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INTERACTION WITH TIME-SPATIAL WORKS-OF-ART AND THEIR BEHAVIOURS IN A VIRTUAL GALLERY

Abstract.
The paper focuses on problems involved in interaction with time-spatial works-of-art (i.e. sculptures, especially modern ones, and installations) in immersive virtual environment and describes the research results obtained by an interdisciplinary team of computer scientists and artists. With the cognitive aspect of this particular kind of presentation in mind, special attention has been paid to recipient – work-of-art relationship including user – work-of-art interaction along with work behaviour simulation perceived as inseparable parts of successful presentation. Interaction techniques employed in virtual environment as well as requirements imposed on this environment have been discussed. The solutions considered to be the best, i.e. the simplest and the most intuitive ones, and enabling the recipient's active co-creation of numerous realisations of the work-of-art have been discussed using two selected works by students of The Lodz Academy of Fine Arts as examples.

keywords : *Virtual reality, Interaction, Behaviours, Virtual art gallery.*

1 Introduction

Time spatial work-of-art are sculptures, especially modern ones, and installations. Many of them are characterised by potential motion possibilities, which especially destines them for presentations in virtual environment (VE). While sightseeing the virtual gallery it is possible not only to navigate freely within its space, observing the works-of-art from different positions and directions, but interact with the works as well. Interaction with a model becomes complicated when it is a complex spatial system, the elements of which are movable due to user's direct action or specific environment conditions (i.e. work-of-art's element changeability generated by air movements). In such a situation interaction should be considered parallel with behaviour simulation of work-of-art's components.

There are many works that take up the problem of interaction and modelling of objects' behaviours [1-4]. To achieve the cognitive aim of presenting art it is necessary to identify interaction techniques elaborated for the virtual environment, in order to be able to select those that are best suited for the purpose, that is the simplest and the most intuitive ones, which, moreover, meet the requirements considered essential from the viewpoint of the artist who created the presented works-of-art [5]. In this paper the process of interaction will be discussed according to the constraints of the available equipment: 5DT cyber gloves and V6 HMD – all supplied with tracking systems with 2 and 3 degrees of freedom, respectively.

1.1 More details information about references

An exhaustive work regarding problems of interactions for common tasks in immersive virtual environments was presented by D. A. Bowman [1]. Analysis of interaction understood as: navigation, selection and manipulation resulted in precious taxonomies and performance metrics, essential for evaluating proposed solutions. There are also some further works, which discuss new techniques applied in selection and manipulation in virtual environment [2]. On the other hand, M. Kallmann [3] and K. Kaur [4] presented certain improvements of interaction techniques, which went beyond simple virtual equipment implementation and supported their models with intelligent behaviours, aiding user's activities.

Despite the increasing role of electronic media in popularising works-of-art, the issues essential for the initial stage of presentation designing are very sparsely taken up in publications. Recognition of characteristic features of presented time-spatial works, propriety of choosing specific techniques and technologies, as well as requirements imposed on virtual environment have been discussed by L. Miskiewicz and M. Pietruszka [5].

2 CHOICE OF INTERACTION TECHNIQUES FOR VIRTUAL ART GALLERY.

Time-spatial works-of-art are sculptures that can assume one of three different characteristics [5]:
Group 1 - works that last in reality and remain still. These works can be, for example, free-standing sculptures, architectonic systems, exhibition sequences, and others;
Group 2 - works the elements of which can be moved by spectators;
Group 3 - works the elements of which appear independently of the viewer and form an organised sequence of elements or phenomena. They are light projections of images and mobile spatial systems, like kinetic sculptures called mobiles.

Behaviours of works belonging to groups 2 and 3 depend on potential movement abilities, imposed by their construction, which are triggered by user's actions or environmental influence. Viewer's behaviours should be as close to those characteristic of the direct contact with the work-of-art as possible, i.e. easy and unceremonious yet excluding any destruction or actions contributing nothing to gaining knowledge about the work. These obviously result in certain limitations of works' behaviours. The requirements imposed on a presentation of time-spatial works-of-art are shown in table 1 [5].

A software developer has to decide, from an increasing number of options, which interaction technique fits best given requirements. Figure 1 shows some possible solutions to elementary tasks of interaction: selection, manipulation and release of an object [1]. The underlined solutions are those chosen by us after an analysis of all interaction techniques.

Tab. 1 Analysis of requirements to be met while presenting time-spatial works in virtual environment (based on works by students of the Academy of Fine Arts in Lodz) [5].

<table>
<tr><th colspan="2">Behaviours of the work-of-art</th><th colspan="2">Visitor’s behaviour</th></tr>
<tr><th>Group 2</th><th>Group 3</th><th>Group 2</th><th>Group 3</th></tr>
<tr><td rowspan="4">1. Movability of elements of the work as intended by the artist</td><td rowspan="4">1. Movement of elements as intended by the artist</td><td colspan="2">1. Free navigation in the space (obeying gravitation rules)</td></tr>
<tr><td colspan="2">2. All spatial features of the work (provided by the artist) accessible for viewing from any place in the space.</td></tr>
<tr><td rowspan="3">3. Fixed way and succession of viewing the elements of the work by: dislocation, rotation, lifting,
i.e. moving particular elements (in accordance with possibilities incorporated in the model construction)</td><td>3. Possibility of setting in motion and halting of the movable elements</td></tr>
<tr><td rowspan="2">4. Finding a place in the space, which is optimal for observation and the best from the artist’s viewpoint.</td></tr>
<tr><td colspan="2">2. Simulation of phenomena resulting from movability of elements</td></tr>
</table>

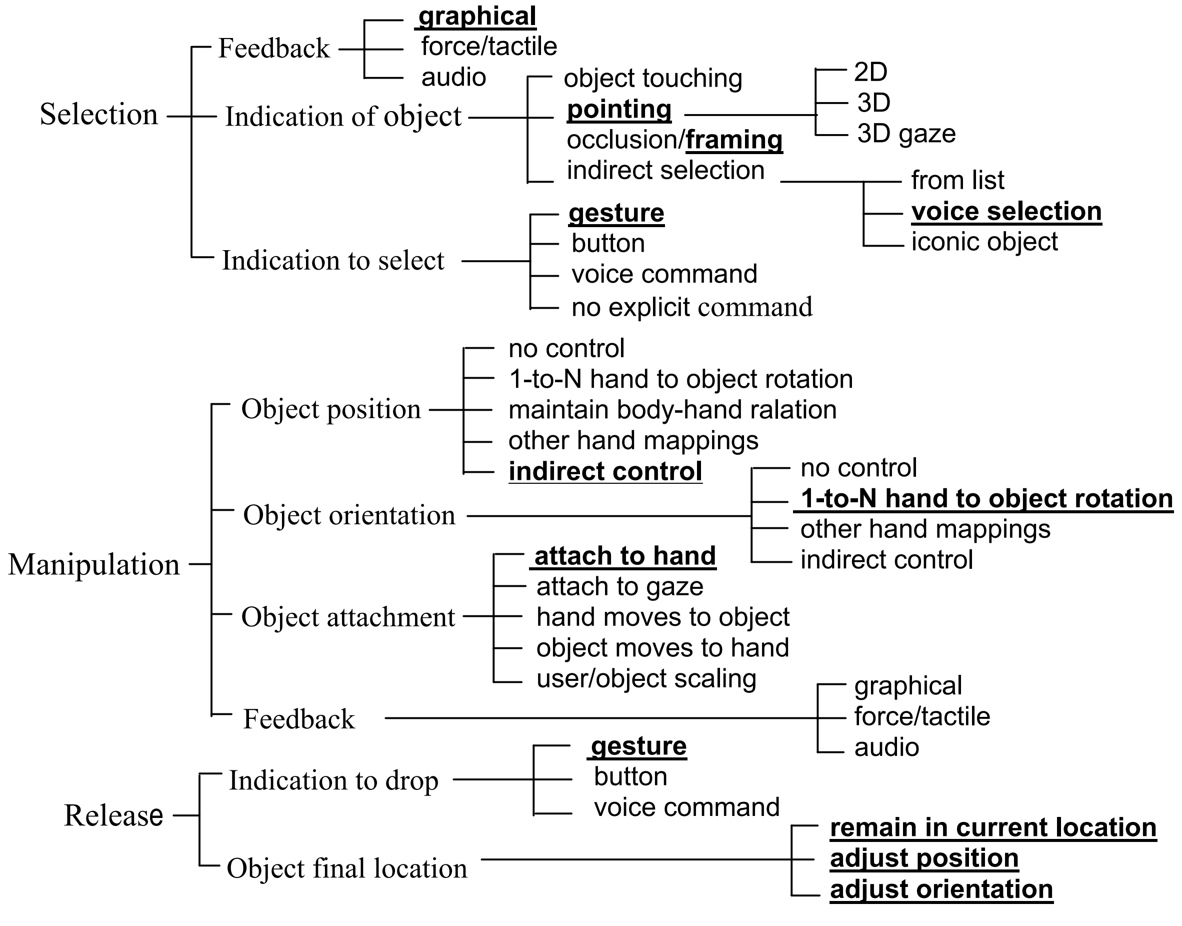

Fig. 1 Taxonomy of Selection/Manipulation Techniques [1]. The solutions chosen for interaction with virtual works-of-art are underlined.

The analysis has been based on the following performance metrics [1]: speed (efficiency of task completion), accuracy of selection (the ability to select the desired object), accuracy of placement (the ability to achieve the desired position and orientation), ease of learning (the ability of a novice to use the technique), ease of use (the complexity of cognitive load of the technique from the user’s point of view), presence (the user’s sense of immersion within the environment while using the technique), expressiveness of selection (the number and distance of objects that can be selected), expressiveness of manipulation (the ability to position and orient the object at any desired location in the environment), user’s comfort (lack of physical discomfort, including simulator sickness). All factors mentioned above can be important to many of the target applications. On the other hand, many of the techniques that allow to complete 6 DOF (degrees of freedom) manipulation of virtual objects can force the users to assume awkward head or hand position. That is why each technique implementation should be considered thoroughly and a decision should be made as to which performance metrics are the most important for particular implementation.

Popularisation of time spatial works-of-art through virtual presentation should provide the recipients with a possibility of making their own decisions as to the way, range, and time of his contact with the work. It ought to depend on the users, which object being within their reach will be selected to pass by, while walking about the virtual gallery (indication by framing), and which element or elements of the object, chosen by the artist to activate the work, will be picked out (indication by pointing or voice commands). Manipulation of an object, or a part of a complex one, should make it possible to change position or orientation resulting from its construction. The precision of undertaken actions, which however should not lead to object's destruction, is not of the highest priority. On the other hand, attention must be focused on easiness of learning and making use of interaction methods, as well as on execution of interaction tasks, with the speed not distinct from the one used in the real world.

3 IMPLEMENTATION OF WORKS-OF-ART AND VISITORS BEHAVIOURS.

The implementation to be discussed in this paper is based on two works created by students of The Academy of Fine Arts in Lodz: a black box with a rotary inner cylinder, revolving about its inner symmetry axis (Fig 2a) and a maze, the rotation of which is feasible around two horizontal axis and causes movements of two independent balls (Fig 2b).

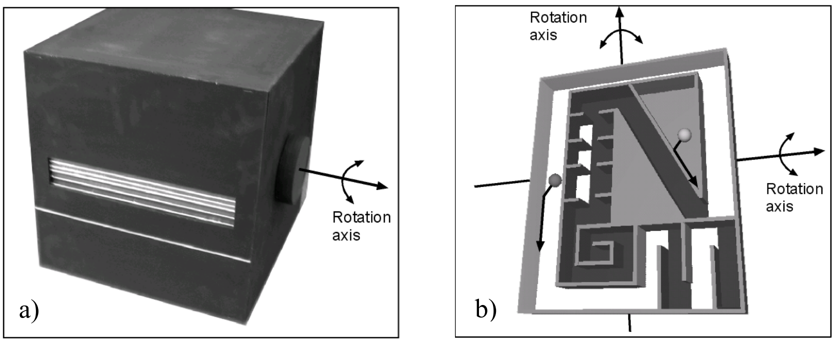

Fig. 2 Virtual models of works by students of The Academy of Fine Art in Lodz. Some of their elements have potential movement ability. According to Table 1, the box belongs to group 2 and maze to group 3.

In order to design behaviours of the objects from Fig. 2 the following events have been taken into consideration: inertia of a solid rigid body in rotary motion (Fig. 2a), accelerated motion of a solid sphere following a downward path on an inclined plane, as well as collisions and contact determinations of a mobile object with surrounding obstacles (Fig. 2b). All of these events are defined basing on physical laws and observations, which substantially increases the level of realism, simultaneously presenting the essence of works-of-art in a more detailed manner.

A revolution of a rigid body depends on multiple factors including rotation axis and angular velocity. The latter is determined by an applied force provoking the rotation and specifies a type of motion. The mutual dependence of the above quantities is directly proportional. Therefore, since our research refers to exploration of works-of-art, the rotating force is inseparably connected with users' interaction, which is prone to continuous lability, allowing us to consider the movement as a non-uniform variable motion. Inertia is a property of physical bodies, which in rotary motion is measured by a moment of inertia. According to the second law of Newton's dynamics, the unbalanced system of forces causes the body to alter its motion, or state of rest, not instantly, but gradually, depending on body's inertia in an inversely proportional manner. The above statement depicts the essentials of simulating an inert rotating object. Thus, the problem under analysis, reduces to constraining an adequate uniform retarded rotary motion of a selected object (i.e. a black dial in Fig. 2a) after having released it. The movement causes the angular velocity of an object to gradually diminish until absolute cessation. Rotating of an object is performed about a sole, preset axis.

Accelerated motion of a ball following a downward path on an inclined plane of a maze is strictly combined with the gravity force; more precisely – with its component responsible for translatory motion. A two-dimensional plane requires defining two independent motions along a pair of perpendicular axes, respectively. Since the velocity of the sphere is a function of time and pitch of the plane, which can be freely altered by a user within specified boundaries imposed to prevent the ball from falling out, the motion of the ball appears to be non-uniform variable. Defining a two-dimensional translation vector considerably simplifies computing a position of the sphere. Each of the components of the vector is determined according to the velocity towards an adequate direction. Several additional restrictions have been imposed upon the motion of the sphere: it moves only within strict boundaries of the plane and it does not rotate about any of its axes (Fig. 2b). The vast subject of collision detections and contact determination has been reduced to detecting collisions between a mobile sphere and the surrounding walls of a maze, represented by cuboid objects, and determining its path afterwards.

In order to obtain a satisfactory solution for all of the three events mentioned above, specific algorithms have been used. Amidst them, contact determination is calculated basing on a known collision detection algorithm, while the other two, including rotary inertia and a sphere movement on an inclined plane, utilize computationally simple algorithms which considerably improve efficiency of the discussed application, and have been suggested in an attempt to substitute simplifications, based on observations and experience, for mathematically described physical events that often require huge amounts of computing. The above behaviours, bound to certain objects, require defining rules of interaction techniques in order to determine, trigger, observe and experience them.

The first task concerning interaction is selection of object, which is indicated by changing the colour of hand's avatar immediately when one of the following occurs: hand's avatar bounding box and object's bounding box intersect; a ray cast from the current point-of-view running through hand's avatar intersects with a desired object from the scene; a voice command has been used for an object having its own ID (the commands are made by object names such as: *box*, *dial*, *maze*). Selection can comprise the whole object or only its part (i.e. the black box or the dial). When object is selected it can be gripped by making a fist gesture.

Another task of interaction is manipulation of object. A selected object is formally bound to the hand's avatar which is subsequently connected with the user's body and indirectly with the point of view. Consequently, changes in the user's position have an influence on the position of the selected object. As far as orientation is concerned, it is thoroughly dependent on hand's orientation (cyber glove's tracking system orientation). Hand rotation can affect either the whole object or its part, for example the black box or only the dial (Fig. 2a). Moreover, the following rotation restrictions have been imposed upon the behaviours of works-of-art: the box can be rotated about two horizontal axes but the dial with the inner cylinder only around one - its main symmetry axis. The maze depicted in Fig. 2b can be revolved around two horizontal axes, however within a limited range of degrees (the rotation angle cannot exceed 80 degrees in each direction), which prevents the balls from falling out. The speed of manipulation has been bound to the speed of hand movements, which lets the user stimulate and control the motion velocity and inertia of an object – the swifter the hand moves, the greater inertia the dial with the inner cylinder gets.

The last task of interaction regards release of object. Its implementation is quite facile, for simply hand relaxing (any gesture but fist) releases the object and lets the user switch to the free navigation mode, which is indicated by changing the colour of hand's avatar.

4 CONCLUSIONS

The experience gained while designing presentations of time-spatial works of art allows drawing of the following conclusions. Freedom of choice concerning ways of communication between a user and a virtual work-of-art is a vital issue. Basing on one's preferences, a user should have a possibility to decide which method to choose from among several alternatives and whether utilize voice commands or gestures. From the midst of numerous conceivable ways of interaction, the most intuitive and straightforward should be chosen. A user should be chiefly focused on exploring and experiencing works-of-art and not practising gestures or pronunciation of commands. Graphical representation of hand's avatar should not be a large object (we have used a small sphere), otherwise it would obscure and affect scene composition, distracting user's attention.

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