

. . . for the World Checkers Championship

Jonathan Schaeffer, Norman Treloar, Paul Lu, and Robert Lake

■ In August 1992, the world checkers champion, Marion Tinsley, defended his title against the computer program CHINOOK. Because of its success in human tournaments, CHINOOK had earned the right to play for the world championship. Tinsley won the best-of-40-game match with a score of 4 wins, 2 losses, and 33 draws. This event was the first time in history that a program played for a human world championship and might be a prelude to what is to come in chess. This article tells the story of the first Man versus Machine World Championship match.

It has been 30 years since Arthur Samuel's (1967, 1959) pioneering efforts in machine learning gave prominence to checkers-playing programs. Samuel's successes included a victory by his program over a master-level player. In fact, the opponent was not a master, and Samuel himself had no illusions about his program's strength. This single event, a milestone in AI, was magnified out of proportion by the media and helped to create the impression that checkers was a solved game. Nevertheless, his work stands as a major achievement in machine learning and AI. With only a few exceptions, notably the DUKE program (Truscott 1978), little effort has been devoted to checkers programs since this work. Perhaps because of Samuel's early success, most of the subsequent research efforts into game-playing programs has been directed toward chess.

CHINOOK is a checkers program (8 x 8 draughts) developed at the University of Alberta (Schaeffer et al. 1991, 1992) as part of a research project in game-playing strategies started in 1989. In August 1990, the program earned the right to play for the World Checkers Championship as a result of its success at the U.S. National Checkers Championship for human players. After two years of preparation, the match was finally played in August 1992. The world champion, Marion Tinsley, emerged victorious, winning 4 games, losing 2, and drawing 33 in the best-of-40-game match. Considerable work remains to be done

with CHINOOK before we can expect to defeat Tinsley in a match, but the close score and the two wins represent a milestone from the computing point of view.

CHINOOK is the first program to play for a human world championship in a nontrivial game of skill. Computers have played world champions before, for example, DEEP THOUGHT in chess (Hsu et al. 1990) and BKG9 in backgammon (Berliner 1980), but they were exhibition matches with no title at stake. Tinsley is to be congratulated for putting his reputation on the line against a computer. This match might be a prelude to what will eventually happen in chess.

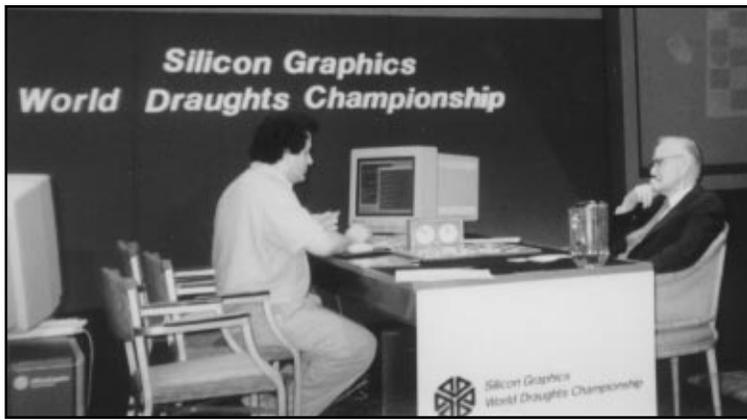
The Champion

Since 1950, the checkers world has been dominated by Tinsley. He first became world champion in 1954 and then retired from the game in 1958, having vanquished all the best players in the world. He returned to the competitive arena in the early 1970s and became champion again in 1975. He has been champion since then, successfully defeating all challengers.

Tinsley's record is unparalleled in checkers or any other competitive game of skill. Over the past 42 years, he has won every match he has contested, usually by an embarrassingly large margin. For example, in his 1989 world championship defense against Paul Davis, Tinsley won 10 games, lost 0, and drew 20. He has finished first in every tournament he has played in, usually by a wide margin. Over this period, consisting of thousands of competitive and exhibition games, Tinsley has lost only seven games! His record in checkers is as close to perfection as is humanly possible.

The Challenger

CHINOOK's strength comes from *deep searches* (deciding which positions to examine), a good *evaluation function* (deciding how favor-



Jonathan Schaeffer and Marion Tinsley

able a position is), an *opening book* (knowledge of the first few moves of the game), and *end-game databases* (perfect information on all positions with seven pieces or less). The program is similar in structure to its chess counterparts, with the exception of the end-game databases, which play a major role in checkers but only a minor role in chess (Schaeffer et al. 1991, 1992).

CHINOOK uses a parallel, iterative, alpha-beta search with transposition tables and the history heuristic. During the world championship match, the program searched to an average minimum depth of 17-, 19- and 21-ply (1 ply is 1 move by 1 player) in the opening game, middle game, and end game, respectively, playing at the rate of 20 moves an hour. The search also uses selective deepening to extend lines that are tactically or positionally interesting. Consequently, some lines of play are often searched many ply deeper. It is common for the program to produce an analysis of lines of play that is 30-ply deep or more.

The program's evaluation function has 25 heuristic components, each of which is weighted and summed to give a positional evaluation. The game is divided into 4 phases, each with its own set of weights, resulting in 100 different parameters to tune. The definition of the heuristics and their weights was arrived at after long discussions with our checkers expert, Norman Treloar. This effort provided the program with sufficient knowledge to play a strong game of checkers. The evaluation function is constantly being tuned using human knowledge, the results of playing different versions of CHINOOK against itself, and the experience gained from games against human checkers grand masters.

For the match, we had solved all checkers end-game positions with 7 or fewer pieces on

the board (checkers or kings) and 40 percent of the 111 billion 8-piece positions. Work on the eight-piece positions continues (we now have 70 percent computed). For each of these board positions, the program has perfect information about whether the position is a win, loss, or draw. This information is stored in a database of almost 70 billion positions. Although some humans can play end games with six or fewer pieces on the board nearly perfectly, the complexity of six-piece end games is such that there are many positions that humans do not understand. CHINOOK knows the value of every one of these positions without error. The eight-piece database, once completed, will significantly extend the gap between the program's perfect information and the human's heuristic knowledge of end games.

However, the initial board position has 24 checkers, and extensive knowledge of the openings is important for world championship play. CHINOOK currently has a small opening library of roughly 6000 positions, consisting of both prepared lines and an *antibook*. CHINOOK has consistently shown that on its own, it finds interesting opening innovations, and we do not want to stifle its creativity. However, some opening positions are known by humans to be losing, and CHINOOK cannot detect these positions under game constraints. To solve this problem, we maintain an *antibook*, a library of moves not to make. The *antibook* allows CHINOOK to play its own openings and avoid the positions that are known to be lost.

Prelude to the Match

CHINOOK surprised the checkers world in August 1990. First, it won the Mississippi State Open, going undefeated and winning matches against two of the strongest players in the world. Then the following week, it went undefeated to finish second in the U.S. National Checkers Championship, behind Tinsley, the world champion. In the tournament, the program drew a four-game match with Tinsley and won a match with Don Lafferty, the acknowledged second-best player in the world. By coming second to Tinsley, CHINOOK earned the right to play for the world championship. In subsequent exhibition matches against Tinsley, Lafferty, and former World Champion Asa Long, the program acquitted itself well, affirming its position as one of the top players in the world.

In early 1991, the American Checker Federation (ACF) and the English Draughts Associ-

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ation (EDA), two of the governing bodies of checkers, decided not to sanction a CHINOOK-Tinsley match. Their position was that machines should not compete for human titles. Both organizations received numerous protests against the decision because the prospect of Tinsley facing the computer appealed to many checkers players.

Tinsley has remarked that over the past decade, he has found competitive checkers increasingly boring. His opponents are in awe of his abilities, and they play every game to draw. CHINOOK, being a computer program, is not influenced by Tinsley's reputation and plays every game to win. Tinsley found this style of play refreshing, and it reawakened his interest in the game. He wanted to play the match and tried his best to convince ACF and EDA that it would be good for the game of checkers.

In June 1991, Tinsley surprised everyone by resigning as world champion. In his resignation letter, he cited the failure of ACF and EDA to sanction the CHINOOK match as the major reason for his decision. Within two months, Tinsley signed a contract to play the match with CHINOOK. ACF and EDA tried unsuccessfully to convince Tinsley to withdraw his resignation. In August, they awarded him the title of world champion emeritus in recognition of his contributions to the game and the fact that he is still considered by most players to be the best in the world. Subsequently, the World Draughts Association, the International Checkers Hall of Fame, and the Mind Sports Olympiad sanctioned the match. ACF changed its mind and sanctioned it as the newly created Man versus Machine World Championship.

In April 1992, Silicon Graphics International agreed to sponsor the event. They also made available an SGI 4D/480 with 8 processors, 256 megabytes of random-access memory, and 3 gigabytes of disk space to run CHINOOK on. David Levy, Raymond Keene, and Tony Buzan of the Mind Sports Olympiad were the match organizers.

The Match

The match was played at the Park Lane Hotel in London, England, on 17–29 August 1992. Interestingly, this venue was the same as that for the 1986 Kasparov-Karpov World Chess Championship. Tinsley won the match by winning 4 games, losing 2, and drawing 33 in the best-of-40-game match. Some of the match highlights are presented in the following paragraphs:

Game 1: Tinsley pressed for five hours, trying to win an end game in which he had the advantage. His efforts were futile because the end game was in CHINOOK's databases, and it knew how to draw the game. After the game, Tinsley said he was shocked by our draw offer because he fully expected to win.

Game 2: CHINOOK came up with a new move in the opening that the spectators labeled as ugly but turned out to be strong. Tinsley defended accurately, and the game was drawn. Checkers Grand Master Richard Pask considered this game to be the best of the match.

Game 5: CHINOOK followed a line from its opening book taken from an authoritative human book on checkers openings (Fortman 1982). After the match, the author admitted that the line is bad and should never have been included in his book! CHINOOK walked a tightrope and finally slipped. In the critical position, an additional 2-ply search (requiring a 400-percent increase in computing power) would have found the draw. Tinsley led the match 1–0.

Game 7: A weak move in the opening by CHINOOK led to a long-term advantage for the champion. At the critical position, Tinsley rejected the winning move, incorrectly analyzing it to a draw. Tinsley did not get another chance, and the game was drawn.

Game 8: CHINOOK played a complicated opening, and on move 10, Tinsley was faced with a dilemma. He had a choice between a move that simplified the position and ended the complications or a move that increased the tension. Knowing that computers excel in complications, Tinsley tried simplifying and discovered on the next move that he was actually in trouble. CHINOOK played it perfectly thereafter to ensure the win. This game was the first time CHINOOK defeated Tinsley and was only Tinsley's eighth loss in the last 42 years. The match was now tied 1–1.

Game 14: CHINOOK played an unusual opening line, forcing Tinsley to recall 30-year-old analysis. Eventually, he made a mistake, and the program sacrificed a checker to get a king. CHINOOK's king harassed Tinsley's checkers from behind and forced him into a bad end game. Ironically, when Tinsley resigned, the spectators rushed up on stage and congratulated him on drawing a difficult game! CHINOOK now led 2–1. Since 1950, the only other time Tinsley was behind in a match was in his 1958 world championship defense against Derek Oldbury. Tinsley lost the first game but went on to win 9–1.

Game 18: On move 17 in a drawn position,

CHINOOK's Wins in Games 8 and 14

The following games are annotated by Jonathan Schaeffer (1992). Comments in quotation marks are extracted from Marion Tinsley's notes. Standard checkers notation assigns each square with a number, as in figure 1. Moves are given as from-square-to-square pairs. Black initially occupies squares 1–12 inclusively, and white occupies squares 21–32 inclusively. If an opponent's checker is on an adjacent square, and there is an empty square behind it on the same diagonal, it can be captured (that is, jumped) and removed from the board. In checkers, captures must be taken. Multiple captures are allowed, and if more than one capture is possible, the player can choose. Checkers can only move and capture forward. When a checker reaches the opponent's back rank (that is, a white checker reaches one of 1–4, a black checker reaches one of 29–32), it is promoted to a king. Kings can move and capture both forward and backward. A player wins if the opponent has no more pieces on the board or has no more legal moves. Black moves first.

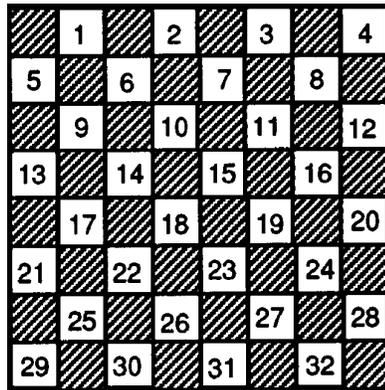


Figure 1. Checkers Notation.

Black: CHINOOK
White: Tinsley
Game 8

11–15 23–18 10–14 In tournaments, the first three moves are chosen by lottery, which forces the players to know all the openings and adds more excitement to the game. Because some of these openings are strongly favorable to one side, two games are played with the players playing each color of the opening. In the previous game with this opening, Tinsley played black and came close to victory.

18–11 08–15 22–17 14–18 This move caught everyone by surprise. Tinsley was mad at himself after the game for allowing these complications. "As soon as I made this move and CHINOOK made its reply (immediately) I knew that trouble was heading my way."

24–19 "Nothing appealed to me here."

15–24 28–19 07–11 17–14 11–16 19–15 04–08 21–17 16–19 17–13 12–16 (see figure 2) **25–21** CHINOOK predicted 26–22 with advantage to white. After the game, Tinsley demonstrated that 26–22 was markedly superior to 25–21. He explained his move

choice by stating that the position was complicated, and 25–21 appeared to simplify things. "I spent a lot of time on 26–22—but it was just too complicated." Now CHINOOK's assessment of the position grows from move to move.

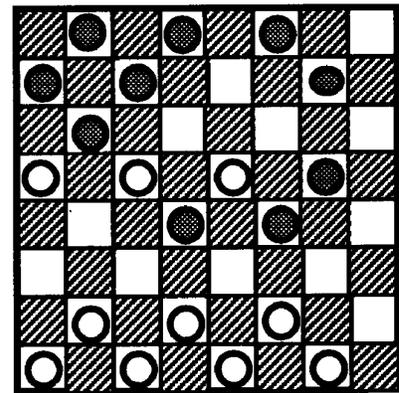


Figure 2. After Move 9, 12–16.

18–22 A 19-ply search shows a 20-point advantage, where a checker is worth 100 points.

26–17 09–18 29–25 16–20 A 21-ply search increases the advantage to 35 points.

17–14 02–07 21–17 19–24 This move surprised everyone in the audience except Tinsley who had seen it coming shortly after making his 25–21 move. At first glance, it appears that white wins a checker after 32–28. However, CHINOOK planned 18–23, sacrificing a man to get a king. The king would then attack Tinsley's men from behind, easily winning.

30–26 07–10 The advantage is now 51 points. On several occasions in the past, CHINOOK had advantages as big as this one against Tinsley, but they always petered out to a draw.

14–07 03–19 27–23 18–27 32–16 24–27 The program is up 81 points. Now the result is obvious to the contestants; CHINOOK sees it is win-

ning a checker.

31-24 20-27 26-22 08-12 16-11 At this point, CHINOOK announced it had seen to the end of the game and announced a win. Even though I knew it was coming, I was stunned. Norman Treloar, who often sat beside me on stage, today was in the audience watching. Paul Lu, who was monitoring the computer, saw that CHINOOK had stopped calculating. He thought that the program had died, or the machine had crashed. No one in the audience had an inkling of what was about to happen.

27-31 11-07 31-26 25-21 26-30 22-18 30-26 18-14 26-22 Chinook wins. When Tinsley and I shook hands, most of the audience thought we were agreeing to a draw. Checkers Master Tom Landry writes, "CHINOOK would now force a win as follows: 07-02 06-09 13-06 22-13 14-10 13-09 21-17 09-13 and Black wins. The man on 17 cannot move because White would then lose two pieces, e.g. 17-14 13-09. Therefore it must remain on 17 to be captured next move."

Black: Tinsley

White: CHINOOK

Game 14

12-16 21-17 09-14 17-13 16-19 24-15 10-19 23-16 11-20 26-23 08-11 22-18 07-10 18-09 05-14 25-22 04-08 22-18 CHINOOK comes out of the opening with a seven-point advantage.

14-17 31-26 Searching a bit deeper shows a 17-point advantage.

10-15 18-14 08-12 "I used to laugh at [Grand Master Willie] Ryan for forgetting his own published play. But no more! In World Championship Checkers I give 11-16,..., to draw. [Grand Master] Pat McCarthy asked me later why I didn't take this route. The answer? I had forgotten it!"

28-24 A 19-ply search downgraded the assessment to even. CHINOOK analyzed 06-10 to a draw.

12-16 You can imagine the shock on my face when CHINOOK reported it was suddenly up 47 points. Obviously, 12-16 was a mistake, but the win was far from easy.

29-25 17-21 14-09 A 68-point advantage: Black is going to start run-

ning out of safe moves and will be forced into accepting white's upcoming sacrifice. When a score becomes this big, the win is usually achieved easily. To Tinsley's credit, he put up the best defense possible. At several points in the game, CHINOOK wavered and thought that the win was gone.

03-08 09-05 "After this move, I never saw the glimpse of a draw."

06-10 13-09 (see figure 3) 01-06 The checker on 9 is trapped and is lost, but CHINOOK can crown the man on 5.

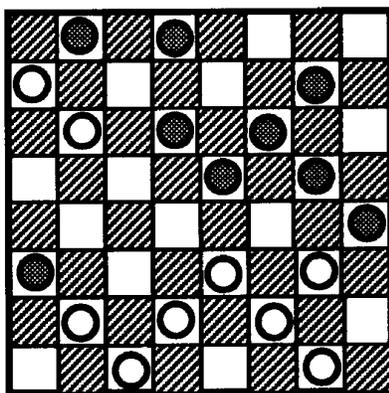


Figure 3. After Move Fifteen, 13-9.

05-01 CHINOOK sacrifices a checker for positional considerations. As part of our preparation, CHINOOK played 64 tournament games against master and grand master opposition in the month before the Tinsley match. CHINOOK lost two games that revealed a major flaw in how the program assessed positions where one side sacrificed a checker for positional considerations. This problem was found and fixed the week before the Tinsley match began. Tinsley had confided to me that this type of position seemed to be a weakness in the program. After this game, he had to change his assessment!

06-13 01-05 02-07 05-01 Was it a win? Our position looked so strong, but a 23-ply search said CHINOOK was only up 37 points. Originally, the program was going to play 25-22 with a 53-point advantage. However, at depth 21, the score dropped to 30 points, and 05-01 emerged as best. At the time, I thought this move was a mistake. This move was the last one

before time control for Tinsley. CHINOOK said that after 25-22, the piece had to be returned with 21-25. I (naively) thought this move might be difficult for Tinsley to find with the few minutes he had remaining on the clock. After the game, he told me 25-22 draws, and 05-01 is the only way to win.

08-12 32-28 10-14 01-06 15-18 06-10 11-15 10-03 16-19 23-16 12-19 03-07 14-17 26-22 At this point, CHINOOK's analysis revealed why the score had been low over the past few moves: It saw it was winning a checker but thought black could achieve a man-down draw (as did most of the audience). With a 23-ply search, CHINOOK found a way of forcing the game into a winning position in its end-game databases.

17-26 30-16 21-30 07-10 18-22 10-19 22-26 16-11 26-31 11-07 30-25 19-23 25-22 07-03 22-17 23-18 CHINOOK wins. "A few games back I was relishing what an easy match this would be, and now I was a game down! What a psychological roller coaster this [match] had become." Several experienced masters rushed to the table to congratulate Tinsley on a beautiful man-down draw! Landry writes, "White wins by 17-21 (31-26 instead allows an exchange by 18-23) 03-07 13-17 18-23 17-22 07-10 22-25 10-15 25-30 24-19 31-24 19-16, and the king on 24 is trapped. A brilliant game."

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CHINOOK entered a deadlock situation. The program was unable to make its next move and forfeited the game. The match was now even at two wins for each player.

Game 25: Tinsley inadvertently transposed moves, and CHINOOK was out of its opening book in a difficult position. On move 10, the program made the decisive mistake, and Tinsley flawlessly concluded the game. Tinsley led 3-2.

Game 26: Tinsley appeared to be in trouble in this game, and many spectators thought he was lost. In fact, he had seen through all the complications and had found the only route to a draw.

Game 31: CHINOOK got into trouble early in the game and struggled, eventually finding the draw in a game most people, including Tinsley, thought was lost.

Game 39: Always playing to win, CHINOOK spurned a safe draw in favor of a move that led to a small and illusory advantage. In the resulting end game, Tinsley outplayed the program and won. The final score was 4-2 for Tinsley.

Analysis of the Results

A post mortem analysis of the games by several checkers grand masters indicates that Tinsley was indeed the better player. However, although Tinsley won the match by two games, the final score could have been different. On the one hand, game 18 was a forfeit by CHINOOK. If Tinsley had started the second half of the match behind by one game, he would have had to play more aggressively. On the other hand, CHINOOK was lost in game 7 and in trouble in two other games.

From the match, a number of points are evident:

First, some of CHINOOK's mistakes require considerably more search depth to overcome than is possible under tournament conditions with a move every three minutes on average. A 1000-fold faster computer or a 1000-fold more search time, resulting in an additional 10 ply of search, would still be inadequate. For example, CHINOOK has searched some of the difficult opening positions for 48 hours, without being able to find the correct move.

Second, CHINOOK's search is sometimes too deep in that the program can search beyond the resolution of some problems. For example, in game 26, CHINOOK could have played a move that would have made it difficult for Tinsley to draw the game. CHINOOK had seen far enough to know that the line led to a draw but did not appreciate that it was a diffi-

cult draw, leading to many opportunities for the opponent to make a mistake. The program chose a better move, missing its best practical chance.

Third, the biggest weakness of the program is the opening. When the program is out of its opening book or antibook, it sometimes cannot find the correct move, such as in game 25. It is unrealistic to expect that in a typical three-minute search, the program can correctly play a position that took humans many years to solve.

Fourth, we cannot blindly trust published human analysis. Although all moves in our opening book and antibook have been verified with 19-ply searches, this depth is still inadequate to discover the problem with the opening line played in game 5.

Fifth, the end-game databases are a tremendous asset. The completion of the eight-piece databases, a challenging task with the resources we currently have available, will significantly improve the program's play. With them, it might also be possible to compute the game-theoretic value of the game of checkers.

Clearly, we have considerable work to do before any rematch with Tinsley.

Conclusions

Can CHINOOK defeat Tinsley in another year or two? This question is a hard one to answer. Although it seems inevitable that a computer program, not necessarily CHINOOK, will exceed human capabilities in checkers, it is not clear when this match might take place. It will be difficult to wrest the title away from Tinsley.

CHINOOK is yet another demonstration of the potential for brute-force computations. Largely on the basis of deep brute-force searching and end-game databases, CHINOOK established itself as the second-best checkers player in the world. However, this traditional approach to building game-playing programs appears to be inadequate to defeat the best player in the world. In particular, we believe that a deeper search of a few extra ply will be inadequate to eliminate the performance gap between Tinsley and CHINOOK.

Adopting the path of least resistance to success, most of the current work on CHINOOK concentrates on the opening knowledge and end-game databases. Acquiring more opening knowledge is of significant benefit to CHINOOK, given the small number of moves in its opening book. Although it has its share of danger, this rote learning has not yet reached its point of diminishing returns. Each end-

game database adds more perfect knowledge to the program, which is something Tinsley cannot compete with. Because this process is now automated, the program can continue to improve with limited human intervention.

Tinsley's remarkable record shows what a human being is capable of and what we must do to defeat him. The human spirit, when confronted with a challenge, is capable of putting forth the extra effort needed to raise its abilities. As CHINOOK improves, we believe Tinsley's abilities will grow to match the program's.

Acknowledgments

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Jonathan Schaeffer is an associate professor of computing science at the University of Alberta. He received his B.Sc. degree from the University of Toronto (1979) and his M.Sc. (1980) and Ph.D. (1986) degrees from the University of Waterloo. His research

interests include heuristic search and parallel computing.



Norman Treloar provided the checkers expertise for CHINOOK. He was born in England and has an M.S. in astrophysics and a Ph.D. in chemistry. He currently works for Environment Canada in Winnipeg, Manitoba, Canada, on atmospheric chemistry

problems such as acid rain and ozone depletion.

Paul Lu holds a B.Sc. in computing science from the University of Alberta, Edmonton, Alberta, Canada, where he is currently finishing his M.Sc. thesis on the parallelization of CHINOOK's alpha-beta search. In the fall of 1993, he hopes to begin a Ph.D. program on parallel and distributed computing,

parallel algorithms, and operating systems.

Robert Lake is a lead research analyst in the Department of Computing Science at the University of Alberta. He received his B.Sc. (1979) and M.Sc. (1990) degrees from the University of Alberta. His research interests include computer animation of human figures using dynamics, distributed systems,

and virtual reality.

