

GUI of vector analysis on spreadsheets for students and teachers

Atteeq Razzak

Department of Mathematics, University of Karachi, Pakistan.

e-mail: atteeq.razzak@uok.edu.pk

Zaheer Uddin

Department of Physics, University of Karachi, Pakistan.

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A Graphical User Interface (GUI) teaching tool has been developed to teach different vectors modules to college and undergraduate students. The Physics and Mathematics students can benefit from these executable spreadsheets for practicing vector algebra with minimum inputs and through diagrams and answers as output. The spreadsheets are employed to calculate vector resolution, addition, projection, and multiplication because they are ubiquitous. Some GUI on vectors available online gives the results, whereas this GUI shows the calculation steps to reach the results, which helps learn the subject effectively. The developed GUI also assists the mentors regarding their lab work and exams to make different papers with answer keys.

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1. Introduction

Technology has revolutionized the ways of teaching. Undergraduate and college-level teaching has changed manifolds due to computer technology. Changes happen swiftly in physics research, move faster, and are well received. Teaching physics to students through simulations is an interesting and engaging method. In recent years, many scientists have been using spreadsheets to simulate physics and other science subjects. Spreadsheets are useful tools for teaching physics and related experiments online through simulation. It got more importance, particularly in this pandemic situation [1]. Microsoft Excel is a popular spreadsheet that is very simple to use. Most people from different areas of life are familiar with Microsoft Office and Excel spreadsheets. These sheets are also common to students, and most are familiar with how to use them for data analysis. The impacts of various factors in a physical system may be seen using MS Excel. It can be used in situations [2]. A graphical user interface (GUI) makes it easier to utilize computers by displaying information to allow quick acquisition and modification. Visual constructs (widgets) that imitate physical items such as 'switches' and 'buttons' help expedite learning by intuitively sending input to the computer. The use of graphical user interfaces (GUIs) designed with MATLAB guide tool for university-level optical communications courses and research is highlighted in work by [3]. Varied model settings, allowing students to have a participatory experience. Scientists have made various GUIs related to time series analysis, DNA, and crystallography [4-6]. This paper aims to make a GUI on vector analysis for college and undergraduate students; as discussed earlier, Excel is a very accessible and readily understandable tool. That's why we used vector analysis which is an integral part of many branches of science; a few of the main phenomena like solenoidal or irrotational fields are described by

their properties [7]. It has an extensive fractal theory, image processing, and chemical demagnetization [8-10].

2. Theory

A vector can be resolved into two or more vectors; in rectangular components, the vector has two components parallel to x and y axes. These components (A_x and A_y) for vector A . Which makes an angle θ with the horizontal axis given by

$$A_x = A \cos \theta,$$

$$A_y = A \sin \theta.$$

Two different methods are employed for the addition of vectors. In the first method, vectors are added by head to the tail rule, where the resultant vector is obtained by a line joining the tail of the first vector and the head of the last vector. In vector addition by rectangular method, the sum of horizontal and vertical components is obtained as the component of the resultant vector (R_x and R_y) which are used to find the Magnitude and direction of the resultant vector by following equations

$$R = \sqrt{(R_x^2 + R_y^2)}, \quad (1)$$

$$\theta = \tan^{-1} \left(\frac{R_y}{R_x} \right). \quad (2)$$

The scalar product gives scalar quantity by multiplication of two vectors. To represent a scalar product dot sign is used between vectors; therefore, it is also known as the dot product. The dot product of two vectors is obtained by multiplication of the first vector's Magnitude, the second vector's Magnitude, and the cosine of the angle between given vectors.

$$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos \theta. \quad (3)$$

Projection of vector \vec{A} on vector \vec{B} is the horizontal component of the vector \vec{A} when vector \vec{B} is considered as horizontal direction.

$$\text{The projection vector } \vec{A} \text{ over } \vec{B} = \frac{\vec{A} \cdot \vec{B}}{|\vec{B}|}, \quad (4)$$

$$\text{The projection vector } \vec{B} \text{ over } \vec{A} = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}|}. \quad (5)$$

The vector product gives a vector quantity when two vectors are multiplied. The Magnitude of the vector product represents the area of the parallelogram formed by given vectors, and the direction is given by the unit normal to the plane containing the given vectors \hat{n} . A cross sign is used between the vectors to represent the vector product; therefore, the vector product is also called the cross product. The vector product of the vectors \vec{A} and \vec{B} is given by

$$\vec{A} \times \vec{B} = |\vec{A}||\vec{B}| \sin \theta \hat{n}. \quad (6)$$

3. Results and discussion

There are five spreadsheets on which examples of addition of vectors, resolution of vectors, projection of vectors, and scalar product vector product are shown. The spreadsheet is independent of other sheets. The following is the detail of each sheet.

3.1. Sheet 1: The resolution of vectors

This sheet shows an example of the resolution of vectors into their rectangular components. The vector's Magnitude and direction are given in cells A2 and B2. There are two buttons on the sheet; the resolve vector button draws a graph that shows the given vector (in red line) besides its rectangular components. The horizontal component is blue, and the vertical components are green. In the second button, the Magnitude of the vector component shows the numerical values of the given vector components in a message box as shown in Fig. 1.

3.2. Sheet 2: Addition of vectors

The students can learn the addition of vectors by head-to-tail rule and addition by rectangular components. The spread-

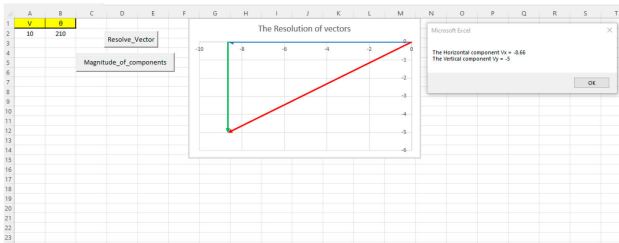


FIGURE 1. The screenshot of the resolution of vectors.

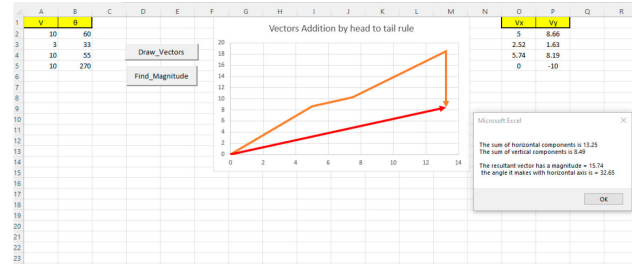


FIGURE 2. The screenshot of the addition of vector.

sheet allows students to add up to hundred vectors to be added. The vector's information (to be added), *i.e.*, the Magnitude and direction, are given in columns A and B. The add vectors button draws vectors on the graph using the head-to-tail rule and shows their rectangular components in cells O and P. The resultant vector is also shown. The button finds Magnitude and gives the Magnitude and direction of the resultant vector.

A straight line shows the resultant vector in red color. On pressing the find magnitude the answer will appear as a statement on right bottom of the screen as shown in Fig. 2.

3.3. Sheet 3: The projection of a vector on another vector

The two vectors are given in cells B2:C3 as input vectors, say \vec{A} and \vec{B} . The sheet has two buttons, namely, the projection of \vec{A} on \vec{B} and \vec{B} on \vec{A} ; pressing one of the buttons draws both vectors on a graph and a perpendicular vector \vec{A} on to vectors \vec{B} or from vector \vec{B} on to \vec{A} , respectively. A dotted line shows the fourth vector and, in red, gives the projection of one vector on the other. On pressing the buttons answer will appear on extreme right in red.

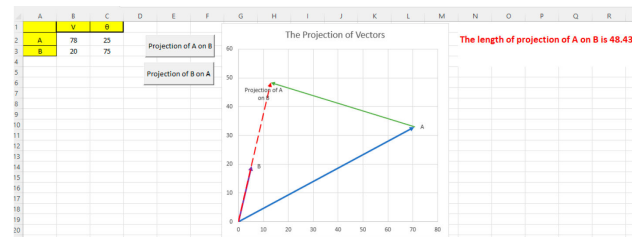


FIGURE 3. The screenshot of the projection of a vector on another vector.

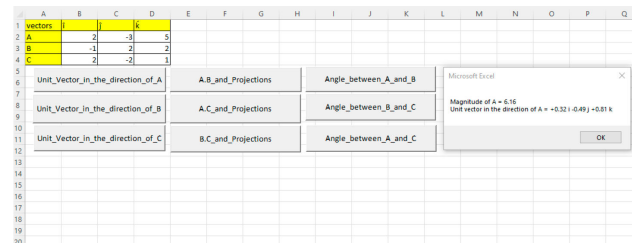


FIGURE 4. The screenshot of the vector product.

3.4. Sheet 4: The scalar product

The sheet takes three vectors, \vec{A} , \vec{B} , and \vec{C} As input vectors in cells B2:D4. The unit vectors in the direction of vectors \vec{A} , \vec{B} , and \vec{C} , can be found by the first three buttons. The vectors are given in 3d with their components in the direction of x , y , and z . The unit vectors are shown in a message box as an expression, a combination of unit vectors \hat{i} , \hat{j} and \hat{k} The scalar products of $\vec{A} \cdot \vec{B}$, $\vec{A} \cdot \vec{C}$, and $\vec{B} \cdot \vec{C}$ can be found using three buttons.

When one of these buttons is pressed, a message box pops up, showing complete steps of scalar product calculations, and it also shows the projection of both vectors onto another vector. The last three buttons calculate the angle between any two vectors: the calculation's detail is shown in a message box. For the demonstration purpose an example is given below in the Fig. 4, on pressing the first button the answer is appeared in the extreme left of Unit vector in the direction of vector A.

3.5. The vector product

This sheet helps the student to learn the vector product of two vectors. The student can find the vector product of any two given vectors in Cells B2:D4. Each button $\vec{A} \times \vec{B}$, $\vec{A} \times \vec{C}$, and $\vec{B} \times \vec{C}$ when pressed, it generates four steps; in the first step, it gives a determinant of the vector product. The second step shows the working of solving the determinant; the third step gives the final value of the vector in the form of unit vectors \hat{i} , \hat{j} and \hat{k} . The fourth and last step shows the Magnitude of the vector product. In Figs. 3, 4 and 5 vectors are represented in bold letters.

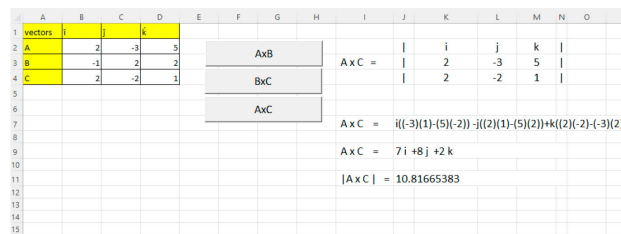


FIGURE 5. The screenshot of the vector product.

4. Conclusion

We have developed a GUI to assist college and undergraduate physics and mathematics students. This GUI describes five different modules of vectors, *i.e.*, resolution, addition, projection of vectors, and their multiplication (scalar and vector products). Though there are a few online GUI on vector algebra, this GUI has few distinguishing features. For instance, the developed GUI is on excel spreadsheets; usually, school students know spreadsheets, so it is easy for everyone to understand the theme behind the GUI. Moreover, the students can practice as many examples of each module as possible. These spreadsheets are also helpful for teachers who want to make different papers with answer keys. This work can further be extended towards analytical geometry, where we see a lot of use of applications of vectors. Video of the program is available on <https://drive.google.com/file/d/1pBR4GjPHTL-ojgek8TcL-6OhJNSquLHJ/view?usp=sharing>.

1. M. Iqbal *et al.*, Teaching physics online through spreadsheets in a pandemic situation, *Physics Education* **55** (2020) 063006.
2. Z. Uddin, M. Ahsanuddin, and D. A. Khan, Teaching physics using microsoft excel, *Physics Education* **52** (2017) 053001.
3. T. Almeida, R. Nogueira, and P. André, Graphical user interfaces for teaching and research in optical communications, (Optical Society of America) p. EThF4.
4. D. Rosadi, Rplugin. Econometrics: R-GUI for teaching Time Series Analysis, *COMPSTAT'2010 Book of Abstracts* (2008) 165.
5. B. H. Toby, EXPGUI, a graphical user interface for GSAS, *Journal of applied crystallography* **34** (2001) 210.
6. G. S. Randhawa, K. A. Hill, and L. Kari, MLDSP-GUI: an alignment-free standalone tool with an interactive graphical user interface for DNA sequence comparison and analysis, *Bioinformatics* **36** (2020) 2258.
7. L. Brand, Vector analysis (Courier Corporation, 2012).
8. R. Machuca and K. Phillips, Applications of vector fields to image processing, *IEEE Transactions on Pattern Analysis and Machine Intelligence* (1983) 316.
9. S. G. Henry, Chemical demagnetization: methods, procedures, and applications through vector analysis, *Canadian Journal of Earth Sciences* **16** (1979) 1832.
10. M. Hinz and A. Teplyaev, Vector analysis on fractals and applications, *Contemp. Math* **601** (2013) 147.