Electromagnetic Visualization and Interaction Tools to Aid Electromagnetic Education

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Background & Motivation

The field of electromagnetics often suffers from students getting confused by or lacking interest in the subject, hence making it more difficult for students to understand the concepts involved. This can in part be due to the heavily mathematical and theoretical nature of the material which makes it difficult to perform 'hands-on' experiments that can show the operation of electromagnetic principles, especially at radio frequencies. To hopefully address this issue in some degree, a collection of tools has been created that aim to engage and instruct students about the properties of electromagnetic phenomenon by being interactive and observable to complement instruction that is often delivered in lecture format. One such tool, delivered in app format, calculates the electric field and voltage in 2-dimensional plane cuts of the 3-dimensional space, in which charges reside, at discrete points resulting from point charges in a region of space. It presumes electrostatic conditions and that the point charges are infinitesimal in size. Moreover, the app allows the user to move the charges around with their mouse and to set the charge magnitude, polarity, coordinate positioning, and more. Another tool enables the features of the former along with more programmatic control, that enables, among other things the creation of an animation depicting the charges moving throughout 3-dimensional space, at the cost of accessibility and convenience. The tools can thus facilitate student interaction with electromagnetics via an uncommon medium to help electromagnetics education sink in.

Methods Utilized

MATLAB and MATLAB App Designer were used in this project in order to design and build an app capable of displaying the electric field vectors at discrete points and voltage contour lines. Beyond my own code, MATLAB official documentation [1] and MATLAB Answers [2] by MathWorks staff was frequently used as a resource and is cited further in the paper. Sources referred to outside of MathWorks and staff include code provided by Dr. Elsherbeni and with authorship from Dr. Demir in segments [3], and additionally, an answer on the MathWorks forums was consulted and is referenced in the "References" section [4].

A novel feature of graph interactivity, or that one can physically drag charges in the graph screen presented, is introduced as well. Regions Of Interest, or ROIs, were utilized in order to enable interactive features with the main graph presented. Reference [4] proved useful in implementing ROIs, along with [1] and likely [2].

Electrostatics calculations in MATLAB were also performed, and requisite data storage, processing, display, etc… were also utilized, drawing on [1], [2], and likely [3].
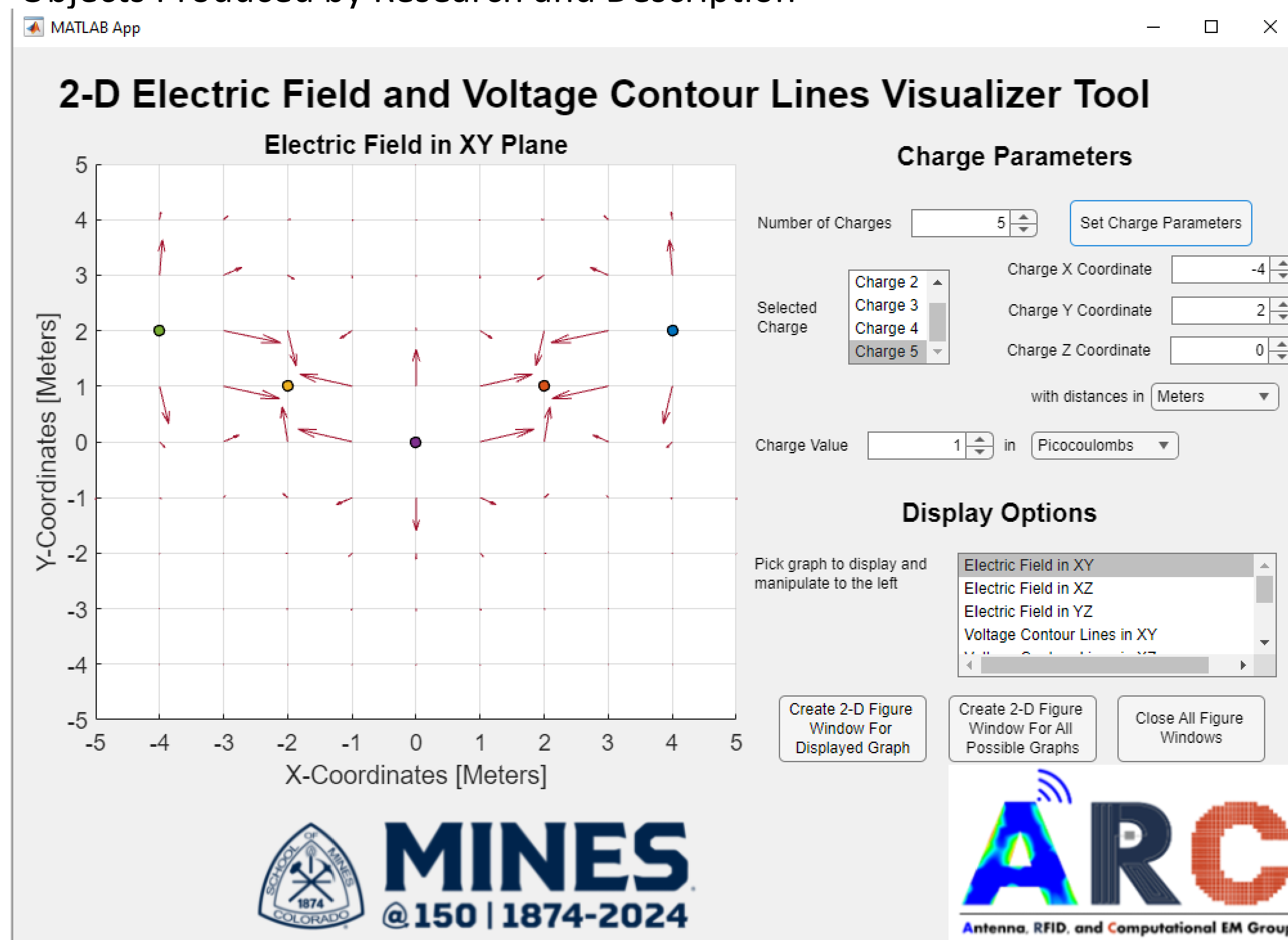
Objects Produced by Research and Description

Fig. 1. Picture of the screen for the "2-D Electric Field and Voltage Contour Lines Visualizer Tool", or the app produced by the research. The current charge configuration is listed to the upper right as "Table 1.". The charges precede in number from right to left, i.e. 1 is to the far right in the "Electric Field in X-Y Plane"

The object produced by the research is an interactive app to help display electrostatics. Users can manipulate charges in the main graph to position them how they like in the screen. They can select a different display option to move the charges around in different planes beyond the X-Y plane shown below, and different display options can produce the graphs shown to the right as Fig. 2 – 10.
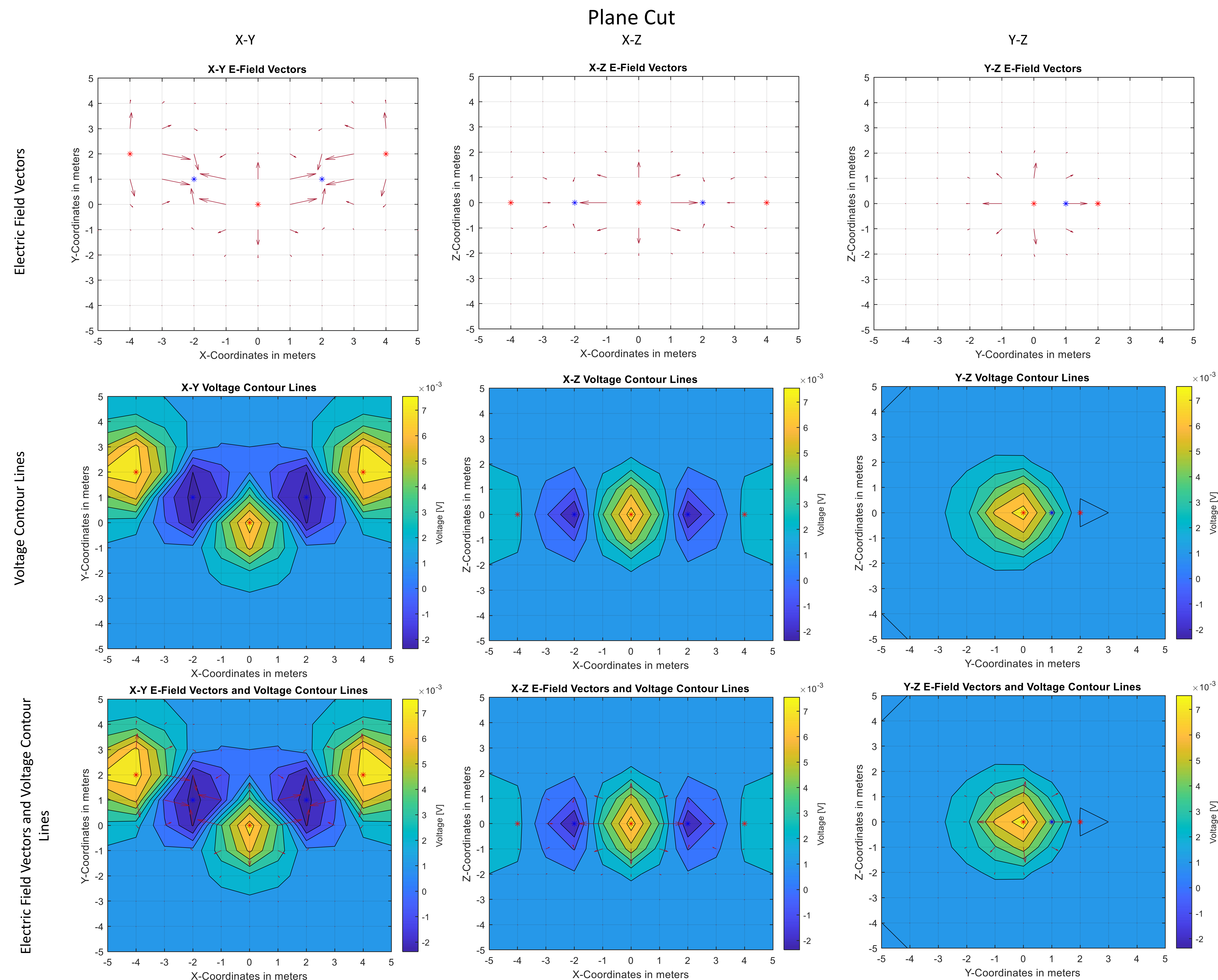

Fig. 2 – 10. All these figures were produced by the MATLAB App produced as part of this research project. The graphs are organized by the type of graph vertically and the plane cut horizontally. Specifically, the plane cut should be at 0 for any variable not shown in a plane, i.e., if 'X-Y' is shown, Z should be at 0. The parameters for the charges used to create these graphs are listed below in Table 1.

Charge Number	X coordinate [meters]	Y Coordinate [meters]	Z Coordinate [meters]	Charge [pC]
1	4	2	0	1
2	2	1	0	-1
3	0	0	0	1
4	-2	1	0	-1
5	-4	2	0	1

Table 1. This table shows the parameters used in producing Fig. 2-10 below in the app itself.

Charges may also be changed in more conventional ways, such as by selecting a specific charge in the menu from which one can edit its parameters, or one can change the settings file the MATLAB app draws from on start-up. Charge values can be changed to units of coulombs, microcoulombs, and picocoulombs, Users can edit the number of charges by increment, decrement, or numerical input into the correct window, and edit the coordinates and charge value windows in a similar manner. Users can then set the charges to save the charge parameters, and produce graphs by selecting the wanted option from the Display Options box and clicking the appropriate button, produce all possible graphs by the app for the charge set-up, or close all figures created.

References

[1] MathWorks. "MATLAB Documentation." MathWorks. https://www.mathworks.com/help/matlab/.

[2] MathWorks and MATLAB staff. "MATLAB Answers." MathWorks. https://www.mathworks.com/matlabcentral/answers/index.

[3] V. Demir and A. Elsherbeni, MATLAB files for "Electric Field due to static charges", distributed in MATLAB files.

[4] Tommy. "(app designer) Callback for ROIMoved event does not work" MathWorks. https://www.mathworks.com/matlabcentral/answers/518601-app-designer-callback-for-roimoved-event-does-not-work#answer_426554

Acknowledgements