TRANSITION DYNAMICS TO COMPLEX RULES IN ELEMENTARY CELLULAR AUTOMATA FROM WOLFRAM CLASSES

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ABSTRACT
We overview the basis of Elementary Cellular Automata and Wolfram's Classes, subsequently we show a technique known as Memory Based Rule Analysis, to extract complex systems from a family of chaotic discrete dynamical system . Cases of study rules 30 and 126.

KEYWORDS: Cellular automata, elementary cellular automata, memory, complex dynamic, chaos, rule 30, rule 126.

CELLULAR AUTOMATA

Cellular Automata (CA): Computing model which provides a good platform for studying emergent collective behaviour, complexity, randomness and interaction between order and chaotic systems.

Defined by a four tuple (G, Z, N, F), where:

- G -> Grid (Set of cells)
- Z -> Set of possible cell states
- N -> Set which describes cells neighbourhoods
- F -> Transition function (Rules of automata)

Basic characteristics:

Locality: Each cell can communicate with adjacent cells.

Parallelism: CA performs computations in a distributed fashion on a spatially extended grid.

Simplicity: A cell has a simple structure. If i^{th} cell have to make a transition, it has to depend on own state, left neighbour and right neighbour either.

$$q_i(t+1) = f(q_{i-1}(t), q_i(t), q_{i+1}(t))$$

WOLFRAM'S CLASSIFICATION

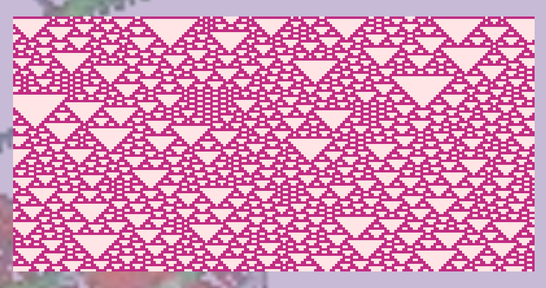
Class I: **Homogeneous** behaviour

Rule 160

Class II: **Periodic** behaviour

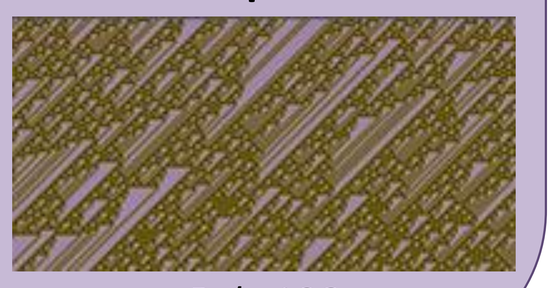
Rule 73

Class III: **Chaotic** behaviour



Rule 126

Class IV: **Complex** behaviour



Rule 106

ELEMENTARY CELLULAR AUTOMATA

Elementary Cellular Automata (ECA): The most basic 1-D CA representation. Alphabet $\Sigma = \{0,1\}$, Evolution rule $\varphi(x_{i-1}^t, x_i^t, x_{i+1}^t) \rightarrow x_i^{t+1}$ Domain D: $(2,1) = 256\, rules$

ECAM, UECAM AND COMPLEX ECAM

Elementary Cellular Automata with Memory (ECAM): A ECA composed with a memory function, i.e. act in a historical mode .

Memory function (MF): Help to discover hidden information in dynamical systems from simple functions (majority, minority, parity) or rules and transform simple and chaotic rules to complex rules or vice versa.

$$chaotic\ ECA \xrightarrow{\text{memory}} complex\ ECA$$

Classification:

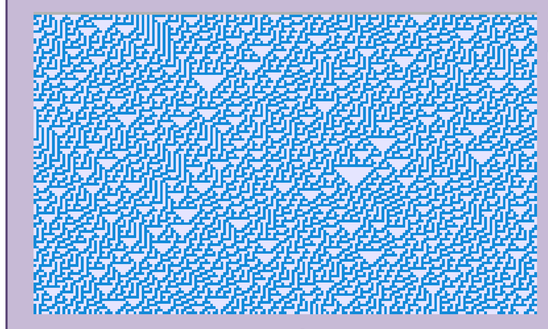
- *Strong*: MF are unable to transform one class to another.
- *Moderate*: MF can transform the rule to another class and conserve the same class as well.
- *Weak*: MF do most transformations and the rule changes to another different class quickly.

Properties:

- *UECAM*: Able to reach every different class called universal .
- *Complex-ECAM*: Yield a complex ECAM but with elements of the original ECA rule.

TRANSFORM A CHAOTIC RULE TO A COMPLEX SYSTEM BY USING MEMORY

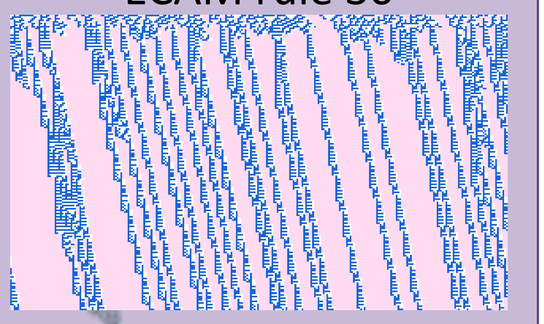
ECA rule 30



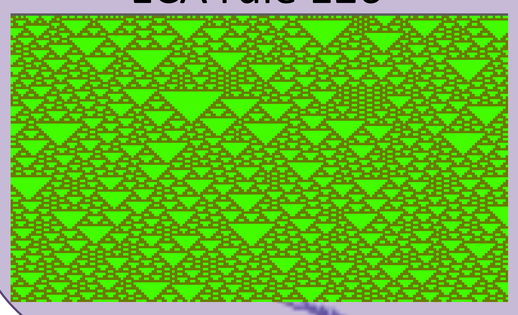
ϕ_{maj}

$\tau = 8$

ECAM rule 30



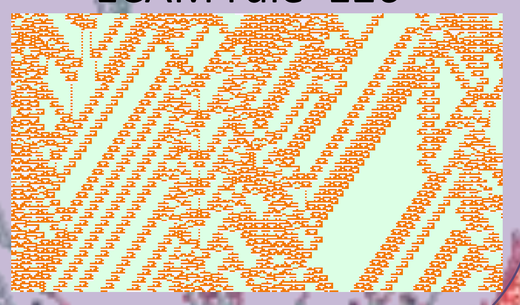
ECA rule 126



ϕ_{maj}

$\tau = 4$

ECAM rule 126



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