

An evaluation of the Valisys 3.0 quality assurance software

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An evaluation of the Valisys® 3.0 Quality Assurance Software.

WPA rapport nr: 0888

Confidential

23rd of April 1990

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Summary

On the 5th of January I got the assignment to examine and evaluate the program Valisys® 3.0, a quality assurance product of Valisys Corporation, a subsidiary of FMC Corporation. Valisys main use lies in the checking whether parts meet their design standards.

The first one and a half month I spent on getting to know the program and the computer it was running on. I could not build on any prior knowledge of this program at our University, as this was the first installation of this program in The Netherlands or maybe even in Europe.

The evaluating of the program took me about another month and a half. After careful evaluation I reached my conclusion namely: The program Valisys does not live-up to the expectations it raised with me.

This report will be divided into several sections:

- An introduction section.
- An evaluation and conclusion section.
- Appendices A & B giving a functional overview of the program and its interfaces.
- Appendix C giving a short working impression of Valisys.

If you are an experienced user of Valisys, you will probably be able to understand the evaluation and conclusion without reading appendices A,B & C. If however you are not all that familiar with Valisys, I think it would be beneficial to first read the above mentioned appendices.

As an aid in reading this report I have added a glossary at the end of this report, so you will be able to find an explanation and or definition of most of the Valisys specific words.

Though I am the one writing this report and signing for it, I didn't do it all myself. There is a number of people I owe thanks to. As it would be impossible to name all of them I would simply like to thank all of those people who helped me in this assignment.

Special thanks, however, I owe to the following two people:

- Jan van der Zee,
- Frans Adamowicz,

they were the one's I could turn to in times of distress.

I hope this report will give a good overview of the program and its capabilities. If, however, some questions remain or arise after reading, I will be more than willing to try and provide the answers.

Hein-Jan van Veldhoven,
Eindhoven, 23rd of April 1990.

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Assignment

Examine and evaluate the program Valisys, using the Unigraphics CAD system, on its abilities and functions, with regard to:

- The checking of drawings for dimensioning, and the used geometric dimensioning and tolerancing.
- The abilities to control 3-dimensional coordinate measuring machines.
- The abilities and inabilities of softgauges.
- The algorithms used in computing the softgauges.

Introduction

Valisys is a program consisting of eight software modules that integrate quality in the design and production process. Valisys is mainly a program that verifies whether actual products comply with the design standards, it does this by comparing the actual design standards to measurements it takes using 3-dimensional coordinate measuring machines.

Until recently the situation used to be like is illustrated in fig. 1.

The design process was a serial process with one activity following the next. The checking at the end of the process wasn't always as thorough as it should be, and some design qualifications couldn't even be checked. Most of the time the checking was done it took rather a lot of time to compute whether a product was indeed complying with the design standards or not.

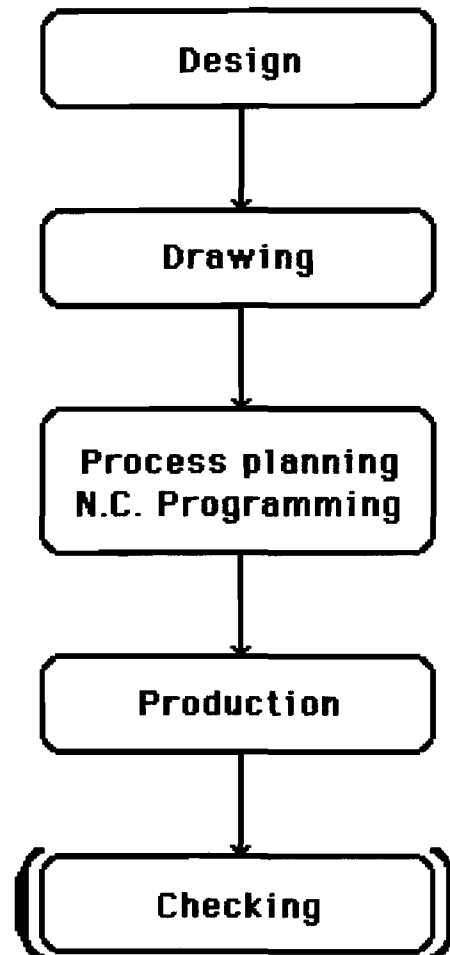


Fig. 1: The "old" design process.

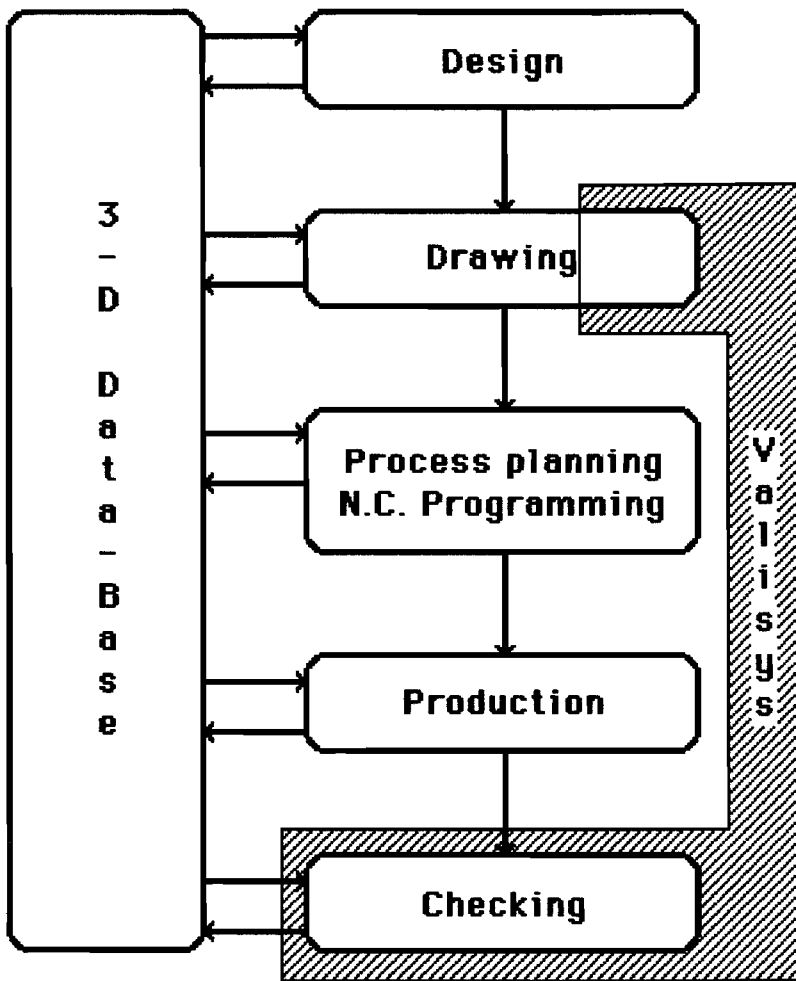


Fig. 2: The "new" design process.

In a modern production environment however, it is now possible to have this checking done integrated with the design process. Valisys can be a powerful aid to complete the design and manufacturing process.

It can do two things:

- 1) It can check whether the Geometric Dimensioning and Tolerancing is done correctly and up to standard. If not it will generate an error telling what is wrong, so one can easily correct the callout.
- 2) It can perform measurements on a CMM and in this way gather the data which is necessary to evaluate a certain product. It does so by creating measurement paths on the product in a dialogue with the user.

The parts are checked with the aid of Softgauges®. This softgauge approach is unique to Valisys.

In the "old" situation machined parts were verified by the use of "hard" gauges, which were tooled to represent worst-case mating parts. The principle is fairly straightforward: if the gauges properly fit, the part passes inspection. If they don't fit, the part fails inspection. A production engineer will have to make an assessment whether the part can still be rework and used in the next production or assembly process, or has to be scrapped.

In the "new" situation these hard gauges are represented by their geometric models in the 3-D database, these representations are called softgauges.

Valisys measures a part, and calculates from these measurements a virtual representation of this part in a 3-D Database. It then compares this virtual representation to the design standards (the softgauges are tried) and flags up the dimensions which are out of tolerance. It can even make a rude assessment of certain rework possibilities.

These softgauges are created with the aid of the geometric dimensioning and tolerancing which is present on the drawing. With the aid of softgauges one can check anything which can be drawn in a CAD system and can be manufactured.

Though the program analyses all the gauges and thus the differences between the actual part and the theoretical part, it is not able to give an advice on how to adjust the production process (E.G. the N. C. programming) to prevent rejects from occurring.

It does give some advice on how to rework the part, if possible, so that it will pass the gauges.

An other piece of valuable data it is possible to provide, is Statistical Process Control (SPC) records. The program is able to save all the crucial data of a gauge in a database, and in that way build a history of that particular gauge and its results. ^This can be used to analyze if a process is going out of control.

Program Evaluation

Valisys consists of eight modules, of these eight modules six are needed, in one way or the other, to perform measurements on a CMM. To these modules I dedicated most of my time.

The two other modules V:Check and V:Tolerance are not all that related to the other six modules. V:Check only checks the geometric dimensioning and tolerancing. It could be a powerful aid in drawing. V:Tolerance could also be a powerful aid in drawing, being able to perform fixed and floating fastener analysis and worst-case mating part studies. Though the program is limited to non critical applications only in case of fixed and floating fastener analyses. This means that it is not able to aid in the design of pre-stressed fasteners.

I feel that these modules should be a part of a CAD system instead of a program for checking whether parts stand-up to their specifications.

This evaluation is not a comparison of Valisys against any other programs, it is solely an assessment of the program Valisys itself.

Advantages

- The programming of the CMM is carried out on the bases of the part model in the 3-D database. This means that everyone in the design process will be working with the same data. But, the updating of the part has to be strictly regulated.
This can be quite an improvement over present situation where engineering design modifications can stop the complete design process. Changes in the part can quite easily be incorporated in the inspection process.
- The coordinate measuring machine can be programmed without an actual physical part being present, or even having been made.
This means that once the part is actually made, it can be checked almost instantaneously. There will be no delay in finding out whether the N.C. programming was done correctly, and the machines are capable of reaching a certain precision.
- The programming of a CMM is independent of a machine control language, which usually is dictated by the manufacturer of the CMM. Different machines from different manufactures are all programmed identically.
- The programming of a CMM can be done off-line.
- It is possible to run a simulation of the measurements which are incorporated in a process, in this way it is possible to check the processes for mistakes, and correct them before they cause damages. It is however not possible to do time studies with these simulations, because Valisys is only familiar with the geometry of the probe and not with the CMM nor its speeds nor its controllers.
- The final result of an analysis will be unambiguous and independent of the CMM, because Valisys is the one doing all the calculations and transformation to the measurement data. These final result however, are of course dependent on the measurement machine's accuracy on the measurements themselves and on the algorithms used by Valisys.
- It is possible to measure complex parts, for instance parts with 3-D surfaces or spline curved surfaces. This is one of the main advantages of the softgauge approach. Using normal CMM operations it would not be able to make assessments on this kind of complex features.
- The program automatically generates the measured points on a feature.
- The analysis routines are capable of using different algorithms in computing the results, so the results can be compared to other CMMs not using Valisys.
- The program can preform a worst case assembly analysis.

Drawbacks

- In my opinion Valisys has not fully matured, I feel it needs a number of changes, especially the user interface, before it can be looked upon as an easy to operate, valuable aid in controlling quality. These changes include a reduction of the error messages and a more user friendly approach when errors are generated. E.G. At a certain stage I got the following error "BASIC DIMENSIONS ARE NOT YET IMPLEMENTED". Is this a program in its third release? This is just a small number of inconveniences, which do not make the program unusable, but they do leave an impression of a not fully matured program.
- If one wants to start working with Valisys it is necessary to install extra computer equipment, because Valisys communicates interactively (on line) with the machines it controls. I think it is probably necessary to install an extra VAX station next to the CMM because I feel that the inputs required on both machines make it almost impossible to have a great distance between the both of them. I found that the 15 meters between the VAX station and one of the CMMs I was using, could be quite a nuisance.
- The program has not yet been fully integrated into the UniGraphics CAD system, it is sometimes necessary to make links between certain items (e.g.: between features and their GD&T frames) where UniGraphics already has such a link.
- The use of the Reject, Terminate Operation and Entry Complete keys is not carried out logically throughout the program, misoperation may lead to considerable loss of data.
- It is sometimes necessary for the user of the program to have to perform certain tasks at system level in order to have everything run smoothly.
It took me some time to find out that in order to operate the interface with one or the other CMM it is necessary that certain processes are running on the VAX. These processes (the Generic Profile Module and the Personality Module) are machine specific and might be running alongside on a computer with two or more serial ports. The VAX station I was using had only one serial port so each time I wanted to switch between the two CMMs I needed to stop one set of processes and needed to start the other set.
- The program does not take software corrected machines into account, it bypasses all the software that is running on the CMM's computer, and might in that way lose a lot of software added accuracy of a CMM.
It doesn't even take simple linear measurement axis corrections into account. I think it must be quite easy to insert a few lines in the program, running on for instance the HP 300 computer controlling the Zeiss, which simply multiply the measurement data by a factor, thus compensating for linearity errors in the measurement systems of the CMM.
- It is practically impossible to delete gauges, paths or processes because this results in parts which may become "corrupt". These parts start generating system and program errors at strange unpredictable places.
- It is not at all possible to delete features once they are defined.
- The program does not accept asymmetrical tolerance limits. However, it is possible to use asymmetrical tolerance limits if one uses the dimensionless geometry option in the V:Gauge menu. This means that if asymmetrical tolerances are present on a drawing they can only be used in a softgauge after they have been re-entered into the system with the dimensionless geometry option.
- In the creation of a calibration path the "Delta Equator" does not work.

- The program does not perform a decent collision check. It is possible to run a collision check but this routine only checks whether the probe collides with the feature it is measuring, there is no check whether the probe collides with any other feature of the part. The check routine does not take probe rotations into account, it only occupies itself with the final position of the probe, not how it got there.
- The program generates superfluous transition points at places where I would least expect them. This can be a nuisance because it can take up quite a lot of time during executing of an inspection for the CMM to reach these points.
- The interface running on the Zeiss CMM generates an "Unexpected Hit" error which stops the machine when it is sent to the same point twice in a row, even if the machine is nowhere near a part or any other obstacle.
- The interface running on the Zeiss does not correctly inform Valisys if an error occurs, Valisys keeps on running and there is no way to stop this but to abort Valisys.
- The interface running on the Mitutoyo requires a lot more computing power than is advised in the manual. The interface won't run on an ordinary PC. It at least needs a PC AT, but then there is still an average waiting time per point of 1 seconde. Only when I was running the interface on a HP Vectra 386 did the pauses disappear.

At this moment in time Valisys is still working with wire frames, this introduces a number of operations, such as telling the computer which arrow is pointing away from the material, which might have been superfluous would the program be working with solid models. As solid modelling has only recently been introduced into the Unigraphics CAD system it is of course understandable that Valisys is not yet working with solid models. I feel however that a great improvement can be made if Valisys were to incorporate the use of solids in a new or updated version.

One of the major problems in performing measurements is being sure that the outcome is correct. With Valisys I cannot be sure of this at all, I have no information on the algorithms used to calculate the softgauges and the analyses, and I have no way of checking them. A recent investigation into similar algorithms used with 3-D CMMs showed that a major part of these algorithms fail, in some way or the other, to produce a correct description of a part when confronted with a number of points on this part.[BCR information: Testing of three coordinate measuring machine evaluation algorithms. By: C.Porta and F. Waeldele. EUR 10909 EN]

The program gives no indication whatsoever on the accuracy of the measurements performed. It doesn't even give a standard deviations of the measurements.

Conclusion

Considering all the advantages and drawbacks I have listed above I feel that at this moment in time I would not be in favour of Valisys. The only real advantages it has over normal CMMs is that different machines become easier to program, and that it is possible to measure 3-D surfaces, including free curved surfaces. The drawbacks however are multiple. The most important ones to me are, loss of accuracy and none bug-free operation.

In my opinion Valisys would find much benefit from an update making it bug-free, being able to incorporate the software correction of machines, and making it more user-friendly.

Appendix A: A functional overview**Introduction**

Valisys version 3.0 is a set of software modules that integrate quality into engineering design, manufacturing, and quality assurance functions. Valisys allows the creation of Softgauges within its system which serve as the data base for linking a variety of shop floor functions.

Valisys version 3.0 is a set of eight software modules, namely:

V:Check
V:Gauge
V:Path
V:Inspect
V:Qualify
V:Control
V:Tolerance
Utilities

These Valisys functions allow one to:

- Check engineering drawing callouts against the ANSI-Y14.5M-1982 standard.
- Define the gauge to be created and verify the gauge validity.
- Create the inspection to be used when measuring a part.
- Define a job (which includes the final inspection process) and execute the job on a machine.
- Analyze the inspection results to verify that the part meets accepted standards.
- Analyze position tolerances for mating parts and geometry and drafting text for fixed and floating fasteners.

The functions of the eight modules of Valisys version 3.0 are briefly explained in the following sections of this document. An overview of the different modules and the way they cooperate is given in figure 3 on the next page.

Functional Flow Chart

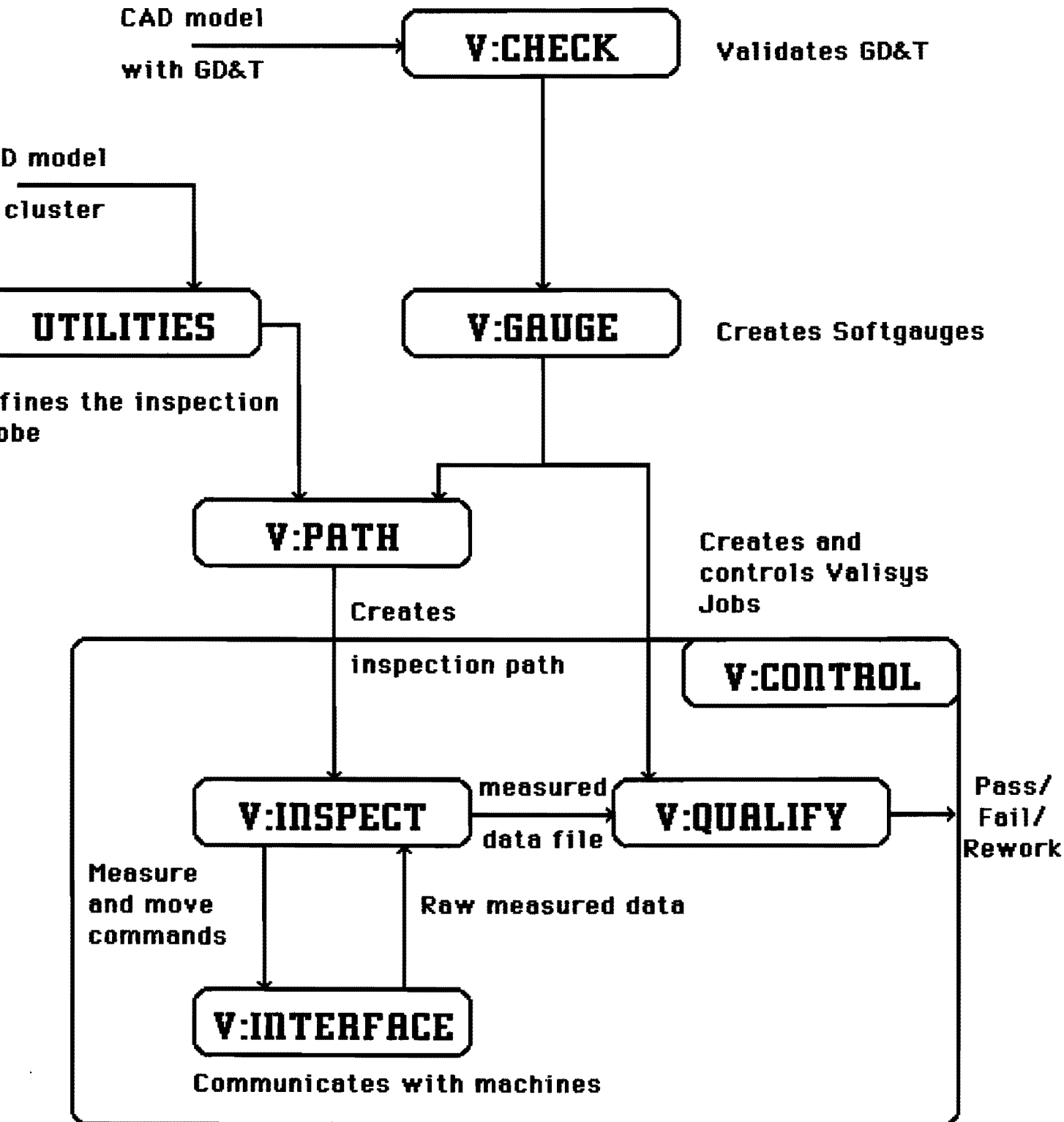


Fig. 3: Functional flow chart.

V:Check

The V:Check module verifies the Geometric Dimensioning and Tolerancing requirements in a CAD model in accordance with a predefined standard. The GD&T requirements may appear as datum symbols and GD&T feature control frames.

The V:Check module performs a syntax check only for these GD&T callouts, no geometry is checked. V:Check also performs syntax checks for multiple text strings or GD&T callouts which form a composite feature control frame, or a double feature control frame with a unit basis.

The entire syntax checking process is currently based on the American National Standard ANSI Y14.5-1982 Dimensioning and Tolerancing. This standard is only marginal different from the ISO standards on Dimensioning and Tolerancing. Though the differences may only be marginal, they may be critical for certain applications. E.g. there is no such thing as symmetry tolerances.

V:Gauge

The V:Gauge module allows one to create, display, list and delete datums and softgauge models. One can assign a name to a certain gauge and also define tolerances associated with dimensioning in various ways.

Introduction

The proper design and geometry of machined parts is usually verified by the use of "hard" gauges which are tooled to represent worst-case mating parts. The principle is straightforward: if all appropriate hard gauges properly fit the part under inspection, it passes inspection. If they don't fit, that part fails inspection.

Valisys performs this same function in software by creating Softgauges, which are three-dimensional graphical representations of hard gauges stored in the CAD's system data base.

Understanding Softgauges requires a prior knowledge of several basic Valisys concepts:

- Features:** A feature is a physical proportion of a part, such as a surface, a hole, a pin, a slot or a tab.
- Datums:** A datum feature is a feature of a part (such as a surface, or an axis or a plane) used by a gauge as a reference for establishing the proper location and geometry of another feature. For example, if a pin is to be perpendicular to a part's surface, the surfaces it is to be perpendicular to is a datum feature.
- Tolerance:** Tolerance is the total amount by which a specified dimension is allowed to vary. It is the difference between maximum and minimum limits. These upper and lower limits are themselves often referred to as tolerances. For example, the length of a feature may have upper and lower tolerances, or limits, of 0,1 millimetres, for a total tolerance of 0,2 millimetres. Tolerances may be specified for individual features, or they may be implied by default for other features where they are not specified. These default tolerances are referred to as block tolerances.

Datum definition and softgauge creation can be done by using the drafting text and the associated design geometry from the CAD model. Softgauges may also be created for size dimensions (such as ring or plug gauges), and for plus/minus gauges.

Softgauges conform to, and embody, established international geometric dimensioning and tolerancing standards, and are fundamental to the way Valisys Software works. Different gauges are created to measure the different features one wishes to inspect. Gauge types vary according to the characteristics they measure, such as perpendicularity, position, and flatness.

For gauge creation, all selected features must be located at their perfect positions (design nominal). Otherwise invalid inspections and analyses may be performed.

Valisys supports a dimensionless geometry option. This enables one to enter GD&T and tolerances requirements instead of selecting an existing drafting callout. This is a useful option, especially if you wish to create Softgauges and your three-dimensional CAD model is not dimensioned. With this option, you can enter the tolerance information by typing it in as you are creating the Softgauge.

V:Path

The purpose of the V:Path module is to create paths which are used for inspecting manufactured parts on coordinate measuring machines (CMMs), machine tools and other measuring machines.

Understanding the V:Path module requires a prior knowledge of several basic Valisys concepts:

Valisys Path

A valisys path is a collection of points, sequentially strung together, which measures a single feature of a part (e.g. a surface, a hole, a pin etc.).

Multiple paths are required to measure a composite feature (a composite feature, such as a slot or a tab, is made up of other features). A single path is used to inspect the features within the composite feature. For example, to measure a tab, a path is required for each of the planes which make up the sides of the tab.

Valisys paths are generally created one at the time for the individual features of the part. The exception to this rule is when a part contains a pattern of features. In this case, Valisys provides the option of "copying" the path of the first features to all the remaining features of the pattern.

Points within a path

There are four types of points used to make up a path: home points, measured points, safe points, transition points. A brief description of these points follows underneath:

- Home Points:** The home point is the first point of the first path in a process. Each process has a home point and it must be defined before the process is created.
- Measured Points:** Measured points are the points within a path where a measurement is to be taken. At these points, contact with the feature being measured is expected and the measuring machine slows down to a measure speed as it approaches the point on the part.
- Safe Points:** Safe points are the points in a path where no contact with the part is expected. If points within a path are not measured points, then they are safe points. The measuring machine approaches a safe point at a rapid speed since no contact with the part is expected. If contact is made (or the probe switch of the measuring machine is tripped) when moving to a safe point, the machine stops instantly, and generate an "Unexpected Hit" error.
- Transition Points:** Transition points are added to make a safe transition (or move) from one path to the next path in a process. They are usually placed at a height where movement from one feature to the next does not collide with the part. Since no contact with the part is expected at these transition points they are considered a type of safe points.

Valisys Process

A valisys process is a collection of paths. These paths are placed sequentially in the order they are specified when the process is created.

There are three types of Valisys Processes: Calibration, Orientation, and Inspection. Underneath is a brief description of each of these processes:

- Calibration process: A calibration process is used to qualify the cluster during inspection. The effective tool lengths and diameters of the cluster's probes are determined during calibration. The derived lengths and diameters are then applied to all subsequent orientation and inspection processes, to ensure accurate and error free inspection. A calibration must be run prior to any orientation or inspection process. The calibration results may be stored in a file and used at any later time.
- Orientation Process: An orientation process is used to orient (or align) the CAD model of the part with respect to the actual part on the machine. The orientation results are used to adjust all subsequent inspection processes. Three features of the part are required to perform the orientation. As with inspection processes, the measured data for these feature may be used in analysis. Orientation is not required, but it can greatly simplify the fixturing requirements, especially for complex parts.
- Inspection Process: An inspection process is used to measure all the desired features of the part. The results of the inspection process are later analyzed to determine if the part is in tolerance (acceptable) or out of tolerance (not acceptable). Features inspected with an orientation process do not need to be reinspected with an inspection process.

Tool range distances

There are four different tool range distances that are used when creating paths: an approach distance, a retract distance, a search distance, and a Z safe plane height. (fig. 2)

- Approach distance: The approach distance is the distance above the measured point that the probe is armed and a contact with the part is expected. The probe travels along this distance at the machine's measure (slow) speed.
- Retract distance: The retract distance is the distance above the measured point the probe moves to after it has touched the part.
- Search distance: The search distance is the distance the probe travels past the expected point of contact (the measured point) before aborting.
- Z safe plane height: The Z safe plane height is the height in the Z axis (above the part) that clears all feature of the part. I have not been able to establish whether this is the Z-axis as defined by the CMM, or the Z-axis as defined by the part, or the Z-axis as defined by the cluster.

Tool Range Distances

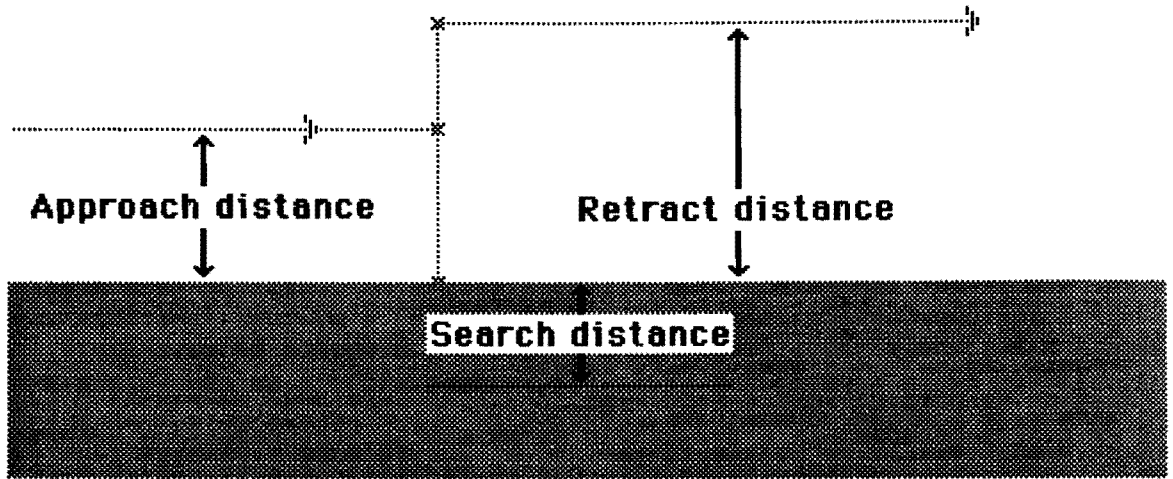
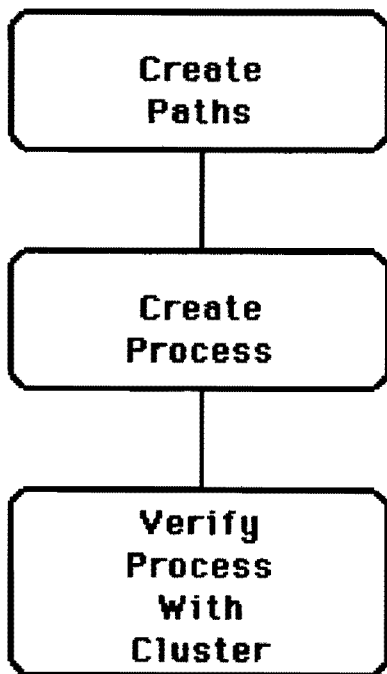


Fig. 4: Tool Range Distances.

Creating a process consists of the following three steps:



1) Create the paths which inspect all the features of the part to be measured.

2) Assemble the paths together in a process.

3) Verify the process with the cluster which will be used during the inspection.

Fig. 5: Creating a process.

- ad 1) The steps to create a path are as follows:
Specify the features to be inspected by identifying feature or gauge numbers. If gauge numbers are identified, the features included in the gauge are used.

To build the path, the path parameters must be entered according to the feature type. The path parameters set a grid pattern for placing the measured points. Then Valisys generates measured points on the feature. Additional measured points can be added or deleted. Once all the desired measured points are generated, the path is accepted. Valisys asks for the approach and retract distances and displays the finished path on the screen.

ad 2) The steps to create a process are as follows:

Specify the paths to be grouped together to form the process. Paths can be identified by path, feature, or gauge numbers. If gauge numbers are specified, the paths that measure the gauge/feature within a gauge are used. The order in which the paths are specified will be the order they are added to the process.

To build the process Valisys asks for a name and description of the process and then will create it by assembling the specified paths.

ad 3) Verifying a process assigns a cluster to be used and creates the transition from path to path for each path in the process. Verification allows one to:

- Add, move, or delete safe points.
- Perform collision detection.
- Change probe tips and angles.
- Display cluster at inspection points.

V:Inspect

The V:Inspect module allows one to operate machine tools (or CMMs) interactively, through V:Interface, with a sequence of commands which control the real time interaction between Valisys, the 3-D CAD system, and the machine tools (or CMMs) on the shop floor. In V:Inspect it is possible to measure a part by running the inspection programs (processes) generated in V:Path, and record the measured data from the machine in a file called the Measured Data file.

The primary functions of V:Inspect are:

- Connect and disconnect machine tools and coordinate measuring machines (CMMs). (Basically putting them on- or off-line.)
- Select and calibrate a cluster.
- Teach the location of a specific point.
- Control the movement of the connected machine.
- Download specific NC files.
- Inspect the part.

V:Qualify

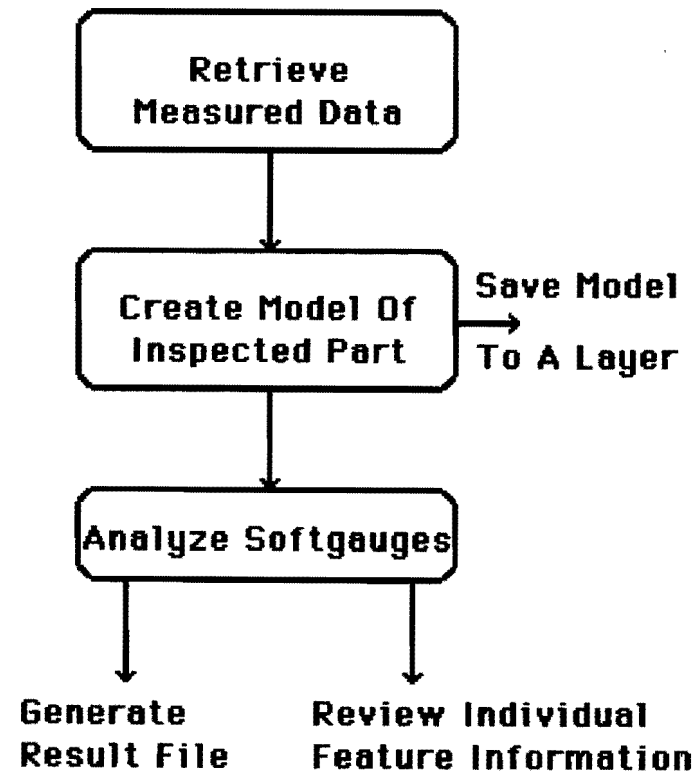
The V:Qualify module allows one to compare Softgauges created by the V:Gauge module with the measured data generated by inspecting a part with the V:Inspect module or the V:Control module. V:Qualify allows one to retrieve and analyze measured data and provides a summary of the analysis results.

In addition to analyzing retrieved measured data, V:Qualify allows one to "copy" the measured data (points and measured cylinders) to a specified layer of the CAD database. This might be useful when one wishes to have a model of the actual measured part. (Reverse Engineering Applications). However, it is not possible to use Valisys in a scanning application.

The measured data created by V:Inspect or V:Control is stored in a external text file. This data is read into the CAD database by V:Qualify. Once the measured data is retrieved V:Qualify can analyze all the softgauges whose features and datums have been inspected. A summary of the analysis results or detailed feature information can also be displayed.

There are three main functions within V:Qualify:

- Retrieve measured data
- Create model of inspected part
- Analyze Softgauges



Nothing can be done in V:Qualify until a set of measured data is "read" into the CAD database. Once measured data is retrieved Valisys creates a model of the inspected part.

Softgauges can now be used to determine if the inspected part falls within its specified tolerance zones. Results of the analysis are stored in an external file called a Result File. Valisys adds the extension .RES to the filename so that the files can be easily found in one's operating system directory.

Fig. 6: A functional overview of V:Qualify

Analysis Modes

There are three areas in which one has the option in performing an analysis: High Point Datums, Result File Options and Analysis Results Mode. Each of these options are specified with logical names on the operating system. A description of each mode follows underneath.

High Point Datum	<p>The High Point primary Datum analysis mode is selected by setting the logical HIPNT to YES. If HIPNT is set to YES, the calculation of the primary planar datums is done by using high points. If HIPNT is set to NO, the primary datum is calculated using a least square fit. If the logical HIPNT does not exist, or is not set to YES or NO, then NO is assumed default and the HIPNT primary datum is not used.</p> <p>All secondary and tertiary datums are evaluated using high points.</p> <p>When HIPNT is set to Yes a note appears in the header of the result file.</p>
Result File Options	<p>Result File Options are selected by setting the logical RESOPT to YES.</p> <p>When RESOPT is set to YES two additional items are printed in the result file.</p> <p>For size gauges, the top and bottom axis locations for holes and bosses are reported.</p> <p>For position gauges, the measured diameter, total tolerance, and measured position are reported for each feature within the gauge.</p> <p>The coordinates of the axis locations for holes and bosses are in the active working coordinate system at the time the analysis is performed.</p>
Analysis Results Mode	<p>Three different analysis modes are available by setting the logical Val_Los_Analysis_Mode to one of the three values:</p> <ul style="list-style-type: none"> - Functional - MRS_Average - Two_Point

V:Qualify calculates the sizes of bosses and holes by using the Minimum Radial Separation technique (MRS) as defined in ANSI B89.3.1-1972, Measurement of Out-Of-Roundness. The MRS analysis technique calculates a maximum cylinder and a minimum cylinder which encompasses the measured data for the hole or boss. These MRS cylinder sizes are used differently by the three analysis modes to report the measured size of the hole or boss. A description of how the MRS cylinder sizes are used can be found underneath:

Functional: A functional check is performed to assure that the functional size of a hole (or boss) is within the upper and lower limits as defined by the Softgauge. The functional size for a hole is the minimum cylinder size found using the MRS technique. The functional size of a boss is the maximum cylinder size found using the MRS technique. A form value is also reported for holes and bosses when the functional option is used. The form value is equal to the (maximum cylinder size - minimum cylinder size) / 2.0 where the maximum cylinder size and minimum

cylinder size are found using the MRS technique.

MRS_Average: This option checks that the average of the minimum MRS cylinder size and the maximum MRS cylinder size falls within the upper and lower limits defined by the Softgauges. A form value is also reported for holes and bosses when the MRS_Average option is used. The form value is identical to that calculated when Functional is used. Under this option any length measured by a plus/minus gauge is calculated as the (maximum length + minimum length) / 2.0. A spread is also reported which is the (maximum length - minimum length) / 2.0.

Two_Point: This option checks that both the maximum MRS cylinder size and the minimum cylinder size are within the upper and lower limits as defined by the Softgauge. The minimum and maximum measured sizes are both reported in the result file.

A note appears in the header of the result file telling one which mode is active.

The functional option is the recommended option to use on a daily basis, it is also the default option. If an application is checking extremely critical parts and one wishes the most conservative option, the Two_Point option should be used. If one wishes to compare one's results with conventional Least Square analysis methods, the MRS_Average option can be used.

V:Control

The V:Control module allows one to create and execute a Valisys job or execute a VCL command.

VCL (Valisys Control Language) is a high level programming language, derived from C, which is used to control the real time interaction between the Valisys program, the three dimensional data base, and the shop floor. Because VCL is a programming language, VCL statements can be grouped together to form a function (i.e. a series of VCL statements that are executed when that function is called). In addition to functions, mathematical and flow control operations can be performed within a VCL program. VCL programs are contained in ASCII files on the operating system.

A Valisys job is a sequence of VCL commands which resides as an ASCII file. This file of VCL commands can be used later to control the interaction between Valisys, the CAD system, and the shop floor. A Valisys job provides:

- Control of NC machine tools and Coordinate Measuring Machines (CMMs)
- Control of the interaction between the operator and the CAD data base.
- Analysis of the measured results generated by the inspection.

Creating a specific Valisys job is a one time procedure. V:Control allows one to build a Valisys job by sequentially selecting a series of tasks from a set of menus. Each menu-item corresponds to a specific VCL command. It is also possible to create these jobs with the systems editor, the same you create programs.

The VCL commands are placed in an ASCII file on the operating system. The order in which the menu-items are selected, corresponds to the order the VCL commands are placed in the job file. Messages to the CMM operator and prompts for the operator actions can be inserted as desired. The job file can be edited and customized to include additional VCL statements at any time using standard operating system text editing methods. Once the job is created it can be executed over and over again.

The V:Control module is very similar to the V:Inspect module in fact that both modules create VCL commands. The major differences between V:Control and V:Inspect are:

- V:Control stores the VCL commands in an ASCII files as a Valisys job, V:Inspect does not.
- V:inspect executes the menu driven VCL commands instantly, where V:Control does not unless the command is requested through the EXECUTE VCL COMMAND option of the V:Control menu.
- V:Control has access to all VCL commands, where V:Inspect can only access a small subset of VCL commands.
- V:Control is used to develop sophisticated shop floor programs, where V:Inspect is used for quick and routine shop floor operations.

V:Tolerance

V:Tolerance performs fixed and floating fastener analyses and worst case assembly analysis. Floating fastener analysis aids the designer in the creation of geometry and GD&T callouts for the clearance holes used for floating fastener cases.

Fixed fastener analysis aids the designer in the creation of geometry and GD&T callouts for the clearance holes and threaded holes used with fixed fastener cases.

Worst case assembly analysis determines whether the position callouts on the current path and its mating part will result in the parts fitting together.

Three tables must be present in order to perform the fixed or floating fastener analyses. These tables are named V_FASTENER_TABLE, V_DRILL_TABLE, and V_OVERSIZE_TABLE. Each table is to be placed in a text file on the operating system.

V_FASTENER_TABLE: The fastener table contains the fasteners which can be referenced during a fixed or floating fastener analysis. This table should be tailored to contain the specific fastener identifiers used at a specific site.

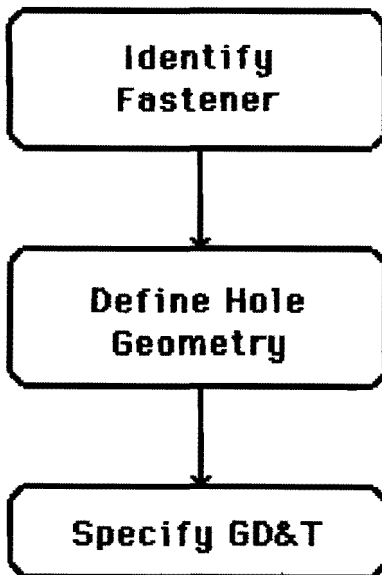
V_DRILL_TABLE: The drill table contains all the available drill sizes which V:Tolerance considers when looking for the best drill to use for a desired hole size. This table needs to be tailored to contain only the drill sizes used at a specific site.

V_OVERSIZE_TABLE: The oversize file contains an oversize or safety factor which is used to determine the best drill size for the clearance holes calculated during a fixed or floating fastener analysis. The equation used to calculate the finished hole size is as follows: Finished Hole Size= Drill Size + Oversize. The oversize values may be 0.0 if no oversize factor is to be considered, or may be a small number reflecting the machining or process capabilities.

Fixed or floating fastener analysis

Both the fixed and floating fastener analyses create geometry and drafting text for the clearance holes used when two parts are assembled with fasteners such as nuts and bolts. The fixed fastener analysis also creates the geometry and drafting text for the fixed (or threaded) holes used when two parts are assembled. For both types of fastener analysis, the clearance hole size is designed for non critical applications only. For non critical applications the size of the clearance hole is assumed to be the largest diameter hole which will be completely covered by the fasteners head.

To perform a fixed or floating fastener analysis the following three steps are executed:



- Identify the fastener,
- Define the hole geometry,
- The final step is to identify the datums and their modifiers which are to be included in the position callout controlling the location of the holes. If one is performing a fixed fastener analysis, one is asked if a projected tolerance zone is to be used. Finally, one specifies the location for the text to be placed. Valisys then creates the drafting text at the specified location.

Fig. 7: Fixed or floating fastener analysis

Worst case Assembly Analysis

The worst case assembly analysis is used to determine whether the positional callouts on the current part and its mating part will result in a successful fit. Before a worst case assembly analysis can be performed, datums and softgauges must be created for both the current and the mating parts which are to be analyzed.

Three steps are required to perform a worst case assembly analysis:

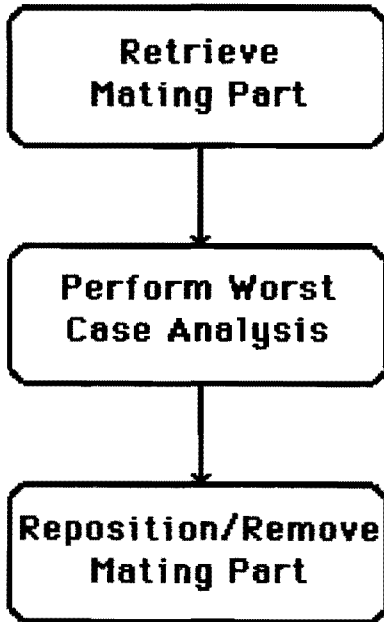


Fig. 8: Worst case assembly analysis

- The first step is to specify the CAD model of the mating part. Valisys merges the model of the mating part into the current part.
- perform worst case analysis: once the mating part is merged into the current part, one can perform the worst case analysis. To line up the two parts, one is asked to select the GD&T position callouts for the current and mating parts which control the hole patterns to be assembled. In addition one is asked to select a single hole within each hole pattern used to align the two patterns together. If both parts contain hole patterns, one must enter the maximum diameter of the fastener used with the holes. Once "assembled", Valisys identifies if any of the holes have interference fits or if clearances are present. If functional datums are used, Valisys checks them for consistency. For example mating part surfaces should be coplanar or coaxial. Checks are made to determine if each part references the same number of datums, and whether the datum pins fit into the corresponding holes.

- The final step is to either reposition (if another worst case assembly analysis is to be performed) or remove (when finished) the mating part from the current part.

Utilities

The Utilities option in the Valisys main menu allows one to define features and clusters.

Features

Features serve as the basic Valisys building block from which other Valisys Modules extract information. For instance, when one creates a Valisys gauge in V:Gauge, the process of creating that gauge first causes features to be generated. Next those feature are used for the creation of that gauge. As the feature are defined automatically as one creates a gauges the Utilities option is rarely used for creating features.

Clusters

A cluster in Valisys is a 3-dimensional CAD model of the sensing device to be used during the verification of an inspection path in V:Path. These cluster models are equivalent to the geometry of the actual inspection probe being used on the Coordinate Measuring Machine (CMM).

During V:Path verification and calibration creation, Valisys reads the geometry of the cluster to determine how best to control the movement of the cluster relative to the part being inspected. Valisys can create (and subsequently control) two types of clusters:

- Fixed clusters with multiple sphere tips,
- 2-Axis cluster (such as Renishaw PH9 heads).

In either case the user has complete control over the type of geometry and complexity of the cluster being created.

Appendix B: A functional overview of the interfaces

V:Interface

In this section of my report I wish to give some special attention to the way Valisys communicates with the machines it can control. Valisys has a unique way of communicating with all the different machines it can control.

System flow

VCL commands are transmitted by Valisys to the interface process via IPC, the Valisys Inter Process Communication facility. In the interface process, these commands are translated and formatted for the particular target machine and are then passed on to the machine for processing. Machine responses are handled likewise, handling information to the interface process which does the appropriate formatting and then sends the information back to Valisys, completing the communication.

Inter-process communication (IPC)

Inter-process communication (IPC) is a system by which data (messages, measurements, and so forth) are passed between processes. Any process may have a "Mail Box" associated with it. For one process to send a message to another, all that is required is to construct the message and to obtain the mail box number of the target process. This is the mechanism that Valisys uses to send machine commands to the interface and to receive measurement data back from the interface. It is important to notice that Valisys sends and receives the same kind of commands (VCL) and data through IPC regardless of the type of machine the interface process is currently driving.

Valisys Name Server (VNS)

The valisys name server (VNS) is essentially a directory that associates the names of Valisys services with the mail box numbers of the process that implement those services. So, if one has the name of a service (for example ZIS1), the name server will give one the information needed to initiate IPC with that interface process and do an inspection on the measuring machine.

Interface process communication

One communicates with the interface processes via IPC. To Valisys, the interface process is logically the machine. There is one interface process for each CMM or NC machine in the current Valisys environment. The interface process is composed of two main components: The Generic Profile Module and the Personality Module. The two modules provide a complete and generic interface unit for any CMM or NC machine while keeping the details of that machine completely transparent to Valisys.

The interface process functions to:

- Receive IPC requests.
- Translate VCL requests into the appropriate machine command string.
- Send the request to the machine.
- Take the result from the machine and send them back to Valisys in the appropriate

format.

Additionally, the interface process handles a variety of environmental events such as machine error handling, allocation contentions, and owner-process failure in such a way as not to interfere with the ongoing functioning of the system.

Generic Profile Module

The generic profile module is an event handler that responds to the various system events by causing certain routines in the personality module to execute. IPC events (VCL commands), machine responses, and extraneous system occurrences, such as EOFs and dead processes, are all handled by the generic profile module. The module also has the necessary utility functions to provide management services or status information to the Personality Module (such as user ID information or queue management functions).

Personality Module

The Personality Module provides three essential functions: Posts Events, implements protocol, and handles queue and machine requests.

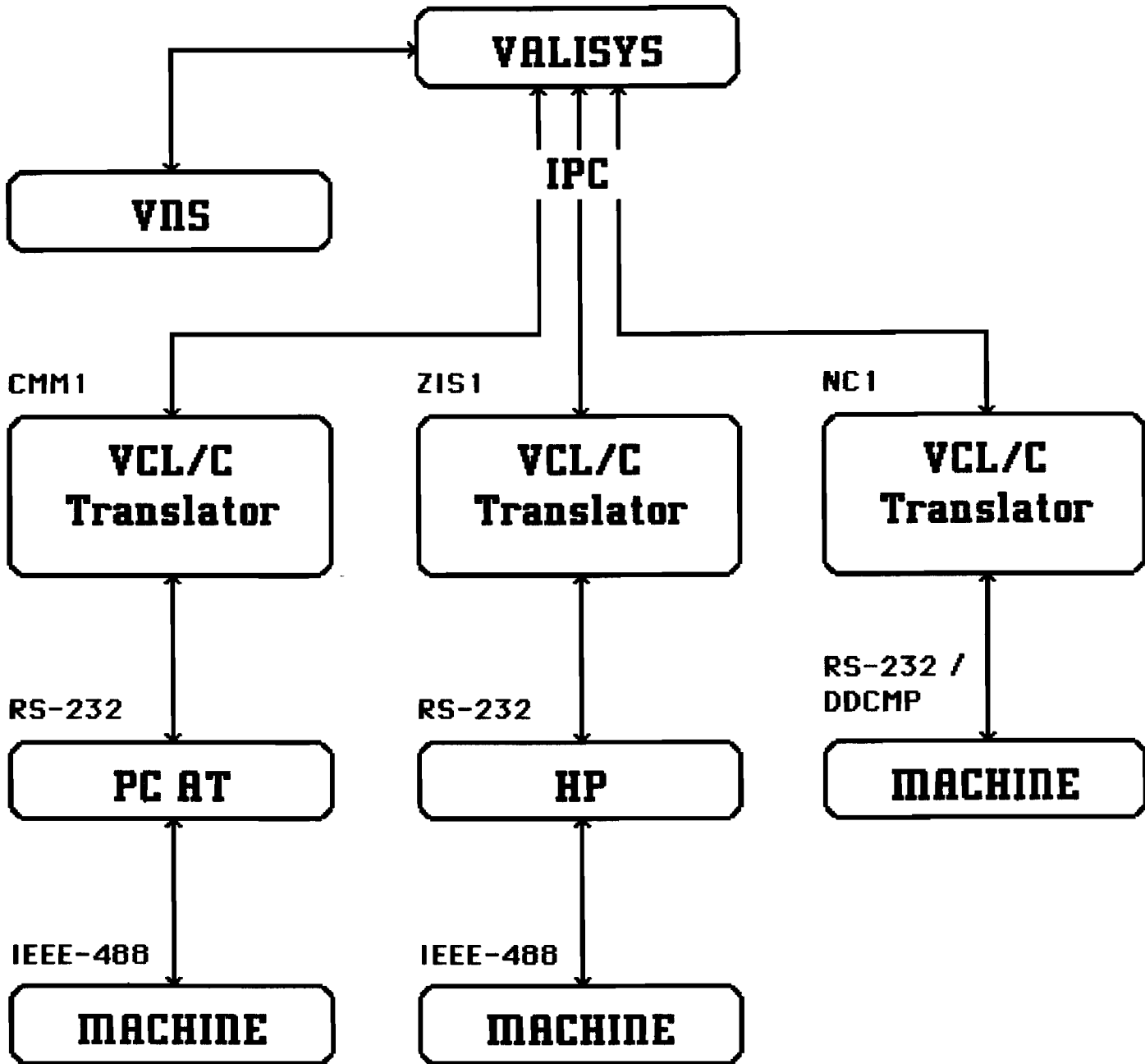
The personality module "Posts Events" to the event handler in the Generic Profile Module; that is, the Personality Module describes the type of event to look for and the function to activate on the occurrence of that event. Thus, the Personality programs the event handler in the Generic profile Module to respond only to the events relevant to a specific interface. It also provides the routines to handle the events.

The Personality Module implements the protocol or the actual command language of the particular machine on a specific interface. Routines associated with each Valisys command take the generic Valisys system action requests and translate them into the appropriate routines for the machine. Appropriate routines then translate the machine responses in Valisys format.

The personality module handles the queue of machine requests. The queue is a means of controlling command flow between the interface process and the machine. How this flow control is implemented depends on the type of machine being used.

Summary

Generally, the IPC is used to send generic machine commands to the interface process. The Generic Profile Module handles communication to and from Valisys as well as other system events. The Personality Module handles all the machine specific processing in an entirely transparent manner. By limiting the new code necessary to the Personality Module only, the integrity of the Valisys system code is unaffected by the addition of new machinery.



Valisys Machine Communication Overview

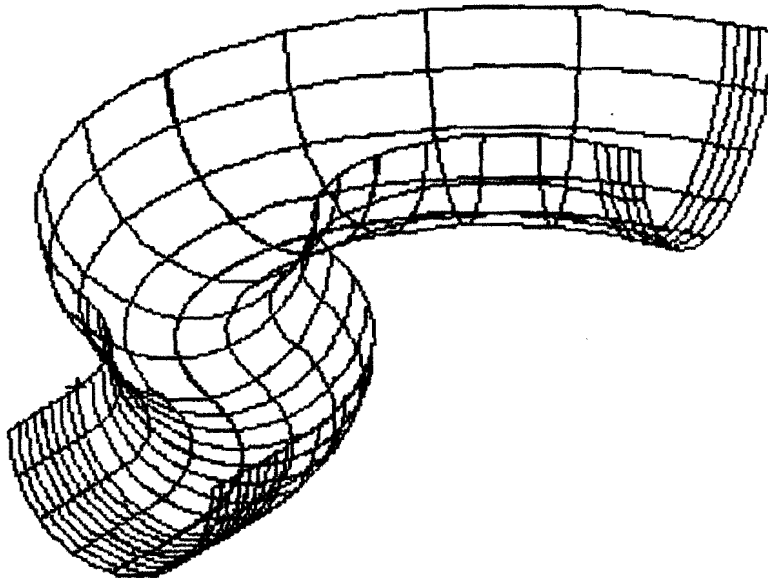
Fig. 9: Valisys machine communication overview.

Appendix C: A working impression of Valisys

In this section of my report I will dedicate some of my attention on the way Valisys presents itself. This will be done with the aid of two product examples:

- A test-product supplied by McDonnell Douglas and
- A section of an exhaust pipe create and machined with the aid of the Unigraphics system of Eindhoven, University of Technology by Roger Senden.

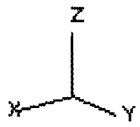
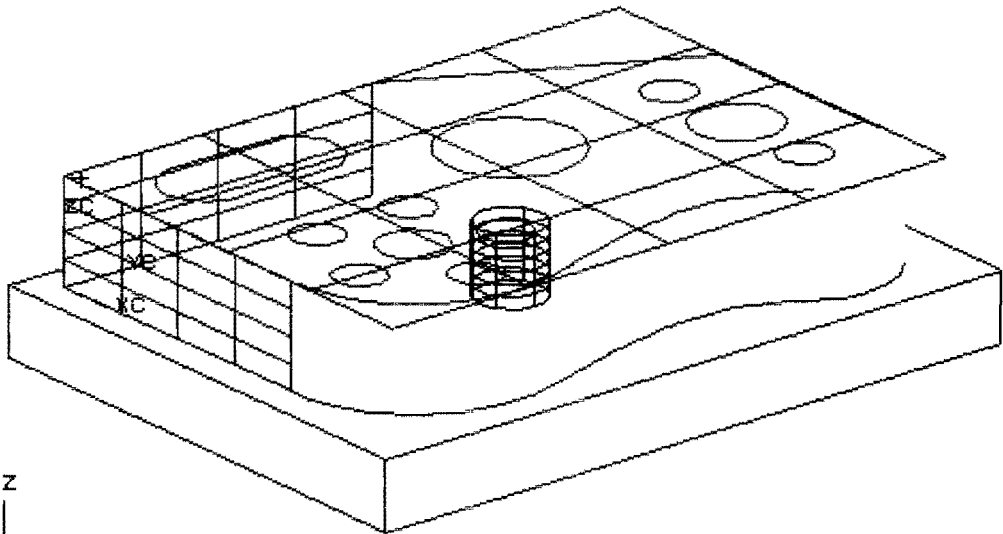
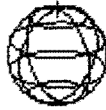
The first part is illustrated on the next page, the second part is illustrated on page 33.

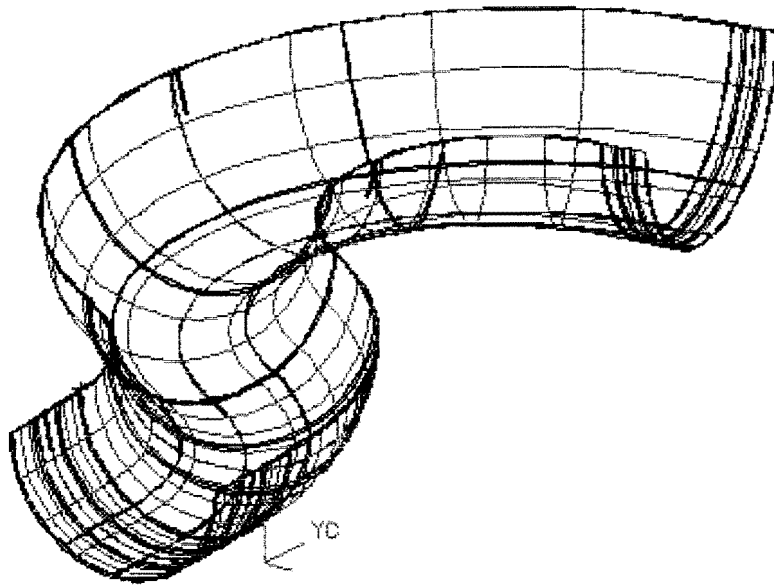


The first thing to do if one wants to start Valisys is to load a part into the Unigraphics system. Once the part is loaded Valisys can be started.

The first module to be used will be V:Check, to verify whether all the GD&T are of a correct format.

Next the V:Gauge module is activated. This module is used to create the softgauges and their datums. Some examples of softgauges and their datums are illustrated on the following two pages.

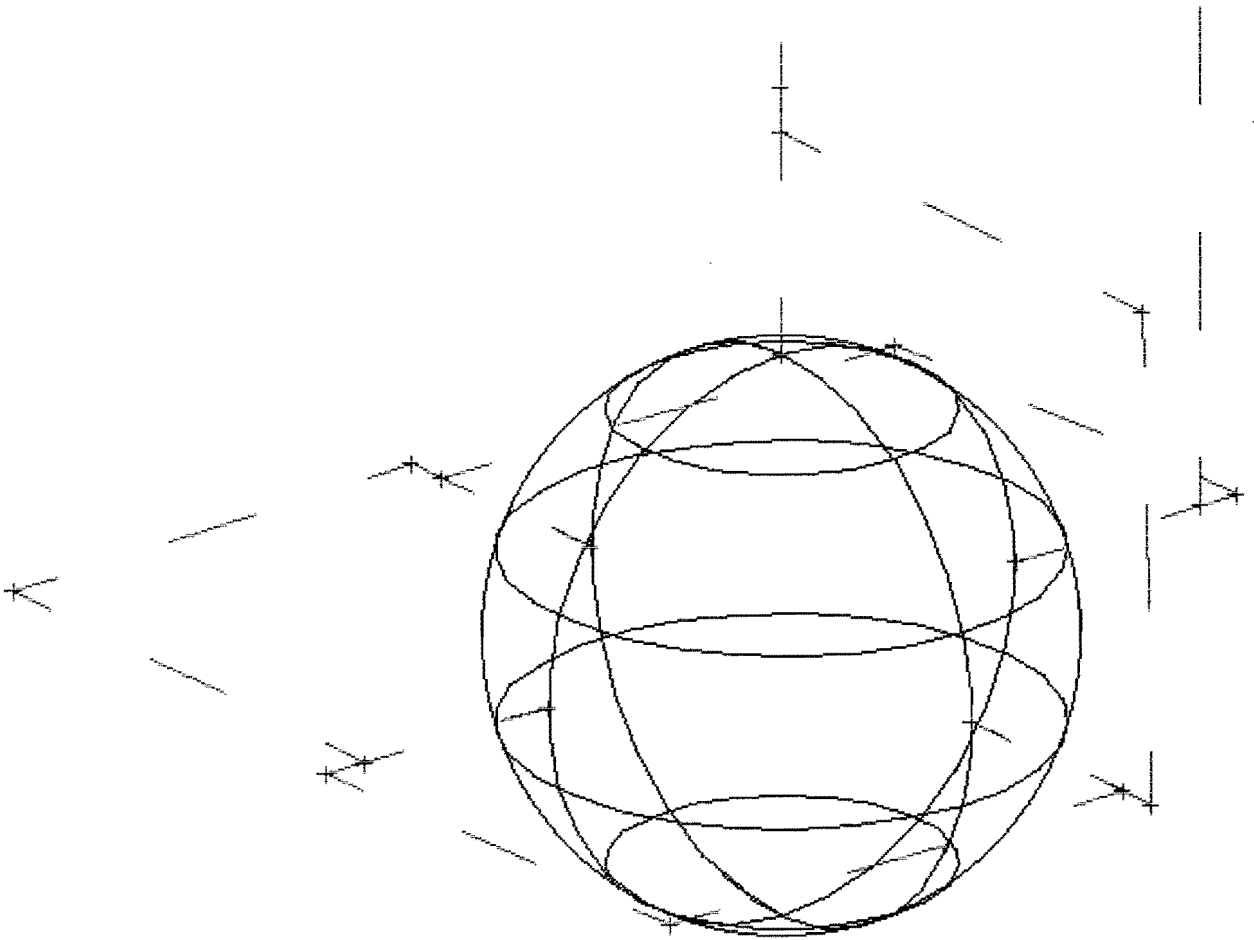




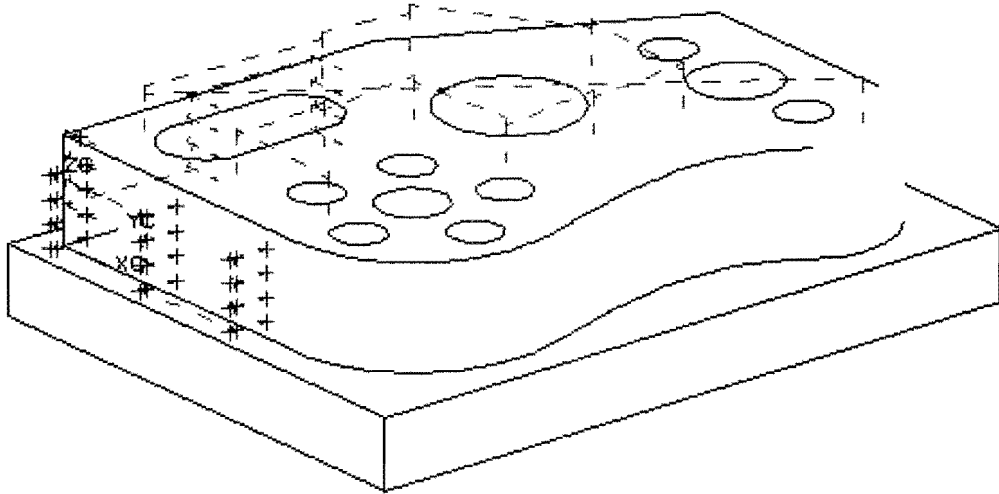
After this the module V:Path can be activated in order to create the measured paths and processes.

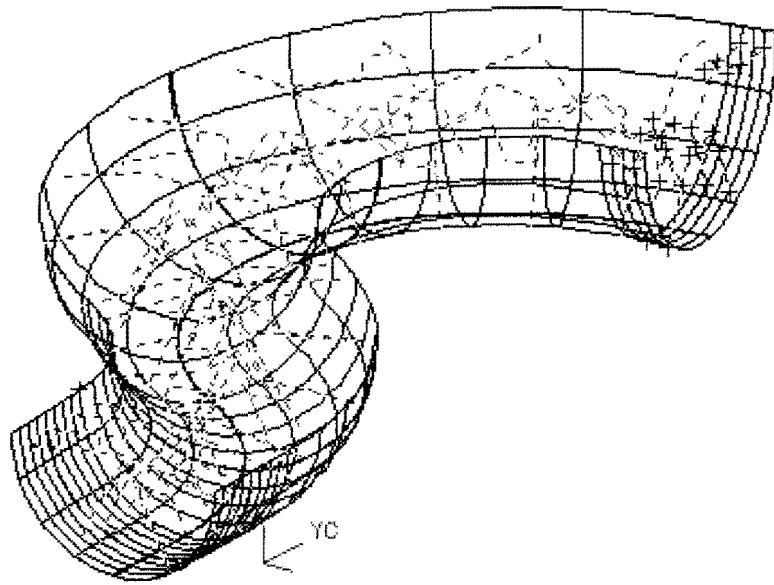
First a Calibration process has to be created in order to be sure that all of the cluster's deviations are taking into account when performing a measurement.

An example of a simple calibration process is shown on the next page.



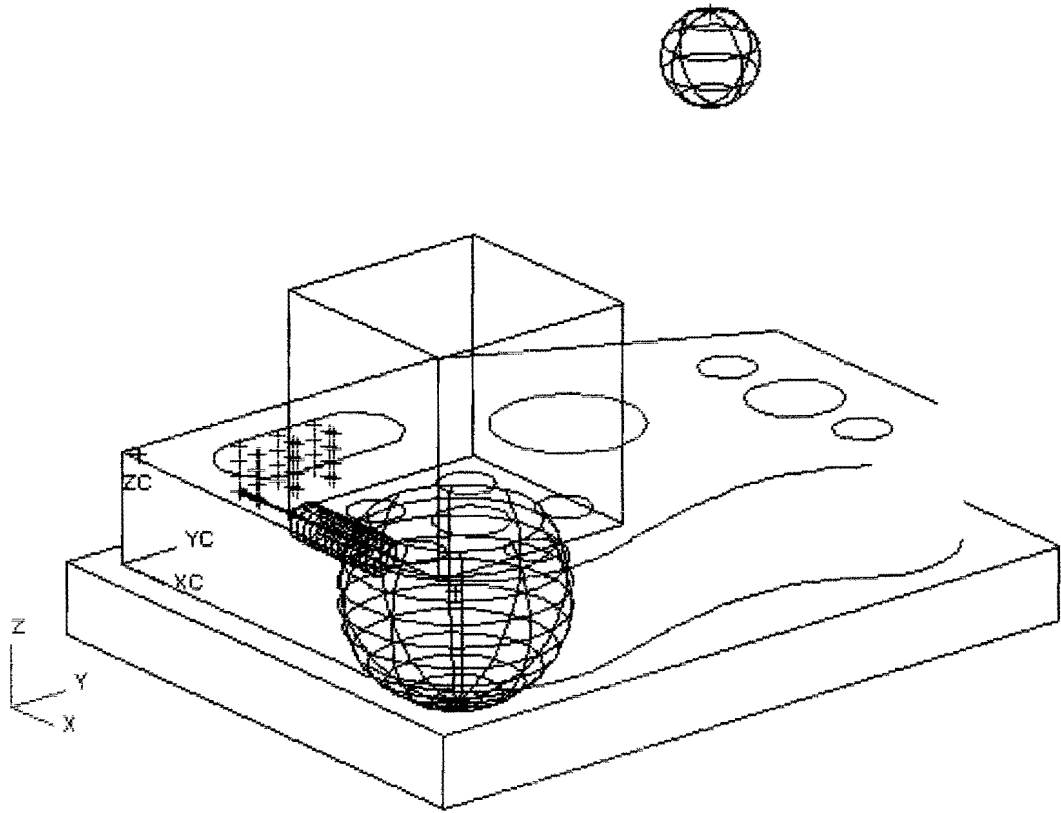
Next the orientation and inspection paths are made.
An example of these is shown on the following two pages.





After the paths have been made they have to be grouped into a process. After these processes have been formed, they have to be verified with a cluster.

It is possible in this module to perform a simulation of the measurement process. This is most of the times very necessary as is illustrated on the following page. During this simulation it is not possible to perform time studies as only the cluster is known to the program and not the machine it will be connected to or the speeds of the machine it will be connected to.



The next module that can be activated is the V:Inspect module. Within this module it is possible to control the CMM interactively, control of the CMM is returned to the VAX after each command.

An other module to control the CMM is the V:Control module. This module creates batches of VCL commands, called jobs, to control the measurement and analysis process. An example of such a job is shown underneath.

```
CONNECT:MACHINE=CMM1
USE_CLUSTER:MACHINE=CMM1, CLUSTER=PH9A
LOAD_CLUSTER:MACHINE=CMM1, FILE_NAME=PH9ACAL.DAT
TEACH_POINT:MACHINE=CMM1, FEATURE=709, TIP=-Z, A_ANGLE=0.0, B_ANGLE=0.0
ORIENT:MACHINE=CMM1, PROCESS_NUMBER=902, OUTPUT=OR1.MEA
INSPECT:MACHINE=CMM1, PROCESS=903, MEA_FILE=CAPE1.MEA, DISPLAY=CYAN
DISCONNECT:MACHINE=CMM1
ANALYZE:MEA_FILE=CAPE1.MEA, RESULTS_FILE=CAPE1.RES, GAGE_LIST=ALL, -
DISPLAY_GAGES, DISPLAY_DATA
```

If the analysis is not done from a job the module V:Qualify can be activated. This module computes all the result of a measurement and puts them in a so called Result file. An example of such a result file is shown on the next pages.

*** Results File ***

!
HEADER
VALISYS VERSION 3.0
PART NAME TESTCAPE3
PROCESS NO. 903
PROCESS NAME INSPECTION
DATE Fri Feb 16 15:13:05
ANALYSIS MODE FUNCTIONAL
END HEADER
!

GAGE 1
SPC RECORD TYPE LIMITS OF SIZE
FEATURE TYPE ROUND HOLE
NUMBER OF FEATURES 1
NOMINAL SIZE 19.90000
UPPER LIMIT OF SIZE 20.00000
LOWER LIMIT OF SIZE 19.80000
!
FEATURE 704
MEASURED SIZE 19.96594
FORM 0.08899
END FEATURE
!

! |=====|
! |A Successful Fit|
! |=====|
!

END GAGE
!=====

GAGE 2
SPC RECORD TYPE POSITION
!
DESCRIPTION
GAGE # 2
POSITION OF 1 ROUND HOLE
TOLERANCE = 0.2000 @MMC
DATUMS: A,B,C
ZERO DEGREES OF FREEDOM
END DESCRIPTION
!

GEOMETRIC TOLERANCE 0.20000
TOLERANCE AT LMC 0.40000
GEOM TOL + BONUS TOL 0.36594
!
MEASURED DEVIATION 5.34531
QUALITY OF FIT -13.60700
!

! |=====|
! |Out of Tolerance|
! |=====|
!

! |=====|
! |Valisys attempted|
! |rework but it failed|
! |=====|
!

END GAGE

!=====

!
!

GAGE	3
SPC RECORD TYPE	LIMITS OF SIZE
FEATURE TYPE	ROUND HOLE
NUMBER OF FEATURES	1
NOMINAL SIZE	39.90000
UPPER LIMIT OF SIZE	40.00000
LOWER LIMIT OF SIZE	39.80000

FEATURE	705
MEASURED SIZE	40.02936
FORM	0.01987

```

!=====!
! THIS FEATURE DOES NOT !
! MEET LIMITS OF SIZE AND !
! REWORK ATTEMPT FAILED !
!=====!

```

END FEATURE

```

!
!           |=====|
!           |Out of Tolerance|
!           |=====|
!

```

END GAGE

!=====

!
!

GAGE	4
SPC RECORD TYPE	POSITION

DESCRIPTION

GAGE # 4

POSITION OF 1 ROUND HOLE

TOLERANCE = 0.0500 @MMC

DATUMS: F@MMC

6 DOF : ROTATION ABOUT Z
 ROTATION ABOUT X
 ROTATION ABOUT Y
 TRANSLATION IN X AND Y
 TRANSLATION IN Z

END DESCRIPTION

GEOMETRIC TOLERANCE	0.05000
TOLERANCE AT LMC	0.25000
GEOM TOL + BONUS TOL	0.25000

MEASURED DEVIATION	0.00000
QUALITY OF FIT	0.99999

```

! |=====|
! |A Successful Fit|
! |=====|
!

```

END GAGE

!=====


```

!*****
!*** Results File ***
!*****
!
HEADER
VALISYS VERSION      3.0
PART NAME            UITLAAT3
PROCESS NO.          901
PROCESS NAME         INSPECTION
DATE                 Fri Mar 16 13:32:42
ANALYSIS MODE FUNCTIONAL
END HEADER
!
GAGE                  1
SPC RECORD TYPE      PROFILE
!
DESCRIPTION
GAGE # 1
PROFILE OF A SURFACE OF 4 3-D SURFACE
TOLERANCE = 0.5000
END DESCRIPTION
!
GEOMETRIC TOLERANCE      0.50000
!
POSITIVE TOLERANCE      0.25000
NEGATIVE TOLERANCE      0.25000
!
! Maximum Positive Deviation from Design:      0.08686
! Maximum Negative Deviation from Design:      0.08686
!
MAXIMUM DEVIATION      0.08686
QUALITY OF FIT         0.65254
!
! |=====|
! |A Successful Fit|
! |=====|
!
END GAGE
!=====
!

```

The Utilities module is added to perform simple operations like creating, listing and displaying features. It is also used to define clusters.

The only module left is the V:Tolerance module, which I have never used and of which I feel that it doesn't belong in a program like this.

Appendix D: Glossary

Basic Dimension	A theoretical value used to describe the exact size, shape or location of a feature.
Calibration	The process of ensuring that a measuring device is accurate and that all of its parameters are precisely known.
Calibration Artifact	A usually spherical device used to aid in the calibration process.
Cluster	A combination of probes and a ram, used in tandem on a CMM or machine centre as measuring tool. It is the part of the measurement machine which actually touches the part being inspected.
CMM	Coordinate measuring machine.
Datum	The theoretical exact point, axis, or plane derived by contact of the datum feature with a true geometric counterpart (datum simulator). A datum is the origin of location or geometric characteristics of a feature.
Datum Feature	The feature of a part which establishes a datum by contact with a datum simulator.
Datum Reference	The identifying letter on a drawing which indicates datum features.
EOF	End Of File.
Feature	The term applies to a physical proportion of a part.
Functional Gauge	A manufactured representation of the worst case mating part.
GD&T	Geometric Dimensioning and Tolerancing
Job	A sequence of VCL commands which reside as an ASCII file on the system.
Least Material Conditions (LMC)	The condition of a feature of size which contains the least remaining material.
Maximum Material Conditions (MMC)	The condition of a feature of size wherein it contains the maximum remaining material.

Modifier	The term is used to denote the application of material conditions of toleranced features of size or datum feature of size on a drawing.
Orientation	The process by which the part is touched on several surfaces in such a way so as to ascertain the exact position on the stage unambiguously. The exact position information is essential if Valisys measurement data are to have any meaning.
Path	An ordered sequence of points that define a continuous motion of the probe in order to execute an inspection of one feature.
Probe	That element of the cluster which actually touches the part under inspection. Consists of one or more styli and probe tips.
Process	A collection of inspection paths. Each inspected feature has one path.
Ram	It is the part of a cluster that holds the actual probe and connects to the CMM or NC machine.
Softgauge	The graphic and mathematical representation of a functional gauge.