An Active-Vision System for Recognition of Pre-Marked Objects in Robotic Assembly Workcells

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Abstract - In this paper, a new 3D-object-recognition method for robotic assembly workcells is presented. The proposed method is focused on two basic concepts, namely active vision and object preconditioning. The paper will briefly present the main aspects of the proposed system.

1. The Proposed Recognition Method [1]

Herein, it is proposed to model an object using only a small number of 2D topologically-distinct perspective views. These are referred to as *standard-views*, each with a corresponding *standard-view-axis*. For successful recognition purposes, the input image of an object must be one of its standard perspective views. Thus, a mobile camera is used, such that its optical axis can be aligned with one of the standard-view-axes of the object in order to acquire a standard-view. Then, the matching process is performed between the acquired 2D standard-view of the object and the library of 2D standard-views of a set of objects.

To enable the vision system to acquire standard-views, standard-view-axes must be pre-defined. This can be accomplished by defining a local surface normal for each distinct view of an object. The local surface normals can be defined by pre-marking the objects using circular markers.

In the context of the above scheme, active vision is used for two purposes: (1) Acquiring only specific views of an object (i.e., standard views) by controlling the external parameters of the camera; and (2) Acquiring additional images (standard views) if needed by virtue of the possibility that the recognition process is not successful after the analysis of the first image, either due to significant distortion and noise, or, insufficient visual information in the image initially acquired.

On the other hand, object pre-marking, serves the following purposes: (1) Specifying a set of object surfaces to be viewed; (2) Defining a local surface normal -- a standard axis-of-view -- (which can be estimated from the shape of a marker in the image plane); and (3) Conveying *local* 3D orientation and 3D position of a surface of an object, which can be subsequently used for 3D-location estimation of the object with respect to a reference frame.

Based on the above scheme, the major steps for the identification and 3D-location estimation of a pre-marked object can be listed as follows: (a) *Marker detection*, (b) *Surface-normal estimation* (*local*-orientation estimation), (c) *Marker's 3D-position estimation*, (d) *Standard-view acquisition*, (e) *2D-standard-view matching*, (f) *Additional standard-view acquisition* (when several candidates exist in Step (e)), (g) *Object's 3D-orientation estimation*, and (h) *Object's 3D-position estimation*.

2. Off-Line and On-Line Issues [2,3]

In the context of *off-line* planning aspects of the proposed system, several important problems have been addressed: a new boundary-based 2D-shape-representation and identification scheme for both off-line modeling and on-line recognition of objects [4], the optimal marker arrangement on a set of objects [5], and the optimal camera placement in the scene [6].

In the context of *on-line* issues and system implementation, the following aspects of the new technique have been addressed: a sequential distortion-compensation procedure, marker boundary detection to a sub-pixel accuracy, elliptical parameter estimation [7], and 3D-location estimation of circular markers [8].

For a complete presentation of each of the above issues and the proposed solution method and experimental results, please refer to the corresponding references indicated above.

3. An Experimental Prototype of the Active-Vision System [3]

In an attempt to verify the validity and performance of the presented active object recognition technique, a prototype of the system was developed. The prototype is able to recognize the identity of manufactured objects which appear randomly oriented in the field of view of a camera, provided that the standard views of all objects are available and stored in a standard-view database.

In this particular implementation, the functions of the active object recognition are distributed between a loosely-coupled vision subsystem and robot-control subsystem. The system is an integration of the following subsystems:

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- *Imaging subsystem:* This consists of a Hitachi CCD camera, a plug-in PIP Matrox digitizer board with 640x480 resolution, and a means to control the condition of the work-area illumination. The visual information is being acquired on two video channels: from the composite video output of the camera, and a separate channel dedicated for filtering out color markers, attached to the RGB output of the camera. The focal length and aperture size of the camera are fixed.

- *Recognition subsystem:* This is implemented on an IBM-compatible PC 486 computer and consists of visual-information-processing routines performing the functions of the "shape-recognizer" module and part of the functions of the "standard-view locator" module. It has access to a local database of standard views. The database contains the feature information of the standard views of a set of objects already optimally pre-marked.

- *Robotic subsystem:* This consists of an S-100 GMF robot, a KAREL robot controller, and KAREL operating software. The command responder is written in the KAREL programming language, and performs some of the functions of standard view locator related to controlling the movement of the robot. It accepts messages sent by the PC-resident part of the standard-view-locator module and responds to them by issuing the corresponding commands for moving the robot. The KAREL controller performs simultaneous robot axis control in response to 'robot-move' command issued by the command responder.

- *Communication interface:* This is to provide exchange of commands and data between the recognition subsystem and the robot controller. It is implemented on a 9600-bps RS-232C serial communication line, and according to the information-exchange protocol specified by the GMF.

4. Experimental Results [3]

The described prototype of an active-vision system was successfully implemented for recognition of a set of pre-marked objects. The objective of the experiments carried out was to verify the capability of the system to recognize the identity of randomly-oriented objects by using mobile-camera, provided the standard views of the objects are stored in a database. To this end, each object was randomly placed in the field of view of the camera. When started, the system locates a standard view, moves and aligns the camera's optical axis, and acquires the corresponding standard view. The measure of dissimilarity between the acquired standard view and each standard view from the database was recorded. These results confirm that, due to the fact that the standard views are selected so as to maximize their distinctiveness, the recognition process yields reliable shape identification by using a minimum-distance rule. As a consequence, it can be concluded that the processes of standard-viewing-axis locating and camera positioning have been accurately performed.

5. Conclusion

In this paper, the 'shape from contour' paradigm is presented in the framework of active-vision sensing of pre-marked objects. The recognition process is performed by locating, acquiring and matching pre-marked standard views of the objects. This involves detection of the contour of a marker, estimation of the parameters of its shape and inferring the 3D position and orientation of a pre-marked surface in order to align the optical axis of marker with a standard-viewing axis. When a standard view is acquired, the identity of the sensed object is recognized by extracting the contour of the silhouette of the standard view, converting it to an angle-of-sight signature [4] and eventually, matching the signature against a database of standard views. An experimental prototype of an active object-recognition system is presented, consisting of loosely-coupled microprocessor, robot controller and a robot with a camera mounted on robot's wrist. Some results of applying the system to identity recognition of a set of pre-marked objects have been obtained. The results show that a judicious combination of the two basic ideas, namely object preconditioning and active-visual processing, can potentially lead to a more effective and efficient recognition methodology in an industrial environment.

References

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