A Summary of *Deep Blue*

This paper provides an overview of the Deep Blue paper written by Murray Campbell, A. Joseph Hoarne Jr., and Feng-hsiung Hsu. In it, I will cover the goals for Deep Blue, and the techniques employed to reach them. Finally, I will summarize the results of the Deep Blue machine.

The goal for Deep Blue was to ultimately build a world-class chess machine. What eventually became Deep Blue started in the 1980s at Carnegie Mellon University as ChipTest and Deep Thought. In fact, in 1988, Deep Thought became the first machine to beat a Grandmaster in tournament play. After moving over to the IBM T.J. Watson Research Center in the early 1990s, and several iterations later, "Deep Blue I" was ready for tournament competition. In 1996, Deep Blue I faced off against several Grandmasters, including Garry Kasparov, who decisively won 4-2. However, using observations from that match, the Deep Blue team worked to improve the machine. Finally, in 1997, Deep Blue defeated Garry Kasparov 3.5-2.5, becoming the first machine to beat a human world champion in a regulation match.

Between the 1996 and 1997 Kasparov matches, the Deep Blue team implemented a number of improvements and techniques to beat the world champion. One key improvement was increasing the number of features in the evaluation function, from 6400 to over 8000 (most of which came from observed moves from the Kasparov match and other test matches). As a result, the team had to more than double the number of chess chips in the system to increase computing power and efficiency. With the increased demands of the evaluation function, the processing power had to increase as well to ensure the machine could still evaluate far enough down the game tree for effectiveness. Lastly, the team improved the software's debugging and match preparation tools for better analysis.

There are a few techniques employed in Deep Blue that are worth noting. One such technique is that Deep Blue uses both hardware and software search capabilities. The hardware search is parameterized and fixed, so there is little flexibility. However, its main advantage is its speed and simplicity, so it's generally used to explore shallow searches. On the other hand, the software search is complex, yet flexible and programmable. Its core feature, what the team calls "dual credit with delayed extensions," assigns credit to players given certain moves. Another fascinating technique is the use of the extended book, which is essentially a Grandmaster database of moves. The extended book gives Deep Blue information on certain moves based on previous history, such as how often that move has been executed, and even *who* executed the move. It's noted in the paper that a move by a player of Kasparov's caliber would be weighted higher than a lower level player.

As a result of the aforementioned improvements between the Kasparov matches, Deep Blue achieved its goal and defeated Kasparov. The techniques described above, and countless others not mentioned, all contributed to its winning performance. As the paper notes, it is hard to pick just one improvement or technique that made the difference. However, it is clear that the foundation behind all the improvements is that the Deep Blue team learned from computing data and actual game experience versus human players to improve Deep Blue. As mentioned, many of the increased features in the evaluation function were a result of watching Deep Blue test against human players, and recognize its strengths and weaknesses. Yet, the team did not stop there, knowing that with the growing complexity of the evaluation, the machine would have to compute faster than it had before. The success of Deep

Blue and its winning performance against are largely due to these facts.