Symbiosis of Mathematics Academia and Information Technology Industry

Dr Urvashi Arora

Department of Mathematics,

Rajdhani College (University of Delhi), New Delhi-110015

Email: - urvashi.arora@rajdhani.du.ac.in

Abstract

Mathematics is generally seen as a subject, which provides the tools and techniques for solving numerical problems. This problem solving role of mathematics is the one role of this subject, with which anyone who has been a mathematics student at some point of life, is familiar with. But looking at mathematics, only as a tool or a technique provider would amount to narrowing its deep potential in serving not only as a tool but rather being a foundation subject of several areas of practical applications. Although mathematics plays an indispensable role in almost any field of practical importance, but in today's scenario, when our lives are depending more and more on information technology (IT), the role of mathematics in IT is far more than what it used to be. With computers invading every territory of our life and with information technology expanding its horizons each day, the role and responsibility of the underlying mathematics and the mathematicians is becoming more and more significant. The paper discusses the important role of various fields of mathematics in various IT related fields, by citing various real life applications. The paper also discusses the vital role the mathematicians can play in taking the information technology ahead and beyond its bounds. Also it is discusses, how both academia in mathematics and industry can benefit from each other by reaching out to each other. The paper also mildly suggests changes in the curricula for the enhancement of these benefits of the symbiotic relationship of academia and industry.

Keywords: academia, industry, mathematics, information, steam

Introduction:

Using the 'Google maps' mobile phone app for finding the shortest possible route to an unfamiliar location while one is travelling in a car in any part of the world is a common phenomenon. This app 'Google Maps' used so extensively worldwide [1] rests on the application of the shortest path algorithm in graph theory, namely, the Dijkstra's algorithm. This algorithm which is the backbone of every navigation system [2] is an algorithm of graph theory which is a branch of applied mathematics, namely discrete mathematics. This simple but essentially significant example clearly indicates how the pillars of modern technology rest on mathematical methods.

Mathematics as a subject in its own right is introduced first in school formally to anyone who can be called a literate. For the less fortunate ones who do not get a chance to read or write, mathematics still finds its role in their life too, may be while they are paying for the groceries they bought or when they count the money paid by a customer or in some other way. Even a toddler uses the mathematical concepts of one to one correspondence and logic, while calling out a specific person or a specific thing by a specific name. And not just humans, even insects in their activities, like a spider making its web or a bee building its hexagonal comb, or numerous ants moving in an orderly manner in a line, display the use of mathematics. So mathematics is an innate quality of humans rather than just a subject, which provides the tools and techniques for solving numerical problems. The above mentioned real life example of Google maps app brings to light the immense potential mathematics has in conducting itself not only as a tool but also as a foundation subject of several areas of practical applications.

Objectives of the paper

Section 3 discusses the methodology that has been followed to establish the important role of various fields of mathematics in various IT related fields. The methodology followed is also used to establish the mutual benefit relationship between academia in mathematics and industry. Section 4 of the paper discusses the foundation role of mathematics in IT related fields. Section 5 discusses the symbiotic relationship between mathematics and IT, where each has a role to play for the benefit of the other. Section 6 suggests changes in the curricula for the enhancement of these benefits of the symbiotic relationship of academia and industry. Section 7 discusses the conclusion of the paper. The paper ends with a set of references for further reading on this topic.

Methodology

To establish the foundation role of mathematics in various IT related fields, the structure of various academic programs offered by various universities in India and abroad was studied. Using online sources and print sources the structure of various degree courses in IT fields was studied. Also the role of mathematics and mathematicians in various IT field was assessed with the help of literature available on this subject. The online information available for IT

industry was also assessed.

Foundation role of mathematics in IT industry/ related fields

Although mathematics plays a crucial role in almost any field of practical importance but in today's milieu when our life is technology dependent, the role of mathematics has increased by manifolds than before. With more and more processes being made online day by day, the invasion by information technology (IT) has taken place in almost every field which has finally increased the role and responsibility of the underlying mathematics and the mathematicians. Although the term 'information technology' is used generally synonymously with the terms 'computers and computer networks', but IT also encloses other information distribution technologies such as television, telephones and products/services such as electronics, semiconductors ,internet ,telecomm equipment ,e-commerce e.t.c besides just computer hardware and software.

Believing in the fact that mathematics is a fundamental intellectual requirement for computing, various universities in India and abroad have included mathematics as a mandatory subject in the curriculum of their computer science degree courses. This includes Indian universities like Delhi university [3], IGNOU [4],Osmania university[5],GGSIPU[6] and several others. Several universities placed outside India have been following a similar culture for many years[7].As a matter of fact the university of Oxford, started a degree course in 2018, offering a joint degree of Bachelors in mathematics and computer science(for three years course duration) which could be extended to a Masters in mathematics and computer science(for four years course duration).The document describing the course structure, dated November10,2017,which is readily available online[8] shows that the designed course has more core papers of mathematics than computer science. This clearly indicates that academic universities of great repute worldwide are finding it hard to deny the significant role of mathematics as foundation subject in the field of computer science.

Mathematics plays a vital role in various contemporary and conventional IT fields. The role of mathematics in some of the IT fields is briefly presented in the remaining part of this section.

(i) Field of artificial intelligence

Out of the many fields of practical importance, the one field where mathematics is an essential part of the underlying technology is that of artificial intelligence (AI). Speaking factually, on November 26th 2019, a news item was published in the Times of India newspaper describing, how Rajasthan's tiger reserves were using AI to reduce poaching. It was reported in the article that Rajasthan government had partnered with the US analytics Company SAS to analyze the data associated with wildlife. With the use of video management software and AI capabilities, the data and live images gathered were analyzed and interpreted. Thus a centralized monitoring system was created

which was of immense help in controlling the Wildlife Management Challenges like Poaching, illicit felling and illegal grazing. According to Raghavendran Kandaswami, associate director (advanced analytics and AI) at SAS institute India, such kind of automated systems-where instincts and knowledge are coupled with technology- could make a marked difference.

Colloquially speaking the term 'Artificial intelligence' is a wide ranging branch of computer science dealing with building of smart Machines that are capable of performing the tasks that require Human intelligence. There are numerous problems/fields, where AI methods are applied such as optical character recognition, handwriting recognition, speech recognition, face recognition, artificial creativity, image processing, photo and video manipulation, robotics, hybrid intelligent system and many more.

The foundation of AI is mathematics, essentially the fields: the propositional logic, The predicate logic, fuzzy systems and fuzzy set theory, linear algebra, calculus, probability, mathematical logic

(ii) Field of computer graphics

Computer graphics (CG) is the field of visual computing, where one utilizes computers both to generate visual images (like sketch, drawing, artwork or other like material) and to integrate or alter visual information (by making change in shape, size, motion e.t.c) sampled from the real world. It includes creating business graphics (e.g. bar-chart, pie-chart, pictogram, and e.t.c), scientific graphics (e.g. flowcharts, x-y plot e.t.c), scaled drawings (e.g. drawings of buildings, bridges, machines) cartoons and advertisements, graphical user interfaces (e.g. a system like windows where images or icons are present on the desktop for user to click and perform tasks), interactive computer graphics (e.g. computer games) and passive computer graphics (e.g. movies, where user has no option to interact) are also developed using CG. The various algorithms used in CG for developing graphics like line generation algorithm, circle generation algorithm, polygon filling algorithm , clipping algorithms e.t.c and 2D & 3D transformations, projections are totally dependent on the fields of mathematics like coordinate geometry, three dimensional geometry and matrix algebra.

Besides the mathematics being used in the above contemporary specializations of computer Science, the concepts of mathematics are used recurrently in every core course of computer Science. To list a few instances:

- Writing a program using any programming language whether it is C, C++, Java e.t.c essentially requires logic and mathematical formulas for developing algorithms, which is nothing but using mathematics.
- Boolean algebra, which is a specialization of lattice theory (which is a study of discrete systems in mathematics), is the basis of construction of digital/logic circuits.
- Conventional set theory ,fuzzy set theory, calculus, graph theory, dynamic

programming, numerical analysis and combinatorics are used extensively in computer science to analyze/study processes and algorithms

- Analyzing algorithms and comparing them for efficiency is done by using concepts of real analysis, for e.g. the big O notation ,the small o notation, the omega notation e.t.c use nothing but concepts related to functions in analysis
- The field of AI has been into existence for a very long time now. The Greek mythology has stories about mechanical men mimicking human behavior. But a major breakthrough in recent years has been emergence of another area which is machine learning that can be referred to as a subset of AI. This is based on the realization credited to Arthur Samuel in 1959 that rather than teaching computers everything they need to know about the world and how to carry out tasks, it might be possible to teach them to learn for themselves. Although concepts of mathematical statistics are used enormously in computer science but as far as machine learning is concerned, statistics forms the foundation of machine learning. So much so that statisticians refer to machine learning as 'applied statistics' or 'statistical learning'[9],[10]
- Cryptography which is a science with mathematical background, used for writing secret codes plays an important role in computer network security. The purpose of cryptography is to protect transmitted information from being read and understood by anyone except the intended recipient. Modern cryptography uses sophisticated mathematical equations and secret keys to encrypt (hide) and decrypt (trace) data (that is information).
- Coding Theory which deals with design of error-correcting codes for the reliable transmission of information across noisy channels (i.e. channels with disturbances), makes use of classical and modern algebraic techniques involving finite fields, group theory and polynomial algebra. Codes designed in coding theory are used for data compression(which involves removing redundancy from the data generated from a source in order to transmit data efficiently, for e.g. transmitting a file after converting it into a zip file reduces internet traffic),cryptography, error detection and correction ,data transmission and data storage. An ordinary user of the many real life applications uses them without realizing that the underlying error correction technology comes from coding theory, for e.g. a typical music CD uses the Reed-Solomon code to correct for scratches and dust. Cell phones use coding techniques to correct disturbances due to high frequency radio transmissions. Data modems, telephone transmissions and even the NASA deep space network all employ the coding techniques.

- Operations research, which is another field of mathematics, is used to model computer science applications by dealing with problems systematically and trying to optimize the solution. The aim here is generally to find the minimum cost and expected time to finish a given project. The optimization models are very useful in computer science in software engineering and computer network domains.

The symbiotic relationship between mathematics and IT

With such intervention of mathematics in technological applications as discussed before, it is quite evident that the roof of Information technology rests on the pillars of mathematics. Mathematicians in academia can contribute to the new technological advancements by assisting the professionals in IT industry with their tremendous and deep knowledge in mathematics. As an example, the mathematicians can assist the working of systems analysts, who are people involved in designing of information systems, just as an architect designs a house. Both traditional set ups and modern set ups require systems analysts for developing information systems. The systems analysts identify the problem, analyze it and try to find solutions and then select the best possible solution. The mathematicians and systems analysts can work hand in hand with mathematicians providing them with suitable tools for the intermediate stages of information systems development and with the systems analysts developing more and more systems, including those required by academic and related environments. This would also amount to generating careers in Industry for academically inclined intellectual community. In the same way mathematicians could assist managers and computer programmers involved in developing and implementing information systems. Also the IT professionals could train mathematicians regarding latest softwares/new technologies to make the mathematicians visualize/simulate theoretical aspects of mathematics. Thus this symbiotic association would benefit both the mathematics academia as well as information technology industry.

Changes in curricula

On November 26th, 2019 in the Times of India it was reported 'How DU plans to become a research hub'. There was a detailed report as to the steps to be undertaken by DU in this direction, such as, developing new academic centers, promoting interdisciplinary studies, injecting foreign expertise e.t.c. Evidently, as the scenario suggests, for making the bond between mathematics academia and information industry strong and for a beneficial symbiotic association there is strong need of evolving more and more courses of interdisciplinary nature. Also universities can promote conducting of joint programs/workshops to make academia and industry acquainted with the fields where they can work in collaboration. Suitable changes in the curricula and like steps will greatly benefit the symbiosis of academia and industry in long

terms.

Conclusion

The discussion in the paper reveals that the mathematicians of current era have a significant role to play in accelerating the technological developments. The mathematicians can contribute in various ways in accelerating the advancements in IT sector and these are:

- More and more mathematicians could work in the research and development (R&D) field which would definitely lead to solving of many open problems and also help in unraveling the yet to be explored technological aspects.
- The young minds have lot of aptitude in adapting to the ever changing and transient nature of technology, which arises out of more and more expectation from technology driven machines and processes to cater to real life situations. In such a scenario, the onus lies on the mathematicians in inclining the young generation to become flag bearers of the new technology, by educating them in an innovative and playful manner relating the conventional mathematical fields to practical applications, as much as possible. And for this to be practically possible, the mathematicians need to evolve their own ingenious ways of imparting education making use of STEAM techniques for better training of students.

References

[1] https://en.wikipedia.org/wiki/Google_Maps

[2] Lanning, Daniel & Harrell, Gregory & Wang, Jin. (2014). Dijkstra's algorithm and Google maps.

[3] www.du.ac.in

[4] www.ignou.ac.in

[5]https://www.osmania.ac.in/AcademicInfo2012/Courses22008.pdf

[6] http://www.ipu.ac.in/

[7]https://studyabroad.shiksha.com/be-btech-in-computer-science-engineering-from-abroad-ds11510277

[8] https://www.ox.ac.uk>sites>files

[9] https://www.forbes.com

[10] An Introduction to Statistical Learning, with applications in R,(Springer texts in Statistics)Gareth James, Daniela Witten, Trevor Hastie,2017 Edition.