Computer based teaching aid for basic vector operations in higher institution Physics

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Abstract

The concept of vectors is widely applicable in describing mechanical systems. However in most Ethiopian High Schools, Colleges and Universities, this concept is carried out by employing a traditional chalk and talk lecture-oriented teaching method in which most students face difficulties in understanding and visualizing the physics of vectors. The purpose of this paper is to develop a simulator that could describe the graphical demonstration of basics of vector operations in more interactive and student-oriented method. It is believed that this simulator could demonstrate basic vector operations in both two and three-dimensional spaces. We used MATLAB as a background and developed a standalone program such that anyone can run on any PC. We named our simulator as BDU Physics Vector Simulator.

Keywords: Vectors, simulator, Active learning methods.

Resumen

El concepto de vectores es de amplia aplicación en la descripción de los sistemas mecánicos. Sin embargo, en la mayoría de las Escuelas Secundarias, Colegios y Universidades etíopes, este concepto se enseña empleando el método tradicional de conferencias orales de pizarrón orientado a que la mayoría de los estudiantes se enfrentan a dificultades en la comprensión y la visualización de la física de los vectores. El propósito de este trabajo es desarrollar un simulador que podría describir la demostración gráfica de los elementos básicos de las operaciones de vectores en un método más interactivo orientado a los estudiantes. Se cree que este simulador podría demostrar las operaciones vectoriales básicas en dos y espacios tridimensionales. Se utilizó MATLAB como fundamento y se desarrolló un programa independiente de tal manera que cualquiera lo puede correr en cualquier PC. Llamamos a nuestro simulador, BDU Physics Vector Simulator.

Palabras clave: Vectores, simulador, métodos de aprendizaje activo.

I. INTRODUCTION

The knowledge of vector is very crucial especially for students majoring in science and engineering. It is available in many courses, which are delivered in high schools and Universities. Different teaching methods and teaching aids are used in teaching vectors. In the Ethiopian context, one usually employees chalk and talk teaching method and demonstrates vector operations by drawing schematics on the blackboard and also using still pictures and diagrams available in the textbooks. This kind of instruction offers very limited activities for the students and essentially makes them passive listeners. However, it is widely acknowledged that students learn best in an interactive and active learning environment. Students should have the possibilities to learn by exploring their ideas.

Different kinds of learning environment could be established to facilitate learning and nowadays the possibilities of using modern technology to create a suitable learning environment are getting significant attentions [1]. Particularly computer has provided unprecedented opportunities to create different learning environment [2]. The physics community has recognized for sometimes now that different concepts of physics can be demonstrated and thought easily by using virtual systems. For example, the Physics 2000 and Physics Education Technology (PHET), which cover many topics of physics, are popular online, interactive learning environments. Essentially, all the available virtual physics learning environments are limited in their scope and coverage. It is impractical to cover all topics of high school and University physics in a single virtual learning environment. This means that there are still many crucial topics in physics that don't have proper interactive learning environment.

The present paper aims at creating an interactive virtual teaching aid for basic vector operations in high school physics. This kind of work have been reported for other topics in physics including the simulation of the magnetic

field from a long straight wire [3], the physics of simple pendulum [4] and optical interference effects [5].

II. BASIC VECTOR OPERATIONS

A. Mathematical representation of vector Operations

Basic vector operations presented in most physics textbooks include addition, subtraction, dot product and cross product of vectors. We can describe how one might teach these operations mathematically by considering two vectors for simplification. These two vectors are given by

$$\mathbf{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} , \qquad (1)$$

$$\mathbf{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k} ,$$

where *i, j,* and *k* are the units vectors along x −axis y−axis and z −axis and $A_x, A_y, A_z, B_x, B_y, B_z$ are the corresponding scalar coeficients. The vector sum of these two vectors is given by

$$\mathbf{A} + \mathbf{B} = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k} . \qquad (2)$$

The dot product of vector A and B is expressed by

$$\mathbf{A}.\mathbf{B} = A_xB_x + A_yB_y + A_zB_z . \qquad (3)$$

Here we have used the fact that the dot product of two perpendicular vectors is zero. One can also compute the cross product of vector A with B as

$$\mathbf{A} \times \mathbf{B} = (A_yB_z - A_zB_y)\hat{i} - (A_xB_z - A_zB_x)\hat{j} + (A_xB_y - A_yB_x)\hat{k} . \qquad (4)$$

B. Physical interpretations of vector Operations

Teachers usually give physical interpretations for the mathematical presentations of basic vector operations in subsection A.

Basically the cross product of two vectors refers to the projection of one vector over the other. Moreover it can be considered as a mechanism that generates another third vector which is perpendicular to the plane that contains the two vectors. Typically, the cross product of three vectors is interpreted as the volume of a parallelepiped formed by these three vectors.

III. BDU PHYSICS VECTOR SIMULATOR

The name BDU Physics Vector Simulator (BDU-PVS henceforth) is in accordance with the naming of virtual systems developed at virtual physics laboratory in BDU. The original code for BDU-PVS is written in MATLAB.

However, it is compiled to make it usable in a computer without the installation of MATLAB. BDU-PVS is designed to demonstrate basic vector operations in two and three dimensional spaces visually in an interactive manner. The operations include addition, subtraction and multiplication of vectors by a scalar, cross and dot product s vectors. BDU-PVS provides an easy to use graphical interface where users can interact with the system without going into lines after lines of code. The users can set the input parameters as they wish and see what they get out from the system. In this stage we have limited the number of inputs to three vectors having three dimensions. However, the basic physics can still be demonstrated by taking these limited cases. It is pedagogically sound to consider the simple case.

The three input vectors to BDU-PVS are denoted by **A**, **B** and **C**, where

$$\mathbf{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} ,$$

$$\mathbf{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k} , \qquad (5)$$

$$\mathbf{C} = C_x\hat{i} + C_y\hat{j} + C_z\hat{k} .$$

Here *i, j* and *k* are respectively a unit vector along *x*-axis, *y*-axis and *z* -axis. The users are required to insert the components of *A, B* and *C* in the empty spaces that they will get when they run BDU-PVS for the first time (See Figure 1).
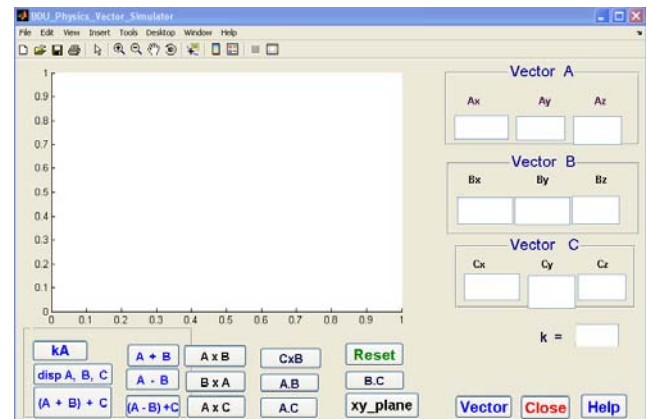

FIGURE 1. Matlab gui BDU-PVS working window.

Let us see some vector operation outputs of BDU-PVS by considering the following input values.

$$\mathbf{A} = 2\hat{i} - \hat{j} + \hat{k} ,$$

$$\mathbf{B} = 3\hat{i} + 4\hat{j} + \hat{k} , \qquad (6)$$

$$\mathbf{C} = -4\hat{i} + 6\hat{j} + 7\hat{k} .$$

By using the above values, if the users click at the button dispA, B, C, the simulator displays the three vectors **A**, **B** and **C** as it is shown by Figure 2.
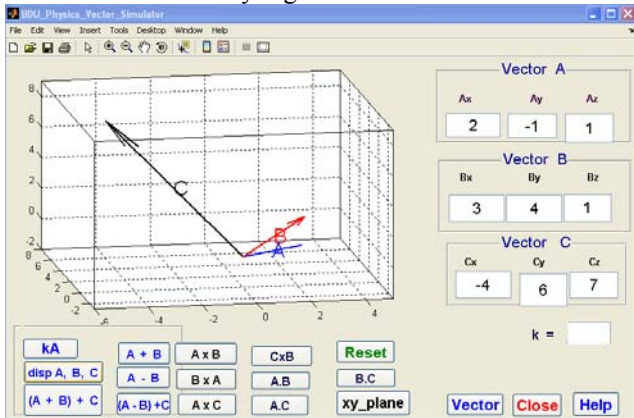

FIGURE 2. Vectors *A, B* and *C*.

Similarly clicking at the button A + B results addition of vector **A** and **B** as given by Figure 3. Moreover clicking at the button **A**x**B** gives the cross product of vector *A* with *B* as it is displayed by Figure 4. Finally if the user click at the button k**A**, vector A with its components will be displayed (see Figure 5).
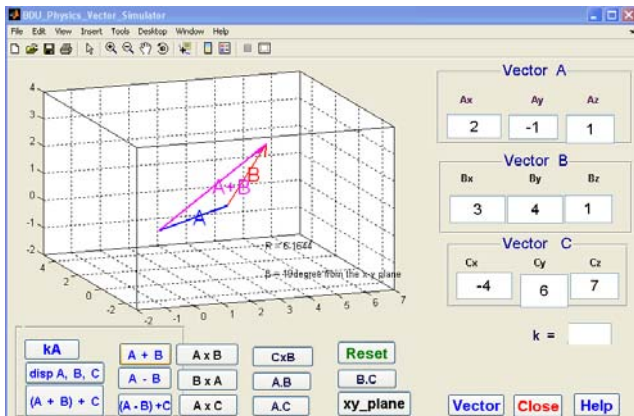

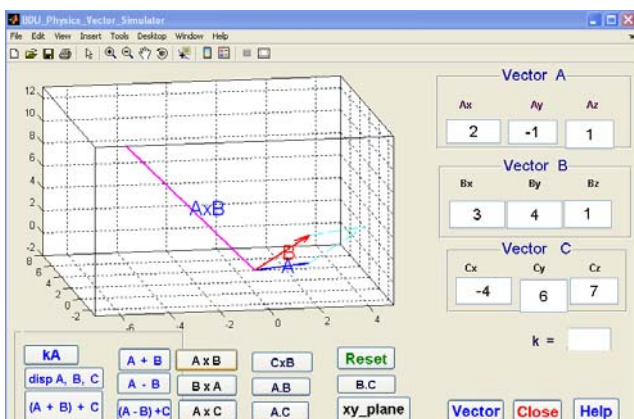**FIGURE 3.** Addition of Vectors *A* and *B*.

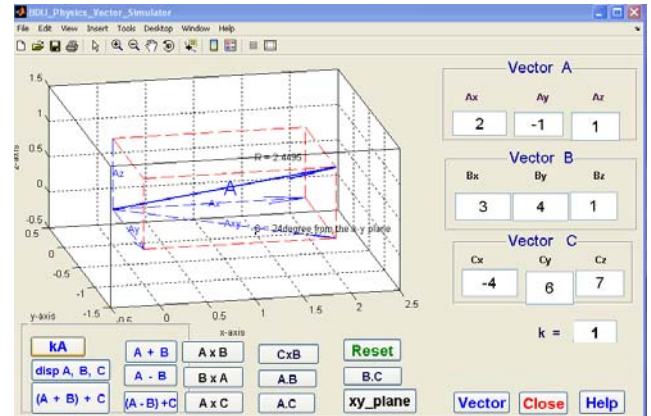**FIGURE 4.** Cross Product of Vector *A* with *B*.

FIGURE 5. Resolving vectors into components.

IV. CONCLUSIONS

It is time to have a shift from the traditional trend of teaching to student-centered approach. This inclination can be fruitful with the help of applying different teaching styles. Accordingly developing virtual systems in teaching our students, who are in the ages of computer development, is one of the alternative ways of facilitating active participation of students in the teaching learning process.

We developed BDU-PVS on the basis of the fact that simulation enhances active learning environment of students [6]. The significance of BDU-PVS can be seen from the point of replacing chalk and talk traditional lecture-oriented teaching method to the modern interactive and learning by doing oriented approach. So teachers can easily use this simulator as a demonstration setup instead of trying to draw and show vector operations on the blackboard.

BDU-PVS has unique features in its power of demonstrating the physics of basic vector operations as compared to the traditional chalk and talk teacher - centered method. This can be confirmed by considering the following cases.

1. Using BDU-PVS, one can easily and clearly visualize the three components (*x*, *y* and *z*) of a given vector (see Figure 5).

2. BDU-PVS can also applicable to clearly demonstrate the fact that the cross product of two vectors is perpendicular to the plane that contains the individual vectors (see Figure 4).

3. We believe that displaying three-dimensional plot is better on screen than on paper and black board.

Generally speaking, BDU-PVS is on sides of both the students and the teachers in maximizing the efficiency of teaching learning process and also in increasing the standards of students' achievement. Our evidence to conclude this is the research outputs conducted by [7] on the effect of computer simulations on student's achievement, group interaction and attitude. According to

these outputs, teachers can easily teach very complicated physical phenomena using computer simulations.

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