3D Pose Registration of Antenna Board Based on Genetic Algorithm for AR Application

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Abstract. In view of the requirement of high geometric consistency and robustness of the Augmented Reality technology in the field of industrial auxiliary assembly applications, a theoretical model is proposed which can detection and tracking target pose and position in short period time by using the point features on the surface of base station antenna. Based on the Genetic Algorithm, the PnP matching problem can be transformed into ge evolution in the feature space. Comparing with the Hough transform method, the experimental result shows that the antenna pose detection method proposed in this paper can effectively adapt to the actual working scenario.

Keywords. Augmented Reality; pose monitoring; position solving; genetic algorithm.

1. Introduction

Augmented reality (AR) is a kind of technology to enhance the real scene information by using computer and related display equipment to overlay the virtual information into the user’s vision [1]. Compared with the text information overlay in the early stage, current research of AR focus on how to “place” the 3D virtual model in the real world accurately and stably [2]. In order to achieve this goal, the position and orientation information of the camera have to be obtained in real time [3], and the pose and position of the target object should be perceived correspondingly, in order to calculate the spatial state of the virtual model in the real scene [4], so as to show the two-dimensional projection without deviation, and then add the three-dimensional virtual object to the real environment seamlessly.

At present, the detection of target’s pose is a research hotspot in computer vision [5, 6]. On the hardware system, there are two main methods of target reconstruction and matching based on binocular vision combined with depth information, and feature matching based on monocular camera and image edge, texture or feature points [7]. Among them, the method of binocular vision can effectively recover the depth information, but with a large calculation cost [8]. So that it is much more suitable for the application of target model construction, and difficult to meet the real-time performance of the target workpiece position and attitude monitoring for the AR application.

In view of the mismatch between these laboratory methods and application requirements, a plate target 3D position and orientation tracking algorithm based on the speckle feature and genetic algorithm is proposed in this paper, which can overcome the unstable light, the natural characteristics are easy to be blocked, and the metal surface materials under the actual production environment.
2. Production Environment and Monitoring Objects

The application object of the algorithm studied in this paper is the AR auxiliary system of large base station antenna board routing process. For the practical application needs, artificial markers are not allowed to appear in the actual working scenes such as antenna board and worktable. At the same time, light intensity, angle, plate surface state (parts gradually increase) and other factors are not stable. Combined with cost control and other requirements, the antenna board AR wiring auxiliary system adopts the architecture shown in figure 1. The overhead camera is the main information acquisition equipment, which uses the camera equipment of global monitoring to obtain the position and attitude transformation information of the target antenna board, and controls the virtual model in the AR scene to complete the corresponding movement.

![Figure 1. AR wiring auxiliary system work scenario and architecture.](image)

3. Genetic Algorithm for 3D Plate Target Pose and Position Monitoring Problem

3.1. Monocular Vision Pose Monitoring Model

Monocular vision monitoring is difficult to obtain depth information, but it has comprehensive advantages such as low cost, fast calculation speed and moderate accuracy. The monocular perspective imaging model is shown in figure 2, which defines the world coordinate system $O-x_0y_0z_0$ and the camera coordinate $C-x_cy_cz_c$.

![Figure 2. Monocular vision detection model.](image)

$$
\begin{bmatrix}
x_j \\
y_j \\
1
\end{bmatrix} = K \begin{bmatrix}
R_0 & T_0 \\
0 & 1
\end{bmatrix} \begin{bmatrix}
x_j \\
y_j \\
1
\end{bmatrix}
$$
To solving the pose vector $R_0$ and position vector $T_0$, at least 4 pairs of homonym points should be found to substituted in equation (1) [9].

### 3.2. Genetic Algorithm Based Homonyms Matching

Since the metal surface of the antenna board, and the surface parts and wires are also changing in actual assembly. The black speckles distributed irregularly on the surface of the antenna board are used as the sample features in this study, shown as figure 3.

![Figure 3. Sample scene and control points.](image)

After the sample is selected without occlusion, the feature point set extracted from any frame image can be used to match with the sample point set for feature matching, and then the coordinate transformation of the same point can be used to solve the position and attitude change of the target under the world coordinate system. In order to quickly find the corresponding relationship between two sets of plane point sets, the Genetic Algorithm is applied in homonym points matching:

1. System initialization. Firstly, the virtual model is matched with the real workpiece space position manually, and the sample points are extracted from the initial frame, which denoted as $S_n$;
2. The feature center of the speckle in the current frame is extracted and recorded as the target point set, which denoted as $T_m$;
3. GA initialization. The length of a single gene is set as $\text{Min}(m,n)$, and every gene in the population, which denoted as $X_i$, is composed from a random extraction of $T_m$;
4. Fittest for evolution. To evaluate the fitness of every gene, the sum of the Euclidean distance of the first 50% of gene nodes are used as equation (2):

$$F_i = \text{Fit}(X_i, S_n) = \frac{1}{\text{Min}(n, m)} \sum_{i=1}^{j} \sqrt{\Delta R_{\alpha}^2 + \Delta C_{\alpha}^2}$$

where $\Delta R_{\alpha}$ and $\Delta C_{\alpha}$ are the difference of the row-coordinates and column-coordinates of the $\alpha$th node pair of $S_n$ and $X_i$ respectively. In order to reduce the possible mismatches and the interference of wrong feature points, the last 50% of gene nodes are not calculated regard as a slack space.
5. Crossover and mutation. After the fitness of every gene is computed, a standard crossover and mutation can be done [10], while the mutation gene will be change to a random node remained in $T_m$;
6. Termination condition. The GA iteration will be terminated while the generation number reaches 10000 or the best fitness of a gene reach 0.05; Otherwise return to step (5) and run new generation.
7. After finding the matching relationship between the target point set and the sample point set, the homographic matrix can be calculated in equation (1) to update the display location of the virtual model.

### 4. Result and Conclusion

Figure 4 shows the matching effect of GA-speckle feature matching algorithm under normal operation and various influences.
Figure 4. Speckle feature matching result.

From figure 4 it is can be seen that, for various situations that may be encountered in actual production, the pose and position tracking methods based on GA effectively obtain the translation and rotation of the antenna board target in the current frame. And figure 5 shows the superposition of virtual guide panel and virtual harness in the perspective of AR display device.

Figure 5. Superposition result of virtual and real in the perspective of augmented reality.

Experiment result shows that the geometric consistency of virtual model and real object can meet the work requirements through real-time detection of the change of antenna board position and posture.

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