

Replacement Schemes and Two-Level Tables

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ABSTRACT

This note completes the comparison of the performance of seven replacement schemes, as a function of the transposition-table size. A large number of chess middle-game and endgame positions has been studied. It turns out that the number of nodes of a subtree is a better estimate for potential savings than the depth of a subtree. A two-level table, using the number of nodes in the subtree searched as the deciding criterion, performs best and is recommended. Previous results based on fewer experiments are confirmed.

1 Background

This note is a sequel to our previous article (Breuker *et al.*, 1994) in which we compared the performance of seven replacement schemes on 18 middle-game positions. We then concluded that the *number of nodes* of a subtree is a better estimate of the work performed (and therefore potentially to be saved) than the *depth* of that subtree. Moreover, we arrived at the tentative conclusion that the traditional one-level implementation (one position per entry) was not the best. A two-level scheme, first proposed by Ebeling (1986), seemed to work better. However, the observations were only based on 18 consecutive middle-game positions taken from one champion's game. Therefore, it was only a preliminary result we arrived at.

2 Experimental

In this note the experiments are extended in two ways.

- The experiments are performed on 94 middle-game positions (including the 18 already tested), taken from six games between top-level Grandmasters.
- The experiments are conducted on 112 endgame positions², taken from five historic games between well-known chess (Grand)masters.

The test positions are listed in the Appendix. In the experiments time stamping is used (Breuker *et al.*, 1994). It only requires one additional bit per table position and requires little additional computation. The seven replacement schemes (DEEP, NEW, OLD, BIG1, BIGALL, TWODEEP and TWOBIG1) have been tested on eight different table sizes, viz. from 8K to 1024K positions³, each time doubling the number of positions in the table. The middle-game positions have been searched

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² The endgame positions consist of positions both with and without blocked pawns.

³ K positions is equal to 1024 positions

Figure 1: Effect of table size in the middle game; 7-ply searches.

Figure 2: Effect of table size in the endgame; 10-ply searches.

From this graph it follows that the conclusions given for the middle-game experiment also hold for the endgame, with one exception. In middle-game positions it is clear that the concept BIG works better than the concept DEEP: schemes BIG1 and BIG ALL use fewer nodes than scheme DEEP, and scheme TWOBIG 1 uses fewer nodes than scheme TWODEEP. However, the difference between the two concepts has disappeared in the endgame. This is explained as follows. If a subtree contains many forcing moves or is well-ordered, many cutoffs occur. Since in the middle game the mobility of each player is higher than in the endgame (Hartmann, 1989), such pruning will on average cause larger savings in middle-game positions than in endgame positions. Therefore, the size of search trees of equal depth will vary more in middle-game positions than in endgame positions. The concept DEEP does not have a preference for any of two such subtrees, whereas

the concept BIG has a preference for the largest subtree. Thus, in the middle game the size (as compared to the depth) of the search tree investigated will be a better characteristic measuring the work performed than it is in the endgame.

4 Two Conclusions

Based on preliminary experiments we have stated that “On logical grounds, one is tempted to conclude that the *number of nodes* of a subtree is a better estimate of the work performed (and therefore potentially to be saved) than the *depth* of that subtree” (Breuker *et al.*, 1994). Our recent experiments support this tentative conclusion for middle-game positions. There the schemes based on the concept BIG perform better than the schemes based on the concept DEEP. In endgame positions the difference has been disappeared. The lower mobility then diminishes the differences in effects by the two measures.

Based on the 7-ply results in middle games and the 10-ply results in endgames we also confirm our previous suggestion that a two-level scheme is better than any one-level scheme. Hence it follows that DEEP, the most widely used scheme, is not best. Based on these conclusions we recommend using scheme TWOBIG1.

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Appendix: The Test Positions

The transposition-table experiments on middle-game positions use the following 94 positions:

the 6 White-to-move positions from move 15 onwards of

Kasparov–Ivanchuk, Amsterdam (round 1) 1994

1. e4 e5 2. ♘f3 ♘c6 3. d4 exd4 4. ♘xd4 ♘f6 5. ♘xc6 bxc6 6. e5 ♖e7 7. ♗e2 ♘d5 8. c4 ♙a6 9. b3 g6 10. ♙a3 ♗g5 11. g3 ♘c3 12. ♘xc3 ♙xa3 13. ♘e4 ♗e7 14. ♘f6+ ♚f8 15. ♙g2 ♙b4+ 16. ♚f1 ♚d8 17. ♗b2 ♙a3 18. ♗c3 ♙b4 19. ♗b2 ♙a3 20. ♗c3 ♙b4 $\frac{1}{2}$ - $\frac{1}{2}$

the 18 White-to-move positions from move 15 to move 32 of

Kasparov–Short, Amsterdam (round 2) 1994

1. e4 e6 2. d4 d5 3. ♘c3 ♘f6 4. e5 ♘fd7 5. f4 c5 6. ♘f3 ♘c6 7. ♙e3 cxd4 8. ♘xd4 ♙c5 9. ♗d2 0-0 10. 0-0-0 a6 11. h4 ♘xd4 12. ♙xd4 b5 13. ♚h3 b4 14. ♘a4 ♙xd4 15. ♗xd4 f6 16. ♗xb4 fxe5 17. ♗d6 ♗f6 18. f5 ♗h6+ 19. ♚b1 ♚xf5 20. ♚f3 ♚xf3 21. gxf3 ♗f6 22. ♙h3 ♚f7 23. c4 dxc4 24. ♘c3 ♗e7 25. ♗c6 ♚b8 26. ♘e4 ♘b6 27. ♘g5+ ♚g8 28. ♗e4 g6 29. ♗xe5 ♚b7 30. ♚d6 c3 31. ♙xe6+ ♙xe6 32. ♚xe6 1-0

the 20 Black-to-move positions from move 15 to move 34 of

Timman–Kasparov, Amsterdam (round 3) 1994

1. d4 ♘f6 2. ♘f3 g6 3. ♙g5 ♙g7 4. c3 b6 5. ♙xf6 ♙xf6 6. e4 ♙b7 7. ♙d3 c5 8. d5 e6 9. ♙c4 0-0 10. 0-0 ♘a6 11. ♗d3 ♘c7 12. d6 ♘e8 13. ♘bd2 ♙g7 14. h4 a6 15. a4 ♗b8 16. e5 f6 17. h5 fxe5 18. hxg6 h6 19. ♚fe1 ♗xd6 20. ♗xd6 ♘xd6 21. ♘xe5 ♙xe5 22. ♚xe5 ♚f4 23. ♙d3 ♚af8 24. f3 a5 25. ♚f2 ♚g7 26. ♚h5 ♘e8 27. ♚g3 ♘f6 28. ♚e5 ♘d5 29. ♙e4 ♚4f6 30. ♘c4 ♘f4 31. ♙xb7 ♚xg6+ 32. ♚h2 ♚xg2+ 33. ♚h1 d5 34. ♘xb6 ♚b8 35. ♚xe6 ♚xb7 36. ♚d6 ♚g5 37. ♚d1 d4 38. ♘c4 ♚h7 39. ♚e1 ♚h5+ 40. ♚g1 ♚g7+ 0-1

the 24 Black-to-move positions from move 15 to move 38 of

Ivanchuk–Kasparov, Amsterdam (round 4) 1994

1. e4 c5 2. ♘f3 d6 3. d4 cxd4 4. ♘xd4 ♘f6 5. ♘c3 a6 6. f4 ♗c7 7. ♗f3 g6 8. ♙e3 ♙g7 9. h3 e5 10. fxe5 dxe5 11. ♙h6 ♙xh6 12. ♗xf6 0-0 13. ♘d5 ♗a5 14. b4 ♗d8 15. ♘e7+ ♗xe7 16. ♗xe7 exd4 17. ♙c4 ♘c6 18. ♗c5 ♙e3 19. ♚f1 ♘d8 20. ♚f3 ♙e6 21. ♚xe3 dxe3 22. ♙xe6 ♘xe6 23. ♗xe3 a5 24. b5 ♚ac8 25. 0-0-0 ♚c5 26. ♚d5 b6 27. ♗g3 ♚c7 28. ♗d6 ♚fc8 29. ♚d2 ♚b7 30. g4 ♘c5 31. ♗f6 h6 32. e5 ♚e8 33. h4 ♚h7 34. h5 g5 35. ♚d6 ♚e6 36. ♗d8 ♚g7 37. a3 a4 38. ♚b2 ♚be7 39. ♚xb6 1-0

the 15 White-to-move positions from move 15 to move 29 of

Kasparov–Timman, Amsterdam (round 5) 1994

1. e4 e5 2. ♘f3 ♘f6 3. ♘xe5 d6 4. ♘f3 ♘xe4 5. d4 d5 6. ♙d3 ♘c6 7. 0-0 ♙e7 8. ♚e1 ♙g4 9. c4 ♘f6 10. ♘c3 dxc4 11. ♙xc4 0-0 12. d5 ♘a5 13. ♙d3 c6 14. h3 ♙h5 15. ♚e5 ♙g6 16. ♙g5 ♙d6 17. ♚e2 ♙b4 18. ♙xf6 gxf6 19. ♚c1 ♚c8 20. ♘e4 f5 21. ♘g3 ♗xd5 22. a3 ♙d6 23. ♘xf5 ♚cd8 24. ♚e5 ♙xe5 25. ♘e7+ ♚g7 26. ♘xd5 ♙xb2 27. ♘f4 ♙xd3 28. ♘xd3 ♙xc1 29. ♗xc1 ♚xd3 30. ♗g5+ 1-0

the 11 Black-to-move positions from move 15 to move 25 of

Short–Kasparov, Amsterdam (round 6) 1994

1. e4 c5 2. ♘c3 e6 3. ♘f3 a6 4. d4 cxd4 5. ♘xd4 d6 6. g4 b5 7. a3 h6 8. ♙g2 ♙b7 9. 0-0 ♘d7 10. f4 ♚c8 11. ♙e3 g5 12. ♗e2 gxf4 13. ♚xf4 e5 14. ♚f5 exd4 15. ♙xd4 ♘e5 16. ♘d5 ♙g7 17. ♚af1 ♚h7 18. ♚h1 ♙h8 19. c3 ♘e7 20. ♙xe5 dxe5 21. ♗f3 ♘xf5 22. ♗xf5 ♚g7 23. ♘f6+ ♘f8 24. ♘d7+ ♚g8 25. ♘f6+ ♚f8 $\frac{1}{2}$ - $\frac{1}{2}$

The transposition-table experiments on endgame positions use the following 112 positions:

the 28 White-to-move positions from move 31 onwards of

Gossip–Mason, New York (round 20) 1889

1. e4 e6 2. d4 d5 3. ♘c3 ♘f6 4. e5 ♘fd7 5. f4 c5 6. dxc5 ♘c6 7. ♘f3 ♙xc5 8. ♘e2 ♗b6 9. c3 ♙f2+ 10. ♚d2 ♗e3+ 11. ♚c2 ♗e4+ 12. ♗d3 ♘c5 13. ♗xe4 ♘xe4 14. ♘e4 ♙d7 15. ♘xc6

bxc6 16. ♖d3 ♗c5 17. ♙e2 ♗b7 18. ♚f1 ♙b6 19. ♙d2 c5 20. ♙a6 ♚b8 21. ♚ae1 ♗d8 22. ♙d3 a5 23. ♗c1 a4 24. a3 ♗b7 25. f5 c4 26. fxe6 ♙xe6 27. ♙c2 ♗c5 28. ♗d4 0-0 29. ♗xe6 fxe6 30. ♚xf8+ ♚xf8 31. ♙e3 ♗b3+ 32. ♙xb3 ♙xe3 33. ♚xe3 cxb3 34. ♚e2 ♚f4 35. ♗d2 ♗f7 36. ♚e3 ♚f2+ 37. ♚e2 ♚xe2+ 38. ♗xe2 ♗g6 39. ♗e3 ♗f5 40. ♗d4 h5 41. g3 g5 42. h3 h4 43. g4+ ♗f4 44. ♗c5 ♗xe5 45. ♗b4 d4 46. ♗xa4 d3 47. ♗xb3 ♗e4 48. a4 ♗e3 49. a5 d2 50. ♗b4 d1 ♚ 51. b3 ♚a1 52. c4 ♗d4 53. ♗b5 ♚c3 54. ♗c6 ♚xb3 55. a6 ♚xc4+ 56. ♗b7 ♚b5+ 57. ♗a7 ♗c5 58. ♗a8 ♗c6 0-1

the 21 White-to-move positions from move 34 onwards of

Rabinovich–Romanovsky, Leningrad championship 1934

1. c4 ♗f6 2. ♗c3 c6 3. d4 d5 4. ♗f3 ♗e4 5. e3 e6 6. ♙d3 f5 7. ♚c2 ♗d7 8. b3 ♙b4 9. ♙b2 ♚a5 10. ♚c1 0-0 11. 0-0 ♙d6 12. ♗e2 ♚d8 13. ♗e5 ♚h4 14. f3 ♗ec5 15. g3 ♚h6 16. ♗f4 ♗xd3 17. ♗exd3 g5 18. ♗g2 ♗f6 19. ♚ce1 g4 20. fxf4 ♗xg4 21. ♗gf4 ♗f6 22. ♚e2 ♚f7 23. b4 ♗e4 24. ♗c5 ♚b8 25. a3 b6 26. ♗xe4 fxe4 27. ♚ef2 ♙d7 28. c5 ♙xf4 29. ♚xf4 ♚xf4 30. ♚xf4 b5 31. ♚f2 ♙e8 32. ♚f6 ♙g6 33. ♚f4 ♚xf4 34. ♚xf4 h5 35. h3 ♗g7 36. ♙c3 ♙f5 37. g4 hxg4 38. hxg4 ♙g6 39. ♗g2 ♗h6 40. ♚f6 ♚e8 41. ♙e1 ♗g7 42. ♚f1 ♚a8 43. ♗h3 a6 44. ♙g3 ♚h8 45. ♙h4 ♚f8 46. ♚xf8 ♗xf8 47. ♙g3 e5 48. ♙xe5 ♗f7 49. ♗h4 ♗e6 50. ♗g5 ♙e8 51. ♗h6 ♙f7 52. ♗g7 ♙e8 53. g5 ♗f5 54. ♗f8 1-0

the 17 White-to-move positions from move 26 onwards of

Capablanca–Alekhine, Buenos Aires world championship (round 5) 1927

1. d4 d5 2. c4 e6 3. ♗c3 ♗f6 4. ♙g5 ♗bd7 5. e3 c6 6. a3 ♙e7 7. ♗f3 0-0 8. ♙d3 dxc4 9. ♙xc4 ♗d5 10. ♙xe7 ♚xe7 11. ♚c1 ♗xc3 12. ♚xc3 e5 13. dxe5 ♗xe5 14. ♗xe5 ♚xe5 15. 0-0 ♙e6 16. ♙xe6 ♚xe6 17. ♚d3 ♚f6 18. ♚b3 ♚e7 19. ♚fd1 ♚ad8 20. h3 ♚xd3 21. ♚xd3 g6 22. ♚d1 ♚e5 23. ♚d2 a5 24. ♚d7 b5 25. ♚c3 ♚xc3 26. bxc3 ♚c8 27. ♗f1 ♗g7 28. ♚a7 a4 29. c4 ♗f6 30. ♚a5 ♗e6 31. ♗e2 bxc4 32. ♚c5 ♗d6 33. ♚xc4 ♚a8 34. ♚d4+ ♗e6 35. ♗d3 c5 36. ♚h4 h5 37. g4 hxg4 38. ♚xg4 ♗d6 39. ♚f4 f5 40. ♚h4 ♗d5 41. ♗c2 ♚a6 42. ♗c3 $\frac{1}{2}$ - $\frac{1}{2}$

the 17 White-to-move positions from move 38 onwards of

Fischer–Reshevsky, New York championship (round 5) 1962

1. e4 c5 2. ♗f3 d6 3. d4 cxd4 4. ♗xd4 ♗f6 5. ♗c3 a6 6. h3 g6 7. g4 ♙g7 8. g5 ♗h5 9. ♙e2 e5 10. ♗b3 ♗f4 11. ♗d5 ♗xd5 12. ♚xd5 ♗c6 13. ♙g4 ♙xg4 14. hxg4 ♚c8 15. ♚d1 ♗d4 16. c3 ♗xb3 17. axb3 ♚e6 18. ♚a5 f6 19. ♚d5 ♚xd5 20. ♚xd5 ♗d7 21. gxf6 ♙xf6 22. g5 ♙e7 23. ♗e2 ♚af8 24. ♙e3 ♚c8 25. b4 b5 26. ♚dd1 ♗e6 27. ♚a1 ♚c6 28. ♚h3 ♙f8 29. ♚h1 ♚c7 30. ♚h4 d5 31. ♚a1 ♚c6 32. exd5+ ♗xd5 33. ♚d1+ ♗e6 34. ♚d8 ♗f5 35. ♚a8 ♚e6 36. ♚h3 ♙g7 37. ♚xh8 ♙xh8 38. ♚xh7 ♚e8 39. ♚f7+ ♗g4 40. f3+ ♗g3 41. ♗d3 e4+ 42. fxe4 ♚d8+ 43. ♙d4 ♗g4 44. ♚f1 ♙e5 45. ♗e3 ♙c7 46. ♚g1+ ♗h5 47. ♗f3 ♚d7 48. e5 ♚f7+ 49. ♗e4 ♚f5 50. e6 ♙d8 51. ♙f6 ♙xf6 52. gxf6 ♚xf6 53. ♗e5 ♚f2 54. ♚e1 1-0

the 29 White-to-move positions from move 38 onwards of

Lisitsin–Capablanca, Moscow (round 5) 1935

1. ♗f3 d5 2. c4 c6 3. e3 ♗f6 4. ♗c3 ♙g4 5. cxd5 ♗xd5 6. ♙e2 e6 7. d4 ♗d7 8. 0-0 ♚c7 9. ♙d2 ♙d6 10. ♗e4 ♗7f6 11. ♗xd6+ ♚xd6 12. ♗e5 ♙xe2 13. ♚xe2 0-0 14. ♚c1 ♗b6 15. ♗d3 ♚e8 16. ♚fe1 ♗bd7 17. h3 ♚d5 18. b3 ♚b5 19. ♙c3 ♗d5 20. ♚d2 ♗xc3 21. ♚xc3 ♚ad8 22. a4 ♚b6 23. b4 ♗f6 24. ♚c4 ♗e4 25. a5 ♚c7 26. a6 ♚c8 27. axb7 ♚xb7 28. ♚a1 ♚c7 29. ♚ec1 ♚b8 30. ♚c2 ♚c8 31. ♚a5 ♚b6 32. ♚a4 ♚b8 33. f3 ♗f6 34. ♚c5 ♗d5 35. ♚xc6 ♚cxc6 36. ♚xc6 ♚xc6 37. ♚xc6 ♗xe3 38. ♗c5 ♗d5 39. b5 ♗b6 40. ♗d7 ♚d8 41. ♗xb6 axb6 42. ♚c4 h5 43. ♗f1 g6 44. ♗g1 ♗g7 45. ♗f1 ♚d6 46. ♗g1 ♚f4 47. ♚c3 ♗h7 48. ♗f1 ♚f5 49. ♚c4 ♗g7 50. ♗f2 ♚g5 51. ♚e2 ♗f6 52. ♚b2 ♚d5 53. ♗e3 e5 54. f4 exf4+ 55. ♗xf4 ♗e6 56. h4 f6 57. ♗e3 ♚c4 58. g3 g5 59. hxg5 ffg5 60. ♚h2 ♚b3+ 61. ♗e4 g4 62. ♚e2 ♚xg3 63. ♚c4+ ♗e7 64. ♚c8 ♚f3+ 65. ♗e5 ♚f6+ 66. ♗d5 ♚d6+ 0-1