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A Review on the Relationship between Computer Engineering, Discrete-Math and Graph Theory

***Keywords*:**

Artificial Intelligence, Discrete-Math, Graph Theory, Machine Learning.

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ABSTRACT

This review is based on understanding the main concept between computer engineering and mathematics based on two of their most important fields, the discrete-math and graph theory. and answering the question that was asked by many students over the years of working in the university, about the necessity of studying mathematics while majoring computer engineering. Most of the students face the same problem over years for not having the vision to connect between studying materials of their specialization and general ones, in particular between studying discrete-math engineering as in Engineering analysis, and discrete-math as in the Digital signal Processing (DSP), and between algebraic mathematics. Moreover, they do not understand the main idea of the transition between different time or frequency domains, by converting the work in real-time domain systems to work in discrete–time or frequency domain systems. And they do ignore the importance of studying graph theory, in which recent researches have proved the powerful of using graphs in learning tasks, developing an important field of computer engineering, the machine learning, where the standard neural networks (SNNs) have been developed to graph neural networks (GNNs). A figure was concluded at the end of the review to brief the importance of discrete-math developing the relationship between computer engineering in general and graph theory's role in developing machine learning in particular.

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دراسة عن العلاقة ما بين هندسة الحاسبات , الرياضيات الرقمي و نظرية البيانات

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الخلاصة

تقوم الدراسة على فهم الفكرة الأساسية بين هندسة الحاسوب والرياضيات بناء على اثنين من الحقول المهمة وهي الرياضيات الرقمي ونظرية البيانات فضلا عن إعطاء الإجابة لأكثر الأسئلة طرحا بين الطلاب خلال فترة الدراسة الجامعية والتخصص في هندسة الحاسوب ألا وهو:

-ماهي أهمية دراسة الرياضيات بالتفصيل؟

وللإجابة عن هذا التساؤل نقول : أكثر الطلبة يواجهون المشكلة نفسها في عدم امتلاك الرؤية للربط بين المواد الدراسية للتخصص الدقيق والتخصص العام وبخاصة عند الرياضيات الهندسية كما في مادة التحليلات الهندسية والرياضيات الرقمية كما في مادة معالجة الإشارة الرقمية وبين دراسة الرياضيات الجبرية، فضلا عن عدم إدراك الطالب الفكرة الأساسية في إجراء تحويلات ما بين مديات الزمن والتردد، والانتقال بالعمل من أنظمة الزمن الحقيقي إلى العمل بأنظمة الزمن الرقمي، أو المتقطع، أو أنظمة تتعامل مع مديات التردد، وجهل الطالب لأهمية دراسة نظرية البيانات إذ أثبتت الدراسات الحديثة أهمية وقوة الرسم

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البياني بإعطاء تفاصيل أكثر في عملية التعلم، إذ طورت حقلا مهما من حقول هندسة الحاسوب ألا وهو تعلم الماكنة، فضلا عن تطوير الشبكات العصبية الأساسية إلى شبكات عصبية بيانية.

ثم استنتاج شكل توضيحي في نهاية الدراسة يبين ملخص عن أهمية الرياضيات الرقمي في تطوير العلاقة ما بين هندسة الحاسوب بشكل عام ودور نظرية البيانات في تطوير تعلم الماكنة بشكل خاص

الكلمات الدالة: الذكاء الاصطناعي ، الرياضيات المتقطعة ، نظرية البيانات ، التعلم الآلي.

1. INTRODUCTION

Computer engineering and mathematics give a reality as if everybody and everything is networked and connected. Communication has taken place to ease people's lives in work and in living by using internet and computers' networks and smart devices' communications [1, 2, 3, 4]. Engineers, make use of a huge amount of data for analyzing, designing but it is also considered to be a big challenge for them on different security levels.
The development in technology has increased on periods that machine learning became very powerful. Machines were learnt, trained and tested to perform many tasks based on the rising of computational level, leading to more simulation and increasing prediction levels which in turn increased the process of solving many problems; furthermore it is not just trying and observing the errors based on engineering matters only but working on more advanced methods.
Every engineer has to face the following problems:
1. How to make a decision.

2. Processing on a machine or system by troubleshooting.

3. Planning to design and simulate the problems for practical uses.

For engineers, solving problems is not a measure of true or false to decide solution in one direction only but developing machine learning which had helped to find in-between solutions. Taking for example, fuzzy system is a way of finding other possibilities based on (OR), (And) rules, than considering the digital solution to be measured in neither of one status (one) or (zero).
More emphasis in our curricula on solving unstructured real-life problems by combining fact based on data analysis and highly subjective and even intuitive judgements about aspects of a problem, should make the students more familiar with the uncertainty of real problems. In daily life, finding solutions for many problems require knowledge to make a decision but not in all cases, for engineering students making decisions is quite different from their experience in studying at university. They must combine between that gained knowledge and practical skills in order to be able to overcome difficulties of finding and deciding solutions.
The rapid increase and need in technologies had led to more studies and analyzing in computer sciences, engineering and designing which basically depend on mathematics.

There is an easy relationship that gathers between elements of mathematics in certain areas of computer, taking for example using Boolean algebraic to translate conditional states, but it is not an easy process to say the opposite and explain the uses of computer in mathematics in details. The top-level category based on ACM 2012 (Association for Computing Machinery) which is a classification in computers' system has been used to identify the important role of mathematics according to authors of the computer science and engineering [5], as shown in Fig.1.
Fig.1. shows clearly the deep connection between computer science, networking and computer engineering in particular with mathematics.

The articles in [6, 7, 8] does answer the question of many students, becoming a computer engineer is related to become good at math and that for the following reasons:

1.Computer engineering degree in general and computer science in particular requires math intensive courses, because they are basically math–intensive, so no degree would be given without passing the mathematics courses. All over the world and in many technical institutes and colleges one basic concept of completing computer engineering courses is required covering math requirements by studying different subjects to cover the curriculum according to authors of *Calculus I* and II but that would not be quite enough because for the second year an introduction to differential equations and the way that data can be structured and defined to create algorithms are required. Even more studies should be done by the third year to cover discrete–math in all its aspects and details moving to statistics and probability as well.
2.Exposure of too many concepts of math will increase the way that problems could be analyzed and then finding solutions will be much more a possible way in return to increase the ability of critical thinking skills to solve real life problems based on analyzing, designing and creating new applications and projects. For a computer engineer, a challenge will be on two levels, finding the problem and the solution for both the hardware and software, because he needs to think in a logical way that he could only gain through mathematical courses that he has been given during his study.
The same idea was supported by [9] in which pursing a profession or work in technology requires quite knowledge in both of algebraic and engineering math, as computer engineering is about studying structure, communication, mechanization, processes of storing data expressions and information encoding process within bits in computer memory, according to authors *[9 ,10, 11]* computer engineering degree requirements – math contain.

-A Major in general Education which requires:

a. Calculus with *Analytic Geometry* book one
b. Calculus with *Analytic Geometry* book two

- Main Requirements to be covered:

a. Statistical Analysis I
b. Elementary Probability

- Selected:

a. .Analysis I introduction.
b. .Differential Equations.
c. Fourier series.
d.. Partial Differential Equations.
e. Operations Research Introduction.
f. Discrete Models I and Linear Algebra.
g. Discrete Models II and Linear Algebra.
h. Basic Algebra.

-Students might take some of the computer engineering courses that include:

1. Discrete Mathematics for Computer Engineering.
2. Design and Analysis of Algorithms.
3. Formal Languages with Applications

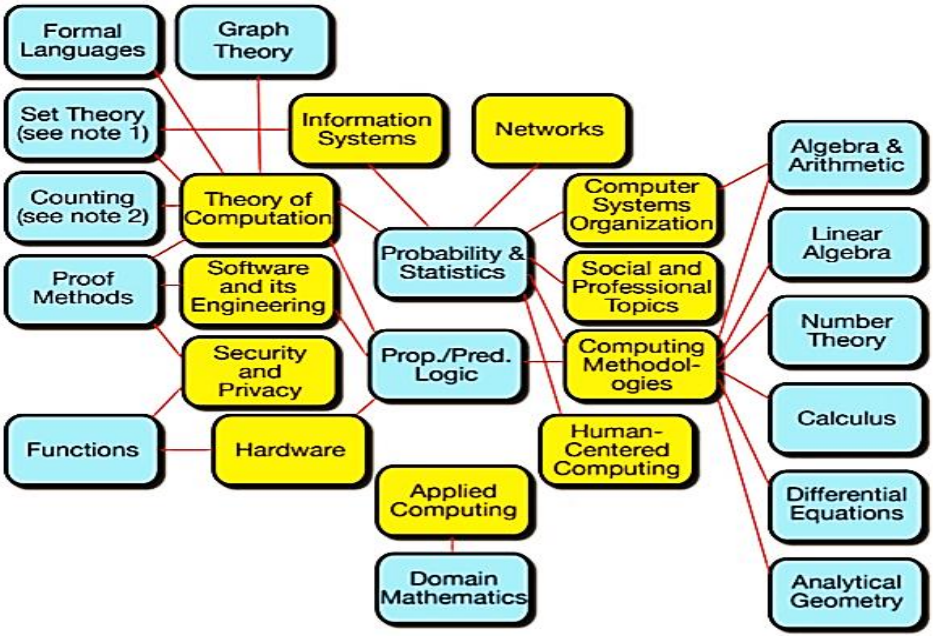

Fig. 1. Computer Sciences associated with Mathematics

2. MODEL

Computer engineering's mathematics can be divided into three basic courses as can be seen in the tables [1,2,3] and according to authors [12, 13, 14].

3. DISCRETE - MATH

Discrete math played a great role in technology and according to authors [15, 16] computer engineering and computer science are both based on discrete math which covers wide important topics:

1. Combinatorics
2. Numbers Theory
3. Set Theory
4. Logic
5. Algorithms
6. Graph Theory
7. Probability

3.1. The importance of Discrete-Math in Universities:

In addition to studying both Calculus and Algebra, the discrete math is one of the most important subjects or courses that have been studied in under graduate studies and considered one of the requirements that the student must complete to pursue his graduation degree. Understanding the transition from working in real–time systems to work in discrete-time system, is very important to understand how to solve complicated systems and how to design and manage work in discrete-time systems saving time of achievement [17 ,18].

3.2. The Importanc of Discrete- Math in Technology:

Modern computer sciences' mathematic is basically built on discrete mathematics, in particular graph theory and the field of combinatorics which both led to build many important applications and satisfy many projects in machine learning field.

Discrete-mathematics provides transformed systems for Analyzing digital world problems from computers to smart phones and assignments to genetics. Discrete mathematics depends on proof that used to determine the truth while science depends on analyzed experiences. Computer engineers must study discrete math to equip them with logical and mathematical skills as it focuses on discrete structures, graphs and networks.

3.3.Discrete Math is a Real World Mathematics:

The discrete math, Is also the type of math that represents real world problems, taking for example particular counting and probability problems which both make a challenge and are interesting topics widely needed and used in real life. It teaches mathematic

reasoning and proof techniques providing creative mathematical thinking in which few formulas to memorize but numerous fundamental concepts to apply in different ways [19].

3.4.Mathematics of Computers:

It is also defined as the mathematics that is used to optimize finite systems, work on discrete elements that may assume only distinct values including integers and rational numbers. It basically includes [3, 4, 15, 19]:

-Graph Theory
-Computation Theory
-Congruence and Recurrence relations.

The Mathematics is very essential for computer engineers and scientists because it helps to work on infinity or large quantities and indefiniteness and the results could be reused in different ways and covers the problem of designing many applications in need in daily life [20].

3.5.Mathematics of Reasoning:

Mathematics of reasoning is based on the logic which in turn is the science of reasoning. It's most important applications that are used practically are:

-Computing machines designing
-Systems specifications
-Machine learning and Artificial intelligence
-Programming of computers and their systems
-Languages programming
-Cryptography
-Software development

Computer programs are verified by proofs which resulted from correct mathematical arguments that are based on reasoning. According to author in [21] discrete-math has a significant role in analyzing huge mass of data. A high-dimensional data could also be managed, data sounds could be taken out from huge noisy sets of data using scaling algorithms of computations, which help to find reasons for solving problems and gaining skills.

Table .1.

Algebraic – Math

Fundamental Math (I)	**Fundamental Math (II)**
Review of functions	Basic Principles of Integration Techniques
Integration	Partial derivatives
Derivatives	Solution of different equations
Complex numbers	Applications of Integrations
Matrix calculations	……
Transcendental Functions	……

Table .2.

Engineering – Math

Continuous Math (I)	**Continuous Math (II)**
Fundamental of Fourier Series	Vector and Analytic geometry in space
Fourier Transform	Vector valued functions
Review of Infinite Series	Laplace Transform
Multiple Integral in various forms and coordinates	Engineering Applications
Engineering Applications	……..

Table .3.

Discrete – Math

Discrete –Time signals	Discrete – Time Systems
Signal Transformations	Properties
Amplitude Transformations	Engineering Applications
Z- Transform	Digital Filters
Fourier Transform and Convolution	Computer Controlled Systems
DTFT	Programmable Gate Array

4. GRAPH THEORY IN MACHINE LEARNING AND TECHNOLOGY

As graph theory is considered to be an important part of the discrete math, it has been used recently in research fields of computer science and machine learning, according to authors [22 ,23] graph analysis in machine learning has received more attentions because of the powerful expressive methods for graphs, which are used in many various areas including learning tasks that requires dealing with graph data which contains great information between elements such as modes learning from graphs inputs, for example learning molecular finger prints and in other fields it is considered from non-structural data learning as images and texts, reasoning based on the extracted structures as the tree of sentences dependency, and graph of image forming scene, which is considered to be also graph reasoning models.

4.1. Graph Theory in Classification, Prediction, Recognition and Clustering:

Graph theory added more power to the fields that are related to classification, recognition, prediction and clustering. According to authors [21, 24, 25] a machine learning of a unique non- Euclidean data structuring, the graph analysis that based on nodes classification, prediction of links and data clustering.

4.2. Graph Neural Networks (GNNs):

GNNs are connectionist models that capture the dependence of graphs by a message passing between nodes of graphs. The difference between standard Neural Networks (NNs) and Graph Neural Networks (GNNs) is that the latter retain a state of information from its neighborhood with arbitrary depth, though primitive GNNs were difficult to train for fixed set of points but recent researches and work in network architectures and optimization techniques beside the parallel computation have enabled successful learning using them [26, 27, 28, 29, and 30].

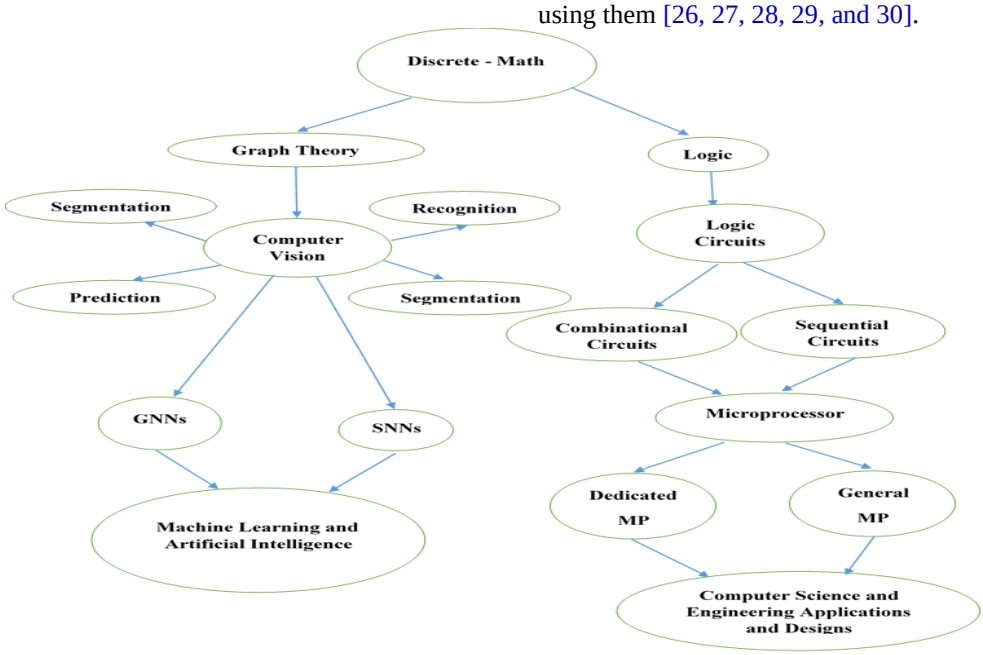

Fig.2. Computer engineering, discrete math and Graph theory

5. CONCLUSIONS

This review helps to focus on two important topics in computer engineering, the discrete-math and graph theory. Many researches were produced to clear the image about the importance of studying math, algebraic and engineering in order to understand the main concept behind developing many fields in computer engineering. We tried to shed light on current researches which aimed at change the old concepts by modifying new methods in the field of machine learning using graphs. This deep connection could not have been achieved without focusing on studying maths in details during the period of majoring computer engineering. So, studying in university must change the students' vision in understanding the courses materials in order to make progress on a scientific level besides passing the courses with success. Computer engineering students must have the will to understand the basic concepts behind every studied material and connect their importance to each other, and the need for them in their practical life after graduation. A computer engineer should have the vision to analyze, design and create his project or application, making use from the knowledge that he gained during the period of his study Universities must consider updating the courses materials on regular basics, following the new changes in other international universities plays an important role to make a real change in understanding the main basics of each subject and the need to follow the progress in all technology fields.

The logic based on the binary system of ones and zeros has led to design the logic gates which are combined and connected together to build either combinational circuits or sequential circuits and both are used as standard blocks for building larger circuits as the microprocessor, which has developed to more general–purpose microprocessors like Pentium CPU and dedicated microprocessors that is also defined as application-specific integrated circuits ASICs like in smart electronic device, that rapid speed in developing technology including the machine learning field and artificial intelligence, made a huge necessity to study discrete-math in all details considering, graph theory which must be covered during the courses. Recent researches focus on the development of the standard neural networks to more advanced networks as the graph neural networks and deep learning.

And from here, we may suggest several things that might help to raise the academic studies to encourage the students to focus on understanding, analyzing, designing and practicing their vision in real life.

1. More tutorial hours in algebraic and engineering math.
2. Involvement in making small projects among the students groups.
3. Making a connection between theoretical materials and practical materials.
4. Helping the students bring examples from everyday life and make the analysis themselves.
5. Helping the students understand the basic elements of their projects connecting between computer vision and discrete math.

We have concluded Fig.2 represent and understand the basic relationship between computer engineering, discrete math and graph theory.

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