

# Visualisation and Grid applications of electromagnetic scattering from aircraft

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## Abstract

Electromagnetic scattering behaviour plays a central role in the design of aircraft and other complex structures. This paper describes progress on visualisation tools in this area and on initial development of a web portal to enable scientists at remote locations to collaborate.

## 1 Introduction

The study of electromagnetic scattering has a central role in the design and remote sensing of aircraft and other complex structures. Engineers may use calculations of radar scattering behaviour, for example, to optimise the design of shape and of material properties, with collaborating scientists often at geographically remote sites.

This paper describes progress on visualisation tools for electromagnetic scattering and on the initial development of a web portal interface to the scattering codes. Both aspects are expected to be of use for similar projects in the future.

The visualisation tools allow interactive examination of scattering patterns across the structure surface, and of the radar cross section (RCS) and electromagnetic fields in 3D space around and within the structure. The high computational cost makes interactivity particularly demanding. Interpolation is first used to provide higher-resolution interrogable data, from values calculated at an initial set of points. Several representations can then be applied, to allow investigation of key features in radar data, their causes, and how they can be eliminated. The user can for example view isosurfaces, ie surfaces of equal intensity in 3D; alternatively colour contour plots which reveal high-intensity areas by steering a cutting plane interactively along the waveguide, in a virtual ‘fly-through’.

The web portal provides a user friendly, platform-independent and location-independent frontend to the scattering codes. It locates suitable compute resources, runs the code on behalf of the user and transfers the output datasets back for visualisation. This allows the user to concentrate on the design process and the science without having to worry about the operational details of running the simulation.

We now describe the scientific background and progress on the project, and several new aspects which are emerging as the work evolves.

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## 2 Scientific Background and Tasks

Over recent years the Waves Group at DAMTP [1] has developed highly efficient and accurate methods for large scale electromagnetic and acoustic calculations, driven both by scientific curiosity and industrial need. The project has evolved from tackling simple idealised scattering problems to treatment of electrically large objects on a scale unavailable by other approaches. With the development of a parallel code on the Cambridge High Performance Computing Facility [2] and its validation jointly with BAE on test cases, the project has become of increasing commercial relevance to the aerospace industry. It has brought closer the eventual goal of calculating the RCS of full-sized aircraft at operating frequencies and its incorporation in the design process. However, the increasing scale has led to large data storage, handling, and visualisation requirements.

The main scientific tasks in the modelling process are:

1. Specify/generate the surface geometry and material properties on a structured grid;
2. Calculate surface currents, induced by interaction of the structure with an illuminating or incident electromagnetic wave;
3. Find the electromagnetic fields (using surface currents) around and within the structure and the radar cross section (RCS) in the far field.
4. Visualise and manipulate the electromagnetic field patterns.

These quantities are of crucial importance in several aspects of aircraft design, for example in minimising RCS or electromagnetic compatibility (EMC) including interaction with radar or radio equipment. Steps (3) and especially (2) are computationally highly intensive, and for realistic problems accurate results currently require extended use of parallel codes.

Small or localised changes in shape or material properties can have a dramatic effect on the scattered EM fields. However, the effects of such changes cannot easily be predicted without going through a full computational procedure. In addition, the high-dimensional data (3D fields, with additional dependence on parameters including angle of incidence) present difficulties in both data handling and visualisation. A major goal of the project is therefore to allow the end-user to run the model, use the visualisation to identify problems or RCS features needing modification, and interactively change the surface properties and repeat the process.

## 3 Web portal development

The Globus Toolkit [3] is an open source, reference software base for building grid infrastructure and applications. Its use in this project allows access to appropriate local and remote compute resources for the purpose of running the scattering code and retrieval of the output datasets. As Globus is currently based on a rather low level set of command line tools, a user friendly front end has been developed (a “portal”) to guide the user through running the code and visualisation of its output. With web browsers being ubiquitous nowadays, a web interface is a natural choice for portal development.

The Cambridge EMS Web Portal (CamEMSWP) is based on the Grid Portal Toolkit (Gridport) v2.2 [4]. It provides the following capabilities through a web browser:

- Login/logout through MyProxy [5] delegation
- Remote job submission either interactively or in batch mode
- A batch job manager
- File transfer including upload, download and third party transfer

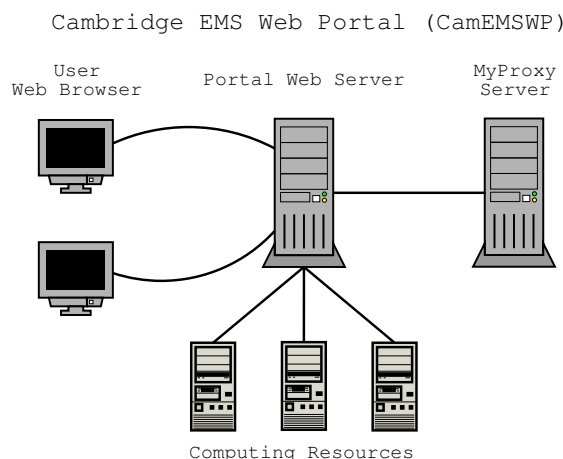


Figure 1

Figure 1 shows the architecture of CamEMSWP. The portal web server plays a key role. Firstly, all user interaction happens via the portal. Secondly, it handles the location of suitable compute resources and job submission using the Globus MDS and GRAM protocols.

When a user logs in to the portal it retrieves a temporary Globus GSI proxy credential from a MyProxy server, thus relieving the need to store a user's private keys on the portal server itself. This allows the portal to access Grid resources on the user's behalf.

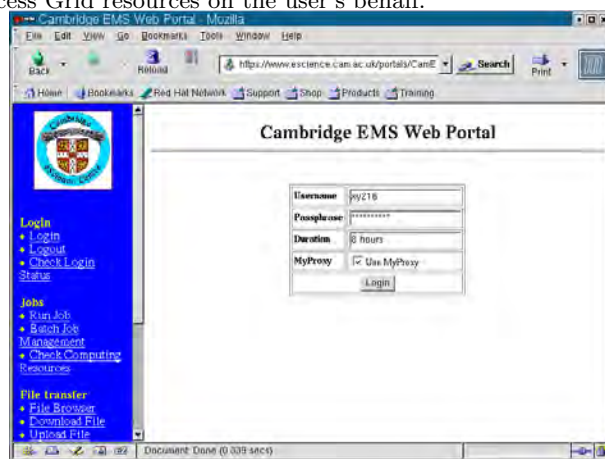


Figure 2: CamEMSWP login window

Having logged in the user is now able to submit jobs to run the electromagnetic scattering code, monitor jobs while they are running and transfer the output datasets back from the remote compute resource. Figure 3 shows the batch job management window giving the current status of two batch jobs. The first job has completed while the second job is still ac-

tive. Results from completed jobs may then be visualised using the tools described below.

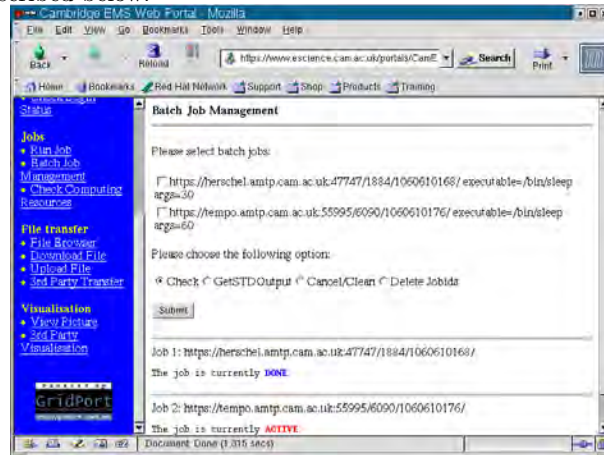


Figure 3: CamEMSWP batch job management

## 4 Visualisation

Visualisation is a vital aspect of the project, providing insight into the complex data generated at each stage of the scattering calculation. We describe the open source tools currently under development, based on the Visualization Toolkit [6].

VTK is a C++ class library that directly implements a number of visualisation algorithms. There are separate wrappers for Python, TCL and Java, although these are true wrappers and thus the underlying libraries built from the C++ code are always required. The software is open source with a large and active user community, with many commercial and academic projects successfully utilising it. These range from NCSA's Cave Visualization [7] project, for viewing astronomical datasets to the Visible Human [8] project at General Electric.

VTK's architecture makes the creation of sophisticated three dimensional graphics applications relatively straightforward, with the additional advantage of using C++, allowing object oriented techniques to be applied. Moreover, the implementation of many visualisation algorithms provides a well-defined platform on which to base a new project where interactive graphics are a necessity.

### 4.1 Techniques

At every spatial sampling point there is a complex-valued 3-vector, which in the simplest case provides a single scalar value in the form of its amplitude or intensity. These scalar intensities are then mapped against a colour lookup table, with the application of a variety of filters and mappers creating a geometry that can be rendered.

The surface currents and the interior field values have essentially the same data layout format and this simplifies the data loader classes for visualisation. Indeed, the same loader class can be used for both the surface current data and the interior field data. Once the data is loaded it is stored in VTK based arrays, where higher level functionality can be

accessed such as bounds checking and dynamic array sizing. All the data from the simulation is stored in a custom dataset object.

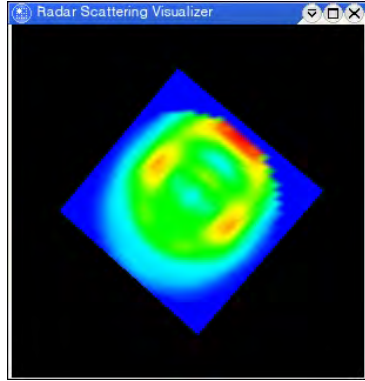


Figure 4: Single slice of interior field values

The visual appearance of the object depends on the topological and geometric representations of the underlying dataset. For example, the data may be plotted as single points with a scalar attribute at each point, using the VTK vertex cell type. Indeed, this representation was used initially, which was interesting but not necessarily useful in this context, other than to manipulate the geometry and get an approximation of how the surface currents and interior fields lay within the sample object.

Other cell types such as lines and quadrilaterals often give better results, with scalar attributes interpolated across the cell. A line cell representation of the surface currents on our sample duct-shaped object is shown in figure 5.

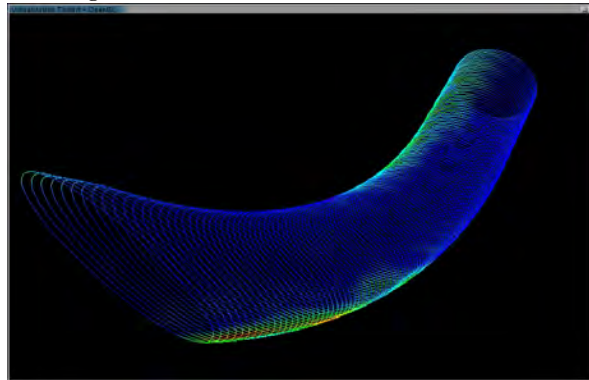


Figure 5: Line representation of surface currents

The electromagnetic fields interior to the object are best represented using three dimensional cell types. Initially a voxel cell type was used with interpolation between the slices. This gave some visually pleasing results that will need to be tested more, especially with the volume rendering classes of VTK on high performance hardware.

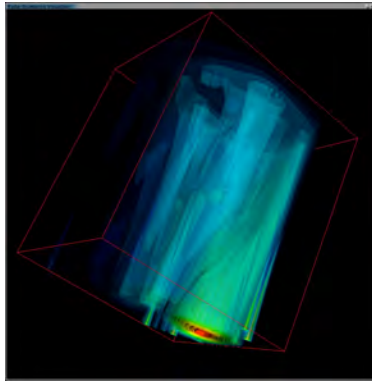


Figure 6: Voxel representation of three interior fields

Other aspects of the data are more clearly revealed by use of isosurfaces. The dataset consists of several interior field 'slices' which may be used as input directly to a `vtkDatasetMapper` object, passed to a `vtkContourFilter` object and finally rendered. A cutting plane allows parts of the duct to be sliced away, revealing the underlying representation.

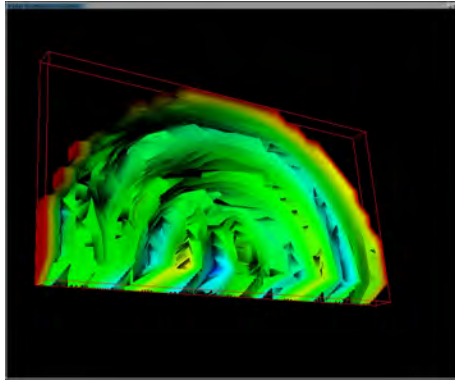


Figure 7: Isosurface with cutting plane

Future work will include the addition of a graphical user interface, with the `wxWindows` [9] toolkit currently under evaluation. Like VTK it is an open source project with a strong user base. Written in C++, the software development process is simplified due to a single language implementation. Moreover, `wxWindows` is a cross platform product which will considerably simplify porting to other operating systems and architectures, should the need arise.

It is envisaged that remote visualisation will be supplied by providing precompiled shared libraries on the initiating workstation, along with the visualisation application, thus harnessing local graphics processing hardware. Other methods have been investigated but have proved to be incompatible with the project aims. SGI Vizserver [10] provides remote rendering via framebuffer compression but the server component only runs on SGI Irix and is a closed source system. VNC [11] also provides a mechanism for remote desktop, but OpenGL support is well known to be incomplete. Indeed, further work needs to be done on the area of remote visualisation and how this can be integrated with the Grid.

## References

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- [9] wxWindows, <http://www.wxwindows.org/>
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- [11] VNC (Virtual Network Computing), Laboratory for Computer Engineering, University of Cambridge, <http://www.uk.research.att.com/vnc/>