Discovering and understanding the vector field using simulation in android app

A Budi1* and D Muliyati1

1Department of Physics Education, Universitas Negeri Jakarta, Jakarta, Indonesia

*Corresponding author’s email: agussb@unj.ac.id

Abstract. An understanding of vector field's concepts are fundamental parts of the electrodynamics course. In this paper, we use a simple simulation that can be used to show qualitative imaging results as a variation of the vector field. Android application packages the simulation with consideration of the efficiency of use during the lecture. In addition, this simulation also trying to cover the divergences and curl concepts from the same conditions that students have a complete understanding and can distinguish concepts that have been described only mathematically. This simulation is designed to show the relationship between the field magnitude and its potential. This application can show vector field simulations in various conditions that help to improve students' understanding of vector field concepts and their relation to particle existence around the field vector.

1. Introduction

Understanding the concept of physics can be improved by learning materials are integrated with information technology, e.g. simulation. This is in line with the development of computational skills, modelling and simulation practices [1]. In its use, the simulation can direct students to think the interconnection between the representation, for example the relationship between mathematical equations and its visualization. With the utilization of simulation in the process of learning physics, students gain a deeper understanding of a physical variable, more than just its mathematical equations. As in previous research, that the simulation very helpful learning goes on that many displays of abstract concepts and built from many mathematical equations [2,3].

On the other hand, the use of android as a means of supporting learning in the classroom has become a popular choice for teachers. Today, many virtual software lab-based desktop getting turned into an android-based. This trend because the consideration of android is an open source platform. Some study, android-based learning materials development makes the learning process more effective and efficient [4,5].

Electrodynamics course in our College is given to the 4th semester student requirements have passed courses of Basic Physics, Calculus, Mathematical Physics, and Programming. However, during 3 last semester in teaching electrodynamics, lecturers should review the concept of vector analysis at the beginning of the lecture. Its because this concept is a fundamental concept to understand another concept of electrodynamics. Discussion the vector analysis topic can spend 4 times face-to-face lectures and does not include additional meetings for exercise completion problem. It is certainly becoming not effective. It is necessary the learning strategies and learning materials development so that the courses be more effective without reducing the substance of the matter. In this paper, we
discuss the development a simulation for visualizing vector fields and related concepts. The goal is the comprehensive understanding of the students. The vector analysis topic still discussed with the appropriate time allocations. In the class, students use simulations to support the explanation lecturer, and outside the classroom this simulation can be used as self learning materials.

2. Methods
Understanding of vector analysis is fundamental to the various concepts of physics, especially in electrodynamics subjects. Many textbooks, The vector analysis be the first chapter or prior knowledge. Its because electrodynamics concepts can be understood if students understood the vector analysis. The most interesting topics in the vector analysis are the vector field. Its because this concept is connecting the other concepts, e.g. potential, divergence, and curl. All of these concepts will always be used in discussing various cases of electrodynamics. This section will discuss the list of the concepts of vector analysis related to vector fields.

2.1. The divergence of a vector
Vector fields in electrodynamics can be an electric field, \( \mathbf{E} \) or magnetic field, \( \mathbf{B} \). The vector fields \( \mathbf{F} \) can be operated by a nabla operator in the form of divergence and curl as the following equation [6]:

\[
\nabla \cdot \mathbf{F} = D
\]

From Eq. (1), the divergence of a vector will produce the result as a scalar function, \( D \), with \( D \) shown in Eq. (2).

\[
D = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}
\]

If we interpret the divergence of a vector, this is a spread measure of the vector \( \mathbf{F} \) is coming out from a point of the origin. In some sources [6, 7], the divergence is exemplified with the simple shapes like the following figure.

![Figure 1](image)

**Figure 1.** Figure 1a and 1c, have a positive divergence while the Figure 1b have a zero divergence

2.2. Curl of a vector
The next concept is the curl of a vector. The curl of a vector \( \mathbf{F} \) can be written as follows.

\[
\nabla \times \mathbf{F} = \begin{vmatrix}
\hat{x} & \hat{y} & \hat{z} \\
\frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\
F_x & F_y & F_z
\end{vmatrix}
= \hat{x} \left( \frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z} \right) + \hat{y} \left( \frac{\partial F_x}{\partial z} - \frac{\partial F_z}{\partial x} \right) + \hat{z} \left( \frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y} \right)
\]
If we interpret the curl of a vector, this is a measure of how much the \( \mathbf{F} \) vector rotates around a point. Figure 2 shows the curl visualization from some sources [6, 7].

![Figure 2. Some visualization the curl of a vector](image)

A vector which has a zero divergence, it can only have the value of the curl, and otherwise.

2.3. The potential of a vector field

The potential of a vector field \( \mathbf{F} \) can be written in the form of the scalar as follows [6].

\[
\nabla \times \mathbf{F} = 0 \iff \mathbf{F} = -\nabla \mathbf{V}
\]

(4)

From the equation, required if and only if the curl of a vector field is equal to zero, then the vector fields is the negative gradient of its scalar potential. This mathematical relationship can be expressed as the integrated visualization of vector fields, divergence, curl, and potential.

To understand the meaning and the interpretation of the divergence and the curls of the vector and the vector field associated, we required supporting materials. Through the simulation which is developed, it is expected students can get a "feel" of the divergence and the curl of a vector field.

3. Results and Discussion

Simulations developed can visualize the vector domain, divergence, curl, and potential of the equation of vector fields. Equation of the vector fields can use the data already provided or inputted by the student. Input the equation is in need of a consiste

3.1. Qualitative imaging results as a variation of the vector field

This simulation visualizes the domain and vector field as shown in Figure 3.

![Figure 3. The domain visualization in the form of equipotential and the magnitude field shown in blue color for the field equations \( 1/r \). This visualization can be rotated as required](image)
simulation can show gradations as difference of field magnitude. This expression of the field magnitude aimed so that students can connect with potential visualization such as shown in Figure 4. The potential shown by the red color.

![Figure 4. The potential visualization of $1/r$ shown by the red color](image)

The magnitude of vector field also expressed in the form of arrows pictures as shown in Figure 5. This form confirms the Figure 3. Students can compare tint between model simulation in 3d view or 2d view. The student can input field equations form panel. Figure 6 shows several input equation and visualize the 2d view of field vector.

![Figure 5. The magnitude of vector field visualization](image)

![Figure 6. Visualization of field equation which input by user, (a) $xi + yj$ and (b) $x^2i + y^2j$](image)
3.2. The simulation also trying to cover the divergences and curl concepts
The vector fields are also related to the divergence and curl concepts. Our simulations can indicate divergence with the color and streamlined. Curl was shown using curl (moving animation) detector. Figure 7 shows the divergence and the curls of the detector to the equation \((x^2 - y) \mathbf{i} + (x + y^3) \mathbf{j}\).

![Figure 7. Visualization of divergence and curl to the equation field \((x^2 - y) \mathbf{i} + (x + y^3) \mathbf{j}\)](image)

3.3. The simulation also trying to cover the influence of the field to the particle existence
The simulation can show how the influence of the field to the existence of particles as shown Figure 8. The particles are described by white dots. The number of particles can be arranged on a simulation panel. Visualization displayed moving animations.

![Figure 8. Visualization of the influence of field to the particle existence](image)

3.4. Appearance on device
The simulation may run well on Android devices, but the resulting application needs improvement at some points based on the qualitative assessment from the validator. The improvement on the character from the screen, the screen should be able to adjust the size of the simulation on different devices
(smartphone or tablet size variation) so that the display is mobile responsive. Figure 9 shows the display when the application is run on an Android device.

![Figure 9. The appearance of simulation on android device.](image)

3.5. **How to measure the student understanding after simulation using**

The success of using this simulation can be measured through objective tests related to vector fields. Students may be required to determine if a visualization of vector fields unknown or equations can estimate equation of vector field visualization if it’s known. An example of this evaluation as shown in the following Table 1.

| Sample Question |  |
|-----------------|-------------------|
| 1               | Which is the vector field sketches $$\mathbf{F}(x, y, z) = xi$$… |
| ![Diagram a](image) | ![Diagram b](image) | ![Diagram c](image) |
| 2               | Which is the vector field sketches $$\mathbf{F}(r, \theta, \phi) = a_{\phi}$$ |
| ![Diagram a](image) | ![Diagram b](image) | ![Diagram c](image) |

The ability to read the vector field figure and understand mathematical equations in association with representation is one of the competencies that must be established for students of physics.
undergraduate. In the future, particularly used in many fields such as applied physics, geophysics [8], astrophysics [9] and material science [10].

4. Conclusion

The vector field simulation Android-based device have been developed. In this article we describe how to use the simulation developed for the learning of vector fields. Simulations have successfully demonstrates vector field visualization, and related concepts such as: potential, curl, divergence. At the initiation of a virtual lab on vector fields, the simulation also features an input vector field equations. This section will continue to be developed. Based on the limited tests, this simulation can support materials to help students improve the understanding of the concept of vector fields through visualization of various mathematical equations either provided or inputted by students. Additional competencies of learning with this simulation is the ability to read and analyze the image which is the visualization of vector fields.

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