The Hoffman Tutorial

Brent Baccala

May 25, 2008

Hoffman is a program to solve chess endgames using retrograde analysis. A retrograde analysis program is much different from a conventional computer chess programs. Retrograde analysis is only useful in the endgame, runs very slowly, and produces enormous amounts of data. Its great advantage lies in its ability to completely solve the endgame. In a very real sense, a retrograde engine has no "move horizon" like a conventional chess engine. It sees everything. For those not up on Americana, the program is named after Trevor Hoffman, an All Star baseball pitcher who specializes in "closing" games. It was written specifically for The World vs. Arno Nickel game.

The first thing to understand is that Hoffman uses XML control files to govern its operation. Hoffman comes with an `xml` directory containing a number of these control files. I'll illustrate how Hoffman works using these examples. For example, Figure 1 shows about the simplest possible XML control file, for the king vs. king endgame, contained in the file `xml/kk.xml`.

What does this all mean? Well, the first two lines identify this as a Hoffman XML tablebase file; copy them verbatim at the top of any new Hoffman control file. The third line illustrates XML's comment format; anything between `<!--` and `-->` is a comment, in this case the identity of the Perl script that created this file. The bulk of the file is contained between the two lines `<tablebase>` and `</tablebase>`. `tablebase` is a simple example of an XML *element*, which come in basically two flavors: the simple kind and the complex kind. The simple kind, like, say, `piece`, have only a single tag that ends with a slash. The complex kind have both a beginning and an ending tag. The beginning tag does not have a slash, and the ending tag is identical to the beginning tag except that it starts with a slash (like `tablebase`). Complex elements allow you to put things between the starting and ending tags. Follow my lead; it'll start to make sense soon.

The `index` element controls how Hoffman numbers the positions in the tablebase. I'm using the "compact" index type, which is a pretty good choice right now for just about everything, and I've also specified a "symmetry" to indicate that

```
<?xml version="1.0"?>
<!DOCTYPE tablebase SYSTEM "http://www.freesoft.org/software/hoffman/tablebase.dtd">
<!-- Created by genctlfile.pl -->

<tablebase>
   <index type="compact" symmetry="8-way"/>
   <format><dtm bits="8"/></format>
   <piece color="white" type="king"/>
   <piece color="black" type="king"/>
   <generation-controls>
      <output filename ="kk.htb"/>
   </generation-controls>
</tablebase>
```

Figure 1: `kk.xml`

I only want to store positions where the white king is in a little triangular eighth of the board. Why? Because you can rotate and reflect the board around to put the white king anywhere you want him. Think about it. Symmetry doesn't work with all tablebases. If there were pawns involved, for example, you can't just rotate the board 90 degrees. But since all we have are kings, symmetry is OK, and it makes the resulting tablebase a lot smaller.

Now we have a `format` line, indicating that we want an output format with one field — an eight bit *distance to mate* (DTM) — for each position. In other words, the classic "mate in N" or "mated in N", so long as N can fit into eight bits (so it has to be "mate in 126" or less, since DTM is a signed field). Eight bit DTM is big enough for every three, four, or five piece tablebase except kppkp, so just copy this line verbatim, too.

Next up are the `piece` elements, probably the most self-explanatory part of the entire configuration. Notice that I didn't specify where on the board the kings were. That's because we're going to compute results for every chess position possible with these two pieces. Their movements are completely unrestricted — they can be anywhere on the board. Later we'll see more complex piece elements that restrict where on the board the pieces can be.

Finally, we come to `generation-controls`, which contains parameters that really have nothing to do with the tablebase itself, but are settings to be used during generation. The simplest generation control is `output`, which tells the program where to put the output tablebase, in this case, into a file called `kk.htb`. You can rename the resulting tablebase file as you wish; the tablebase isn't tied to a particular filename. It's just, well, a "generation control".

Now you put all this into a file called something like `kk.xml`, (or just copy it from the `xml` directory) and run Hoffman like this:

```
C> hoffman -g kk.xml
Initializing tablebase
Checking futuremoves...
All futuremoves handled under move restrictions
Intra-table propagating
Pass 0 complete; 840 positions processed
Pass 1 complete; 0 positions processed
C>
```

There isn't much to see, of course. The "`-g`" option meant "generate". King vs king is nothing more than figuring out the difference between illegal positions and draws. But this information is important, because it's needed to back propagate from the (slightly) more complex three piece endgames, like the king and queen endgame whose XML configuration is shown in Figure 2.

Notice the new "futurebase" line. This tells Hoffman where to get the information about what happens when the black king can capture the white queen, because a tablebase contains information for *exactly* the piece configuration it is set up for — nothing more, nothing less.

So put all this in a file called `kqk.xml`, make sure the `kk.htb` file from the first run is present, and run Hoffman again:

```
C> ./hoffman -g -o kqk.htb kqk.xml
Initializing tablebase
Back propagating from 'kk.htb'
Checking futuremoves...
All futuremoves handled under move restrictions
Intra-table propagating
Pass 0 complete; 131516 positions processed
```

```
<?xml version="1.0"?>
<!DOCTYPE tablebase SYSTEM "http://www.freesoft.org/software/hoffman/tablebase.dtd">
<!-- Created by genctlfile.pl -->

<tablebase>
   <index type="compact" symmetry="8-way"/>
   <format><dtm bits="8"/></format>
   <piece color="white" type="king"/>
   <piece color="black" type="king"/>
   <piece color="white" type="queen"/>
   <futurebase filename="kk.htb"/>
   <generation-controls>
      <output filename ="kqk.htb"/>
   </generation-controls>
</tablebase>
```

Figure 2: `kqk.xml`

```
Pass 1 complete; 364 positions processed
Pass 2 complete; 2448 positions processed
Pass 3 complete; 1352 positions processed
Pass 4 complete; 5012 positions processed
Pass 5 complete; 2956 positions processed
Pass 6 complete; 9064 positions processed
Pass 7 complete; 7480 positions processed
Pass 8 complete; 19964 positions processed
Pass 9 complete; 14144 positions processed
Pass 10 complete; 26164 positions processed
Pass 11 complete; 25484 positions processed
Pass 12 complete; 32064 positions processed
Pass 13 complete; 39908 positions processed
Pass 14 complete; 32104 positions processed
Pass 15 complete; 54052 positions processed
Pass 16 complete; 15000 positions processed
Pass 17 complete; 43800 positions processed
Pass 18 complete; 2680 positions processed
Pass 19 complete; 11300 positions processed
Pass 20 complete; 8 positions processed
Pass 21 complete; 56 positions processed
Pass 22 complete; 0 positions processed
C>
```

See, it's a little more interesting this time, right?

Now is a good time to introduce the "`-i`" (information) option. Once you've got a bunch of `.htb` files sitting around, and you can't remember which XML control file was used to generate which tablebase, there's no need to panic. Everything from the original XML configuration is saved into the resulting tablebase, along with a bunch more information, and all of it can be retrieved from the tablebase using `-i`:

```
C> hoffman -i kqk.htb
Hoffman $Revision: 1.6 $ $Locker:  $
```

```
0 piece Nalimov tablebases found
<?xml version="1.0"?>
<!DOCTYPE tablebase SYSTEM "http://www.freesoft.org/software/hoffman/tablebase.dtd">
<tablebase offset="0x0fe4">
   <index type="compact" symmetry="8-way"/>
   <format><dtm bits="8"/></format>
   <piece color="white" type="king"/>
   <piece color="black" type="king"/>
   <piece color="white" type="queen"/>
   <futurebase filename="kk.htb"/>
   <tablebase-statistics>
      <indices>59136</indices>
      <PNTM-mated-positions>10152</PNTM-mated-positions>
      <legal-positions>47136</legal-positions>
      <stalemate-positions>115</stalemate-positions>
      <white-wins-positions>44183</white-wins-positions>
      <black-wins-positions>0</black-wins-positions>
      <forward-moves>686465</forward-moves>
      <futuremoves>2838</futuremoves>
      <max-dtm>11</max-dtm>
      <min-dtm>-11</min-dtm>
   </tablebase-statistics>
   <generation-statistics>
      <host>debian.freesoft.org</host>
      <program>Hoffman $Revision: 1.6 $ $Locker:  $</program>
      <args>./hoffman -g -o kqk.htb kqk.xml </args>
      <start-time>Sat Dec 16 02:11:28 2006 EST</start-time>
      <completion-time>Sat Dec 16 02:11:36 2006 EST</completion-time>
      <user-time>2.782s</user-time>
      <system-time>0.018s</system-time>
      <real-time>8.052s</real-time>

      ... about 60 more lines deleted ...

   </generation-statistics>
</tablebase>
```

In addition to the configuration information from the input XML file, the program also added two new sections when it created the tablebase — `tablebase-statistics` and `generation-statistics`. The first reports various interesting information the program determined about the tablebase, such as how many total indices there are, how many correspond to legal chess positions, how many white mates, or black mates, or stalemates there are, etc. The second reports information about the actual generation of this tablebase, like when it occured, which version of the program was used, and which computer actually computed it.

OK, so what's next? After `kk.xml` and `kqk.xml`, then you can easily understand `krk.xml`, `kbk.xml` and `knk.xml`. Once all five of these are processed, you're now ready to build `kpk.xml` (Figure 3).

Notice we've added a new type of `futurebase` — pawn promotion. Hoffman has to know what happens after that pawn transforms into a queen, rook, bishop, or knight to be able to understand what happens to the pawn! Note also that we can no longer use "8-way" symmetry, although we can still use a 2-way symmetry, since pawns don't care if they're on the right or left hand side of the board.

It's starting to get more complex, right? So how do I know there isn't a bug in all of this complexity? Well, my most important blunder check is to verify the program's operation against the Nalimov tablebases. You can do this, too. If you download the appropriate Nalimov tablebases from the Internet (in this case, the two KPK files), you can verify

```
<?xml version="1.0"?>
<!DOCTYPE tablebase SYSTEM "http://www.freesoft.org/software/hoffman/tablebase.dtd">
<!-- Created by genctlfile.pl -->

<tablebase>
   <index type="compact" symmetry="2-way"/>
   <format><dtm bits="8"/></format>
   <piece color="white" type="king"/>
   <piece color="black" type="king"/>
   <piece color="white" type="pawn"/>
   <futurebase filename="kk.htb"/>
   <futurebase filename="kqk.htb"/>
   <futurebase filename="krk.htb"/>
   <futurebase filename="kbk.htb"/>
   <futurebase filename="knk.htb"/>
   <generation-controls>
      <output filename ="kpk.htb"/>
   </generation-controls>
</tablebase>
```

Figure 3: `kpk.xml`

that Hoffman's results are identical to Nalimov's using the "`-v`" (verify) and "`-n` *directory*" (location of Nalimov files) options, like this:

```
C> ./hoffman -v -n Nalimov/ kpk.htb
Hoffman $Revision: 1.6 $ $Locker:  $
5 piece Nalimov tablebases found
Loading 'kpk.htb'
Verifying tablebase against Nalimov
C>
```

There were no complaints, so that means everything verified OK.

So now you've got all of the three piece tablebases. Ready to try a four piece? Figure 4 is `kqkq.xml`.

Notice several things. First, we no longer specify `kk.htb` as a futurebase. We're only interested in the single captures that lead out of the tablebase we're building. `kk.htb` has already been used to build `kqk.htb`, so its data is in there. Two queens can't be taken on a single move, so all we need to worry about is what happens if one of them is captured. That's why I use the `kqk.htb` tablebase. Notice that I use it twice, depending on which queen is being captured. The `kqk.htb` tablebase has a white queen in it, and the `colors="invert"` option to the `futurebase` element handles the case where the white queen is captured and we're left with a black queen on the board.

You'll notice also that a four piece tablebase takes a good bit longer to compute than a three piece one.

Oh, and I suppose having generating all of these tablebases, you now want to query them, huh?

You do that using the probe (-p) option, followed by a list of tablebases. Since we've got a small collection of simple tablebases, it's easiest to just load them all, like this:

```
C> ./hoffman -p *.htb
```

```
<?xml version="1.0"?>
<!DOCTYPE tablebase SYSTEM "http://www.freesoft.org/software/hoffman/tablebase.dtd">
<!-- Created by genctlfile.pl -->

<tablebase>
   <index type="compact" symmetry="8-way"/>
   <format><dtm bits="8"/></format>
   <piece color="white" type="king"/>
   <piece color="black" type="king"/>
   <piece color="white" type="queen"/>
   <piece color="black" type="queen"/>
   <futurebase filename="kqk.htb" colors="invert"/>
   <futurebase filename="kqk.htb"/>
   <generation-controls>
      <output filename ="kqkq.htb"/>
   </generation-controls>
</tablebase>
```

Figure 4: `kqkq.xml`

```
4 piece Nalimov tablebases found
Loading 'kk.htb'
Loading 'knk.htb'
Loading 'knkn.htb'
Loading 'knkp.htb'
Loading 'kpk.htb'
Loading 'kpkp.htb'
Loading 'kpkq.htb'
Loading 'kqk.htb'
Loading 'kqkn.htb'
Loading 'kqkp.htb'
Loading 'kqkq.htb'
Loading 'kqkr.htb'
Loading 'krk.htb'
Loading 'krkn.htb'
Loading 'krkp.htb'
Loading 'krkr.htb'
FEN? 8/8/8/8/p7/8/1P4k1/2K5 b
FEN 8/8/8/8/p7/8/1P4k1/2K5 b - -
Index 12658437
Draw

Nalimov score: DRAW
   g2h2    White moves and wins in 22
   g2f2    White moves and wins in 25
   g2g3    White moves and wins in 25
   g2g1    White moves and wins in 25
   g2f3    Draw
   g2h3    White moves and wins in 22
   g2f1    White moves and wins in 25
   g2h1    White moves and wins in 21
```

```
   a4a3    White moves and wins in 16
FEN or move? g2f3
FEN 8/8/8/8/p7/5k2/1P6/2K5 w - -
Index 12659332
Draw

Nalimov score: DRAW
   c1d1    Draw
   c1b1    Draw
   c1c2    Draw
   c1d2    Draw
   b2b3    Draw
   b2b4    Draw
FEN or move? b2b4
FEN 8/8/8/8/pP6/5k2/8/2K5 b - b3
Index 12593797
Draw

Nalimov score: DRAW
   f3g3    White moves and wins in 15
   f3e3    White moves and wins in 15
   f3f4    White moves and wins in 23
   f3f2    White moves and wins in 15
   f3e4    Draw
   f3g4    White moves and wins in 15
   f3e2    White moves and wins in 15
   f3g2    White moves and wins in 15
   a4xb3   Draw
FEN or move?
baccala@debian ~/src/endgame$
```

At the "FEN?" prompt you want to enter a chess position in FEN notation (you can leave off the castling rights and en passant square if you want). The program spits back its evaluation of the position (if it has one), along with a list of moves and how they evaluate. It has a history feature, so once you've typed a FEN position in once, if you end the program with a CNTL-D and not a CNTL-C, it will save everything to a history file, and you can retrieve it again on a later run using the up arrow key.

After you've put a FEN position in, you get a "FEN or move?" prompt, which allows you to enter moves and thus step forward in the game. The move parser isn't very smart right now; you can make illegal moves pretty easily and there's no way to back up. The quirkiest thing at the moment is that if you want to promote, you need to specify EXACTLY the piece you're promoting into; "b7b8=Q" is radically different from "b7b8=q"!!

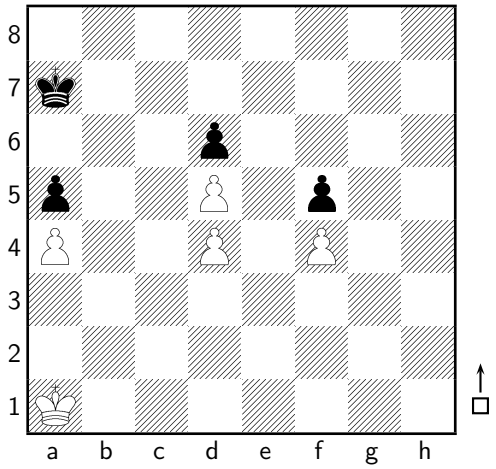
The `xml` directory contains all of the XML configuration files needed to generate a complete set of three- and four-piece tablebases. These files were created by `genctlfile.pl`, a Perl script that can also create control files for five- and six-piece tablebases, though actually generating them can be quite demanding of a computer. `genalltb` is a shell script that will run Hoffman repeatedly on these files, and in the correct order, though it may take several hours to run. Hoffman has also been used to generate a complete set of five-piece tablebases, but this takes considerably longer.

Hoffman can thus duplicate much of the functionality of the Nalimov programs, but that's not all it can do. It can also duplicate much of the functionality of Eiko Bleicher's Freezer (`http://www.freezerchess.com/`). Aside from Freezer's nice GUI, the only thing Hoffman lacks is the ability to use Nalimov tablebases as futurebases, which

```
<?xml version="1.0"?>
<!DOCTYPE tablebase SYSTEM "http://www.freesoft.org/software/hoffman/tablebase.dtd">

<tablebase>
   <prune-enable color="white" type="concede"/>
   <prune-enable color="black" type="concede"/>

   <index type="compact"/>
   <format><dtm bits="8"/></format>

   <piece color="white" type="king"/>
   <piece color="black" type="king"/>
   <piece color="white" type="pawn" location="a4"/>
   <piece color="white" type="pawn" location="d4"/>
   <piece color="white" type="pawn" location="f4"/>
   <piece color="white" type="pawn" location="d5"/>
   <piece color="black" type="pawn" location="a5"/>
   <piece color="black" type="pawn" location="f5"/>
   <piece color="black" type="pawn" location="d6"/>

   <prune color="white" move="KxP" type="concede"/>
   <prune color="black" move="KxP" type="concede"/>

   <generation-controls>
      <output filename="lasker1901.htb"/>
   </generation-controls>
</tablebase>
```

Figure 5: `lasker1901.xml`

matters because 6 piece Nalimov tablebases are available on-line, while only 5 piece tablebases are currently available for Hoffman. For example, here is a 1901 composition by Lasker and Reichhelm, used as a demo on the Freezer website:



The Hoffman XML configuration for this problem (Figure 5), is in the `xml` directory as `lasker1901.xml`. Several new features in the configuration should be apparent.

First, note the new `location` parameter that can be specified for a piece to nail it down to a particular spot. You can actually specify a list of multiple squares, such as "`a4 a5 a6 a7`"; we'll see an example of this later.

Note also the disappearance of the `futurebase` element; it's been replaced by a pair of `prune` statements. The program pretty much has to have either `futurebase` or `prune` statements in order to figure out how to handle things like captures. In this case, we don't use futurebases at all (so this is a stand-alone analysis), and instead tell Hoffman to regard any pawn capture as an immediate victory for the capturing side (that's the `concede` part).

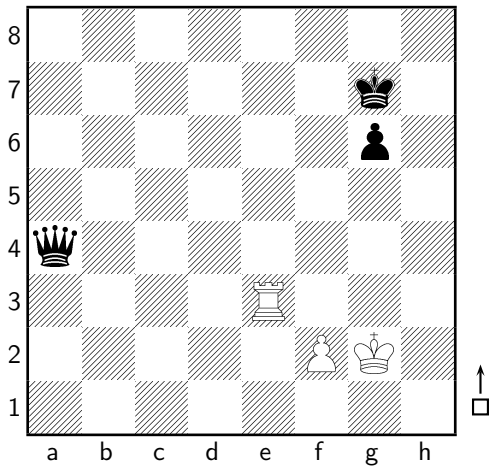
Finally, let me point out the `prune-enable` elements at the beginning of the `tablebase` section. They don't do very much, but they're very important because the program will refuse to process this tablebase without them. They're there because it's easy to lose track of pruning statements if they get buried inside futurebases. You could easily use a pruned futurebase to build a tablebase that wouldn't be accurate, but that also wouldn't be apparent just from looking at the tablebase configuration. That's why the `prune-enable` elements are there. The program will refuse to allow any pruning statement, or pruned futurebase, unless there is a matching `prune-enable` at the beginning of the `tablebase` section. This prevents "hidden" prunes from slipping into an analysis by mistake. As their name suggests, the `prune-enable` elements "turn on" pruning; the program won't prune unless they're there.

OK, so by now we know how to generate `lasker1901.htb` (`hoffman -g lasker1901.xml`, right?), and we can probe the resulting tablebase for the original problem position:

```
C> ./hoffman -p lasker1901.htb
Hoffman $Revision: 1.6 $ $Locker:  $
0 piece Nalimov tablebases found
Loading 'lasker1901.htb'
FEN? 8/k7/3p4/p2P1p2/P2P1P2/8/8/K7 w
FEN 8/k7/3p4/p2P1p2/P2P1P2/8/8/K7 w - -
Index 2368
White moves and wins in 14
Can't find Nalimov tablebase
   Ka1b1    White wins in 14
   Ka1a2    Draw
   Ka1b2    Draw
FEN or move?
C>
```

So what's the point? Can White win in 14 moves? No. White can *capture a black pawn* in 14 moves, but only if he plays Kb1! Any other move would allow Black to "draw", i.e, to prevent White from capturing a pawn without allowing Black to capture first. In fact, those other two moves allow Black to prevent White from capturing at all, but it's important to note that this Hoffman analysis doesn't guarantee that, since Black might be able to "win" by capturing a pawn.

Here's my final example, also from the Freezer website:



It's a fortress. We're White, and we're out to show that we can draw this position. My Hoffman analysis is in the "`fortress*.xml`" files in the `xml` directory. You need to have several of the four-piece tablebases built in order to process them. I'm not going to copy them all into this document; I'll just ask you to study them on your own while I point out some salient features.

Notice how `futurebase` and `prune` statements can be used together in a single configuration file (in case you were wondering). Notice how wildcards can be used in `prune` statements. Notice how a piece can be restricted to more than one square. Notice how comments can be put into XML configurations. And yes, there are some alternate ways to specify `index` and `format`; see the Reference Guide for more details on these and other Hoffman XML elements.

That's all for now, except for one "final exam" question that you should be able to answer after studying the fortress example:

In the Lasker 1901 example, I noted that after a move like Ka2, Hoffman can't guarantee that White can't take a pawn, only that White can't take a pawn before Black does. What changes to the configuration would allow us to prove that Black can, in fact, completely prevent White from making any capture? (answer on next page)

Answer: Change the black `prune-enable` and `prune` elements from `concede` to `discard`. Now the analysis will not consider any black captures, and the only kind of "draw" will be one that completely prevents white from making any kind of capture. There is one gotcha, however. White might put black in a position where his *has* to capture a pawn, but the new analysis would regard this as a stalemate. To avoid this problem, you should also add a third pruning element: `<prune color="white" move="stalemate" type="concede"/>`