Gliders in One-Dimensional Cellular Automata

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Gliders are non-trivial complex patterns emerging typically in complex cellular automata (CA). The most famous glider (mobile self-localizations, particles, waves) is the five-live cells glider moving diagonally in five steps in the two-dimensional CA Conway's Game of Life [59]. Gliders are abstractions of travelling localizations often found in living systems, and used to derive novel properties of objects in artificial life, complex systems, physical systems, and chemical reactions. Examples include, gliders in reaction-diffusion systems [3, 125], Penrose tilings [63], three-dimensional glider gun [2], gliders in hyperbolic spaces [98].

Gliders are found in one-, two- and three-dimensional automata, in complex cell state transition rules and chaotic rules. All space-time configurations of cellular automata (CA), shown in this chapter, use gliders in one dimension and are coded using regular expressions derived from the de Bruijn diagram and tiling theory. We use filters to eliminate the periodic background and to get a better view of gliders. The filters are useful tools for inspecting details of glider collision, especially when configurations are very large.

Pictures shown here are space-time configurations of elementary CA rule 110 [101]. In 2004 Cook demonstrated that the rule 110 CA is universal because it simulates a cyclic tag system. The cyclic tag system if programmed into an initial configuration of CA. The processing of just four values on the tape of this machine requires over three millions of cells [32, 165, 108, 31].

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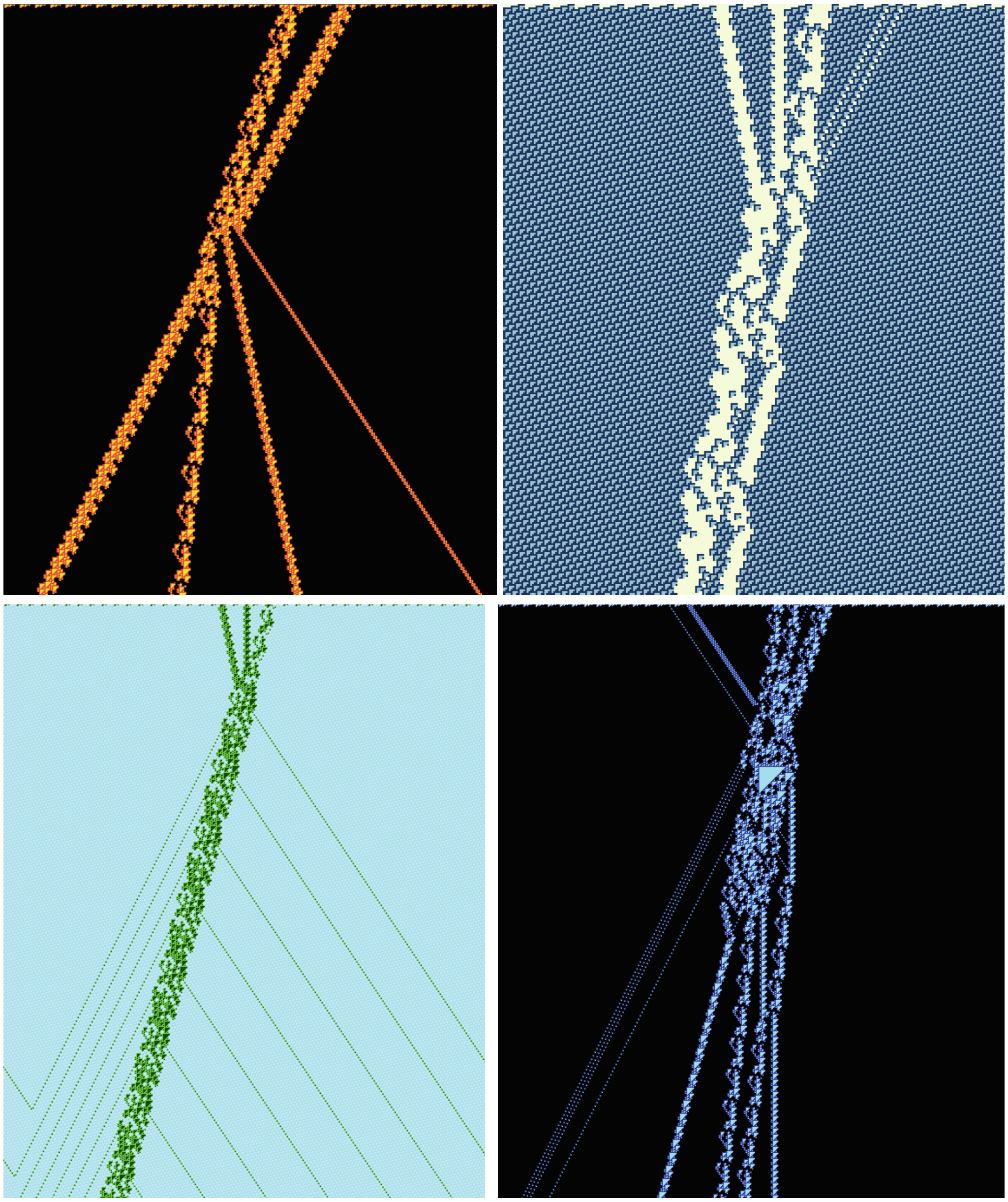
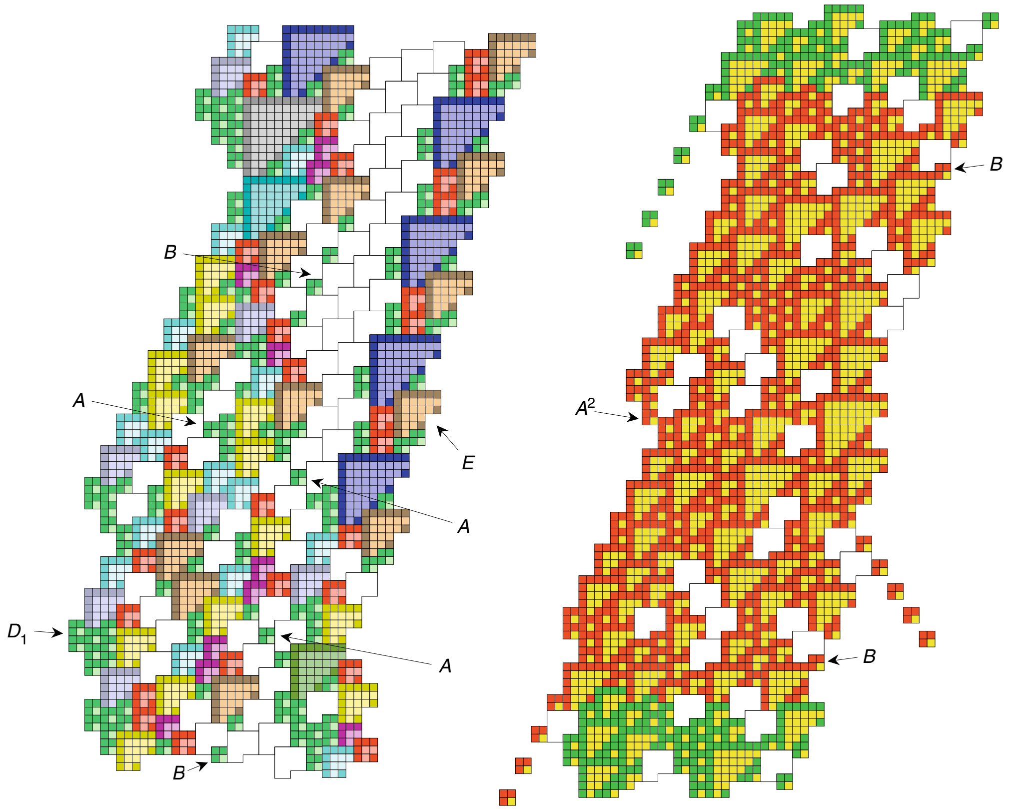
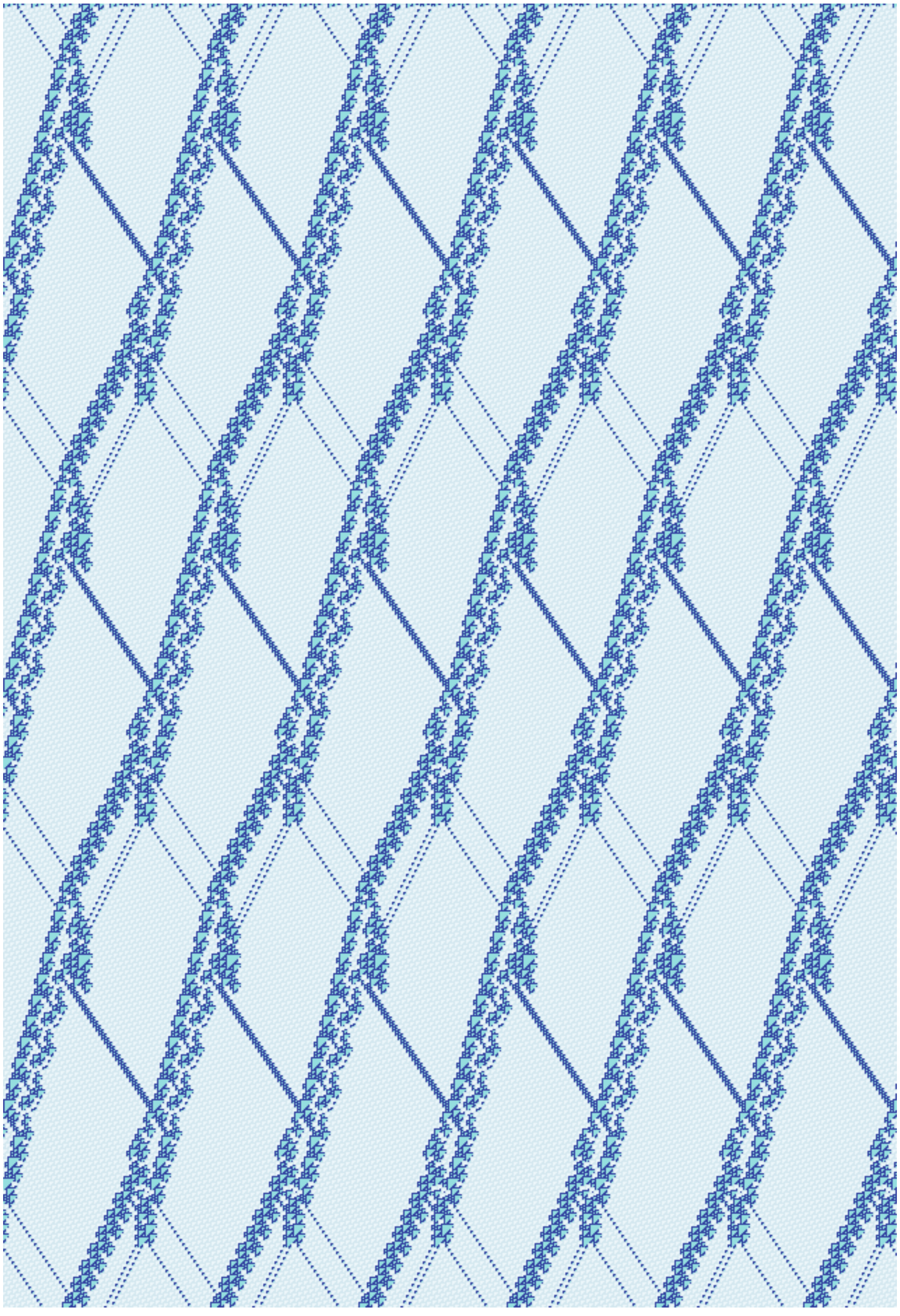


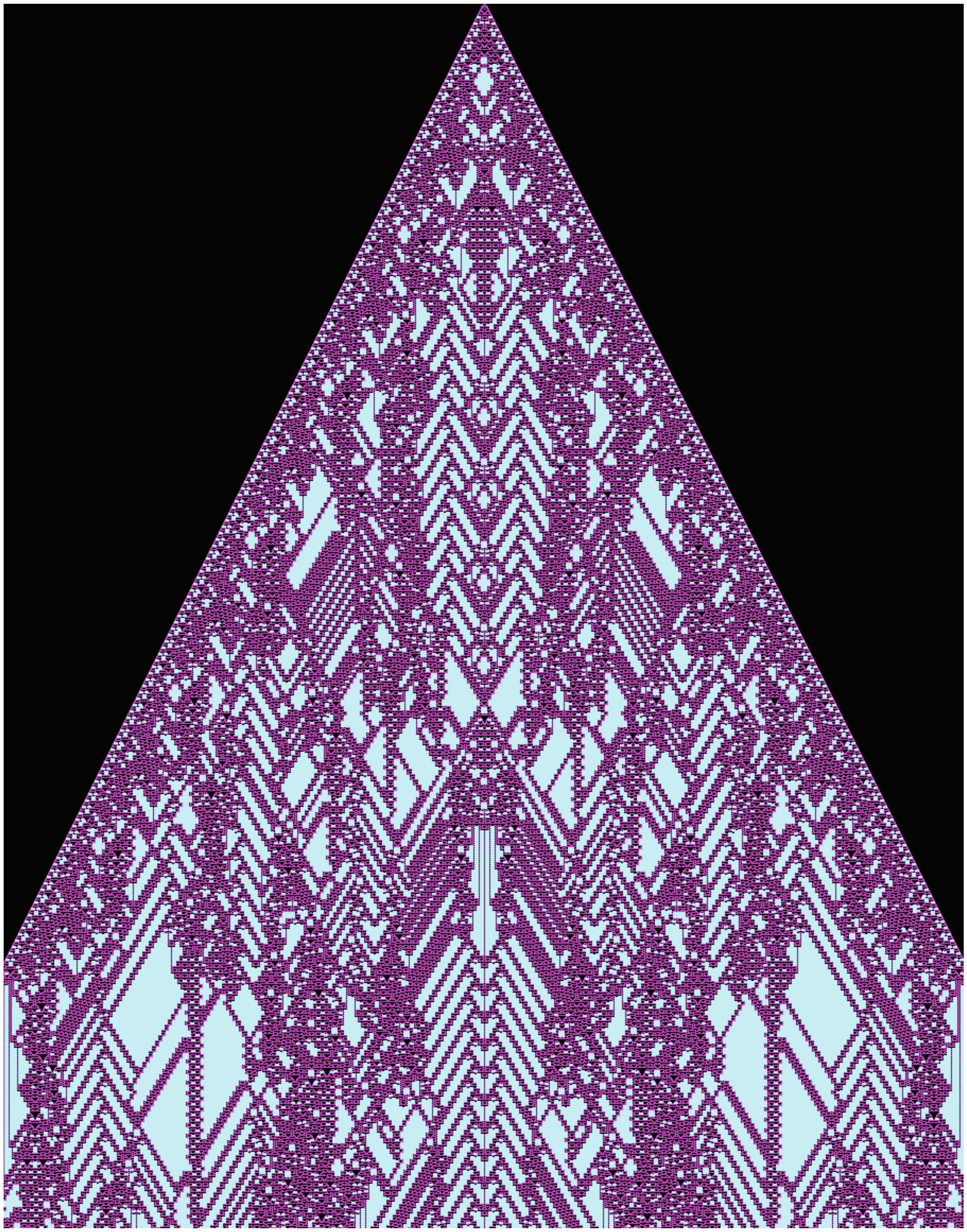
Collisions in rule 110. ©2010 Genaro J. Martínez. Elementary CA rule 110 displays a non-trivial behaviour first discovered by Wolfram in 1986 [163]. The rule is proved to be a universal by simulating a cyclic tag systems [32]. Rule 110 support 12 gliders and one glider gun [106, 115]. Top left pattern shows a collision between two gliders (G and $\bar{B}$ in Cook's nomenclature), splitting in four gliders ($\bar{B}$, F, D_2, and A^3). After the collision, one glider continues along its original trajectory while second splits into five gliders. Top right picutre displays a collision between five gliders (D_1, C_3, F, and $2B$), they produce a larger glider (H) in the result of the collision. Bottom left picture shows a triple collision (D_1, C_1, and $\bar{E}$) that results in formation of a glider gun. Bottom right space-time configuration show collision between gliders to get a big tile in rule 110; ten gliders (A, A^5, $2F$, B, and G) are necessary to yield a T_{30} tile [107].



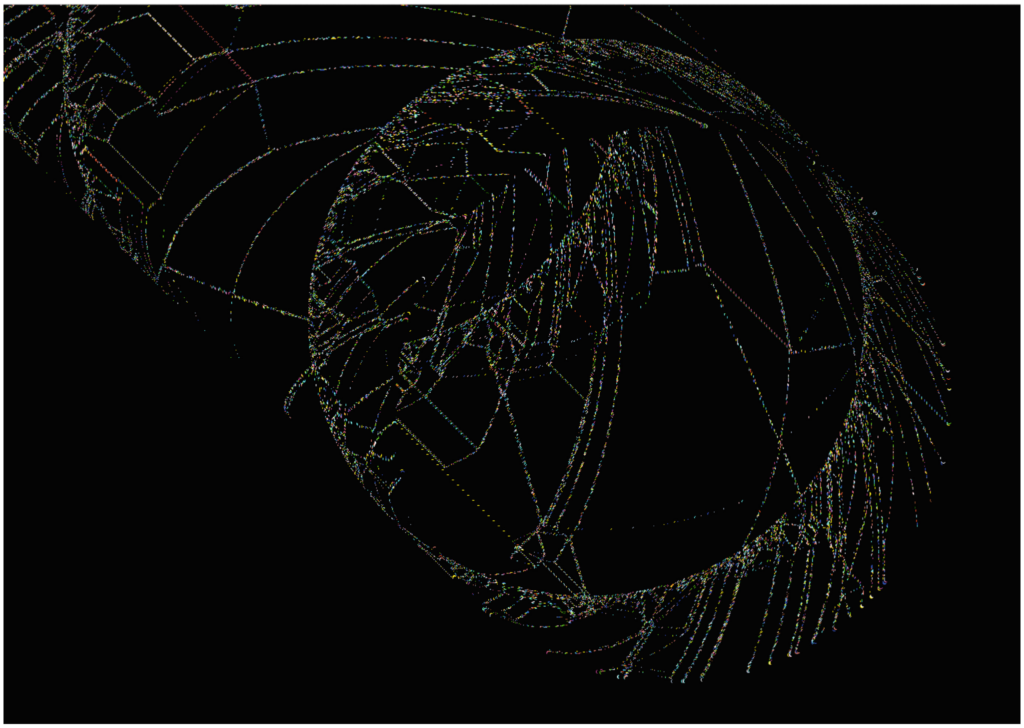
Tilings and Complex Dynamics ©2001 Genaro J. Martínez. The automaton rule 110 displays a diversity of gliders (mobile self-localizations, particles, waves). The rule 110 can be assembled just with polygons. This figure shows in full details what is the number of polygons, kind, interaction, and position to construct a *H* glider (largest glider in rule 110) and a glider gun [106].



Meta-Glider in Rule 110 ©2007 Genaro J. Martínez. A meta-glider is constructed with a lot of gliders colliding, these collisions are synchronised and repeated cyclically. These meta-gliders are very sensitive to any external perturbation and they can be destroyed in few steps. Elementary CA rule 110 supports a number of meta-glider constructions [109]. This simulation displays a concatenation of five gliders colliding in different times to get a new series of six gliders. To synchronise the whole set of collisions we use the phase codification of the gliders. The collisions between gliders can be also seen as solitonic collisions [103].



Gliders in CA with Memory ©2010 Genaro J. Martínez.
In CA with memory cells update their states depending on cumulative states of their neighbourhoods [14]. A systematic analysis of CA with memory is done in [102]. In [110] we shown that a 'classical' chaotic rule — rule 126 — exhibits a complex behaviour when equipped with majority memory. CA with memory $\phi_{R126maj:4}$ display an amazing range of collisions between gliders. The space-time configuration shows evolution of the binary CA from one cell in state '1' during one thousand of generations. Colours represent different periodic backgrounds.



CA Collider ©2011 Genaro J. Martínez. Computations in CA are implemented from von Neumann's era till present, and a number of different designs have been produced [100] using signal interaction, glider collisions, tiling assembling, self-reproduction machines, or deriving formal languages. In [111, 105] we shown how to implement computation in one-dimensional CA using cyclotrons and virtual colliders. Our CA collider works with a finite set of cyclotrons. We design a finite state machine where nodes are meta-nodes than represent states of a set of gliders. A transition between two nodes of the CA collider is a result of cascaded collisions between gliders. This figure shows how a number of gliders travel a long of a cyclotron, and the history of all collisions and trajectories are projected in three dimensions. This simulation presents thousand of gliders in 20,000 cells space. All non-trivial patterns are represented just as dots. Details of any particular structures are not relevant just the kind of collision and its result. An interesting design relates several cyclotrons synchronised to simulate a cyclic tag system in rule 110 in a virtual collider [104].