CICERO: an assistant for planning visits to a museum

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Abstract - In this paper we present CICERO, a system for the assisted planning of personalized itineraries to visit the Ducal Palace in Urbino, Italy. The graphic interface gives users a structured and exhaustive view of the artistic content of the museum, and enables them to choose consciously which aspects to privilege during the visit. According to the user preferences, the system derives a set of constraints and then determines a personalized itinerary by means of a heuristic path-planning algorithm.

1 Introduction

The adoption of computer-based techniques for the enjoyment of the cultural heritage opens a wide and interesting range of possibilities. The significant aspects we will consider in this work are:

Understanding. The works of art must be presented in a simple, though incisive and comprehensive way, in order to help the user to understand them thoroughly. A hypermedia presentation radically contributes to solve this problem, since it creates an exhaustive picture of the work to be presented [6].

Investigation. An adequate understanding of the good enables the user to choose consciously which aspects should be further investigated. Multimedia technology allows a detailed and exhaustive outlook of the specific aspects of the good by combining text, images, animation and sound.

Planning. Users should plan the enjoyment of the good consistently with their main interests. Computer systems make it easier to determine optimal plans for accessing the good satisfying the given constraints.

Personalization. The user's attitude, together with his/her specific needs, may affect the enjoyment of the good in different ways. Hence, the planning algorithm should allow for the itinerary to be personalized according to the user's profile.

The above considerations are equally valid for planning both visits to a museum and cultural itineraries within a city. In this paper we present CICERO, a system capable of assisting the user in planning an itinerary for visiting a museum. Within CICERO, understanding is accomplished by means of a guide showing an exhaustive picture of the works of art and of the most relevant authors. Investigation is effectively addressed by presenting simultaneously the artistic content of the museum according to different organization criteria: by author, historical period, etc.; the adoption of multimedia techniques is essential in giving the user an all-round view of each single work. As to planning, CICERO solves instances of the "travelling agent problem", whose general definition can be found in [12]. An interesting aspect of the sub-optimal algorithm employed is the capability of satisfying constraints expressed both as specific works ("visit the Flagellazione") and as categories of works ("visit at least one work for each historical period"). Personalization is carried out in two ways: on the one hand, the criteria used for presenting the works change depending on whether the user is visiting the museum for the first time or not; on the other, the planning algorithm takes into consideration the user's attitude (student, tourist, expert in the field, etc.) and his/her specific needs (time available for the visit).

The museum environment is represented by means of a hierarchy of knowledge layers, progressively defined by applying one of the three abstraction operators: classification, generalization, aggregation. The architecture we propose is general-purpose, even if the hierarchy structure may depend on what museum is being modelled.

The paper is organized as follows. Section II briefly introduces the Ducal Palace in Urbino, which has been chosen to test the application. Section III gives a detailed description of CICERO, focusing on the hierarchical architecture used to represent the knowledge about the museum environment, on the path-planning algorithm adopted, and on the criteria followed in designing the user interface.

2 The Ducal Palace

The Ducal Palace in Urbino, Italy, is considered a milestone of Italian Renaissance [2]. It was built on the will of Duke Federico di Montefeltro, to hand on his deeds and magnify his lineage, by summoning the highest artists of his time.

Since 1912 the Ducal Palace has hosted the National Gallery of Marche. The decorations of the Palace are remarkable: the façades, suggesting a Medieval castle, the Cortile d'Onore, the Hall of the Throne. Few native movable works of art are present: some sculptures of the Fourteenth Century, some tapestries, Federico's Alcove. Among the great artists whose works have been acquired by the Gallery we mention Piero della Francesca, Raffaello, Luca della Robbia, Tiziano. Besides paintings and sculptures, the Gallery contains drawings and ceramics.

3 Cicero Overview

CICERO has been developed on personal computer, in the Windows environment; the programming language used is Visual C++. In the following paragraphs we will discuss the main characteristics of CICERO: the formalism adopted for representing the knowledge about the museum, the path-planning algorithm and the user interface.

3.1 Hierarchical Representation of the Knowledge

According to many researchers, a cognitive map is organized into successive layers at different abstraction levels [14]. Some interesting multi-layered models are proposed in the literature. In [5], the authors describe a hierarchical model for representing a topographic surface at successively finer levels of detail. In [10], the layered model is called *spatial semantic hierarchy* and consists of a control level, a topological level and a geometric level. In [15], human navigation in the highway network is modelled through a cognitive map including three abstraction levels: the planning level, the instructional level and the driver level; the problem of classification of spatial objects is not addressed.

The approach used for the representation of the knowledge about the museum reminds the one proposed in [11] for representing environmental knowledge in autonomous agents entrusted with exploration and navigation tasks. The *knowledge layers* are determined by the structure of the environment and by the tasks which must be carried out. Each layer can be imagined like a view of the environment at a specific abstraction level; it includes only those details of the environment which are significant for a specific family of tasks or sub-tasks, and represents them in the most suitable formalism. Layers may be abstracted by classification, aggregation or generalization, so to create a hierarchy of layers.

In general, a layered representation of the environment is semantically richer than a "flat" representation, and enables a more flexible formulation of path-planning problems. Consider, for instance, a consultant system for planning visits in a city or in a museum. In these applications, the language for user-machine interaction should allow for constraints to be stated as precisely as possible (for the museum consultant: "two hours available time, definitely see all Van Gogh and Monet, a brief stop at Leonardo's Gioconda, overlook English painters"; for the city consultant: "one-hour shopping in downtown (consider the shop hours), walk in the park before sunset, be back to airport by 19.00"). These natural-language requirements are formulated at different levels of abstraction; they can be easily mapped on different knowledge layers to be translated into formal constraints for path planning.

In most route-planning applications, obtaining the solution in real-time has priority over obtaining the optimal one. Our knowledge architecture allows for complex path-planning tasks to be hierarchically decomposed into a number of sequential or parallel sub-tasks, each supported by a specific layer.

In the model adopted for CICERO, the layer at the lowest abstraction level is a graph whose vertices correspond to relevant objects and places in the museum (*landmarks*: they may be works of art, facilities, information desks, etc.); the arcs represent the paths which connect pairs of landmarks. Consistently with the terminology used in [11], we call this graph *symbolic layer*.

Two *meta-layer* are abstracted from the symbolic layer; they classify landmarks, respectively, by type (painting, sculpture, shop, etc.) and by author (works by Raffaello, works by Signorelli, etc.). A third meta-layer is abstracted by generalization from the author layer: it groups the works of art according to their historical period (Renaissance, Fourteenth Century, etc.). The user can thus quickly locate any work he/she is interested in seeing.

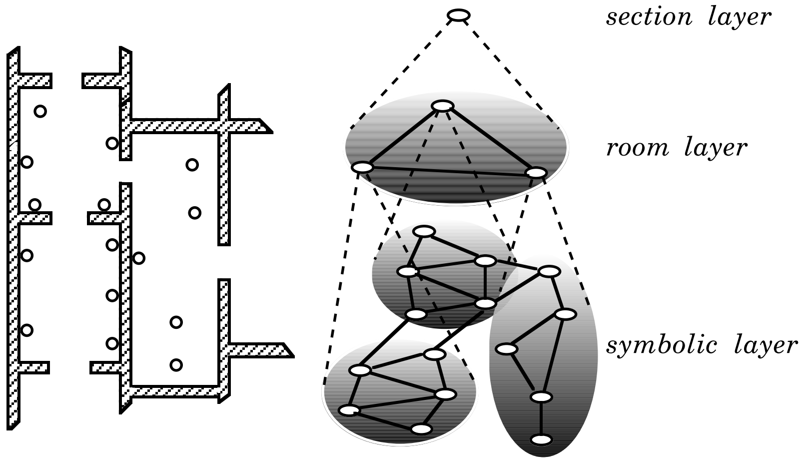

Fig. 1. Definition of clustered layers. On the left, the placing of the works of art in three rooms is shown; the picture on the right shows that a vertex of the room layer corresponds to a sub-graph of the symbolic layer, and a vertex of the section layer to a sub-graph of the room layer.

At the Ducal Palace, landmarks are placed inside rooms; rooms are grouped into sections and apartments, which are distributed along three floors. This structuring is represented through a taxonomy of *clustered layers*, each abstracted by aggregation from an underlying layer. For instance, the room layer is a graph whose vertices and arcs are, respectively, rooms and thresholds; each vertex of this layer corresponds to a sub-graph of the symbolic layer. By applying progressively a clustering process, we define a section layer (a section is a set of rooms), a floor layer (a floor is a set of sections), a museum layer (this layer is a graph including only one vertex, which represents the Ducal Palace and is a set of three floors). An example of definition of clustered layers is shown in Figure 1.

The complete taxonomy of layers used for representing the Ducal Palace is sketched in Figure 2.

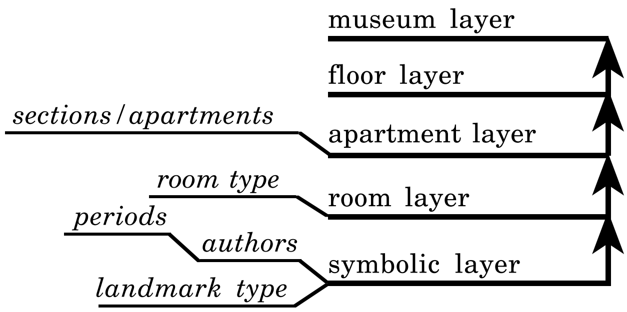

Fig. 2. Taxonomy of layers adopted in CICERO. Meta-layers are in italics, clustered layers in plain text. Vertical arrows represent abstraction by aggregation; diagonal lines represent abstraction by classification/generalization.

An object-based formalism has been adopted to represent the knowledge about the museum. In order to support integration and co-operation of the different layers aimed at solving path-planning problems, we have designed primitive methods for horizontal (intra-layer) and vertical (inter-layer) conceptual navigation of the taxonomy.

It is remarkable that the mechanisms provided for defining and navigating layers are completely general, hence, they can be used again to build taxonomies which represent museums structured differently from the Ducal Palace. For instance, a small museum may not be partitioned into sections, so that the floor layer would be abstracted directly from the room layer. On the other hand, the works of art might be placed inside different buildings; in this case, an intermediate building layer should be introduced.

3.2 Constrained Path Planning

Knowledge layering impacts on path planning in two ways: by establishing a general framework for a more flexible formulation of path-planning problems, and by reducing the computational effort enabling their solution through hierarchical decomposition techniques. The problems we consider are instances of the "travelling agent problem" defined in [12] as a generalization of the Travelling Salesman Problem to the case of hierarchies of graphs. First, it is possible to address the new abstraction levels introduced by hierarchical clustering ("visit the Duke's Apartment"). Besides, due to the definition of meta-layers, constraints can be formulated not only in terms of specific objects and places ("visit the Muta"), but also in terms of categories of objects and places ("visit a (any) painting by Raffaello", "visit all the apartments").

The formulation of the path-planning problem is then translated into a set of constraints that must be satisfied by the path being planned. The constraints we consider are the following:

- Maximum total duration of the itinerary. The duration is calculated by taking into account an average time for a stop in front of every work of art; this time depends on the user's attitude (tourist, expert, etc.).
- Visiting hours for the different sections of the museum.
- Landmarks (works of arts/facilities) and apartments which must be included in the path.
- Categories of landmarks that must be included in the path.

An example of a natural language description is the following: "plan an itinerary that considers the Flagellazione, La Città Ideale, at least one sculpture, at least one work by Raffaello, and that takes no more than two hours".

Once the problem has been formulated, it is solved by means of a heuristic algorithm which decomposes the search for the path on the different clustered layers, starting from the museum layer and descending towards the landmark layer, following a hierarchical approach.

The hierarchical approach to the solution of planning problems consists first in constructing an abstract plan which achieves the more general goals, and then in refining it into detailed subplans which achieve more concrete goals. The advantage is that the plan is first developed at a level where the details are not computationally overwhelming. There have been a number of attempts to devise hierarchical planning systems, beginning with Sacerdoti's ABSTRIPS in which a hierarchy of abstract spaces, each dealing with fewer details than the space below it and with more details than that above it, is defined. By considering details only when a successful plan in a higher level space gives strong evidence of their importance, a heuristic search process will investigate a greatly reduced portion of the search space [13]. In [9], the author shows that the use of abstraction hierarchies in planning can reduce exponential problems to linear complexity if the number of abstraction levels and their sizes are properly determined.

The application of abstraction hierarchies to path planning has been specifically treated in the literature. In [7] the authors propose a cognitive model of path-planning and show how humans often move between different abstraction levels when planning. An architecture that supports hierarchical planning involving deadlines, travel time and resource considerations is described in [4]; a partially constructed plan is refined into a plan at a lower level of abstraction by decomposing a complex task into a set of simpler subtasks by applying routines called *task expanders*. In [3], a route-finding algorithm working on a hierarchical representation of the environment based on clustering is outlined.

The hierarchical path-planning algorithm we adopt is described in detail in [12]. In our divide-and-conquer approach, at each step, the path planned on a given clustered layer is expanded into a path on the underlying clustered layer, in order to express the solution on a lower abstraction level. For instance, a path expressed as a sequence of rooms to be visited is transformed into a path expressed as a sequence of works of arts. This is done first by choosing, for each room in the path, the first and the last works to be visited (*entry* and *exit points*; the choice is guided by a heuristic criterion); then, inside each room, the shortest path including all the works to be visited is calculated (see Figure 3).

Let each clustered layer be associated to an integer representing the level of the layer within the taxonomy; the symbolic, room, section, floor and museum layers have, respectively, levels 0, 1, 2, 3 e 4. We call *k-clusters* the vertices of the graph representing the clustered layer at level k (for instance, a room is a 1-cluster), and denote with $\mathcal{P}^{(k)}$ a sequence of k-clusters (i.e., a path at level k); we call *resources* the landmarks/apartments/categories to be included in the path. Our divide-and-conquer approach to the planning can be outlined as follows:

$\mathcal{P}^{(4)}$=("Ducal Palace");
for k=4 downto 1 **do**
{ **for each** (k-cluster $v_i^{(k)}$ in $\mathcal{P}^{(k)}$) **do**
{ find the entry and exit points for $v_i^{(k)}$, say $v'_i{}^{(k-1)}$ and $v''_i{}^{(k-1)}$;
determine the set of the resources to be visited inside $v_i^{(k)}$, say R_i;
find, within $v_i^{(k)}$, the shortest path of (k-1)-clusters starting from $v'_i{}^{(k-1)}$,
ending in $v''_i{}^{(k-1)}$, and visiting all the resources in R_i;
}
concatenate the sub-paths within each $v_i^{(k)}$ into a path $\mathcal{P}^{(k-1)}$;
}

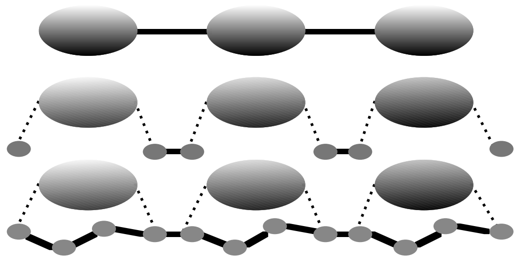

Fig. 3. Expansion of a path from a clustered layer to the underlying one: a) initial path; b) the entry and exit points are determined; c) the optimal sub-paths are calculated and concatenated.

The resulting path $\mathcal{P}^{(0)}$ is a sequence of landmarks which satisfies all the constraints expressed, thus solving the problem formulated. The use of a heuristic algorithm reduces dramatically the computation time; of course, the solution is sub-optimal (that is, sometimes the path planned is not the shortest among those which satisfy the given constraints) [1] [8].

3.3 The User Interface

Within the window-based user interface of CICERO, understanding and investigation are accomplished together at three subsequent levels. The first two levels act as *guide*, since they assist the user having no deep artistic knowledge in planning a satisfactory and meaningful itinerary. Here, the sequence of the windows is fixed: the inexperienced user examines the works of art proposed and, in case, chooses to visit them. The third level, called *interests*, is intended for the users who are capable to find their way autonomously in the complex setting of the works of art present in the museum, and enables them to carry out a well-reasoned investigation.

The users who choose the guide want to clear up their mind about what can be seen in the museum. At the first level, designed for the users who have never visited the museum before and are interested in an elementary visit, the ten most famous works of arts are presented. Each work is proposed in an exhaustive way by combining an explanatory text with a high-resolution colour image. The whole-screen image engraves itself on the user memory, so that the work will be easily recognized during the visit.

Users who choose the guide though having already visited the museum, wish to work out a more complete itinerary from an artistic point of view. Hence, at the second level, the forty most interesting works of art are presented. These works can be accessed in three ways: *overview*, where low-resolution pictures are shown in groups of nine; *guide*, oriented to the understanding, where a detailed presentation of one or more works can be seen; *visit*, oriented to the investigation, where the works can be directly selected for the visit.

The third level was conceived in order to satisfy the most demanding connoisseurs. The presentations of the works of art can be accessed by four criteria: by author, period, type of the work, section/apartment. For instance, following the author criterion, a list of the authors is proposed where the most interesting ones are pointed out, and a news window containing curiosities and new acquisitions is shown. If an author is selected, the list of his/her works is proposed: the user may choose to see the detailed presentation of one or more of them and, in case, may select them for the visit. The user may also decide to visit any work of the author; in this case, the work to be visited will be chosen by the system.

The selection of works to be inserted in the path can be carried out at any level in a very simple way. Once the consultation is over, the user can calculate the visit itinerary. The path resulting from planning is visualized by superimposing it to the plans of the three floors of the museum (see Figure 4). Each work of art to be visited is denoted by a number, and a list of the names and authors of the works is printed.

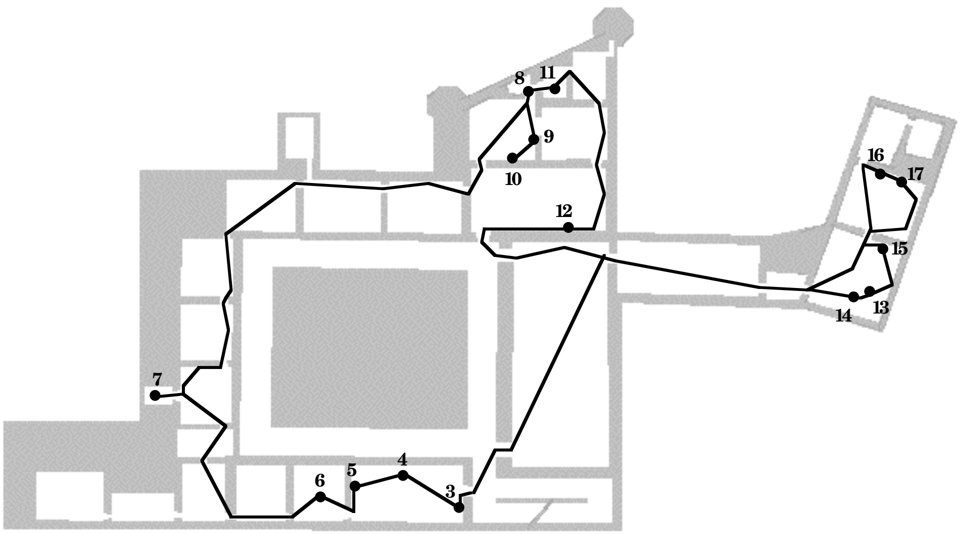

Fig. 4. Printing of the path to be followed on the first floor.

In Figure 5, the sequence of the windows displayed in the user interface of CICERO is sketched. Every single window was designed considering that most system users have no computer skill. The keyboard is not necessary; users interact with the system through a pointing device (a mouse or a touch-screen). Icons and pictures are widely used in order to make clear the meaning of the different windows. Within each window, the functions that can be invoked are depicted by buttons characterized by a brief explanation and a picture. The pictures corresponding to the main functions (for instance, *guide*) recur in several windows, so that the user can easily identify them even in different contexts.

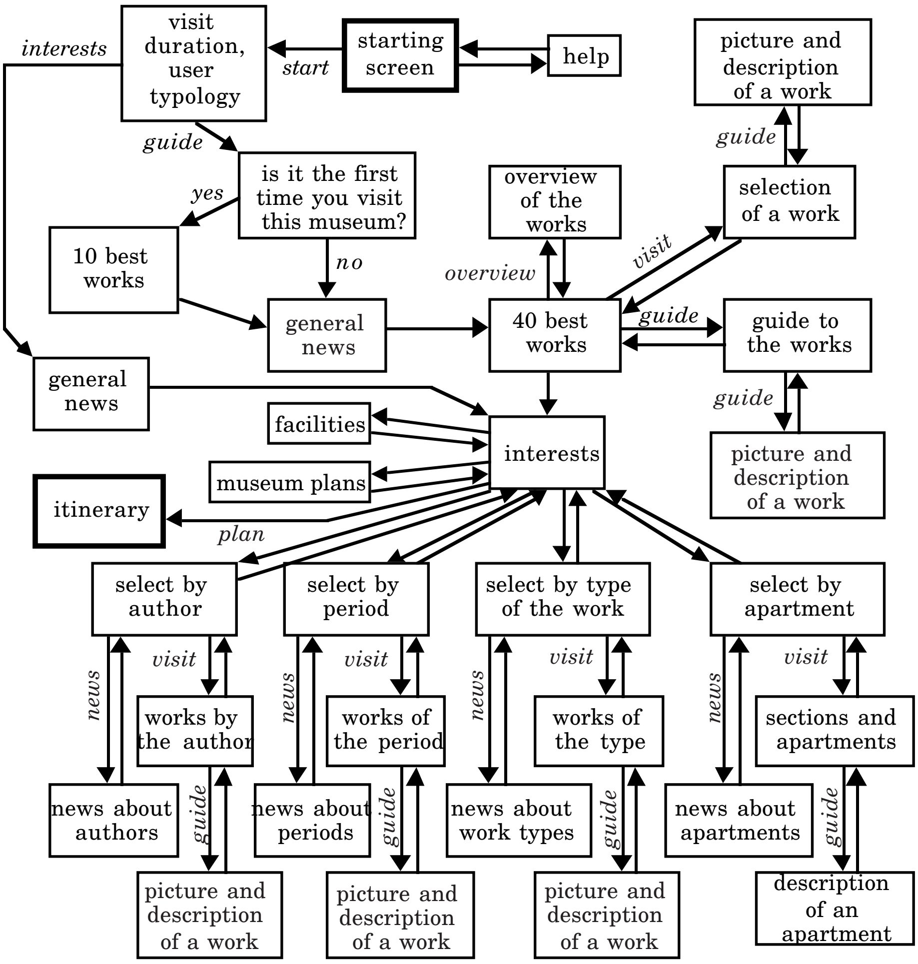

Fig. 5. Dynamic model of the user interface of CICERO. Every box represents a window; the arcs represent transitions between windows caused by pressing a button on the screen.

Figure 6 and 7 show two windows designed for the user interface of CICERO.

4 Conclusions

In this paper we have introduced CICERO, an assistant for planning visits to the Ducal Palace in Urbino. The system adequately addresses the requirements of understanding of the cultural heritage in the museum and of conscious investigation of the most interesting artistic aspects. A peculiar characteristic of the application is that the proposals are tuned according to the artistic knowledge of the user.

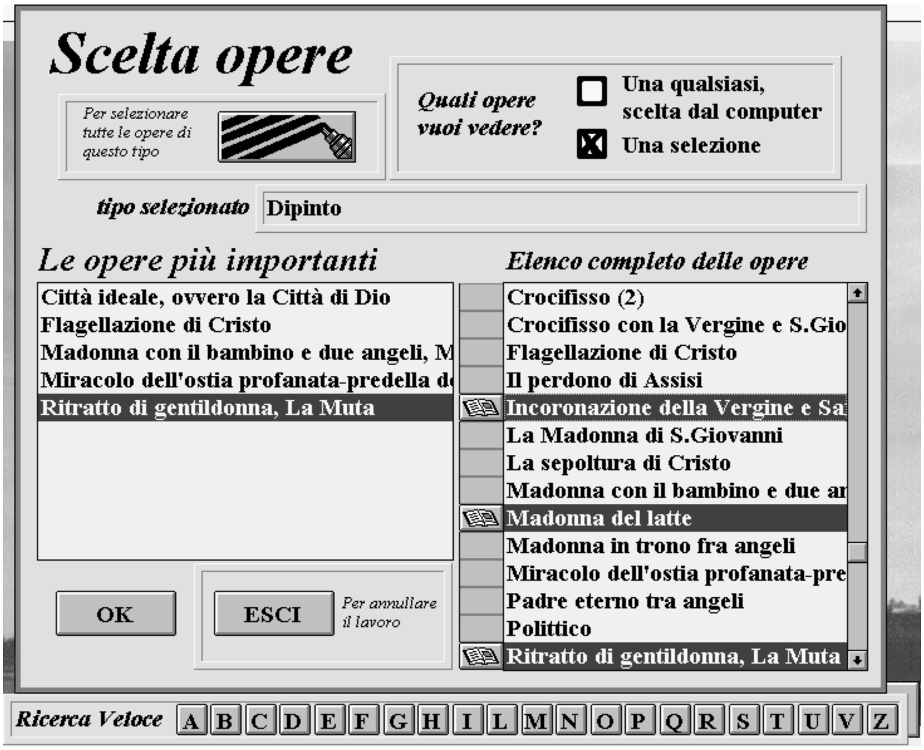

Fig. 6. Window for selecting the works of art according to their type (here, type painting is selected). If the user clicks on the book icon beside the name of a work, its guide is visualized.

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Fig. 7. *Guide* window for presenting a work of art to the user.