

IMPROVED MESH GENERATOR FOR THE POISSON GROUP CODES*

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Abstract

This paper describes the improved mesh generator of the POISSON Group Codes^[1]. These improvements enable one to have full control over the way the mesh is generated and in particular the way the mesh density is distributed throughout this model. A higher mesh density in certain regions coupled with a successively lower mesh density in others keeps the accuracy of the field computation high and the requirements on the computer time and computer memory low. The mesh is generated with the help of codes AUTOMESH and LATTICE; both have gone through a major upgrade. Modifications have also been made in the POISSON part of these codes. We shall present an example of a superconducting dipole magnet to explain how to use this code. The results of field computations are found to be reliable within a few parts in a hundred thousand even in such complex geometries^[2].

Introduction

The POISSON Group Codes are used to perform electromagnetic field computations for magnets and radio-frequency cavities. These programs require a discretization of the physical geometry with mesh points. The accuracy of field calculations depends on how well these mesh points approximate the geometry, especially in the vicinity of the region where a detailed analysis is to be performed. This is particularly important when the geometry includes curved surfaces and when sections of geometry are not well separated. To deal with such cases one must (1) have a high mesh density in these regions and (2) have a control (leverage) on the way the mesh is generated so that the details of the geometry can be incorporated by refining the mesh further. In an earlier paper^[3] we reported the incorporation of few techniques in AUTOMESH for creating such a mesh; in this paper we report more progress in that direction, and describe an alternative way of generating the mesh, which is easier to use. We shall discuss it with the help of an example.

Improved AUTOMESH

The improved AUTOMESH gives the user complete control over the way the mesh is generated. One can describe several areas of different mesh densities at various places and can resolve the finer details of the geometry.

The distribution of the mesh density is managed with the help of several special regions, referred to here as SREG (normal regions are referred to as REG). The points in these regions are referred to as SPO. In the input to AUTOMESH, in addition to the NREG normal regions, there may be NSREG special regions. They appear before the normal regions and most of the rules which apply to normal regions apply to these special regions as well. For example, in special regions too, one starts with the outermost region first and goes successively in by overlaying a new region on top of the previous one.

However, there are three exceptions :

1. Instead of using the NAMELIST variables MAT, CUR etc., one uses the new NAMELIST variables with the purpose of defining the mesh size and other related quantities. These variables are SX0,SX,NX0,NX, SY0,SY,NY0,NY and their default

value is zero. To understand how it works, let us consider the following statement

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$ SREG SX=10.,NX=10,SY0=2.,SY=5.,NY0=8,NY=6 $
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This means that we shall have 10 (NX) divisions between 0.0 (SX0) and 10.0 (SX) in X dimension and 6 (NY) divisions between 2.0 (SY0) and 5.0 (SY) in Y dimension; moreover 8 (NY0) mesh points will be left before 2.0 (SY).

2. One need not define the first special region completely. If in the first \$SREG statement (second statement in the input file) NSREG is not zero, the program will automatically generate a rectangular region with the following points:

(SX0,SY0), (SX,SY0), (SX,SY), (SX0,SY), (SX0,SY0).

The next NSREG regions need not be rectangular.

3. These special regions should either be closed regions or the end points of them should lie on a region boundary of a previously defined special region.

The implementation of the mesh density management system into the program is described here. In each special region the program freshly computes the parameters such as XMIN, XAMX, DX, ... with the help of NAMELIST variables SX0, SX, NX0, NX, ... The necessary points on the boundary of each special region are found and the region data are generated. An intermediate file TAPE74.DAT;1 (similar to TAPE73.DAT) is created with the NSREG+1 number of regions. At this stage the program calls several subroutines of LATTICE to generate a complete mesh using the file TAPE74.DAT;1 as input. This mesh is later used to find the logical coordinates in the normal regions.

Although it is advised that one ordinarily has a number of additional normal regions with their geometry being similar or close to those of special regions, the NAMELIST variables SX, NX, etc. should never be used in normal regions. That would result in creating a completely new mesh and thus destroying the previously generated mesh.

We have also included four new variables XADD, YADD, RADD, TADD in the \$SREG NAMELIST statement. These variable are used to bias the path of finding the logical coordinates in a certain desired direction. This is particularly useful when the separation between the two curves is less than a mesh spacing.

Improved LATTICE

LATTICE is known to have a weakness of creating "Negative Area Triangles". Sometimes such triangles are created by some points which are collectively incompatible or undesirable to the way LATTICE works. The program now finds such points in the input file so that they may be corrected in the next run. It also points out if two points have the same logical coordinates but different physical coordinates. That would result in replacing the previous physical coordinates by the newer ones. It also looks into the relationship between various points and issues cautions if these points seem to have the potential of creating a bad mesh. However, in most cases these cautions may be ignored.

Some time the "Negative Area Triangles" are created even when the input is alright. This is especially seen when the mesh size is not the same throughout the model. The problem is solved differently for the interface points (points on a region boundary) and for the interior points. For the interface points the new LATTICE computes and inserts a few intermediate points at the appropriate places by analyzing the other points. It is done in the beginning of the run and this not only solves the problem at the interface points but it also helps in creating a better mesh for the interior points. To further improve the mesh for interior points we have modified the process of initialization and relaxation. If the "Negative Area Triangles" are still created, then first the program will try to fix them by repositioning its three points within an allowable limit. The interface points will not be moved in this process. If this repositioning fails, the control is returned to the user to correct these points interactively.

Improved POISSON

Modifications have been made in POISSON to improve the convergence and to provide the user with full access to the intermediate results while the original run is in progress for a better convergence. Please see Ref. 3 for these and other improvements.

Example: A Superconducting Magnet

The physical geometry of the problem, which we need to describe in our model, is shown in Fig.1. It is a quadrant of a symmetric dipole magnet. The accuracy of the field computation at the center of aperture depends on a good coil description. The details of coils are more visible in Fig.2. For a good model, it is important that each block of this coil structure is separated from others — these blocks should not bump into each other. The primary requirement for this is to have a dense mesh in the coil region. However, as we shall point out in the next Section, this mesh needs to be further deformed to resolve the details of dimension less than a mesh size. To keep the total number of mesh points low (and thus computational time and memory requirements also low), the mesh density is successively reduced in the outer regions. The mesh, so generated, is shown in Fig.3. The mesh around the coil region can be seen more clearly in Fig. 4.

Input to the improved AUTOMESH to generate this mesh is given on the next page.

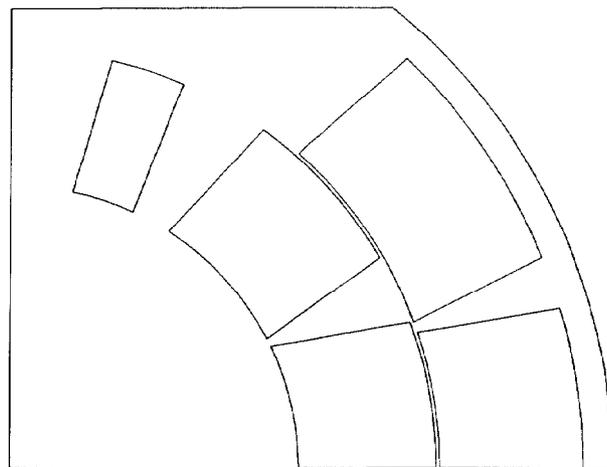


Fig.2. The model for the coil.

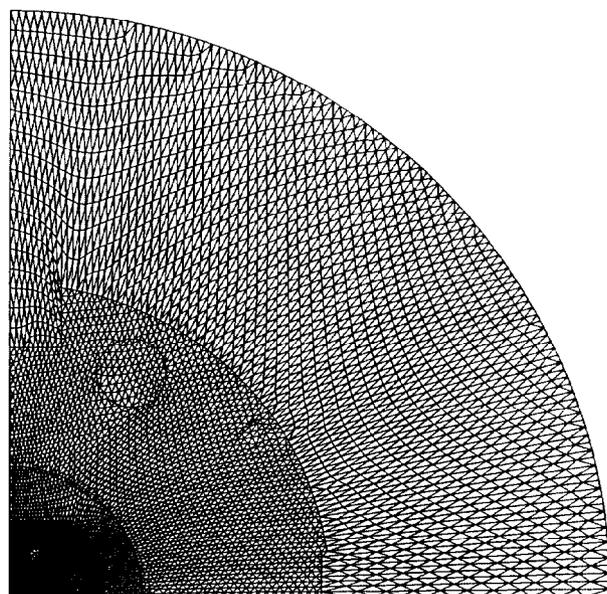


Fig.3. The mesh for the magnet.

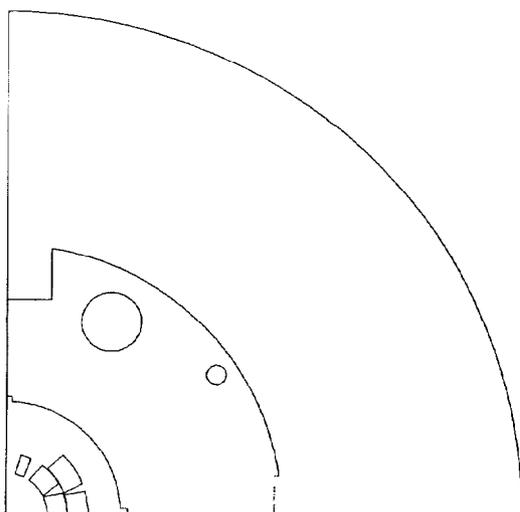


Fig.1. The model for the magnet.

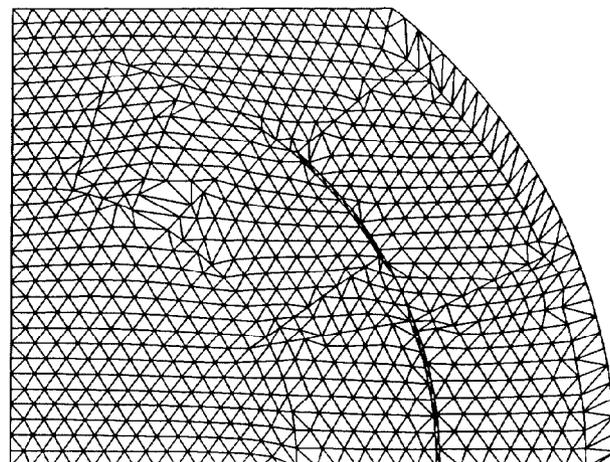


Fig.4. The mesh for the coil.

A Superconducting Dipole Magnet

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$ REG NSREG=3,NREG=11,SX=25.,NX=70,SY=25.,NY=70$
$ SREG SX=14.0,NX=62,SY=14.0,NY=62,NPOINT=2$
$ SPO X=14.0,Y=0.$
$ SPO X=0.,Y=14.0,NT=2$
$ SREG SX=6.0,NX=40,SY=6.0,NY=40,NPOINT=2$
$ SPO X=6.0,Y=0.$
$ SPO X=0.,Y=6.0,NT=2$
$ SREG SX=4.20,NX=30,SY=3.25,NY=30,NPOINT=3$
$ SPO X=4.2,Y=0.$
$ SPO R=4.2,THETA=51.,NT=2$
$ SPO X=0.,Y=3.25$
$ REG IREG=1,MAT=1,CUR=0.,NPOINT=4$
$ PO X=25.,Y=0.$
$ PO X=0.,Y=25.,NT=2$
$ PO X=0.,Y=0.$
$ PO X=25.,Y=0.$
$ REG IREG=2,MAT=3,CUR=0.,NPOINT=8$
$ PO X=12.9791,Y=0.$
$ PO X=12.9791,Y=1.905$
$ PO X=13.1995,Y=1.905$
$ PO X=2.159,Y=13.1604,NT=2$
$ PO X=2.159,Y=10.6172$
$ PO X=0.,Y=10.6172$
$ PO X=0.,Y=0.$
$ PO X=12.9791,Y=0.$
$ REG MAT=1,IREG=3,NPOINT=4$
$ PO R=1.4605,THETA=0.,X0=5.08,Y0=9.525$
$ PO R=1.4605,THETA=120.,NT=2,X0=5.08,Y0=9.525$
$ PO R=1.4605,THETA=240.,NT=2,X0=5.08,Y0=9.525$
$ PO R=1.4605,THETA=0.,NT=2,X0=5.08,Y0=9.525$
$ REG MAT=1,IREG=4,NPOINT=4$
$ PO R=0.4832,THETA=0.,X0=10.16,Y0=6.915$
$ PO R=0.4832,THETA=120.,NT=2,X0=10.16,Y0=6.915$
$ PO R=0.4832,THETA=240.,NT=2,X0=10.16,Y0=6.915$
$ PO R=0.4832,THETA=0.,NT=2,X0=10.16,Y0=6.915$
$ REG IREG=5,MAT=1,NPOINT=8$
$ PO X=5.8865,Y=0.$
$ PO X=5.8865,Y=.3207$
$ PO X=5.5470,Y=.3207$
$ PO X=0.254,Y=5.5505,NT=2$
$ PO X=0.254,Y=5.823,NT=1$
$ PO X=0.,Y=5.823 $
$ PO X=0.,Y=0. $
$ PO X=5.8865,Y=0.$
$ REG NPOINT=3,IREG=6$
$ PO X=4.2,Y=0.$
$ PO R=4.2,THETA=51.,NT=2$
$ PO X=0.,Y=3.25$
$ REG IREG=11,NPOINT=5,CUR=354.,RADD=-.06,YADD=.08$
$ PO R=1.999,THETA=0.218$
$ PO R=1.999,THETA=25.517,NT=2$
$ PO R=2.962,THETA=20.463,NT=1$
$ PO R=2.962,THETA=0.15,NT=2$
$ PO R=1.999,THETA=0.218$
$ REG IREG=12,NPOINT=5,CUR=413.,RADD=-.06,TADD=2.5$
$ PO R=1.999,THETA=27.267$
$ PO R=1.999,THETA=56.77,NT=2$
$ PO R=2.962,THETA=53.836,NT=1$
$ PO R=2.962,THETA=30.201,NT=2$
$ PO R=1.999,THETA=27.267$
$ REG IREG=13,NPOINT=5,CUR=177.,RADD=-.06$
$ PO R=1.999,THETA=64.962$
$ PO R=1.999,THETA=77.615,NT=2$
$ PO R=2.962,THETA=76.349,NT=1$
$ PO R=2.962,THETA=66.226,NT=2$
$ PO R=1.999,THETA=64.962$
$ REG IREG=14,NPOINT=5,CUR=472.,RADD=.06,YADD=.08$
$ PO R=2.987,THETA=0.15$
$ PO R=2.987,THETA=18.789,NT=2$
$ PO R=3.993,THETA=16.484,NT=1$
$ PO R=3.993,THETA=0.11,NT=2$
$ PO R=2.987,THETA=0.15,NT=1$
$ REG IREG=15,NPOINT=5,CUR=708.,RADD=.06,TADD=2.0$
$ PO R=2.987,THETA=20.278$
$ PO R=2.987,THETA=48.198,NT=2$
$ PO R=3.993,THETA=46.5,NT=1$
$ PO R=3.993,THETA=21.975,NT=2$
$ PO R=2.987,THETA=20.278,NT=1$
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Discussion

This discussion refers to the Input to AUTOMESH and to the figures shown in the last page. Please compare SX, NX, SY, NY in the first region (which will generate a special region) and in the three special regions. This choice of parameters changes the mesh density rapidly with the lowest being in the fringe field region and the highest in the coil region. This relatively high mesh density in the coil region, although enough to construct a basic coil geometry, is not enough to represent the actual coil structure. We do the following to make a more realistic model.

To resolve a small separation between the inner and the outer layers (see Fig 3 and Fig 4), we use a negative value (-0.06) of RADD for the coil regions in the inner layer (IREG=11, IREG=12, IREG=13) and a positive value (+0.06) for the regions in the outer layer (IREG=14 and IREG=15). It logically increases the separation between the two layers by 0.12 cm. Similarly, to resolve an angular separation between the first and second blocks in both inner and outer layers, we use an angular bias with the variable TADD in the second blocks (region number 12 and 15). A very small midplane gap is incorporated with the help of parameter YADD in the first blocks of these two layers (IREG = 11 and IREG = 14).

It may be pointed out that we have included a normal region (IREG=6) whose geometry is the same as that of the last special region. We did not include other such regions because we already had some normal regions (IREG=2 and IREG=5) which are quiet close to those special regions (first and second) and they followed the required rule (No. 3) for describing a special region.

References

- [1] A.M. Winslow, "Numerical Solution of the Quadilinear POISSON Equation in a Nonuniform Triangular Mesh", J. of Comp. Phys., 2, pp. 149-172 (1967).
- [2] R.C. Gupta, G.H. Morgan and P. Wanderer, "A Comparison of Calculations and Measurements of the Magnetic Characteristics of the SSC Design D Dipole", to be published in this conference.
- [3] R.C. Gupta, "Improvements in the AUTOMESH and other POISSON Group Codes", Workshop on Electromagnetic Field Computation, Schenectady, NY, Oct. 20-21, 1986.