Augmented Reality as an Interactive Tool for Microscopic Imaging, Measurement and Model Based Verification of Simulated Parts

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ABSTRACT

Presently microsystems are gaining in interest. Microsystems are small, independent modules, incorporating various functions, such as electronic, micro mechanical, data processing, optical, chemical, medical and biological functions. Though improving the manufacturing technologies, the measuring of the small structures to insure the quality of the process is a key information for the successful development. So far strong microscopes are needed to measure the micro structures. The key idea behind our project is to use the intuitiveness and the 3D visualization of VR environments coupled with a 3D vision system to perform measurements and verification of real micro structures at a high 3D accuracy. The direct feedback between real microscope and virtual reality by 3D vision as internal loop enables a realistic visualization of measured and analyzed micro structure data. Future developments will include dynamic 3D measurements for microactuator characterization, automatic modeling and 3D visualization of dynamic behaviors like force sensing in microrobotics.

Keywords: augmented reality, geometric point matching, micro part verification, micro measurement, 3D microscopy

INTRODUCTION

Many engineering fields have a requirement to exchange data concerning their products in computer readable form. This greatly improves communication and makes engineering data generated by one program readable by another. The automation provided by the computer is thus greatly increased and helps to reduce engineering and development costs thereby improving the effectiveness of an enterprise. Archiving is likewise facilitated by adequate 3D data exchange and storage methods.

In this paper, following our approach described in [1], we focus on data exchange and verification between 3D measurement and 3D visualization systems (Virtual Reality, Augmented Reality).

New developments in fast 3D measurement under a 2D microscope will be discussed. The use of this data extraction in the Virtual Reality (VR) environment to visualize the CAD designed components and simulation models is described. 3D measurement for very small structures exists [5] - [13], using a light stereo microscope, a light microscope or a Laser Scanning Microscope (LSM). [3] and [4] have developed a 2D and 3D vision systems to control the quality LIGA-micro structures.

Modeling of the Information

So far to measure the micro structures strong microscopes are needed. The use of highly magnifying computerized microscopes is expensive. To insure high quality measurements and to robustly verify the geometry of the manufactured microparts, our proposed system called Virtual Reality Microscopic Environment (VRME) is divided into four blocks namely modeling, process, measuring and correlation as shown in Figure 1.

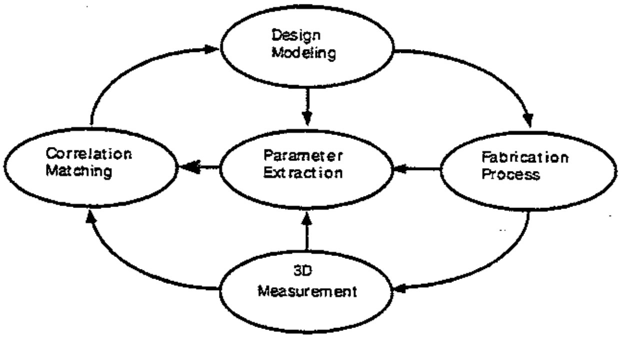

Figure 1. The information flow (data exchange) between the 3D measurement station and the Virtual Reality Microscopic Environment.

The user-interface is implemented on a SGI workstation and allows to prepare the models and the measurement tasks. CAD as a geometric model is mostly used for visualization of geometric object data. This data is used to generate the 2D mask for fabrication of microstructures in batch where the first errors in the chain appear. The 3D fabrication process is a further error source in the manufacturing process.

Figure 2 represent the data set corresponding to the key elements in information modeling.

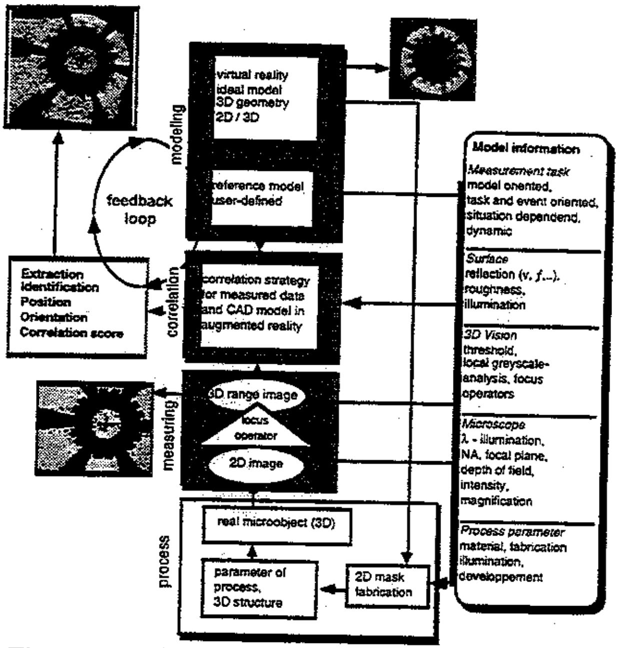

Figure 2. The information flow (data exchange) between the 3D measurement station and the Virtual Reality Microscopic Environment.

The sensed data (measuring) is represented by a cloud of points. In order to inspect this data (correlation) the exact coordinate transformation between the 3D scanner and the object has to be known. Traditionally, this needs a lengthy registration and fixturing process of the sample to be inspected. Several authors proposed registration methods for data of free-form objects and CAD models [17] [19]. Since these methods directly work on the sensed data points, no segmentation is needed and any object shape can be processed. Furthermore, the matching results can be easily visualized by attributing a color corresponding to the matching error to every datapoint [18]. In this work, the iterative matching algorithm of [19] is extended to include surface orientation information and triangulated CAD models. The complete system is integrated in a graphic 3D interface. (modeling)

Basically 3D range images are taken during a scan of images under a 2D microscope. The reconstruction of these information has as result all the necessary information for the 3D correlator. The augmented reality based 3D model correlator extracts the position, verificates the models and builds the virtual reality environment. The access to the generated and verified model is direct and intuitive. The mixing of simulated and real images adds a realism to the scene and enables the user to quickly understand the measurements related to the component designed.

So, finally in using the CAD data and correlating the measured data after the manufacturing process relates the necessory information for the designer:

He visualises a FEEDBACK between the Design and real strucutres helping him to evaluate manufacturing processes and adapt his future design.

SYSTEM COMPONENTS

3D computer vision from 2D microscope

The measuring block uses a computerized 2D light microscope combined with a 3D vision system to inspect the scene and to acquire the 3D images of the specimen. Newly developed vision algorithms are used to analyze the micro structures in the scene corresponding to the known a priori model. This vision extracts the position and the 3D shape of the objects and then transmits them as a feedback to the user of the VRME system to update the virtual environment. Measurements are performed using a newly developed high precision 3D computer vision tracking system to characterize the spatial positions of the microparts. A microscope image CCD receives high frequency changes in light intensity from the surface in the focal plane. Using high resolution camera calibration, passive focus operator algorithms and 2D object recognition, the position and shape of the micropart can be extracted in 3D space.

Algorithms for 3D-range image extraction are also discussed in [9], [12] and [13] and are working with the same principle described in Figure 3. [13] has implemented the software using passive contrast analyses following the steps:

1.) Model based initialization of the system of the geometric base information

2.) Mechanical Z - scan of the object using the a-priori knowledge: Several scans having a small step on the upper surface, quickly scanning through the vertical walls and fine scanning on the bottom.

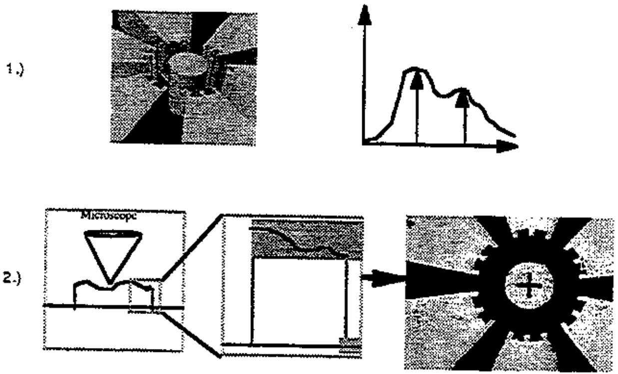

Figure 3. We present a graph to illustrate the basic ideas to extract height information out of a set of 2D images.

Numerous advantages can be withdrawn, the most obvious is the gain in time and accuracy using the geometric model to plan the measurement task.

3D model matching of real and virtual 3D images

Finally the correlation block compares the real measurements with the virtual model. A geometric matching algorithm snaps the roughly vision tracked object model onto its real world counterpart and permits to update the virtual world with the recognized model. The matching works iteratively using a closest point matching algorithm. The real data is augmented by superimposing the virtual object representation and by coloring the measured points according to their fitting error. Some snapshots of the user interface showing real and virtual data are represented in Figure 4. Potential applications for VRME are telemeasurement systems for expensive microscopes, the teleoperation of complex microassembly tasks and world construction for mobile micro robotics.

RESULTS: AUGMENTED REALITY SYSTEM FOR 3D REAL AND VIRTUAL IMAGING

Single 3D image correlation

The augmented reality system uses as input a range image and the CAD model of the sensed object as shown in the following picture. A range image codes the surface geometry by attributing an intensity value to every pixel according to the height of the surface. The triangulation of the data points uses the order of the range image to calculate a triangle mesh of the object surface. Here the object height is colored by varying the color hue from red to blue indicating near and far points.

The operator can manipulate the data and the model in all 6 degrees of freedom using a space mouse. He enters a rough pose estimate of the model whereas the geometric point matching aligns the data and the model precisely. as shown below.

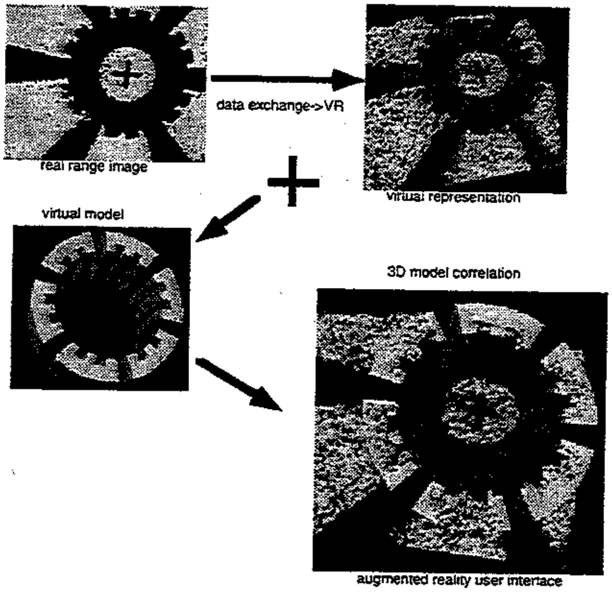

Figure 4. 3D Model correlation between the computer generated (simulated) and the real 3D range image generated using vision algorithms. The shown micromotor has 132 microns in height and 280 microns in diameter [16].

Multiple 3D image correlation and model matching

Several scans performed at different microscope positions can be easily integrated in one range image since the object is placed on a computer controlled table. The following picture shows the composed range image with about a million of pixels.

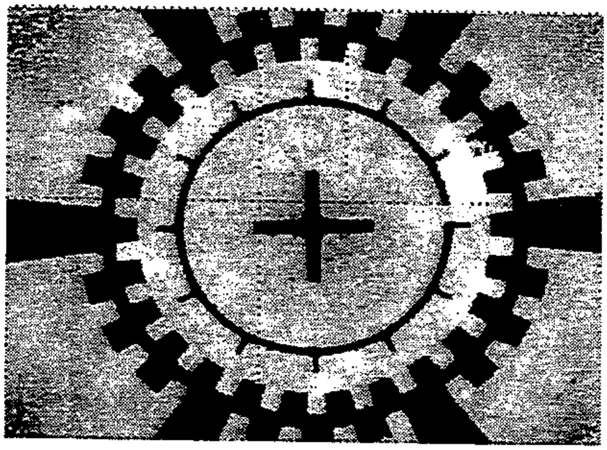

Figure 5: Multiple real 3D range image generated using vision algorithms.

The computation of the geometric matching grows rapidly with increasing number of points. The presented system allows to use a multiscale approach which results in a large gain of computation time. A first matching is performed with a reduced data set and the complete data is only used for the final inspection. The matching results are coded by coloring the data according to the matching error. The color of the points which are inside the matching tolerance ranges from red to blue, where blue represents a perfect match. Points which are outside the tolerance are rendered in grayscale according to their height.

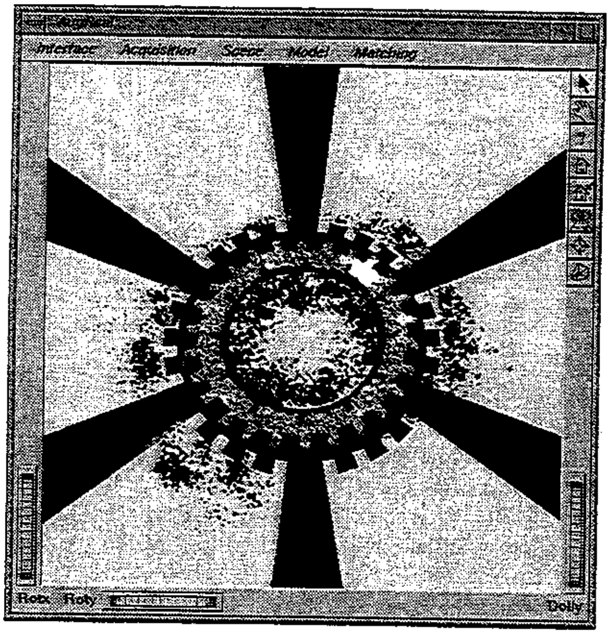

Figure 6: 3D multiple model correlation between the computer generated (simulated) and the real 3D range image generated using vision algorithms. The shown micromotor has 132 microns in height and 280 microns in diameter.[16]

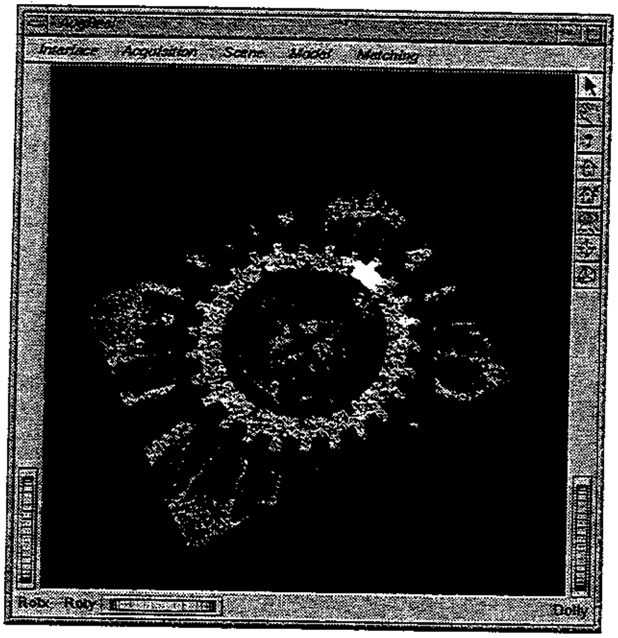

Figure 7. Augmented 3D Reality, model correlation has brought up (in blue) the very well matching zone (within tolerances) and in red color the "mismatching. White indicates no matching.

CONCLUSION

Miniaturized, integrated sensors and actuators called microsystems are a rapidly growing field with great future potential. In order to promote their use further, specialists must make them more accessible to system designers at all stages of development.

The methodology and software tools for the shape modeling and visualization of microsystems presented in this paper are based on the generation of 3D-models describing device geometry using the extraction of 3D range images from a microscope to control , measure and inspect the components. Geometric matching allows an efficient and fast data inspection of any shape. An augmented reality interface presents the results by visualizing the errors directly on the sensed data.

The small dimensions of microsystems make manipulation and assembly of their constitutive components by had or using traditional assembly stations difficult or impossible. Virtual reality environments, specialized vision systems, micro-robots, force feedback and miniaturized end-effectors are required to accurately and rapidly assemble hybrid microsystems. Models of the Characterization of future actuators could be automatically extract and modeled. The use of computer aided design and simulation tools in this field is critical owing to the high prototyping costs. Data exchange between the various systems is advantageous and reduces design and manufacturing costs while speeding up time to market. The use of these tools also helps the designer to rapidly extract production errors and visualize the effect. We firmly believe that the methodology and software tools presented will find application in the field of mechatronics.

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