The Parametric Grid Generation System MegaCads

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Introduction

During the last decade, advances in the field of numerical aerodynamics lead the way to very powerful codes capable of handling problems in two and three dimensions [1, 2]. The solution of the Navier–Stokes equations for a complex configuration, including the wall boundary layers, requires structured grids of high resolution. Even today the creation of such grids of high quality is very costly in time and thus in manpower. On the one hand, the long development times can be the result of using batch generators which usually can handle variations in parameters (like a flap deflection angle) easily, but are tailored to specific topologies which cannot be changed quickly. On the other hand, interactive methods, often integrated into existing CAD systems, are time consuming if modifications in geometry or parameters force the user to do a redesign of large parts of a grid.

Over the last years, the DLR Institute of Design Aerodynamics has used commercial products and has developed batch generators for grids around complex transport configurations [3, 4]. Special interactive tools were developed for the smoothing and refining of algebraic grids [5]. The experiences gained while using these systems were not fully satisfactory and formed the base for the requirements for a new grid generation tool which should be oriented towards the needs of a research institute as well as industrial applications [6] :

- Open grid generation software development platform
- Parametric design and replay mode concept
- Capability to handle multiblock grids
- Elliptic and biharmonic smoothing of grids
- Basic CAD techniques
- Machine independent source code
- UNIX, X–Windows, OpenGL standards

All these requirements are combined into the **M**ultiblock–**E**lliptic–**G**rid–Generation–**A**nd–**CAD**–**S**ystem (MegaCads), which is currently under development.

Grid Generation Concept

MegaCads is an interactive grid generation system, which enables the user to build block boundaries, distribute points on them, create surface grids and fill volume blocks with grids, based on simple representations of shapes through the use of basic objects like polygons and splines in 2D and 3D. The resulting algebraic grids can be smoothed using elliptic or biharmonic techniques. The whole design is done in a parametric fashion and each design step is stored in a script file. The hierarchical structure of the design process is reflected in the script file, which can be visualised and edited using the interactive MegaEdit application. Using the built in restart capability, it is quick and easy to change parameters and replay the script file.

In the past, a combination of elliptic smoothing in all three dimensions has proven to be successful for the creation of smooth grids. MegaCads distributes points by solving the poisson equation along spline curves, which form the edges of blocks. These block boundaries are filled with elliptic/biharmonic smoothed grids, which form the boundary faces for the volume grids [7, 8, 9].

The Development of MegaCads

The first version of MegaCads had been developed in 1992 using FORTRAN 77 and simple, proprietary graphics software. The concept proved to be very successful for 2D and simple 3D applications, but necessary extensions to more complex 3D configurations forced a redesign [7, 8]. After evaluating various programming languages and graphics software systems, the decision was made to develop a new version using a completely new data structure, user interface and standard graphics software. Starting in mid 1994, the development uses the C language, the Motif tool kit for X11 and OpenGL/GL compatible graphics software. The graphical user interface (GUI) is created by using a commercial interface builder. The standard behaviour of the user interface results in a short learning period, and easy user customisation through resource files. The graphics system is based on a subset of the OpenGL/GL language, which can easily be replaced by vendor specific implementations and optimised for specific hardware. The portable software implementation is based on the basic 2D graphics commands contained in the X11 protocol and is thus capable of driving even the simplest X-Window terminals.

Structure of the System

MegaCads is separated into three large blocks: the GUI part, the graphics subsystem and the CAD and grid generation routines. The parts are connected by a few well–defined interfaces to guarantee that the grid generation can also be used without the GUI and graphics part as a subfunction in design and optimisation software.

The CAD and grid generation routines are distributed in manager, working, and service functions. The manager functions are responsible for the evaluation of the commands coming from the GUI block or from the script file processor and for the management of the geometric data base. The working functions perform mathematical operations on basic geometric objects such as calculation of point distributions along a curve or locating the intersection of two surfaces. The service functions handle the interaction with the basic objects. They can provide, for example the arclength of points on a spline curve or the local slopes and curvature of a point on a surface.

GUI / Graphics Structure

The user interface consists of a main window for displaying the geometry and for the selection of functions from the menu bar (Figure 1). The implemented functions are attached to the following six main menus :

- File menu : includes functions like choosing a work directory, input/output of geometry data, user–specific configuration data and exit.
- Edit : provides the possibility to edit the script file and to make a restart from a specific process. An Undo feature is also implemented.
- CAD and Grid : see below.
- Options : allows to switch on/off visualisation resources (e.g coordinate axis, marker sizes).

- Help : offers assistance with a context sensitive on–line help system MegaHelp (Figure 2) on all relevant topics. The system uses a network wide database which can be viewed using a hypertext browser. Also available is a library of examples which can be copied and modified to fit a specific user need.

All functions have its own dialog window with the necessary text fields and option buttons to read the user input (see distribute points dialog window in Figure 1). The dialog windows can be placed on the screen by the user so that no main window area has to be permanently reserved. The graphic function buttons can be found in the graphic utility window. Together with the mouse these buttons provide the basic techniques such as translation, rotation, zoom, grid browsing etc. To find frequently used functions more easily the short–key feature is implemented and the user has the possibility to put functions in a favorite list located on the right of the main window.

The result of every CAD or grid process will be displayed in the main window and in an entity list window. The list helps the user to memorize the generated geometries and it offers the possibility to switch them on and off using different selection criterias (see entity list window in Figure 1). In addition to the Edit–function of the main menu the interactive tool MegaEdit displays the hierarchical structure of the grid generation process and supports an edit mode for the parameters. Figure 3 shows a geometric object (curve with point distribution) which is currently being edited.

CAD Techniques

Basic CAD techniques are necessary to design block topologies in 2D/3D and on surfaces. Currently the following functions are available :

- Parametrisation of input data for the representation as spline curves or Coons surfaces.
- Split/Trim techniques for curves and grids.
- Concatenate functions for curves and grids.
- Definition of vectors for direction specifications of new curves.
- Definition of curves.
- Clone/Translation for copying and translating of geometries.
- Curve/curve and surface/surface intersection.

Currently a simplified version of the surface/surface intersection algorithm of [10] is tested. A working plane concept allows the user to define whether the resulting geometry of a selected CAD function can be found on a parametrised surface or somewhere else in 3D physical space. For example, a polygon between two points will be the euclidean connection if the working plane is the 3D space. But it can also be a line on a surface when this is the current working plane. All processes use the current working plane until a different one is selected.

Grid Techniques

The main objectives of the grid functions are to distribute points on curves, on block boundaries and in 3D blocks following the philosophy of MegaCads. The following functions are currently implemented :

- Point distributions on curves. The first and the last spacings can be specified.

- Algebraic grids (2D/3D).
- Definition of first layers to define spacings and angles as boundary conditions for elliptic/biharmonic smoothing (2D/3D).
- Elliptic/biharmonic smoothing using techniques described in [4, 8, 9, 11].

Examples

Topology Definition

Figure 1 and figure 4 show the definition of a C–O–topology for the upper part of a wing grid. Based on wing sections, the wing surface grid and six block faces can be generated.

Replay Mode

Figure 5 and figure 6 show the grid of the rear part of an airfoil with slotted flap. Setting a new flap angle and running the script file again produced the grid shown in figure 6. Other parameter also could have been changed (e.g. number of grid cells, spacings, etc.).

Conclusion / Future Developments

MegaCads is an interactive parametric grid generation system for complex geometries. The implemented CAD and grid generation techniques give the possibility to create arbitrary grid topologies. All processes are stored in a script file. The replay mode together with the interactive variation of the script file supports parameter variations in an easy way. The script files for different grid topologies are stored in a grid generation library. The files are available for users to simplify future applications to similar problems.

The current work focuses on the integration of additional 3D functions and the application of the new version of MegaCads for complex 3D configurations. Furthermore the system is undergoing the integration of macro techniques and variable substitution into the script file parser. This has already been completed for the MegaEdit application.

Final Paper / Demonstration Session

A final paper would include a detailed discription of MegaCads and examples of generated grids for complex geometries. The interactive grid generation process and the variation of grid parameters could be shown in a demonstration session.

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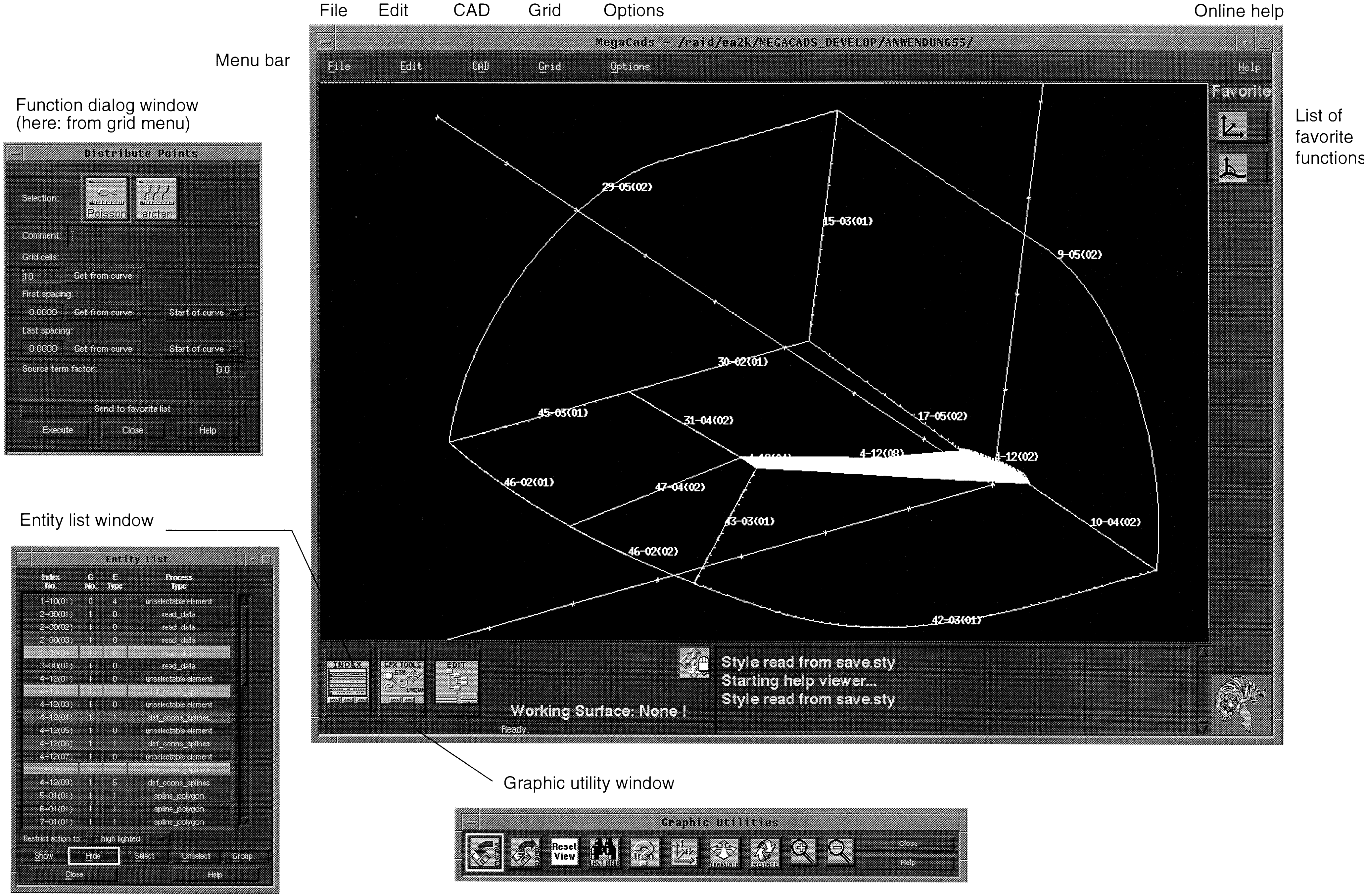

Figure 1: MegaCads user interface, block topology definition for C-O wing grid (upper side).

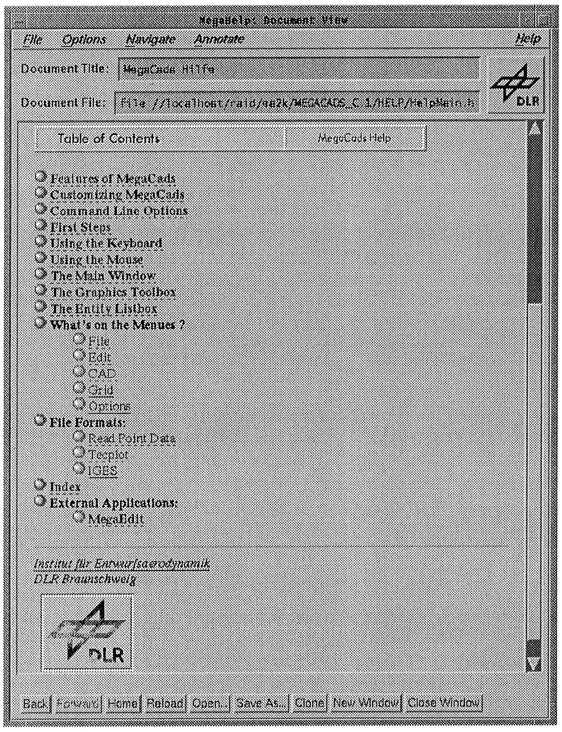

Figure 2: MegaHelp browser

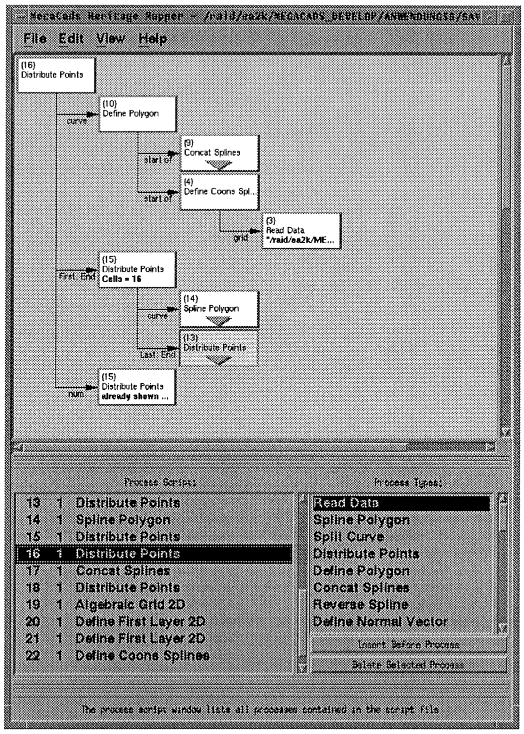

Figure 3: MegaEdit tool

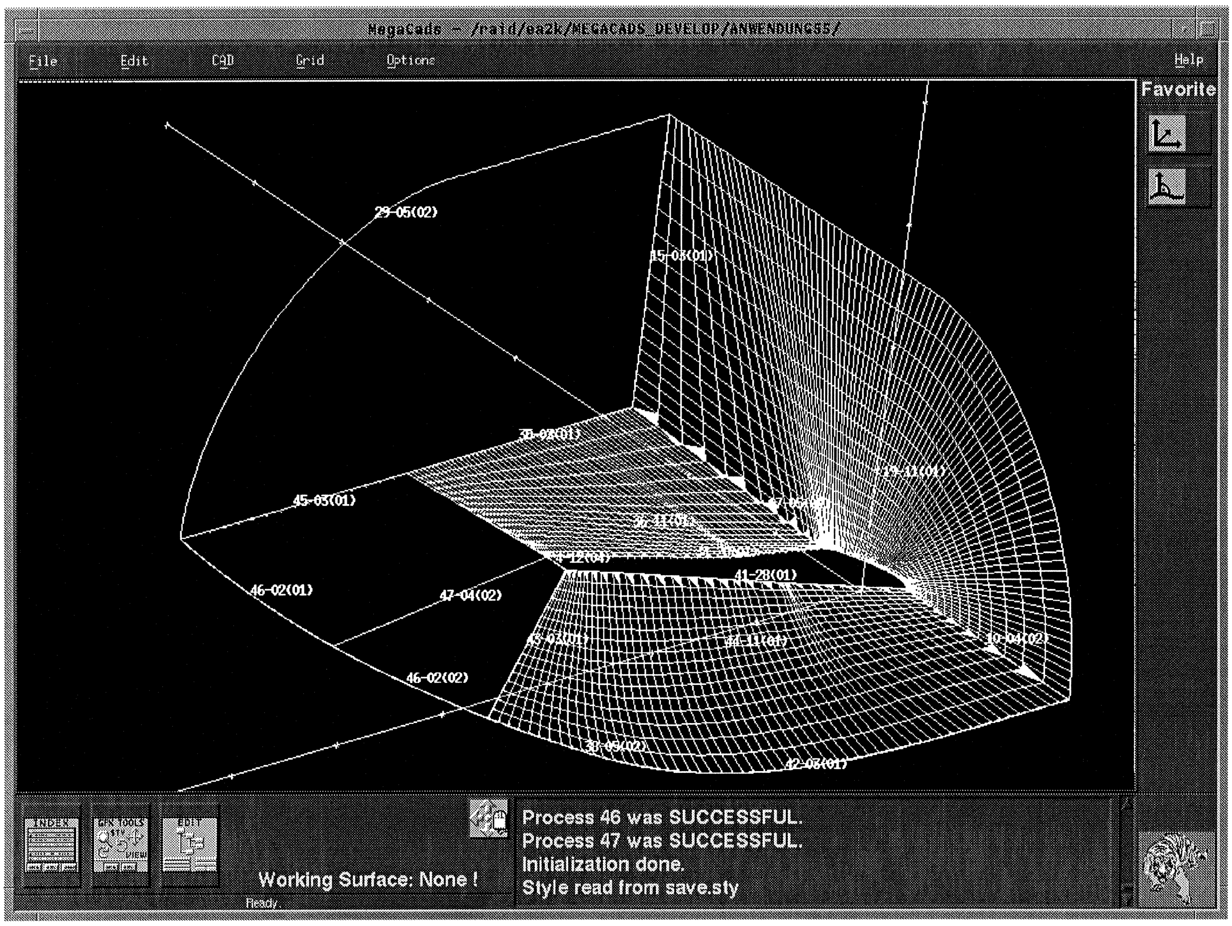

Figure 4: Algebraic grids on 3 block faces for a C-O wing grid (upper side)