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# Utilization of Mathematics in Computer Science

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**ABSTRACT:** Mathematics is a fundamental tool for computer applications. So, in each application or software, there are many uses of mathematics such as binary, statistics, linear algebra, calculus, discrete mathematics, etc. This article contains the application of mathematics in computer science. Mathematics is a fundamental part of computer application, every computer scientist or programmer needs to have some basic knowledge about mathematics. Imagine a skyscraper. What is the most important part of this building? No, not its height but mainly the foundation of these buildings. If these skyscrapers did not have a strong foundation, they would have been more likely to fall than stand. Now in the case of computer application, mathematics is the foundation on which computer science is built. There is wide usage of application of mathematics in computer science and the command of mathematics depends on these particular demands. Some computer science careers require only basic knowledge of mathematics. For example, if you know simple arithmetic and basic programming languages, then you can develop basic mobile apps. But if you want to explore advanced fields such as computer security or operating systems, then you'll have to understand some advanced-level math concepts.

**KEYWORDS:** mathematics, computer, programming, statistics, calculus, algebra, operating, science

## I. INTRODUCTION

Some mathematics concepts used in computer applications are as follows:-

### Binary Number System

In computer science the number system is a way to represent numbers. Computers use the binary number system instead of the decimal number system. According to digital electronics and mathematics, this system uses only two digits, 1 and 0, to express all mathematics concepts. It can be inconvenient for humans to deal with this system, but computers can read only binary. There are three more number systems as other alternatives which are octal, decimal, and hexadecimal which makes more sense to humans and converts electrical signals into binary systems.[1,2]

### Discrete Mathematics

Discrete Mathematics is tangible math and the foundation of computer science. It analyses the relationship between distinct and separate things. It is also used to test out multiple algorithms and find which is the most efficient. It will help you, how to approach programming and developmental tasks more methodically. The concept of discrete math includes probability, combinations, logic, number theory, graph theory, set theory, algebra, etc. Discrete math is used in various areas such as functional programming, computer architecture, databases, algorithms, distributed systems, computer systems, machine learning, networks, operating systems, and computer security. Some examples are given below with applications

### Statistics

In the past few years, Data has become an increasingly important aspect from personalised app performance to machine learning and artificial intelligence. This increased assuredness of scientific data has made statistics an important topic for all computer science students. Statistics is used in computer science that uses representations, quantified models, and synopsis for a provided collection of experimental data. In the statistics field, we study methodologies to review, obtain, evaluate and form conclusions from experimental data. Some statistics parameters include analysis of variance, mean, skewness, and regression analysis. It plays a fundamental role in computer applications as it is used for machine learning, data mining, future modelling, vision and image analysis, speech recognition, and artificial intelligence. It is also used for simulations.[3,4]

### Calculus

It is concerned with the calculation of continuous change and the rates of change that occur. It considers the finding and properties of derivatives and integrals of functions. It is used in an array of computer science areas such as creating graphs or visuals, problem-solving applications, simulations, coding in applications, the design and analysis of algorithms, and creating statistical solvers. There are two different types of calculus in mathematics.

- Integral calculus
- Differential calculus.

Integral calculus is used to determine the quantity where the rate of change is known and differential calculus deals with the rate of change of a quantity. A differential equation calculates how fast that change occurs so a computer can predict future results.

### Linear Algebra

Linear algebra is concerned with mathematical structures. It is the study of linear combinations and their transformation properties. It includes various topics such as polynomials, linear equations, matrices, factoring, operations, determinants, exponents, rational expressions, quadratic equations, ratios, radicals, rectangular coordinates, proportions, and vector spaces. Algebra is used to design formulas that are used in numerical programs and for scientific computations. It also is used in computer applications to develop software and algorithms for working with mathematical objects. Algorithms are basically a set of instructions that takes you from a specific input to the correct output. All the concepts of linear algebra have real-world computer science applications. For example, exponential relationships can help you to adapt visuals.[5,6]

### Mathematics as an Analytical Tool

In computer applications, analytical skills are necessary for data analysis and problem-solving. Mathematics is always used to analyse equations and understand the mistakes that we made. In programming computer scientists or programmers are guaranteed to make a mistake. This mistake needs to be fixed to get a final solution. So, mathematics provides us with these analytical skills to find and fix bugs. The experience and knowledge gained about debugging are invaluable. In mathematics, students analyse their own work. When a student answers a question, then realises that the answer is unreasonable then he analyses his own process to understand his mistakes and know how to fix them. In short, mathematics prepares students for fixing bugs or errors.

### Mathematics to Understand Abstract Language

Computer Science has its own language which is abstract. Using syntax, one must represent specific commands, symbols, processes, single words, and visuals through punctuation. Learning a computer programming language can be difficult without experience thinking and communicating in abstract language. Mathematical languages that students learn in maths class are very similar to abstract programming languages. From simple mathematical equations to complex representations, learning mathematics teaches students the art of comprehending, formulating thoughts, reading, and communicating with abstract language.

### Mathematics in Modelling

Facts and figures are essential for computer applications. As computer applications interact more with our real world, the importance of accurate modelling to that world grows through mathematics. For example, to build a self-driven car that is based on the concept of artificial intelligence and machine learning, the equations used to program its acceleration, turns and the acceptable distance from other cars must be spot-on. This article comprehensively discusses the role of mathematics in computer science which justifies that mathematics is the foundation on which computer applications are built. A fair amount of mathematical knowledge and skills are required to become a computer scientist. From UI to hardware, everything is designed based on some mathematical models. In short, to succeed in computer science you need to think mathematically.[7,8]

## II.DISCUSSION

In fact, the importance of mathematics in computer science is more and more evident with the advent of life-changing technologies like Machine learning and AI. Following are some points that illustrate the importance of mathematics in computer science.



### 1) 1. The Foundation of Computer Science

The basics of mostly what is used in computer science, be it the hardware or the software part, are derived from mathematical concepts. Say, for example, probability, number theory, logic notations, etc. are very commonly used in different branches of computer science. These things that computer science use are collectively called Discrete Mathematics. Another example would be the use of Boolean Algebra in Logic gates and perhaps Relational Algebra in RDBMS. Moreover, Statistics has a very important part to play nowadays, as Machine Learning is en route to conquering the entire industry. Statistics is one of the most revered parts of mathematics since its inception. So the importance of Mathematics in Computer Science is pretty much from the foundation itself.

### 2) 2. Algorithms Used in Computer Science

Basically, all the people who belong to the Computer Science stream, professionally or academically, are aware of the term Algorithm. Algorithms are nothing but a procedure broken down into a step-by-step version. Now beginners use algorithms while learning GW-Basic. And professionals who develop enterprise systems for their respective clientele make use of algorithms. But the question is, how is mathematics important in this. As a matter of fact, the very first algorithm that anyone ever learns is during childhood while learning the basic mathematical operations like addition and subtraction. That “ $2 + 2 = 4$ ” is perhaps the first and basic algorithm everyone has learned. This process of getting four after adding 2 to 2 has been broken into steps. Hence algorithm, which is an important part of computer science, is also based on such basic methods of mathematical calculations.[9,10]

### 3) 3. Analytical Skills Required in Computer Science

The people who are related to computer science in one way or the other are very well aware of the fact that one has to have proper analytical skills to exist in this field. The basics of every complex program or methods lie in the analysis made by the group involved to do so. Analyzing every factor before developing any programs or applications is the most important part of any software development life cycle. Now, where do we develop our tendency to analyze anything that seems to be complex to us? It is obvious from the method of simplification of equations that we have developed this habit. Once we realize an equation, we analyze the steps to break it down into an easier solvable form. We exactly do this to analyze the different steps for developing anything in computer science.

### 4) 4. Concepts of Mathematics Involved in Computer Science

Well, as we all know, computer science is a collection of many subjects or rather technologies together. This includes Operating systems, Databases, Networking, AI, Data Analytics, and many more. Each and every single branch involves a different branch of mathematics. For example, Data Analytics requires a good prior knowledge of statistics, Linear algebra, Multivariable Calculus, Probability Theory, and analytical skills as well. Like this, there are a lot of branches that require a thorough knowledge of mathematical concepts. Until and unless people are pretty fluent in the discussed mathematical concepts, they may not be able to deal with complex computing scenarios.[11]

### 5) 5. An Application of Computer Science

It is not always that importance of Mathematics in Computer Science is only about how it came into existence. But there is also another important aspect of this discussion which includes the application of Computer Science into Mathematical areas. One such biggest example is tutorial apps. Programmers developed it based on the mathematical concepts discussed above. But they teach people about mathematics itself. There are platforms where people get to know and perform in different branches of mathematics like graph plotting, calculus, geometry, statistics, and others. These platforms where users can perform such activities are solely developed using core mathematical concepts. All the above things that we have discussed can actually describe the importance of Mathematics in Computer Science and its influence. But of course, still, many people would say that writing a blog or creating a simple HTML webpage doesn't require prior mathematical knowledge. But with the development of recent technologies, it will rather be a good option to get handy with mathematics in order to perform well in any computer science-related area.

## III.RESULTS

Programming is the art of telling the computer what to do using some set of laid down rules and principles to make digital applications, e.g software, apps, websites, and operating systems. The argument of whether programming is an

art or science will be a topic to be discussed another day, but for now, let's just call it an art since programmers write code.[12]

## 6) Paradigms

We are aware that there are various styles of writing programs. The kind of problem you're solving will determine which style you are to use. These styles are also sometimes called paradigms. In case you're not clear what these styles are, they're:

- Object-oriented
- Functional
- Logical
- Imperative

## 7) Abilities to do different things

**These paradigms offer us different abilities.**

### *Object-oriented*

The object-oriented paradigm offers us the ability to have objects which we can give methods and properties peculiar to only that object.

### *Functional*

The functional paradigm allows us to write programs in the form of mathematical equations or functions.

### *Logical*

The logical paradigm allows us to write programs that draw conclusions or deduce results from given values through comparisons.

### *Imperative*

The imperative paradigm allows us to write programs in a step by step sequence and have the program change some of its values while working. All of these paradigms are borrowed from mathematics. Let's explore some of the significance of mathematics on programming/development.[10,11]

## 8) Bring on the Math

Mathematics teaches the usage of algorithms, which helps to develop logical thinking. Analytical thinking, which is the way of breaking down problems from unknown to known, can be quickly achieved through mathematics. Let's take a deeper dive. What is an algorithm? An algorithm is a process or set of rules to be followed in a calculation or other problem - solving operations, especially by a computer. Solving math problems relating to algebra requires you to use the algebraic process, and that in itself teaches the usage of algorithms. Solving math problems bends your mind to think critically and analytically at the same time and this helps in developing your brain to think logically. Analytical thinking is studying a particular problem to develop more ideas about it or find a solution by breaking it down to the smallest pieces of information known about the problem. This is called the First Principle. Analytical thinking can help you investigate problems and find solutions to them.

**Analytical thinking requires the following steps:**

1. Identify the problem.

2. Give detailed information about the problem.
3. Provide a solution to the problem using the known information about the problem.

#### 9) Applications of mathematics in computer science

Looking at the steps listed above, let's relate them to how they're used in solving mathematical problems. Below are some of the uses of mathematics in various fields of computer science.

- Game development
- Artificial Intelligence
- Machine Learning
- Simulation
- Cryptography[9,10]

#### *Game Development*

Games employ math for most of their functionalities. In big games like PUBG and EVE online, and even little games like Pong and Pacman, mathematics is needed for the actions and movements between characters, with geometry and trigonometry underpinning the angles at which characters move.

#### **Mathematical topics employed in Game Development are:**

- Algebra
- Trigonometry
- Geometry
- Calculus

In advanced fields of programming like AI and ML, mathematics is essential. A very extensible part of mathematics found in AI and ML is statistics. Data is the basis of AI and ML and how that data is analyzed and consumed is statistics. Other mathematics used in AI and ML include:

- Algebra
- Calculus
- Simulation & Cryptography

#### *Simulation & Cryptography*

Random numbers are used for simulation, cryptography, and some other areas. The way these random numbers are generated is purely mathematical. These random numbers are used in data encryption. The popular topics used in the field of simulation and cryptography are:

- Number Theory
- Calculus

Mathematics is the underlying foundation of programming. For you to build a solid career in programming, it's helpful to have a solid foundation in mathematics.[8,9]

### IV.CONCLUSIONS

Math matters for computer science because it teaches students how to use abstract language, work with algorithms, self-analyze their computational thinking, and accurately modeling real-world solutions. President Obama recently called to expand access to computer science education in American schools. As the educational community focuses on this challenge, the relationship between math education and

computer science is undoubtedly moving into the spotlight. This relationship can be a controversial subject. Part of this debate springs from differing ideas of what constitutes a "strong background in mathematics." For some, it's getting a PhD in mathematics. For others, it's being able to solve multistep equations mentally. But there's another way of identifying a strong math background: having the capacity for abstract reasoning, critical thought, and logical deduction -- a mathematical way of thinking. In this regard, a strong background in mathematics is imperative to succeeding in computer science.

#### ***1. Math teaches understanding and communication through abstract language.***

Computer programming has its own languages, which are very abstract. Using syntax, one must represent specific processes, commands, and visuals through punctuation, symbols, and single words. To someone with no experience thinking or communicating in abstract languages, learning a programming language can be terrifying. However, abstract programming languages are very similar to the mathematical language that students learn in math class. From simple equalities to complex mathematical representations, learning mathematics teaches students the art of reading, comprehending, formulating thoughts, and communicating with abstract language. Of course, mathematical language and computer programming languages aren't exactly the same. But experience using any abstract language gives beginning computer scientists an advantage.[7,8]

#### ***2. Math teaches how to work with algorithms.***

Algorithm is among the most bandied-about terms in the technology scene. In short, an algorithm is an abstraction of some process into a form in which the process can be repeated, implemented in different ways, and applied to new problems. The word may be used more frequently in computer science, but most students first use algorithms in mathematics. For example, consider an equation like  $5 + x = 7$ . Students learn to find an unknown summand by subtracting the known summand from the sum. This is an algorithm -- one that students quickly learn to apply to new problems and implement in different ways.

#### ***3. Math teaches students how to analyze their work.***

In a day's worth of programming, any computer scientist is guaranteed to make a mistake. As such, programmers must know how to assess a problem, analyze their work, and fix errors. Math is one of the few subjects where students analyze their own work in this way. A student might answer a math question (How much do the puppy and kitten weigh together?), realize that their answer is unreasonable (231 pounds), and analyze their own process to understand their mistake and how to fix it (maybe they forgot to convert from ounces to pounds). Math, in short, prepares students for fixing bugs.

#### ***4. General skills aside, computer science still involves a lot of math.***

In addition to general skills important for computer science, the facts and figures of math are essential. As computer programming interacts more with our world, the importance of accurately modeling that world through mathematics grows. For example, to build a self-driving car, the equations used to program its turns, acceleration, and acceptable distance from other cars must be spot-on. Becoming a computer scientist requires a fair amount of mathematical knowledge and skill. Even more importantly, success in computer science requires the ability to think mathematically. So why is it necessary to talk about how math helps prepare budding computer scientists for their academic careers.[6,7]

#### **10) A More Effective Approach to Math Education**

A strong math background develops all of the skills mentioned above. Unfortunately, as it's currently taught in the U.S., math education doesn't always develop a strong math background in its students. Many math classes focus on the rote memorization of formulas. These classes neglect building the critical thinking and logical reasoning that help students in future math classes and computer science careers.

Math education has started to see some promising movement in developing students' ability to think as opposed to memorize. For example, Reasoning Mind creates math education software that leads students

through a comprehensive math curriculum and adapts to their individual strengths and weaknesses. Its lessons help them develop the thinking skills necessary to reason through simple problems before challenging them to tackle tougher ones, building their critical thinking and problem-solving skills. Another good example is Oracle Academy, a free program that enables students to build fundamental computer science skills through engaging learning opportunities, including hackathons, student workshops, and even a global weather station project. Using a project-based learning approach, Oracle Academy's curriculum moves students away from rote memorization and engages them to become critical thinkers and problem solvers. Eureka Math is another helpful resource with a comprehensive suite of math curricula. Its mission is ensuring that students receive a content-rich education by connecting math to the real world in a way that helps build student confidence. Further, educational nonprofit Destination Imagination offers lessons in the fields of STEM (science, technology, engineering, and mathematics) to teach students creative processes and empower them with skills needed to succeed in school, their careers, and beyond. All too often, students are allowed to back away from math without understanding why math matters. We want our students growing up to become the next leaders in computer science and STEM careers in general. But we need to recognize that as long as we're short-changing our students on their mathematical educations, we're missing an important part of the equation. [11,12]

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