

## NEW FACILITIES OF VIRTUAL MACHINES: OPERATING MACHINES FROM CAD BROWSERS, FOR ANALYSIS

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**Abstract:** The main purpose of this paper is to show advances on the concept of virtual coordinate machines, already developed for aiding calibrating and teaching tasks. It is now possible to operate these machines directly from CAD browsers. No matter how distorted are the machines, it is possible to perform the analysis.

**Keywords:** virtual machines, analysis from CAD, modelling CMMs.

### 1. INTRODUCTION

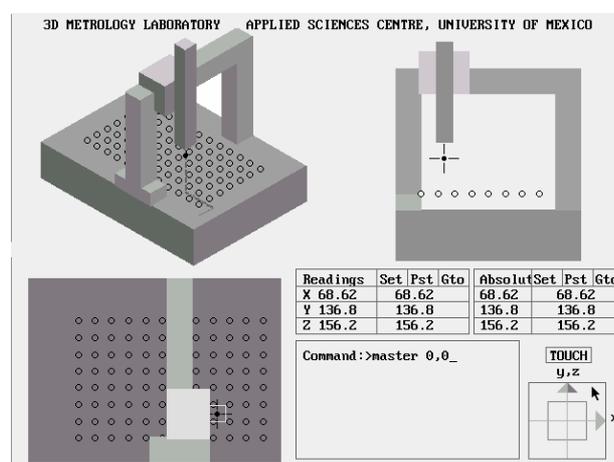
Virtual instrumentation of coordinate measuring machines (CMMs), are mostly for aiding in calibration, for correcting measurements, or for improving their operation [1][2]. Some concepts of virtual machines were focused to budget for uncertainties caused by distortion; other ones were developed to link measured values with master values, applying correlations for improving accuracy of measures. More recently developments employ CAD browsers for simulating protocols of measures. None of them do geometric meaning to results of a calibration; nor as parts, nor as whole assembled arrays of parts.

#### 1.1 Development of the virtual machine concept.

In the 1990's a model based on CAD primitives was proposed by Sánchez [3] as a non linear computational instrument. This model describes at once: distortions of all parts for all degrees of freedom; and the physical aspect of bodies as well.

The computational model was extended for simulating basic tasks of measuring and calibration, up to the level of composing a virtual instrument. States of machines reported by their interfaces, as that showed in figure 1, may be launched to CAD trough processors like DXF or IGES. From CAD browsers, those files are imported, updating assembles for new positions. Other electronic devices may catch those vectors, moving real machines to new positions.

Up to this point, real and CAD machines have passive unidirectional behaviour, driven from Interface. Verifications and correlations among real and CAD machines were not quick and ready for any time.



**Fig. 1. Graphic interface which links CAD machines, real machines, and mathematical models.**

### 2. THROUGH THE DEVELOPMENT OF CAD DRIVERS

Operation of real machines from CAD is the desired facility that permits to validate directly the theoretical models verifying matching to real instruments. Additional products based on this facility are: (a) a simulation space for teaching precision engineering, and (b) a laboratory for designing measuring protocols, where the powerfulness of CAD is ready for analysis

#### 2.1 Principles of CAD interface

As analyzed in geometric text books like [4], two properties have the b-splines at once: a shape viewed from outside; and its points distributed along the shape, according a parametric function. In the same way, the shapes of bodies of CMMs may be related with functions of distribution.

B-splines 2 x n degree representing scale and guide-ways, may be grouped and assembled for a particular vectors of measures, as showed in figure 2.

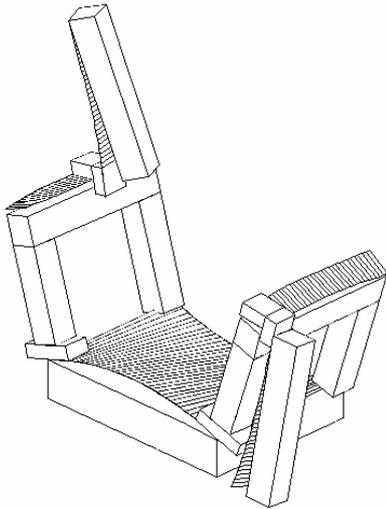


Fig. 2. Assemblies of all bodies of a CMM, for lowest and highest positions.

Starting from positions of encoders taken as measures, B-splines and associated bodies may be transformed; be written as IGES files; and be imported from CAD browsers. Additionally, the processors may be able to send the vector of measures through ports (RS232), which cached from electronic devices, will move bodies in the real machines.

Up to this point, a theoretical machine is operated inside CAD, and assembled with high accuracy. But that machine may not coincide with none real, or the probe may not reach the desired absolute position. Two problems of reverse engineering have we to face: (a) how to define the unknown splines for getting the same behaviour of virtual machine with the real, and (b) how to define the measures for a final position of probe which must coincide with masters.

### 2.2 Defining the best CAD interface, or approximating to diagnoses.

If previous primitives are not already defined, it is not possible to drive a virtual CAD machine; but a preliminary array of splines, let us to draw a set of approximated positions. Differences among desired and approximated positions may feedback hypothetical shapes of splines in a process, reaching tolerances. If tolerances are reached, we assert that that machine is one of the family that produce that input-output data. See figures 4 for seeing the last hypothesis about the shape of main guide-way, and figure 5 for seeing coincidence with that of the real machine.

But it is necessary to answer the question: Are there many distorted CMMs producing the same correlation among measures and data of masters? The answer is “yes”, depending on the embodiments of CMMs. Moreover, many orthogonal equivalencies produce the same input-output data.

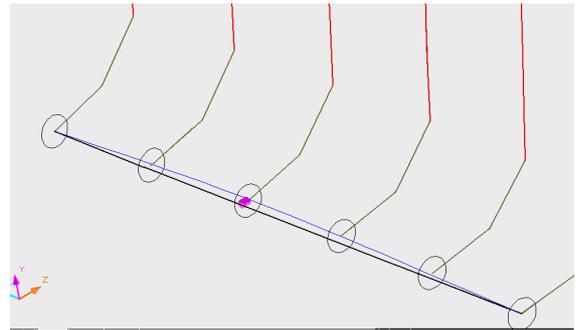


Fig. 3. CAD drawing of the lowest hypothetical path, in blue, on which car slides.

However, the answer is “not many” if invariance of paths is conditioned as a part of the process of solution. A deeper discussion about the use of invariant paths for doing true diagnoses is taken into account for further analysis in TC-8, TC-10, TC-14 meetings; and in the Measurement issue.

### 2.3 Short process for matching inputs outputs.

Supposing that absolute positions are defined as functions of measures, through shorts polynomials like the next:

$$x = f(u, v, w) \quad y = g(u, v, w) \quad z = h(u, v, w) \quad (1)$$

Then, positions  $x, y, z$ , may be calculated if external functions are ready for incoming  $u, v, w$ , which are called through the *shell* CAD command. The protocol of next paragraph will produce paths from actual position to  $u=100, v=200, w=300$ :

```
shell <↓
xyzFuvw 100 200 300 <↓ <↓
dxfin <↓ <↓
```

where the procedure *xyzFuvw* is programmed for giving a DXF data-base as result. Paths of probe are drawn for linear variations of  $u, v, w$ , parameters.

For inverse processes, where we look for a vector  $u, v, w$ , which an  $x, y, z$ , absolute position is desired, two possibilities are available: to nest (1) in recursive processes up to reach tolerances, or getting inverse functions. Inverse functions however, need a more deep mathematical analysis. Advantages of the first short process, is that it requires only a few seconds to run; but the main disadvantage is that information for assemblies are not ready since functions don't involve shapes.

### 2.4 Large process for moving from CAD

“Moving from CAD” means here, that measures, distortions, assemblies and master probe position, match, and may be verified inside CAD.

But we have again two possibilities: (a) The assembly at final position, and (b) the true path of probe between the initial and the final position. The first is a particular case of the second.

For the fist case, we have a simpler solution than that used for diagnosing mentioned in 2.2, since guide-ways are

already defined. Hypotheses are established only for the position and tilting of assembled bodies.

Simulation of true paths on the other hand, is useful when used for checking linearity of movement, using light beams or straight edges. Since there are many paths between two points, the most probable case is that, with linear movements in the operational space. The solution is then to store a  $u_i, v_i, w_i$ , vectors in a database got from xyzFuvw which satisfy an  $x_i, y_i, z_i$  array, where all points of this last, are aligned. For linear paths of probe in white, or for movements along guide-ways in yellow, see the figure 4.

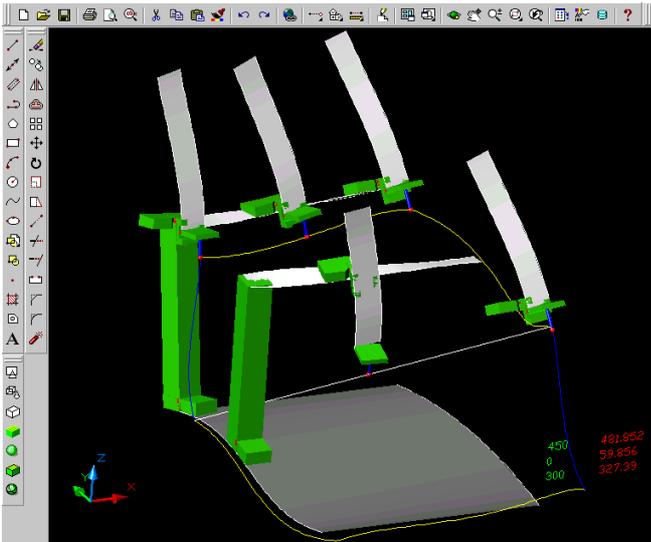


Fig. 4. The machine built inside Autocad, calls functions of paths and assemblies, for both movements: linear and freeze axis.

### 3 RESULTS AND VALIDATION

As virtual tool for analysis, the CAD machine uses the AutocadCAD facilities for testing models and processors, once states are converted to CAD files. For all cases they produced errors less than  $0,1 \mu\text{m}$ . Cases of more than one solution, apart than orthogonal equivalencies as considered in 2.2, were not presented. Abundance of generic cases could constitute a validation.

Although the resource is verifiable by itself using CAD, its interfacing with physical instruments produces new uncertainties. Validation would require abundance of physical machines, deformed in many ways, and calibrated for all distortions. A preliminary validation was reported using a high distorted machine reported in [5], and showed in fig. 5. Discounting 2<sup>nd</sup> order factors of instability, all states matched: (a) correlations among masters and measures, (b) the state of real machine (c) the state of CAD drawing.

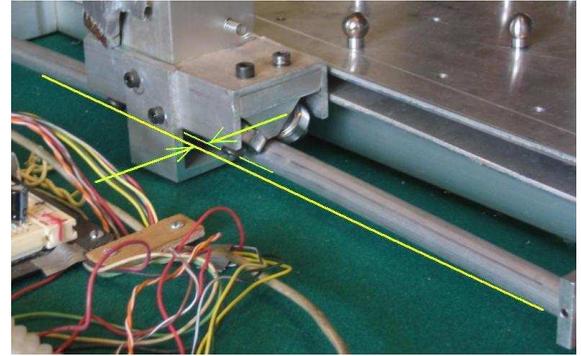


Fig. 5. The distortion of lowest guide-way coincide with CAD equivalent, drew in magenta in fig 3.

### 3. CONCLUSION

Under this concept of virtual machine, the loom that weave the relations among real machines, models for their simulation, interfaces for operation, and equivalent CAD for analysis, was built. Diagnoses of machines and analysis of propagated errors is now possible to do surely inside CAD.

### 4. REFERENCES

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