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QUALITY ASSURANCE OF MEASUREMENT RESULTS BY WORKPLACE-INTEGRATED ASSISTANCE

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ABSTRACT

In coordinate metrology, the operator may cause the largest measurement uncertainty. To reduce the operator's effects and to achieve reliable measurement results, it is necessary to place the emphasis on the enhancement of the operator's skills. Additionally to a solid training, another way of reducing their influence is to provide operators with direct support during the measuring process.

The paper introduces a comprehensive, workplace-integrated assistance system for coordinate measurements, which is notably appropriate to support the operator during the execution of measurement tasks. Such an assistance system is capable to compensate common shortcomings of an operator. By providing a methodical procedure for the complete measurement task, an assistance system enhances an efficient determination of the measurement strategy and enables to reproduce the decisions made during the determination process.

1. INITIAL SITUATION

For successful manufacturing of innovative and high-quality products it is essential that a company applies efficient methods and strategies of quality management. Decisions in quality management are mainly based on knowledge about the manufactured workpieces, which are gathered by measurements. Thus, the importance of correct and precise measurement results become apart. In order to prevent that inappropriate measures are taken based on erroneous assumptions measurement results have to be subject at least to the same quality requirements as the products do.

Since the tolerances for manufacturing continuously become smaller, whereas the complexity of workpieces increases capable measuring techniques have to be applied in order to achieve sufficiently precise measurement results. Due to their precision, universality and flexibility, the use of coordinate measuring machines (CMM) constantly increases. In particular they are used for measurements with high demands on accuracy. But also measurement results of CMM’s are affected by deviations, which are caused by the operator, environment and workpiece as well as by the CMM. It can be assumed that these influencing factors have a relative importance of approximately 100:10:1 in causing deviations [1].

Nowadays, the influence of the CMM’s on the measurement uncertainty is downright very small, due to the highly sophisticated machine technology, the back tracing of the CMM’s to national and international standards and the application of powerful compensation software. Influences of workpiece and environment can be reduced by appropriate measures, e.g. by temperature soaking of workpiece and clamping, by consideration of expected form deviations at the workpiece or by elimination of environmental influences in a climatised measuring room. On the contrary, there are currently not sufficient possibilities to reduce the operator's influence, which is also caused by the operator's motivation and the applied elaborateness, but mainly by the operator's skills and experiences. For measurements with a CMM comprehensive and multidisciplinary knowledge is required, e.g. in natural and engineering sciences as well as in function and construction of the CMM. In order to reduce the dependence of the measurement results from the operator and thus to advance their quality it is necessary to provide the required knowledge so that it can be applied during the measurement.

Since in most countries, even in Germany, no occupational profile and thus no vocational education exists in manufacturing metrology, the employees have to gain the competencies during job-accompanying measures. This can happen while the participation in attendance-based training courses or in up-to-date e-learning courses as well as by self-conducted learning using technical literature or by exchange of experiences with competent colleagues.

In addition there are alternatives to provide the required knowledge, e.g. through the support of the operator during the measurement by a workplace-integrated assistance system. However, the main task of such a system is to avoid mistakes of the operator, which are caused by typical human shortcomings, e.g. the limited awareness, the high distractibility or the dependency of the human capacity on the daily constitution. Therefore, an assistance system can advance the quality of measurement results in different ways:

- *directly*, through detection and prevention of mistakes by proving the executed work steps for conformance with stored rules.
- *indirectly*, through the provision of knowledge that is actually required for the professional execution of measurement tasks and that contributes to a more efficient and more competent execution in a long run.
- *supportive*, through a better knowledge transfer which has been gained otherwise.

Thus, workplace-integrated assistance systems, separately, in addition to conventional training or after a vocational adjustment, present a notably efficient opportunity to reduce the operator's influence on the measurement result.

2. PROBLEM FORMULATION

So far, in coordinate metrology such assistance systems do not exist. No available system uses the whole potential, although several facilities exist, which are either integrated in the software of the CMM or available additionally. But they do not offer comprehensive support; they only provide support for certain work steps. Software-integrated help systems are mainly solely programming aid for the preparation of measuring routines, which only supports the operator for the compliance with the proprietary syntax. In some cases these help systems are hardly more than digital manuals, where special terms can be searched for.

In order to use the complete potential of an assistance system to reduce the operator's influence on the measurement result it have to meet higher requirements than are met by existing systems. For this purpose, the operator is to be supported during all steps of the measurement procedure. Besides all knowledge, which is required for execution of the measuring tasks, has to be provided as well as additional background knowledge. This knowledge results in a better understanding of own activities and in this manner in a more careful execution of the tasks. The provision of knowledge should be context-related and user-specific, that means according to the currently prepared work step and to the pre-knowledge of the operator.

Since no assistance system meets these requirements the Chair QFM intended to develop an appropriate concept and to implement the concept prototypically. The results and experiences gained during the conception and implementation can be a basis for the industrial preparation and consequently a common application of assistance systems in coordinate metrology.

3. METHODOLOGY – BASIS FOR ASSISTANCE

Precondition for a comprehensive assistance is that the execution of measurements can be based on a uniform and methodical procedure. Thus, it becomes possible to provide assistance and information targeted on the currently prepared work step. Furthermore, a methodical procedure allows for an efficient execution of tasks, so that no iteration has to be done and no mistakes occur, which are caused in a non-systematic approach. Furthermore, the definition of a methodical procedure also contributes to a uniform and comparable but also to a target-oriented and efficient working. Even though such a procedure not only can be applied for the work with an assistance system but also is advantageous in each case, the utilisation of such a procedure is notably reasonable. Based on the methodology the assistance system can provide the operator an important orientation guide.

Since for successful application the assistance has to be adapted precisely to the currently executed work step a methodology is required that describes and systematises the different steps in detail. Among experts a procedure consisting of seven steps is widely accepted [1]:

- *Analysis of the measurement task*: indication of features to be measured out of the technical drawing and transformation of the indicated requirements into a measurement task
- *Determination of the measuring strategy and evaluation strategy*: definition how the required features will be measured and evaluated
- *Planning of the measurement and setting up of the inspection plan*: definition of all specifications required for the execution of the measurement
- *Preparation of the measuring routine*: transformation of the determined strategies into CNC program
- *Execution of the measurement*: preparation of the measurement and subsequently starting the measuring routine or processing the defined inspection plan
- *Evaluation of the measurement results*: extraction of required characteristics out the gathered measurement data
- *Estimation of the measurement uncertainty*: to be assigned to the measurement results

This sequence is commonly applicable and approved, but does not include any detailed information about the required work steps. A further specification of the work steps offers the base plan “Good coordinate measurement practice” that was developed at QFM for the training concept AUKOM [2], wherein mainly for the steps “Determination of the measuring strategy and evaluation strategy” and “Planning of the measurement” the required knowledge is specified and appropriate standards are compiled.

Since also these procedures were not sufficient to build the basis for an assistance system it was necessary to setup an adequately subdivided methodology for coordinate measurements. Based on the above-mentioned procedures, corresponding literature [3, 4] to the organisation of the several work steps as well as under consideration of approved procedures of experienced metrologists this detailed methodology has been setup.

The developed methodology includes all individual operations in a defined sequence, which results in a most effective execution of the measurement task and which avoids the subsequent modification of already defined parameters. It can be used for both as basis for an assistance system and for the optimisation of not assisted executions of measurement tasks.

4. CONCEPT OF THE ASSISTANCE SYSTEM

In addition a concept for the technical realisation of the assistance solution for coordinate measurements had to be developed. Therefore the requirements on an optimal assistance system have been analysed as well as its required functionalities. On the one hand demands of the operator had to be considered, who desires a system that is easily applicable and that supports the execution of measurements comprehensively and efficiently. On the other hand requirements on the software-technical design of the system had to be regarded. The assistance system has to be appropriate to available hardware and software at a typical workplace in coordinate metrology. Furthermore, the system has to allow for an easy maintenance of the content, in order to offer continuous assistance that is according to actual standards and guidelines as well as technical developments. The required functionalities were classified and compiled so that three basic components have been identified (fig. 1):

- The *knowledge processing* offers active assistance, i.e. the component analyses input data and parameters, identifies mistakes and errors and determines presets for the current operation. It interacts with the knowledge base that stores all required information and decision rules.
- The *knowledge presentation* offers passive assistance, i.e. the component presents required information and thus supports the decision process and execution of the individual operations. It also provides background knowledge that can be accessed on demand.
- The *communication logic* serves for the interaction between assistance system, operator and CMM as well as for the data transfer with other systems, e.g. quality-related data from CAQ or design information from CAD. It also comprises the GUI and presents the data that are provided by the knowledge processing and the knowledge presenting component.

For a comprehensive assistance these components have to interact well-adjusted, so that active and passive assistance complement each other.

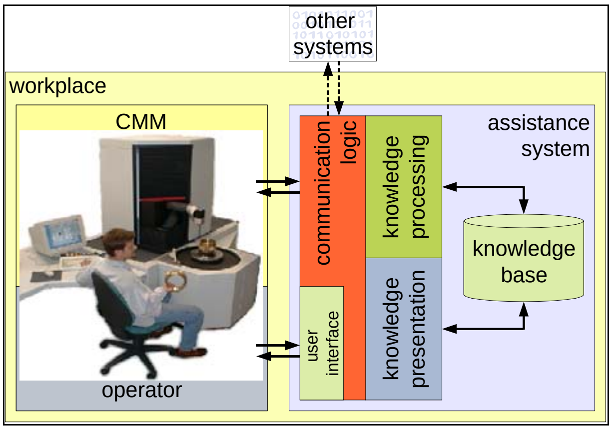

Figure 1. Basic Structure Of The Assistance System

After the definition of the components, for each individual operation it had to be analysed, how the assistance system should support the operator, which components are to be utilised for the support and which information and knowledge are to be presented. This also includes the indication of required background knowledge, which can be accessed on demand for better understanding of the presented primary information.

The access on demand allows for a user-sensitive knowledge provision; to an advanced metrologist only that information is offered that is required for the execution of the measurement tasks, whereas to an unskilled operator additional explanations are offered in order to make the presented content understandable. Just as the sequence of the individual operations the action flow of the assistance system is prepared in form of flow charts (fig. 2).

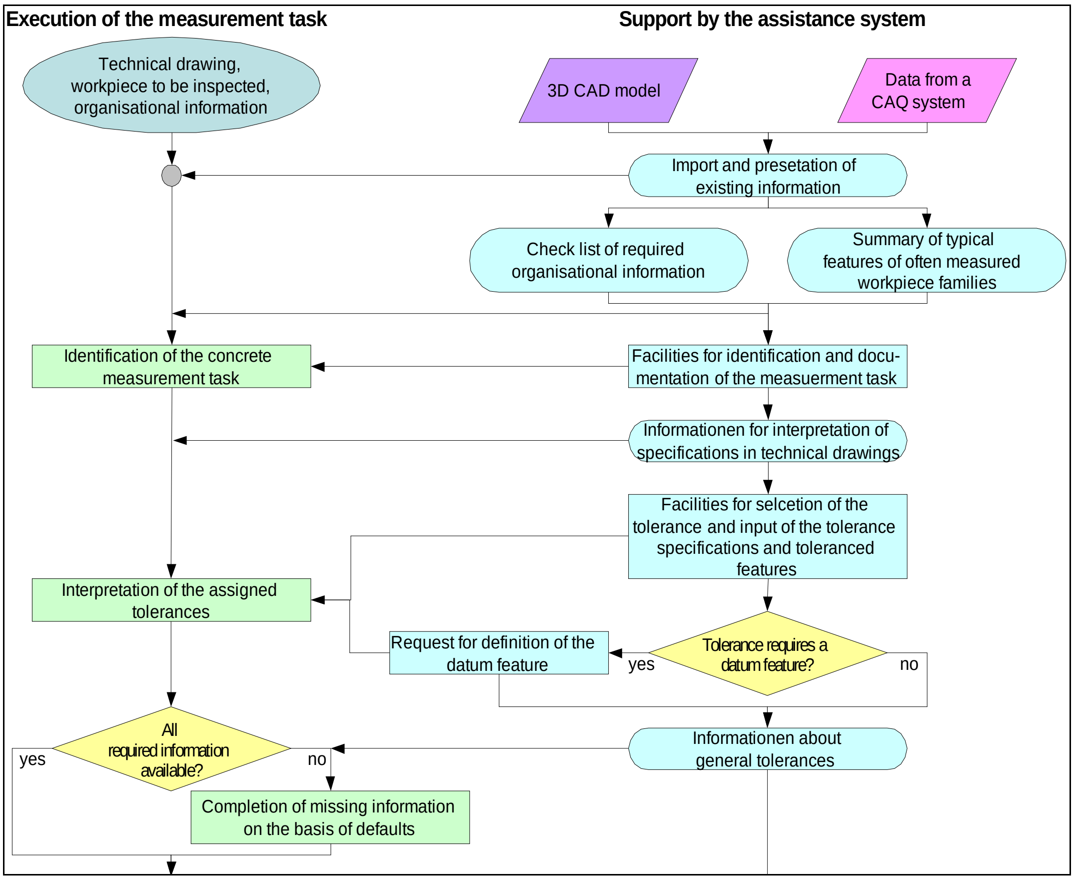

Figure 2. Actions of the Assistance System for the Work Step "Analysis of the Measurement Task" (Extraction)

5. IMPLEMENTATION OF AN PROTOTYPE

The concept should subsequently be verified by a prototype. In order to reduce the workload for development and implementation to an accomplishable extent, some restrictions were accepted. But to ensure the transfer of the solution to common problems, the utilisability of the assistance system was not to be endangered. Thus, primarily the support was limited to the work steps up to the setup of the inspection plan.

This limitation significantly reduces the programming effort, since no interface to the CMM has to be implemented and no machine-specific data has to be processed. But the effect is almost not reduced, since the operator's influence mainly arises from these steps. All necessary parameters for execution and evaluation of the measurement are determined, which have an important influence on the quality of the results and which require an extensive knowledge for parameter setting according to existing rules. The preparation of the measuring routine is also supported in common CMM software and is in general a transfer of the inspection plan into machine-code, so the operator's influence while programming is rather small. The quality of the execution of the measurement depends to a lower degree upon the knowledge of the operator as rather on the operator's concentration and applied elaborateness. Thus, it can be expected that the assistance during the preparation of the focused work steps already results in a noticeable reduced influence of the operator on the measurement result.

Secondarily, the information and knowledge to be stored in the data base has been limited to the assistance of a representative measurement task. This limitation also reduces the effort notably, since the data base has not to be as complex as it is necessary for the support of all kinds of measurement tasks. Checking the specifications at a piston pin bore has been selected as representative measurement task, since this task is so complex that several decisions have to be made and does not represent a routine job. Otherwise, the task is not so complicated that only a well-skilled and well-experienced metrologist can execute the measurement. Finally, the defined prototype provides assistance for the execution of the representative measurement task and for all other tasks, which do not require further knowledge. Currently the implementation of the prototypical assistance system is running (fig. 3).

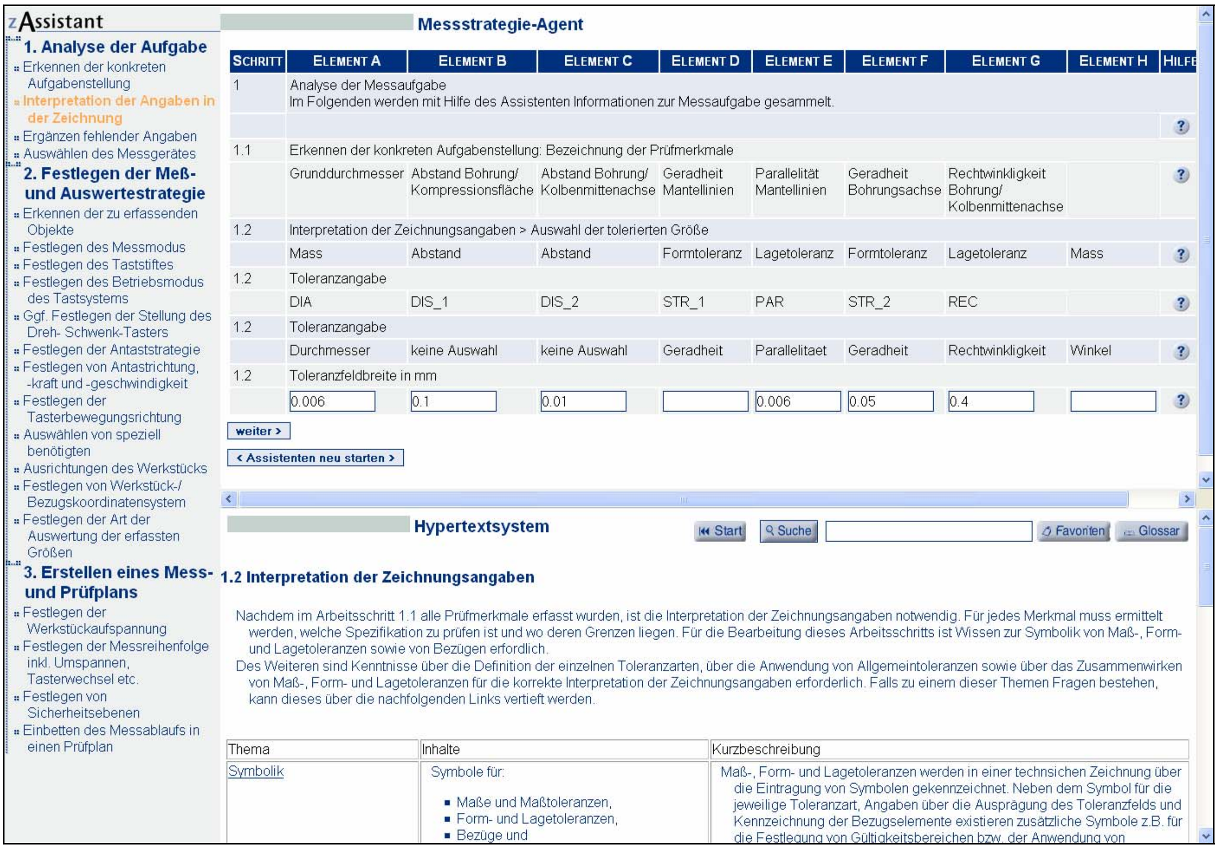

Figure 3. User Interface of the Assistance System Prototype "Zassistant"

Out of several options a hypertext-based expert system based on the processing logic of a "structured search" has been selected to realise the knowledge processing component. According to the concept of the "structured search" the required information is selected from all available data in dependence on earlier operations. The system provides input boxes and selection boxes for each individual operation, where the operator can input the required data or can select appropriate options, e.g. inputting a tolerance value or selecting a geometrical tolerance from a list. According to these inputs the subsequent operations are carried out, e.g. the request for a datum feature, if as tolerance parallelism was selected.

The knowledge presenting component is realised in a hypertext system, since this offers the possibility to integrate and link different type of media logically and contextually. While executing the individual operations the actual task is explained and important information is presented in the hypertext system. During the transition of the process from one individual operation to the following the processing logic addresses "initial elements" in the hypertext system, where the most important information according to the actual task are summarised. Via links further knowledge can be achieved. Thus, the operator can control the extent of the presented knowledge that allows for a proper adjustment to the operator's previous knowledge. Furthermore, the navigation of the hypertext system is easy to handle and familiar to most of the operators, since its analogies to the Internet.

The user interface of the assistance system is formed by the front-end of the expert system and the hypertext system. The server architecture, where the hyper-textual components are implemented, serves for the data transfer between the components.

6. CONCLUSION

Supporting coordinate measurements with an assistance system contributes to the reduction of the operator's influence on the measurement result and thereby on the measurement uncertainty. On the one hand the system should avoid mistakes and errors during the execution of the measurement and should assist the operator while decisions and while the selection of optimal procedures. On the other hand the system should provide actual required knowledge, background knowledge and further information and thus in a long run should contribute to the qualification of the operator and to a lastingly improved work approach. Since such assistance did not exist the development of an appropriate solution was intended.

Thus, a general concept for the realisation of a comprehensive assistance system has been developed. That includes the setup of a detailed methodology for execution of measurements using a CMM as well as the conception for the technical realisation of the assistance system. By means of the developed methodology measurement tasks can be executed according to a uniform, efficient and target-oriented procedure that can be utilised as basis for an assistance system as well as guideline for a self-directed execution of measurements. The technical concept comprises an analysis of all requirements on the assistance system regarding functionalities and properties as well as the setup of a basic structure consisting of three components.

Based on the methodology and on the basic structure of the system the required assistance during the execution of each individual operation and the involved components have been analysed. These results are currently implemented in a prototype that assists exemplarily the work steps up to the setup of the inspection plan for a representative measurement task.

After completion of the implementation process the prototype will be used to verify the prepared concept for the assistance system. Possibly existing weaknesses can be identified during the application of the prototype and can be eliminated. Furthermore, the prototype will be used to test how far the assistance system is capable to reduce the operator's influence on the measurement result. Based on these findings further requirements for the advancement and optimisation of the concept can be indicated, which have to be taken into account for the realisation of the final comprehensive assistance system for commercial application. The gained experiences can serve as a base to enhance the efficiency, but primarily to improve the quality of coordinate measurements, when using an assistance system.

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