# Minerva: An Artificial Intelligent System for Composition of Museums

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**ABSTRACT**
The employment of artificial intelligence techniques for supporting activities traditionally performed by humans and considered as creative has increasingly spread in recent years. In this paper, we present a novel artificial intelligence system, called *Minerva*, devoted to support one of such activities: the composition of museums.

**KEYWORDS:** Automatic composition of museums, multiagent systems.

## INTRODUCTION

The adoption of machines for performing some of the intellectual and interactive activities of humans has recently spread. Initially, machines were only employed for carrying on somehow mechanical or "fabricative" human activities. Nowadays, they are also employed for supporting the execution of somehow artistic or "creative" human activities. In particular, we are referring to the class of machines, called *information machines*, which emulate some of the intelligent intellectual and interactive abilities of humans: computers and robots.

The purpose of this paper is to present a novel system of artificial intelligence, called *Minerva*, devoted to automatically compose museums in a virtual setting. The activity of composing museums, namely disposing a number of works of art in the spaces of a museum, is commonly considered as a creative activity traditionally performed by humans, since it involves a large number of complex artistic criteria.

In order to achieve the automation in the composition of museums, Minerva is based on the modern, powerful, and flexible technology of multiagent systems, developed and established in the field of artificial intelligence.

This paper is organized as follows. In the next section, we outline the general theoretical framework in which the significance of Minerva is captured. Then, we briefly illustrate the technical concepts of multiagent systems within artificial intelligence. At that point, we present both the architecture and the functioning of Minerva. Finally, we conclude the paper.

## MAN AND MACHINES

We are observing nowadays computers and robots which are able to emulate

some intellectual and interactive human abilities. Within these activities we distinguish between the activities that can be described in rational terms (*fabricative* activities) and the activities that cannot be described in rational terms (*creative* activities) [2].
According to this framework, we stress that information machines, not only improve their skills to partially reproduce some of the fabricative activities of humans, but they are also designed and built in order to support humans in performing some of their creative activities. That is particularly interesting when we consider that the automatic composition of museums performed by Minerva is parallel and not substitutive to the traditional human composition. The composition of a museum resulting from the operation of Minerva is an activity not totally performed by a machine; humans still play a determinant role both in designing and in settling down the system by introducing their artistic criteria. The machine is not able to independently and autonomously carry on the whole creative activity of museum composition. However, we state that many processes in this composition can be automated and, therefore, delegated to information machines when it is considered useful.

**MULTIAGENT SYSTEMS**

In this section, we shortly introduce some technical issues about multiagent systems developed within distributed artificial intelligence (DAI, for short).
*Multiagent systems* [11] are systems of DAI that are composed of several entities, called *agents*, which are spatially distributed but connected together. In multiagent systems, the grain of the distributed entities is coarse; therefore, agents are loosely connected. There is no global agreement on the definition of agent [5]. For our purpose, we consider computational processes, computers, and robots as instances of agents. An agent is usually thought as exhibiting several properties [11], such as autonomy (the agent controls its actions and its internal state), social ability (the agent interacts with other agents), reactivity (the agent perceives and responds to changes in its environment), and pro-activeness (the agent exhibits goal-directed behavior).
A multiagent systems is, in general, composed of several interacting agents but, when these agents are cooperating, it is profitable to consider the whole system as a unitary machine called *agency* [3]. The adoption of the wording 'agency' emphasizes our conception of a multiagent system as a unitary machine, even if the composing agents have very complex natures. The concept of agency has been firstly introduced by Marvin Minsky under the metaphor of "The Society of Mind" [7] to set up a rich and precise description of the human intelligence. We consider an agency as a machine made up of intelligent agents interacting each other in order to offer or receive collaboration for achieving a global goal. By intelligent agents we mean that each component of the agency has inferential abilities [6]. Each agent is able to perform some functions, namely to carry on some high-level tasks, that require inference. In addition, each agent has the abilities for cooperating with other agents when it is necessary. Thus, an agency can be viewed as a machine of DAI able to perform distributed inferential reasoning. From the previous considerations it emerges that the agents have to be connected

together by a communication network, that represents the necessary infrastructure for cooperation and coordination among them.
Several proposals have been advanced for implementing the two essential activities of an agent involved in an agency: operation and cooperation. The operation activities of an agent can be based on architectural solutions that are usually classified as ranging from two extremes [10], namely the reactive architectures, which prescribe that the agent simply reacts to its sensory inputs, and the deliberative architectures, which conceive an agent as a system that integrates its sensory inputs with its past knowledge to determine its future actions. However, the most adopted solution is to develop agents with intermediate architectures between the two extreme ones. The cooperation activities of an agent can be based on different mechanisms such as, for example, negotiation [8] and auctions [10].
In our research, we have developed agencies that address several problems involving both computer and robotic agents (see [1] for a summary of these agencies). In this paper, we describe a new agency that addresses the problem of automatically composing a museum.

**MINERVA SYSTEM**

The experimental efforts we have taken up are inserted in a project, called *Minerva Project*, that aims to design, develop, and implement a system for the automatic composition of museums. As already stated, this is commonly considered an artistic activity since several subjective, creative, and imaginative abilities are involved in it. By adopting the term 'composition' we mean both the *preparation* and the *allocation* of a museum. The preparation is the arrangement of the given works of art to be displayed in ordered groups. The allocation is the placement of these works of art within a given geometrical space preserving their arrangement. The system resulting from Minerva Project is called *Minerva Agency* (we will refer to it as Minerva in the following). Hence, Minerva is an artificial intelligence system composed of several agents, where some agents are expert systems in particular domains and some other agents perform service activities, that cooperate together to compose museums.
The activity presents several difficulties that have to be overcome for obtaining a final result that exhibits a global coherent setting and that allows an effective (possibly virtual) visit of the museum. It has to take into account many different parameters: for instance, some works of art cannot be inserted in some rooms, some rooms can be scarcely lighted, some other rooms can be too hot or too cold to keep works of art in them. An interesting aspect is that the museums managed by Minerva may contain any kind of works of art, from archeological finds to paintings. All are virtually reproduced according to their three-dimensional models obtained either from the real objects or from other representations (e.g., pictures) of such objects. The allocation of the works of art is performed in a virtual environment that can be selected by the user and that can differ from the real environment in which the works of art are exposed. At the end of the operation of Minerva, it is presented to the user a subjective point of view in a virtual three-dimensional environment, which contains the works of art and that can be navigated by the user.

Minerva has multiple applications that show why it is interesting and useful adopting intelligent systems to compose museums. Simulation of proposed compositions for existing museums to study and evaluate them, simulation of existing compositions in existing museums for allowing their virtual visits, and simulation of compositions in imaginary museums for building personalized cultural paths are among the ways in which Minerva can be employed. Until now, Minerva has been tested on the collections of the Archeological Museum in Milan and of the Paolo Giovio Museum in Como.

The architecture and functioning of Minerva are shortly described in what follows (see Figure 1). In this paper we are not going to give a detailed presentation of all the technical issues of the Minerva; instead, we give an outlook to the main features of the system.

The user interacts with a *supervisor agent*, which presents different interfaces according to the user's level of knowledge. We have provided four levels and, thus, four typologies of users:

- the museum expert users, who are usually going to use Minerva for simulating proposed museums they have already conceived, in order to study and evaluate them;
- the artistic expert users, who are usually going to use Minerva by making requests on the works of art to be displayed, but who are not going to interfere in the composition of the museum;
- the inexperienced users, who are going to visit already composed museums;
- the technical users, who modify the system, for instance the database of collections of works of art and the database of environments.

In the following, in order to illustrate the functioning of Minerva, we will refer to the museum expert users who have the most complete control over the parameters of the system. Starting from the initial window (see Figure 2), these users select a collection (i.e., a set of works of art, such as paintings, sculptures, or archeological finds), that they would visit, and a real or imaginary environment (i.e., a set of rooms in a building), within which they would allocate and visit the collection. For example, a user can choose to visit the Leonardo da Vinci's works in the Versailles Residence. The collection and the environment are chosen from a set of collections and a set of environments, respectively, for which knowledge (descriptions, geometrical features, characteristics, ...) has been inserted in Minerva.

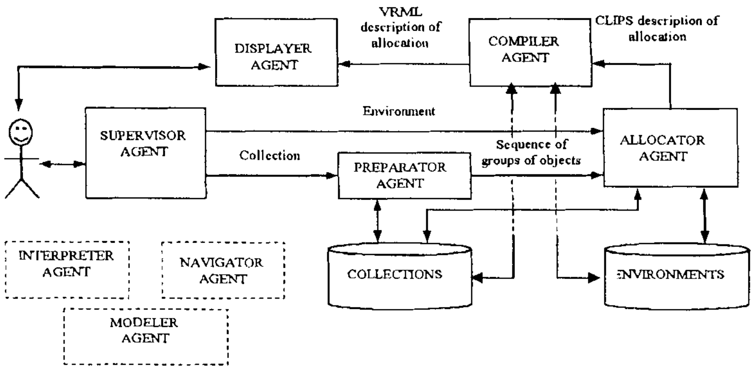


**Figure 1 – The architecture of Minerva**

Once the user has selected a collection and an environment, two further agents operate to find, respectively, a preparation and an allocation. More precisely, the first agent, called *preparator agent*, automatically determines the arrangement in which the objects of the collection will be displayed to the user. In order to achieve this goal the preparator agent exploits the expertise, inserted in its knowledge base, about museum criteria concerning the possible ways in which the pieces of a collection can be grouped. This expertise has been inserted in Minerva following a procedure of knowledge acquisition. By adopting the preparation criteria, the preparator agent divides the works of art of the collection into groups, each one composed of homogeneous objects. The criteria the preparator agent adopts to assemble similar objects in groups are based on both cultural (such as age, type, place of origin, and culture of origin) and physical (such as size, weight, shape, and material) characteristics of the objects. The user can tune the application of the criteria by acting on some parameters.

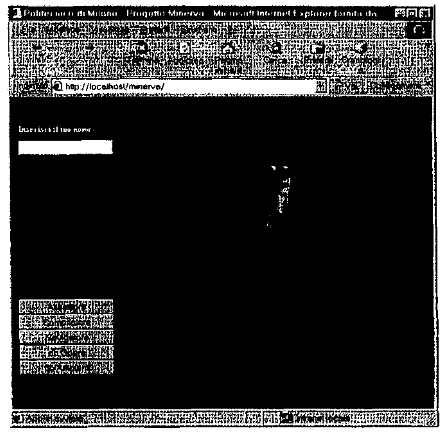

**Figure 2 - The opening window of Minerva (this window, as the following ones, is in Italian since Minerva has been initially developed for Italian museums)**

For example, the objects composing an hypothetical Leonardo da Vinci's collection can be grouped according to several different criteria (that can be selected by acting on the parameters): the chronological criterion, based on the ages of the pieces, the type criterion, based on the kind of the pieces (e.g., paintings, projects, drawings, and so on), or the subject criterion, based on the subject that pieces represent (e.g., about nature, about artifacts, about human body, and so on). These criteria can also be combined together to obtain, for example, a first division based on the subject, a second subdivision based on the type, and then a further subdivision based on the age. The preparator agent represents the obtained groups of works of art by a *taxonomic tree* (see Figure 3). Each leaf of the tree represents a group of artistic objects. The tree expresses the parental relations among groups and the criteria used for their formation. The groups are ordered according to their importance. The importance of a work of art is function of its historical value, aesthetic value, and condition. The importance of a group is function of the importance of the composing works of art. The taxonomic tree can be accessed by means of rules, called *access rules*, which act as methods for accessing and manipulating the taxonomic tree object. In conclusion, the preparator agent performs firstly a classification of the works of art in groups and then an ordering of these groups. The ordered groups of objects provided by the preparator agent and the environment selected by the user constitute the feed for the *allocator agent*.

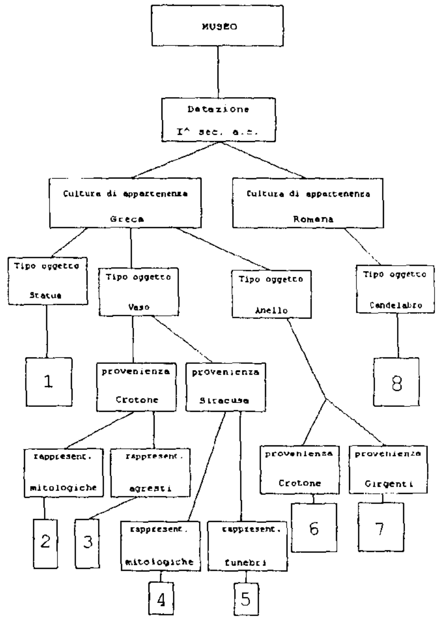


**Figure 3 – The taxonomic tree of some archeological finds from I century BC**

This agent automatically finds, within the given environment, the geometrical allocation for the objects of the groups in the taxonomic tree, preserving the ordering on groups imposed by the preparator agent. Again, in order to achieve this goal, the allocator agent exploits the knowledge, inserted in its knowledge base, about museum criteria concerning where to place the works of art in a given museum environment whose geometrical characteristics are known. These criteria concern, for example, the occupation of the space in a room, the occupation of the perimeter of the room, the collocation of the shrines according to the collocation of the doors, windows, and other shrines. The application of these criteria can be tuned by the user. The groups of works of art are allocated in the rooms in decreasing importance order (as established by the preparator agent). In particular, the allocator agent tries to allocate each group in a room; if it fails, the group is split over more rooms or more groups are allocated in the same room. In order to operate, the allocator agent accesses the taxonomic tree, generated by the preparator agent, by means of the access rules. The allocator agent discretizes each room of the environment to a matrix model (see Figure 4), in which it inserts the works of art. The result of the allocation is the geometrical description of the position of the works of art in the environment. The format of this description is a set of facts of CLIPS language [4], in which both the preparator and the allocator agents are coded. For example, the sequence of the Leonardo da Vinci's objects can be allocated in the Versailles Residence according to a criterion that places one object in each room, or to a criterion that places a group of related objects in each room, or to a criterion that considers the Residence as a single large space (namely, without considering the division of the whole space in different rooms) in which the objects can be placed. We explicitly note that both preparator and allocator agents are inferential, namely they perform their tasks exploiting inferential techniques of artificial intelligence [6].

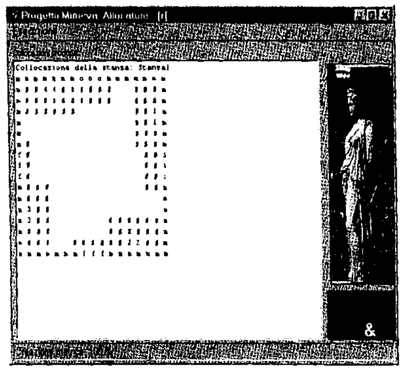

**Figure 4 – The matrix representation of a room of the environment used by the allocator agent. Numbers represent the physical occupation of the artistic objects. # symbols represent the view space of the artistic objects. Letters m, f, i, o represent respectively walls, windows, in door, out door**

Besides the fundamental preparator and allocator agents, Minerva contains other (simpler) agents devoted to carry on some technical tasks. The first one is the *compiler agent*. It translates the geometrical description of the allocation of the collection in the environment, which is provided by the allocator agent in its own format (set of facts in CLIPS language), to a format (VRML model [9]) suitable to be displayed to the user in a virtual reality setting. More precisely, the compiler agent reads the three-dimensional models of the works of art and inserts them in the three-dimensional model of the environment according to the geometrical result of the allocator.

Once the translation has been performed, the *displayer agent* displays the VRML model to the user that can navigate in it (see Figure 5). The displayer agent offers the possibility to follow a list of viewpoints through the museum and to access the information associated to the works of art by clicking on the works of art themselves (see Figure 6). The window that displays the information about a work of art allows also to move around the three-dimensional view of the object.

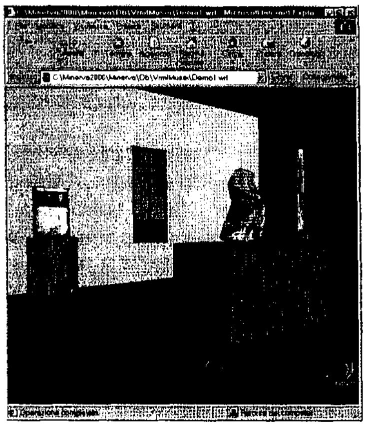

**Figure 5 – The window of the displayer agent**

The Minerva extremely flexible architecture allows for insertion of further agents. We are developing some new agents (depicted as dashed boxes in Figure 1) that will expand and enrich the system with new functionalities. The *navigator agent* will drive the user in the choose of the initial set of works of art and environments. Moreover, it will offer the opportunity of tailoring personal paths for users in already allocated museums. The *interpreter agent* will analyze the requests of the user, expressed in natural language, in order to select a particular set of interesting works of art. The *modeler agent* will allow to edit new environments, by means of the techniques of computer aided design, in order to enrich the sets of available environments.

From a technical point of view, Minerva exhibits many interesting features, such as the client-server division between agents and the possibility of using the system from a remote station which, however, we do not discuss in this paper.

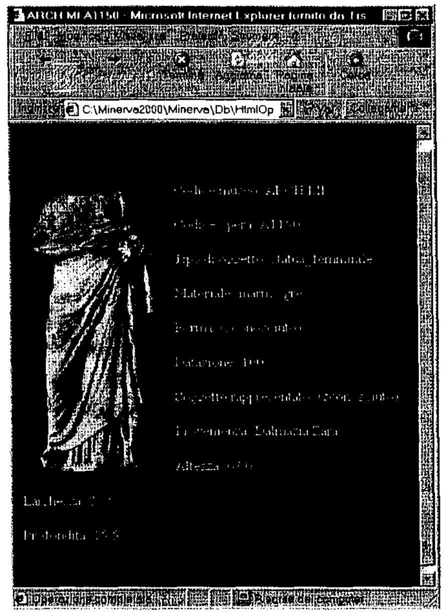


**Figure 6 – A window that displays information about a work of art from the Archeological Museum of Milan**

## CONCLUSIONS

We have proposed an example of machine-supported artistic creativity in composition of museums, presenting the Minerva system for the automatic composition of museums. It is embedded in a theoretical framework in which the role of machines involved in some creative activities traditionally performed by humans is captured. Minerva is an agency composed of specialized agents that cooperate to the

global goal of composing a museum. Minerva applications range from support the activity of museum experts to offer an environment for virtual visits to museums.
Future research work will address both the improvement of the technical apparatus of Minerva and the design of a system progressively more independent from specific applications. The goal is to obtain a system able to easily tackle the compositions of several different museums according to criteria that are specific for each museum. In this perspective, we will soon approach the automatic composition of the future Design Museum of Milan.

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