Stelvio

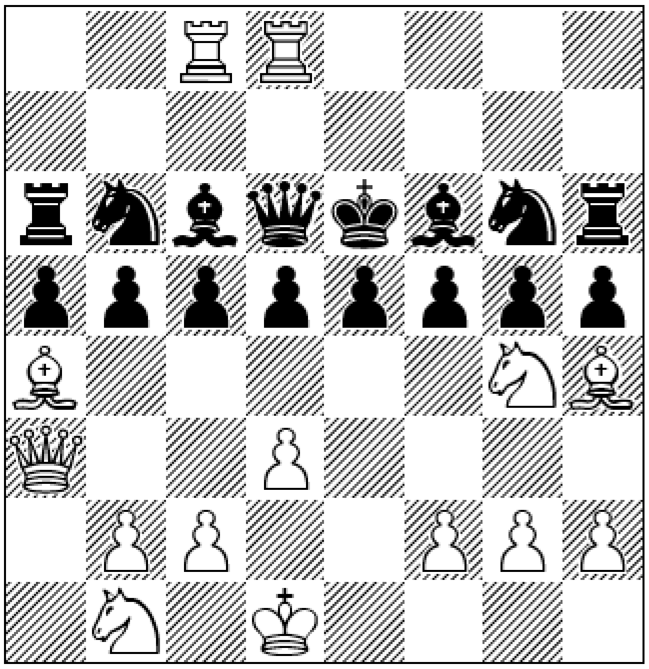
Introduction

Stelvio is a program devoted to solving orthodox SPGs (Shortest Proofgames). To make things bit clearer, its easiest to consider an example. Let us look at a masterpiece from Finland.

Unto Heinonen

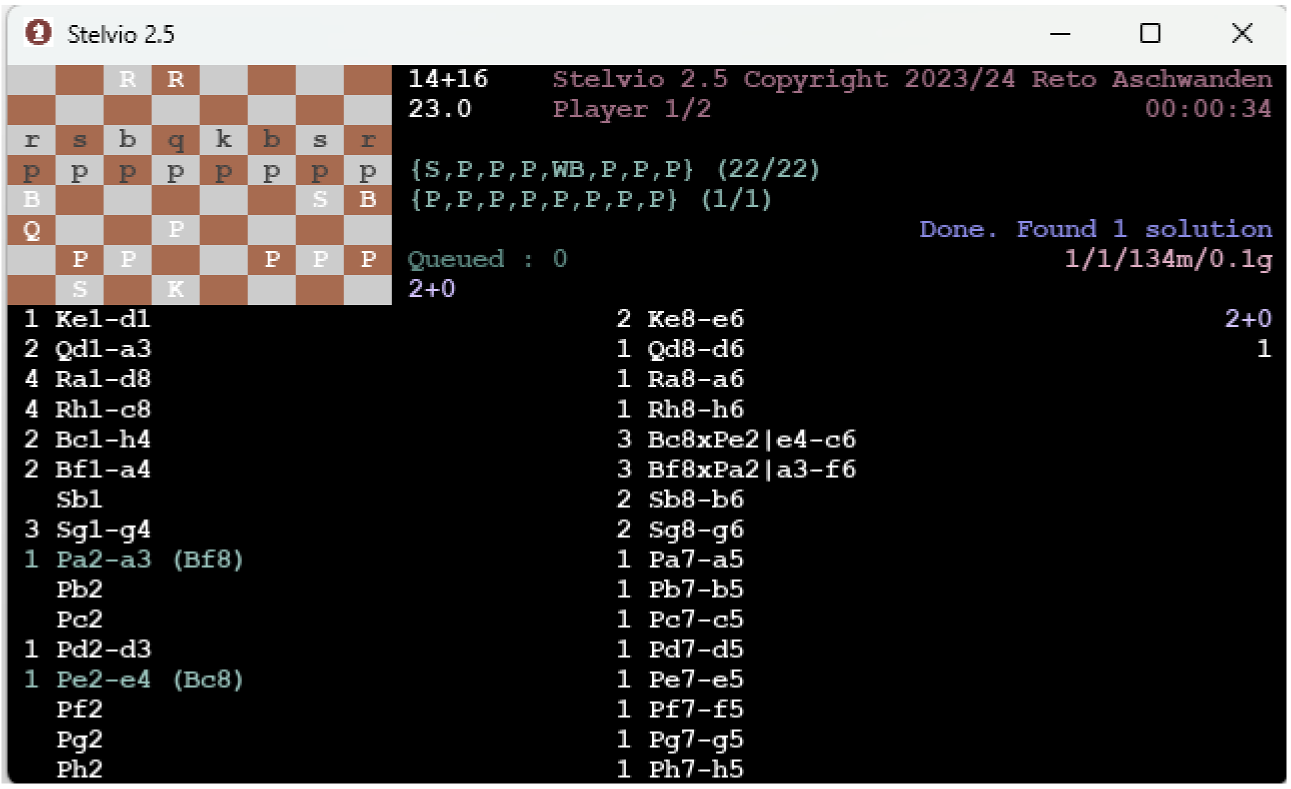
Probleemblad 1998

1. Prize



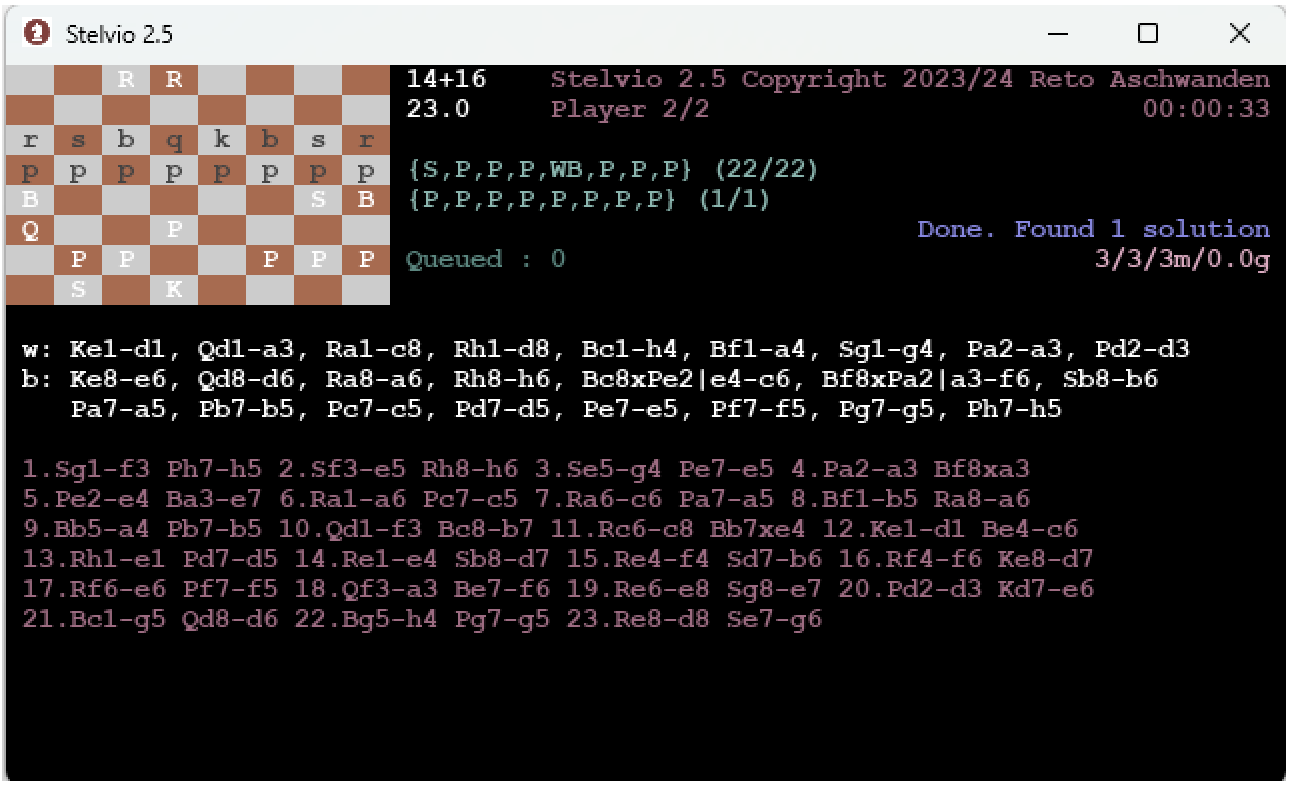
SPG in 23.0 moves

This can be checked by Stelvio, and in less than 1 minute (depending on hardware and other parameters). Stelvio comes to the conclusion, that there is exactly one way to reach this position in 23.0 moves:



```
Stelvio 2.5

14+16     Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
23.0      Player 1/2                         00:00:34

{S,P,P,P,WB,P,P,P} (22/22)
{P,P,P,P,P,P,P,P} (1/1)
                                   Done. Found 1 solution
Queued : 0                                 1/1/134m/0.1g
2+0
 1 Ke1-d1                   2 Ke8-e6                  2+0
 2 Qd1-a3                   1 Qd8-d6                    1
 4 Ra1-d8                   1 Ra8-a6
 4 Rh1-c8                   1 Rh8-h6
 2 Bc1-h4                   3 Bc8xPe2|e4-c6
 2 Bf1-a4                   3 Bf8xPa2|a3-f6
   Sb1                      2 Sb8-b6
 3 Sg1-g4                   2 Sg8-g6
 1 Pa2-a3 (Bf8)             1 Pa7-a5
   Pb2                      1 Pb7-b5
   Pc2                      1 Pc7-c5
 1 Pd2-d3                   1 Pd7-d5
 1 Pe2-e4 (Bc8)             1 Pe7-e5
   Pf2                      1 Pf7-f5
   Pg2                      1 Pg7-g5
   Ph2                      1 Ph7-h5
```

The successful strategy and the unique solution can subsequently be displayed:



```
Stelvio 2.5

14+16     Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
23.0      Player 2/2                         00:00:33

{S,P,P,P,WB,P,P,P} (22/22)
{P,P,P,P,P,P,P,P} (1/1)
                                   Done. Found 1 solution
Queued : 0                                   3/3/3m/0.0g

w: Ke1-d1, Qd1-a3, Ra1-c8, Rh1-d8, Bc1-h4, Bf1-a4, Sg1-g4, Pa2-a3, Pd2-d3
b: Ke8-e6, Qd8-d6, Ra8-a6, Rh8-h6, Bc8xPe2|e4-c6, Bf8xPa2|a3-f6, Sb8-b6
   Pa7-a5, Pb7-b5, Pc7-c5, Pd7-d5, Pe7-e5, Pf7-f5, Pg7-g5, Ph7-h5

1.Sg1-f3 Ph7-h5 2.Sf3-e5 Rh8-h6 3.Se5-g4 Pe7-e5 4.Pa2-a3 Bf8xa3
5.Pe2-e4 Ba3-e7 6.Ra1-a6 Pc7-c5 7.Ra6-c6 Pa7-a5 8.Bf1-b5 Ra8-a6
9.Bb5-a4 Pb7-b5 10.Qd1-f3 Bc8-b7 11.Rc6-c8 Bb7xe4 12.Ke1-d1 Be4-c6
13.Rh1-e1 Pd7-d5 14.Re1-e4 Sb8-d7 15.Re4-f4 Sd7-b6 16.Rf4-f6 Ke8-d7
17.Rf6-e6 Pf7-f5 18.Qf3-a3 Be7-f6 19.Re6-e8 Sg8-e7 20.Pd2-d3 Kd7-e6
21.Bc1-g5 Qd8-d6 22.Bg5-h4 Pg7-g5 23.Re8-d8 Se7-g6
```

The name

Stelvio, with its 2757m of altitude above sea level, is one of the highest and one of the most beautiful mountain passes of the Alps. As a bike rider, I've been up there many times and have good memories of it. I needed a name, and I liked the way Stelvio sounds. This name breaks the "tradition" of naming the program after a famous mathematician like Jacobi or Euclide. Let's say the idea of naming it Scholze was not very appealing…

Compatibility

As Stelvio is written in Java, it can run on various platforms, among them Windows, Mac and Linux.

Requirements

Solving SPGs is often memory-intensive, especially for SPGs with a lot of free moves. For that reason, it can be very beneficial to run Stelvio with most of the RAM that you have on your machine. You can find the amount of RAM you have in the System properties, common values for a notebook would be 8g-32g. I'd say 4g is bare minimum (can Tetris run with less?).

Btw: Running Stelvio with way more RAM than is needed for a particular SPG will likely increase the solving time for this SPG, as there are costs involved accessing large amounts of memory on hardware level. You can witness this e.g. in the required ramp-up time: When given a lot of memory, Stelvio needs much longer to get going. This is due to the fact that a large cache needs to be initialized. But for SPGs that take a long time to solve, and added 20 seconds or so up front do not matter. When giving Stelvio almost all or all of your RAM, it is advised to close other applications so that the memory is in fact free to use.

Installation

As Stelvio is written in Java, there needs to be a corresponding Java Runtime Environment installed for it to run. You can get your OS-specific version from here: https://www.oracle.com/ch-de/java/technologies/downloads/. I have tested Stelvio with Java 11 and Java 17. E.g. for Windows, you can download Java 17 with this link: https://download.oracle.com/java/17/latest/jdk-17_windows-x64_bin.msi. You then need to run the downloaded file and install it to a directory of your choice, recommended is "c:\java\java17" (this path should not contain spaces). Now download stelvio<version>.zip and unzip it to a directory of your choice, e.g. "c:\spg\stelvio". The zip file contains the following:

- bin folder containing some *.jar files (the code)
- doc folder containing PDFs (documentation)
- stelvio<version>.bat (the file to run)
- stelvio<version>.sh (the file to run on Linux)
- stelvioUI.ini (the parameter file)
- problems.txt (example input)

Adjust stelvio<version>.bat

You should open stelvio<version>.bat in a text editor and adjust the maximum memory settings. Per default, it says "-Xmx8g" in the file, which means Stelvio is allowed to use 8g of RAM. If you have more memory available, then give most of it to Stelvio, e.g. "-Xmx16g" for 16g of RAM. Also make sure that the path that points to the Java Runtime Environment is correct. The default is "c:\java\java17\", but you need to adjust this in case you opted to install Java at some other location.

To test your installation, just double-click stelvio<version>.bat, which should run Stelvio with the provided problems.txt file.

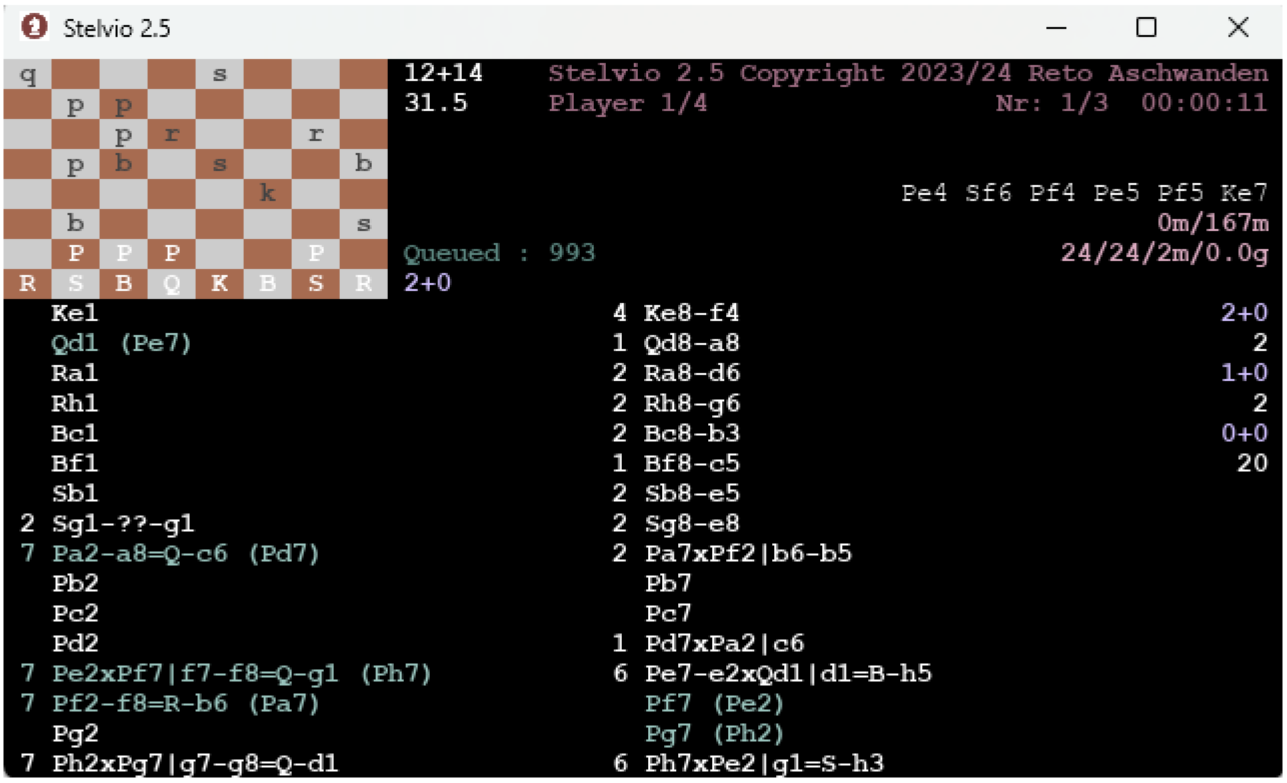
Troubleshooting

If Stelvio does not start when double-clicking on the stelvio<version>.bat file, then most likely the Java Runtime Environment cannot be found or its version is too old. Check if the path contained in stelvio<version>.bat pointing to java.exe is correct and adjust if needed.

UI

The simple terminal-based UI gives some impression where Stelvio stands in the solving process.

Here is what is displayed for a strategy player:



```
Stelvio 2.5
q       s                12+14    Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
  p p                    31.5     Player 1/4                  Nr: 1/3   00:00:11
    p r     r
  p b   s     b
          k                                      Pe4 Sf6 Pf4 Pe5 Pf5 Ke7
  b             s                                                 0m/167m
  P P P       P          Queued : 993                        24/24/2m/0.0g
R S B Q K B S R          2+0
   Ke1                                  4 Ke8-f4                      2+0
   Qd1 (Pe7)                            1 Qd8-a8                        2
   Ra1                                  2 Ra8-d6                      1+0
   Rh1                                  2 Rh8-g6                        2
   Bc1                                  2 Bc8-b3                      0+0
   Bf1                                  1 Bf8-c5                       20
   Sb1                                  2 Sb8-e5
 2 Sg1-??-g1                            2 Sg8-e8
 7 Pa2-a8=Q-c6 (Pd7)                    2 Pa7xPf2|b6-b5
   Pb2                                    Pb7
   Pc2                                    Pc7
   Pd2                                  1 Pd7xPa2|c6
 7 Pe2xPf7|f7-f8=Q-g1 (Ph7)             6 Pe7-e2xQd1|d1=B-h5
 7 Pf2-f8=R-b6 (Pa7)                      Pf7 (Pe2)
   Pg2                                    Pg7 (Ph2)
 7 Ph2xPg7|g7-g8=Q-d1                   6 Ph7xPe2|g1=S-h3
```

What it all means:

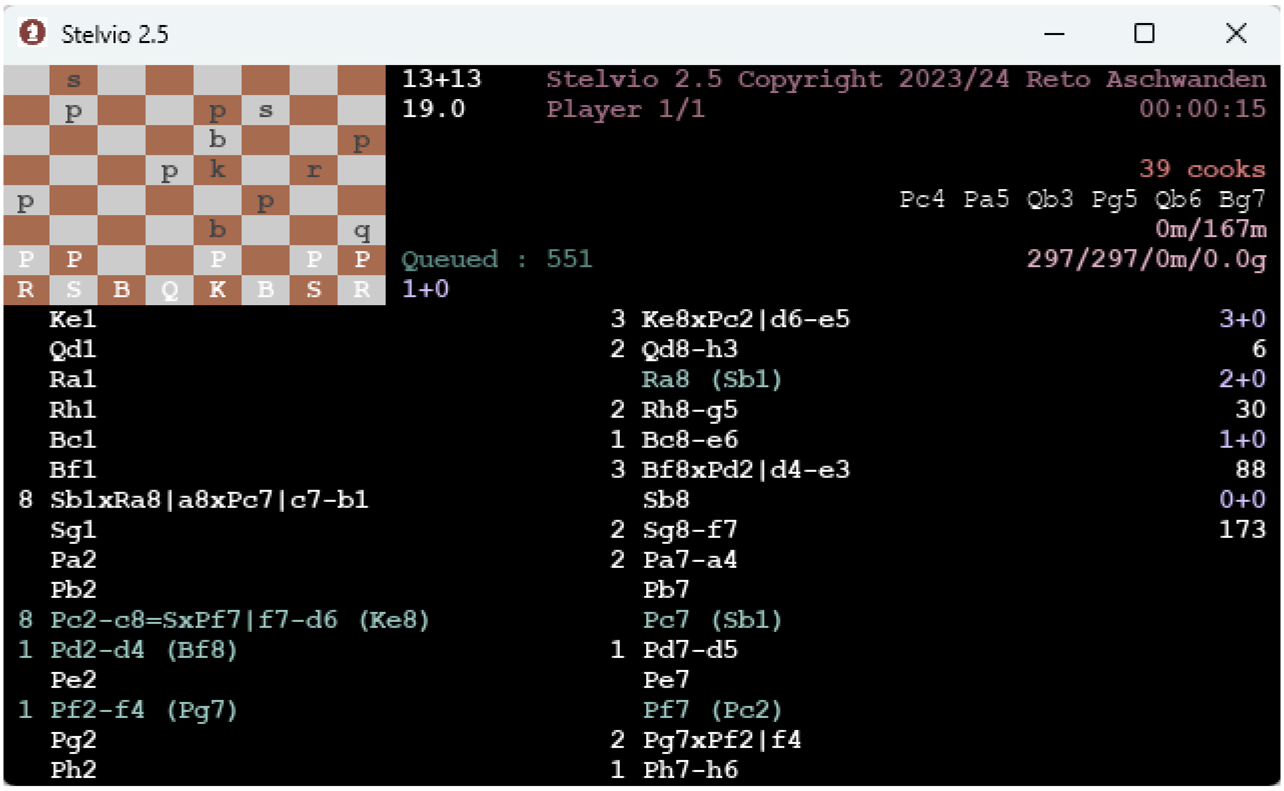
- Below the copyright notice:
    - Player 1/4: Which page is being displayed. We are currently looking at the page for strategy player 1 out of 4 such players. Pages can be switched using left-arrow/right-arrow in order to see pages for other strategy players/strategy seekers.
    - Nr: 1/3: The SPG being solved. In the example, there are 3 SPGs contained in the input file, and we are currently solving the first SPG.
- Next to the board:
    - Number of pieces and number of moves are obvious.
    - Queued: 993: Number of strategies that have been found that still need to be played. The numbers here are before any possible strategy splitting.
    - 2+0: Number of free moves for the current strategy by color, so 2 for white and 0 for black.
- On the right:
    - Solving time so far (hh:mm:ss).
    - Current move path (not to be taken too seriously, this can be stale/inconsistent data for technical reasons. If garbage is displayed, this has no effect on the solving itself, only the display is invalid).
    - Cache/strategy metrics:
        - 0m/167m: Currently, the playing cache is basically empty (0 million). Cache can hold 167 million positions (this is actually just an approximation, but good enough). This cache is bigger if you have more RAM available, which can be very useful depending on the SPG in question.
        - 24/24/2m/0.0g:

        - 24: The number of strategies already taken off the strategy queue (before any strategy splitting).
        - 24: The strategy number being played (possibly after strategy splitting). In the current case, no strategy splitting was needed, and therefore the numbers coincide.
        - 2m: Number of moves played for the current strategy in millions.
        - 0.0g: Total number of moves played for all strategies so far, in billions. Currently, less than 100m have been played, so this displays 0.
- Below the board:
    - The current strategy, i.e. what each piece does, white on the left and black on the right, with associated move count per piece.
    - The column on the far right: Histogram of already played strategies (top 8 entries, as there is limited space). So in the example, 2 strategies with 2+0 free moves have already been played, next to strategies with 1+0 and 0+0 free moves.

As already displayed above, when a solution is found, pressing up-arrow/down-arrow displays the solution and the successful strategy.

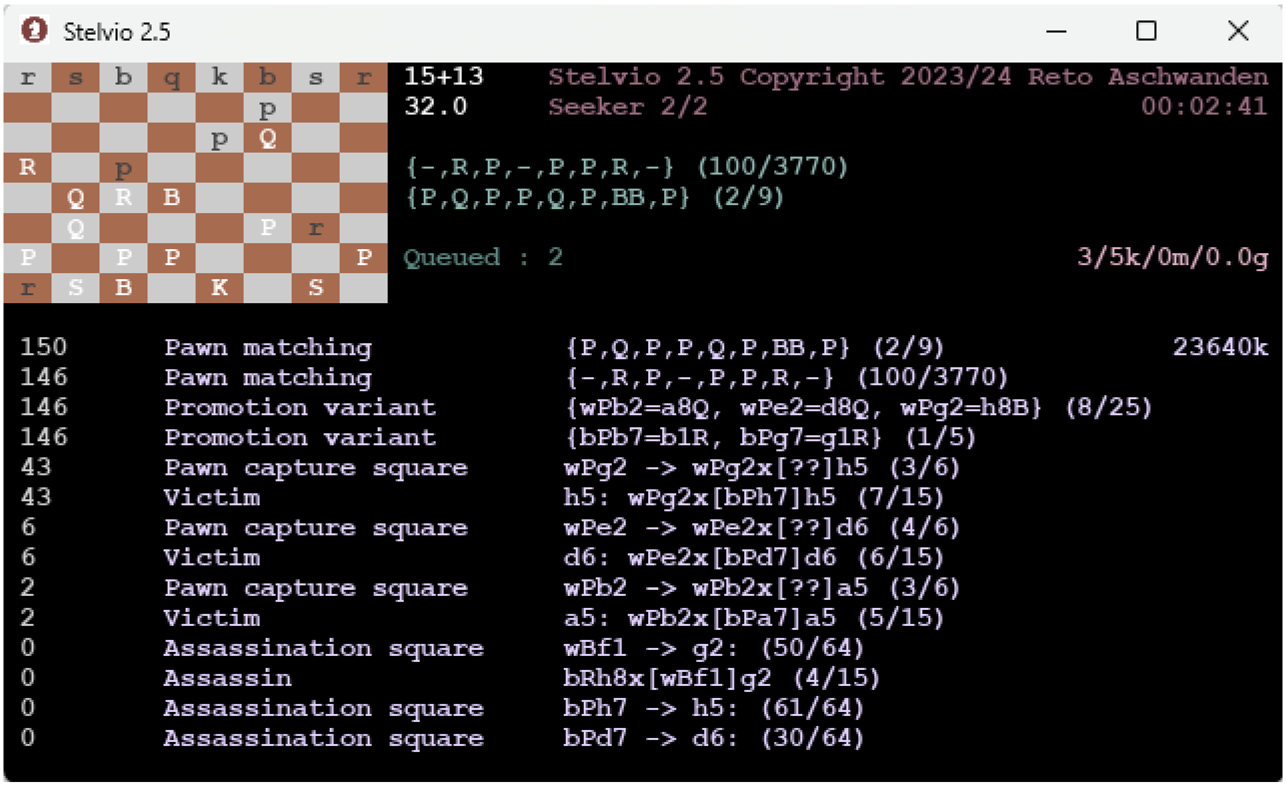
When there are cooks, Stelvio counts the number of strategies that contribute to cooks, in the below example 39 cook strategies where found so far. In case strategies which can be uniquely played are found, these are counted as valid solutions and displayed as well.

A brief note on what Stelvio counts as a cook/solution: In case a strategy can be played in multiple ways, then this counts as a cook strategy for Stelvio. This is the correct approach to take for 99.9% of the SPGs out there. In case a SPG requires an even number of half-moves, e.g. 22.0, then any solution/cook needs to have an even number of half-moves. Correspondingly for SPGs requiring an odd number of half-moves. This seems a good approach to take, since who is at play is part of the position to reach. So in case in the example one could reach the diagram position in 21.5 moves, then this does not count for Stelvio. Any shorter move-path with same parity of half-moves does count though, so in the example, Stelvio would count solutions/cooks in {21.0, 20.0, 19.0, … 1.0} moves.



```
   s                   13+13     Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
   p        p   s      19.0      Player 1/1                            00:00:15
            b       p
         p  k    r                                                     39 cooks
p           p                                       Pc4 Pa5 Qb3 Pg5 Qb6 Bg7
            b       q                                                0m/167m
P  P        P    P  P  Queued : 551                             297/297/0m/0.0g
R  S  B  Q  K  B  S  R  1+0
   Ke1                               3 Ke8xPc2|d6-e5                      3+0
   Qd1                               2 Qd8-h3                               6
   Ra1                                 Ra8 (Sb1)                          2+0
   Rh1                               2 Rh8-g5                              30
   Bc1                               1 Bc8-e6                             1+0
   Bf1                               3 Bf8xPd2|d4-e3                       88
8  Sb1xRa8|a8xPc7|c7-b1                Sb8                                0+0
   Sg1                               2 Sg8-f7                             173
   Pa2                               2 Pa7-a4
   Pb2                                 Pb7
8  Pc2-c8=SxPf7|f7-d6 (Ke8)            Pc7 (Sb1)
1  Pd2-d4 (Bf8)                      1 Pd7-d5
   Pe2                                 Pe7
1  Pf2-f4 (Pg7)                        Pf7 (Pc2)
   Pg2                               2 Pg7xPf2|f4
   Ph2                               1 Ph7-h6
```

Above we have seen the UI for a strategy player, let’s now look at what is displayed for a strategy seeker:



```
r  s  b  q  k  b  s  r  15+13    Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
               p        32.0     Seeker 2/2                             00:02:41
            p  Q
R     p                 {-,R,P,-,P,P,R,-} (100/3770)
   Q  R  B              {P,Q,P,P,Q,P,BB,P} (2/9)
   Q           P  r
P     P  P           P  Queued : 2                                  3/5k/0m/0.0g
r  S  B     K     S

150     Pawn matching            {P,Q,P,P,Q,P,BB,P} (2/9)                  23640k
146     Pawn matching            {-,R,P,-,P,P,R,-} (100/3770)
146     Promotion variant        {wPb2=a8Q, wPe2=d8Q, wPg2=h8B} (8/25)
146     Promotion variant        {bPb7=b1R, bPg7=g1R} (1/5)
43      Pawn capture square      wPg2 -> wPg2x[??]h5 (3/6)
43      Victim                   h5: wPg2x[bPh7]h5 (7/15)
6       Pawn capture square      wPe2 -> wPe2x[??]d6 (4/6)
6       Victim                   d6: wPe2x[bPd7]d6 (6/15)
2       Pawn capture square      wPb2 -> wPb2x[??]a5 (3/6)
2       Victim                   a5: wPb2x[bPa7]a5 (5/15)
0       Assassination square     wBf1 -> g2: (50/64)
0       Assassin                 bRh8x[wBf1]g2 (4/15)
0       Assassination square     bPh7 -> h5: (61/64)
0       Assassination square     bPd7 -> d6: (30/64)
```

- Next to the board:
    - The green lines: How the pawns are assigned to partitions currently in the strategy seeking process. Partitions are the types of pieces on the board that are mutually exclusive, we have partition values (K, Q, R, WB, BB, S, P). WB stands for white square bishop and BB for black square bishop. Top line is black assignment {-,R,P,-,P,P,R,-}, lower line is white assignment {P,Q,P,P,Q,P,BB,P}. This means for white, that a/c/d/f/h pawns remain pawns, b/e-pawns are

    queens in the diagram position and g-pawn is a black square bishop in the diagram. For black, c/e/f pawns remain pawns, the b/g-pawns are rooks visible in the diagram and a/d/h pawns are captured. At the outset of strategy seeking, all possible assignments of pawns to partitions are calculated, in the example we have 9 for white and 3770 for black. During strategy seeking, these assignments are all gone through in a big loop, and we are currently at assignment 2 for white and 100 for black. This information gives you a hint how far strategy seeking and therefore solving already is.

    - Queued : 2. The number of strategies in the queue that are waiting to be played. This queue is the link between all the strategy seekers and all the strategy players.

- On the right:
    - Solving time so far (hh:mm:ss).
    - Strategy metrics:
        - 3/5k/0m/0.0g:
            - 3: The number of strategies that were retained after strategy analysis and which therefore need to be played.
            - 5k: The number of strategies initially found (before strategy analysis), in thousands.
            - 0m: Since the strategy seeker is not playing, this number remains 0.
            - 0.0g: Since the strategy seeker is not playing, this number remains 0.

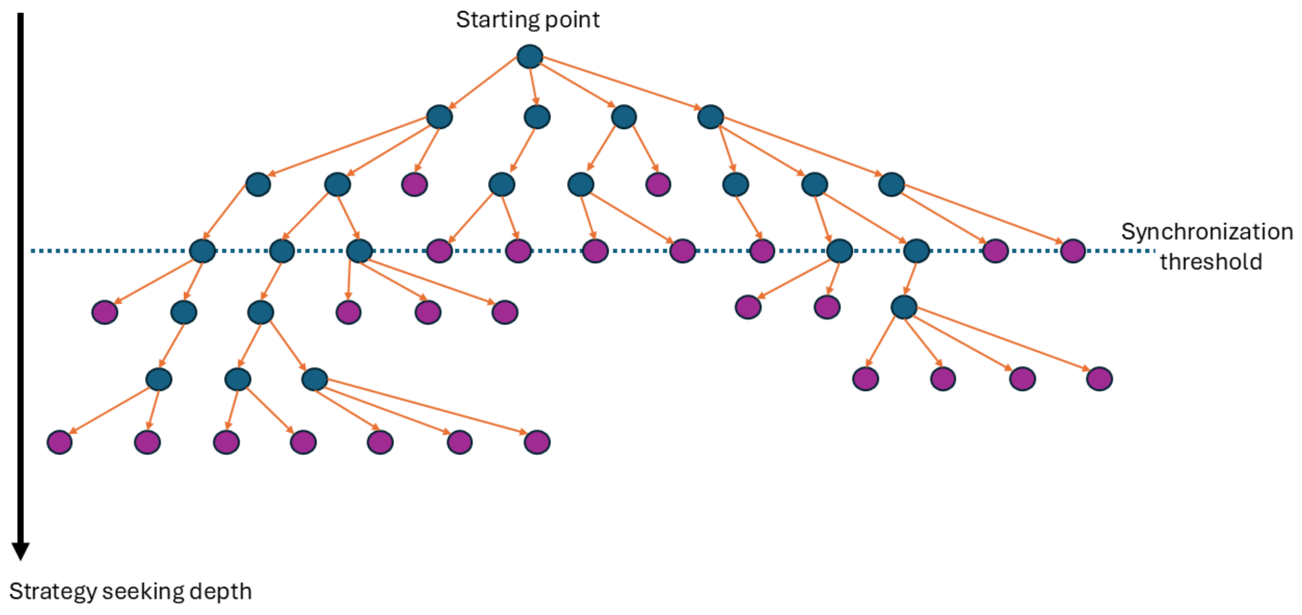
From version 1.6 onwards, the current strategy seeking path can be displayed. This is helpful in order to get an estimate of how long the seeking process will take. The first 14 levels of seeking are shown, together with how long the corresponding seek node has been active (in seconds, the number on the left). This information is somewhat analogous to the first 6 moves displayed when playing, only here, we have the first 14 "seeking moves". The information should be read top-down, so the two pawn matching choices have been active for 150 seconds respective 146 seconds. The next thing the seeking algorithm looks for are promotion variants. After that, a pawn capture square is chosen for the Pg2, currently we chose h5. Btw, the amount of possible options displayed to the right is sometimes only an estimate, but better an estimate than nothing.

If you are in histogram mode, then up-arrow/down-arrow switches between histogram and this new seeking information. Gathering this information takes a bit of time and in case you are not interested, it can be fully turned off. See the StelvioParameters file for details.

Strategy seeking parallelization algorithm

With version 3.0, Stelvio uses an embarrassingly simple but much improved approach to parallelize the strategy seeking workload. Once I saw this approach, I could not figure out why I had not seen it earlier.

On an abstract level, strategy seeking traverses a tree of search nodes, usually billions of nodes. At the top of the tree (i.e. the starting point), the strategy is basically empty, containing only the things that are visible from the diagram position. While moving down the search tree, the strategy becomes more and more defined, until the strategy is either fully defined or we have reached a dead end. All found strategies are leaves in this tree. The converse is not true: Not all leaves are strategies, as most search paths are simply dead ends that do not lead to a fully defined strategy.



For the new approach, there is a synchronization threshold defined by the parameter strategySeekingSyncDepth (dashed line in the image). This is the tree depth at which all the strategy seekers compete for tree nodes. All tree nodes above this level are computed by all strategy seekers. As the tree grows exponentially, the top few levels pale in size compared with the lower levels, so computing the top levels multiple times is usually negligible. When a seeker reaches the synchronization threshold level, it tries to acquire the corresponding node n. Two things can happen:

- Acquiring the node n is successful (for any node on the synchronization level, this is true for exactly one seeker). This seeker is then solely responsible to compute the whole subtree of n. No parallelization takes place for this subtree.
- Acquiring the node is not successful. The seeker interprets this path as a dead end and goes on searching (moving backwards first)

All the strategy seekers agree on the order of all the nodes that are found up to the synchronization level (i.e. the subtree defined by the synchronization level and all nodes above it is traversed in deterministic fashion by all seekers). So all these nodes can be viewed as numbered, and all seekers agree on these node-numbers. The synchronization mechanism simply keeps track of the maximal node-number max_n on the synchronization level that has been acquired. An acquisition attempt for node-number n is successful if and only n > max_n. Such a successful attempt then increases max_n to n. Therefore, any later seeker trying to acquire this same node n fails, because n <= max_n.

On a side note: The invariant that all seekers must find the same amount of nodes above the synchronization level is checked at the end of strategy seeking. If the numbers do not coincide, then an internal error occurs.

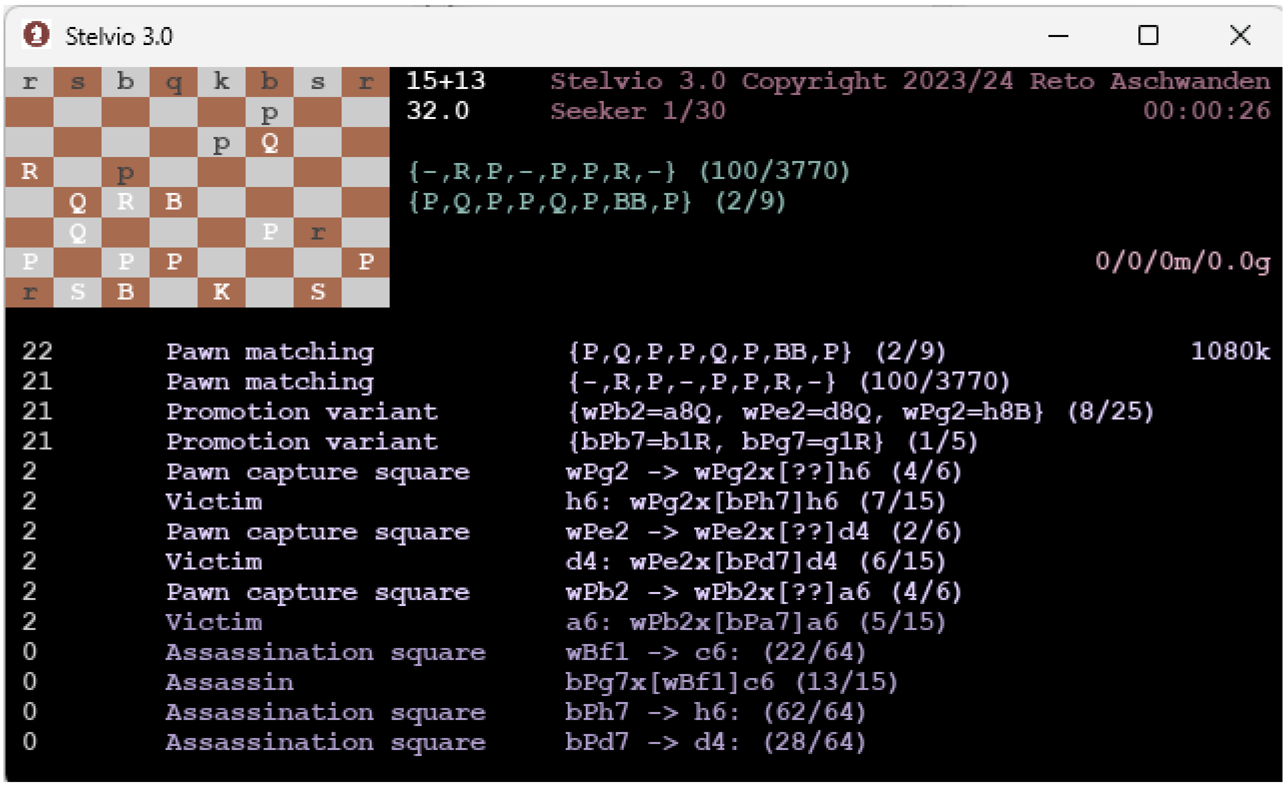
Effects of strategySeekingSyncDepth (i.e. synchronization level)

The default level is 12 and should be ok for most SPGs. I assume that levels between 8 and 18 could be useful.

- Level too low: This can lead to strategy seeker starvation, as the work items get too big in a skewed search tree. So you might have 10 seekers, but after a short time, only 1-2 are still active. That is a sign that you should increase strategySeekingSyncDepth.
- Level too high: If the level is set too high, then the part of the tree that all seekers calculate becomes large (if you set the level to say 100 (i.e. a level which is greater than the tree depth), then all seekers calculate the whole tree and nothing is parallelized). So arbitrary high values are not useful either.

So there is a tradeoff to be made here and the optimal value depends on the SPG at hand.

The synchronization level is actually visible in the UI:



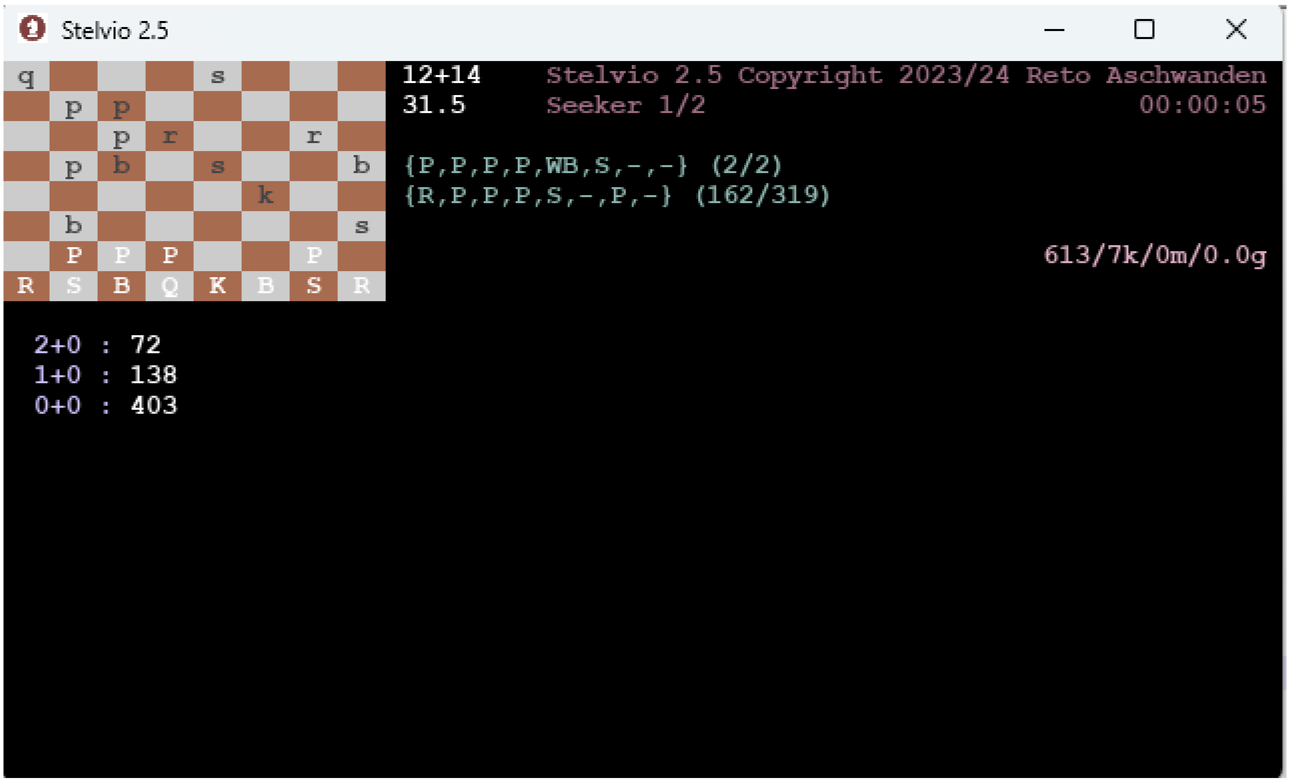
Stelvio 3.0

```
r s b q k b s r   15+13     Stelvio 3.0 Copyright 2023/24 Reto Aschwanden
          p       32.0      Seeker 1/30                          00:00:26
        p Q
R   p               {-,R,P,-,P,P,R,-} (100/3770)
  Q R B             {P,Q,P,P,Q,P,BB,P} (2/9)
  Q       P r
P   P P       P                                               0/0/0m/0.0g
r S B   K   S

22      Pawn matching           {P,Q,P,P,Q,P,BB,P} (2/9)                1080k
21      Pawn matching           {-,R,P,-,P,P,R,-} (100/3770)
21      Promotion variant       {wPb2=a8Q, wPe2=d8Q, wPg2=h8B} (8/25)
21      Promotion variant       {bPb7=b1R, bPg7=g1R} (1/5)
2       Pawn capture square     wPg2 -> wPg2x[??]h6 (4/6)
2       Victim                  h6: wPg2x[bPh7]h6 (7/15)
2       Pawn capture square     wPe2 -> wPe2x[??]d4 (2/6)
2       Victim                  d4: wPe2x[bPd7]d4 (6/15)
2       Pawn capture square     wPb2 -> wPb2x[??]a6 (4/6)
2       Victim                  a6: wPb2x[bPa7]a6 (5/15)
0       Assassination square    wBf1 -> c6: (22/64)
0       Assassin                bPg7x[wBf1]c6 (13/15)
0       Assassination square    bPh7 -> h6: (62/64)
0       Assassination square    bPd7 -> d4: (28/64)
```

The current strategy seeker path can be seen here (top-down). So first, the pawn partition matchings are chosen, then promotion variants etc. The lower 4 nodes are displayed in slightly darker violet. These darker nodes depict nodes below the synchronization level, and they are therefore not parallelized. Btw: Some nodes do not have a useful UI representation (sometimes). So even if you have strategySeekingSyncDepth=12, you might not see all 12 nodes in the UI (like in the example: there are only 9 lighter nodes displayed).

Histogram mode

In order to get a first impression if an SPG can be solved in a reasonable amount of time, it can be useful to simply search for all the strategies without actually playing them. This is what the histogram mode is for. In this mode, strategies are added up and grouped by white/black free moves.

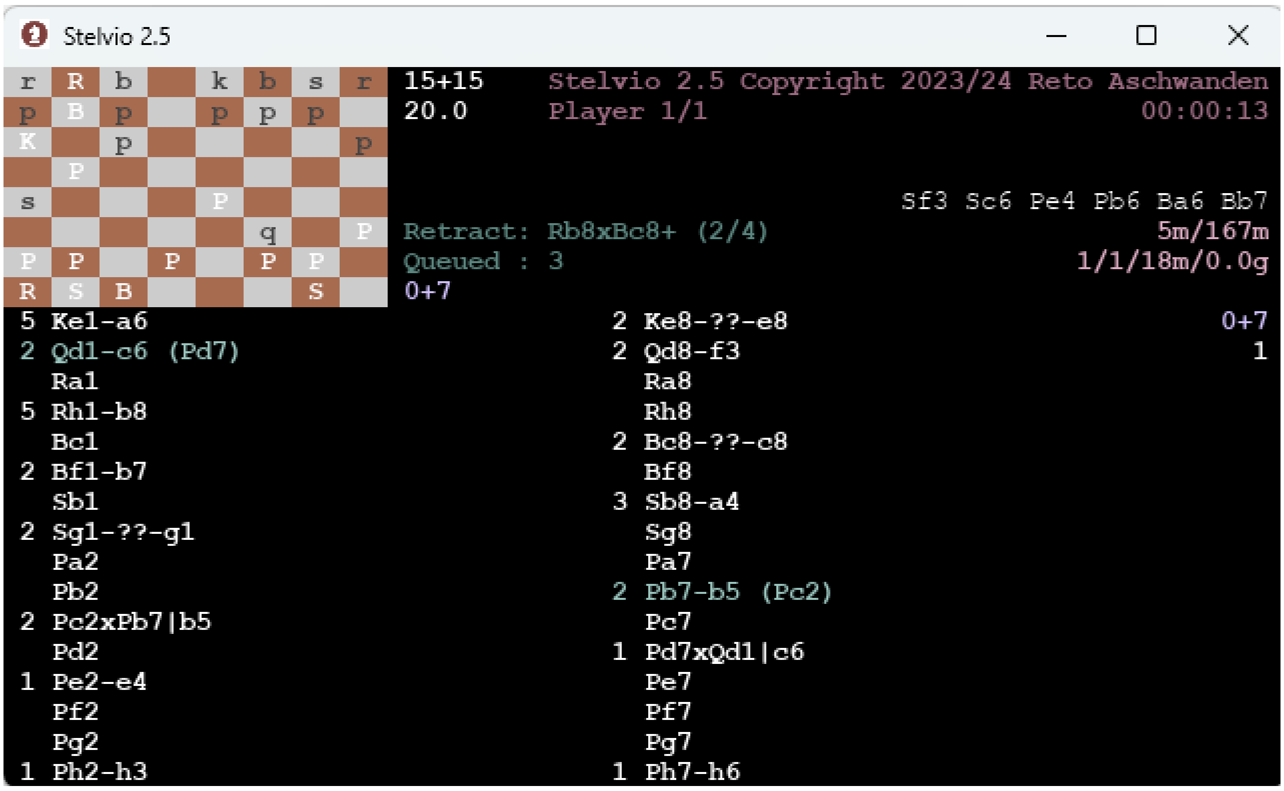


```
12+14     Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
31.5      Seeker 1/2                             00:00:05

{P,P,P,P,WB,S,-,-} (2/2)
{R,P,P,P,S,-,P,-} (162/319)

                                          613/7k/0m/0.0g

  2+0  :  72
  1+0  :  138
  0+0  :  403
```

So in the example, there are 72 strategies currently found by this strategy seeker (numbers are per seeker) with 2+0 free moves, 138 with 1+0 and 403 with 0+0 free moves. When all seekers are finished, the strategy numbers are added up and written into the output file. It is also possible to attain a partial histogram: You can tell Stelvio to only start adding up strategies after strategy number X. Beware though that strategy numbers are only deterministic in case only 1 strategy seeker is used. This can be useful if you want to know what is left in terms of strategies, if Stelvio already solved up to strategy X.

Last move retraction

In case a king is in check in the diagram, it can be very helpful to retract the last half move and solve all implied shorter SPGs and combine their results thereafter. By default, this is what Stelvio now does in such a case. While solving, the retracted move is displayed next to the diagram, as well as how many such moves there are. In the example, there are four possible last moves, and we have currently retracted the second. The problem displayed is the one with the move retracted. In the special e.p. retracted case, 2 half moves are retracted, as these 2 half moves cannot be split up. In the special castling retracted case, Stelvio makes sure that the king and involved rook are not moving beforehand. In histogram mode, the histogram of all sub-SPGs are written to the output file, as well as an overall histogram. Beware that this overall histogram will not coincide with the histogram you get when solving the SPG without retraction. This retraction functionality can be switched off by a new parameter named retractionMode. Limitation: Last move retraction and save/read strategies from/to file are not currently supported in combination. Btw: The retractionMode=always (i.e. even if king is not in check) will probably be added in a future release.



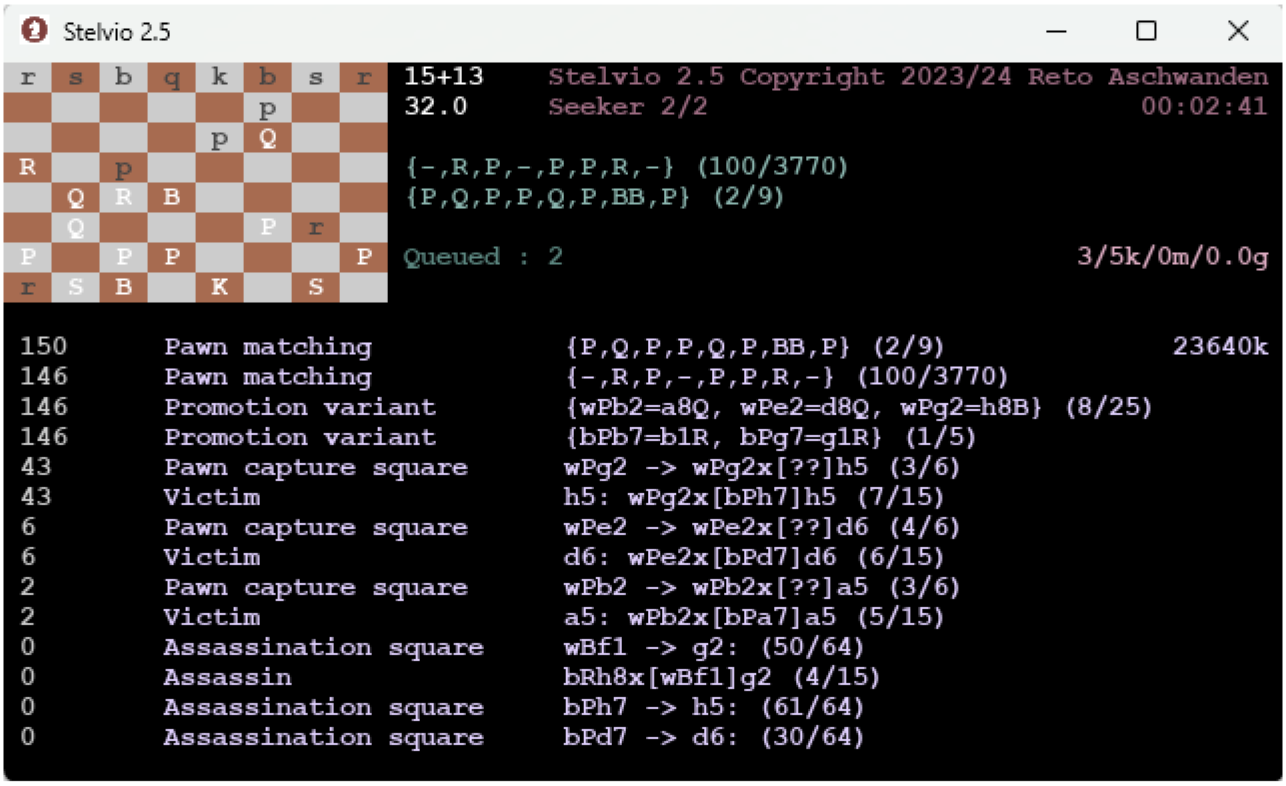
Stelvio 2.5

```
r R b   k b s r  15+15     Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
p B p   p p p     20.0      Player 1/1                          00:00:13
K   p         p
  P
s       P                         Sf3 Sc6 Pe4 Pb6 Ba6 Bb7
          q   P  Retract: Rb8xBc8+ (2/4)                          5m/167m
P P   P   P P    Queued : 3                                  1/1/18m/0.0g
R S B       S    0+7
 5 Kel-a6                               2 Ke8-??-e8                   0+7
 2 Qd1-c6 (Pd7)                         2 Qd8-f3                        1
   Ra1                                    Ra8
 5 Rh1-b8                                 Rh8
   Bc1                                  2 Bc8-??-c8
 2 Bf1-b7                                 Bf8
   Sb1                                  3 Sb8-a4
 2 Sg1-??-g1                              Sg8
   Pa2                                    Pa7
   Pb2                                  2 Pb7-b5 (Pc2)
 2 Pc2xPb7|b5                             Pc7
   Pd2                                  1 Pd7xQd1|c6
 1 Pe2-e4                                 Pe7
   Pf2                                    Pf7
   Pg2                                    Pg7
 1 Ph2-h3                               1 Ph7-h6
```

Some thoughts on parallel solving

Both histogram and normal solving are executed in parallel. Modern computers come with several CPUs, so calculating in parallel can be beneficial for performance.

The basic architecture is quite simple: There are x strategy seekers and y strategy players. The numbers x and y can be parametrized to suit the SPG at hand and your hardware. When running in parallel, the strategy seekers search for strategies and put the found strategies into a queue. The strategy players on the other hand consume strategies from this queue and try to play them. The granularity for the strategy seekers is a single pawn partition matching combination plus some further few seeking choices. This can be a bit coarse, and I might adjust this in the future. In the example below, there are 9 * 3770 such combinations, which the seekers consume one by one until none are left.



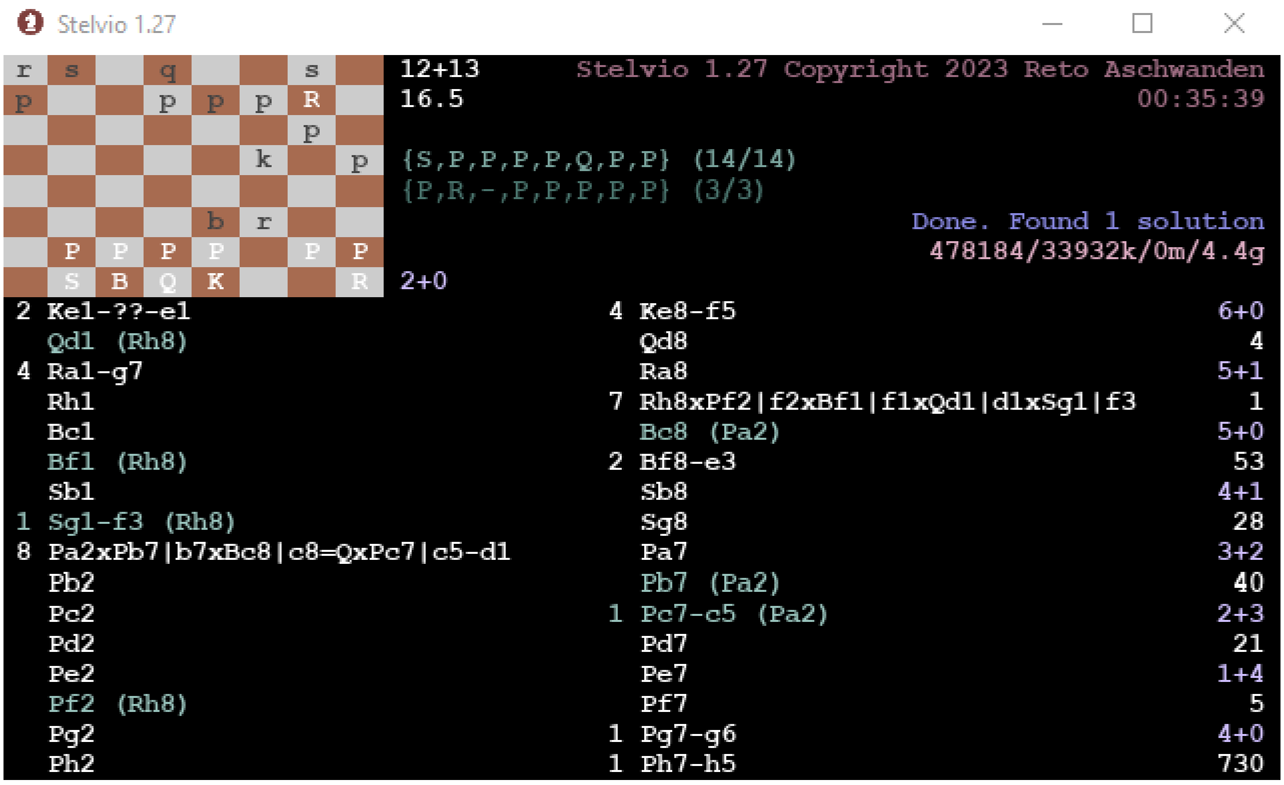
```
Stelvio 2.5

15+13      Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
32.0       Seeker 2/2                            00:02:41

{-,R,P,-,P,P,R,-} (100/3770)
{P,Q,P,P,Q,P,BB,P} (2/9)

Queued : 2                                  3/5k/0m/0.0g

150        Pawn matching             {P,Q,P,P,Q,P,BB,P} (2/9)          23640k
146        Pawn matching             {-,R,P,-,P,P,R,-} (100/3770)
146        Promotion variant         {wPb2=a8Q, wPe2=d8Q, wPg2=h8B} (8/25)
146        Promotion variant         {bPb7=b1R, bPg7=g1R} (1/5)
43         Pawn capture square       wPg2 -> wPg2x[??]h5 (3/6)
43         Victim                    h5: wPg2x[bPh7]h5 (7/15)
6          Pawn capture square       wPe2 -> wPe2x[??]d6 (4/6)
6          Victim                    d6: wPe2x[bPd7]d6 (6/15)
2          Pawn capture square       wPb2 -> wPb2x[??]a5 (3/6)
2          Victim                    a5: wPb2x[bPa7]a5 (5/15)
0          Assassination square      wBf1 -> g2: (50/64)
0          Assassin                  bRh8x[wBf1]g2 (4/15)
0          Assassination square      bPh7 -> h5: (61/64)
0          Assassination square      bPd7 -> d6: (30/64)
```

Parallel solving examples

The screenshots below are from version 1.27, but the insights gained are still valid in the current version.

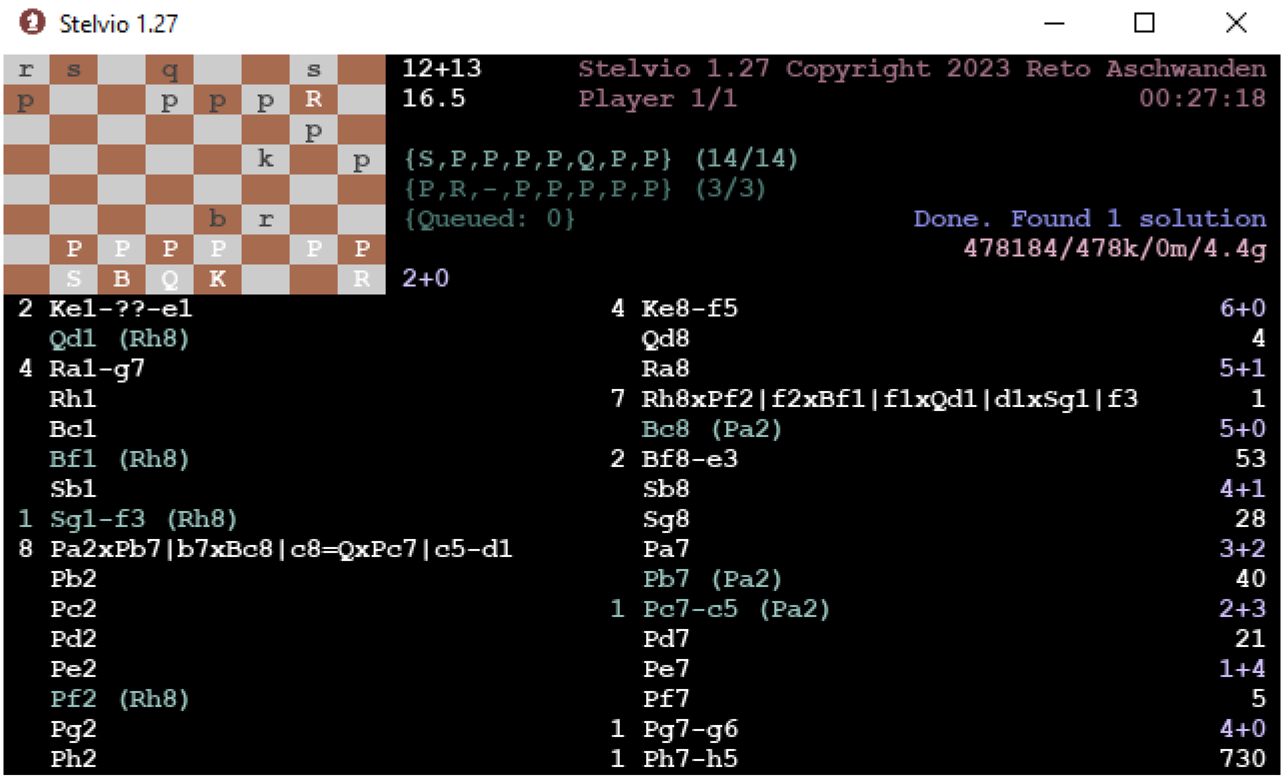
Same SPG but different concurrency metrics

I give a few examples of the effect of parallelizing, when it is beneficial and when it is not. Let’s take the 2023 Andernach TT winner by Michel. In non-parallel mode (the only mode available in Stelvio 1.2), this SPG is solved on my notebook in some 35 minutes:



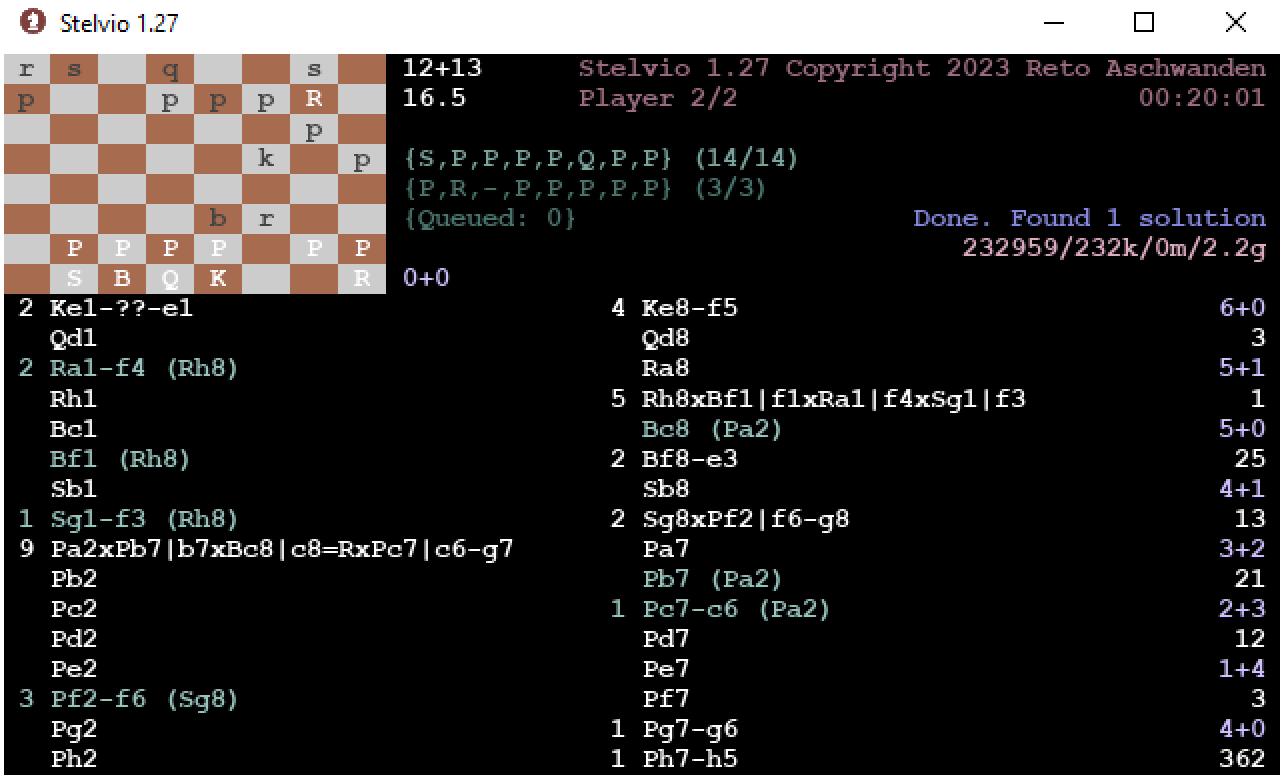
```
Stelvio 1.27

12+13        Stelvio 1.27 Copyright 2023 Reto Aschwanden
16.5                                            00:35:39

{S,P,P,P,P,Q,P,P} (14/14)
{P,R,-,P,P,P,P,P} (3/3)
                                       Done. Found 1 solution
                                       478184/33932k/0m/4.4g
2+0
2 Ke1-??-e1                         4 Ke8-f5                          6+0
  Qd1 (Rh8)                           Qd8                               4
4 Ra1-g7                              Ra8                             5+1
  Rh1                               7 Rh8xPf2|f2xBf1|f1xQd1|d1xSg1|f3   1
  Bc1                                 Bc8 (Pa2)                       5+0
  Bf1 (Rh8)                         2 Bf8-e3                           53
  Sb1                                 Sb8                             4+1
1 Sg1-f3 (Rh8)                        Sg8                              28
8 Pa2xPb7|b7xBc8|c8=QxPc7|c5-d1       Pa7                             3+2
  Pb2                                 Pb7 (Pa2)                        40
  Pc2                               1 Pc7-c5 (Pa2)                    2+3
  Pd2                                 Pd7                              21
  Pe2                                 Pe7                             1+4
  Pf2 (Rh8)                           Pf7                               5
  Pg2                               1 Pg7-g6                          4+0
  Ph2                               1 Ph7-h5                          730
```

Both strategy seeking and strategy playing take significant time for this SPG, so splitting up is beneficial. With 1 seeker and 1 player, the solving time drops to 27 minutes in Stelvio 1.3:



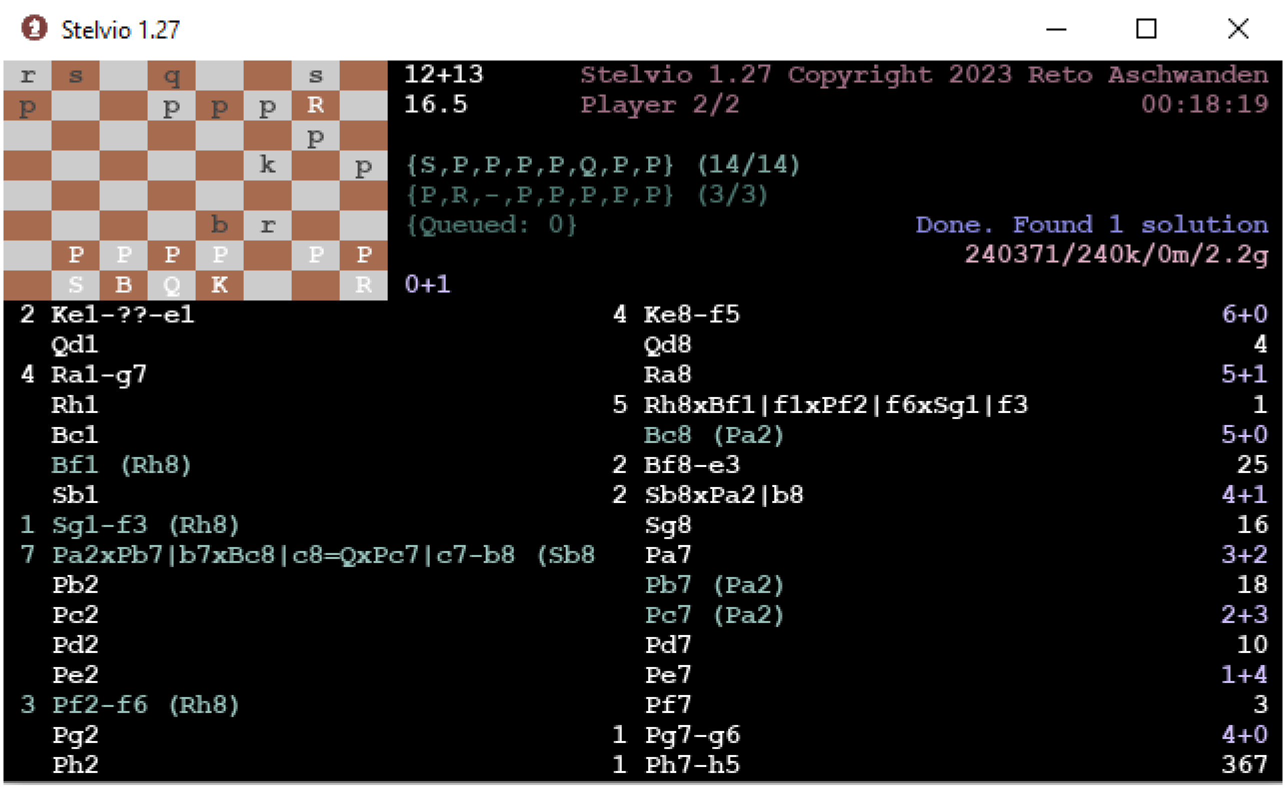
```
Stelvio 1.27
r s   q     s   12+13      Stelvio 1.27 Copyright 2023 Reto Aschwanden
p     p p p R   16.5       Player 1/1                          00:27:18
            p
          k   p {S,P,P,P,P,Q,P,P} (14/14)
                {P,R,-,P,P,P,P,P} (3/3)
        b r     {Queued: 0}                      Done. Found 1 solution
  P P P P   P P                                  478184/478k/0m/4.4g
  S B Q K     R 2+0
2 Ke1-??-e1                     4 Ke8-f5                            6+0
  Qd1 (Rh8)                       Qd8                                 4
4 Ra1-g7                          Ra8                               5+1
  Rh1                           7 Rh8xPf2|f2xBf1|f1xQd1|d1xSg1|f3     1
  Bc1                             Bc8 (Pa2)                         5+0
  Bf1 (Rh8)                     2 Bf8-e3                             53
  Sb1                             Sb8                               4+1
1 Sg1-f3 (Rh8)                    Sg8                                28
8 Pa2xPb7|b7xBc8|c8=QxPc7|c5-d1   Pa7                               3+2
  Pb2                             Pb7 (Pa2)                          40
  Pc2                           1 Pc7-c5 (Pa2)                      2+3
  Pd2                             Pd7                                21
  Pe2                             Pe7                               1+4
  Pf2 (Rh8)                       Pf7                                 5
  Pg2                           1 Pg7-g6                            4+0
  Ph2                           1 Ph7-h5                            730
```

As no strategy requires a lot of memory, we can also split up strategy playing without harm. With 1 seeker and 2 players, the solving time drops to 20 minutes:



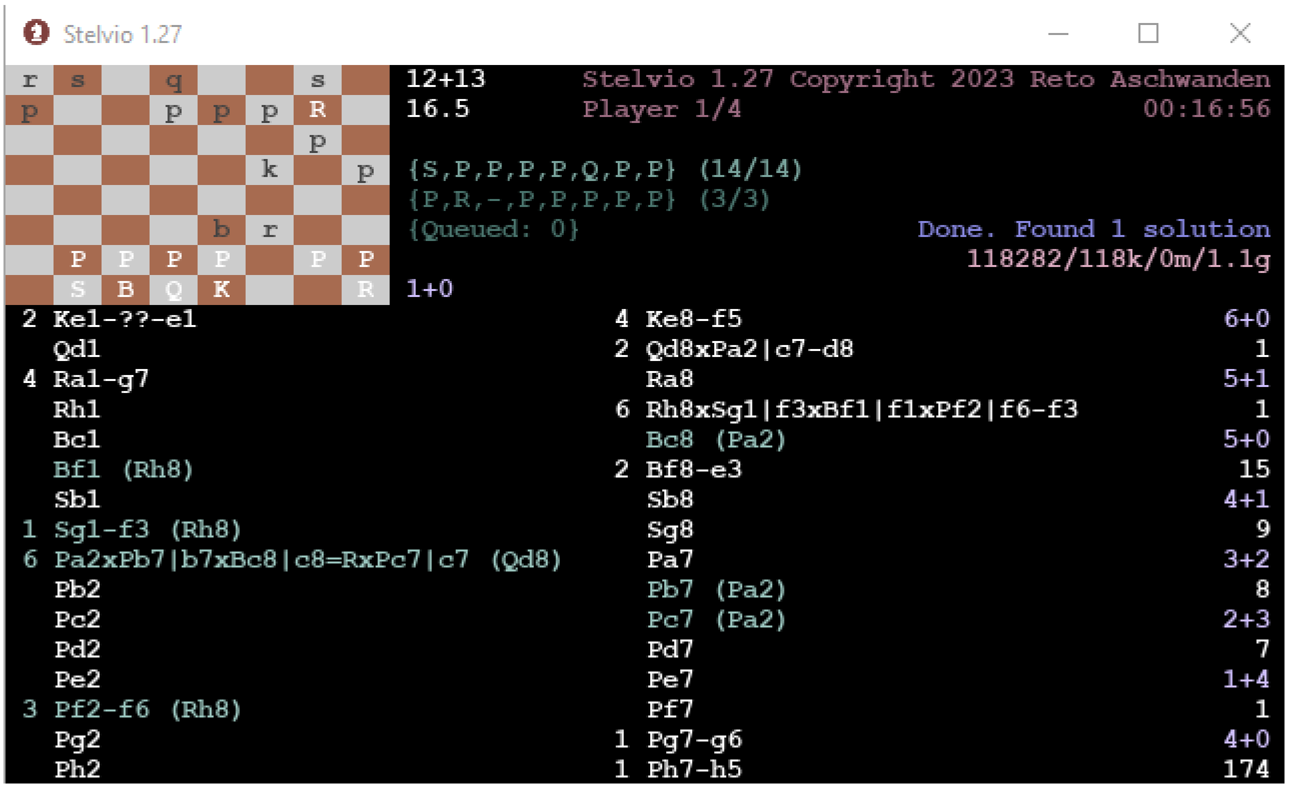
```
Stelvio 1.27
r s   q     s   12+13      Stelvio 1.27 Copyright 2023 Reto Aschwanden
p     p p p R   16.5       Player 2/2                          00:20:01
            p
          k   p {S,P,P,P,P,Q,P,P} (14/14)
                {P,R,-,P,P,P,P,P} (3/3)
        b r     {Queued: 0}                      Done. Found 1 solution
  P P P P   P P                                  232959/232k/0m/2.2g
  S B Q K     R 0+0
2 Ke1-??-e1                     4 Ke8-f5                            6+0
  Qd1                             Qd8                                 3
2 Ra1-f4 (Rh8)                    Ra8                               5+1
  Rh1                           5 Rh8xBf1|f1xRa1|f4xSg1|f3            1
  Bc1                             Bc8 (Pa2)                         5+0
  Bf1 (Rh8)                     2 Bf8-e3                             25
  Sb1                             Sb8                               4+1
1 Sg1-f3 (Rh8)                  2 Sg8xPf2|f6-g8                      13
9 Pa2xPb7|b7xBc8|c8=RxPc7|c6-g7   Pa7                               3+2
  Pb2                             Pb7 (Pa2)                          21
  Pc2                           1 Pc7-c6 (Pa2)                      2+3
  Pd2                             Pd7                                12
  Pe2                             Pe7                               1+4
3 Pf2-f6 (Sg8)                    Pf7                                 3
  Pg2                           1 Pg7-g6                            4+0
  Ph2                           1 Ph7-h5                            362
```

In the above configuration, the queue is sometimes empty. That means that the players have nothing to do at times, so an additional seeker will likely reduce the solving time. With 2 seekers and 2 players, the solving time drops to 18 minutes:



```
Stelvio 1.27
r s   q     s     12+13        Stelvio 1.27 Copyright 2023 Reto Aschwanden
p     p p p R     16.5         Player 2/2                          00:18:19
            p
          k   p   {S,P,P,P,P,Q,P,P} (14/14)
                  {P,R,-,P,P,P,P,P} (3/3)
        b r       {Queued: 0}                      Done. Found 1 solution
  P P P P   P P                                       240371/240k/0m/2.2g
  S B Q K     R   0+1
2 Ke1-??-e1                                 4 Ke8-f5                        6+0
  Qd1                                         Qd8                             4
4 Ra1-g7                                      Ra8                           5+1
  Rh1                                       5 Rh8xBf1|f1xPf2|f6xSg1|f3        1
  Bc1                                         Bc8 (Pa2)                     5+0
  Bf1 (Rh8)                                 2 Bf8-e3                         25
  Sb1                                       2 Sb8xPa2|b8                    4+1
1 Sg1-f3 (Rh8)                                Sg8                            16
7 Pa2xPb7|b7xBc8|c8=QxPc7|c7-b8 (Sb8          Pa7                           3+2
  Pb2                                         Pb7 (Pa2)                      18
  Pc2                                         Pc7 (Pa2)                     2+3
  Pd2                                         Pd7                            10
  Pe2                                         Pe7                           1+4
3 Pf2-f6 (Rh8)                                Pf7                             3
  Pg2                                       1 Pg7-g6                        4+0
  Ph2                                       1 Ph7-h5                        367
```

Just for fun, I tried with 4 seekers and 4 players, which still shaves a minute of solving time:



```
Stelvio 1.27
r s   q     s     12+13        Stelvio 1.27 Copyright 2023 Reto Aschwanden
p     p p p R     16.5         Player 1/4                          00:16:56
            p
          k   p   {S,P,P,P,P,Q,P,P} (14/14)
                  {P,R,-,P,P,P,P,P} (3/3)
        b r       {Queued: 0}                      Done. Found 1 solution
  P P P P   P P                                       118282/118k/0m/1.1g
  S B Q K     R   1+0
2 Ke1-??-e1                                 4 Ke8-f5                        6+0
  Qd1                                       2 Qd8xPa2|c7-d8                   1
4 Ra1-g7                                      Ra8                           5+1
  Rh1                                       6 Rh8xSg1|f3xBf1|f1xPf2|f6-f3     1
  Bc1                                         Bc8 (Pa2)                     5+0
  Bf1 (Rh8)                                 2 Bf8-e3                         15
  Sb1                                         Sb8                           4+1
1 Sg1-f3 (Rh8)                                Sg8                             9
6 Pa2xPb7|b7xBc8|c8=RxPc7|c7 (Qd8)            Pa7                           3+2
  Pb2                                         Pb7 (Pa2)                       8
  Pc2                                         Pc7 (Pa2)                     2+3
  Pd2                                         Pd7                             7
  Pe2                                         Pe7                           1+4
3 Pf2-f6 (Rh8)                                Pf7                             1
  Pg2                                       1 Pg7-g6                        4+0
  Ph2                                       1 Ph7-h5                        174
```

As my notebook now runs out of hardware, increasing the numbers further will have a negative effect, since in the end, all seekers/players compete for the same underlying hardware.

Different SPGs and the usefulness of parallelism for them

Histogram mode in parallel (strategy seeking in parallel)

With the new improved method of parallelizing introduced with version 3.0, strategy seeking parallelization should be useful in all the cases that require substantial strategy seeking time. As a rule of thumb, the number of captures contributes heavily to strategy seeking time, but also the number of possible promotions and of course SPG length.

Solving in parallel

- Parallel solving can be detrimental under some circumstances, in case there are multiple players. The reason is that the players each need their own position cache, and this cache requires a lot of memory. So in case you have 2 players instead of 1, then each position cache is only half the size. Now in case while playing a strategy, the position cache is close to full, then solving performance for this strategy decreases dramatically. Therefore, it can be slower to play strategies in parallel than to play them serially. A case where this happens is the length record problem (P1407171), which by the way still cannot be solved.
- In the Andernach TT winner above, parallel solving is pretty useful, cutting the solving time in half.
- Parallel solving is the most useful in case strategy seeking takes up most of the time, and you have a lot of hardware (CPUs) that can be used for parallelizing. As there is almost no limit for number of seekers (given enough available CPUs), you can go all-in in that respect. An order of magnitude can be shaved of the solving time in that way for P1386153.

Current limitations, possible future developments

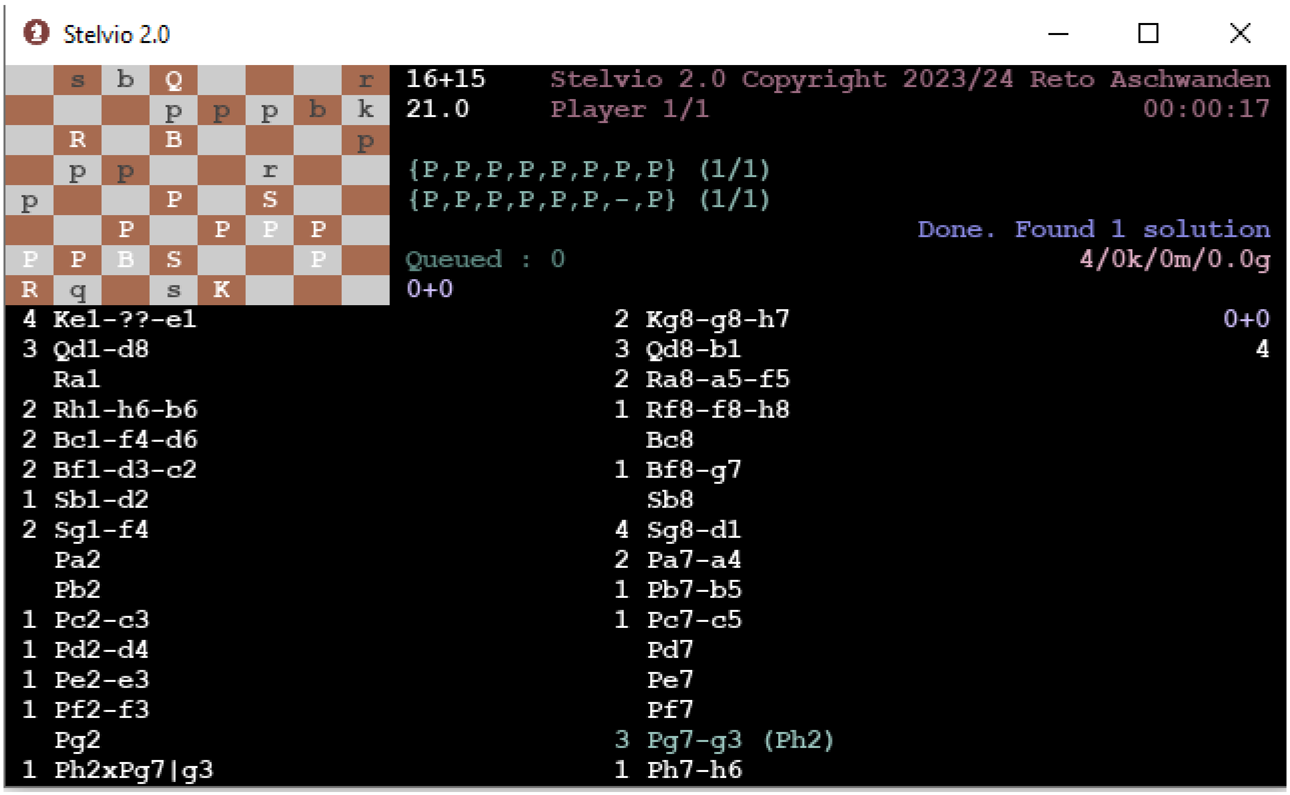
Two things come to mind:

- Parallel playing of a single strategy.
- Parallelize not only on one machine, but across a cluster of machines.

Collision detection modes

With v2.0, Stelvio has two modes of collision detection: A more involved mode (expensiveCollisionDetectionMode = on) and a less involved mode (expensiveCollisionDetectionMode = off). Both modes have their merit, as both can be orders of magnitude faster than the other, depending on the problem. In case expensiveCollisionDetectionMode = default, then the expensive mode is chosen for an SPG if and only if it has at least 28 pieces, which seems like a reasonable heuristic.

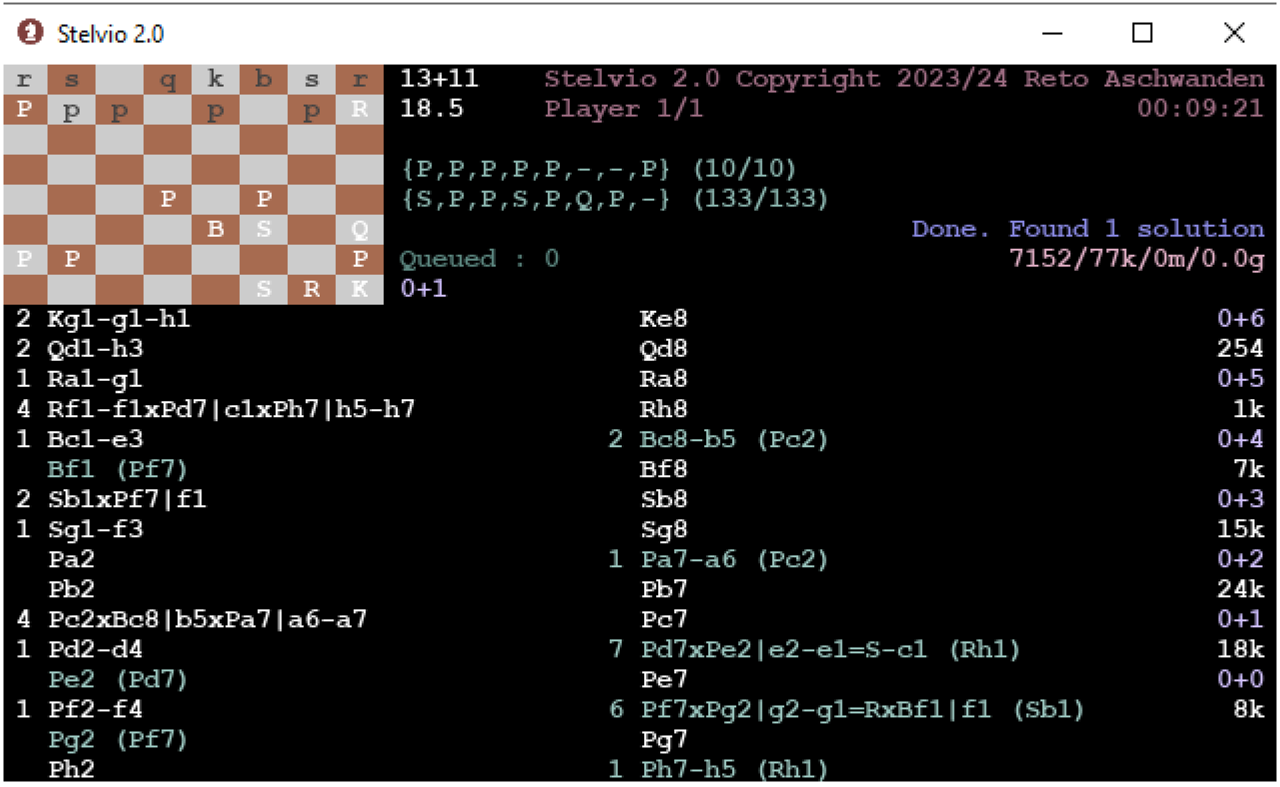
Collision detection is done for every found strategy. In case there are only few strategies to analyze, then the additional costs of more involved collision analysis will be negligible. One example where the involved analysis is very beneficial is the 4th Prize in the Champagne Tourney 2023 by Peter van den Heuvel.



```
Stelvio 2.0
                    16+15      Stelvio 2.0 Copyright 2023/24 Reto Aschwanden
                    21.0       Player 1/1                            00:00:17

                    {P,P,P,P,P,P,P,P} (1/1)
                    {P,P,P,P,P,P,-,P} (1/1)
                                                        Done. Found 1 solution
                    Queued : 0                                   4/0k/0m/0.0g
                    0+0
 4 Ke1-??-e1                         2 Kg8-g8-h7                          0+0
 3 Qd1-d8                            3 Qd8-b1                               4
   Ra1                               2 Ra8-a5-f5
 2 Rh1-h6-b6                         1 Rf8-f8-h8
 2 Bc1-f4-d6                           Bc8
 2 Bf1-d3-c2                         1 Bf8-g7
 1 Sb1-d2                              Sb8
 2 Sg1-f4                            4 Sg8-d1
   Pa2                               2 Pa7-a4
   Pb2                               1 Pb7-b5
 1 Pc2-c3                            1 Pc7-c5
 1 Pd2-d4                              Pd7
 1 Pe2-e3                              Pe7
 1 Pf2-f3                              Pf7
   Pg2                               3 Pg7-g3 (Ph2)
 1 Ph2xPg7|g3                        1 Ph7-h6
```

The involved analysis detects that the black queen must pass through e1, eliminating any free moves that white would otherwise have. In case this is solved with expensiveCollisionDetectionMode = off, then solving takes hours if not days.

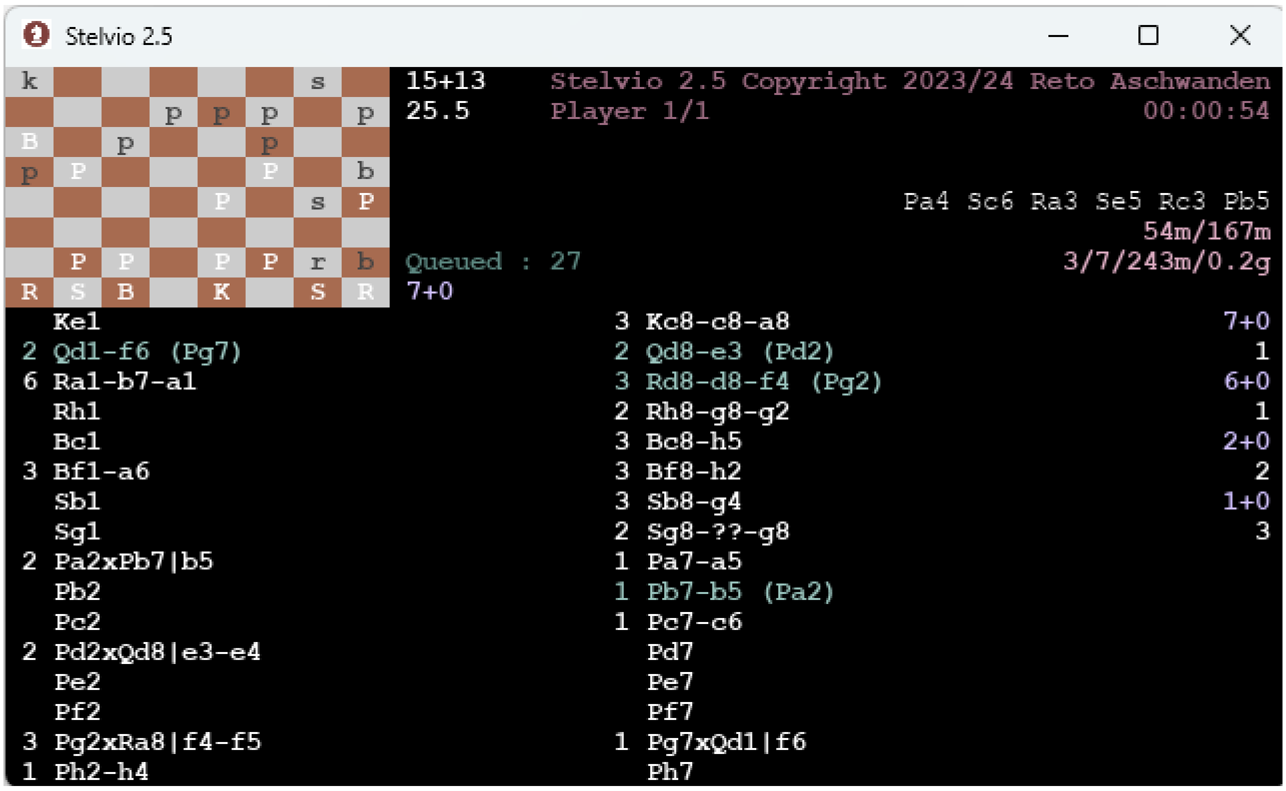
Any massacre style SPG will be solved quicker with expensiveCollisionDetectionMode = off, as there are billions of strategies to analyze and involved analysis is not needed. But not only massacres can benefit from less collision detection, the following SPG (P1013138) by me, Michel and Gerd is also solved quicker with less analysis (by a factor 4).



```
Stelvio 2.0
                    13+11      Stelvio 2.0 Copyright 2023/24 Reto Aschwanden
                    18.5       Player 1/1                            00:09:21

                    {P,P,P,P,P,-,-,P} (10/10)
                    {S,P,P,S,P,Q,P,-} (133/133)
                                                        Done. Found 1 solution
                    Queued : 0                               7152/77k/0m/0.0g
                    0+1
 2 Kg1-g1-h1                           Ke8                                0+6
 2 Qd1-h3                              Qd8                                254
 1 Ra1-g1                              Ra8                                0+5
 4 Rf1-f1xPd7|c1xPh7|h5-h7             Rh8                                 1k
 1 Bc1-e3                            2 Bc8-b5 (Pc2)                       0+4
   Bf1 (Pf7)                           Bf8                                 7k
 2 Sb1xPf7|f1                          Sb8                                0+3
 1 Sg1-f3                              Sg8                                15k
   Pa2                               1 Pa7-a6 (Pc2)                       0+2
   Pb2                                 Pb7                                24k
 4 Pc2xBc8|b5xPa7|a6-a7                Pc7                                0+1
 1 Pd2-d4                            7 Pd7xPe2|e2-e1=S-c1 (Rh1)           18k
   Pe2 (Pd7)                           Pe7                                0+0
 1 Pf2-f4                            6 Pf7xPg2|g2-g1=RxBf1|f1 (Sb1)        8k
   Pg2 (Pf7)                           Pg7
   Ph2                               1 Ph7-h5 (Rh1)
```

Check protection

With v2.0, Stelvio can sometimes determine that check protection is needed. This can greatly reduce solving times. An example is the classic 1999 Phénix first prize by Michel (P1000010), which can now be solved in reasonable time on an ordinary machine.



```
Stelvio 2.5

k . . . . . s .   15+13     Stelvio 2.5 Copyright 2023/24 Reto Aschwanden
. . . p p p . p   25.5      Player 1/1                           00:00:54
B . p . . p . .
p P . . . P . b
. . . . P . s P                         Pa4 Sc6 Ra3 Se5 Rc3 Pb5
. . . . . . . .                                            54m/167m
. P P . P P r b   Queued : 27                         3/7/243m/0.2g
R S B . K . S R   7+0
  Ke1                           3 Kc8-c8-a8                     7+0
2 Qd1-f6 (Pg7)                  2 Qd8-e3 (Pd2)                    1
6 Ra1-b7-a1                     3 Rd8-d8-f4 (Pg2)               6+0
  Rh1                           2 Rh8-g8-g2                       1
  Bc1                           3 Bc8-h5                        2+0
3 Bf1-a6                        3 Bf8-h2                          2
  Sb1                           3 Sb8-g4                        1+0
  Sg1                           2 Sg8-??-g8                       3
2 Pa2xPb7|b5                    1 Pa7-a5
  Pb2                           1 Pb7-b5 (Pa2)
  Pc2                           1 Pc7-c6
2 Pd2xQd8|e3-e4                   Pd7
  Pe2                             Pe7
  Pf2                             Pf7
3 Pg2xRa8|f4-f5                 1 Pg7xQd1|f6
1 Ph2-h4                          Ph7
```

By looking at the displayed strategy, it becomes apparent that check protection necessity for the black king was detected, as a white rook is planned to make a detour (Ra1-b7-a1). Check protection gives rise to strategy splitting: Once check protection necessity is detected, all the possible ways to provide it are calculated. The original strategy is subsequently split into several sub-strategies. This splitting is visible in the UI in the metrics on the right hand side: In the example, we already took 3 strategies from the queue, but we are currently playing the 7th (sub-)strategy.

Btw: Strategy splitting can also arise from baseline collisions when it is unclear who makes a detour, e.g. Ra1-g1, Rh1-b1 is split into 2 sub-strategies.

User interaction

The playing of the current strategy can be stopped by typing 's'. Stelvio will move on to the next strategy thereafter. Pressing Ctrl-C cancels the solving process. In parallel mode, you have different UI pages per seeker/player. You can switch between these pages using left-arrow/right-arrow.

Input / Output

A simple text file (by default problems.txt) serves as input. It needs to be in the same directory as stelvio<version>.jar. In problems.txt, the SPG needs to be given in FEN notation on the first line, and the number of half moves on the second line, something like:

1nbq4/ppk1p3/Rp5p/3npr2/R3P3/2br1B1P/PP2P2P/1NBQNK2
65

Pieces are denoted by:

- K/k = King
- Q/q = Queen
- R/r = rook
- B/b = bishop
- N/n/S/s = knight
- P/p = Pawn

You can add several problems to the input file, which will then be solved in succession.

The result is written into an output file (by default named problems_out.txt). There is a stelvioUI.ini file for parameters that can be adjusted by the user. If no such file is present, then default values are used. See also StelvioParameters.pdf.

Read/write strategies to file

Stelvio can be advised to save all found strategies in structured format to disk. In a second step, instead of searching for strategies, Stelvio can thereafter read these strategies from disk and try to play them. This is especially useful in case one uses histogram mode at first. Calculating the histogram sometimes requires a lot of time, only to find very few strategies. In order to subsequently play these strategies, they can now be read from disk in no time, instead of recalculating all of them all over again. Limitation: Last move retraction and save/read strategies from/to file are not currently supported in combination.

Known issues

Given a cooked SPG and a cook-strategy s for it (i.e. a strategy s that can be played in multiple ways and therefore cooks the SPG). It is possible that not all permutations of how this strategy s can be played are found. This should usually be irrelevant, as the verdict is unaffected (the SPG is cooked, the strategy s is found to be a cook-strategy in any case).

Explicitly finding all the different ways a cook-strategy can be played seems pretty pointless, so I have not invested time in fixing this. As possible fixes imply a performance penalty, I'm inclined to leave this as is for the moment at least.