Deep Blue: Computer Chess and Massively Parallel Systems (Extended Abstract)

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1.Introduction

Since the dawn of the computing age, programming a machine to play chess at grandmaster level has been a grand challenge of computer science. As early as 1949 Claude Shannon described how to program a computer to play chess. He introduced many fundamental algorithms that are still used today in almost all chess programs.

It was not until 1988 that a computer called Deep Thought, designed by F. H. Hsu, finally defeated a human grandmaster. In 1989 Hsu and Murray Campbell joined IBM Research and carried forward their research into computer chess algorithms and parallel system architectures. A year later a fellow researcher, A.J. Hoane, joined the team and together they started a remarkable journey toward building the world's first massively parallel chess system, Deep Blue. This system, when completed in late 1995, will play chess at the same level as the strongest human chess player. In this paper we will describe IBM's effort in developing this system and its significance in the history of computing.

2. Technical Foundations of Deep Blue

The dawn of modern computer chess systems closely followed the advancement of computer platforms, from micro's to massively parallel systems. In the 1970's, the emergence of the supercomputers, including the CDC Cyber series, provided the computing platforms upon which chess programs were developed for the first time to play at the human expert level.

The dominance of supercomputers in chess lasted till the early to mid 1980's. This trend should not be surprising to anyone, since the basic algorithms, as

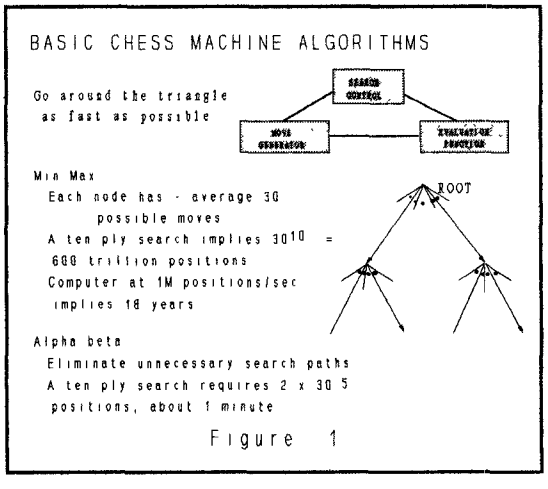

Figure 1

developed by pioneers such as Shannon, Turing, McCarthy and others [1], all required intensive computing resources. The algorithm as shown in Figure 1, involves iteration around the three steps: move generation, search, and function evaluation, for each board position. Since each node has on average, 30 possible moves, searching ahead for 10 plies in the search tree would involve 48 million board positions!

Supercomputers, starting with CDC and then the Cray YMP, were soon eclipsed by other technological innovations in computer chess systems Ken Thompson of Bell Laboratories clearly foresaw the coming of this computing bottleneck for chess playing programs even in the late 1970's. He started to develop a series of workstation attached special purpose hardware engines for accelerating the search algorithms. His efforts succeeded, as he expected, by

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winning the ACM Computer Chess Championship in 1980, defeating the then reigning champion running on a CDC Cyber 176. As shown in Figure 2, Belle's reign was taken over a couple years later by a program called Cray Blitz. However, Thompson's pioneering work had a major influence on later computer chess champions including Deep Thought and its successor Deep Blue.

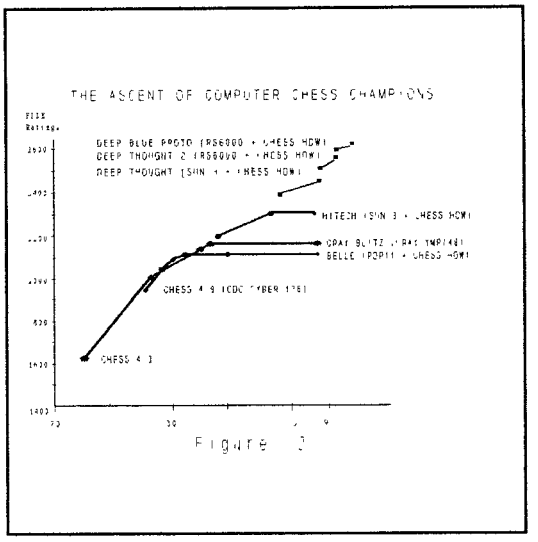


Figure 2

Thompson had shown that by judiciously embedding search algorithms in hardware, and attaching these search engines to inexpensive workstations, he could dramatically outperform supercomputers! In essence, such systems can effectively out-compute general purpose supercomputers for specific applications. Deep Blue, for instance, will carry out searches at a speed equivalent to a Tera-op level general purpose computer [2]. Thompson showed, in effect, that, for a certain range of chess ratings, there is an almost linear speed up in a computer chess program's playing strength with respect to the number of plies a given system can compute, as is shown in Figure 3. Furthermore, there is a 200-point ELO rating improvement for each order of magnitude improvement in computing speed of the chess machine platform. With algorithmic and architectural improvements in Deep Blue, Hsu and his team members have demonstrated that this range of linearity can be extended to approach the ratings of the top human chess players [2].

3. Deep Blue and other Modern Computer Chess Systems

Deep Blue employs a specially designed chess search engine [2], with the following special features: 1) a scalable architecture that allows the deployment of one to hundreds of these application specific chips in a given system, 2) parallel search algorithms that can effectively exercise the hardware to obtain the desired speedup in the algorithm, and 3) the deployment of

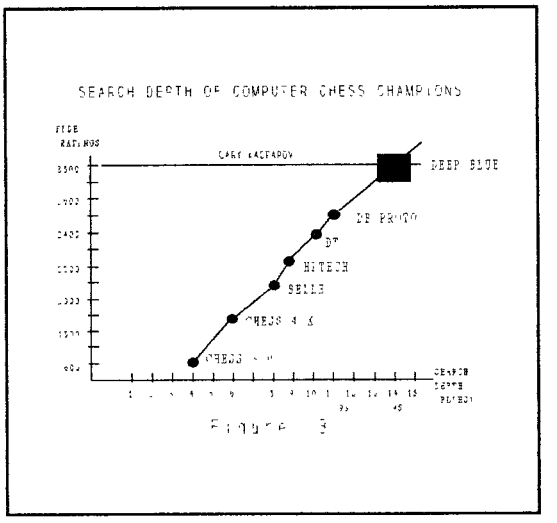


Figure 3

modern workstations or PC's as host, providing effective synergism between hardware and software for the execution of the basic chess algorithms. A typical PC-based 10-processor system is shown in Figure 4. It is this unique system feature that makes Deep Blue the current top ranked computer chess system in the world. It is also the prime candidate to perform the historic event of playing chess at the same level as the best human chess player.

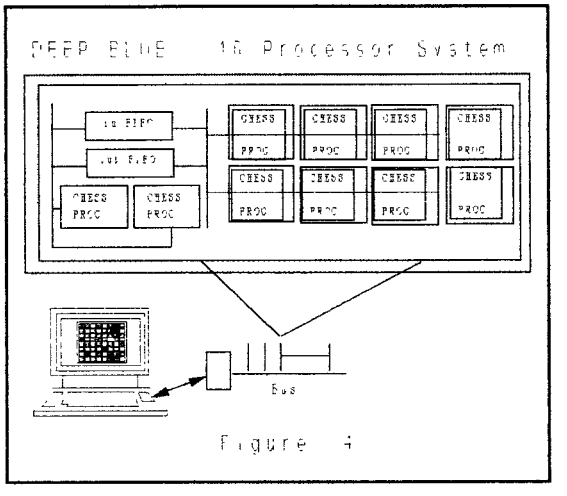
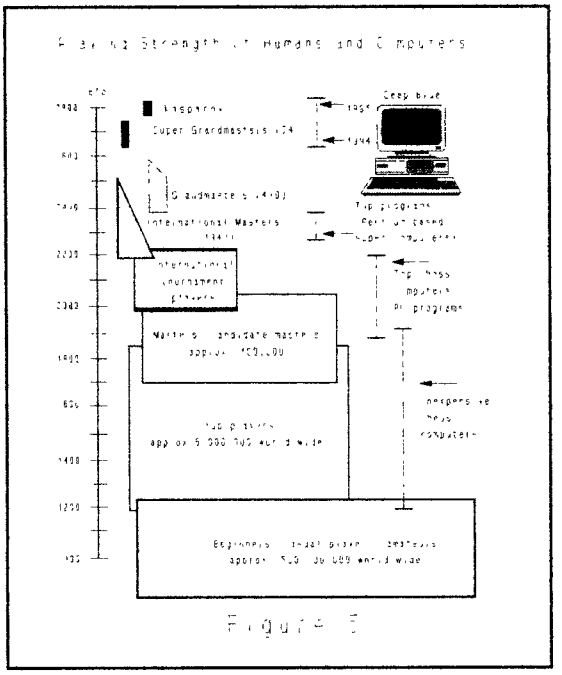


Figure 4

Today many computer chess programs exist that run on a PC and play at the top masters level as shown in Figure 5. With the introduction of ever faster micro-processors, these machines will surely out perform some of the best grandmasters in the foreseeable future. Until then, IBM's Deep Blue and it's team will enjoy the limelight as the best there is.



4. Conclusions

How long will Deep Blue reign as the champion? If computer chess theory holds and we observe the fact that micro-processor speed will double every one and one-half years, then maybe in 3 or 4 years, the PC based programs will come close to the performance of a small Deep Blue system. However, we must also note that another computing revolution is currently taking place in conjunction with the rapid development of micro-processors. In no more than four years a Tera-op massively parallel computer system will be easily obtainable. Thus will the cycle of champions as shown in Figure 2 repeat itself? The only thing definite is that computer chess will remain a harbinger of the trends in computer development. This will continue long after a chess machine has exceeded the playing capacity of the best human player. Until then we believe Deep Blue will reign supreme and we will have fun competing.

Acknowledgement

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[1] David Levy and Monty Newborn, *How Computers Play Chess* , Computer Science Press, 1991.

[2] F.H. Hsu, M.S. Campbell, and A.J. Hoane, "Deep Blue System Overview", this conference.