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Computer Graphics Editor GSE and Some of its Applications in Morphology

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Summary
A simple, vector-based graphics editor, designed for experimental data presentation, schematics, large structured chemical formulae etc. in a modest IBM PC, MS DOS environment is described. Its applications in semi-automatic image analysis, especially in the implementation of design-based stereological methods for estimating global geometrical characteristics of studied samples and in 3D volume reconstruction from serial sections are discussed.

Key words
Computer graphics – Graphics editor – Stereology – Vector – Semi-automatic image analysis – Volume reconstruction

Introduction

The well-known proverb "One picture is worth a thousand words" characterizes the evolution of the computer -> user interface, which is predominantly materialized by a visual display and changes its communication tools from alphanumeric symbols to pictorial ones (e.g. icons). There have been two types of computer graphics developed since the early days of computer history, i.e. the random access and serial access displays (Newman and Sproul 1979, Hill 1990) which differ in hardware especially in the access to the pixels displayed. The computer graphics based on the former approach resulted in vector graphics with analog control of the display. The serial access resulted in raster (scanned) graphics based on digital control of TV displays.

Vector displays, being based on analog oscilloscopes, have been known since the era of analog computers. Their main advantages were the high resolution (precision) achievable (e.g. 2Kx2K pixels), the generation of straight lines regardless of their orientation and efficacy of the displayed picture representation based on its decomposition into vectors, i.e. segments of the figure displayed, e.g. a line is described by the coordinates of its end points only and interconnection of these points is accomplished under software or hardware support. Moreover, pictures represented in vector graphics can easily be changed in terms of shifts, rotations or scaling by changing the vectors accordingly. The main disadvantages of vector graphics consisted in the high price, since high precision, wide-band amplifiers were required and the display refresh rate dependence on the complexity of the picture presented.

Raster display graphics were born with digital computers and the corresponding HW of the display was derived from mass-produced TV monitors. Raster graphics HW is cost-effective, moreover, it keeps the refresh rate constant, i.e. the brightness of the presented picture is independent of its complexity. One of the main objections against raster graphics is the staircase form of slant lines due to the finite size of pixels. Furthermore, it is the low efficacy of the code of the displayed picture resulting from the fact that all pixels of the screen are mapped into a corresponding part of the RAM (so called video RAM). Shifts, rotations and scaling of the displayed figures are more time-consuming when compared with vector graphics, since all displayed pixels should be changed accordingly. Despite this, almost all computer displays are at present based on raster type HW, the terms computer vector and raster graphics still exist and describe the specific coding of the elements of the picture displayed either by a few parameters or by using all pixels involved. The ever growing capacity of the RAM of PCs and the increasing HW support of the display procedures make the above advantages of the vector graphics less pronounced, though this type of computer graphics is still used, especially in modest display systems. The developed and described computer graphics editor was conceived as a small SW system tailored for experimental data and results presentation (including text) in a laboratory environment by using a modest PC set-up. Therefore, vector graphics were chosen to fulfil these requirements.

GSE Description

The developed Graphics Segment Editor – GSE represents a small, vector-based, user friendly, IBM PC, MS DOS (version 3 and higher) oriented computer graphics editor driven by a hierarchically organized menu, which is capable of graphs and text presentation on EGA or VGA monitors and hard-copying by using various printers and plotters (9 and 24 pin matrix printers, HP ink jet, HP laser-jet and HPLG driven plotters). The size of the graph processed by the GSE is up to 64Kx64K pixels out of which a window of 600x400 pixels in various scales is presented on the monitor screen. The primary goal of the GSE is the presentation graphics, i.e. the combination of graphs and text in the environment of a research laboratory. However, its application also includes line schematics, large structured chemical formulae etc. Moreover, the kernel of the GSE was applied in the development of a number of extensions of the system aimed at an interactive analysis of the geometry of biological tissue.

The GSE provides a number of picture generating and editing functions, e.g. interactive drawing, generation of various segments, as lines, circles, ellipses, wedges, and their rotation, shift, scaling, filling the internal area of a closed figure, etc. Already designed segments, e.g. chosen parts of the picture, can be clipped-out, stored for future application or replicated in the same picture, etc. Three types of fonts are available in the text mode so far. The GSE source programme is written in Turbo Pascal and its EXE file represents about 200 KB, so that it fits any IBM PC available nowadays. The GSE system does not require a mathematical coprocessor though its application may shorten its run time. The GSE has been interfaced to a rather large number of printers, plotters and among its outputs there is also a photo exposition control unit (Polaroid Palette).

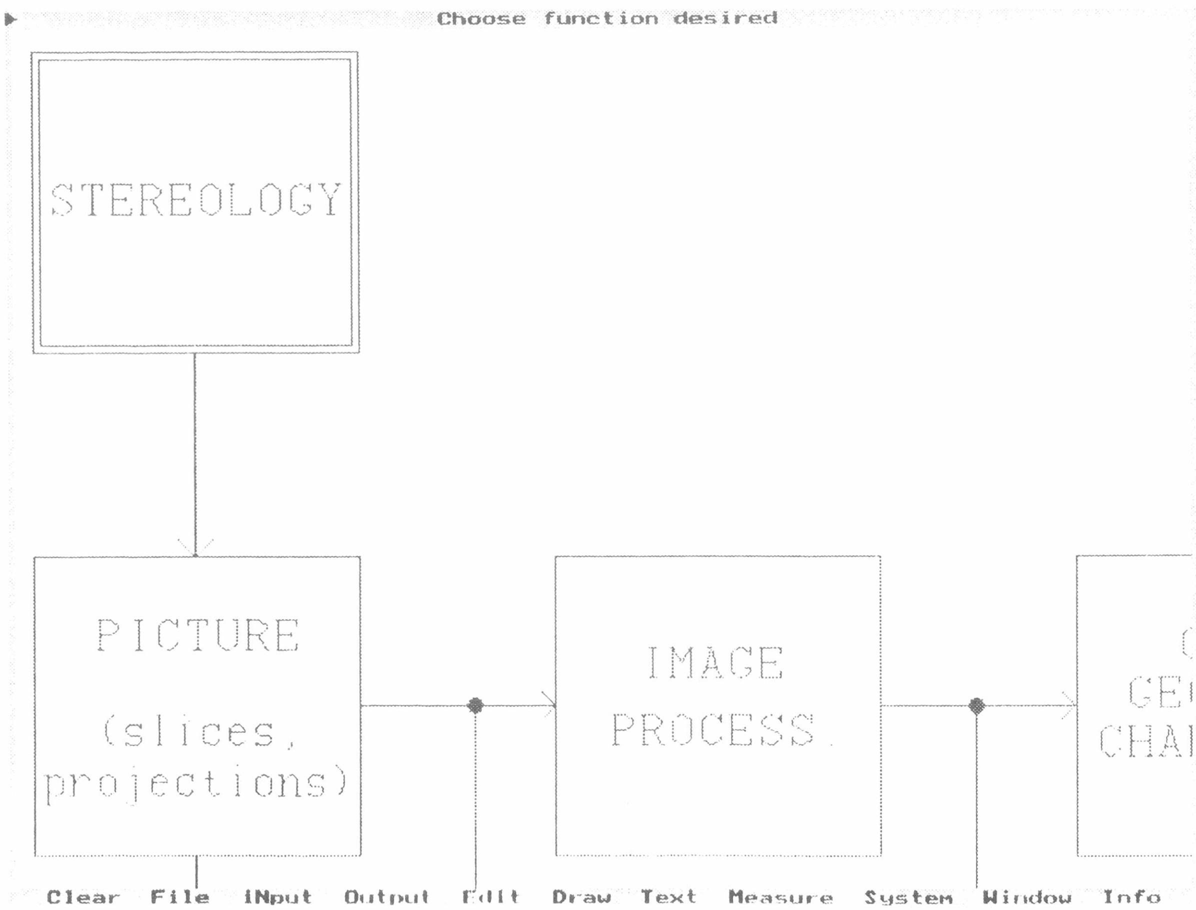
Applications of the GSE

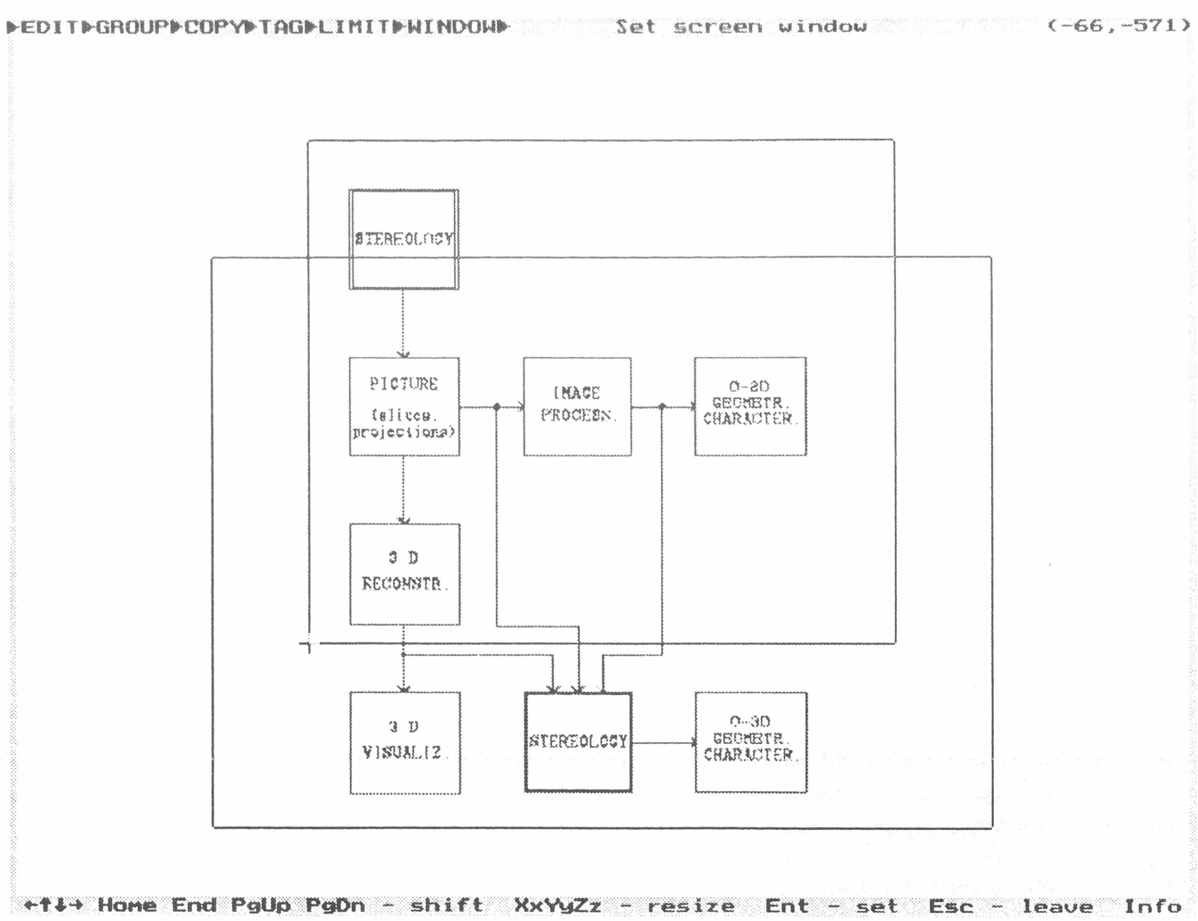
Two main areas of the GSE application will be discussed: a) a general purpose one, i.e. the presentation graphics and b) applications of the kernel of the GSE system in studies of geometry of 3D samples of a biological tissue.

a) General applications of the GSE

The original application domain of the GSE, the presentation graphics in a modest MS DOS, IBM PC environment can be accomplished easily by using specific menu driven self-explanatory commands. The GSE programme communicates with the user through two text lines on the screen, i.e. the top (TL) and the bottom line (BL). The TL, consisting of three different fields, presents the state of the programme. The left field depicts the tree of commands resulting in the current display. The central field announces the action which is expected to be accomplished by the user in the following step. The right field of the TL presents the current coordinates of the cursor. Two fields, the right and the left one are optional, depending on the state of the programme, e.g. the left field is void whenever the menu of basic procedures is displayed, similarly the right field is empty if the cursor is not activated. The BL presents available options which can be activated by pressing the corresponding key (depicted by the capital letter displayed in bold manner) of the keyboard (see Figs 1–3). The main set of procedures consists of 11 items: *Clear, File, Input, Output, Edit, Draw, Text, Measure, System, Window, Info* (see Fig. 1a). The functioning of the above procedures is obvious except for the *Input* which makes it possible to design a new segment in a "free-hand" style by using cursor keys of the keyboard or a mouse, while the *Draw* provides some basic graphics primitive segments, such as lines, circles, etc. The procedure *Edit* deals with graphics only (either by an individual segment or a group of segments), while the *Text* deals with alphanumerics, which can be handled either by individual lines of the text or through a whole DOS text file. The distance between two positions of the cursor is evaluated by calling in the procedure *Measure*. The *Info* procedure provides information on the current state of buffers, i.e. the number of currently tagged segments, size of the window, coordinates of the cursor and marked points, outline of the RAM usage, etc. Whenever a procedure is called in, its specific options are displayed in the BL (see Figs 1–3).

Fig. 1
An example of the application of the GSE to the design of schematics (presentation graphics): Fig. 1a (upper panel) represents a "print screen" of the display of a working window which was clipped out of the schematics shown in Fig. 1b (lower panel). Notice contents of the TLs and BLs. Only the central field of the TL is presented in Fig. 1a, because one of the main procedures (as enumerated in the BL) will be applied to the working window. All three fields of the TL are presented in Fig. 1b. The coordinates shown in the right field of the TL correspond to the position of the marked point, i.e. left lower corner of the window. The BL in Fig. 1b enumerates all activities (options) available within the procedure window, i.e. the working window setting.


Choose function desired
STEREOLOGY
PICTURE
(slices,
projections)
IMAGE
PROCESS.
Clear File INput Output Edit Draw Text Measure System Window Info


▶EDIT▶GROUP▶COPY▶TAG▶LIMIT▶WINDOW▶ Set screen window (-66,-571)
STEREOLOGY
PICTURE
(slices,
projections)
IMAGE
PROCESN.
0-2D
GEOMETR.
CHARACTER.
3 D
RECONSTR.
3 D
VISUALIZ.
STEREOLOGY
0-3D
GEOMETR.
CHARACTER.
←↑↓→ Home End PgUp PgDn - shift XxYyZz - resize Ent - set Esc - leave Info

Each displayed item, i.e. figure or an alphanumeric symbol, consists of elementary parts, i.e. segments (lines, rectangles and parts of the circle or ellipses) and specific point markers (triangles, crosses, squares, asterisks, etc.) which are chained to obtain the desired figure. Moreover, the spline function (up to the 3rd order) to connect a set of defined points by a smooth curve can be called in. The elementary segments can be drawn interactively on the screen (e.g. by determining end points of a line), or the elements (e.g. fonts) already drawn or stored in a library can be called on the display and interactively manipulated there (e.g. by dragging, rotating, slanting, scaling, etc.). Moreover, any part of the figure can be generated/visualized in detail under higher magnification by using a working window. The user input is controlled via the keyboard, mouse or a graphic tablet. The VEGA color palette is supported and painting belongs to the standard procedures of the menu. An example of presentation graphics, as generated by the GSE, is shown in Fig. 1a,b.

b) Applications of the GSE in 3D volume studies

The GSE, especially its kernel, has found following applications in the framework of geometrical characterization of 2D and 3D samples of a biological tissue:

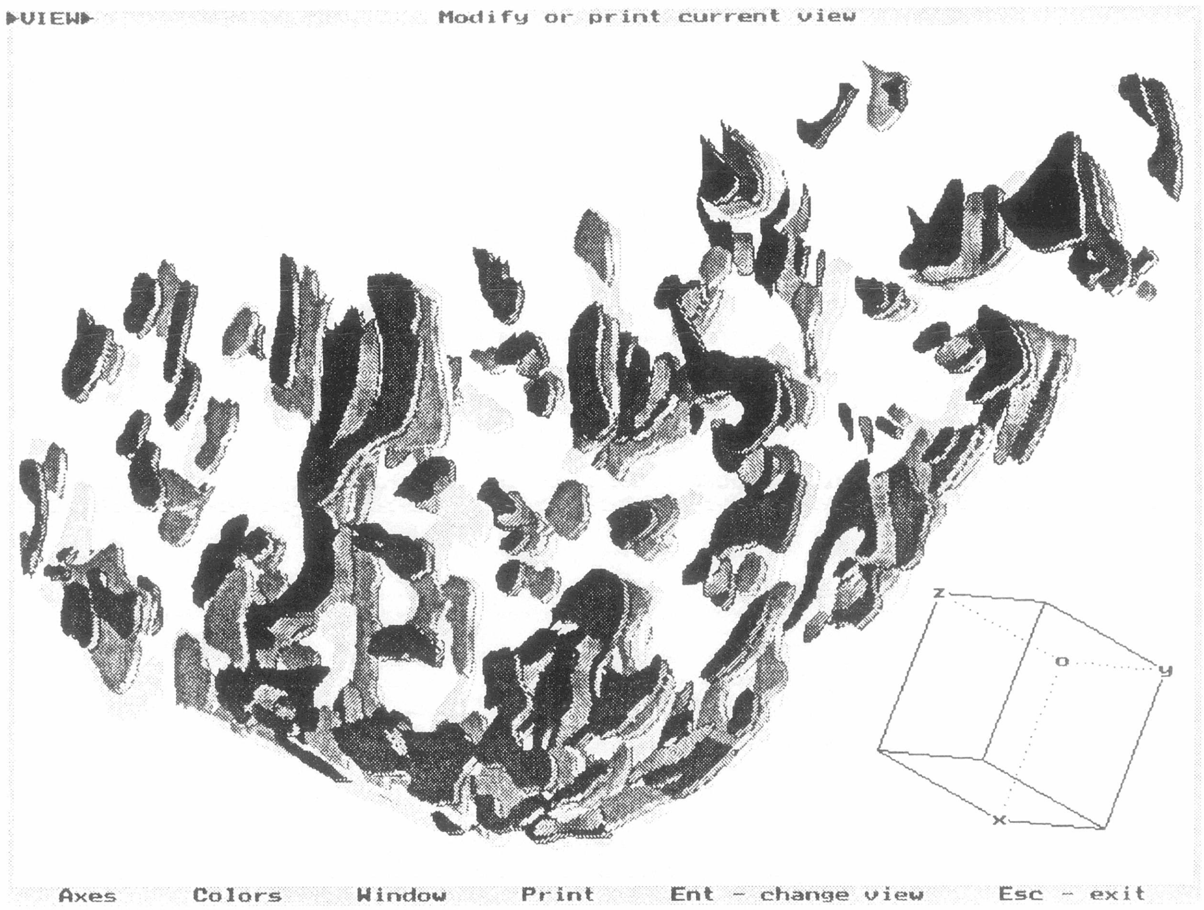
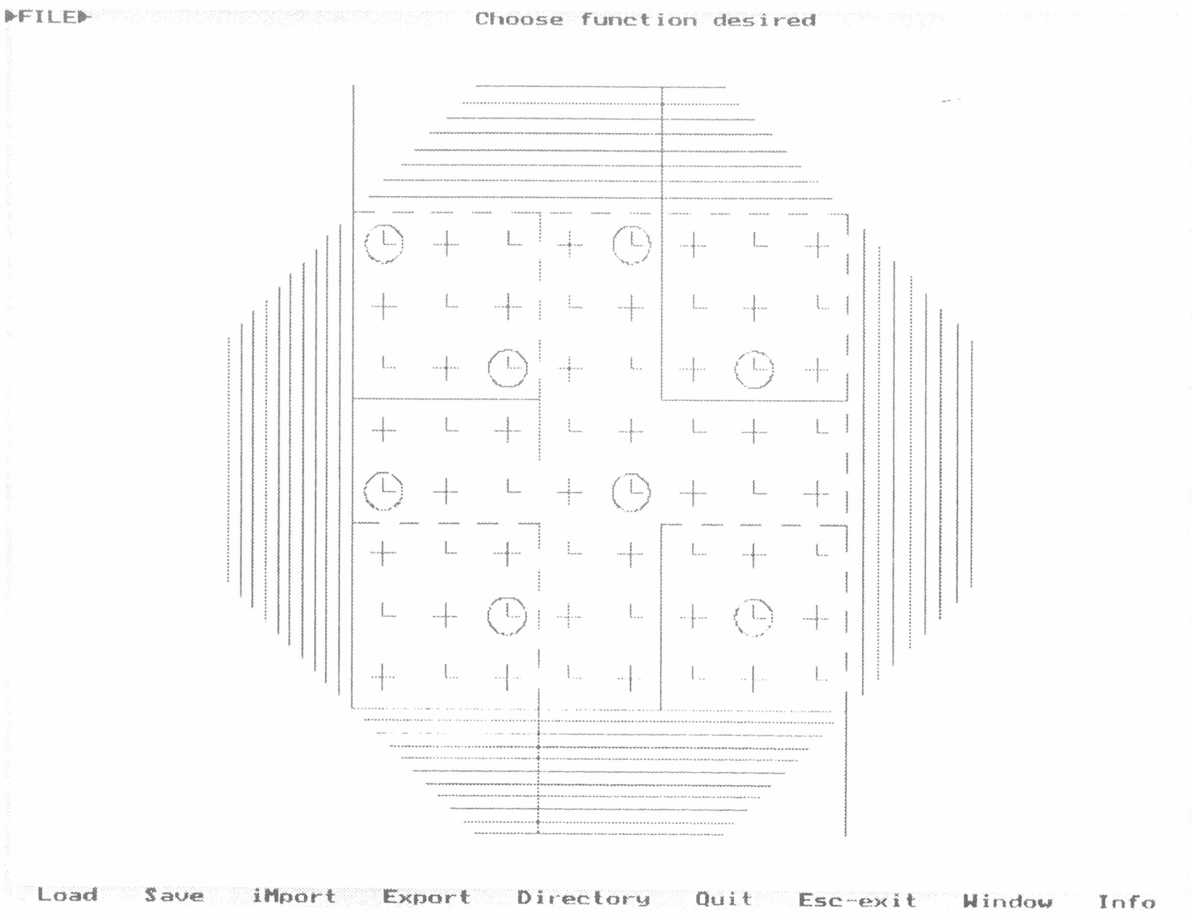
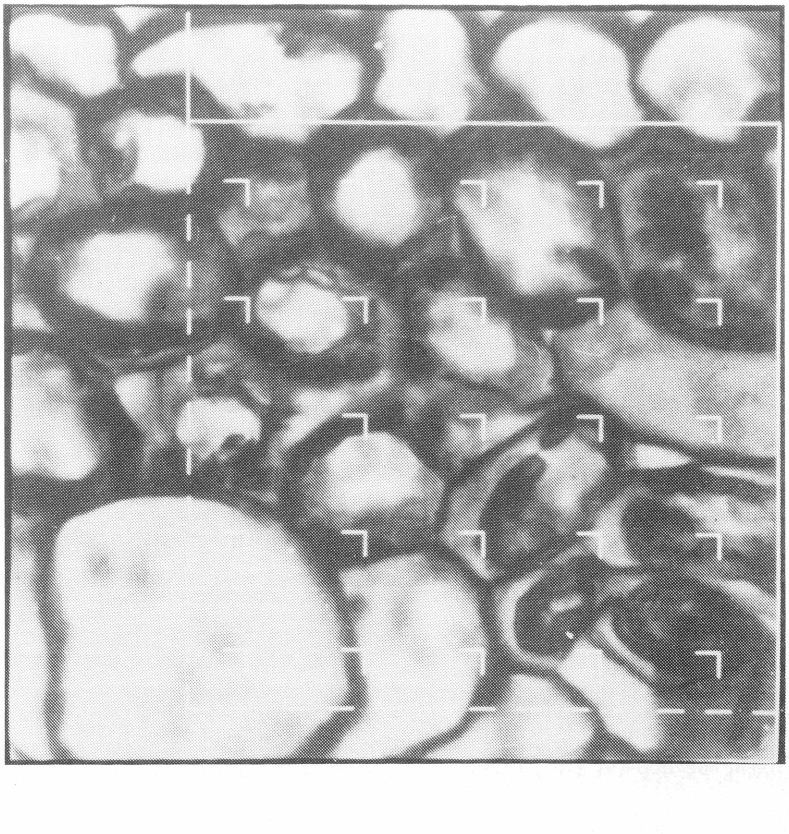


Fig. 2
Picture of the wire-frame/paint presentation of neurotransmitter rich patches in serial slices of nucleus caudatus of a cat (provided by the courtesy of Dept. of Psychiatry, UCSD, La Jolla). Notice the cube in the right lower corner of the picture which serves as a cursor depicting the chosen position (rotation) of the displayed object. The picture was made by using an extension of the GSE programme.

Fig. 3
Upper panel shows an example ("print screen") of a measuring raster generated by the GSE extension. The raster is designed for stereological estimation of the number of particles (provided by the courtesy of Dr. G. Zachařová and Dr. L. Kubínová, Inst. Physiol., Acad. Sci. Czech Republic, Prague). Notice the contents of the TL and BL, the latter depicting options of the File procedure. Lower panel represents an example of a superposition of the measuring raster and picture of a studied tissue presented on screen of a computer display (Karen *et al.* 1994).


▶FILE▶
Choose function desired
Load Save iMport Export Directory Quit Esc-exit Window Info



i) Interactive input of graphical data.

The low contrast of images of studied particles when compared with the background and their inhomogeneities represent the main obstacles to the automatic segmentation and processing of images of a biological tissue. Therefore, a trivial semi-automatic segmentation, based on application of an interactive graphics input (e.g. graphic tablet, light pen, mouse, keyboard) takes place in these cases. The GSE kernel, enhanced by an input procedure for using graphic tablet, was applied to the implementation of the semi-automatic input of image data. The programme makes it possible to change the resolution or scale, to erase erroneously loaded segments, to filter out the oscillations of loaded curves (e.g. compensate for hand tremor of the user) and to change the color of the loaded curve during its input, i.e. to mark its different parts. The semi-automatic input was implemented for two graphic tablets, DG-1 (Academy of Sciences of the Czech Republic) and Genius GS-FC60 (Summagraphics protocol).

ii) Visualization of surfaces of 3D samples

Another modification of the GSE was done to visualize the 3D reconstruction of a sample made from its serial sections by using the wire-frame construction (Royer 1988, Keri and Anhelt 1991). The profiles of the visualized sections are loaded into the computer by using the above modification of the GSE for interactive semi-automatic image input, usually by using a graphic tablet. To improve the perception of the 3D structure presented *via* the wire-frame, the display of the hidden (obscured) edges can be optionally avoided, usually by exploiting the procedure painting. Moreover, an interactive manipulation (rotation) with the display can be accomplished. The different coloring of edges is preserved in the wire-frame display.

iii) Generation of rasters – stereological test systems

The design-based stereological methods, which evaluate interactions of measuring rasters with specific projections or slices of the samples under study, make it possible to obtain unbiased estimates of different geometrical characteristics of the sample (e.g. volume, surface area, number of particles, volume density etc.) (Gundersen *et al.* 1988, Kubínová 1994). The common advantage of these methods consists in the minimal requirements on the HW applied. With growing popularity of these methods their implementation is going to be computerized (Humbert *et al.* 1990). Instead of superimposing the measuring rasters, made of transparent sheets, on prints of the studied objects, the computer-generated rasters, (i.e. test systems) are superimposed on the displayed image of slices or projections of the sample under study (Krekule and Gundersen 1989, Moss and Howard 1989, GRID 1990, FENESTRA 1992, Karen *et al.* 1994). The interactions (e.g. intercepts) are usually evaluated manually, though attempts for fully automatic stereological measurements have already been published (Zhao *et al.* 1991, 1992, Zhao and Browne 1992). The GSE was successfully applied to the generation of various rasters which are superimposed as a graphics overlay on images of the studied tissue sections. The images are obtained either by a TV camera fixed on a microscope and connected with a frame grabber (ZOB 512x512 pixels, 8 bits deep), or as a file acquired by the confocal microscope (BioRad RC 600), or by using a flat-bed scanner (Genius FC-60), or from another source. The measuring rasters can be either loaded from the hard disk or they can be generated on-line on demand.

Conclusion

The PC oriented desk-top publishing systems which are commercially available nowadays provide full support of the presentation graphics. These systems are usually supplemented with a large library of icons and fonts, but they are expensive and have high requirements on the memory capacity, so that the need of a GSE system such as that described in laboratories is obvious. The system has been successfully applied in the domain of the presentation graphics and was modified to enhance methods of the study of the geometry of 3D samples. The GSE system will be developed further to include multimedia output as well as to be applicable to stereological measurements in connection with an automatic image input.

To obtain more detailed description of the GSE system, contact the author. The GSE system is distributed upon request by the Institute of Physiology, Academy of Sciences of the Czech Republic, Prague.

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Reprint Requests

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