ACTA STEREOL 1990; 9/1: 71-75
PROC ECS 5 FREIBURG I. BR. 1989
ORIGINAL SCIENTIFIC PAPER

AUTOCAD IN ANATOMY: VECTORBASED THREE-DIMENSIONAL (3-D) RECONSTRUKTION WITH A PERSONAL COMPUTER

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ABSTRACT
A low-cost personal-computer-based reconstruction system was described. The components were an IBM PC/AT-386 and the AutoCAD program, with AutoShade and AutoFlix. Its efficiency was demonstrated by reconstructing the 3-D surface of given serial slides in ratbrain and human thalamus. Stereopairs were possible. Animation practicability facilitates video documentation and education purposes. (5 pictures)

Keywords:
animation, software, stereoprojection, three-dimensional (3-D) reconstruction.

In 1985 I started 3-D reconstructions of serial-sectionized histological material (brain, heart) according to the Born waxplate-method (Born, 1883; Gaunt, 1979). I realized that there is no way to add new found interesting details to a once built model of styropor, but it is possible to achieve this with computers. So I joined commercial hard- and software to a system that meets the requirements. A personal computer (PC) and the industrial CAD program AutoCAD, which had been made for engineers, but, with its open structure, is eminently suitable (Lotze, 1987; 1989).
Firstly the serial slides were transfered via **AutoCAD** to the PC. With a superimposer you will have the working-surface of AutoCAD and the videoimage of your slide on one monitor simultaneous. I used a drawing-plate (digitizer). It was divided into two domains for commandoinput and digitizing. The digitizer was placed under the "Makropromat" or drawing-tube of a microscope, so that the projection fits to the drawingpart. According to the punture-channel and identifying structures the workbench can be dimensionized. The commandopart allows direct access to 108 commandos, which consists

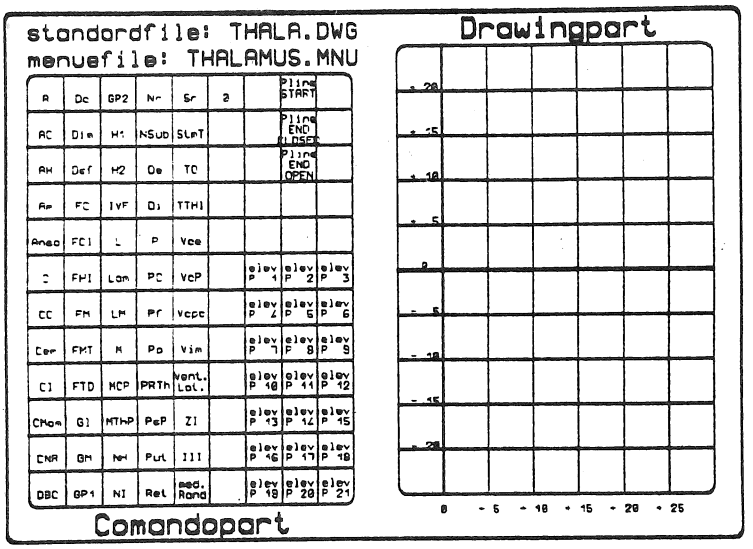

Fig. 1. Partitioning the digitizer for input-handling.

of little programs or commandosequences, for example: *Pline start, - end, open, closed* (Fig. 1). A "click" at *"elev P 1"* opens file P1 and gives the correct elevation and thickness for slide P1 in the later reconstruction. The field *"Nr"* identifies the outlined structure as nucleus ruber thalami. So, after reconstruction, when calling *"Nr"* the nucleus ruber thalami will be shown through all serial slides. With this, somebody can study the connexion, for example, of different nuclei thalami with a simple "click": ON (visible), OFF (unvisible). AutoCAD supports that when layering the drawing. The "pline"-concept gives an angular polyline. Calling "Pline END" at the commandopart they changed to a "Bezier"-polyarc. The 2-D transfering mistake after that procedure will be less than 2 %, that range was also given by Prothero et al., 1974. It is reducible when using shorter polylines (« 1 mm) or a high-resolution display and an extent digitizer. The volume-mistake corresponds directly to the number of slides, I used 21 slides for the human thalamus. Every serial slide was saved in its own file (P1 ... P21), later on they were linked together to the complete object (thalamus). It is useful to proceed in that way if you want to adjust a possible displacement of a serial section in the object (Fig. 2).

Now all slides are digitized. **AutoCAD** allows every wanted PANing, ZOOMing and ROTATION. It creates a wireframe-model and the data and workbench for **AutoShade's** volume-modelling power. **AutoFlix** offers the animation of the object in a trick film (5 pic./sec.) for demonstration or education purpose and documentation on video.

AutoShade shows a more realistic appearence by adding perspective and shading in flat-shading quality, contrary to the Gouroud-shading. It does not control the viewing angle, but also the quality of lighting on the model and surface reflexion (ambient, diffuse, specular,

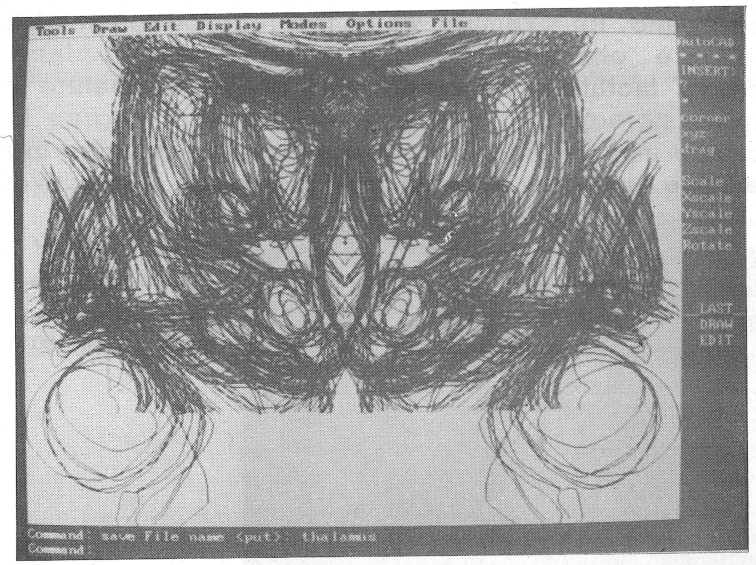

Fig. 2.
Top view to all 21 digitized serial slides,with their outlined structures.

linear lighting, inverse square, Z- shading, RGB components, B&W separation). The lens type may vary from wide angle to telescopic. AutoShade works in conjunction with AutoCAD as a postprocessor, that means, it works on AutoCAD-drawings, after they are created, and produces rendering images of a 3-D model. In analogy to a

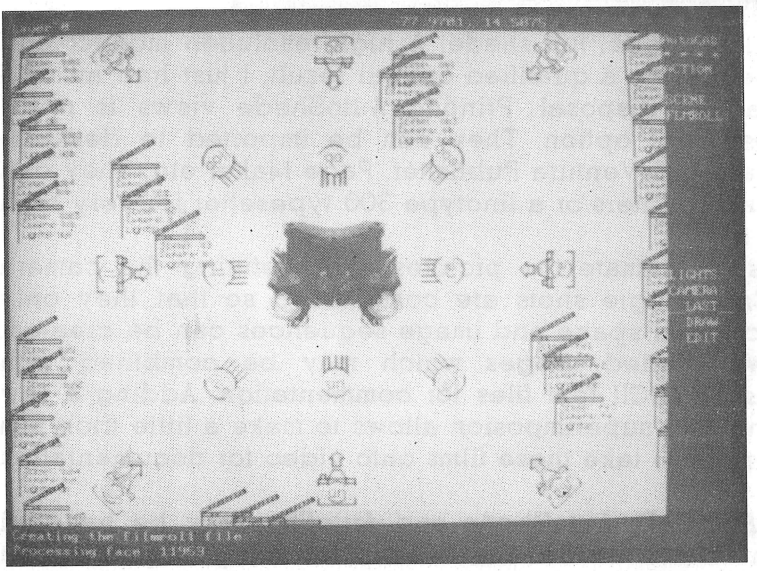

Fig. 3.
The camera setup for different scenes of the whole object, thalamus, definition in AutoCAD.

normal camera setup (Fig. 3). AutoCAD establishes different lightings, camera positions and view angles, then take the pictures and send them to AutoShade for processing. The file contains information about the model and the created scenes. But, in exeption to the camera analogy, the scenes can be manipulated after they have been taken. Sometimes a view is choosen that normally would be obscured by a

surface in the foreground, for example while the reconstruction of a brain, the nuclei are obscured by the brains outer surface. AutoShade's "Clipping" facilitates an interior view. A special feature is the chance to create stereopairs using any wanted twist degree to generate two separate images side by side for stereoscope viewing (Fig. 4). There are three display modi when working online interactive.

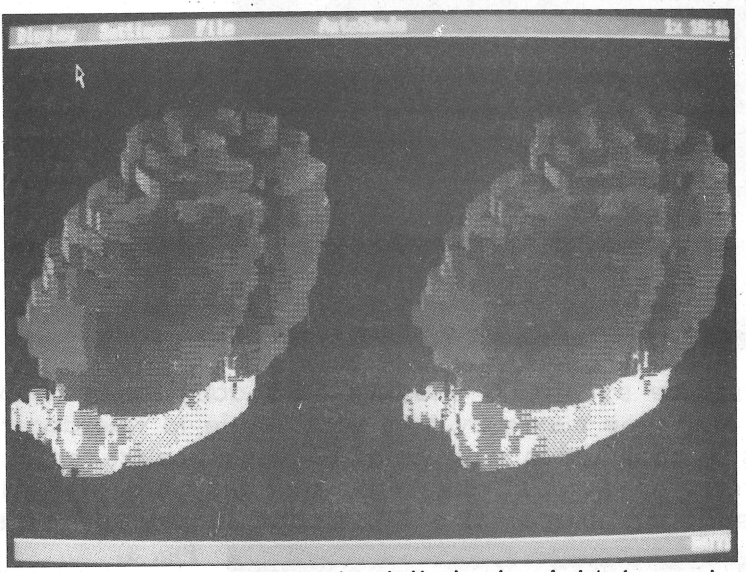

Fig. 4. A stereopair of 20 serial slides of a ratbrain, twist degree 20.

wireframe view, fast shade, full shade. A high-resolution monitor and videocard is essential for a qualified optical result. I just had an EGA graphic system at my disposal. Printing AutoShade views is most flexible with PostScript option. They can be imported to desktop-publishing software like Ventura Publisher, Page Maker etc. They can be printed with laserprinters or a linotype 300 typesetter for very high resolution prints too.

AutoFlix enables to animate the pictures after defining the camera course in AutoCAD. Single shots are compressed so that they only need 5 % of the original space and image sequences can be created. AutoShade shows shaded images which may be combined with wireframe-models or ASCII text files for commentation. Adding a few sequences, fading and superimposion allows to make a little trick film (Fig. 5). It is possible to take these films onto video for documentation and education.

All three units, **AutoCAD**, **AutoShade** and **AutoFlix**, may be handled interactive or in "batch"-mode, that means returning sequences of operations are written in a commandolist for automatic execution. **AutoLISP** gives the ability for individual programing. It refers to Atari's ST computers Public Domain XLISP 1.71. Think of radiation therapy in radiology, when estimating the dose parameters with the image-given and identified tumor location. Arranging the system for special requirements can be done with your own commandopart on

digitizer, a modified menue-bar and pull-down-menue. I have done this for simplifying slide input, measuring the object and analysing the structures.

AutoCAD is one of the most flexible systems for 3-D reconstruction in anatomy when analysing structures. There are similar systems on MacIntosh, Amiga and Atari, for example **AXIS** by Modern Medium BV Germany.
The described system was realized in almost realtime application on SUN-386 or with good handling and answering time, on a PC-386 with minimum configuration:

- 20 MHz,
- MathCo Processor,
- 2 Mbyte RAM,
- 40 Mbyte harddisc,
- EGA/VGA graphic,
- DOS 3.3,
- digitizer (DIN A3).

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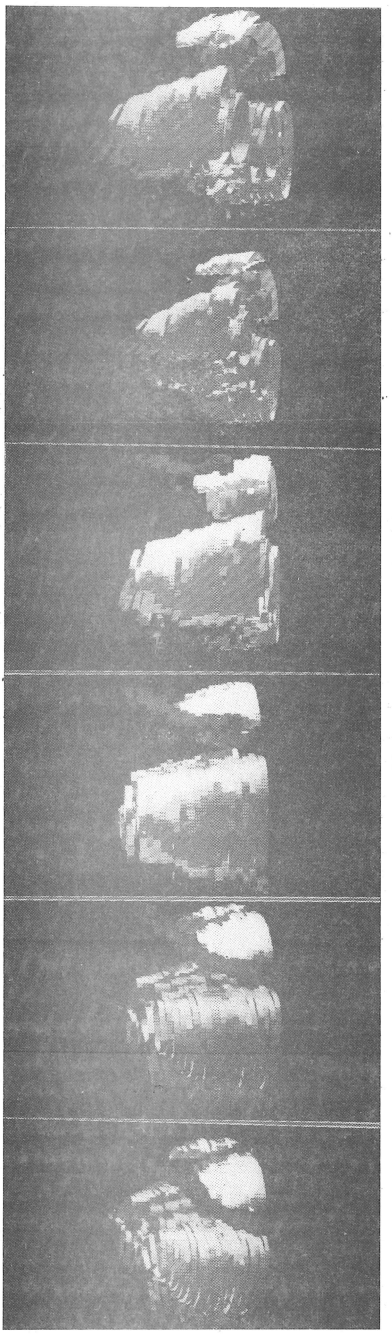

Fig. 5. An animation sequence of the thalamus.