International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 2, January-February 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

An Overview of Hard Computing

Matthew N. O. Sadiku[1], Uwakwe C. Chukwu[2], Abayomi Ajayi-Majebi[3], Sarhan M. Musa[1]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Department of Engineering Technology, South Carolina State University, Orangeburg, SC, USA
[3]Department of Manufacturing Engineering, Central State University, Wilberforce, OH, USA

ABSTRACT

Computing refers to the process of accomplishing a particular task with the help of a computer or a computing device. Hard computing is the traditional computing algorithm, which processes functions and data with a verifiable output. It requires an analytical, precisely stated model. Hard computing is deterministic and precise. It may also be regarded as a heterogeneous collection of traditional computing methods. This paper presents hard computing, the differences between hard computing and soft computing, and their fusion.

KEYWORDS: *hard computing, soft computing, fusion, hybrid mode*

How to cite this paper: Matthew N. O. Sadiku | Uwakwe C. Chukwu | Abayomi Ajayi-Majebi | Sarhan M. Musa "An Overview of Hard Computing" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-2, February 2022, pp.672-676, URL: www.ijtsrd.com/papers/ijtsrd49287.pdf

IJTSRD49287

INTRODUCTION

We are in the era of computing. Computing is experiencing its most exciting moments in history, permeating nearly all areas of human activities. Computing is any activity that involves using computers. It is any goal-oriented activity requiring the use of computers. It includes designing and building hardware and software systems for a wide range of purposes. It has resulted in deep changes in infrastructures and development practices of computing. It is a critically important, integral component of modern life. In this era of computing, the type of computing one uses can make a big difference. Problem-solving technologies can be of two types: hard computing and soft computing [1]. Figure 1 compares hard computing and soft computing [2].

Traditional or hard computing techniques are based on principles of precision, uncertainty and rigor. The problems based on analytical model can be easily solved using such techniques. The analytical models are precise because they require perfect knowledge.

The terms "hard computing" and "soft computing" were coined by Lofti A. Zadeh in 1991. Since then, the area has experienced rapid development. Soft Computing became a discipline within computer science in the early 1990s. The terms "machine intelligence" and "computational intelligence" have been used to have close meaning as soft computing [3]. Soft computing approaches include neural networks, probabilistic models, evolutionary algorithms, artificial neural networks, fuzzy logic swarm intelligence, etc.

HARD COMPUTING

One may regard the whole history of computer science as a record of continuous attempts to discover, study, and implement computing ideas. Computing technology greatly affects nearly every aspect of our modern life including education, entertainment, transportation, communication, economy, medicine, engineering, and science. The history of computing is one of punctuated equilibrium, bringing new and unexpected changes.

Mainframes gave birth to minicomputers, which gave birth to workstations, which gave birth to personal computers, which gave birth to smartphones.

Hard computing (HC) is a traditional computing approach. It emphasizes precision, certainty, and rigor, while soft computing requires that computation, reasoning, and decision making exploit the tolerance for imprecision and uncertainty wherever possible. It is a conventional computing approach which requires precisely stated analytical model and takes very large computation time. Hard computing or traditional computing is fast, efficient, and reliable with deterministic outcomes. It is the sequential kind of computing that provides precise and certain solutions.

Hard computing methods are typically easier to apply. Also the stability of resulting solutions is highly predictable and the computational burden of practical algorithms is typically low. HC often takes a lot of computation time. It strictly follows known steps to solve a task as opposed to soft computing which is heuristic Today, we have microwave ovens, washing machines, cameras, and many other products that manifest an impressive capability to reason, make intelligent decisions, adapt to changes in the operating conditions, and learn from experience [4].

HARD COMPUTING VERSUS SOFT COMPUTING

The traditional hard computing is an ancient approach which came before soft computing. The principles of hard computing are precision, certainty and rigor. The input data should be exact and the output will be precise and verifiable. Hard computing is used in solving the deterministic problems, prototyping, and modeling. Applications of hard computing include mobile robot coordination and forecasting combinational problems.

Soft computing (SC) refers to a collection of computational techniques in computer science, artificial intelligence, and machine learning. It differs from the conventional hard computing as it can handle uncertainty, imprecision easily. While conventional hard computing is based on crisp values and binary numbers, SC uses soft values and fuzzy sets. Soft computing techniques solve the real-life, non-linear problems which involve uncertain, imprecise and approximate solutions of a problem.

Both hard computing and soft computing are illustrated in Figure 2 [5]. The major differences between hard computing and soft computing are summarized as follows [6]:

Hard Computing:

- It requires a precise state analytic model.
- It relies on binary logic and predefined instructions.
- Its features include precision and categoricity.
- It has a deterministic nature.
- It works on exact data.
- It is used to perform sequential computations.
- It produces precise, accurate results.
- The programs have to be written.
- It is settled in nature.
- It cannot handle imprecision and partial truth
- It does not suitable for real-world problems.
- It consumes a large amount of computation time and cost.

Soft Computing:

- It can be associated with being liberal with inexactness, uncertainty, partial truth, and approximation.
- It is based on the model of the human mind or human intelligence.
- It depends on formal logic and probabilistic reasoning.
- It consists of approximation and dispositionality.
- It has a stochastic nature.
- It generally works on ambiguous and noisy data.
- It can be used to perform parallel computations.
- It results in approximate results.
- It can come out with its own programs.
- It incorporates randomness in its computations.
- It uses multivalued logic.

The differences between soft computing and hard computing are summarized in Table 1 [7]. The fusion of the two is considered next.

FUSION OF SOFT COMPUTING AND HARD COMPUTING

In general, it is irrelevant to ask whether one should prefer SC over HC or vice-versa. As the soft computing community is not looking for perfect solutions but competitive ones instead, there exists an implicit commitment to benefit from the fusion of various methodologies. A fusion of soft computing and hard computing appears to be a natural and practical choice. There exists a large amount of applications where SC is used together with HC; these kind of approaches aim at technically and economically competitive systems, products, and services.

Proper fusion of soft computing technology with conventional hard computing technology is key to success [8]. In the fusion of SC and HC, the roles between different methodologies should be assigned based on their individual characteristics. SC aims to exploit tolerance for imprecision, uncertainty, and partial truth to achieve robustness, tractability, and low total cost. HC techniques are typically easier to

analyze, their stability is highly predictable, and the computational burden of algorithms is either low or moderate. A typical example of a fusion of hard computing and soft computing is shown in Figure 3 [9].

There are two obvious alternatives to form hybrid cascades of soft computing and hard computing algorithms, SC-HC or HCSC, depending on the sequential order of those functional blocks. In SC and HC type systems, the soft computing and hard computing constituents both have their independent roles, and there is a loose union, with no explicit connection between them. Although the hard computing and soft computing research communities are somewhat separated, many SC-oriented researchers and engineers are openly favoring the various fusion opportunities. The unfortunate separation is clearly hindering the industrial acceptance of SC [10].

A trend in the fusion of soft computing and hard computing is the simultaneous partnership of HC and multiple SC methodologies. The conventional HC techniques and the emerging SC should be regarded as complementing methodologies. Fusion of soft and hard computing techniques are also useful in applications such as robotics and a nonlinear tracking system. The fusion of individual soft computing methodologies has been advantageous in numerous applications such as providing intelligent behavior. The integration can improve the control performance of nonlinear systems. The integration could be closely or loosely.

CONCLUSION

Hard computing is the conventional methodology, which relies on the principles of accuracy, certainty, and inflexibility. Conversely, soft computing is an emerging modern approach premised on the idea of the approximation, uncertainty, and flexibility. Hard computing is based on a crisp system and binary logic, while soft computing is based on fuzzy logic and probabilistic reasoning. Hard computing performs sequential computations, while soft computing performs parallel computations on the data. Soft computing approach is probabilistic in nature whereas hard computing is deterministic. Soft computing and hard computing are being used together in various industries. The traditional HC techniques and the emerging SC should be seen as complementary methodologies. More information about hard computing can be found in the books in [11-13] and the following related journals:

- Soft Computing
- Applied Soft Computing

REFERENCES

[1] D Morgan, "Hard computing v/s soft computing," https://www.techyv.com/article/hard-computing-vs-soft-computing/

[2] B. Xavier, and P. B. Dahikar, "A comprehensive study on the significance of soft computing in healthcare systems," *International Journal of Engineering Research & Technology*, vol. 4, no. v2, February 2015, pp. 278-281.

[3] M. N. O. Sadiku, Y. Wang, S. Cui, S. M. Musa, "Soft computing: An introduction," *International Journal of Advanced Research in Computer Science and Software Engineering,* vol. 8, no. 6, June 2018, pp. 63-65.

[4] L. A. Zadeh, "Fuzzy logic, neural networks, and soft computing," *Communications of the ACM,* vol. 37, no. 3, March 1994, pp. 77-84.

[5] "Difference between soft computing and hard computing," https://techdifferences.com/difference-between-soft-computing-and-hard-computing.html

[6] A. Diwan, "Difference between soft computing and hard computing," April 2021, https://www.tutorialspoint.com/difference-between-soft-computing-and-hard-computing

[7] "Soft computing vs. hard computing: Difference explained," https://wisdomplexus.com/blogs/soft-computing-vs-hard-computing/#:~:text=Hard%20computing%20relies%20on%20binary,logic%2C%20and%20uses%20multivalued%20logic.

[8] A. Kamiya et al., "Fusion of soft computing and hard computing for large-scale plants: A general model," *Applied Soft Computing,* vol. 5, 2005, pp. 265–279.

[9] S. J. Ovaska et al., "Fusion of soft computing and hard computing techniques: A review of applications," *Proceedings of the IEEE SMC'99 Conference Proceedings. 1999 IEEE International Conference on Systems, Man, and Cybernetics,* October 1999.

[10] S. J. Ovaska, A. Kamiya, and Y. Q. Chen, "Fusion of soft computing and hard computing: Computational structures and characteristic features," *IEEE Transactions on Systems, Man, and Cybernetics—Part C: Applications and Reviews,* vol. 36, no. 3, May 2006, pp. 439-448.

[11] J. Pejaś et al. (eds.), *Advances in Soft and Hard Computing*. Springer, 2019.

[12] G. C. Buttazzo, *Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications*. Springer Science & Business Media, 2011.

[13] S. J. Ovaska (ed.), *Computationally Intelligent Hybrid Systems; The Fusion of Soft Computing and Hard Computing*. John Wiley & Sons, 2005.

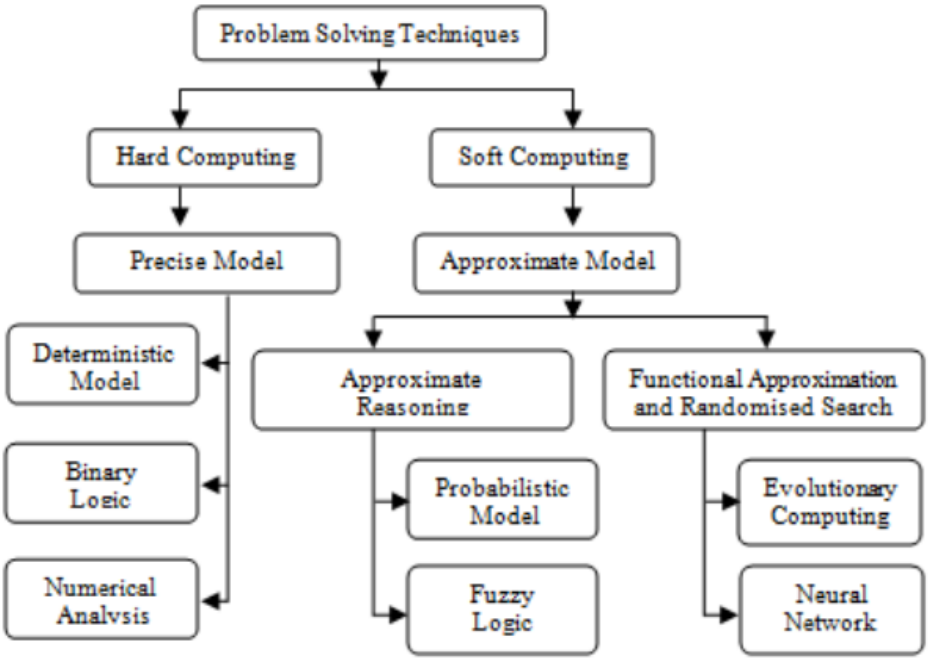

Figure 1 Comparing hard computing with soft computing [1].

Table 1 The differences between soft computing and hard computing [7].

Soft Computing	Hard Computing
It can be evolve its own programs	It requires program to be written
It uses fuzzy logic	It uses two valued logic
It can deal with noisy data	It can only deal with exact data
It allows parallel computing	It allows sequential computing
It gives approximate answers	It gives exact answers
It needs robustness	It needs accuracy
It is also known as computation intelligence	It is also known as Conventional intelligence

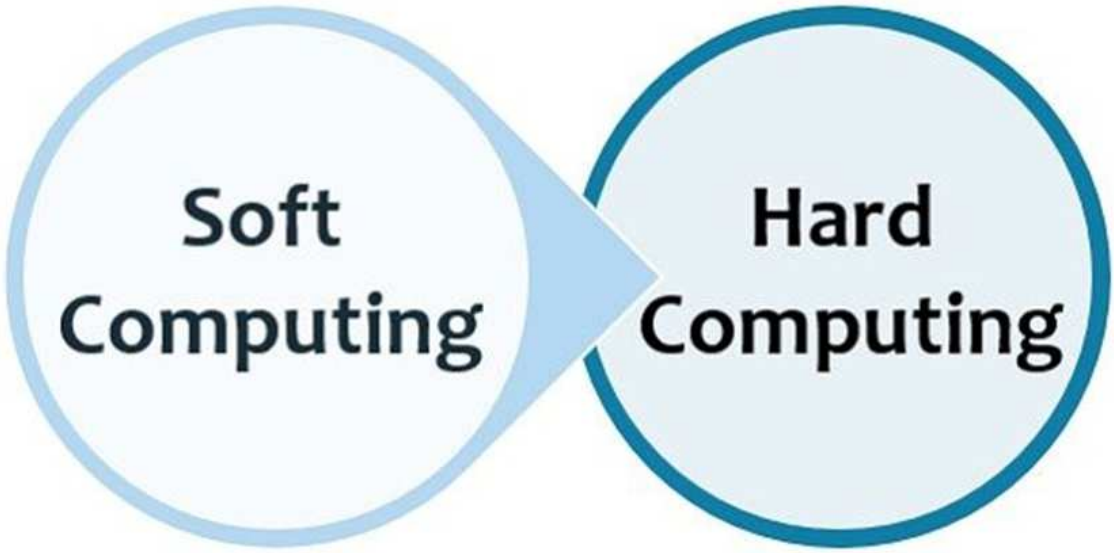

Figure 2 Hard computing and soft computing [5].

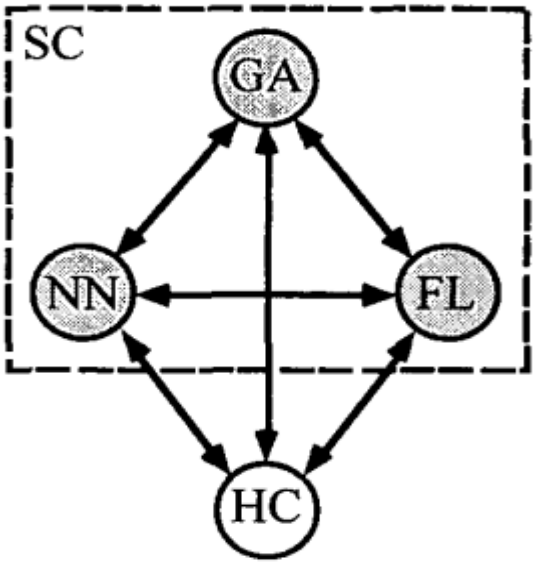

Figure 3 Fusion of hard computing and soft computing methodologies [9].