MAgeLan – A Multi-agent System for Monitoring a Hyper Encyclopedia

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ABSTRACT

In this paper we will introduce the architecture of a monitoring system of agents that we have called MAgeLan and that was developed at the EduSoft SRL and Vasile Alecsandri University of Bacau, Romania. MAgeLan monitors (manages and controls) or assists several human users who wish to create an intelligent hyper encyclopedia. The intelligent hyper-encyclopedia is a distributed multimedia encyclopedia achieved by multiple users, it has references (links) between articles, just like on the web, where each user can have access to the themes he/she develops at a given moment; therefore each of its colleagues resembles a cooperation process coordinated by an automated system.

We will describe both the issues of building up an intelligent hyper-encyclopedia and the architecture of the MAgeLan system and also the way each of the component agents is organized and works.

Keywords: *Hyper-encyclopedia, encyclopedia, hypermedia, multimedia, agents, multi-agent systems, monitoring the user activity, Google search, s-agent*

1. INTRODUCTION

The encyclopedias are reference works containing a summary of information from either all branches of knowledge or a particular branch of knowledge. Usually, the encyclopedias are organized into entries or articles, which are usually accessed alphabetically by article name. In the printed form, the entries can contain text (definitions, examples), and images. On the other hand, the electronic encyclopedias can contain different types of media (text, sounds (including music, voice recordings etc.), graphics, videos, animations). The web started with the idea of hyperlink, and the text including hyperlinks becomes hypertext.

Also, hypermedia is a natural extension of the hypertext. Images, sounds, videos and plain text and hyperlinks intertwine to create a generally non-linear medium of information. Starting from years '90 the experts presented the importance of the hyper media systems. In [1] it is concluded that the merging of hypertext systems with multimedia technology into powerful hypermedia systems creates an infrastructure for working, communicating, and thinking. This influenced the way we work, teach, and learn. The problems of hypermedia systems were discussed in [2], [3], [4] and [5]. Kappe et al. presented in [4] the architecture of a massively distributed hyper-media system.

There are studies about the possibility of generating multimedia encyclopedias using closed captions and detecting video objects from TV programs. With these objects it is possible to create a multimedia encyclopedia [5]. Integrating hypertext with a multimedia encyclopedia, we can obtain hypermedia.

The encyclopedias and hypermedia can be used in educational activities. Maurer and Tomek present [7] the use of hypermedia in tele teaching. The idea of interactivity is not new. In [8], the concept of inter-active encyclopedias is introduced. We developed Rocarta, an inter-active encyclopedia with 3500 hypermedia entries about Romania [9].

The combination of the terms of hypermedia and encyclopedia results in a big distributed encyclopedia, with hypermedia in its nodes, and hyperlinks between nodes [10].

The idea of using intelligent agents for a distributed network used in computer assisted learning is described in [11].

2. THE PROBLEM OF BUILDING UP AN INTELLIGENT HYPER ENCYCLOPEDIA

2.1 The Intelligent Hyper Encyclopedia

In [10] we presented the idea of creating an intelligent hyper encyclopedia. This is a distributed hyper media encyclopedia that multiple users exploit from multiple computers (nodes) on a network. They use this encyclopedia to get information and to make it better according to the knowledge they have or get after consulting the encyclopedia.

Our intention is that the encyclopedia behaves intelligently, as it follows [10]:

a. To consider certain issues in order to generate new information, based on the existing ones;
b. To answer to questions the users may put so as to provide them with the necessary information to generate new pieces of knowledge;
c. To adapt itself to the language the users are using and to the way they work (the

encyclopedia consults and modifies the knowledge basis) or interact with others;

d. To allow an intelligent mediation for the communication between users so that they can learn from one another and the encyclopedia from them.

Building up such an encyclopedia is not an easy task. Concerns about getting an intelligent system like this largely overlap the great challenges of the traditional or distributed artificial intelligence. However, certain elements can be solved, namely [12]:

a. Generating new information following some rules applied on some existent information; it is a restrained version of the requirement in point 1 above, because the encyclopedia has predefined rules; in fact, probably one of the main elements which distinguish man (an intelligent human being) from a machine is the fact that creates new issues by himself and find ways to solve them;
b. Providing user support regarding the main issues needed to improve the encyclopedia; this a restrained version of the requirement in point 2, but can be realized via monitoring mechanism, support and management of the main software the user employs (for instance a text processor and a browsing program);
c. An apparently human interfacing with the user that can be realized via conversational agents, possibly equipped with artificial temperament; this is a restrained version in point 3, but it can have beneficial effects on how computer interact with man;
d. Getting a way by which segments of data or executable code can be sent from one user to another in order to provide inter-aid; this is a restrained practical version of the requirement in point 4.

The intelligent hyper-encyclopedia – which has so many "human" features, even in its restrained version – will have a network structure where each node will have a local knowledge basis, a human user and an intelligent agents system, as follows [12]:

- An agent that studies the user's behavior while consulting the encyclopedia and adapts itself according to the user;
- An agent that studies the user's behavior while updating the local knowledge basis (by modifying, deleting, adding information or generating rules) and according to this it makes suggestions to enrich the local knowledge basis;
- An agent that modifies by itself the local knowledge basis in order to adapt it to the user from that node (so as to facilitate his work).

All mentioned agents communicate and cooperate in order to learn from one another and to modify their own local knowledge bases, but also the way they should interact with users from the nodes. Communication between agents and users will be often realized through natural language, via conversational agents.

Agents also communicate among themselves to improve their activity and to learn from one another. In addition, they can "transform" in order to adapt themselves to the users or, if this is no longer possible, one can resort to shift agents from one node to another.

2.2 Example of Hyper-Encyclopedia

Let us take a computer network. At each node of the network we have a human user. Human users are some students who want to develop such a hyper-encyclopedia. The data the encyclopedia comprises is placed in different nodes of the network, which are connected. We can say that the hyper-encyclopedia is a network of encyclopedias that are placed in the nodes of the network (Figure 1).

Each student has a certain theme (a certain encyclopedic field) to develop. He has to gather information from books, magazines, journals or other media and make some entries in his own encyclopedia. It is both possible and allowed that various students introduce and define the same entry in their encyclopedias, but with different definitions. An article-entry in encyclopedia I has the following form: A = (T,D,LS), where T is the title of the article, D is its definition and LS is the set of links to other articles of the hyper-encyclopedia. One link may be to an article from the same or even other encyclopedia. A $L \in LS$ link has the form L=(u,v), which means that L represents a link to article u from encyclopedia number v [12].

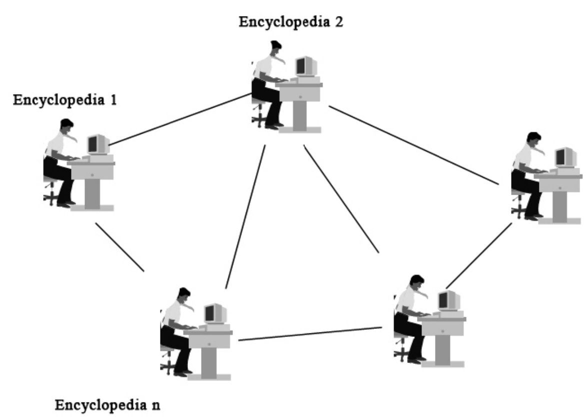

Fig 1: An intelligent hyper-encyclopedia

Therefore, the student's encyclopedia, $i, i=\overline{1,n}$ is $E_i = \{A_{ij}\}_{j=\overline{1,|Ei|}}$, where A_{ij} marks article j from encyclopedia number I (Figure 2).

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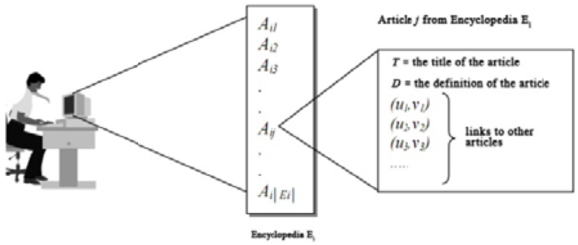

Fig 2: A private encyclopedia

The main issue is that students should enrich their encyclopedias. Each student will introduce the articles of his own encyclopedia. When introducing a particular article A in his own encyclopedia, the student must write down the title, then its definition and create links to other articles/make references to other articles which would have something in common with article A; therefore the student must create connection between A and other articles from his own or others' encyclopedias. The student introduces the title by his own, but when writing down the definition he can make use of books, magazines, journals, etc. In addition, he can draw upon definitions that some of his colleagues may have used. In doing so, he will access others' encyclopedias, he will look there for article A and he will take over the definitions his colleagues have given to A, making up his own definition. In creating his own definition, a student may combine knowledge from books and journals with knowledge from his colleagues.

In order to make links to other articles, they first have to exist/be there. First of all, the student will think about certain articles from the field his encyclopedia has to do with, those which A can be linked with and he will look for them through articles from his own encyclopedia. If they do exist, the links are made, if not, the students has to create them, but he adds on his "to do" list the fact that he has to add this article too to his own encyclopedia. After that, he will try to create links between his article and articles from other encyclopedias. He will seek those articles of their colleagues which have something in common with his article or which make reference to his article and he will create the appropriate links.

Here is an example: the students build up a hyper-encyclopedia on computing. The theme for student 1 is programming languages; student 2 gets as theme peripheral equipments, and student 3 has to write about algorithms and data structures. Let us suppose that 1 has already introduced articles Pascal and C, and now he has to introduce the article Basic. Let us assume now that students 2 and 3 have already introduced the articles from Figure 3.

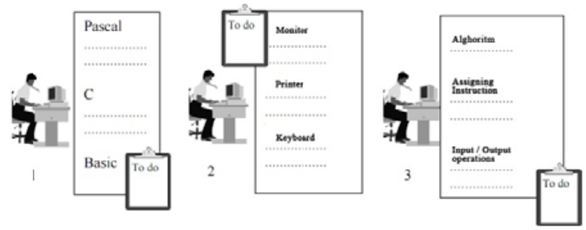

Fig 3: An example with three students. Articles already introduced and lists of tasks

The moment student 1 defines the article "Basic" from his encyclopedia; he can create the following links:

a. Links to already defined articles from his own encyclopedia, such as Pascal or C – in this case, he simply creates the links and they become functional;
b. Links to articles that are not yet in his encyclopedia, but they should be there, such as Fortran or Java – in this case, he will create the link (currently non-functional) and he will add to the list of tasks the fact that he has to introduce corresponding articles;
c. Links to other articles already existing in other encyclopedias, such as "Monitor" or "Keyboard" from encyclopedia 2 or "Input and output operations" from encyclopedia 3 (specifying how the data will be displayed or read in Basic); in this case, he will create the links and they will be functional;
d. Links to nonexistent articles in his own encyclopedia, but that should exist in other encyclopedias (they are to be found on the lists of tasks of those particular students); in this case, he creates the links, even though they are not yet functional.

We can see from the given example that each student must have a list of tasks containing the articles he must add in his own encyclopedia. It would be desirable that each student could add articles on their colleagues' lists of tasks, if they consider it necessary. For instance, student 1 may suggest that in encyclopedia 3 there should be a definition for the term "repetitive control structure", but maybe student 3 has not introduced such an article, neither he intends to do so. In this case, student 1 adds this article (term) to the student 3's list of tasks.

Student had better be helped in their work by trainers. At the beginning, each student will have his own trainer to help him. He will provide him with some knowledge, he will search for him the definitions chosen by his colleagues for one and the same term, he will manage his list of tasks or suggest the links he should do. In short, the trainer will supervise the student's work, he will help him in his routine affairs or he will provide new notions for him. Thus, the model of the encyclopedia should look like in Figure 4, where one can notice that each student is assisted / helped by a personal trainer.

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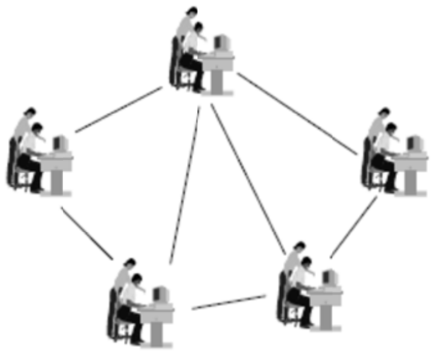

Fig 4: Students and their trainers

2.3 The Artificial Trainer Or The S-Agent

Student will begin building up their own encyclopedias. Some may work better or faster than others. In this case, a trainer may have to go from one student to another that meets difficulties in creating his own encyclopedia. In this instance, the trainer that moves from student X to student Y joins the trainer of Y (the same who called for his help). Having got experience from supervising and observing the behavior of his former students, he can use it to give instructions to Y's trainer but also to help him directly.

There is no specific need that all these trainers be human/ don't necessarily have to be human. They can also be artificial, in the sense that they can be agents, groups of agents or multi-agent systems. Each agent from such a group of agents (they are mobile) has a clear goal and it communicates and collaborates with the others from its group, but also with those coordinated by another instructor. Their common goal is the rapid building up of a consistent encyclopedia that has functional links.

The group of agents that represent a trainer must be made up by (Figure 5):

- An agent that is specialized in assisting the user in creating definitions for terms and links between terms, that is in the editing process (EA);
- An agent that is specialized in monitoring the web search and giving support in this sense (SA);
- An agent that is specialized in creating dialogue between the student and the trainer, also having a coordinative role for the other agents (DA);
- An agents that is specialized on interaction between one trainer and the other trainers (IA).

Such a group of agents that represent an artificial trainer and assist only one student will be considered an s-agent, following the model described in [13].

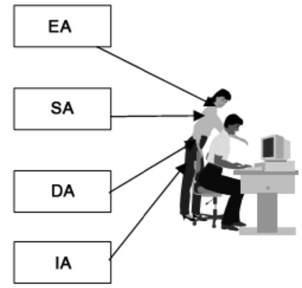

Fig 5: The system of agents that form an artificial trainer (s-agent) for a student

In [13] we defined an environment as a set of elements $E = \{e_0, e_1, e_2, e_3, ..., e_n\}$, among which there is a relation of partial order marked with "<". The environment may take, at some given moment, a certain e state (condition), and we will mark this by st(E)=e. At the beginning, the environment moves from an initial state e_0, where $e_0<e_i$, $\forall i\in\{1,2, ..., n\}$. The e_n state is called final state and it is reckoned that $e_i < e_n$, $\forall i\in\{0,1,2, ..., n-1\}$. In this framework, we define an agent as a triple (1)

$$A=(S, s_0, R) \quad (1)$$

where S is a finite set of states, s_0 from S is called the initial state of the agent and R is a set of evolution rules. If agent A finds himself in the state s, then we will mark this by st(A)=s. Among the states of S there is a special state, marked by λ. At the beginning, st(A)=s_0, and when st(A)= λ we say that the agent is inactive. In all other situations, the agent is active.

The rules from R are of the form (2) or (3):

$$r_1 = (A, s, e) \rightarrow (A, t, f) \quad (2)$$
$$r_2 = (A, s, e) \rightarrow (B, t, f) \quad (3)$$

Rule (2) stands for the fact that if st(A)=s, st(E)=e, then st(A) becomes t and st(E) becomes f if $e\leq f$. The second rule, (3), says that the agent A puts an end to his performance (st(A) becomes λ), giving in the control in favor of the agent B, for whom st(B) becomes t, the environment passes to state f. If st(E) = e and there are two agents A and B with st(A)=$a\neq\lambda$ and st(B)=$b\neq\lambda$ and $(A,s,e)\rightarrow(C,z,f)$ and $(B,t,e) \rightarrow (D,z',f')$ ($C\neq A$, $D\neq B$), then we will consider st(E) will become max(f,f') if f and f' are comparable, respectively one of them, if f and f' are not comparable, while st(A) becomes λ and st(C) becomes z if $f'<f$, respectively st(B) becomes λ and st(D) becomes z', if $f<f'$. All this can be generalized for many other active agents. We define an s-agent a n-uple of the form (4)

$$S=(C, A_1, A_2, ..., A_n) \quad (4)$$

Where C is an agent called coordination agent and A_1... A_n area agents that follow the above definition and are called executive or atomic agents. The coordination agent will interact directly with the user and his architecture and functionality depend on a concrete implementation. As within an s-agent the agents give in control one in favor of another, then an s-agent behaves as communicative multi-agent system.

The system of agents from Figure 5 is an s-agent, with the agents A_1 = EA, A_2 = SA, A_3 = DA, and C=IA.

Therefore, for our goal, we will have an agent specialized in observing the behavior in editing definitions: EA. Assuming that the user employs the text processor Word, the EA will be responsible for handling events such as: typing speed, what he writes, what he deletes, how long the definitions are, what is their form and will help the user by giving him definitions for some terms (definitions that have been taken from various online or offline linguistic resources), also by suggesting web addresses where he can find more information on a certain subject (Wikipedia or even references made by Google or other search engines).

The SA will be the agent that is specialized in assisting the user in searching related articles and in making connections. Assuming that the user (the student) employs Microsoft Internet Explorer as web-browser, the SA will deal with the following issues: which articles is he searching for and where, what other information he may get from the links he clicks on, what had he searched and used and so on.

The DA – the agent specialized in creating dialogue between the student (user) and the trainer (s-agent) will have the following tasks [4]:

- Controlling the activity of EA and SA;
- Generating stereotype questions (What does this article (term) mean? What terms are related to this term? Etc.) for the student in order to add data on what the student is building up (information that cannot be sufficiently analyzed by DA and SA);
- Generating suggestions (from the web or other linguistic resources) for the student in order to complete the definitions of some terms;
- Determining the training level of the current level of the student, possibly expressing his feelings towards the student's current state of training;
- Cooperating with the IA so as to determine, according to the requirements, if the case of data migration emerges.

The IA – the agent specialized in communication between one trainer and other trainers:

- It asks for help from other trainers if the current student is too poorly trained;
- It responds positively to the call for "help" from other trainers; if the DA considers that the current student if sufficiently prepared and another student needs help, then the trainer moves to the other student, having got experience from working with the former student.
- It responds negatively to the call for "help" coming from other trainers if the current student still needs training;
- It transfers potential calls for help from some trainers to others.

In the next paragraph we will see the way that each of the four complex agents that make up an s-agent will be implemented via some agents corresponding to the tasks to be fulfilled.

3. THE ARCHITECTURE OF THE MAGELAN SYSTEM

The MAgeLan system will perform so as to solve tasks corresponding to some artificial trainers; they assist (monitor, help and manage) several students (users) who are building up an intelligent hyper-encyclopedia.

3.1 The System Of The S-Agents

MAgeLan can be defined as being a communicative and heterogeneous multi-agent system, organized in groups of agents. Each group represents an s-agent (see previous section), and each s-agent comprises one of the four agents mentioned above. The support of the MAgeLan system is made out of a Intranet (computer network) running on Windows XP and organized according to the TCP/IP protocol. The net is connected to the internet and each computer from the network has both a unique name and IP address that the other computers recognize. Both Microsoft Word and Microsoft Internet Explorer are installed on each of these computers. Obviously, each computer has its own temporary memory section, Clipboard.

An s-agent will be installed on each computer and its task will be to assist the user of that computer during editing its own encyclopedia, component part of the hyper-encyclopedia.

In Figure 6 one can see the overall structure of the MAgeLan system where one of the agents has been brought out.

A UA_i s-agent is made out of the assisting agents during the editing process (EAi), the search agents (SA_i), the agents responsible for the dialogue with the student (SIA_i), and the agents that deal with interacting with other agents (IIA_i).

In the following paragraph we will present the structure of each of these agents.

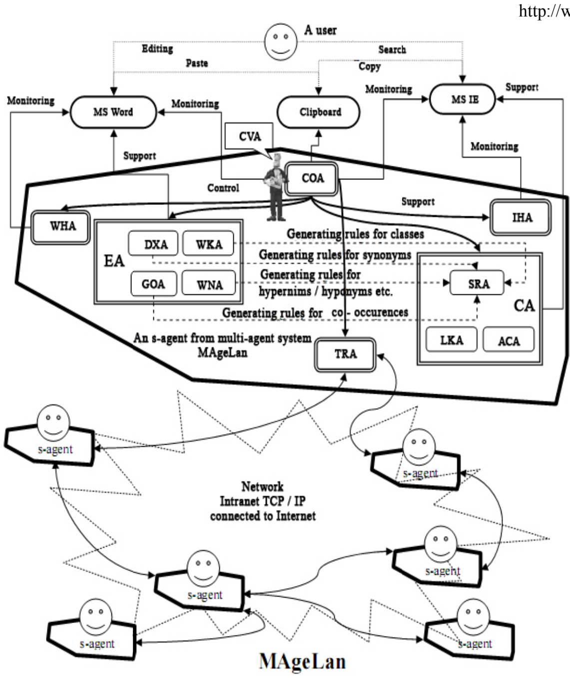

Fig 6: The architecture of the MAgeLan system

3.2 Structure and Functioning Of An S-Agent

An s-agent has the form SA=(IA, EA, SA, DA), where

- EA = (WHA, WNA, DXA, WKA, GOA) stands for the assisting agent during the editing process. It is made out of:

  i. WHA = the Word History Agent – it stores the history of the terms that have been edited in MS Word, having their definitions or related word written or being written, so as to be sent by the transfer agent to other s-agents;
  ii. WNA = the Word Net Agent – gets the meanings of one word from the WorldNet database, provides synonyms, antonyms for that word, as well as heteronyms for a defined meaning of that word; it generates semantic rules for later searches of the user;
  iii. DXA = the DEX (Explanatory Dictionary of the Romanian Language, [16]) agent – gets the definition of word from the data base of the DEX, providing synonyms and antonyms; it gets the lemma (the standard form) of a declined or conjugated word; it generates semantic rules for later searches of the user;
  iv. WKA = the Wikipedia Agent – gets relevant information about a word, using the online search on the Wikipedia; it generates semantic rules for later searches of the user;
  v. GOA = the Google Occurrences Agent – gets the visibility (how much and where) of a term or a full sentence on the web; it generates classes of similar words for semantic rules of web searching; we described a method of classifying words using the Google searches in [14];
  vi. SA = (IHA, LKA, ACA, SRA) stands for assisting agent while searching. The AC is made out of:

  i. IHA = the Internet History Agent – gets information about the history of the searches already made on the web, the location and the frequency of the searches
  ii. LKA = the Hyperlinks Agent – returns the hyper-links from an already searched web page in order to suggest the user new subjects for the search;
  iii. ACA = the Academic Agent – determines whether the current site is of an university of an another educational institution, as well whether the page that is being viewed is a course or something like that and suggests other chapters from materials available on the same site;
  iv. SRA = the Semantic Rules Agent – generates new sequences to make searches for different search engines, according to the words already looked for and related words (provided by agents WNA, DXA, WKA and GOA);

- DA = (COA, CVA) represents the agent that ensures the student-trainer dialogue has a coordination component (COA) and a conversational one (CVA); the CVA is represented by an Ms Agent, endowed with affective elements, feelings and temperament;
- IA = (WHA, IHA, TRA) represents the agent in charge of the interaction between trainers. It is made out of:

  i. WHA = the Word History Agent – plays the role of establishing the words to be sent to other users and to which users;
  ii. IHA = the Internet History Agent – plays the role of determining the addresses corresponding to searches made by a user;
  iii. TRA = the Transfer Agent – plays the role of transmitting data and a possible executable code directly on another computer

It is to be mentioned that the SA agent monitors the Google searches, like Notebook described in [17]. Of course, Google can make more. It can watch your moves anytime, anywhere [18].

3.3 Intercommunication of Agents And Their Contact With The Software Environment

The component agents of the MAgeLan cooperate and interact with the three soft resources employed by the user (Microsoft Word, MS Internet Explorer, and Clipboard) in order to reach the common goals. Therefore, the following communication and interrelating forms exist:

- control;
- monitoring;
- assistance/support;
- rules generation;
- transfer.

In addition, we assume that between MS Word, MS Internet Explorer and Clipboard the Search, Copy, Paste and Edit operations are used (Figure 6).

Communicating by control transferred from agent A to agent B generates entrances for B and determines B's execution over these entries. COA is the coordinative agent that controls the activity of all the other agents. By monitoring we understand that an agent is permanently following the user's activity on a software resource and takes over a part of its exits. For instance, COA takes over the current word and full sentence edited in Word, as well as the searches made using Internet Explorer and WHO takes over certain words from those edited in Word, IHA takes over the URLs viewed in a certain amount of time.

Assistance comes when an agent or a group of agents provide exits for the user in a used software resource.

Agents DXA, WKA, GOA and WNA generate entrances for agent SRA. DXA generates rules for synonyms and antonyms. WNA generates rules for antonyms and hyponyms, WKA generates rules for classes of related words, according to Wikipedia, and GOA – rules for classes of related words according to their co-occurrence on the web.

Communication is made by means of distributed algorithms using messages of the type send and receive. The message exchange occurs either between agents or between users and agents.

4. CONCLUSION

This paper describes the main architecture of the MAgeLan multi agent system, which monitors or assists several human users who wish to create an intelligent hyper encyclopedia.

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