REAL- TIME FIELD DISTRIBUTION OF THE CLOSED OBJECT USING IMAGE RECONSTRUCTION TECHNIQUE

Sharvan Kumar

Dr B R Ambedkar National Institute of Techmology Jalandhar -144011 ,Punjab,India

ABSTRACT: Understanding of the anatomy and functions of an organ or a physiological process, various non-invasive imagining methods allow the clinicians to visualize and diagnose. The imagery is the richest source of information and the most important tool for well-being of the humans. The medical imaging techniques should be non-invasive to see inside the body. The image reconstruction methods have the power to see inside which the imaging device or naked eyes cannot see. The aim of this paper is to develop an image reconstruction algorithm which automatically form the nodes and find the unknown intensity of the closed objects or phantoms.

KEYWORDS: Imaging, IPG, image reconstruction, mesh.

INTRODUCTION

The medical imaging tool is a mean to look inside the body which is not seen by the naked eyes. There are various medical imaging modalities, a non-invasive and minimally invasive technique which are used to see the inner body anatomy and morphology for different inputs energy and generates different signals. These signal are monitored and captured at the surface of the human body and are considered to be signal output which represents the boundary conditions for image to be reconstructed. The signal arising from the patient depends on the physical process governing a given imaging modality. The final output is to create an image from the given boundary conditions through a mathematical image reconstruction algorithm. Voltage signal developed along the current path is sensed with the help of another pair of electrodes called the sensing electrodes or voltage electrodes V1 and V2. If sufficient data of surface voltages are logged for input energy, current patterns, the image can be reconstructed with the help of image reconstruction algorithm such as Finite Element Method (FEM) or Finite Difference Method (FDM) to create an image. Here an effort has been made to develop the image reconstruction algorithm which will generate the inner nodes for the given boundary condition. The inner nodes intensity is calculated and represents the conductance of the image to be reconstructed.

IMAGE RECONSTRUCTION ALGORITHM

In the IPG of 4 electrodes method, the constant magnitude ac current with frequency in KHz is inserted into subject/ phantom, supplied through two electrodes and the voltages produced inside is measured non-invasively between remaining two electrodes on the surface. The same procedure is applicable for imaging also where normally more that 8 electrodes are used. The governing equation of interest becomes the Laplace equation of voltage for non-homogeneous domain with irregular boundary shape and the calculus problem ($\nabla\rho$- * $\nabla V = 0$) in converted into the algebraic problem (YV=C). The domain/closed object of interest where imaged to be reconstructed, is split into grid or mesh using image reconstruction algorithms. The pivotal values at the points of intersection, known as nodes, are denoted by f_{ij} which is a function of the two space variable x and y. The differential equations corresponding to each grid point using function values at the surrounding grid points are written by their finite difference equivalent. Solving these equations simultaneously gives values for the function at each grid point. The image reconstruction algorithm uses finite difference equivalents of the partial derivatives to construct various types of differential equations using Laplace equation. To solve the Laplace's Equation on a region in the xy-plane for 16 electrodes, subdivide the region as shown in figure 1, consider the portion of the region near (x_i , y_i). The approximate equation is written as:

$$\nabla^2 f = \partial^2 f/\partial x^2 + \partial^2 f/\partial y^2 = 0 \quad (1)$$

Replacing the second-order derivatives by their finite difference equivalents at the point (xi, yi), and is written as

$$\nabla^2 fij = 1/h2\ [(fi+1, j+fi-1, j-4fij+fi, j+1+fi, j-1)] = 0 \quad (2)$$

Or

$$fij = 1/4\ (fi+1, j + fi-1, j + fi, j+1 + fi, j-1) \quad (3)$$

Eq. 3 contains four neighboring points around the central point (xi, yj) as shown in figure 1 also.

METHODOLOGY

For N-electrode system, apply a set of N/2 current patterns oppositively. The corresponding voltages patterns are measured and denote by V_1, V_2 … $V_{N*(N-3)/2}$. For finding the field distribution inside the object/ closed object, the software is developed which will generates the mesh automatically. The software is user friendly and graphically interactive. For discretisation, the closed object/domain is divided into a finite number of nodes with boundary conditions; a mesh is generated, with nodes of unknown intensity. After generation of grid the boundary condition are entered and embedded outside the grid. The software itself generates the equations of g_{ij} for all nodes which are stored in the form of [G][V] = [I] which are solved for finding conductivity distribution inside the object.

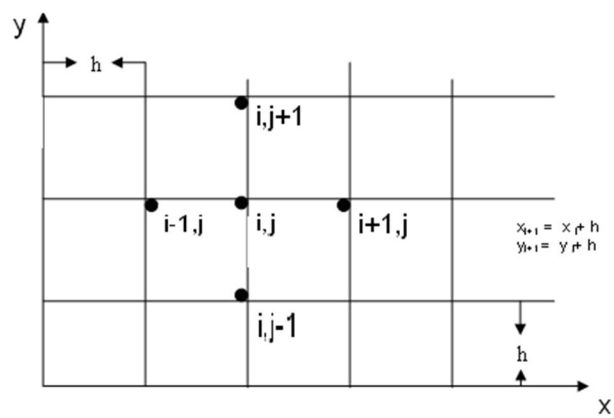
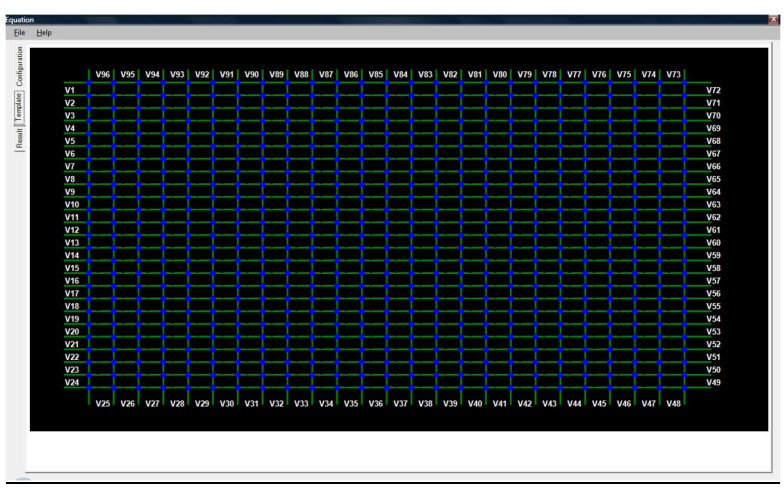


Figure 1. Two-dimensional finite difference grid

Following are the actions performed by the software application design for constructing a mesh:

1. Loading of input file containing voltage values.
2. Defining rows and columns of the grid
3. Validating the input and generating the grid with the supplied values.
   (Template of the final grid to be generated)
4. Form containing the result calculated with the defined formula. (as shown in figure 2)



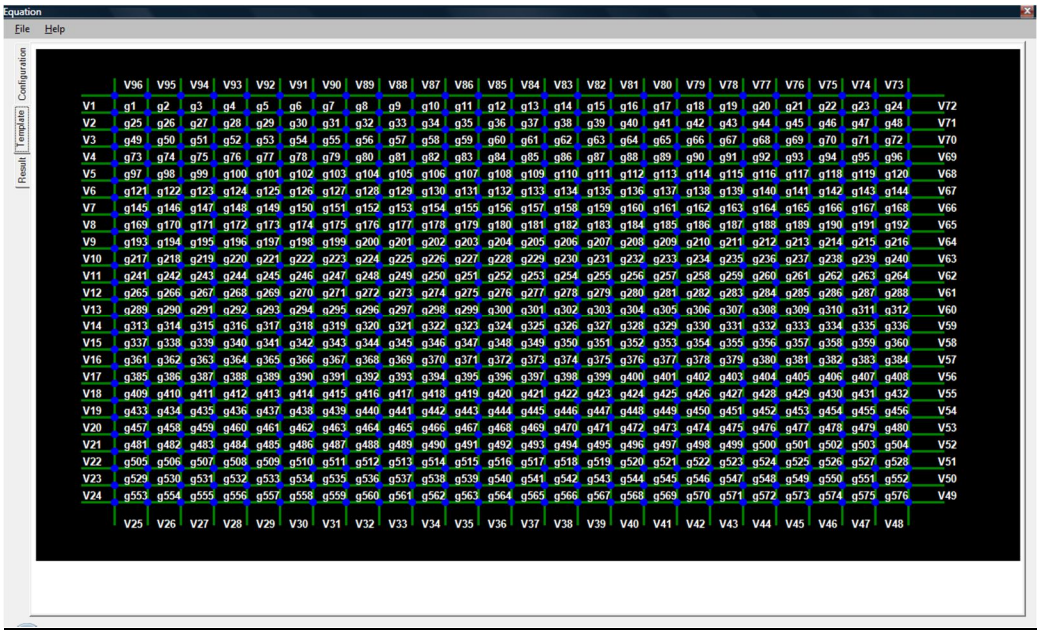


Figure 2. Template grid with supplied voltages and Vi (boundary conditions) is the voltages from the input file. And gij are the unknown values that are to be calculated with the image reconstruction algorithm

IMPLEMENTATION AND RESULT

The proposed algorithm can be implemented for any number electrodes configuration for mesh and boundary conditions. Here the 8 current patterns are applied and measurements of voltages are made on the other electrodes. The total number of boundary measured voltages is 104. The grid takes 26, rows and columns to create a grid. The mesh will have 678 nodes or pixels and same number of equations. The software automatically generates the equations and solves them all for finding the G_{ij} which is the pixel intensity of the conductive image in the closed region. The front panel of which is shown in figure 3. Software is implemented to generate the mesh and unknown pixel intensity is calculated by the algorithms for image formation. The snap shot of which is shown in figure 4.

Figure 3. Front panel of the mesh formation

Figure 4. The mesh shows the boundary voltages and unknown pixel intensity generated by the software

The proposed algorithm when applied for N=10 number of electrodes, the output of grid of 100 nodes are generated, marked as G_{ij} (G_1-G_{100}). The equations are generated for these nodes and the unknown values of G_{ij} are calculated and put back into the nodes which correspond to the intensity or conductivity values at those nodes. The complete procedure is shown in figure 5.

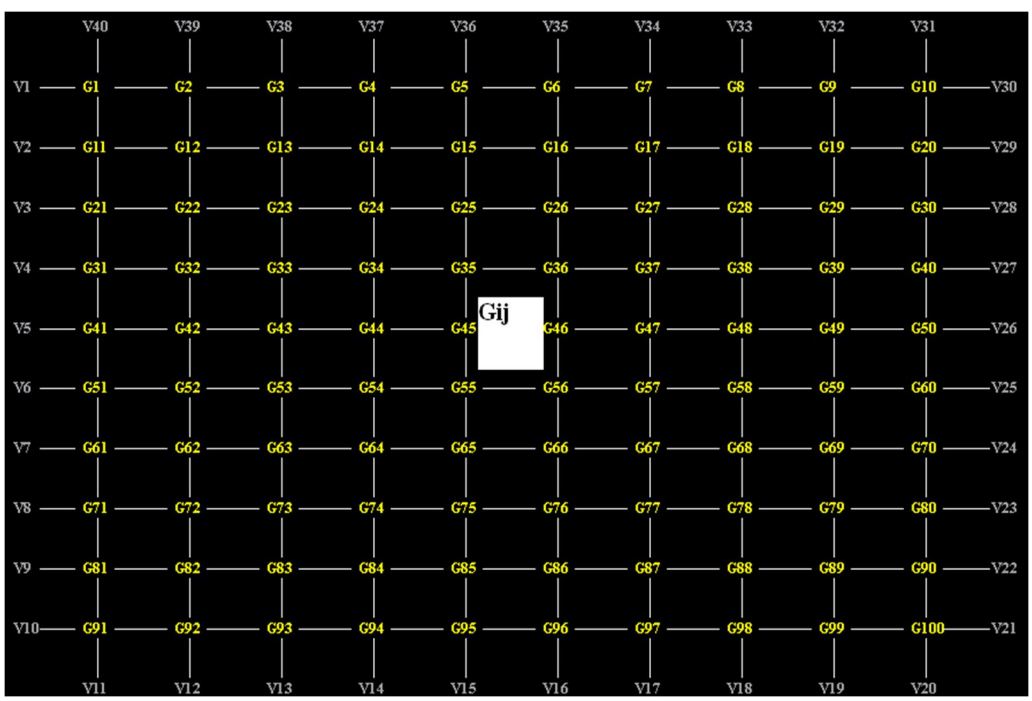


Figure 5(a). Grid of 100 nodes

0.3 + g2 + 0.42 + g11 -4xg1 = 0 ,g1 + g3 + 0.19 + g12 -4xg2 = 0,g2 + g4 + 0.33 + g13 -4xg3 = 0,g3 + g5 + 0.69 + g14 -4xg4 = 0,g4 + g6 + 0.4 + g15 -
4xg5 = 0,g5 + g7 + 0.98 + g16 -4xg6 = 0,g6 + g8 + 0.54 + g17 -4xg7 = 0,g7 + g9 + 0.59 + g18 -4xg8 = 0,g8 + g10 + 0.41 + g19 -4xg9 = 0,g9 + 0.23 +
0.35 + g20 -4xg10 = 0,0.26 + g12 + g1 + g21 -4xg11 = 0,g11 + g13 + g2 + g22 -4xg12 = 0,g12 + g14 + g3 + g23 -4xg13 = 0,g13 + g15 + g4 + g24 -
4xg14 = 0,g14 + g16 + g5 + g25 -4xg15 = 0,g15 + g17 + g6 + g26 -4xg16 = 0,g16 + g18 + g7 + g27 -4xg17 = 0,g17 + g19 + g8 + g28 -4xg18 = 0,g18 +
g20 + g9 + g29 -4xg19 = 0,g19 + 0.24 + g10 + g30 -4xg20 = 0,0.23 + g22 + g11 + g31 -4xg21 = 0,g21 + g23 + g12 + g32 -4xg22 = 0,g22 + g24 + g13
+ g33 -4xg23 = 0,g23 + g25 + g14 + g34 -4xg24 = 0,g24 + g26 + g15 + g35 -4xg25 = 0,g25 + g27 + g16 + g36 -4xg26 = 0,g26 + g28 + g17 + g37 -
4xg27 = 0,g27 + g29 + g18 + g38 -4xg28 = 0,g28 + g30 + g19 + g39 -4xg29 = 0,g29 + 0.25 + g20 + g40 -4xg30 = 0,0.18 + g32 + g21 + g41 -4xg31 =
0,g31 + g33 + g22 + g42 -4xg32 = 0,g32 + g34 + g23 + g43 -4xg33 = 0,g33 + g35 + g24 + g44 -4xg34 = 0,g34 + g36 + g25 + g45 -4xg35 = 0,g35 + g37
+ g26 + g46 -4xg36 = 0,g36 + g38 + g27 + g47 -4xg37 = 0,g37 + g39 + g28 + g48 -4xg38 = 0,g38 + g40 + g29 + g49 -4xg39 = 0,g39 + 0.25 + g30 +
g50 -4xg40 = 0,0.14 + g42 + g31 + g51 -4xg41 = 0,g41 + g43 + g32 + g52 -4xg42 = 0,g42 + g44 + g33 + g53 -4xg43 = 0,g43 + g45 + g34 + g54 -
4xg44 = 0,g44 + g46 + g35 + g55 -4xg45 = 0,g45 + g47 + g36 + g56 -4xg46 = 0,g46 + g48 + g37 + g57 -4xg47 = 0,g47 + g49 + g38 + g58 -4xg48 =
0,g48 + g50 + g39 + g59 -4xg49 = 0,g49 + 0.19 + g40 + g60 -4xg50 = 0,0.18 + g52 + g41 + g61 -4xg51 = 0,g51 + g53 + g42 + g62 -4xg52 = 0,g52 +
g54 + g43 + g63 -4xg53 = 0,g53 + g55 + g44 + g64 -4xg54 = 0,g54 + g56 + g45 + g65 -4xg55 = 0,g55 + g57 + g46 + g66 -4xg56 = 0,g56 + g58 + g47 +
g67 -4xg57 = 0,g57 + g59 + g48 + g68 -4xg58 = 0,g58 + g60 + g49 + g69 -4xg59 = 0,g59 + 0.31 + g50 + g70 -4xg60 = 0,0.28 + g62 + g51 + g71 -
4xg61 = 0,g61 + g63 + g52 + g72 -4xg62 = 0,g62 + g64 + g53 + g73 -4xg63 = 0,g63 + g65 + g54 + g74 -4xg64 = 0,g64 + g66 + g55 + g75 -4xg65 =
0,g65 + g67 + g56 + g76 -4xg66 = 0,g66 + g68 + g57 + g77 -4xg67 = 0,g67 + g69 + g58 + g78 -4xg68 = 0,g68 + g70 + g59 + g79 -4xg69 = 0,g69 +
0.22 + g60 + g80 -4xg70 = 0,0.16 + g72 + g61 + g81 -4xg71 = 0,g71 + g73 + g62 + g82 -4xg72 = 0,g72 + g74 + g63 + g83 -4xg73 = 0,g73 + g75 + g64
+ g84 -4xg74 = 0,g74 + g76 + g65 + g85 -4xg75 = 0,g75 + g77 + g66 + g86 -4xg76 = 0,g76 + g78 + g67 + g87 -4xg77 = 0,g77 + g79 + g68 + g88 -
4xg78 = 0,g78 + g80 + g69 + g89 -4xg79 = 0,g79 + 0.4 + g70 + g90 -4xg80 = 0,0.15 + g82 + g71 + g91 -4xg81 = 0,g81 + g83 + g72 + g92 -4xg82 =
0,g82 + g84 + g73 + g93 -4xg83 = 0,g83 + g85 + g74 + g94 -4xg84 = 0,g84 + g86 + g75 + g95 -4xg85 = 0,g85 + g87 + g76 + g96 -4xg86 = 0,g86 + g88
+ g77 + g97 -4xg87 = 0,g87 + g89 + g78 + g98 -4xg88 = 0,g88 + g90 + g79 + g99 -4xg89 = 0,g89 + 0.33 + g80 + g100 -4xg90 = 0,0.21 + g92 + g81 +
0.16 -4xg91 = 0,g91 + g93 + g82 + 0.15 -4xg92 = 0,g92 + g94 + g83 + 0.07 -4xg93 = 0,g93 + g95 + g84 + 0.27 -4xg94 = 0,g94 + g96 + g85 + 0.23 -
4xg95 = 0,g95 + g97 + g86 + 0.28 -4xg96 = 0,g96 + g98 + g87 + 0.26 -4xg97 = 0,g97 + g99 + g88 + 0.31 -4xg98 = 0,g98 + g100 + g89 + 0.4 -4xg99 =
0,g99 + 0.34 + g90 + 0.33 -4xg100 = 0

Figure 5(b). 100 Equations generated by the software

Figure 5 Results of the Algorithm. Figure 5a shows the grid of 100 nodes with 40 boundary voltages. In figure 5 b the equations are generated by software and are solved. In figure 5(c) the unknown values of Gij are calculated with the image reconstruction algorithm for image formation and inserted into the nodes which correspond to the intensity or conductivity values at those nodes.

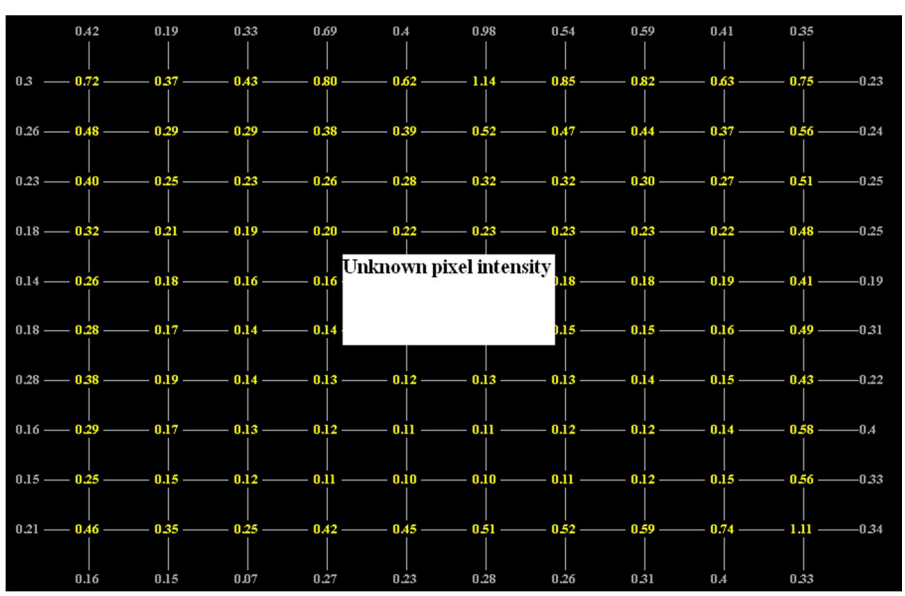


Figure 5 (c). After solving the o is replaced by values

CONCLUSION

The proposed algorithm can be implemented for any number electrodes configuration in medical imaging techniques for image reconstruction. The N/2 current patterns are applied and measurements are made on the other electrodes. The total number of boundary measured voltages is N (N-3)/2. Therefore take [N (N-3)/2]/4 rows and columns to create a grid which correspond to [N (N-3)/2]/4 x[N (N-3)/2]/4 nodes or pixels and same number of equations. The software automatically generates the equations and solves them all for finding the unknown pixel intensity of the conductive image in the closed region.

The software design here is user friendly and generates meshes, nodes and equations automatically for any length of nodes. The software also has a capability to solve these equations which represent the pixel intensity in term of conductivity distribution inside the closed object. The algorithm has very wide application in biomedical area especially in the field of electrical impedance tomography. Also same algorithm can be applied to non-medical such as in industrial processes.

The main objective here is to use the same software in reconstruction of an image of a phantom and human uterus and fetus.

REFERENCES

[1] Rosell J, Cohen KP and Webster JG. Reduction of motion artifacts using a two-frequency impedance plethysmograph and adaptive filtering. IEEE Transactions on Biomedical Engineering.1995; 42(10):1044 - 1048.

[2] Pahuja SK, Anand S, Sengupta A. Electrical Impedance Tomography based Image Reconstruction and feto-maternal monitoring in pregnancy.2011; 3(8): 482-86/ DOI: 10.4236/health.2011.38079.

[3] Gandhi SV, Walker DC, Brown BH, Anumba DC.Comparison of human uterine cervical electrical impedance measurements derived using two tetra polar probes of different sizes. Biomed Engg. 2006; 62(5):1-7.

[4] Choi MH, Kao TJ, Gary DI, Saulnier J and Newell JC. A Reconstruction Algorithm for Breast Cancer Imaging With Electrical Impedance Tomography in Mammography Geometry. IEEE Transactions on Biomedical Engineering.2007; 54:700-77.

[5] Cheney M, Isaacson D and Newell JC. Electrical Impedance Tomography. SIAM review, Society for Industrial and Applied Mathematics.1999; 41: 85–101.

[6] Nowakowski, T. Palko, and J. Wtorek. Advances in electrical impedance methods in medical diagnostics. Bulletin of the Polish Academy of Sciences Technical Sciences. 2005; 55: 231-243.

[7] Tidswell T, Gibson AG, Baybard RH and Holder DS, Three Dimensional Electrical Impedance Tomography of Human Brain Activity, NeuroImage.2001;13(2): 283-94.

[8] Bikker G, Preis C, Egal M, Bakker J and Gommers D. Electrical impedance tomography measured at two thoracic levels can visualize the ventilation distribution changes at the bedside during a decremental positive end-expiratory lung pressure trial, Critical Care. 2011; 15(4):1-8.

[9] Numerical Methods E Balagurusamy Tata McGraw-Hill New Delhi 2004.