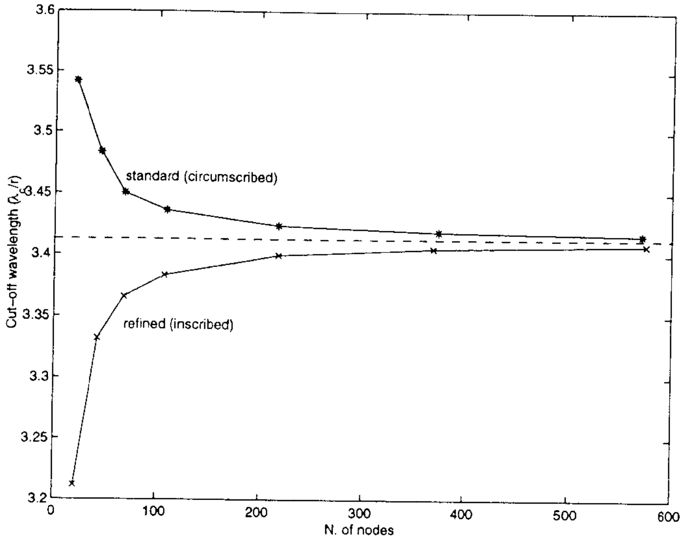

Fig. 6: Upper and lower bounds (TE_{11} mode in circular waveguide).

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THE USE OF THE VIRTUAL REALITY MODELLING LANGUAGE FOR VISUALIZATION OF 3-D ELECTROMAGNETIC FIELD COMPUTATION RESULTS

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Abstract

Research groups working in the domain of electromagnetic field computation are mainly not working on the algorithms for the visualisation of complex geometries in 3D. However, it is necessary to have a graphical representation of computational results. Amongst the general needs are the visualisation of solid models, meshes and field values. In this paper, a platform independent visualisation tool is introduced which is suitable for studying 3D finite element models.

INTRODUCTION

The Virtual Reality Modelling Language (VRML) is a general 3D visualisation language which was originally meant for interactive simulation applications on the Internet [1]. It allows the creation of 3D static worlds with hyperlinks to and from other pages. The language has been selected for 3D visualisation on the Internet from a large group of candidate languages. It is based on the Open Inventor File Format from Silicon Graphics Inc.

VRML is widespread used and becomes more and more a standard language within the World Wide Web. Pro/ENGINEER, a leading CAD program, already includes a VRML exporting possibility for their models. Recent upgrades of the language include interactivity and definition of predefined behaviours[2].

Because of its platform-independence and its ASCII-format, the language is interesting for the visualisation of scientific results. Fig. 1 shows a multicolour example of the magnetic field distribution in a saturated iron core. VRML-models can be incorporated in WWW-pages, sent by e-mail or edited by hand.

THE VRML LANGUAGE

Stated generally, VRML defines a set of objects useful for the construction of 3D graphics. These objects include geometric primitives like cubes and spheres but also transformations, light sources, colour and reflection properties.

The language can be used to view both finite element models, meshes and computed results. To view models, some elementary rendering techniques are included which allow a more realistic appearance of the model. Different light sources (directional light, spot light) exist. In some VRML-viewers, the ambient light can be modified during viewing. The colour of the objects can be specified with values

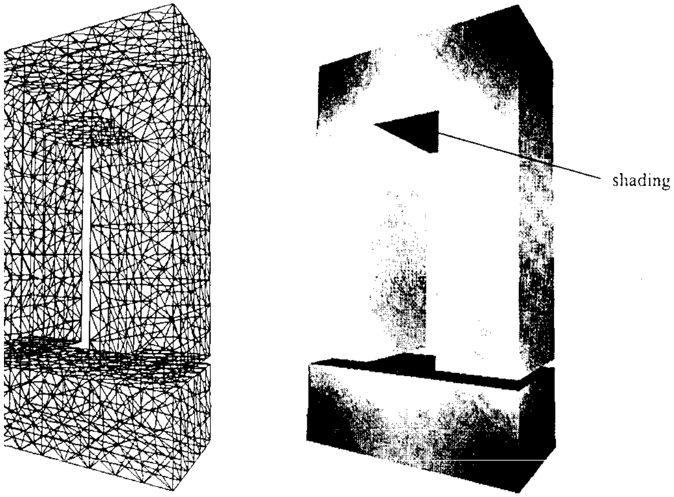

Fig. 1: View of the mesh and the magnetic induction of a saturated iron core of a simple inductor.

l, green and blue intensity. Objects can either emit light or reflect light in a diffuse way. erties exist, but they may not always be included in every VRML-viewing program.

element models, it is important that polygons can be defined in a straightforward way. :an be grouped together by means of the 'Separator{}' keyword. A list of node co-ordinates up followed by a list of node number sequences which form the polygons from the surface ion of the finite element model. Meshes can be visualised easily by means of the neSet{}' keyword. A list of node number pairs forming the edges of the mesh, is then

aphical representation of computed field distributions, it is important that no shading is This shading effect would influence the interpretation of colour shaded plots (Fig. 1). For se, the colour of the polygons has to be emissive. No light sources and no reflection are defined. To obtain colour shaded plots on the models, it is possible to either select one polygon or to select a colour per node of the polygon. In the latter case, a linear n of the colour is then performed within the polygon. This property is useful when viewing y varying properties of 2D/3D finite element models.

recent version of the language, it has become possible to include user interactivity and behaviour. In this way, it is possible to visualise movements of geometrical parts in the h can illustrate the working principle of the model or effects such as geometrical vibrations ions.

RATION IN A FIELD COMPUTATION PROGRAM

view a model, a mesh or a colour shaded plot of computed field values, a VRML-file (.wrl has to be created. To view the results, the file has to be loaded into the VRML-viewer.

VRML-viewers are available as stand alone programs e.g. on HP workstations or as an Internet-browser plug-in (Cosmo Player is very popular). Since most operating systems allow multi-tasking, the combined use of the field computation software with the VRML-viewer is possible.

Since the VRML file format is very compact, it takes very little computational effort to create a VRML-file even for complex models. The ASCII file format enables to program interfacing routines by using standard programming languages. Once the file has been loaded into the viewer, the graphic can be rotated, translated and zoomed in and out by means of simple mouse clicks. No user command line input is necessary.

DISCUSSION

A general discussion of advantages and shortcomings of using VRML in a field computation software environment is given in the following section.

The language specification and the viewers are cost-free. Both can be downloaded from the Internet. Since the language is intended for use within an Internet browser, it is inherently platform independent. It can be used on both powerful workstations and standard PC's. Positioning of the model and changing the viewpoint happens by means of mouse clicks. These actions are performed in real-time at high frame refresh rates. One of the reasons for this is that advanced rendering techniques have been omitted in order to be able to using the tool on regular PC's. No user commands have to be typed in. Fig. 2 shows an example of a simple inductor model with a two-layer winding. The model for the iron core is generated by means of an extrusion based mesh generator. This feature is illustrated by the visualisation of the planes necessary for the extrusion process.

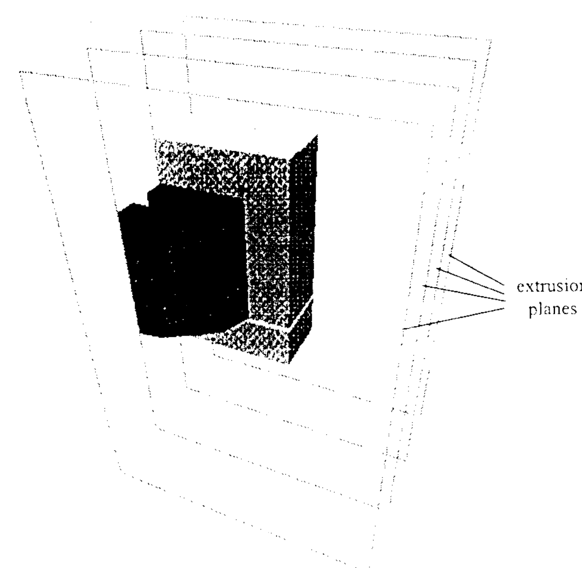

Fig. 2: View of the model of a inductor with the visualised planes necessary for the mesh extrusion.

becoming a world wide standard for viewing 3D objects, it can be used for the exchange of onal results between co-operating research groups. VRML models can easily be :ed in a WWW-page. Because the file is in ASCII-format, it is possible to convert the files lifferent platforms. Because the language is general, the user/programmer is free to include :e axes, select which parts of the model are to be viewed and which not.

file is in ASCII-format, different parts of 3D images can be joined by means of a simple Paste operation between two text files. In Fig. 3 the example shows an image which was ɔy joining a high-voltage tower model with a slice of the electric field distribution at the vel. The tower model was obtained from the mesh generation while the electric field ın represents the field solution of the 3D finite element model.

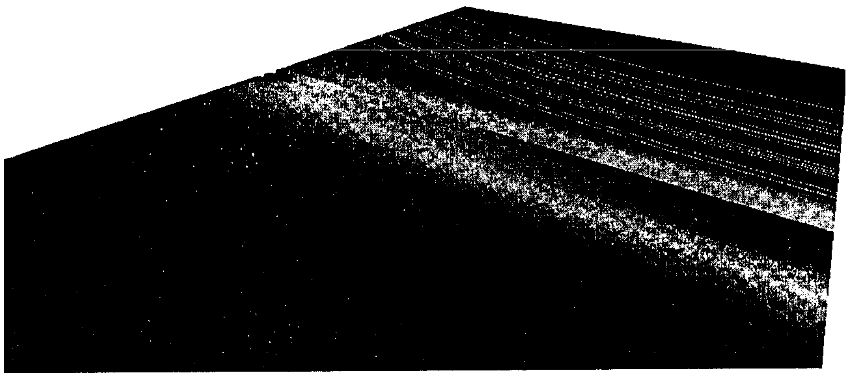

Fig. 3: View of the electric field distribution at ground level below a 150 kV high-voltage line.

obvious shortcoming is the fact that for every 3D image, a new file has to be created. If ɔperties have to be added or changed in the graphic (e.g. changing the background colour), ıs to be edited manually. The previous discussion can now be summarised by listing the advantages and disadvantages of the proposed 3D-viewer for FEM applications:

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Though VRML is widely accepted as the standard for visualising 3D environments, competition is coming from Java3D. Java3D has a lot of advantages in common with VRML: cost-free, platform independent,etc. Java3D will include VRML file loaders but 3D objects created by a Java applet are not necessarily stored in a file. However, VRML is certainly easier to learn. Java3D is an API which means that it can be part of a complete field computation package in Java. Java3D is therefore more powerful but it requires better programming skills than VRML interfacing. However, Java3D cannot be easily incorporated into existing source code. The standard for Java3D has been set by SUN Microsystems.

CONCLUSION

In this paper, the Virtual Reality Modelling Language (VRML) is introduced. This is a visualisation language originally meant for viewing 3D models on the Internet. Here, several aspects of using this language within a field computation software package independent of the Internet are discussed. The language together with an appropriate viewer can be used as a 3D postprocessor tool for finite element models. Writing interfaces for VRML only requires basic programming skills.

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