Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

AUTOMATIC PHOTOGRAMMETRIC CAR-BODY MEASUREMENT

H. Schewe, Stuttgart

1. Car-body Measurement

The new design of a car usually starts with making and styling a real model, especially as far as its shape and external features are concerned. The models, or parts of it, have then to be measured. The results of such primary measurements go into a CAD system which takes over the further technical design and styling, including eventually the preparation of production. Also special parameters, like visibility conditions for the driver, the available headroom or the size of the engine compartment are originally derived from a model. Further applications of car-body measurements are in the fields of assembly control or crash tests. As far as this paper is concerned we deal primarily with the geometrical measurement of design models. The data will subsequently be processed and analyzed, thus contributing to the further design development.

In order to describe the geometrical shape of the car-body as well as possible, usually two different types of elements are measured:

a) Surfaces: The whole car-body is subdivided in areas the surfaces of which are described by the intersections with parallel planes which usually define a 100 mm grid. Along these intersection-lines points are measured densely, which represent the surface between the surface delineations.

b) Shape-lines: The shape-lines are lines which are essentially responsible for the shape of the vehicle. Thereto belong the boundaries of single parts as doors or mudguards, but also all lines where two essentially plain surfaces intersect in surface edges.

2. Coordinate Measurement Machine and Photogrammetry

Very often the geometrical measurement is done with large coordinate measurement machines. For the shape-line measurement narrow tapes are attached on the model, defining the shape-lines which are to be followed manually with the measuring head by the operator. For the intersection-line measurement one coordinate-axis is clamped. Consequently only two degrees of freedom are left. During this measurement the operator has only a controlling task by adjusting the measuring head, in order to keep it orthogonal to the surface, by interrupting or stopping the measurement, when the boundary is reached.

This procedure works quite well. Its main disadvantage is, however, that the design model respectively the car-body has to be available for the whole measurement process which may take 3-5 days. Also, the huge coordinate measurement machines cannot be transported. Therefore, the parts which are to be measured have to be transported to the measuring machine which also can be a time factor.

A photogrammetric system on the other hand has the advantage, that the necessary photographs and control point measurements can be done directly on the scene in a shorter time, perhaps in 1 or 2 days. Equally important is the fact,that the photographs capture, document and store the complete model. The latter aspect is particularly essential with regards to the keeping of archives. Design models are objects which are subject to continuous changes. Already a short time after measurement a model may be changed so much that re-measurement of details may become desirable. In a photogrammetric system the previous photographs remain available for supplementary measurements.

For such reasons a photogrammetric system for the measurement of design models was considered at the VOLKSWAGEN AG in Wolfsburg, leading to a number of operational specifications (cf.[9],[10]).

In order to ensure the required measurement accuracy of about 0.1 mm - 0.2 mm the photographs are taken at a scale of about 1:15, i.e. at a distance of about 1.5 m to the object. Under such conditions between 10 and 20 stereo-pairs are necessary and sufficient to capture a complete design model.

There must be enough control points distributed over the car-body shell to obtain the model orientations with a sufficient accuracy and redundancy. The vehicle's coordinate system is defined and represented by four points at the wheel-houses which are used directly within the conventional measuring procedure. In the photogrammetric case additional control points are necessary, as all stereo-pairs must be oriented with regard to the vehicle system. A theodolite system performs best here for the measurement of the control points which are physically taped onto the surface of the object.

The photogrammetric method requires sufficient texture on the surface to be measured, in order to ensure precise and reliable stereoscopic viewing and measurement. The surfaces in question have usually little texture and poor contrast; therefore the texture must be enhanced or produced artificially. The best results have been obtained from a special texture projector that projects optically an artificial pattern onto the surface. At present, the optical texture projection is maintained and stable throughout the exposure time per photo-pair.

The actual photogrammetric 3D-measurement of the surfaces can be done in the conventional way, with an analytical plotter, for instance. Here, we report about an almost completely automated measuring procedure which is based on digital image processing and digital image matching in particular.

3. Description of the system InduSURF

The automatic measurement system, which operates in connection with the analytical plotter Zeiss Planicomp C100, its computer HP1000 A900 and supplemented Hamamatsu CCD-cameras for the on-line digitization of image windows. The hardware system has been described earlier, see [7] and [8] (see fig.2). In addition a texture projector developed at ZEISS Oberkochen is part of the InduSURF system. It projects texture onto the surface without direct contact to the object (see fig. 3 and 4).

The software equipment of the system was developed at the Forschungsinstitut für Luftbildtechnik GmbH, Stuttgart in cooperation with the Institute for Photogrammetry of Stuttgart University and ZEISS Oberkochen. It consists essentially of three parts:
- Sensor Calibration
- Shape-line Measurement
- Surface Measurement along Grid-lines

3.1 Sensor Calibration

The sensors of the CCD-cameras have to be calibrated against the photo carriages and the floating marks, respectively, of the analytical plotter to ensure that manually oriented models can be measured automatically or that automatic measurements can be supplemented by manual measurements. A point measurement by the operator via the floating mark can be compared or used together with automatic measurements only if sensor and floating mark have been brought in relation.

The sensor calibration can be done in a very short time by grid measurements. It should be executed after longer measurement intermissions as the calibration may drift because of temperature effects on the camera sensors or on the photo carriages. During the automatic measurement the calibration is checked periodically with the help of checkpoints within the photograph and corrected if necessary.

3.2 Shape-line Measurement

Narrow adhesive tapes are fixed onto the prominent edges of the car-body as for the conventional measurement. They represent the shape-lines to be measured.

For the automatic measurement special, retro-reflecting tapes are used which stand out in the image by high contrast. Hence they can be detected as graylevel edges in the images. Retro-reflecting tapes have the property to reflect back the projected light with a very small dispersion angle. If there are dim illumination sources around the cameras during photographing, the tapes appear as very bright lines in the images (see fig. 4). The contrast of the projected texture pattern is not very much affected by the additional dim illumination.

Besides the absolute orientation of the photogrammetric model the preparation of the automated measurement consists of specifying start- and end-points and if necessary intermediate-points on the lines to be measured. In addition the width of the used tape and the maximum allowed stride between the points along the line have to be defined. Thereafter the automatic measurement can be started.

In the software an edge-detection algorithm is used, which looks for the defined side of the tape and determines points on the correspondent graylevel edge. Any selected point is transferred to the second image and the line-point in space is determined. Also the graylevel structure of the neighborhood contributes to the actual matching.

The further course and the expected direction of the edge are estimated by prediction based on the specifications of the operator. The next point measurement is started at the predicted position. If the measurement fails within the edge detection or the matching procedure the stride is reduced and the point measurement is re-attempted. This strategy ensures that the point density is adapted to the line curvature.

The measuring process and the data structure are organized in that way, that normally all given lines are first measured automatically as far as possible. Manual assistance can be called thereafter. It also could take place immediately at each failure spot.

The measured data can be transferred to further programs (e.g. the intersection-line measurement) or to interpretation by separate interface programs.

3.3 Surface Measurement along Grid-lines

Usually the shape-lines form the border of areas, within which the surface is smooth to some extent. To describe these surfaces more exactly a number of profiles are measured which are defined by the intersection of parallel planes with the surface. In general the intersecting planes are orthogonal to the coordinate axes; nevertheless planes with arbitrary orientation in space can be used, too.

For the automatic measurement the imaged surfaces should be essentially free of reflections and contain sufficient texture. The texture is projected by the texture projector (cf. fig. 3 and 4).

The measuring strategy is devised in that way that positions where no measurement is possible (disturbances in the image, hidden parts, reflections) are automatically circumvented and that the arising gaps are kept as small as possible. This strategy is supported by the data structure which allows different approaches to a difficult spot by switching over to other grid lines or other parts of them (cf.[12]).

The point measurement itself is performed optionally by least-squares matching or by a feature based matching algorithm (cf.[5],[6],[12]). The algorithms are modified to take advantage of the epipolar conditions existing after relative model orientation. Hence only x-parallaxes have to be measured to determine a surface point, the y-parallaxes being eliminated by the relative model orientation.

The photogrammetric model must be absolutely oriented for the measurement of grid-profiles which are defined as intersection lines in object space. In addition to the absolute orientation, preparation of the measurement consists in defining some parameters concerning the type of measurement, window size, maximum stride etc.. Also geometric parameters have to be defined like the intersecting planes, boundaries, starting points etc.; pre-measured shape-lines can be used as boundaries for instance. After the preparations the measurement can run optionally with or without operator assistance. The latter mode is chosen especially for running the system during night hours.

With the operator aided measurement the automatic measurement continues until possibly a failure spot occurs, where no automatic measurement is possible. In this case the operator is asked to help the system and to measure some points manually if possible or to stop the measurement at this place and have the measurements continued at another place.

It is preferred to measure without operator assistance. In this mode the system measures grid-lines until completion or until no further automatic measurement is possible anywhere. In case that failure spots are present and have been left out the operator will subsequently inspect the critical spots and continue until completion.

3.4 Accuracy

The matching accuracy of the digital least-squares correlation reaches a standard deviation of about 1/20 of linear pixel size, provided sufficient texture is present. With 20 micron pixel size this corresponds to a parallax accuracy of about 1 micron. Combined with the inaccuracy of the analytical plotter of about 1-2 micron a total parallax accuracy of about 2 micron is obtained. With photo scale of about 1:15 and a base-height-ratio of about 1:2.5 the internal measuring accuracy of depth measurements amounts to a standard deviation of < 0.1 mm in object space.

The absolute accuracy depends, in addition to the measuring accuracy, on the accuracy of the relative and absolute orientation. on the control point measurement the sensor calibration and on image errors.

To obtain the required absolute accuracy in the order of 0.2 mm - 0.3 mm in object space some severe conditions must be met:
- precise control point measurement (better than 0.1 mm)
- good absolute orientation (residuals less than 0.1 mm)
- good relative orientation (residuals less than 2-3 micron)
- well textured surface
- good sensor calibration
- correction of image errors to better than 5 micron

Inaccurate absolute orientation, residual sensor calibration errors and residual instrumental and image errors produce systematic errors which eventually determine the obtainable absolute accuracy.

3.5 Speed

The total measuring process is composed of operational steps, like data sampling data transfer and data decoding, photo carriage movement, stride control, surface prediction, iteration to the grid profiles or shape lines and other organizational procedures. The mean time over the whole measuring procedure per point can be quoted to be < 2 seconds with the presently used hardware. It depends on the quality of the predicted approximate values, the used window size and other parameters such as surface slope, curvature or texture. One photo pair may contain several thousands of points.

By using a faster computer and by speeding up the data transfer it is realistic to expect a reduction of mean measuring time to tenths of a second per point.

4. Application and Further Development

The development of the InduSURF system has been supported by the VOLKSWAGEN AG Wolfsburg. VOLKSWAGEN has been successfully using the system since October 1986 as pilot customer for the survey of pre-design car models.

The project-accompanying support of VOLKSWAGEN AG during the system development resulted in closeness to practice and user comfort. Future improvements and extensions of the system will continue to be made in cooperation with the automobile industry in order to meet the practical requirements for extended application.

Points of interest for the immediate extension of the system are the treatment of rugged surfaces or the continuous measurement and matching of several photopairs. A similar system is being tailored to produce automatically digital terrain models of topographic surfaces from aerial photographs.

Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

REFERENCES

/1/ Ackermann, F.: High Precision Digital Image Correlation, Proceedings, 39. Photogrammetric Week, Stuttgart, 1983.

/2/ Ackermann, F.: Digitale Bildverarbeitung in der photogrammetrischen Stereoauswertung, Proceedings, 40. Photogrammetric Week, Stuttgart, 1985.

/3/ Claus, M.: Digital Image Correlation with the Planicomp System, Proceedings, ISPRS-Symposium Commission V, Ottawa, 1986.

/4/ Förstner, W.: On Automatic Measurement of Digital Surface Models, Proceedings, 40. Photogrammetric Week, Stuttgart, 1985.

/5/ Förstner, W.: Prinzip und Leistungsfähigkeit der Korrelation und der Zuordnung digitaler Bilder, Proceedings, 40. Photogrammetric Week, Stuttgart, 1985.

/6/ Förstner, W.: A Feature Based Correspondence Algorithm for Image Matching, IAP Vol. 26-3/3, Rovaniemi, 1986.

/7/ Gülch, E.: Geometric Calibration of two CCD-Cameras used for Digital Image Correlation on the Planicomp C100, IAP Vol. 25-II, Rio de Janeiro, 1984.

/8/ Gülch, E.: Instrumental Realization and Calibration of Digital Correlation with the Planicomp, Proceedings, 40. Photogrammetric Week, Stuttgart, 1985.

/9/ Happe, A.: Photogrammetrische Meßtechnik, Prinzip und Anwendungen im Automobilbau, Volkswagenwerk AG, Forschungsbericht Nr.FMT7830V/5, 1978.

/10/ Höchtl, W.: Nahbereichsfotogrammetrie im Fahrzeugbau, I. Grundlagen und Anwendungsmöglichkeiten, Volkswagenwerk AG, Forschungsbericht Nr.FMT8401V/5, 1983.

/11/ Pertl, A.: Digital Image Correlation with the Analytical Plotter Planicomp C100, IAP Vol. 25-A3b, Rio de Janeiro, 1984.

/12/ Schewe, H., Förstner, W.: The Program PALM for Automatic Line and Surface Measurement Using Image Matching Techniques, IAP Vol. 26-3/2, Rovaniemi, 1986.

ABSTRACT

The paper gives a short review of the purposes of and the equipment for car-body measurement. The photogrammetric measuring system InduSURF and its present performance is described with special regard to automatic measurement procedures based on digital image processing.

AUTOMATISCHE PHOTOGRAMMETRISCHE KAROSSERIEVERMESSUNG

ZUSAMMENFASSUNG

Es wird kurz dargestellt, zu welchem Zweck und mit welchen Mitteln Karosserievermessung betrieben wird. Das photogrammetrische Meßsystem InduSURF und sein gegenwärtiger Leistungsstand wird beschrieben, mit besonderer Betonung des automatischen Meßverfahrens durch digitale Bildverarbeitung.

Dipl.-Ing. H. Schewe
Forschungsinstitut für Luftbildtechnik GmbH
Smaragdweg 1
D-7000 Stuttgart 1

Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

FIGURES

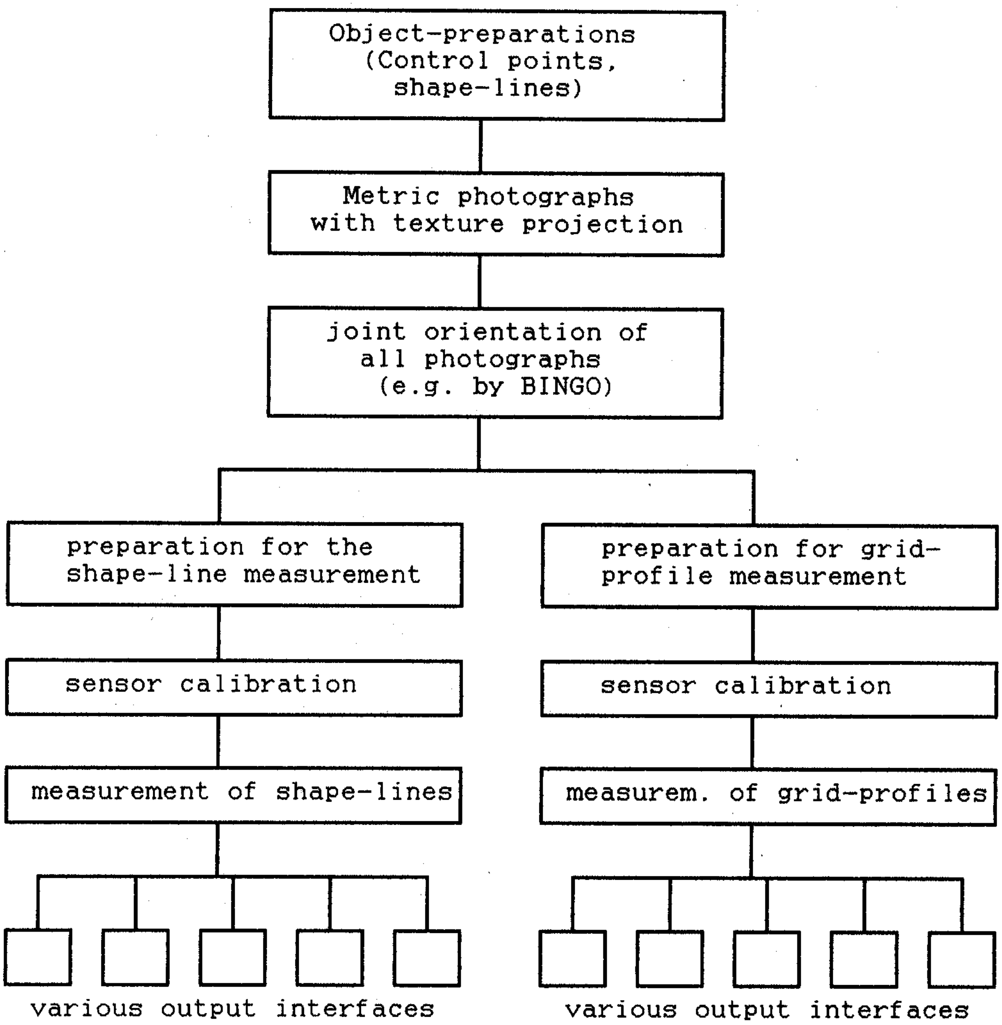

Fig.1: Schematic overview over car-body measurements with InduSURF

Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

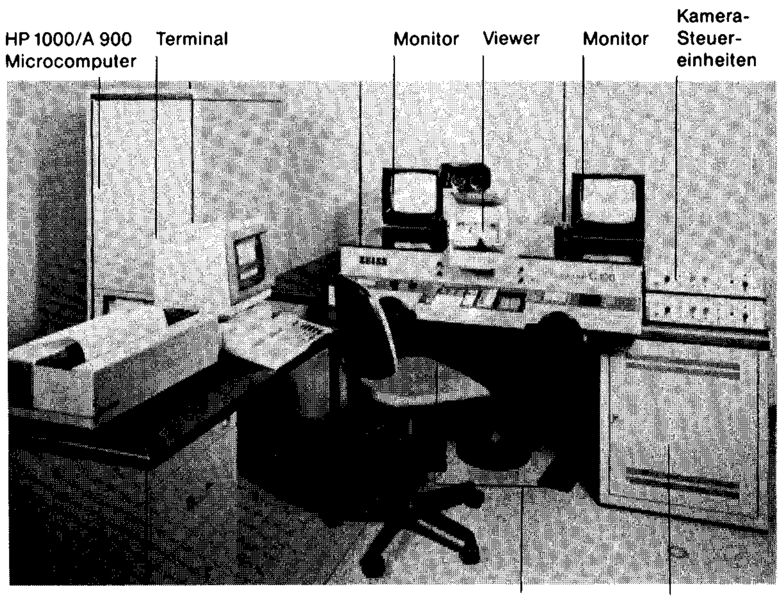

Fig.2 Hardware components of the InduSURF system

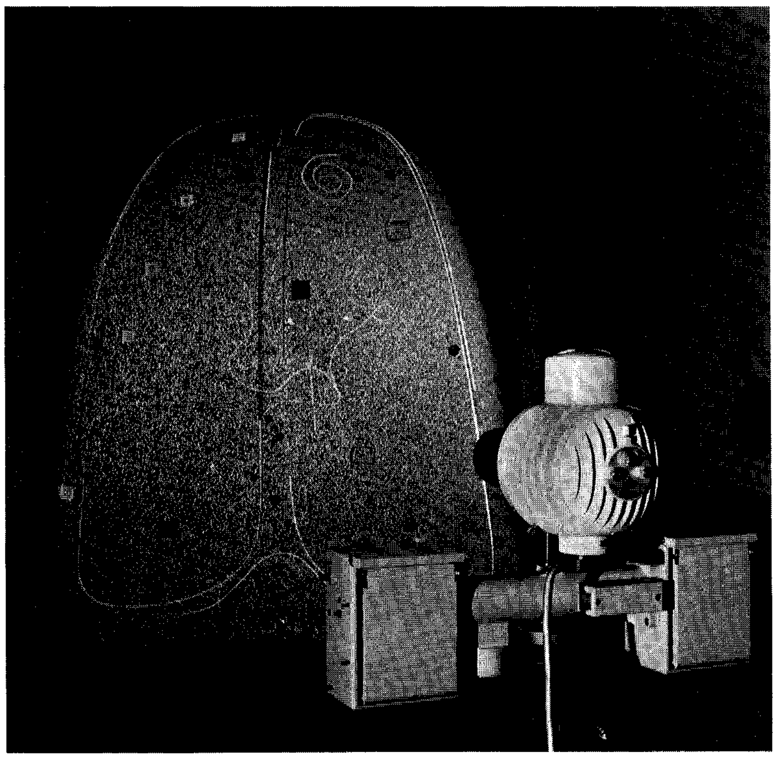

Fig.3 Stereo camera with texture projector and test surface

Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

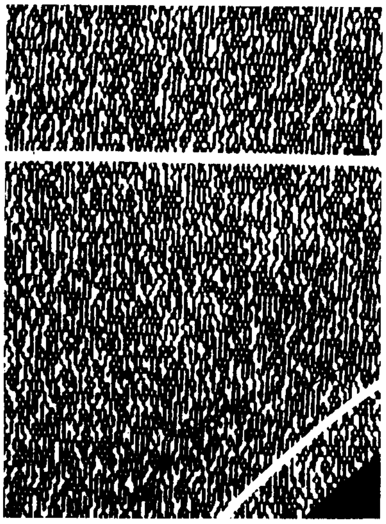

Fig.4 Surface-Texture with shape-lines

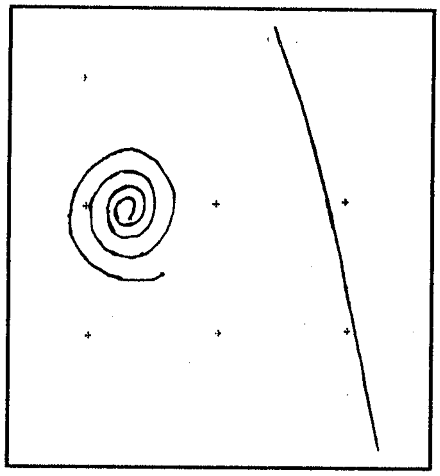

Fig.5 Part of a plot of automatically measured shape-lines on the test surface

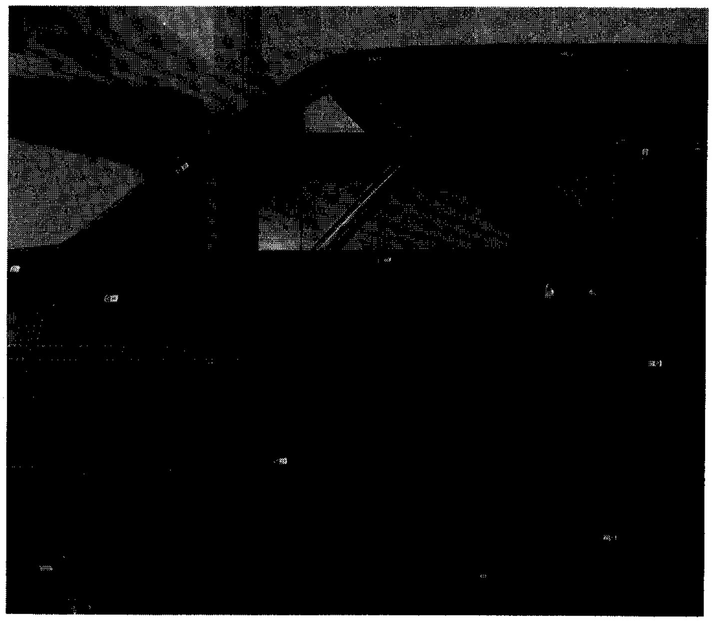

Fig.6 Car-door with sprayed on texture

Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

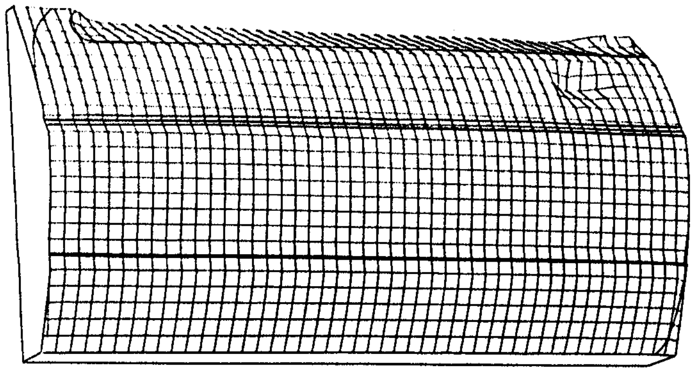

Fig.7 3D-Sketch of an automatically measured car-door

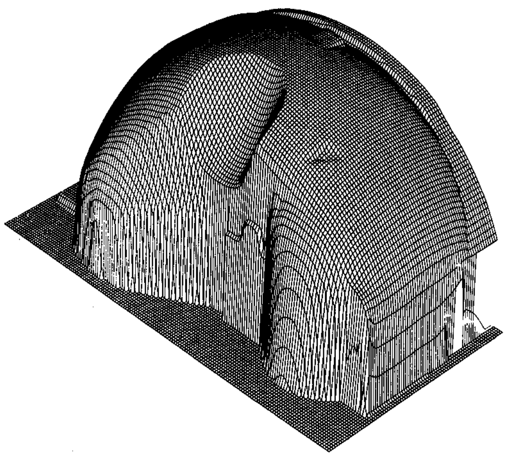

Fig.8 3D-Sketch of an automatically measured wheel-house