CAE SOFTWARE CUSTOMIZATION AND DEVELOPMENT: THE SMARTCAE EXPERIENCE

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1: Introduction

Nowadays, the most important players in the CAE market are driving the development of their products towards the seamless integration between CAD and CAE tools, in order to both simplify the data transfer between applications and reducing the modelling time.

This approach, that is generally appreciated by the end-users, sometimes forces the software house to focus mainly on the most attractive market segments (typically automotive and aerospace industries), ignoring small market niches that could demand special features or enhancements.

Sometimes it happens that a commercial “general purpose” analysis software isn’t the best tool to solve a very “specific” niche problem. Often these usability issues are not due to limitation of the mathematical foundation of the code, that indeed could be suitable for the application, but principally to the lack of a good “interface” to prepare the input for the software, or to manipulate the output for a specific purpose.

On other cases some “home-made” software is developed inside a company that requires an user friendly GUI to be effectively used by a new engineer that join the workgroup.

Finally, some small automations on the pre-processing or post-processing phase can improve the quality of the analysis, leaving to the end-users more time to focus on the real aim of their work: evaluate the simulation results with their engineering judgement.

The aim of this paper is to summarize the experience of SmartCAE in the field of customer-driven CAE software development, in the form of both plug-ins for existing commercial software and new stand-alone products, that are tailored to specific applications.
2: The need for software customization

Often the end-users of commercial simulation software need some level of customization to simplify the daily work or to cover some of the technical limitation of the used code. Some commercial pre and postprocessors allow some degree of customization via macro languages or API interfaces.

While this approach is helpful for small enhancements, mostly to automate some repetitive pre and post-processing tasks (productivity tools), it couldn’t be satisfactory when also some new algorithms must be implemented.

Being at the same time a CAE software end-user and vendor SmartCAE found many limitations of existing FE software and, sometimes, simple and cost effective ways to overcome those limitations. Sometimes a simple Visual Basic application is enough to achieve the goal, while in other cases the situation is more complicated and it requires a graphical application for CAE data handling and manipulation.

The strategy chosen by SmartCAE for the development of graphical applications is to use existing commercial applications as “frameworks” for the software development. This approach leads to many technical advantages for the developers:

- The “framework” database structure is used to handle (create, edit, manipulate) the model entities (geometry, mesh, properties, results)
- The “framework” GUI, often supporting OpenGL hardware, is used for the graphical visualization of entities and results.
- The existing scripting language and/or programming API of the “framework” that allows the customization of the user interface and the development of mathematical algorithms is exploited.
- The customized software may be portable over different OS platforms such as Windows, Linux, Unix (depending on the platforms supported by the “framework”).
- The “framework” licensing tools are used to “lock” the software as a plug-in for the framework (potential revenue source from the developed tool).
- The developer may focus only on the “core” algorithms and procedures, leaving the GUI development to the framework manufacturer.

The last advantage of the list above is probably the most attractive for small engineering companies, such as SmartCAE, that do not have the economical and/or man-work resources needed to develop and maintain a full-featured graphical CAE application.

This paper shows four different applications initially developed by SmartCAE to enhance the productivity of its consulting services, that have also been packaged as commercial software:

- Smart|FRF, a tool for FRF plot generation from Nastran results to Excel;
- Smart|Browser, a productivity plug-in for FEMAP;
- Smart|AISC, an automated post-processing tool to verify structural results according to AISC rules;
- Smart|Coupling, a tool for multi-physics simulation.
3: SmartFRF: A fast route from Nastran to Excel

One of the most widely methods used to compute Frequency Response Functions is the modal superposition techniques. The most used FE solver for this kind of analysis is Nastran because of its fast and accurate eigenvalue solver. In order to simplify the Nastran FRF analysis setup and post-processing SmartCAE developed SmartFRF, a software that:

- creates the input file for modal analysis (measurement points, frequency range, number of residual vectors);
- reads the results from the Nastran Punch file and computes the desired FRF response (dynamic stiffness, inertance, …);
- stores all the results in an Excel file of customizable format.

Figure 1 shows the SmartFRF GUI and a typical FRF plot with many design iterations and the given design targets. SmartFRF is written in Visual Basic.

4: SmartBrowser: Enhanced pre/post processing in FEMAP

One of the most time consuming task in the CAE process is still the preparation of the analysis model. In some cases, the GUI of the commercially available pre-processors may appear “hostile” for new-to-FEA users, especially if compared to user-friendly tools like popular mid-range 3D CAD systems. Furthermore, some automations of repetitive tasks is sometimes required, especially to simplify the access to advanced post-processing features. This was one of the main reasons behind the development of a productivity plug-in for the popular FE pre-processor FEMAP, SmartBrowser.

SmartBrowser (Figure 2) is a collection of utilities that simplifies the handling of complicated FE models, by using an assembly tree logic, directly derived from modern 3D CAD systems. This program provides an intuitive way to manipulate, create and edit.
the FE entities, linking directly the underlying FEMAP database. Smart|Browser not only steepens the learning curve for new users, but it also improves the way to use FEMAP for all the other users, because it adds shortcuts to the most common visualization tasks for FE parts and results.

Together with Smart|Browser comes Smart|Laminate, a specific plug-in for composites pre-processing of laminated composites (Figure 3). This tool simplifies the modelling of complex laminations, providing to the user tools to add multiple plies, automatic computation of the total thickness and the equivalent stiffness properties of the laminate. Smart|Laminate helps the designer to both optimize the lamination and prevent the most common mistakes in the FE modelling of composites with FEMAP.
For the post-processing of FEA results, Smart|Browser provides quick-buttons for filtering the contour map, reverse the contour colour table, or plot vector results such as SPC forces, MPC forces or principal stresses over shells. Please notice that all these functionalities are already available on the FEMAP environment, but they require a relatively long and sometime error-prone sequence of “mouse clicks” to be used.

![Figure 4: Different kind of vector plots](image)

Smart|Browser and Smart|Laminate are written in Visual Basic. They interact with FEMAP via API, by using the Microsoft COM and .NET paradigms.

5: Smart|AISC: Verification of structures according AISC for FEMAP

Another time consuming task is the post-processing of structural results in order to fit prescribed regulation standards. For framed structures, modelled with beam elements, this purposes, SmartCAE developed Smart|AISC, a software that is able to pre and post-process a FE model within FEMAP in such a way to match the AISC code procedure.

Smart|AISC is able to identify automatically the frame geometry topology, to apply the appropriate verification procedure to each member of the structure. The output is given as a contour map over the FEA model, with the Utilization Factors under the different load components, and as a summary of the relevant results in Excel format.

Smart|AISC is written in Visual Basic. It dialogues with FEMAP via API using the Microsoft COM and .NET paradigms.
6: Smart|Coupling: A tool for multidisciplinary simulations

One of the most challenging tasks in today’s simulations is the Multi Disciplinary Optimization (MDO) of a mechanical system.

The goal of MDO is to make engineers able to analyse and optimise complex physical phenomena, where more than one discipline is involved. This class of problem is very wide and it includes, for example, the Fluid – Structure Interaction (FSI), where the structural response of a body under the action of fluid dynamic boundary conditions, has an influence on the calculation of the thermo-fluid-dynamic field and vice-versa (Figure 6).

The main problem for a practical and effective MDO is that, nowadays, only few simulation software are able to handle efficiently a fully coupled simulation, and usually they are applicable only under some modelling restrictions. On the other hand, the engineer can choose between many different good commercial tools, to explore each specific engineering field: CFD, FEA, EMAG, etc.
Practical MDO is then complicated, by the fact that heterogeneous hardware, software and engineering competencies may be involved (Figure 7):

- the hardware / operating system requirements of the codes may be different (RISC, IA32, IA64, Windows, Unix, Linux, etc.);
- the engineering skill and experience required for each discipline may be significantly different;
- different simulation software requires different modelling strategies (grid shape, density) and, in general, one and the same mesh can’t actually be used for different disciplines.

To cover this kind of needs SmartCAE has developed a tool called Smart|Coupling, which enables MDO by interfacing different CAE software. The program provides engineers with many tools for model import/export, multi-model matching, data interpolation, grid transformation and optimization.

The core of Smart|Coupling is its database where two models can be stored, viewed, modified and paired for multi disciplinary simulation. The typical workflow within Smart|Coupling is described in the following steps:

**Step #1 - Multiple model import.** The software can import two models with their results from different sources (CFD, FEA, Process, EMAG, etc.). During the import phase, the user can select the parts of the whole model that are actually subjected to interaction. Then, the engineer can view the model and check the imported results by means of graphic contour.

**Step #2 - Model matching.** The engineer can transform (scale, translate, rotate) one or both of the imported models (both grid and results) to fit the two grids in the space, as shown in Figure 8. This is useful because the two models may have different units: typical for FSI is to have the CFD model with length in meters and the FEA in millimetres. Doing the transformation of the model “a posteriori” doesn’t require the engineers to change their modelling strategies, thus reducing the impact for the MDO deployment on the existing CAE procedures.
Step #3 - Data interpolation. Once the pairing strategy has been decided, it is possible to transfer the result field from the source grid as a boundary condition to the destination one. This is done through a 3D interpolation algorithm that allows a smooth transition of the result field across the two grids. The algorithm works on both volumetric grids and surfaces. The quality of the interpolated field can be shown graphically by means of contours (as shown in Figure 9), or quantitatively by means of checksum values and XY plots.

Figure 8: Overlapping between CFD model (yellow) and FEA mesh (blue)

Figure 9: Pressure interpolation result. Left: the source CFD model, Right the destination FE mesh

Step #4 - Updated model export. The interpolated data may be exported and used as a boundary condition for the next simulation software.

Smart|Coupling is developed by using the FEMtools Framework from Dynamic Design Solutions for model data storing and manipulation.
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7: GiD: a cost-effective CAE software development toolbox

SmartCAE considers GiD a cost-effective and valuable development platform for mesh-based codes and vertical pre/post processors for existing simulation software. The benefits of GiD for the developer, either software houses or end-users are:

- porting of GiD on different OS;
- availability of all the typical pre/post processing tools, from geometry import, to mesh generation, to result visualization (both structural and CFD);
- interfaces for popular commercial FE software such NASTRAN;
- platform-independent scripting language such as Tcl/Tk that allows the development of custom and portable applications.

Possible toolbox to be developed on the GiD framework could be:

- specialty postprocessors for FE result verification according to international rules (civil engineering, shipping registers, …);
- specific pre and postprocessors for laminated composites structures (draping of skins over the mesh, custom failure index criteria, …);
- graphical pre and post processors for automatic Design Optimization routines (sensitivity based, topology, …).

8: Conclusion

Industry-specific tools that are easy to use and able to automate the every day’s CAE tasks are continuously required by the CAE community.

General purpose simulation environments are not always able to cover such specific requirements and there is room for the development of custom programs, which can be in the form of plug-ins for existing software, or brand new vertical applications.

In order to minimize the development efforts, costs and time, an accurate selection of the development framework has to be made, by using, as a preference, software which are well suited to such extensions (i.e. has a scripting language as GiD and/or API interface as FEMAP) or CAE-oriented programming platforms such as FEMtools.