Incredible 18 Piece Burrs

by Frans de Vreugd

0) Introduction

Interlocking puzzles have fascinated me for almost 30 years. Having a set of wooden pieces that will only assemble in a certain way is intriguing. One of the most well-known puzzles is the ***18 Piece Burr***. It was designed in 1952 by Dutch mathematician Willem van der Poel. Ever since that moment this puzzle has been inspiring puzzle designers worldwide. Despite the fact that it has been around for almost seven decades there have been interesting developments recently, in both the classic design and puzzles derived from it. In this article I will show some incredible recent designs and some very interesting ***Pseudo 18 Piece Burrs***.

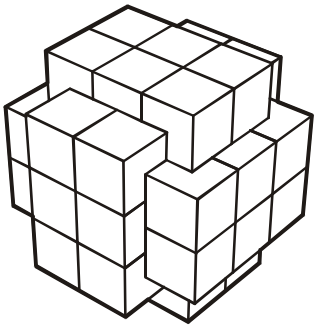

Figure 1.
Van der Poel Puzzle

1) Design criteria for 18 piece burrs

When designing interlocking puzzles, there are a number of design criteria that are used. Having a unique solution for a puzzle (the puzzle pieces will fit together in one way only) is very desirable, both for interlocking puzzles and for packing puzzles. Not every design has a unique solution, but there are many different tricks to make a solution unique (we will look into this later). The shape of the pieces is also important. Ideally the pieces are notchable (which means that they can be made by a tablesaw alone (without having to chisel out blind corners by hand). Second best are millable pieces. No hand chiseling is allowed, but more complicated pieces can be made with a router. Another (practical) characteristic is having as many identical pieces as possible. For practical purposes it is a lot easier to make two or three different pieces rather than 18 different ones. An additional design criterion for the 18 piece burr might be to have identical pieces for the 12 pieces of the outer cage.

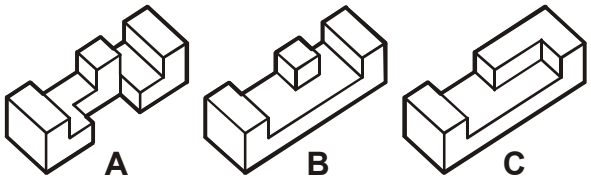

Figure 2. notchable (A), millable (B), non-notchable (C) pieces

2) The 18 piece Burr - unbreakable by computer?

Shown in Figure 1 is the iconic shape of this puzzle. It consists of an outer cage of 12 pieces combined with an internal locking mechanism of 6 pieces. The puzzles are grouped in a 2x3 array in each of its main axis. This first design was not a very difficult puzzle (at least not compared to today's standards), it only needed a few moves to remove the first piece. The principle of having an outer cage with the internal lock proved to be a very fertile starting point for other (more complicated) puzzle designs though. If the number of pieces of a puzzle is small enough (e.g. six or eight pieces) it is possible to do a full analysis by computer. Bill Cutler for instance analysed the infamous ***Six Piece Burr*** (aka ***Chinese Cross***) this way. What you do is determine all the possible different pieces, then find every single combination of six of these and use a brute force attack to calculate all of the different sets by computer. Bill Cutler did his research on the six piece burr in the 1980s. Since then, computer capacity has improved immensely, supercomputers have been developed and initia-

tives to have thousands of computers work together to do large and complicated computations (like SETI) were introduced. All of this is no help at all though for doing a full analysis of the 18 piece burr! The number of combinations to be calculated is mind-boggling. With today's technology, cracking the 18 pieces seems far out of reach. Maybe the development of quantum computers might help. To give an example, on a modern (2012) home computer it might take several weeks of computing a *single set* of 18 pieces. This is probably part of the success of this puzzle: the fact that computers cannot crack it has contributed to its almost mythical proportions.

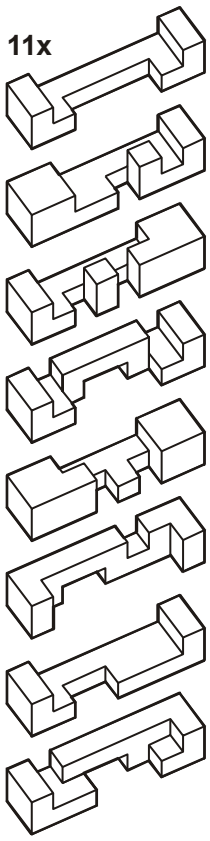

Figure 3. Pieces of *Lovely*

3) The race for the highest level

In the world of interlocking puzzles there seems to be an ongoing race between puzzle designers worldwide to find the puzzle with the highest number of moves to take the first piece out (which is how the level of a puzzle is defined). The original 18 pieces burr only needed three moves and is therefore a level 3 puzzle. Bruce Love from Australia designed a puzzle with the same shape, but using different pieces. This was a great improvement on the original design. His design, called ***Lovely***, was a level 18 puzzle. No less than 18 consecutive moves were needed to get the first piece out. Incredible as this sounds, this was only the start of the race for finding high levels. In the days before computers, designing a puzzle like that was a painstaking and incredible labour intensive job. Finding an interesting combination of 18 pieces out of the trillions of combinations was far from easy. Finding a set of pieces with just one more move was considered a big step forward in these days. Brian Young (also from Australia) found a level 19 puzzle, called ***Coming of age II***, which came out in the 1990s and held the record for quite a while.

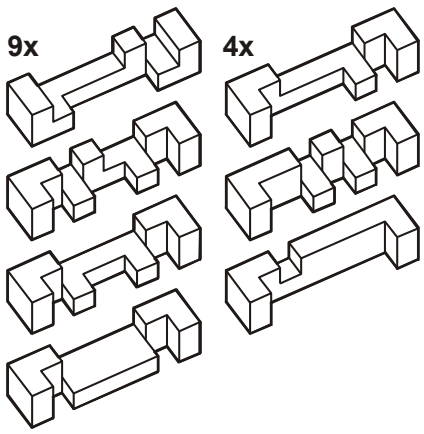

Figure 4. Pieces of *Burrloon*

When the computer entered the world of puzzle designers, this was a major improvement. Although it was not possible to calculate all the possibilities, checking a certain set of puzzle pieces for solutions had become a lot easier. A puzzle called ***Burrloon*** was designed by computer programmer Pit Khiam Goh from Singapore. It beat the record of 19 moves from Brian Young, and not just by one or two moves. To remove the first piece from the Burrloon puzzle no less than a staggering number of 33 moves was required. This puzzle has two other very interesting characteristics, the solution is unique and all the pieces are notchable. The pieces of Burrloon are shown in Figure 4.

In 2003, a puzzle collector from the Netherlands named Jack Krijnen improved the record again. His puzzle ***Tipperary*** has a wonderfully unique level 43 solution. The pieces are shown in Figure 5. At the time when I wrote an article on high-level puzzles in 2004, this was the highest level known for an 18-piece burr. Jack used a combination of techniques by hand and computer to find his high-level designs.

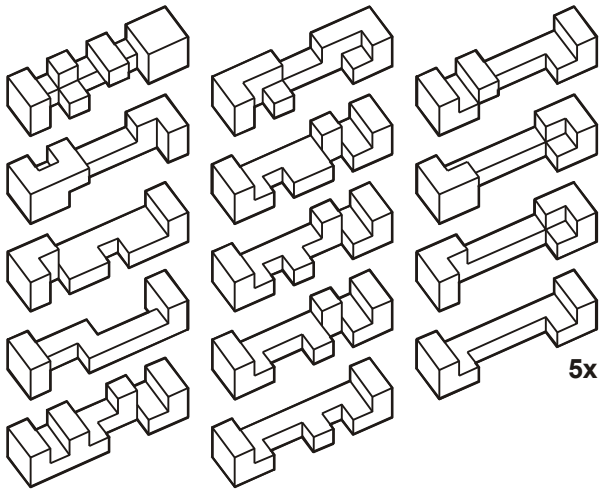

Figure 5. Pieces of *Tipperary*

4) Using new techniques

Finding a new and higher-level solution was still not easy, even with the help of a computer. Dic Sonneveld from the Netherlands came up with a new technique to find high-level puzzles. He used a system called 'burr-growing'. The basic idea is that you analyse an existing puzzle, find out where the vacant units are inside this puzzle, add a single cube to one of these voids and recalculate the puzzle. You can do this for each of the vacant units and then use this technique iteratively. Although this mechanism worked, it was a painstaking process of taking an existing puzzle, building a model of centicubes, figuring out the vacant spaces, adding a cube and then trying to disassemble the puzzle by hand and see if the level had gone up. Dic soon realised that it would be far easier to do this burrgrowing by computer. He wrote a program that started as a simple Word macro, but soon developed in a very complicated Visual Basic program, including many different options for effective burrgrowing. Although Dic Sonneveld did not use this program for 18-piece burrs, puzzle designer Pit Khiam Goh also started using this technique in his own software.

5) Higher and higher

With three different ways to design puzzles (studying mechanisms by hand, trying out many different sets of pieces and burrgrowing), new puzzle designs saw the light very frequently. Although it seems to be a competitive race to find the levels, puzzle designers share ideas and designs. In 2005 Jack Krijnen and Pit Khiam Goh joined forces and came up with ***Burrserk***, taking the record from 43 moves to 50.

Alphons Eyckmans from Belgium (one of the main designers of 18 piece puzzles) came up with a puzzle called ***Conder***, with a level 59 solution. Later that year Jack Krijnen designed a puzzle called ***Condor's Peeper***. Using three colours, the solution is unique, with a level 62 solution. All the pieces are notchable. Generally speaking, the higher the level, the harder it gets to use notchable pieces only.

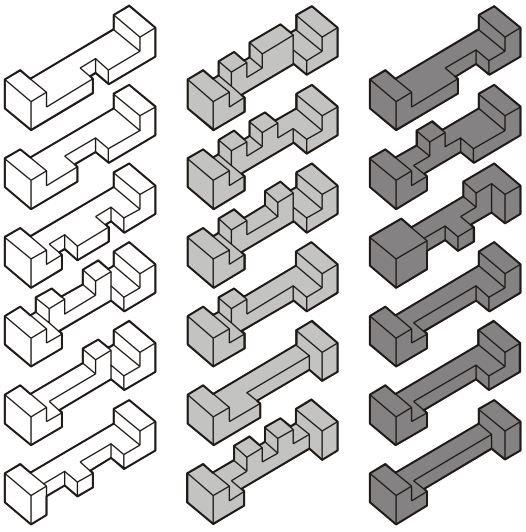

Figure 6. Pieces of *Condor's Peeper*

Using several different techniques and with puzzle designers worldwide focusing on these puzzles, bigger and bigger steps were made. An incredible leap forward was made by Alfons Eyckmans. His Phoenix puzzle almost doubled the number of moves from the previous design. It needed no less than 109 moves for the first piece, which is 47 moves more than the previous record! A small improvement to this design was made by Jack Krijnen who was able to crank the level up to 111 by changing two of the pieces. Alphons Eykmans once more took the lead with his Phoenix Cabracan design, needing 113 moves.

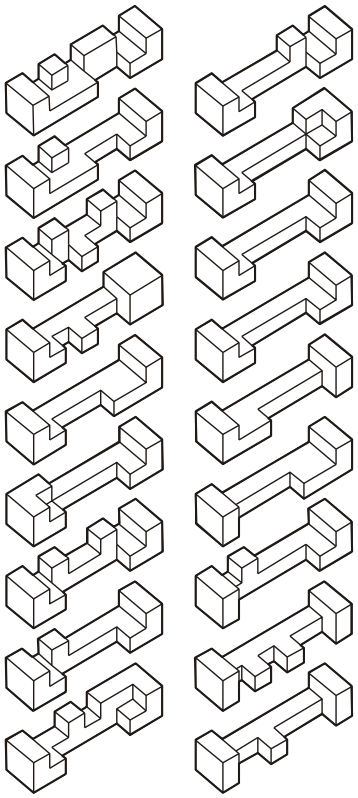

Figure 7. Pieces of *Phoenix*

Compared to the design of Lovely almost 100 moves were added! And still, this was not the end.

It was very hard to predict what more would happen. Sometimes minor improvements were made, raising the level with just one or two moves, but every now and then giant steps were reported. In early 2010 there was another one of these incredible leaps. The record of 113 moves seemed hard to beat, yet Alphons Eyckmans did it again. His design of ***Tiros*** has a level 150 solution. That is another 37 moves added. In regular interlocking puzzles, 37 moves is quite an achievement in itself, but in this case the previous record was impoved by 37 steps! A few months later Jack Krijnen came up with three different designs. One of these, called ***Burrly Sane for Extreme Puzzlers*** broke the record again by taking it to 152. In 2012 Alphons Eyckmans designed ***The Barones***, also with level 152.

In early 2013 Eyckmans and Krijnen joined forces and were able to raise the bar even further. Their joined design ***Excelsior*** had a level 156 solution. Their cooperation continued and led to the current record, which they set later that year. The design of ***Supernova*** is the current record holder with 166 moves. This number is truly mind-boggling. If you look at the puzzle in Figure 1 and tell people, that it will need 166 consecutive moves to get one piece out of the puzzle, they will think you are mad! And that piece will only come out if you make all the moves correctly! If you make a mistake somewhere on the way, it is very difficult to get back on track again!

The 166-move record is truly amazing, but there is no way of knowing what other designs with higher levels might be possible. Theoretically anything is possible, as we cannot do a full search. We will never know. Who knows, we might hit the 200 mark somewhere in the future.

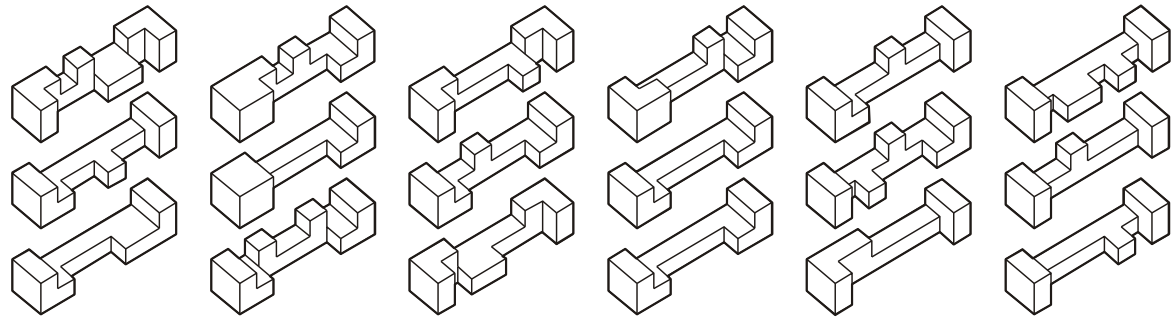

Figure 8. Pieces of *Supernova,* the current record holder

6) Solving puzzles by hand or by computer

The first 18 piece burr designed by Willem van der Poel was an interesting puzzle. With enough perseverance, it was possible to solve this puzzle by hand. This became a lot harder in the case of Bruce Love's Lovely. Taking the puzzle apart is doable (although not easy), but finding the right position and orientation of the pieces from scratch is close to impossible.

This puzzle, and many of its followers are therefore only of theoretical interest. It is virtually impossible to solve these by hand (although some are slightly easier than others). Despite the fact that it is almost impossible to solve these puzzles by hand, puzzle collectors are very keen to get a physical copy of such puzzles (me included). It is hard to determine whether these puzzle designs should be called inventions or discoveries. Surely, the help of a computer has played a vital role in the design of these puzzles, but that is just one part of the equation. If you buy a very expensive table saw, that does not automatically make you a good carpenter! Having good tools is important, but the experience and ingenuity of the puzzle designer is much more important.

7) Making 18 piece burr solutions unique

There is a direct relationship between the number of vacant units inside the assembled puzzle and the level of difficulty. If there are no holes, the puzzle has a level one solution by definition. As there is no room for internal movements, one or more pieces have to be taken out in the first step. The more holes you introduce in the puzzle, the more room there is for pieces moving without being taken out of the puzzle. If you study the level of the puzzle compared to the number of holes, you will notice that usually the higher the level, the more holes are present.

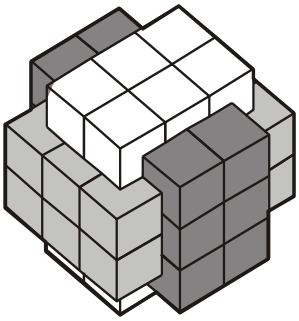

Figure 9.
X-/Y-/Z-colouring

Having many holes inside the puzzle also has a major downside. The number of different ways that the pieces can fit toghether goes up very rapidly. In some cases a certain set of pieces might fit together in millions of different ways. As discussed earlier, you preferable want a solutoin to be unique (only one way to fit the pieces together). This means that you have to use one or more tricks to force certain pieces in certain positions.

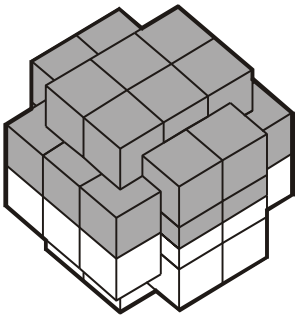

Figure 10.
'Chocolate-dip
'colouring

Using different colours for the pieces is an easy way to force pieces into a certain position. Using three different colours for each of the main axis is an easy way to do this. Apart from that, it will also add to the aesthetics of the puzzle. Although this helps a lot, it does not work in every case, so different ways of colouring or marking the pieces are needed. A second way to make a puzzle unique is to use a two colour scheme, comparable to a chocolate dip on an ice cream. Apart from using different colours for the pieces, you can also add markings on the pieces to force them into certain orientations and/or locations. A technique often used is to use a router to make an decorative edge along the ends of the pieces. This is very restricting. If you combine this with three different colours, almost any 18 piece burr can be made unique.

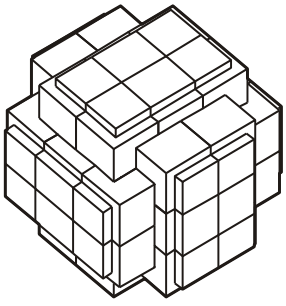

Figure 11.
Using decorative edges to make a puzzle unique

8) Pseudo 18-piece burrs

Some puzzles seem to be identical to an 18 piece burr, but they are actually different puzzles, disguised as the classic puzzle. Different type of puzzles have been designed like this. The simplest variation is to add an extra piece that is hidden inside the puzzle, as ***Save the Gorilla*** (by Alfons Eyckmans),

where a monkey shaped piece complements the 18 other pieces. Strictly speaking this is a 19 piece puzzle, but you cannot tell from the outside. Eyckmans designed six different puzzles like this. Stephan Baumegger also designed one, called ***Beware of the Snake***.

If you want to stick to the number of 18 pieces, there are other ways to make variations. Two puzzle designs called ***Hunchback 12*** and ***Hunchback 32*** were designed by Alphons Eyckmans. In these designs some of the pieces have extra cubes protruding their usual envelope. Some of the pieces are not 2x2x8, but 2x3x8. This is not visible from the outside though.

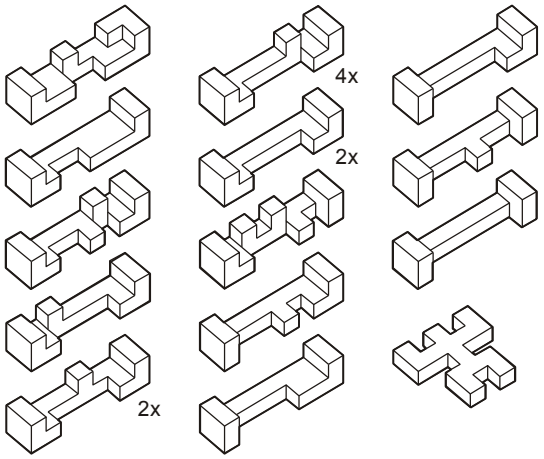

Figure 12. Pieces of *Save the Gorilla*

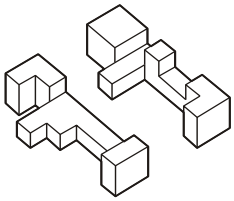

Figure 13. 2x3x8 pieces

Adding extra pieces or making subtle adjustments is relatively easy, but you can also do things the hard way. Jan Naert from Belgium came up with a puzzle called ***Delerium***. This puzzle has 18 pieces and looks just like the standard puzzle when assembled, but the pieces are a complete mess! Most of the pieces do not look like the original pieces at all. Alfons Eyckmans also designed two of these puzzles, called ***Mayhem*** and ***Nightmare***.

9) Other variations

The pseudo 18-piece burrs all look identical to the original puzzle on the outside, but piece numbers or pieces' shapes are different. There are other variations though. Several designs are known where one or more of the pieces are offset. Other variations are also possible, like framed or boxed versions. There are so many of these, that I can fill an entirely new article with those.

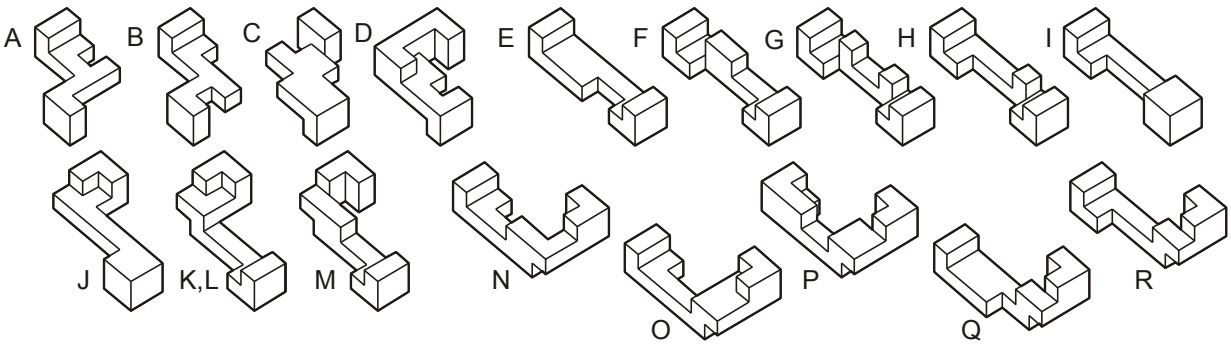

Figure 14. Pieces of *Delerium*

10) Conclusions

What seemed like a relatively simple puzzle has puzzled people for many decades. The introduction of the computer resulted in the race for high-level solutions. The results so far are incredible, but there is no way of knowing what other designs are possible. Doing a full analysis of all the possible pieces and their combinations seems to be well out of reach of today's technology. This probably adds to the myth of the 18 piece burr.

References

[1] http://www.puzzlewillbeplayed.com/-/burr-18t.xml#burr-18t