

Further Notes on the Game of Three-Dimensional Life

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The game of three-dimensional Life, a cellular automaton that exhibits in three dimensions properties similar to John Conway's famous two-dimensional game, was discovered in 1986. Four "life supporting" rules in the cubic universe have been found. These are Life 4555, Life 5766, Life 5655, and Life 6855. The first two numbers give the range of living neighbor cells permitted for a currently live cell to remain so; the second pair gives the range of the number of neighbor cells required to bring a currently dead cell to life. Thus, 4555 means that a living cell must touch 4 or 5 live cells to remain alive and a dead cell must touch exactly 5 to become alive. Conway's rule is 2333.

Each of these rules supports one or more gliders (translating oscillators), some of which are easy to discover and others which are quite rare, turning up only after a considerable number of random "primordial soup" experiments have been performed. Here we present four newly discovered gliders—two for Life 5655 and two for Life 4555. The discovery of more gliders for Life 5655 is particularly surprising because this rule appears just barely to sustain life; that is, almost all primordial soup experiments tend to thin out quite rapidly and leave little or no residue (see [5]). The discovery of new gliders for Life 4555 is rather gratifying because this was the first three-dimensional life rule found and in many ways is still the most fascinating.

The discovery of these four new gliders would probably not have occurred without the use of "symmetric primordial soup." Figure 1 shows the various types of symmetry that have been imposed upon small, otherwise random initial cell configurations (roughly $8 \times 10 \times 10$ in volume), which were placed in the center of a large, otherwise empty universe (about $45 \times 45 \times 45$). Gliders were discovered by performing experiments until some configuration hit the edge of the universe (see [4] for details), checking its signature (see [3]) to find out if it had appeared before, and writing it to a file if it was new. These experiments were all performed on a DECstation 3100.

The two new Life 4555 gliders are illustrated in Figure 2 along with their signatures. The two gliders are similar, with differences appearing only in the "tail sections." To discover these two gliders we used the initial primordial symmetry shown in Figure 1(7). Even with symmetric primordial

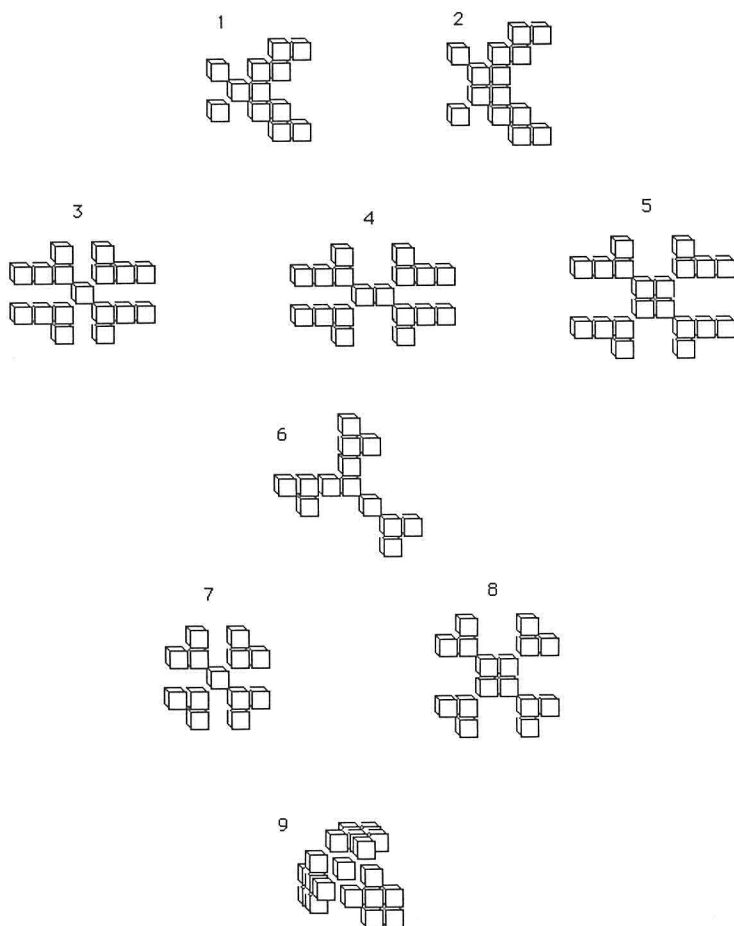


Figure 1: Various types of “symmetric primordial soup” were employed. Usually the initial configurations occupied about an $8 \times 8 \times 10$ area at the center of a $45 \times 45 \times 45$ universe. Here in (1) through (8), a slice from a typical configuration shows the particular type of symmetry utilized. In (9) we see a three-dimensional configuration that is symmetric about a long diagonal through the cubic universe. So far, experiments run with this type of symmetry have yielded no gliders.

soup experiments these gliders are extremely rare objects, requiring about one million experiments before appearing.

The new Life 5655 glider (Figure 3) is likewise a very rare object, requiring the primordial symmetry shown in Figure 1(8) to show itself. The peculiar 5655 glider illustrated in Figure 4 has the unusual period of seven and seems to struggle particularly hard in order to get anywhere, having moved only one

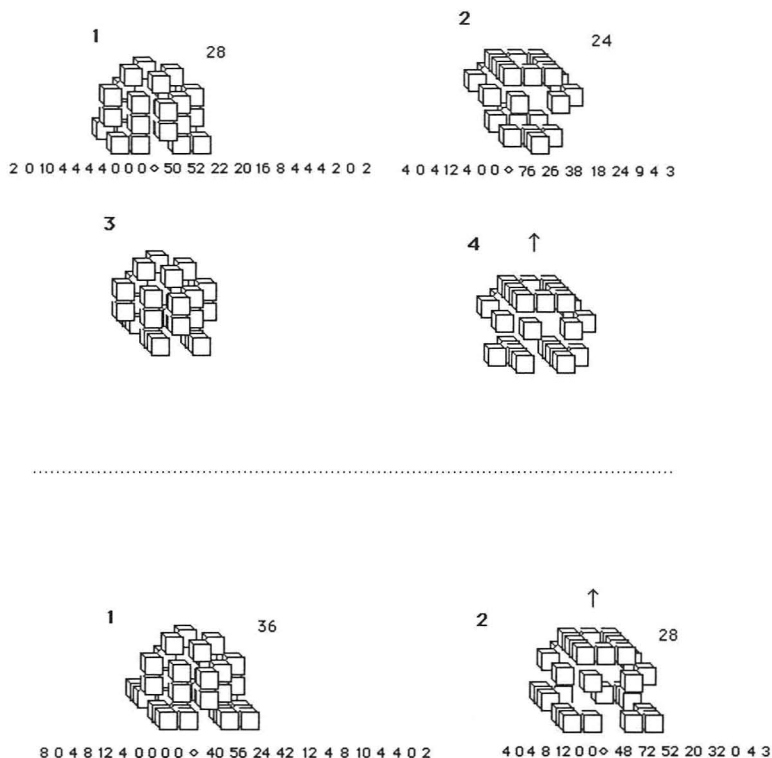


Figure 2: The two new gliders for Life 4555 are similar. They differ only in their “tail sections,” their periods, and their signatures (see [3]). The small number at the right gives the current count of live cells.

diagonal cell after its seven-generation cycle. Its primordial soup experiments required the symmetry illustrated in Figure 1(6). It appears to be more common than the other three gliders pictured; nevertheless, it is unlikely that any of these gliders would have been discovered in a reasonable time by utilizing strictly random primordial soup.

Summary of gliders

All gliders discovered to date are depicted in Figure 5. The two original gliders, discovered in 1986 (see [1] and [2]), are the 4555 and 5766 gliders at the top. The others required symmetric soup to be ferreted out, except for the period-eight 5766 (see [4]), the period-three 6855, and the small period-two 6855 (see [6]). Nevertheless, without the use of symmetric soup these three make their appearances much less frequently than the two at the top of the figure.

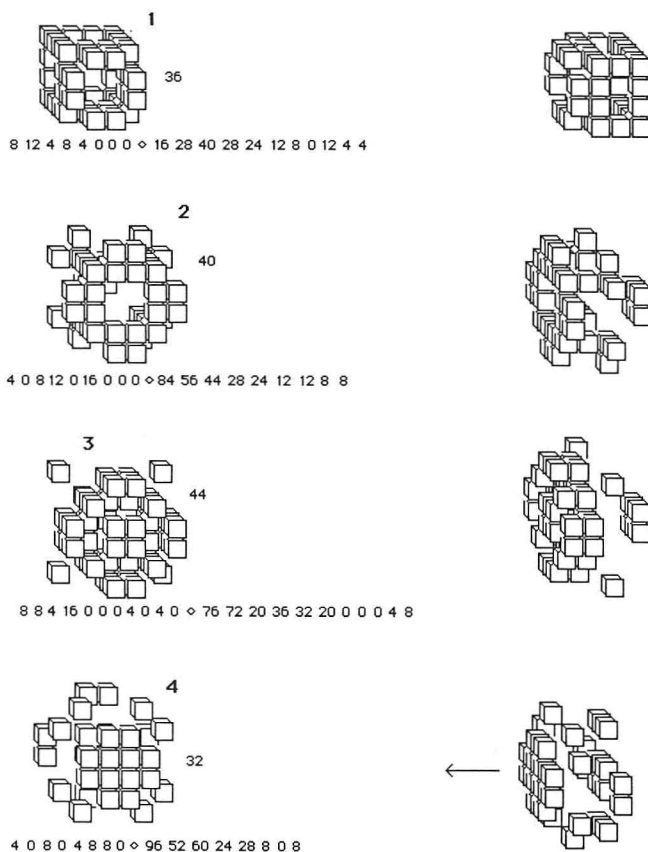


Figure 3: One of the new Life 5655 gliders has a period of 4, after which it has moved a distance of three units in the direction shown. Below each phase is the signature; at the right we see the glider from another view.

Depicted at the bottom are the gliders for two games of Life in a universe of dense packed spheres. Since these gliders were discovered without symmetric soup experiments, it is possible that further experimentation with varieties of symmetry might yield some more complex gliders for one or both of these rules.

For each glider in Figure 5 two views are given. The parentheses contain the period followed by the relative movement accomplished by one period. (The edge of a cubic cell is considered to be unit length, as is the diameter of a spherical cell.) The gliders depicted here represent all that have turned up after millions of experiments have been performed for each Life rule using all of the different types of symmetry depicted in Figure 1. This is not to imply that no others exist. To discover the scarce and rare gliders, we used a 1991

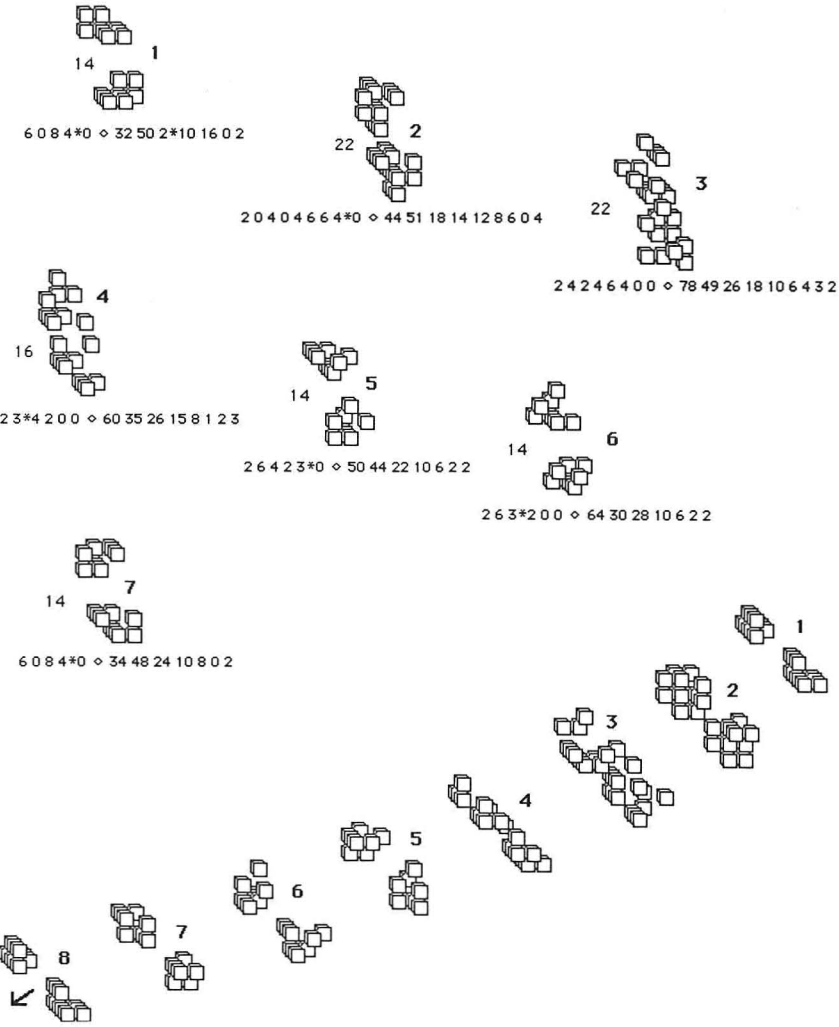


Figure 4: This peculiar Life 5655 glider has a period of 7, after which it has moved a distance of $\sqrt{2}$ as shown. This glider was found by starting experiments with random symmetric soup of the type shown in Figure 1(6). Below each phase is the signature ($u * v$ means that the digit v appears u times).

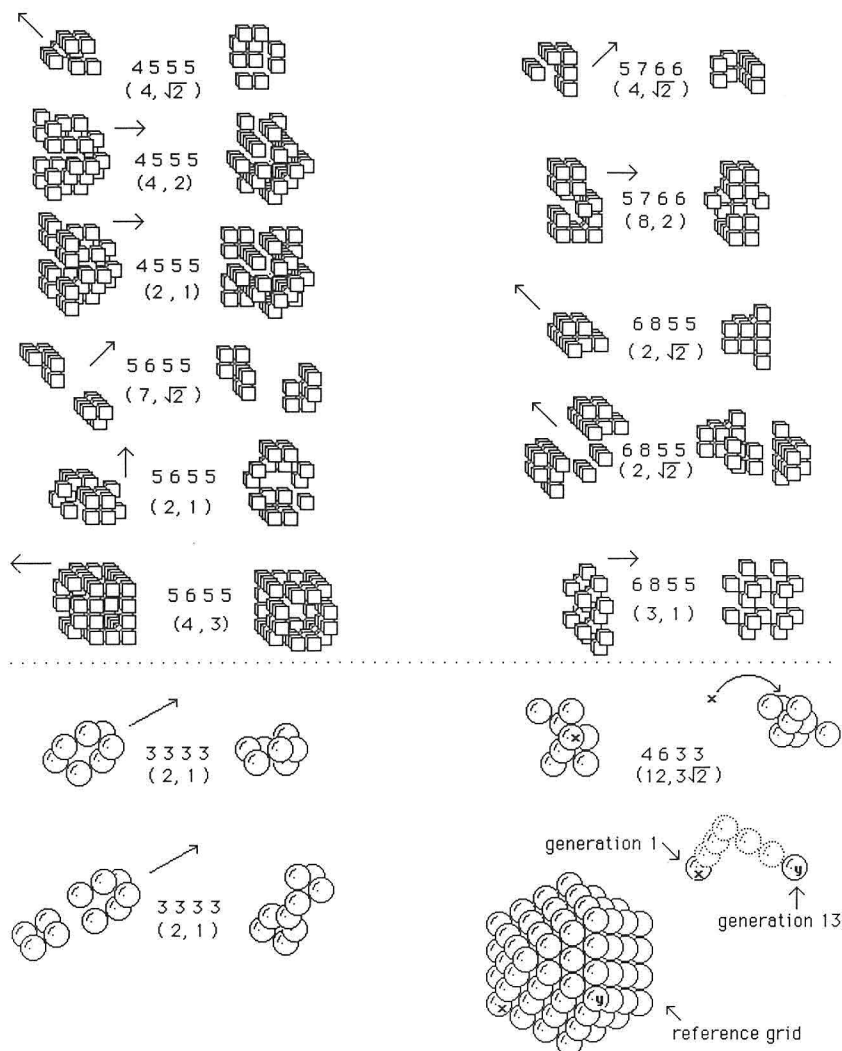


Figure 5: Here we show all three-dimensional Life gliders known to date. Two views for each are shown. The numbers in parentheses give the period and the distance moved after one period; the arrow shows the direction. Gliders below the dotted line run under Life games defined in the universe of dense packed spheres, where each cell has twelve touching neighbors. These three sphere-based gliders show up frequently in random soup experiments with no symmetry imposed. A unit length is defined as the edge of a cube or the diameter of a sphere.

program with a $50\times$ speed improvement over the original (1986) program. Perhaps another $50\times$ improvement will yield some exotic new gliders—or possibly another three-dimensional game of Life.

References

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