GUI of Complex plane on Excel spreadsheets

M. Y. Tufail and S. Gul

Department of Mathematics, NED University of Engineering and Technology, University Road, Karachi, Pakistan
e-mail: tufail@neduet.edu.pk; sagul@neduet.edu.pk

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In this paper, we provide two spreadsheets in `Excel` for university students and teachers. These spreadsheets contain the geometrical representation of complex numbers, conversion in polar and rectangular forms and four basic math operation that are addition, subtraction, multiplication and division. Further, we also established that complex number satisfies the parallelogram law.

Keywords: GUI; teaching mathematics; Excel spreadsheets; complex numbers.

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1. Introduction

Graphical User Interface (GUI) allows users to interact with a computer or software application using visual elements/pictorial representation such as icons, menus, and buttons, rather than typing commands in a text-based interface. Ivan Sutherland is considered as the pioneer of GUI. In 1963, nearly 60 years ago, in his seminal PhD thesis [1] he presented the idea of human computer interaction and demonstrated that the computer graphics can be used for multi purposes. Since 1963 his thesis is considered as the justification of GUI. Researchers have developed several GUI platforms and have applied to variety of fields [2-11].

Graphical User Interfaces allow university students and mentors, computer users, to move one application to another application. GUI provides a platform to demonstrate abstract and complicated ideas of Mathematics/Physics in pictorial/graphical ways. These ways are very simple and user-friendly and can be opted at the university level. Birth of computer revolutionised many fields of sciences. University level teaching has also changed drastically due to this technology. GUI plays an important role to give clear concepts of recent developments and innovations in mathematics to mentors and university students. The need of GUI is rapidly increased in case of natural disaster and pandemics. We all are witnessed the recent outbreak of Covid-19 [12] when whole world was facing lockdowns and work from home was the only preferred method in most of the universities and educational institutes. This pandemic had severe effect on education [13,14]. Thus, without any doubt, GUI provides an alternate way of learning that can be accessed remotely with its great impact in the understanding of typical mathematical ideas.

First year students and sophomore are very much familiar with Microsoft `Excel`. Thus, we provide two `Excel` spreadsheets for the understanding of complex numbers for science students and mentors.

2. Theory

Definition 1. (Complex number): *A complex number has the form:*

$$Z = Z_x + \mathrm{i} Z_y, \tag{1}$$

where $Z_x, Z_y \in \mathbb{R}$ *and* $\mathrm{i}^2 = -1$*. These* Z_x, Z_y *make up the complex plane. Analogously, complex plane is also identified as* $\mathbb{R}^2$ *whenever required. The set of complex numbers is normally denoted by* $\mathbb{C}$*. Equation* (1) *is referred as Rectangular or Cartesian form. Alternatively, complex number can also be represented in polar form as below:*

$$Z = Re^{\mathrm{i}\theta} = R(\cos\theta + \mathrm{i}\sin\theta).$$

where $R = \sqrt{Z_x^2 + Z_y^2}$, $\tan\theta = Z_y/Z_x$, $-\pi < \theta \le \pi$*; or* $-180 < \theta \le 180$, $Z_x = R\cos\theta$ *and* $Z_y = R\sin\theta$.

Definition 2. (Addition/Subtraction of complex numbers): *Addition (Subtraction) of two complex numbers gives another complex number. The required sum is obtained by adding (subtracting) real to part and imaginary to imaginary part of two complex numbers.*

$$Z_1 = x_1 + \mathrm{i}y_1, Z_2 = x_2 + \mathrm{i}y_2$$

$$Z_1 + Z_2^* = (x_1 + x_2) + \mathrm{i}(y_1 + y_2). \tag{2}$$

Definition 3. (Multiplication of two complex numbers): *Multiplication of two complex numbers is a complex number. The real and imaginary parts are obtained as below:*

$$Z_1.Z_2 = (x_1x_2 - y_1y_2) + \mathrm{i}(x_1y_2 + x_2y_1). \tag{3}$$

Definition 4. (Division of two complex numbers): *Division of two complex numbers is a complex number (by providing a non-zero complex number in the denominator). The new complex number is obtained after rationalisation as below:*

$$\frac{Z_1}{Z_2} = \frac{x_1 + \mathrm{i}y_1}{x_2 + \mathrm{i}y_2}; \quad Z_2 \neq 0$$

$$= \frac{x_1x_2 + y_1y_2}{x_2^2 + y_2^2} + \mathrm{i}\frac{x_2y_1 - x_1y_2}{x_2^2 + y_2^2}. \tag{4}$$

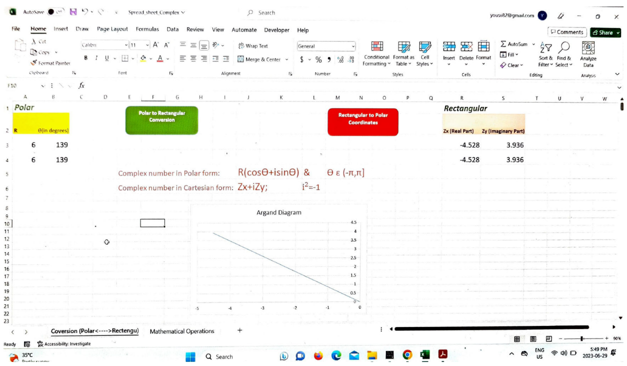

FIGURE 1. Screenshot of conversion of complex number in different forms. Two buttons are given in spreadsheet. These buttons are used to convert the complex number into Rectangular (green button) and Polar form (red button) along with the associated Argand diagram.

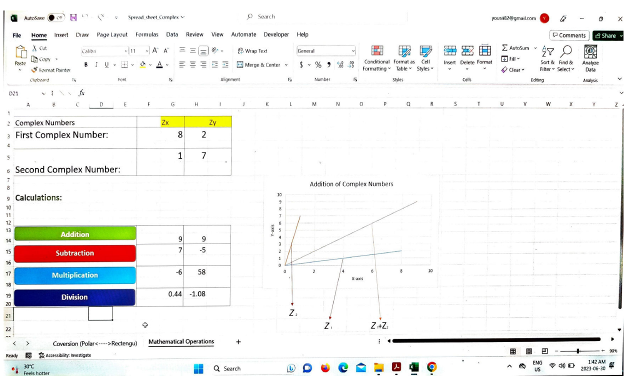

FIGURE 2. The screenshot of math operations between complex numbers. Four buttons are available for basic math operations in the spreadsheet. Graphical representation of addition in complex plane is also demonstrated.

3. Experiments

In this section, we provide two spreadsheets. First spreadsheet will provide the conversion between the two standard forms of complex numbers, *i.e*., Rectangular and Polar form (see Sec. 3.1). Second spreadsheet demonstrates the basic operations between the complex numbers (see Sec. 3.2).

3.1. Spread sheet 1: Conversion

We elaborate the conversion of complex number into two standard forms, *i.e.*, Rectangular form and Polar form. We provide two push buttons for the conversion among the forms. Magnitude of a complex number and associated direction (polar angle) are given in the cells A2 and B2 respectively. Cells R2 and S2 contain the rectangular components (horizontal and vertical components respectively), Argand diagram is given in the separate message box. See Fig. 1 for more details.

3.2. Spread sheet 2: Operations

We provide four buttons of basic math operations in complex plane. These operations are addition (+), subtraction (-), multiplication ($\times$) and division ($\div$). The explanation is given in Sec. 2 (See Eqs. (2), (3) and (4)). Two complex numbers are given in cells A3 and A6. We also illustrate the graphical representation of complex addition in complex plane. This graphical representation confirms that complex numbers follow parallelogram law [15,16]. Analogously, complex numbers can be considered as vectors in $\mathbb{R}^2$. Further, we would like to highlight the fact that the complex plane has one-one correspondence with Euclidean space $\mathbb{R}^2$. See Fig. 2 for more details.

4. Conclusion

In this study, we demonstrated the idea of complex numbers and their representation into two standard forms (Rectangular $< -- >$ Polar forms) and the basic operations for complex numbers. We provide two `Excel` spreadsheets for the explanation along with appropriate push buttons. Our target audience is undergraduate university students and university teachers (For Physics/Mathematics/Computer science). Video of the program is available at `https://drive.google.com/drive/folders/1IivswvtpNWN6fkPQgFmCKC-k2s5bga2Y?usp=drive_link`

(For English speakers) `https://drive.google.com/drive/folders/1WWcaz823zTJ2qpsffYEWxz1xMxsDNETc?usp=drive_link` (For Urdu and Hindi speakers).

∗. Use - sign for subtraction in place of +.

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