A 3D Free Form Object Localization Using Skeletons: Application to teleoperation

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Abstract. Our aim is to develop a vision system for teleoperation to localize an object. This system has to be used through Internet connection. The recognition problem addressed in this paper is to localize a 3D free-form object from a single 2D view of 3D scene. Using a skeletonization process allows to obtain two graphs, the first one representing an object in the scene (2D skeleton) and the second one representing a database object (3D homotopic skeleton). The method encodes geometric and topological information in the form of a skeletal graph and uses graph isomorphism techniques to match the skeletons and find the one-to-one correspondences of nodes in order to estimate the object's pose. Knowing skeleton is a set of lines centred within the 3D/2D objects, our method transforms the problem of free form object localization into points and lines pose estimation. Some experimental results on real images demonstrate the robustness of the proposed method with regard to occlusion, cluster, and shadows.

1 INTRODUCTION

A system of teleoperation allows an operator to achieve a task from afar, while moving him away from his environment of work and machines that he controls. Thus, the teleoperation eliminates risks raising dangerous works as the spatial exploitation or the poisonous substance manipulation. To help the operator to achieve his work in a more efficient way, it is possible to give him the aid offered by other users or by robot with a certain degree of autonomy.

Our laboratory has developed a teleoperation system where it is possible, for everybody, to connect by internet. It is the Augmented Reality Interface for Teleoperation on the Internet system "A.R.I.T.I" [1]. But, in this system, it is now not possible to localize a moved object and to match a model on it.

Our aim is to develop an on-line system which will be able to localize a moved free form object. So, in order to give a good reactivity to the users, all the processes we develop have to be "real time".

Last years we find in literature some works try to resolve the free form object localization using the silhouettes [2], object appearances [3] and shape from shading [4]. These researches leaded in the identification domain, but they rarely study the free-form object localization and the occlusion problem. We notice that tests are realized with synthetic images or they are not done in the real conditions. To solve these lacks, we have used the skeleton method as is explain below.

Conversion of 2D and 3D objects into a skeletal representation forms an essential step in many image processing and pattern recognition applications. For example, in document analysis drawing recognition and off-line script recognition. Most of the topological structure of objects, and information contained in the outline of their shape, are preserved in the skeleton.

In recent work, Siddiqi and *al* have resolved the problem of 2D shape matching using shock graph representation corresponding to a 2D skeletal [5] this compact representation has been used for indexing. In [6] [7] Macrini and *al* unify shock graph indexing, aspect graph and matching techniques to yield an effective method for view-based 3D object recognition.

Our approach is summarized as follows. Each 3D model is stored with their 3D skeletal graph. We compute the 2D skeleton from the image and we generate their 2D skeletal graph as described in [8]. These characteristics are used to compare the image with other 3D skeletal graph in database using the graph matching algorithm. The resulting match gives the pose of the object as well as its identity; the method details are presented in [9].

2 ARITI INTERFACE

The ARITI system [1] is a web site allowing any user with a Java compatible web browser to control our 4 degree of freedom robot. This site is opened for public on 1999 at the http://lsc.cemif.univ-evry.fr:8080/Projets/ARITI/ and it is added in NASA Space Telerobotics Program web site on February 2000.

The ARITI system has been implemented on a PC Pentium 233 MHz with a 128 Mo RAM, under Linux operating system. The PC is equipped with a Matrox Meteor video acquisition card connected to a black and white camera. Thus, images of the environment, within which the robot is, can be obtained and enhanced with virtual models. On the other hand this PC is connected to four degrees of freedom robot via a common RS232 serial link. The figure 1 shows how a communication between an operator (client) and remote robot system is done. Two servers are implied in this communication. Video server, which performs image compression and transfer to the client. And Robot server, which allows to telecontrol the robot. The ARITI interface is written based on Java object programming language. Hence allowing the execution of the Applet using any recent Internet Browser.

3 NEW FREE FORM OBJECT LOCALIZATION

In this section we describe a novel method for searching and locating 3D free-form objects. The method encodes the geometric and topological information in the form of a skeletal graph. Uses graph matching techniques to match the skeletons and to compare them in order to find the one-to-one correspondences of nodes so that the pose of the object is estimate.

The matching procedure is expensive and must be used sparingly. For large databases of object models, it is simply unacceptable to perform a linear search of the database. Therefore, an indexing mechanism is essential for selecting a small set of candidate models using the eigenvalue characterization.

Once a candidate is retrieved by indexing mechanism, we exploit

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this same eigen characterization of hierarchical structure to compute a node-to-node correspondence between 2D skeletal (scene) and 3D skeletal graph (model). Knowing that the skeleton is a set of lines centred within the objects (3D and 2D), our method transforms the problem of free-form object localization into points and lines pose estimation. The localization of a correct model implicitly indicates the recognition of the model.

The object recognition system we use here, as illustrated in figure1, comprises three primary techniques: 2D and 3D skeletonization process, graph isomorphism and robust pose estimation.

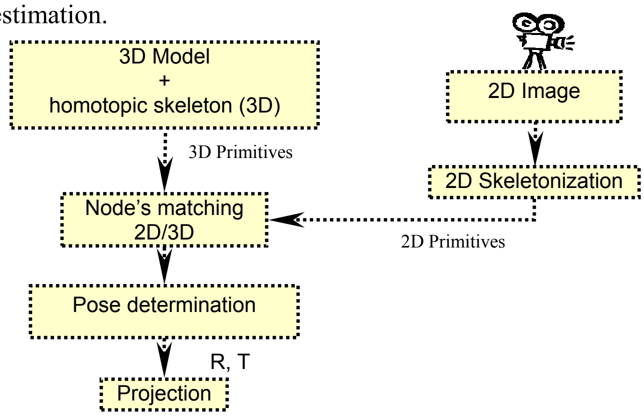

Figure 1. 2D/3D free form localization

4 APPLICATION TO ARITI SYSTEM

Once the feasibility and the robustness of the method are proved, we integrate it to the ARITI system (figure 2). Predictive display is used, in this system, to cope with the time delay problem with Augmented Reality systems and special teleprogramming architectures. The basic control of task execution is through superimposing, on the online video feedback, the corresponding robot, its surroundings virtual model and virtual objects equivalent to the real one. The task of teleoperation consists in guiding the virtual robot toward the virtual object so that the real robot takes the real object. During the manipulation the real object can move. Our method permit to recognize and localize it. For this the system can superimpose the virtual object on the real one, and then human operator can continue our teleoperation task. An example is illustrated in figure 3.

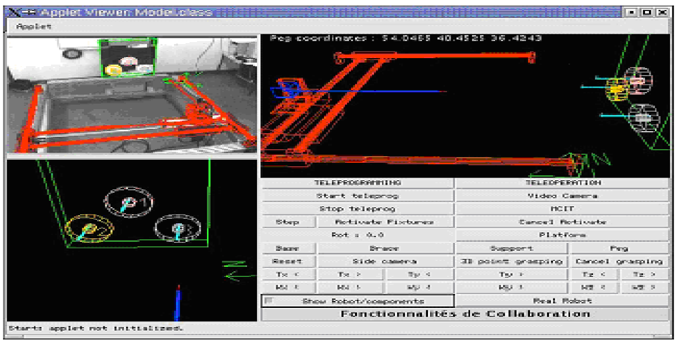

Figure 2. The system interface

5 CONCLUSION

We have presented our initial effort for localization 3D free form object applying to robot-teleoperation. Based upon the skeleton, this method transforms the problem of free form object localization upon points and lines pose estimation. Due to the strength of the graph matching, our approach was successfully applied to different types of noises (shadows occlusion, clutter,)

However additional attributes can be introduced to provide a more accurate matching. However, to improve the localization we must develop more exact skeletonization algorithm. In a future work, we develop a fast and robust matching algorithm.

Figure 3. ARITI Application on free form object (toy)

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