Evolution and exploratory areas in the field of Theoretical Computer Science

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ABSTRACT
Theoretical computer science (TCS) is vast and ever evolving area in every field of engineering and has also immense impact over large domain of science."Church-Turing" thesis was basis for the abstract computational logic. In 60s computational complexity came out as new research interest. In the domain of Biological computation, TCS has strengthen the on going research in many areas such as DNA sequencing, Protein folding, Brain comprehension. This Paper has tried to knock the opportunity and learning of TCS research domain. It will help in realizing the domain of theoretical computer science along with its evolution and emerging trends. It will give the insight in perceiving problems and thus help in providing better alternative solutions for growth research field in TCS.

Keywords
Theoretical Computer Science, Computational Complexity, Computing.

1. INTRODUCTION
Computation in human civilization started with"Abacus" during late 2nd century. With the continuous research and contribution of many people it grew from simple Abacus computation to today's highly complex computer systems. This paper goes through advancement of the theoretical computer science, research areas and their contribution to different fields of science. Theoretical Computer Science (TCS) is a science to understand the computation of algorithms by having an abstract mathematical model. This field has developed, by mathematician in order to find the solutions of real world problems. Computing is the fundamental aspect in understanding the nature of any given problem. Almost everything we perform in our life is directly or indirectly related with computing whether it is decision making, medical science, internet services and others. Theory has always provided a vital contribution in applied science.

In the year 1936 Alan Turing has proposed the computational model. This model explained inner essence of mathematical approach. Church-Turing thesis in late 1936 established that any real world computation can be programmed using the Turing machine. These researches over the abstract computing have led the development of current computer system. As the complexity of solving the computational problem increases. Researcher developed abstract model to analyze discrete logical computing. One of the areas is Computational Complexity.

This paper will get gist of growth in Theoretical Computer Science and its blooming domain of research. Paper first goes through the early development in computing and how it leads to the development of present day computer. Contribution of TCS in different fields of science. Advancement in the field of computing and current research areas in Theoretical computer science.

2. HISTORICAL ASPECT OF THEORETICAL COMPUTER SCIENCE
Major breakthrough in the field of computing begins with Church-Turing thesis. Alan Turing has defined an abstract model of computing. Turing machine has helped in understanding the abstract logic of computing. It helps in finding possible way to circumvent the issue in algorithms.

In 1931 Kurt Gödel proposed incompleteness theorem which is significant in mathematical logic. It was letter between Kurt Gödel and Von Neumann give rise to P vs. NP problems.

2.1 Beginning of core
For any practical implementation of problems, initial step is to have strong theoretical perspective. Computing initiated with underpinning of theoretical models on mathematical problems from Abacus to Turing machine. In the above paragraph we have already discussed about the contribution of Church, Turing, and Gödel. In 1948 another important result is given by Claude Shannon in Information theory. Incompleteness theorem by Gödel state that "in any consistent formal system F within which a certain amount of arithmetic can be carried out, there are statements of the language of F which can neither be proved nor disproved in F. According to the second incompleteness theorem, such a formal system cannot prove that the system itself is consistent (assuming it is indeed consistent). These results have had a great impact on the philosophy of mathematics and logic" [1]

Church-Turing thesis formalizes the notion of automata. Turing's thesis LCMs [logical computing machines: Turing's expression for Turing machines] can do anything that could be described as "rule of thumb" or "purely mechanical". (Turing 1948:7.)[2].

In the year 1941 Stephen Cole Kleen has given the proof of incompleteness theorem. He is responsible for recursion theory and regular expression. His proof on incompleteness theorem has given the result that halting problem is undecidable. Researches in starting of 20 th century on mathematical logic has lead the foundation of theoretical computing, which was concluded with the development of Computer system.

2.2 Intermediate Development
By J Hartmanis "Computer science, is primarily interested in what can exist and how to describe and analyze the possible in information processing. It is a science that has to conceptualize and create the intellectual tools and theories to help us imagine, analyze, and build the feasibly possible." Turing machine was helpful in understanding the discrete logic of computing, but it does not express the complexity of algorithms. In 1960 J Hartmanis & RE Sterans while working on structure theory of finite automata, they found that finite automata theory is not powerful enough for quantitative

theories. Again in their work they explored theory of H Yamada, in which Yamada had explained about the need to know the required time for computation of the given function. These challenges finally thrive as Computational Complexity during the early months of year 1963.[3]

Another important result was put forward during the 1970's by S Cook & L levin working independently. They have formalized NP-complete problem by showing Boolean satisfiability. All four researchers was accord with prestigious Turing award for their contribution in the field of Computation Complexity.

2.3 Advance Development

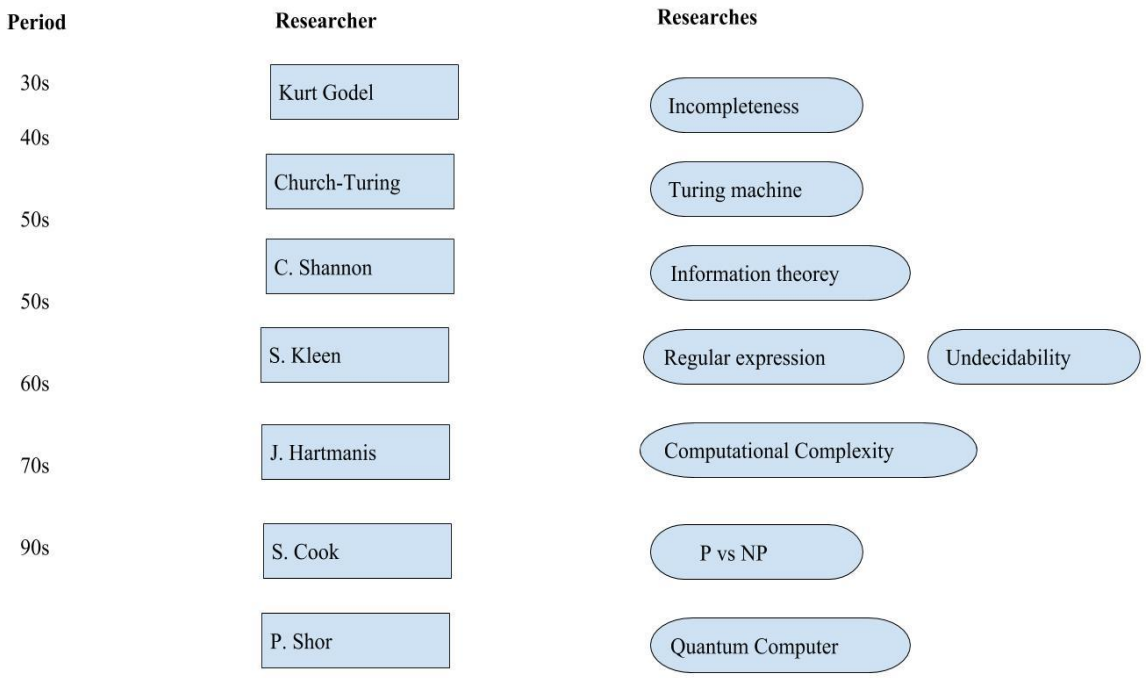

Figure 1 TCS Evolution

3 CONTRIBUTION OF THEORETICAL COMPUTER SCIENCE

TCS act as the base for development in many science researches, like Biology, Database system, Learning system and many more. We listed out some of the important researches which TCS has contributed.

3.1 Basic science

There are significant contribution in Biology and Physics also. Both the fields give much emphasizes on computing. Either it is related to DNA sequencing, Protein structure or Quantum behavior, computation is the primary task for problem understanding.

3.1.1 Biology

Computational genomics is one of the recent linking fields of TCS and Biology. It works on deciphering the Genome sequencing. Genome sequencing helps in obtaining knowledge about variety of species.

3.1.2 Physics

In Physics Quantum mechanics is the area where TCS has its concern. Recent development in QC to get more efficient algorithms is one of such example. Quantum complexity theory which is part of classic Complexity theory is evolve for QC.

With time, researches in TCS have enhanced and it has become more well known area for the researcher. In the year 1990 advancement took place in Quantum computer. Peter Shor has given quantum algorithm for integer factorization. He indicated that factorization problem can be efficiently solve on QC with complexity class BQP (bounded error quantum polynomial time) [4]

P vs. NP is a major open problem in TCS. It is one of the millennium prize problem. Other major areas of research are in field of the Biology on neural system, DNA structure.

3.2 Internet

Internet has a vast area of research from data mining, E-commerce to network security. Internet which can be considered as the biggest graph and graphs are the basic research entity in TCS. This paper explore these areas

3.2.1 Data mining

In Data mining it requires huge computational processing over the data. As it focuses much on the analysis of data. It has application in E-commerce, web, searching and many others. Researcher are continuously working to get more efficient queries and graph algorithms.

3.2.3 Web and E-commerce

There are many challenges in E-commerce and Web because of exponential use of it. This field emphasizes more on the data processing. Web designing requires frequent modification for better design and rendering data. There are current requirement for data model development and performance optimization in website designing.

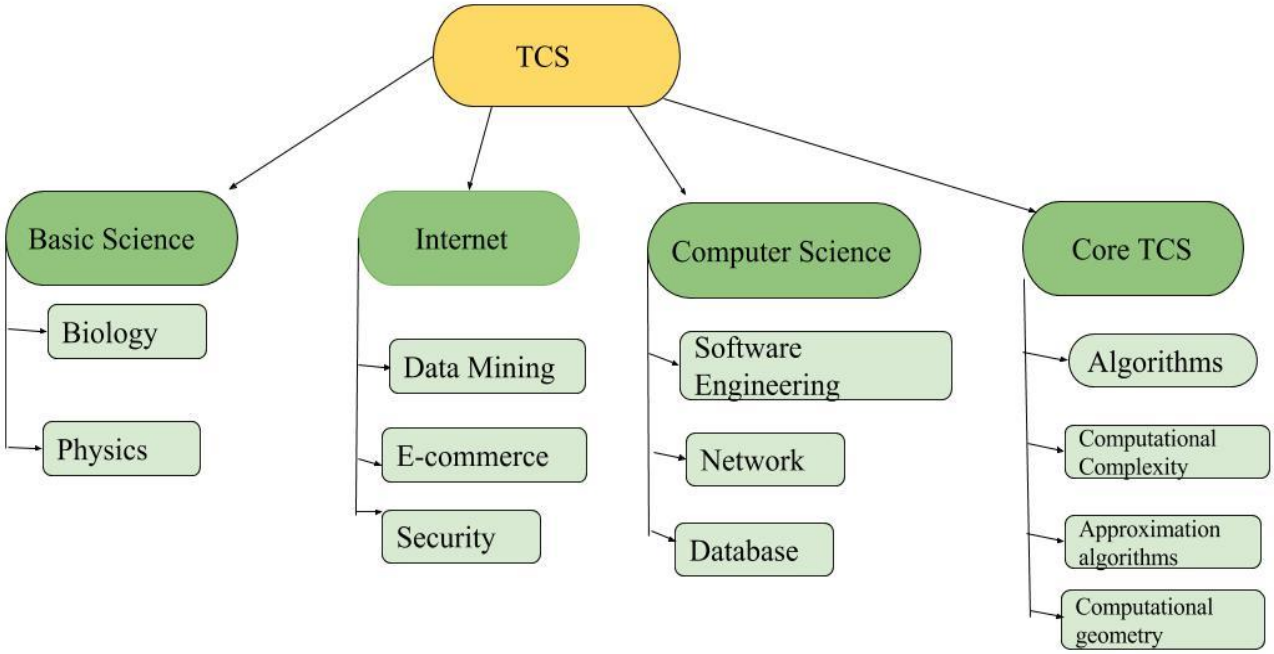

Figure 2: TCS linking fields

3.2.4 Cyber security

Security on Internet is linked with the mathematical functions. Cryptographic algorithms are mostly dependent upon mathematical theory. RSA which is well known security algorithm has the application of Integer factorization. In web, watermarking is another security feature; it is the process of embedding information about originator or owner of the file or data. But it is based on the private key cryptography. Researches are in progress to find out the public key algorithm for watermarking.

3.3 Core Computer science

In core computer science, TCS has an impact on software engineering, network, database, formal methods and others. We are covering some of the few areas which has influenced of TCS.

3.3.1 Software Engineering

Formal method in software engineering which is mathematical based technique for specification development and verification of the software. They particularly use logic, automata and semantic theory of computation. There is need of specification methods for reactive software system that can precisely provide details about its functional and behavioral requirement. There are also open research area for the development of the system which automatically transformthe specification of software.

3.3.2 Network

In network, the routing is specific domain which requires many graph based algorithms. Congestion in the network is also challenging area which requires computation

3.3.3 Database system

Due to rapid increase in online activities, heavily focusing on data have resulted in large date collection and hence surging in vast data management. So there are ample opportunities of researches for the development of efficient and effective of the queries.

3.4 Salient areas in Theoretical Computer Science

The key research areas in TCS are algorithms, Computational Complexity, Combinatorial, Computational geometry, Logic semantic programming methodology and others.

3.4.1 Algorithms

Algorithms are the primitive and most versatile area of research. There is a need for designing of algorithms which has the least time and space complexity. Approximation algorithms, one of such unique area which is use to find theapproximation solution of optimization problems. They are much related with NP-hard problems.

3.4.2 Computational Complexity

Computational complexity classifies the algorithms on the basis of their tractability or intractability. Program can beclassified as well known classes, NP, NP-complete. P = NP is the open problem and one of the millennium prize problems.

3.4.3 Computational Geometry

It focuses on the computational section of geometry. Some of the application domains of computational geometry arerobotics, computer graphics, visualization. Travelling salesman problem is a computational geometry problem.

3.4.4 Approximation Algorithms

There are many computational problems which are difficult to solve. These problems are categorized into NP-HARD problems. NP-hard means there exits no polynomial time solution for the problem, unless P=NP and which is open problem. One of such NP-hard problem is travelling salesman. So approximation algorithms are the algorithms which give approximate solution to optimize the problem. V. Vaziranihas immense contribution on approximation algorithms.[5]

4 FUTURE CHALLENGES

We have already discussed some of the different domains where TCS has its impact. Each domain is going on with progressive development, however there are still challenges. Computational problem in DNA sequencing. Quantum computers for more efficient algorithms. P vs. NP challenging problem in Computational complexity. In distributed computing to processing large number of queries with changein web page. Approximation algorithms for NP-hard problems. Viable solution for the automate cryptographic protocols. Graph isomorphism with unsolved complexity, recent claim has been made to obtain quasi-polynomial time graph isomorphism but not yet verified.[6]

5 CONCLUSION

Theoretical computer science has interlinked large areas of research. TCS not only gives the abstract mathematical computational model but also its essential theory base for the applied science. Results of Theoretical computer science always boost science domains. Here we have highlighted few domains which are influenced by Theoretical computer science. Computational complexity has given has open the research area in P vs. NP problems. Computational biology has developed as new area for researchers interested in mathematical computational model. There are open problems in Approximation algorithms field for optimization ofMax Clique, Vertex cover which are NP hard problems.

Major ongoing research domain are in Stream algorithms, Graph streaming algorithms, Quantum computers.

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