A new interactive approach in teaching complex multi-sensor measuring technology

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Abstract. This document states benefits, possibilities and importance given by a new interactive approach in teaching complex contents of integrated multi-sensor measuring technology, regarding optical and tactile coordinate measuring technology at the Ilmenau University of Technology.

1. Introduction

In terms of handling problems regarding measurement processes, image processing becomes more and more important. Many students face problems abstracting measurement problems and their solutions caused by lack of practical experience in handling complicated measuring technology. On the other hand understanding dimensions and scales, tolerance zones, measurement errors and measurement deviation, specifically regarding small components, is missing. Modern measuring devices come at a high level of complexity, hence the handling of these devices in most of the trainings and teaching concepts covers only a very limited extent of functionality. The potential benefit of each different method and strategy in measuring mechanic or electronic components is seldomly demonstrated. Especially opportunities and advantages given by combining different methods of measuring devices is not included in the regular curricular. The interactive application of multi-sensor measurement devices opens new perspectives for an integrated approach of solving measurement problems.

For students the complexity of handling the measurement device itself is another obstacle. The interactive part of the training will be conducted on the SPECTRUM 700 coordinate measuring machine (see figure 1a), which commands a tactile and an optical sensor. This enables teaching of the different measurement methods at constant conditions.
2. The Teaching Concept
A given mechanical component (production part, see figure 1b) is used to define several tasks to be measured and specified in several assignments. For tactile measurement tasks different sensors will be used to measure geometrical dimensions and positions. For optical measurement tasks the Viscan sensor will be used, which is also available for the Zeiss coordinate measuring machine SPECTRUM 700 (see figure 1a). The measurement results of both, the tactile

![Image](a) Zeiss SPECTRUM 700  
![Image](b) Bent sheet metal part – design drawing

Figure 1: Coordinate measuring machine and production part to be measured

and the optical measurement method, could be compared, due to the fact that environment variables, e.g. the lighting, could change. Differences in the results based on the measurement methods context could explain advantages and disadvantages of different measurement strategies and method’s. The new multistage approach guides students step by step through problems concerning measurement technology. The interactive teaching concept is based on a three stage model, using the following methodology.

A single practical experience as completion of the theoretical knowledge basis is considered not to be very useful in topics of such complexity as metrology. The learning curve will greatly be improved by a tutoring concept with special attention to identifying and resolving possible mistakes immediately. At the same time the students methodological approach is guided. In order to enable the students to handle the complexity of the matter, the following three stages were developed (see figure 2).

**Stage One**
The target of the first stage is to explain the general handling of the measuring device. This requires interdisciplinary theoretical knowledge acquired in the academic career. The structure and the different types of coordinate measuring machines, different types of scanning probes and sensors, measuring points and the number of measuring points to acquire per element as well as important criteria for evaluating the measurement results are explained using a bent sheet metal part as practical example.

In the next step an inspection plan has to be created by the students, using the operating software (see figure 3). The students familiarize with the specific control options of the
device (control panel, positioning methods, probe change). For capturing the elements of the measurement subject the students can choose between the teach-in mode and the selection of single elements within the CAD model.

The inspection plan in stage one contains measuring the distances between the bent longitudinal edges of the production part (see figure 4a). To do this the measurement subject has to be mounted, then the system has to be informed about the current position of the subject. For this purpose the outer contour will be defined using on the outer surfaces of the measurement subject. Furthermore basic needs like the definition and orientation of the basic coordinate system as well as the selection and usage of a suitable scanning probe will be explained. Next
the necessary features that are to be measured have to be added to the inspection plan. Special attention has to be given to the measuring strategies and the basic conditions – they are critical for the measurement results. The practical aspects will be strengthened not only by the operating software itself, but also by the fact that further pc workstations with the same operating software for simulation purposes are available.

After successful creation of the inspection plan students can proceed to the coordinate measuring machine. Possible errors with the positioning path, the selection process of the right scanning probe, an appropriate positioning speed as well as a sufficient number of measurement points become apparent immediately, which encourages the process of understanding. The first stage is completed with a successfully processed inspection plan including the evaluation of the measurement results afterwards.

Stage Two
Stage two contains the determination of form, positional tolerances and relations. Further instructions are necessary to understand roundness, flatness, parallelism, cylindricity, symmetry and perpendicularity (see figure 4b). In contrast to the theoretical instructions the practical experience with dimensional and geometrical tolerances motivates the students. Furthermore they realize the influence of changes in temperature between two comparative measurements.

Stage Three
Stage three of the teaching concept deals with the complex interactions of different sensors for a more complex inspection plan. To measure the boreholes in the production part the scanner probe has to be changed. The students are facing the decision for the right scanning probe again. Scanning probes available are tactile sensors with different sizes and parameters as well as the optical probe system ViScan (see figure 5a). At this stage particular attention will be devoted to the optical probe system. In its adjustments the optical system is more difficult to handle than the tactile one due to additional parameters like lighting, the correctly configured focus or setting criteria for edge detection. The relationship between calibration and adjustment of the
sensors are illustrated. First of all the tactile and the optical sensor are re-measured, then an inspection plan for multisensor technology will be created. This illustrates specific advantages and disadvantages of probe systems (see figure 5b).

The importance of the right setting of criteria like the direction for edge detection and correct focus settings will lead to their influences on the measurement results. Realizing the parameter’s influence on the measurement result is the key element at this stage. The third stage is completed with the successfully processed inspection plan using multisensor technology. An additional task for the students is to find a time efficient measurement strategy. For this purpose the measurement points have to be brought in an order that minimizes the distance of the sensor during the measurement. Also the time of the sensor changes have have to be chosen time efficiently.

Figure 5: Multisensor technology and application

(a) Optical probe system ViScan
(b) Application with multisensor technology (inspection plan)

First experiences
Results from the concepts first validation phase have shown, that the complexity is to high to be handled by students. Specifically the usage of the operating software causes many difficulties and mistakes. In fact, the students motivation decreased by difficulties with handling the user interface of the software. The tutoring concept of direct support usually helped a lot to fix the problems immediately. These results lead to a reduction in the requirements and several adjustments in the concept.

3. The Students Opinion
Asking the students opinion about the new training, most of them agree that it is an interesting and exciting series of experiments, explaining the connection between theory and practical
application. The information was gained with a questionnaire which the students had to fill in directly after the completion of the current stage. The opportunity to gain some experiences working with multi-sensor measuring devices and discovering different influences on the measurement results was highly appreciated by the students. The prospective engineer’s motivation for training the acquired knowledge with practical demonstrations increased significantly. The goal of the teaching concept - solving a measurement task for a production part by creating an inspection plan and successfully processing it on a coordinate measuring device - could be achieved. Unfortunately is has to be pointed out that the number of students participated in the trainings yet is too small to be convincing.

4. Summary and Prospect
The training in optical and tactile measurement technology enables students to gain experience in the usage of measuring devices and encourages the process of understanding measurement machines and their characteristics. The academic education will benefit from the increasing quality by combining theoretical lessons with interactive trainings. The Ilmenau University of Technology is offering such a combined teaching method with its new consecutive degree program ‘Optronik’, which is a cross-section-science, based on the technical disciplines optics, electronics, mechanical engineering and computer science.

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