A system for recording 3D information with applications in the measurement of plant structure

Thomas Mangoldt[1], *Winfried Kurth*[1], *Alexander Bucksch*[1], *Peter Wernecke*[2], *Wulf Diepenbrock*[3]

[1] Brandenburgische Technische Universität Cottbus, Chair for Practical Computer Science / Graphics Systems, P.O. Box 101344, D-03103 Cottbus, Germany
[2] Martin-Luther-Universität Halle-Wittenberg, Department of Agro-Ecology, Hallesche Str. 44, D-06246 Bad Lauchstädt
[3] Martin-Luther-Universität Halle-Wittenberg, Department of Crop Science, Ludwig-Wucherer-Str. 2, D-06099 Halle (Saale)
Mailto: tm@informatik.tu-cottbus.de

Lehrstuhl Grafische Systeme

Virtual Crops

Existing systems for 3-D measurement of plant structure are either very expensive (laser-scanner based technologies) or laborious to apply (electromagnetic devices requiring serial measurement of single points by hand). Furthermore, the existing commercial equipments do usually not well support the specific requirements of plant structures frequent occlusions, wilting under long exposure to strong light, movement of leaves, specific thin shapes... We have thus started to develop and establish a cheap, flexible 3-D recording system which will be specifically tailored to the needs of plant structure measurement, both in the design of its hardware components and in its algorithms.

Methods of optical 3-D measurements are based on:

- fringe projection,
- Gray code projection
- Moiré techniques
- digital photogrammetry or
- phasogrammetry.

Inspired by a commercial 3-D Laser Scanning System, used in Bad Lauchstädt for investigation of barley plants we initiate the development of a cheap, flexible 3-D recording system. The system conception based on a standard (customary in the trade) camera and video projector as well as a turn table is shown in Figure 1.

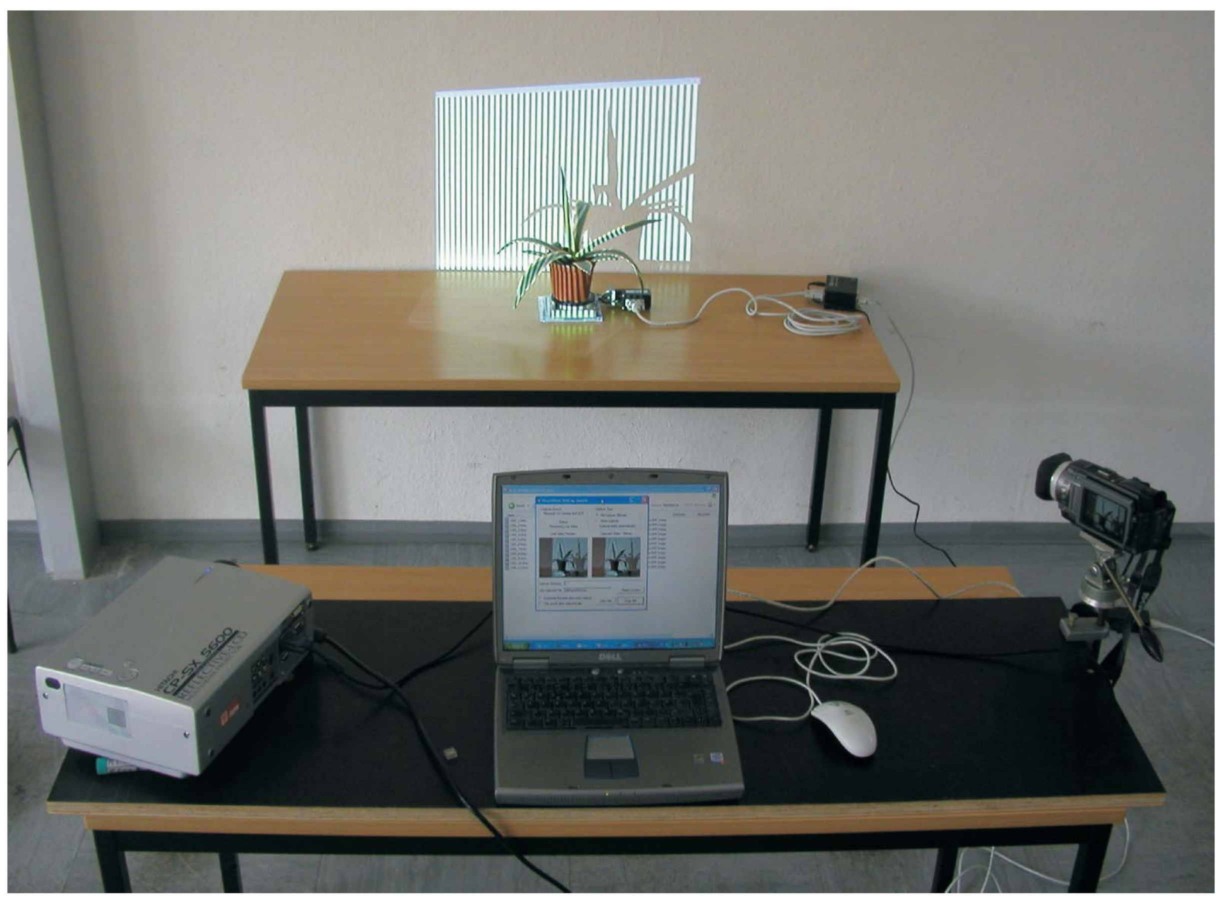

Fig.1

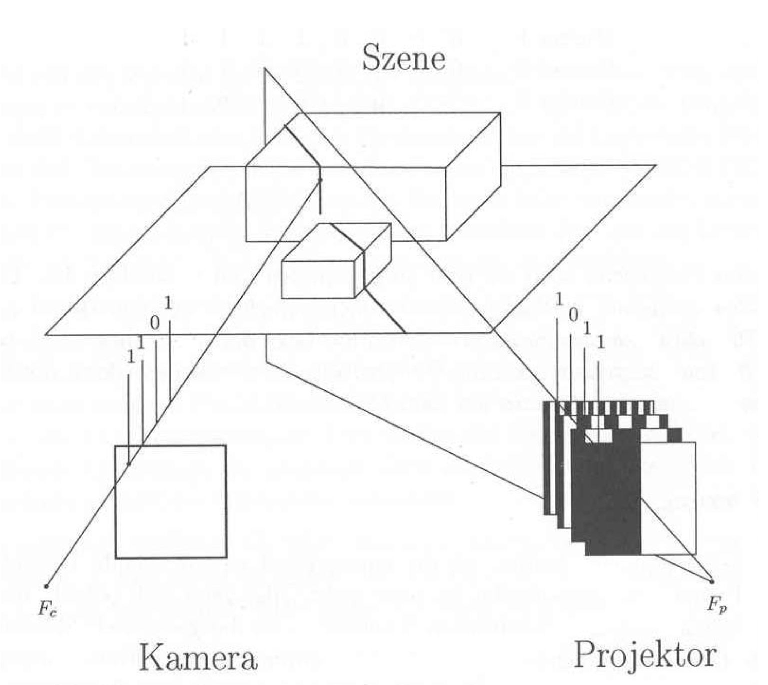

Fig.2 (from[1])

The measurement method is based on gray code (Figure 2) projection. Following the experiences made in Bad Lauchstädt, a combination of this method with phasogrammetry[3] will be investigated. The latter is a self-calibrating system with the highest possible precision. That is important in the measurement of plants, because plants have only small diameters of organs and are flexible. Form stability between two positions of the turn table cannot be guaranteed.

In Bad Lauchstädt by means of a commercial 3D Scanner (RSI) plants are investigated. **System features are:**

- Non-contact shape capturing of physical objects forWindows computers
- Operation principle: Enhanced structured light and phase shift method, 3D coordinate computation using working space based spline interpolation
- Basic configuration: Optical sensor (projector, camera, framegrabber) and software (surface determination and export as a point cloud)
- Implementation using standard image processing components from the application oriented user interface
- Texture option for accurate superposition of color information
- Homogeneous distribution of 3D points
- Turntable option for automated 360° capturing

Disadvantages:

- Size of the working space restricted
- field measurements are impossible
- proper motions of plants cause inaccuracies
- Unsufficient accuracy of small sharp edged and hidden objects
- Calibration is very time consuming

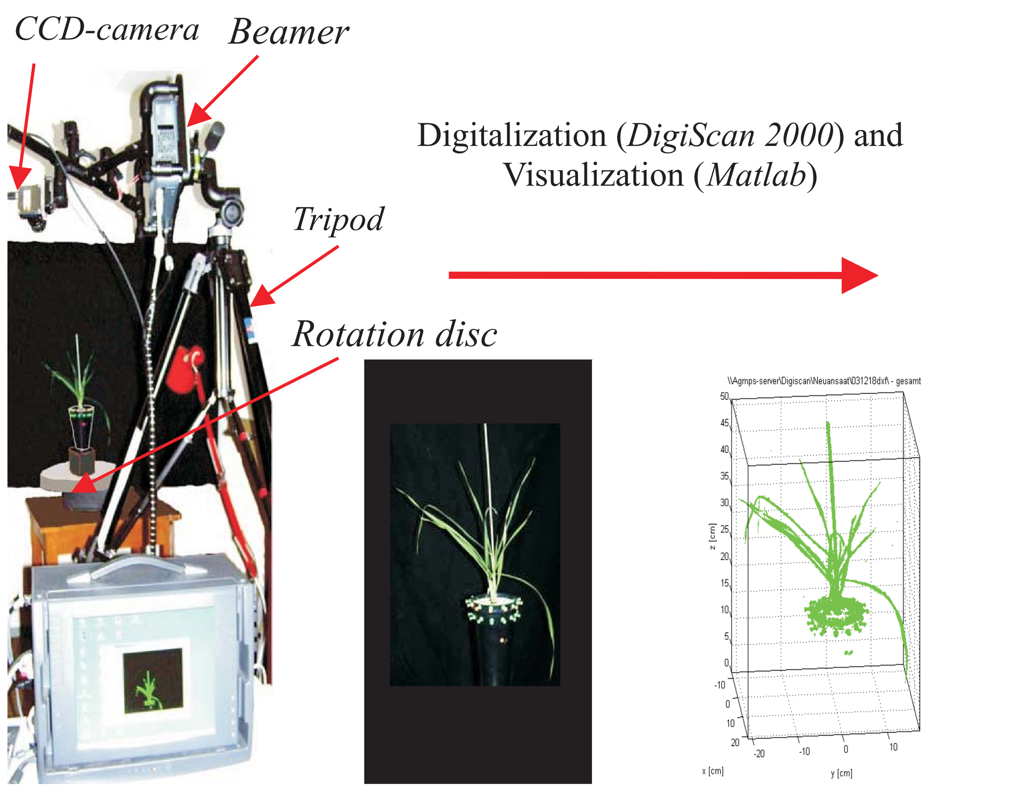

Fig.3: *Digiscan2000* system, barley (*Hordeum vulgare* L.) plant in a pot and the visualization

Figure 4 shows an original point-cloud from the RSI-Scanner. This point-cloud was produced by the technique of structured light, which is described above. The point-clouds of 4 views are matched by a nearest-neighbour algorithm between each of the 4 point-clouds, to identify and merge points.

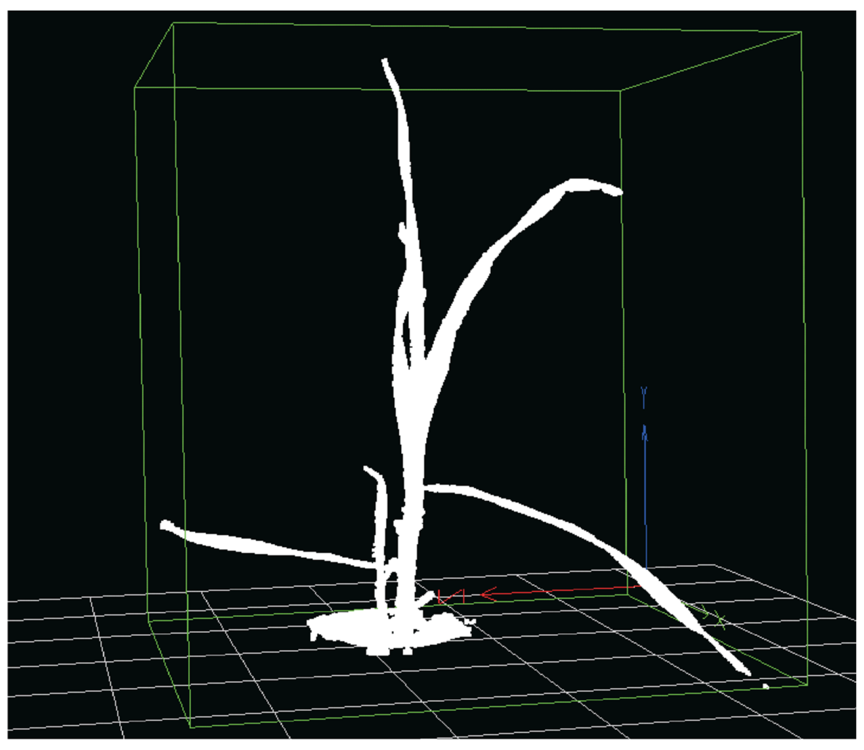

Fig.4

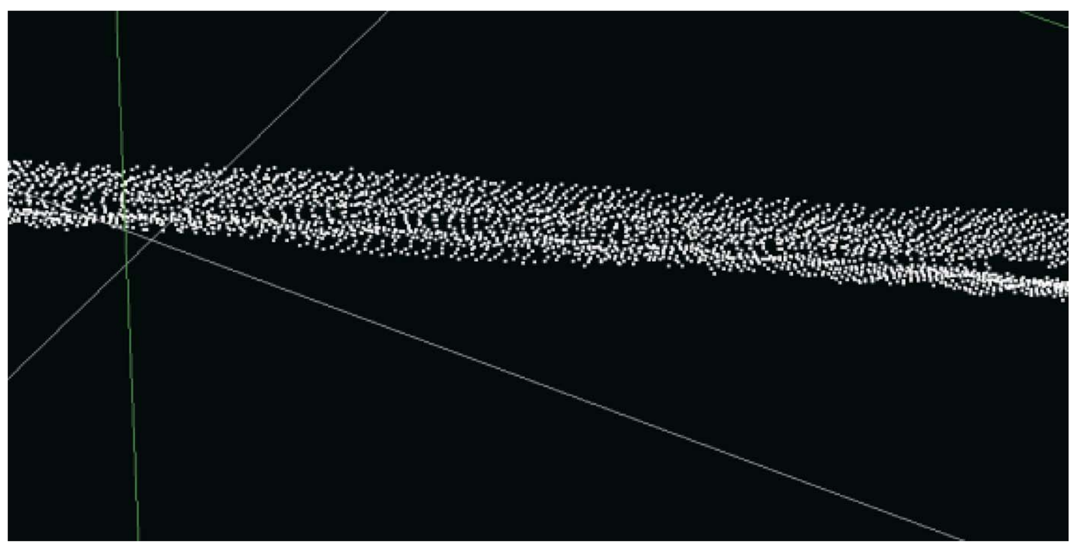

Fig.5

Figure 5 is a zoom into the original point-cloud. The high density of points produced by the scanner is shown.

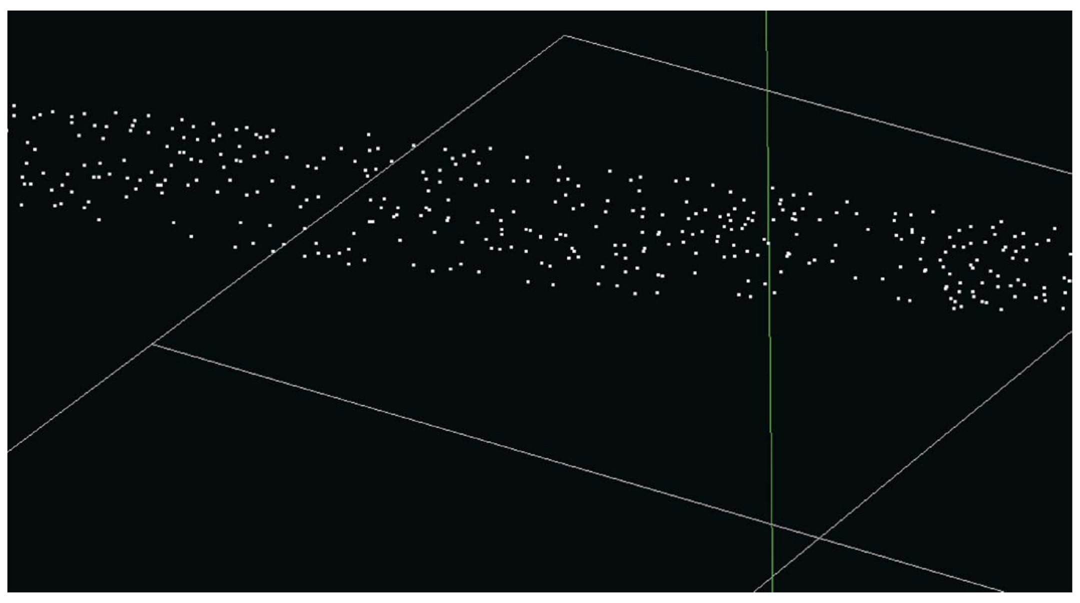

Fig.6

On these points we use quadrics as an approximation for points belonging to a smooth part of a surface. The used quadrics are ellipsoids, cylinder and planes. To achieve the quadrics we use the following strategy. The result is shown in figure 6.

1. Build up a data-structure which holds the 24-neighbourhood of every point in 3D space
2. A simple growing algorithm is used to test if the next point lies within a predefined tolerance limit. The greatest distance between the currently used points is taken as the first axis.
3. From this point we are able to calculate the Euler angles and the translation of the quadric.
4. To calculate the two remaining axes of the quadric, the method of the pseudo inverse is used. This method solves the least-square-problem.
5. We test every point until a predefined tolerance limit is reached.

An adaptive sampling method is used to reduce the number of points. As a measure for the number of points that should be used to describe an ellipsoid surface the Gaussian curvature is used. For planes the points with an infinite point as a neighbour in the Voronoi diagram are chosen. Cylindrical surfaces are currently treated the same way as ellipsoids. Each quadric is triangulated by a Delaunay triangulation. Figure 7 is an example for a result of this algorithm.

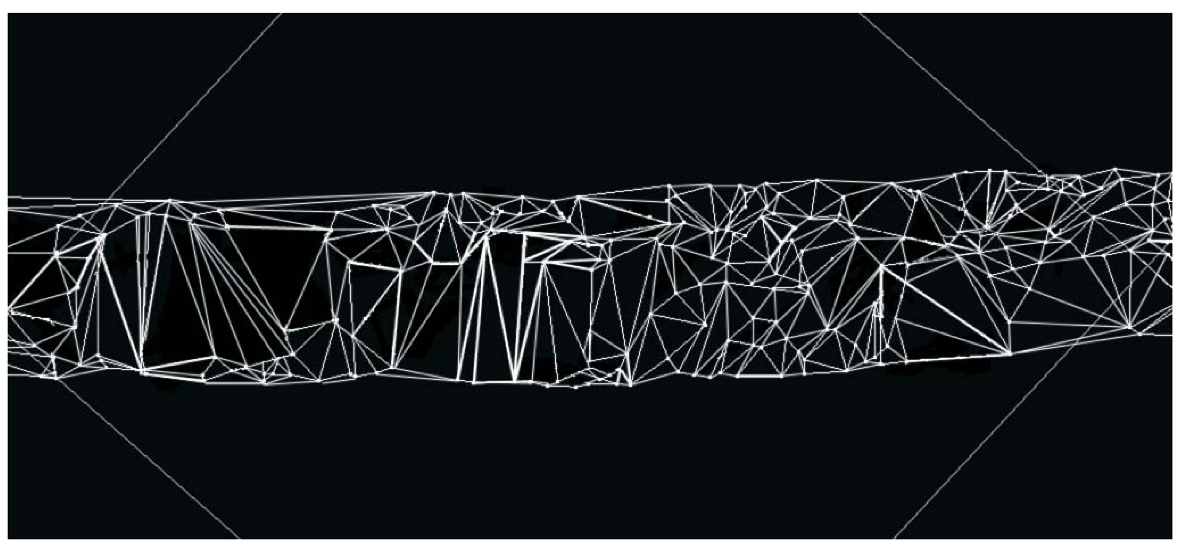

Fig.7

References:

[1] Jiang, X.; Bunke, H.: Dreidimensionales Computersehen. Springer, Berlin 1997 (361 p.).
[2] Kozempel, K.: Kalibrierung eines Bildaufnahmeverfahrens zur Gewinnung von 3D-Informationen. B. Sc. Thesis, Department of Computer Science, BTU Cottbus 2004.
[3] Schreiber, W.; Notni, G.: Theory and arrangements of self-calibrating whole-body three-dimensional measurement systems using fringe projection technique. Opt. Eng. 39 (2000), 159169.
[4] Sonka, M.; Hlavac, V.; Boyle, R.: Image processing, analysis, and machine vision. 2nd ed., PWS, Pacific Grove 1999 (770 p.).