented. The development stages of the information society are discussed. The defining principles of knowledge-based society are stated. The paper discusses the elements that led to the formation of the knowledge-based society. The paper presents the term intelligent agent. Types of intelligent agents are detailed. There are agents that rely on reflexes, utility-based agents, agents that rely on objective, knowledge-based agents and utility-based agents. The role of collaborative intelligent agent is discussed. The paper details the ambient environment of intelligent agents. The main applications of intelligent agents in the economy are listed. The role of intelligent collaborative agents in the transition to knowledge-based economy is very important, they are a factor that directly affects productivity growth, correctness and efficiency of information processes for solving current problems in the economy.*

Keywords: *intelligent collaborative agents, knowledge-based economy, information society, knowledge-based society, computer applications.*

1. Introduction

In [1] the details of the information society are presented:

- information creation by passing from fixed assets to information assets by developing computer systems, implementation of digital libraries and the development of information portals;
- information distribution is achieved through the development of computer networks and the Internet, access to information is much faster and more efficiently through online search engines or networks;
- disseminating information through the Internet, media or email;
- use information each time needed using personal computers or public access terminal to in order to solve citizens problems or improve business processes;
- information integration in complex management information systems that allow easy retrieval by search keys;
- information management processes by optimizing data access by providing effective and simple ways through which people can access information.

Stages of development of information society are:

- transition from product development of physical nature of the industrial society to goods and services of an intangible nature;
- mass development of computers and computer networks has facilitated the emergence of service development and lead to starting the process of business processes virtualization;
- the Internet has facilitated the emergence of information exchange regardless of geographic location paving the way for global cooperation;

- elimination of intermediaries is an important step because it has increased speed of transactions through the emergence of electronic commerce applications and online card payment options.

In [2] the details of knowledge-based society are listed:

- transforming knowledge into the main asset of the company is present in all activities society members undertake, their activities use existing knowledge but also create new knowledge in addition to existing ones thereby ensuring the success and continuity of the society;
- disappearance of geographical boundaries, in the knowledge society the limits imposed by geographical boundaries are eliminated by using the Internet and computer networks for the transfer and dissemination of knowledge;
- using computer resources such as the Internet, portals, video conferencing, virtual conferences, collaborative systems and online learning in daily activities.

Stages of development of knowledge-based society are:

- development of knowledge based economic activities, transition to production of tangible goods to the production of intangible goods;
- services are the main good produced by organizations and companies eliminating tangible monopoly of production;
- increased development of organizations holding assets based solely on knowledge which led to fewer organizations that are based on fixed assets;
- emergence intelligent agents acting rationally based on a broad set of knowledge.

There is an acute need to step forward in the development of collaborative applications in order to improve performance, accuracy and efficiency. By implementing intelligent collaborative applications the user effort is reduced and his work efficiency is greatly improved by the intelligent system which filters out non essential information, makes accurate predictions and implements automatic processes that speed up the user's activity.

2. Intelligent distributed application

According to [14] there are three types of structures associated to distributed informatics applications:

- linear structure that is designed as stated in [15], construction which is released in execution sequentially, Figure 1.

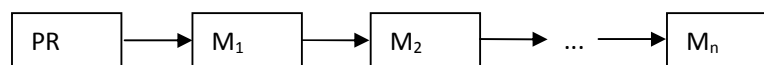


Fig. 1. Linear structure

- tree structure in [14] occurs if a main program calling PR modules arranged by level of appeal under [15] in Figure 2.

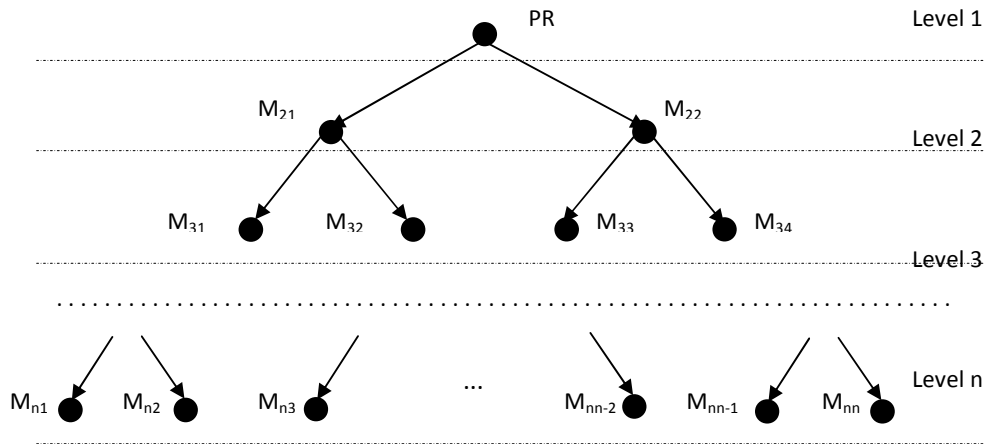


Fig. 2. Tree structure [14]

- network type structure in which according to [14] modules on the I-1 call one or more modules per level and that in turn call on the modules and 1 and i, Figure 3.

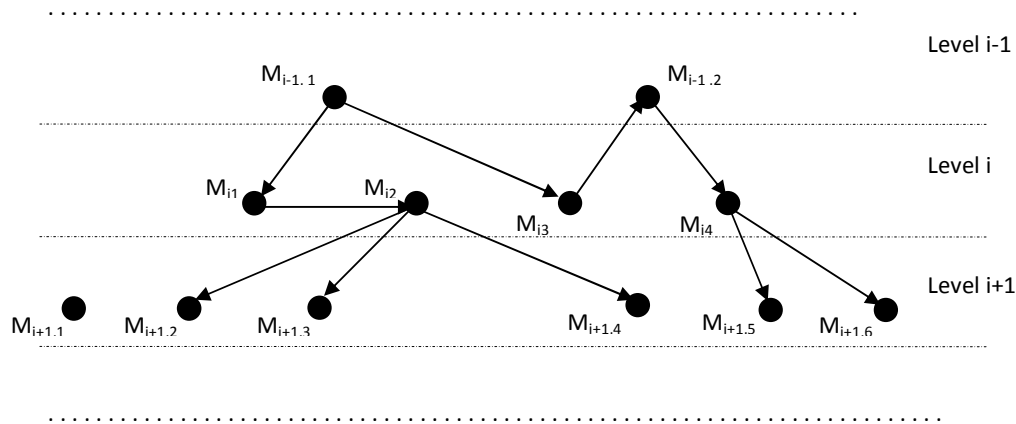


Fig. 3. Network structure

- graph type structure where modules are represented by component nodes of the graph and the modules on level i and call modules on the i + 1 level and modules on the i-1, in Figure 4 this type of structure is graphically represented.

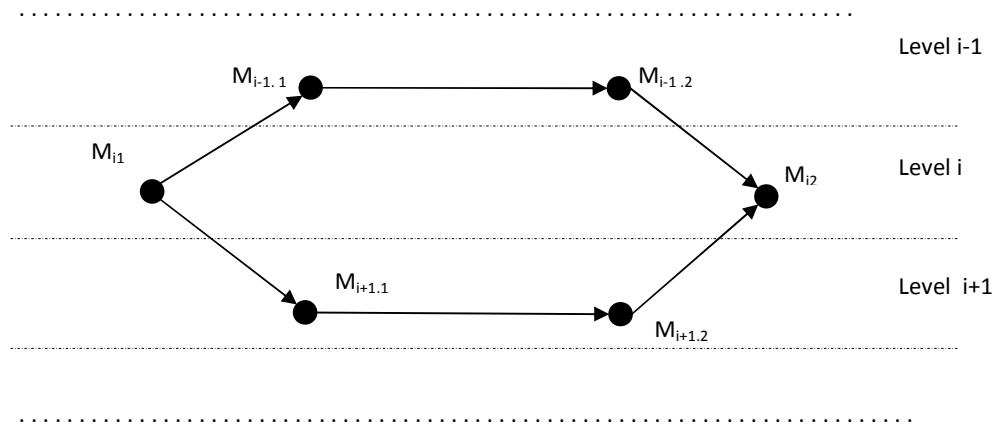


Fig. 4. Graph structure

In the context of the knowledge-based economy and rapid increase of data volume decisions must be made on a large volume of information prices that is difficult to achieve in a non-automated manner.

Given the complexity of data available, selecting information that is of interest is a laborious task requiring attention and thoroughness, the role of intelligent agents is to find the information needed identified using some well established criteria and present it to the user in a comprehensible and coherent way.

Intelligent agents make the transition to knowledge economy easier by their ability to make decisions independently based on experience and knowledge bases available.

The agent is an entity that:

- reacts to external stimuli;
- meets the basic functions based on predefined scenarios;
- generates an output based on knowledge held.

There are several types of agents:

- agents based on reflexes, are represented by those entities that react after receiving stimuli from the environment, figure 5;
- utility-based agents, are those agents who aim to achieve a specific action such as searching, scanning, or opening a door;
- agents that rely on an objective, are those agents that have a defined set of objectives and take all possible steps to achieve them;
- knowledge agents are materialized through entities who base their actions on a knowledge base, figure 6;
- logical agents are that category of entities whose actions are made based on information obtained from the store of knowledge and logical reasoning implemented.

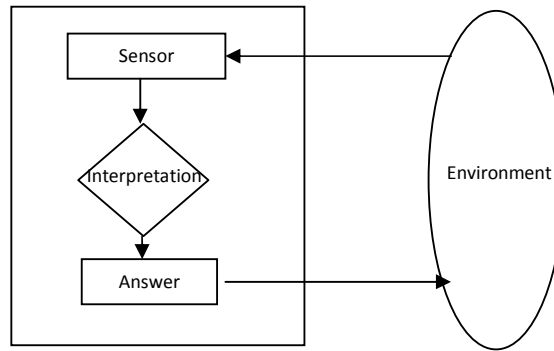


Fig. 5. Agent based on reflexes

The last two categories of agents are able to acquire new knowledge and logical models.

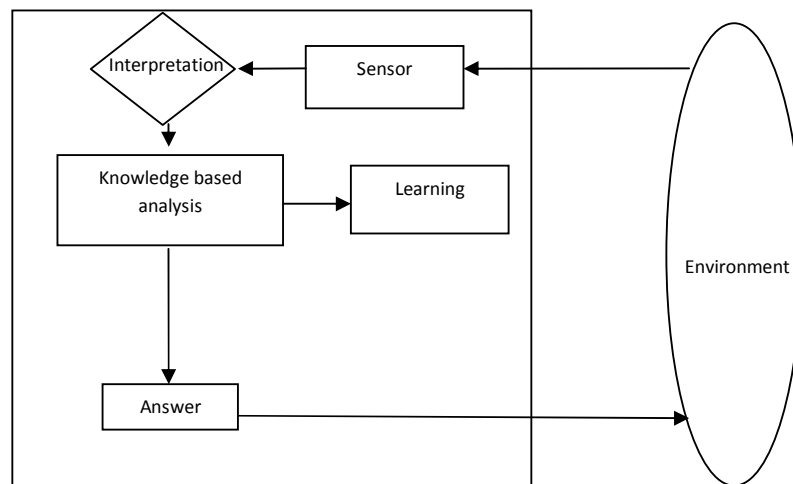


Fig. 6. Knowledge based agent

Characteristics of intelligent agents:

- learning ability is a characteristic of agents to attain new knowledge, which is added to their existing knowledge base;
- autonomy is the feature that allows the operation without human intervention, this helps the learning process;
- targets are the purposes for which agents were created, all actions must be directed towards them;
- learning is the characteristic that allows an operator to acquire knowledge from experiences;
- rationality is the capacity of agent to make decisions based on knowledge;
- pro-activity takes the form of the agent ability to anticipate future events and act in line with expected results;
- scalability is the feature that allows operation of the agent at the same efficiency regardless of the size of the knowledge base that it operates;
- maintainability is capacity of improving the agent without great cost and effort and transparent to users.

Intelligent agents have:

- environment that is made of all entities that surround them and interacting with the agent at some point;
- objective is the scope of the agent and what response is expected from the interaction with the environment;
- perceptions consist of the raw information that is processed by the agent;
- actions are based on information outputted by the agent, following the information obtained from the interaction with the environment.

Collaborative intelligent agents are implemented in simple collaborative applications to provide intelligent behavior. The main characteristics of this type of applications are:

- intelligent behavior based on past actions and attained knowledge from the application's knowledge data base;
- optimized network communication infrastructure to allow fast data transfer between peers;
- high performance algorithms that boost processing speed and minimize the transaction completion time;
- provide a user customized work environment providing the user with necessary and desired tools to complete his tasks;
- implement a user friendly customizable interface that gives the system the ability to learn the patterns the users has when working such that it will be possible for the system to provide the user with the needed interfaces, applications or information he needs most.

Distributed collaborative intelligent applications are to be the future of present collaborative applications by providing the user with better system capabilities, customized graphical user interfaces, helpful hints and most important with desired information by applying customized filters to present only the information the user would be interested in.

3. Intelligent applications

Table 1 shows a number of existing intelligent applications that apply theoretical concepts of intelligent agents.

Table 1. Intelligent application in economics

Agent Type	Perceptions	Objectives	Actions	Environment
Medical diagnosis system. [3]	Symptoms, the patient answers.	Diagnosis.	Questions, tests, treatments	Patient, medical institution.
Image analysis system. [4]	Pixels, quality.	Recognizing patterns.	Pixel analysis, categorization of pictures (landscapes, people, flowers, water, etc...)	Images
Management system documents. [5]	Text, font, semantics.	Recognizing types of documents.	Categorization of documents.	Documents.
Anti-burglary. [6]	Movement, action, noise, shock.	Recognition of hostile behavior.	Behavior analysis Triggering the alarm.	People, animals, wind and rain.
Search system. [7]	Text, phrases, answers user	Information retrieval.	Filtering information. Displaying information.	Documents. Internet.

	data.		Ignoring information	Knowledge base.
Financial prediction system. [8]	Text, answers user data sets.	Generation of predictions as accurate.	Analysis of knowledge. Verification of the model. Analysis of data series. Training neural network.	Knowledge Base, user.
System of loan. [9] [10]	Data about individuals. Criteria for granting loans.	Selecting beneficiaries.	Asked by users. Establishing criteria.	Knowledge Base, user.
Security System. [8] [11]	Data collected about user behavior. Users	Blocking malicious users.	Allowing access. Lock Access. Advertise administrators. Assembly of new knowledge.	Website. Users. Managers.

This kind of applications are used today in the economy and provide real solutions to real citizen needs. Some of them moved on from theoretical concepts to provide better predictions, make work more efficient and implement intelligent behavior in software products.

4. The algorithm performance of distributed applications

To solve the problems there are many algorithms that differ from one another by:

- number of steps required;
- number of elementary arithmetic operations, assembly or multiplication, to obtain a fair outcome;
- number of variables needed to store intermediate results;
- the correlation is established between the extent of the problem to be solved and the volume of processing;
- ability to solve cases;
- accuracy of the final result.

To differentiate an algorithm from another a series of ways to make the differentiation are defined.

For algorithm efficiency analysis [12] *asymptotic notation* is used *for the order of f* by:

$$O(f) = \{t : N \rightarrow R^* \mid (\exists c \in R^+) (\exists n_0 \in N) (\forall n \geq n_0) [t(n) \leq cf(n)]\}$$

$O(f)$ is the set of all functions bounded above by a positive real multiple of f , for sufficiently large values of the argument. Function t is in the order of f even when the value of $f(n)$ is negative or undefined for certain values $n < n_0$. Similarly it will be said about the order of f even when the $t(n)$ value is negative or undefined for a finite number of values of n , in which case it will choose an n_0 large enough so that the situation described is resolved.

Whether an algorithm P which requires an execution time of $t(n)$ time units to solve a problem on a community of size $n \geq 0$.

where:

$$t: N \rightarrow R^*$$

The *invariance principle* is used - two different implementations of the same algorithm do not differ in efficiency by more than a multiplicative constant so that any implementation of the algorithm P will require more time than an order of t.

In some cases a function is used to limit the inferior time boundary of an algorithm for this purpose the following is defined:

$$\Omega(f) = \{t : \mathbb{N} \rightarrow \mathbb{R}^+ \mid (\exists c \in \mathbb{R}^+) (\exists n_0 \in \mathbb{N}) (\forall n \geq n_0) [t(n) \geq cf(n)]\}$$

The execution time of an algorithm is bounded by lower and upper by:

$$\Theta(f) = A(f) \cap \Omega(f)$$

called the exact order of f.

According to [13] if f(n) and g(n) are functions defined on the set of natural numbers then:

f(n) is O(g(n)) if:

positive constants c and n₀ (∃) such that 0 ≤ f(n) ≤ cg(n) for (∀) n ≥ n₀

The O notation is a top edge (for the worst execution time) of a function up to a constant factor.

If f(n) and g(n) are functions defined on the set of natural numbers then:

f(n) is Θ(g(n)) if:

positive constants c₁, c₂, n₀ (∃) such that 0 ≤ c₁g(n) ≤ f(n) ≤ c₂g(n) for (∀) n ≥ n₀

Θ-notation sets lower and upper borders during the implementation of the algorithm. The top edge is used to determine a worst-case limit and the lower edge delimits the most favorable case.

If f(n) and g(n) are functions defined on the set of natural numbers then:

f(n) is o(g(n)) if:

for (∀) constant a c > 0 (∃) a constant n₀ > 0 such that 0 ≤ f(n) ≤ cg(n) for (∀) n ≥ n₀

Demarcation 0 ≤ f(n) ≤ cg(n) occurs for any constant a c > 0 in comparison with O-notation where demarcation takes place for some constant c > 0. Thus f(n) becomes insignificant relative to g(n) when n tends to infinity, i.e.:

$$\lim_{n \rightarrow \infty} f(n) / g(n) = 0$$

For example: 2n is o(n²), but n² is not o²(n²) because there is the condition when n tends to infinity, the ratio f(n) over g(n) to tend to 0.

For the function:

$$f(x) = 5(3(n+1))^3 + n^2 \log_3 n + 3n^2 + 1$$

(i) the order of f(x) is O(n³)

(ii) the order of f(x) is Ω(n³)

(iii) the order of f(x) is o(n⁴)

From (i) and (ii) that the exact order of f(x) is Θ(n³)

For the function:

$$g(x) = 4 \cdot 3^{n+1} + n^3 + 4$$

(i) the order of g(x) is O(3ⁿ)

(ii) the order of g(x) is Ω(3ⁿ)

(iii) the order of g(x) is a o(3²ⁿ)

From (i) and (ii) that the exact order of g(x) is Θ(3ⁿ)

When the present processing algorithms specify the order volume processing as the essential information related to the performance of the algorithm.

There are situations where algorithms are abandoned because their order determines the impossibility of obtaining results for problems larger than a number K considered reasonable.

Considering a constant c and a natural number n a hierarchy is established for simple arithmetic expressions that are used in estimating the amount of basic computer operations, with each function below the next, is: c , $\log n$, $(\log n)^k$, n , $n(\log n)^k$, n^k , $n^k(\log n)^l$, n^{k+1} and d^n . Features that are $O(n^k)$ are called the polynomial order and the functions $O(d^n)$ for a $d > 1$ are called the exponential order. The difference between these two types is very high because a very small exponential function, such as 2^n increases much more than a polynomial function n^k , irrespective of the value of k .

When the present processing algorithms specify the order volume processing, the essential information related to the performance of the algorithm.

There are situations where algorithms are abandoned because their order determines the impossibility of obtaining results for problems larger than a number k considered reasonable.

It goes on to establish models to calculate the amount of processing required for some algebraic calculations.

The distributed application performance determination is established for each implemented algorithm that the distributed collaborative application uses. If after the evaluation there are algorithms that have an above average asymptotic notation indicator then they must be marked for review and optimization in order to attain an equal level of performance throughout the application to ensure predictable behavior under all test cases and possible uses.

5. Conclusions

Intelligent agents implemented in collaborative applications play an important role in the transition to knowledge-based economy by the need automated management of information and knowledge by following established rules.

Intelligent agents take over the tasks that were previously associated with complex algorithms in collaborative applications or human effort and fulfill them better, faster and with minimal cost. With the transition to knowledge economy data volume will increase exponentially and its efficient management and filtering becomes very important. Using intelligent agents the extraction of knowledge from data is achieved easily based on criteria set by the user; because of these economic processes are taking place faster and better already having all the necessary information to base decisions on.

Intelligent agents are used today for predicting share prices and exchange rate on the stock markets, this stage is the beginning is still room for development of prediction systems are not 100% effective, but currently gives faster results than statistical procedures classical model such as ARIMA.

When the transition to knowledge-based economy will be completed intelligent agents will be fully integrated into all economic processes and applications developed for citizens, such knowledge will be easier to access and materialized by retrieving it quickly and with low costs.

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