WORKPIECE ORIENTATION CORRECTION WITH A ROBOT ARM USING VISUAL INFORMATION

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If robots had the capability of supplying machines with workpieces which are not preoriented, there would be a substantial increase in the number of robots used in industry. A significant contribution to this development would be a method which yields a trajectory whereby such a robot held workpiece can be transported from its receptacle to a machine fixture without a collision. An algorithm is described to find such a trajectory. This algorithm employs refinement of an initial estimate of the position and orientation of a robot held workpiece. The refinement procedure uses visual information. With the refined estimate of the hand-to-workpiece transformation, the workpiece can be moved through a safe trajectory, which was established during a prior instruction phase.

The algorithm is based on linear perturbation theory. This means that the change in a particular visual feature on the workpiece can be approximately expressed as a linear function of the perturbations in workpiece position and orientation (pose) relative to a nominal workpiece p£se. Thus [Birk, et ah, 1976], Af - P(Δp) where Δf = change in visual feature values, Ap" = perturbations in workpiece pose, and P = Jacobian matrix.

During the instruction phase of the algorithm when safe workpiece trajectories are defined, the Jacobian matrix for each nominal pose is determined. First, the nominal pose is assumed by the robot held workpiece as it is presented to two TV cameras. The robot arm joint values, feature values, and nominal pose are recorded for future use. Useful visual features include the centroid, the area and the eigenvectors of the binary workpiece image. The workpiece coordinate system is then subjected to a sequence of known perturbations, which may be accomplished by incrementing robot arm joints. For each movement, the corresponding changes in feature values are measured. This permits the Jacobian matrix for that nominal pose to be determined. This procedure is repeated for each specific nominal pose along the trajectory.

The execution phase algorithm is used to refine the estimate of the hand-to-workpiece transformation (hT_w). After a workpiece has been acquired from a receptacle, hT_w is assumed to be known approximately. To verify this, the differences in image feature values from those extracted during instruction are computed. If these differences are within the bounds of the linear region which were found during instruction, the refinement algorithm can be applied.

The perturbations inworkpiece pose can be calculated from Δp" = P+(Af), where P+ = (pseudo) inverse of P. Ap defines a correction transformation matrix, T_c, and therefore can be used to correct the hand-to-workpiece transformation $(hT_w)_c$ = $(hT_W)T_C$-1. To ensure smooth convergence, a new hand-to-workpiece transformation can be obtained by $(^{hT}$w>new * «$(^{hT}$w>c + (l-a)(^hT_w) where 0 * a * 1. If the robot arm joint values were adjusted to reflect this updated estimate of ^nT_w, then the workpiece pose should be closer to that specified during instruction.

After moving the workpiece to a new pose based on $(^bT_w)_{new}$, visual information is again extracted. The correction procedure is repeated, testing for convergence, until the deviations which are used to update the hand-to-workpiece transformation have been reduced to all fall within a tolerance zone.

To servo the workpiece through a safe trajectory which was established during instruction, the deviation of $(^hT_w)_{new}$ from ^hJT_w, the hand-to-workpiece transformation for the j^{tn} legal way in which the workpiece was held during instruction, is found. If this deviation is small, it is assumed that the arm structures will not collide with the workstation. Hence, the following equation can be used.

$$(°Thek> - <°T_hjk> (^{hj}T_w) ((^new)"^1$$

where ^T^g^ is the robot base-to-hand transformation for the k^{th} trajectory point during execution. The robot arm joint values may be obtained from 0Thek. The arm joint solution procedure is specific for different kinematic configurations.

The selection of visual features and procedures to increase the rate of convergence of the estimate of hT_w are issues still to be resolved. The status of experimental results will be reported at the conference.

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Reference

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