LINEAR AND ANGULAR MEASUREMENTS

METHOD OF DETERMINING THE ANGULAR POSITION OF PARTS OF AN OBJECT RELATIVE TO ITS CENTER

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A method is considered for determining the angular position of parts of an object relative to its center which makes it possible to implement a system operating on a real time scale.

In automated systems with technical inspection the problem arises of determining the angular position of parts of an object relative to a fixed point on the same object. Such problems must be solved in order to ensure the correct mutual positions of parts during assembly, welding, automatic selection of objects in microelectronics, and for monitoring masks and printed circuit boards.

In a number of studies the calculation of the angular position of objects is based on determining the position of the principal axes of inertia relative to the coordinate axes. In order to determine the positions of the principal axes of inertia one must first calculate the area of a binary coded image, the coordinates of the center of gravity, and the linear, quadratic, and product moments. Such a method was described in [1]. Its disadvantage is its low sensitivity to changes in the shape of an object and the impossibility of determining the orientation of parts of the object relative to a given point on it. In addition, because of the large volume of calculations, the productivity of a device employing this method turns out to be low.

The method and apparatus having the highest productivity and the highest accuracy are those described in [3]. During the time taken to calculate one image frame they enable information to be obtained on the areas and coordinates of the centers of gravity of all objects in the field of view and also the areas and coordinates of the centers of gravity of all markers in each object.

This information, fed into a computer, can be used both to select objects having specified properties and to determine the angular positions of each of a set of objects relative to the center of gravity of the whole system or relative to the center of gravity of an object whose properties are defined by a system of informative indicators.

In certain cases it becomes necessary to determine the orientation of parts of an object relative to a fixed point, for example, relative to centers of gravity of the object or of markers. Here it is not the whole field of the image which is considered but only its monitored region.

The method and apparatus presented in [2] can be used to analyze very simple images in the form of a circle, when one marker is present. The essence of the method is to calculate the area and linear moments of the image and use these to determine the coordinates of the center of gravity. A circular or annular search region is then formed around the center of gravity. After this the significant optical information in the search area is separated from the whole image of the object. The angle of rotation of the image of the object is then determined either by calculating the position of the principal axes of inertia or by calculating from the difference between the coordinates of the center of gravity of the whole object and of the image of a marker in the search area. This method which is aimed solely at determining the angular position of a marker relative to the center of gravity of an object is very sensitive to the presence of fragments of the image both in the object itself and in the close-lying objects, and this reduces its accuracy and practical value.

We propose overcoming this disadvantage by using a method and creating an apparatus which enable a two-scale image of an object to be processed during the time taken to calculate one frame and simultaneously to eliminate the influence exerted by fragments of neighboring interfering images on the accuracy of determining the angular position.

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Let us give the initial image in the form of readings $a_{ij}$, where $i$ is the element number in a line and $j$ is the line number.

In the monitored part of the object let us form some analysis zones, for example zones $F^{(1)}_{ij}$ to $F^{(5)}_{ij}$, where $F_{ij}$ assumes the value "1" in the analysis zone and the value "0" outside this zone. Each of the zones includes a fragment of the image, the shape of a zone being of no special importance. Let us take the simplest shape, a disk, a circle, and an annulus having a common center in the vicinity of the center of gravity of the marker relative to which the angular positions of the individual parts of the image of the sought object are to be determined.

For the purposes of simplifying the technical implementation of the apparatus we shall take the zone $F^{(1)}_{ij}$ bounding the significant region of the whole calculated image and the zone $F^{(2)}_{ij}$ bounding the region of the marker or aperture in the