Computer synchronized 3D-triangulation-sensor for robot vision

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ABSTRACT

The development and design of a computer synchronized 3D-triangulation sensor is presented. By combining the high resolution of both an electrooptical position detector and a galvanometer-deflector, located in the observation beam, a nearly perfect synchronisation of illumination and observation beam for arbitrary contours could be achieved. High resolution for large measurement ranges was obtained.

1. INTRODUCTION

Triangulation based 3D-sensors are appropriate tools for inspection and measurement in industrial environments. Especially synchronized single-spot scanner fulfil the high requirements upon range, resolution, robustness[1,2].

However, existing synchronized scanners, in which lateral and longitudinal measurement is partly decoupled, suffer from their fixed geometry, which determines the performance of the systems and prevent an adaption of the scanner's performance to the given task.

To overcome this disadvantage we used two independent deflecting devices, whose angles are synchronized by a computer according to an eligible reference shape.

By measuring relative to the reference shape, which is now independent of the sensor geometry, we are able to determine the shape of extended objects with the accuracy to be obtained by an one-dimensional triangulation-sensor.

2. PRINCIPLE OF COMPUTER SYNCHRONIZED TRIANGULATION

Synchronized triangulation-sensors are best suited for the measurement of objects with large depth. High performance in accurracy and large field of view together with reduced shadow effects can be achieved[3].

Up to now the synchronisation of the observation beam with the illumination beam of the scanner is realized in a optomechanical way, typically by leading the observation beam across a mirror, which is rigidly connected to the scanning mirror of the illumination beam. Due to this rigid coupling of the mirrors there exists one fixed shape, which is imaged onto the same position on the detector. For the optomechanically synchronized scanner of Rioux et al [4] this reference shape is a sphere with a radius given by the scanning geometry. Häusler et al [5] proposed to control the deflectors of the two beams in such a way, that any arbitrary reference shape could be generated. However the proposed telecentric

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setup requires a large lens for large lateral measurement fields, which limits the usage of the system in robot vision.

As a measure of the quality of synchronisation we used the angle Θ between the observation beam considered as a reference (measurement spot in the center of the measurement volume $z_p = x_p = y_p = 0$) and the actual observation beam. In the autosynchronized scanner of reference 4, Θ is zero for all imaged points, laying on the reference sphere. For all other points laying not on this reference contour, the angle Θ contains the typical information of the triangulation, namely the longitudinal z-component, and an additional contribution from the lateral position (x,y), as shown in figure 1 b.

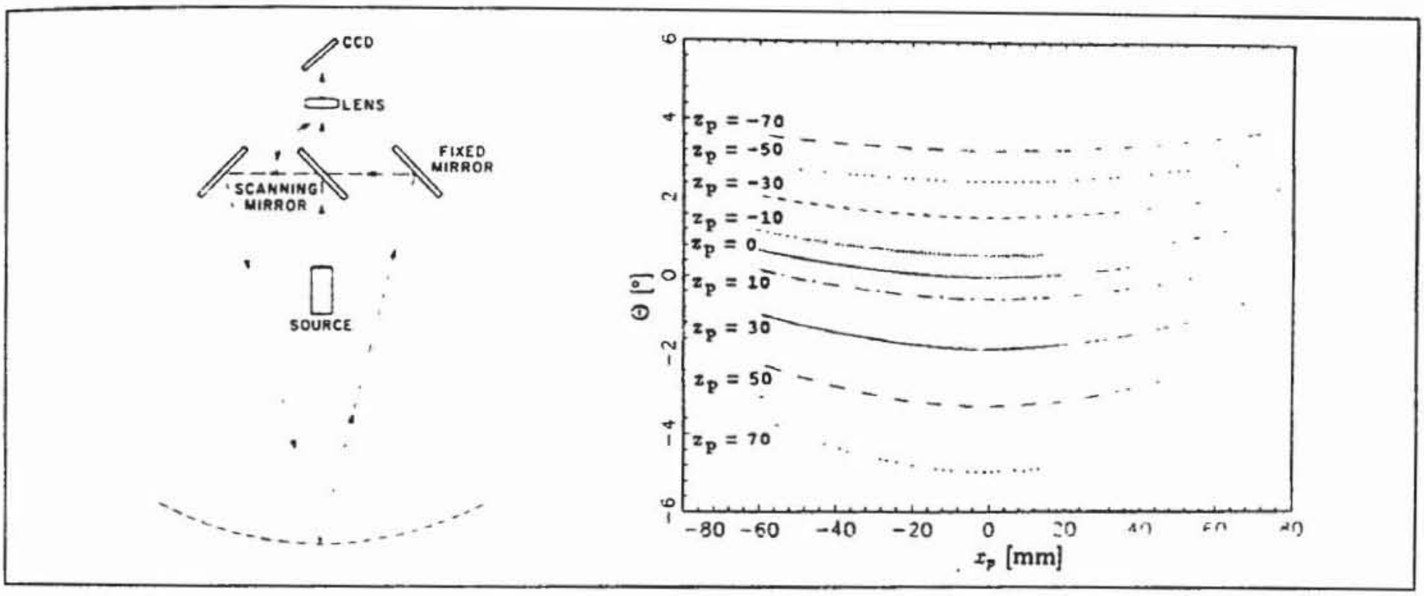

Figure 1: **a)** Schematic of the optomechanically synchronized scanner in reference 4
b) Shift of the observation beam as a function of the lateral coordinate x_p with the longitudinal coordinate z_p as parameter

To overcome this lack in synchronisation we decided to realize a free, computer controlled synchronisation principle (figure 2). Here a galvanometer scanner driven mirror is located in the observation beam in front of the imaging lens. This mirror deflects the observation beam dependent on the angle α so, that $\Theta = 0$ for all points which lie on the selected reference contour. Any other points, yields a shift of the imaging spot according to their distance from the reference contour. Figure 2 b shows the good synchronisation-quality for the reference contour of a straight line. Unfortunately we could not achieve a perfect decoupling of the coordinates for the whole measurement volume.
Nevertheless nearly the whole length of the detector is used for the pickup of the distance information, while the lateral position is determined seperately by the direction of the illuminating beam. Therefore a maximum range/resolution ratio of a one-dimensional triangulation scanner could be achieved. Computer synchronisation could be considered as a combination of the detector resolution and the resolution of the synchronisation deflector. The range/resolution ratio of a galvanometer scanner is 10 times higher (approx. 3×10^5) than that of the detector (approx. 4×10^4) and can therefore be used as a reference against which the detector measures.

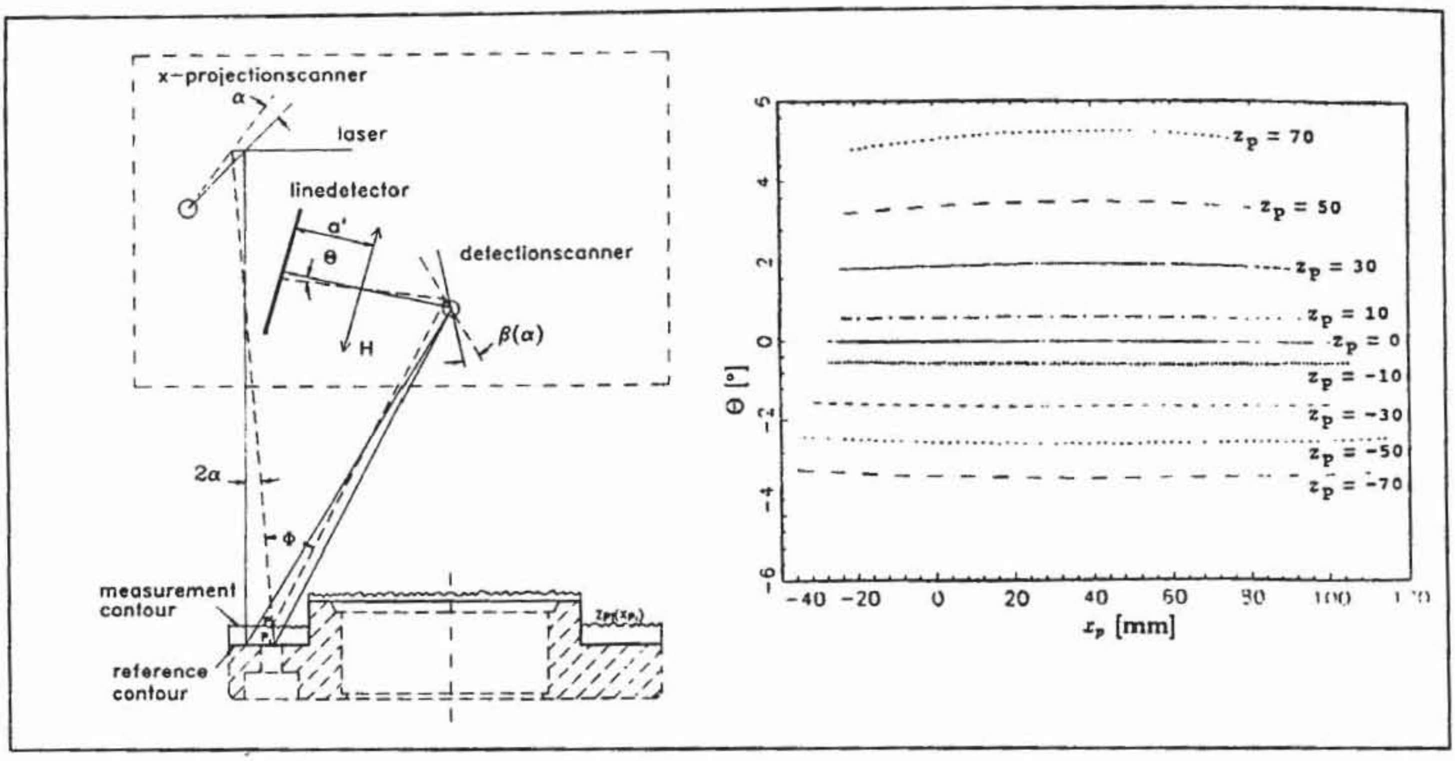

Figure 2: **a)** Principle of the computer synchronized triangulation
b) Shift of the observation beam as a function of the lateral coordinate x_p with the longitudinal coordinate z_p as parameter

The main advantage of the computer synchronisation however is the possibility to generate an arbitrary reference contour by altering the dependence between the detection and the projection scanner. This dependence can be found by means of a teach-in process, where the shape of a masterpiece is measured, in order to act as a reference for the measurements of the following working parts. It is also desirable to get the reference contour from construction-data by an analytical expression for instance.

3. 3D-TRIANGULATION SYSTEM

The extension the 2D-sensor-system explained previously to a 3D-system is made by a second projection scanner S_y, which deflects the illuminating beam in y-direction (figure 3).

The spot on the sample is imaged by an anamorphotic optics onto a linear photo-diode array with a large aperture to collect most of the light. Figure 4 shows a sectional view of the y-z-plane of the optics for an observation beam in the center and at maximum field angle (maximum y-coordinate). The spot imaged on the detector has an elliptical shape with the long axis perpendicular to the axis of the linear-array. As the y-coordinate of the measurement spot and therefore the field angle increases, the ellipse of the imaged spot on the detector is shifted slightly out of its center position.

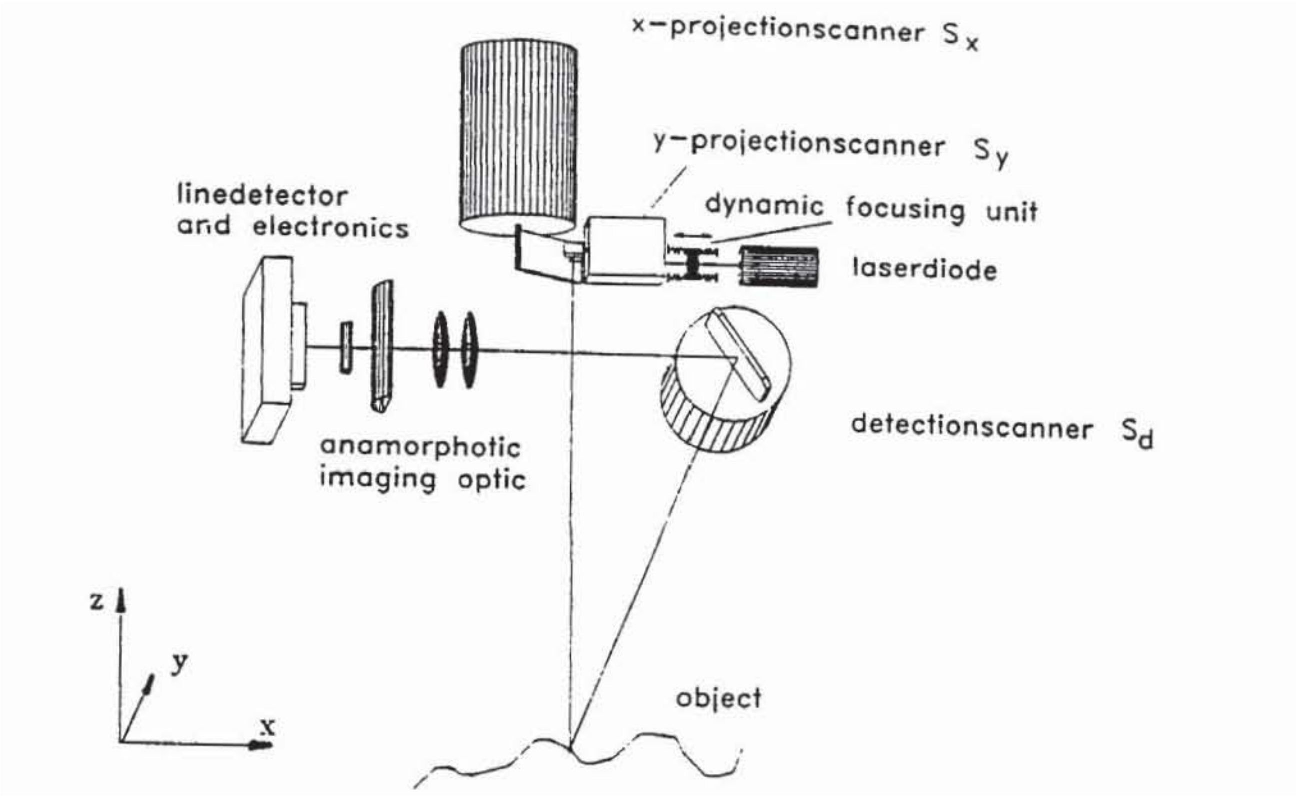

Figure 3: Schematic presentation of the realized 3D-triangulation scanner

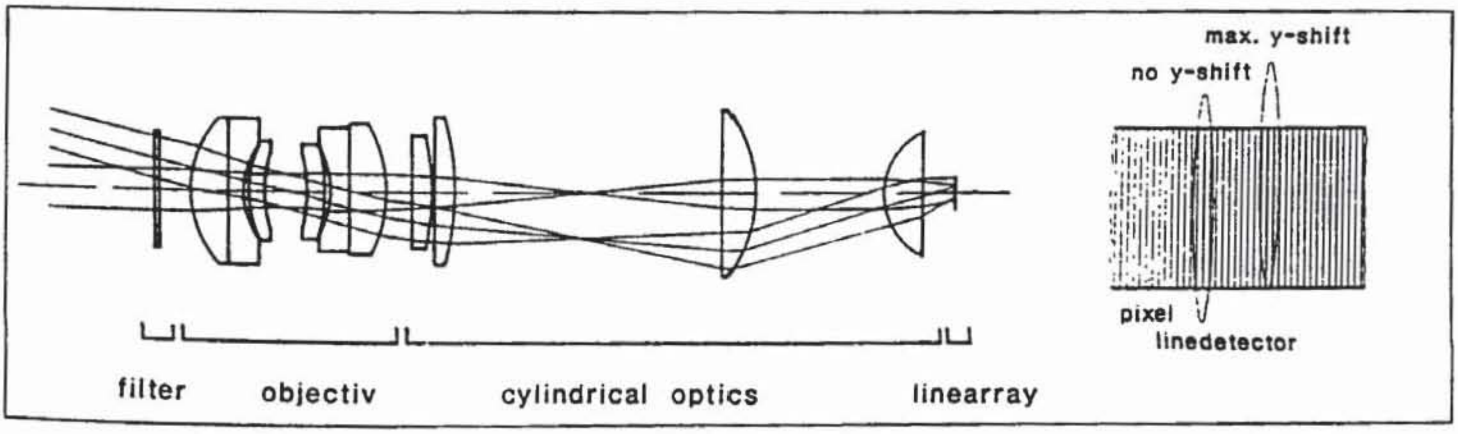

Figure 4: Anamorphotic detection optics

The heart of the signal processing (figure 5) is the random-accessible photo-diode-array, which allows a defined read-out of the illuminated detector region. The whole system, incorporating an illumination control of laser power and exposure time and dynamic focusing device of the illuminating beam is controlled by a PC/AT which could be connected to a host computer.

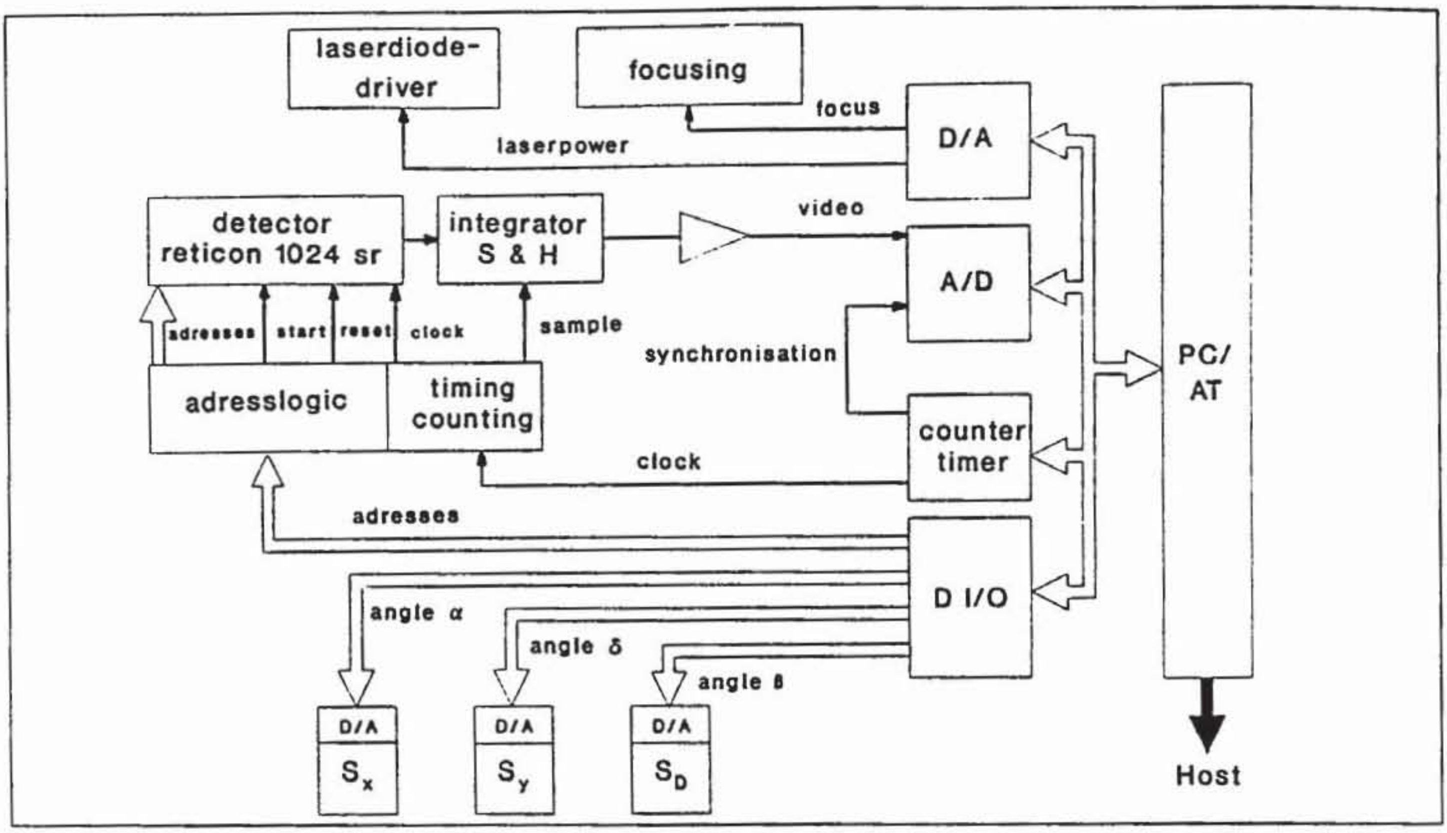

Figure 5: Schematic of the signal processing unit and control

4. INFLUENCE OF SCANNER ERRORS

It is obvious, that scanner errors may seriously affect the accuracy of the computer synchronized sensor. Especially high repeatability of the scanners is required. Fortunately there are today scanners available, with a repeatability error of less than 5 µrad, so that the shift of the imaged spot, induced by scanner errors, is below the minimum resolvable distance on the detector.

5. APPLICATION OF THE SYSTEM IN THE AUTOMATED WORM-GEAR ASSEMBLY

A first application of the system was in the automated assembly of worm-gears. To adjust the gear-wheel to the worm properly, the dimensions of the gearbox and the components need to be measured with high accuracy Therefore the sensorhead was handled by a roboter and the measured dimensions were calculated by the PC and delivered to the host computer for further processing.
The technical data of this first setup are:

- measurement volume 150 mm (x), 130 mm (y), 120 mm (z, relative to reference contour)
- measurement uncertainty 40 µm longitudinal on technical surfaces
- spot diameter: max. 130 µm
- mean distance: 220 mm

- measurement time: max. 40 ms per point
- size of sensorhead: 230 mm x 230 mm x 230 mm
- weight of sensorhead: 6.5 kg

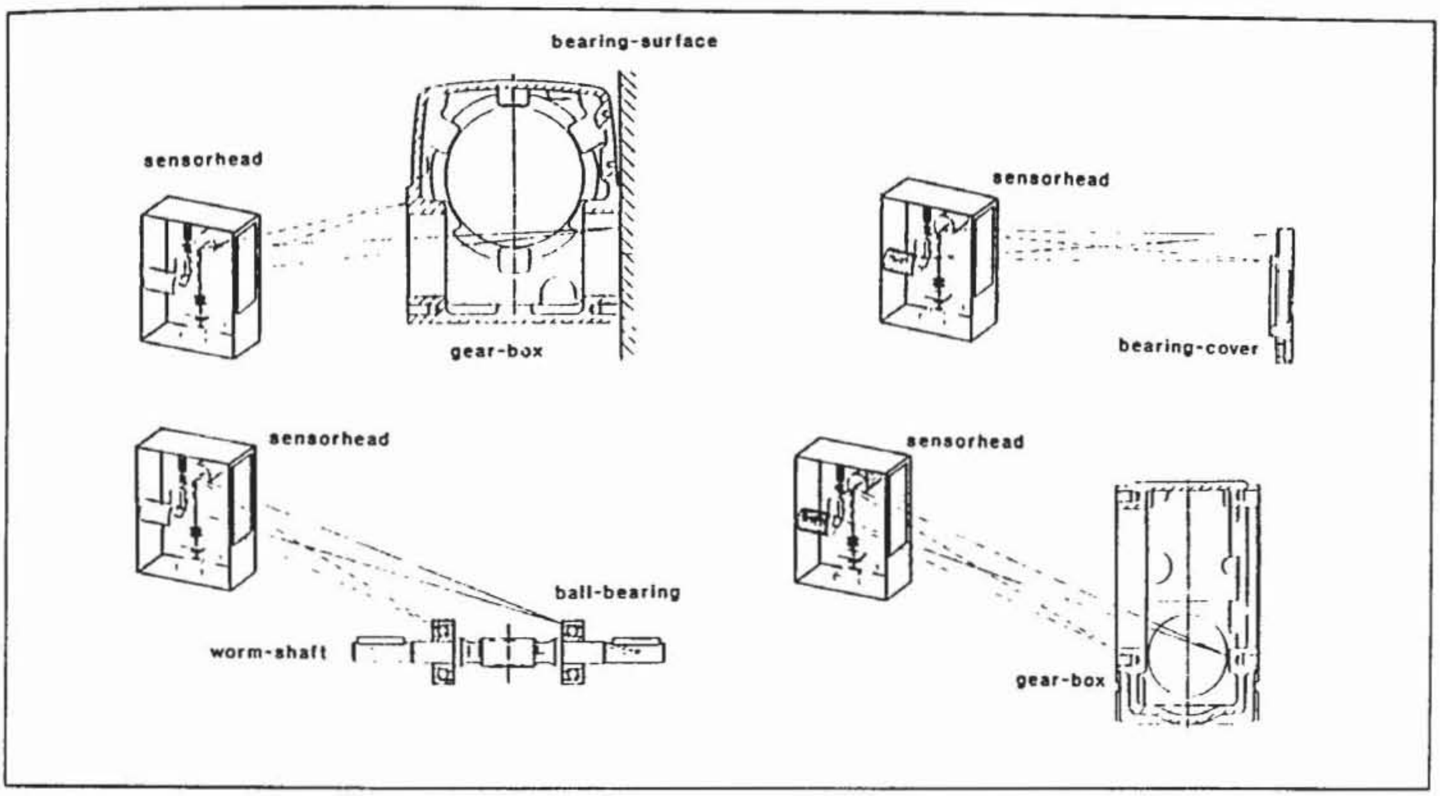

Figure 6: Application of the sensor system in the automated worm-gear assembly. Measurement of the components for the mounting procedure

6. CONCLUSION

The principles and a realisation of a computer synchronized 3D-triangulation system were presented. Computer synchronized triangulation enables the 3D-measurement of extended objects with the accuracy of a 1D-sensor by measuring against an arbitrary reference contour.
A first application of the sensor in the automated assembly was shown.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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