4. Summary
3. Tannion’s Lambda Parameter
2. Wolfram’s CA Classification
1. Universal Computation

Lecture 10: Cellular Automata and Complex Systems
2. A is false: the gun propagates freely towards the output; the result is true.

The result is false.

1. A is true: the slider of a block the gun that then cannot join the output.

Not Gate
A. A and B are true: A blocks the bottom gun, B can join the output.

B. A is false and B is false: A blocks the bottom gun, B blocks the B slider.

3. A is false and B is true: The bottom gun blocks B which cannot join the output.

4. A and B are true: A blocks the bottom gun, B can join the output.
up gun's either can join the output.
4. A and B are true: A blocks the bottom gun, B is stopped by the gate, the

3. A is false and B is true: B blocks the bottom gun.
2. A is true and B is false: A blocks the bottom gun.
1. Both A and B are false: the up gun is blocked by the bottom gun.
Wolfram's CA Classification: Class I

- Class I CAs are also similar to dynamical systems that fall into a fixed point.
- Execution steps.
- Class I CAs are very much like trivial programs that halt after only a few
  iteration steps.
- Class I CAs always evolve to a homogeneous arrangement, with every cell
  becoming the same state, never to change again.
Simple periodicity in the finite-sized space and unbounded periodicity.

execute in an infinite loop, or dynamical systems that fall into limit cycles.

Class II CAs are repetitive and bear some resemblance to programs that

number of states.

Class II CAs form periodic structures that endlessly cycle through a fixed

Wolfram's CA Classification: Class II

Your Liu
system back into chaotic behavior.

Similar to Class II CAs, however, any slight perturbation will force the

With the right starting state, Class III CAs might have regular behavior

Class III CAs are sensitive to initial conditions.

- Guaranteed to never repeat themselves.

- Given a finite space of reasonable size, Class III CAs are almost

Class III CAs have been compared to chaotic dynamical systems.

- Compared with Class I CAs.

Class III CAs are so random-like that they have opposite configurations.

Wolfram's CA Classification: Class III
configuration of a Class III CA is sensitive to a slight variations.
produce a dramatically different sequence just the way the initial
With a slightly different seed, a pseudo-random number generator will
randomness. Given an initial seed, a pseudo-random number generator can produce

Class III CAs and Pseudo-Random Number Generators
capable of universal computation.

The Class IV CA can perform computations with some of them being

between chaos and periodicity.

The dynamical behaviour of the CA as a whole is hovering near boundary.

Random, instead, it contains a little bit of each of these types of behavior.

It is difficult to describe a Class IV CA. It is not regular, periodic, or

Wolfram’s CA Classification: Class IV
How do we view a CA rule space in such a transition?

- Class IV is somewhere between other classes.

- Of Class I, Class II, Class IV, and Class III.

There appears to be a transition in CA rule space that proceeds in the order
\[ \frac{N}{b \mu - N} = \lambda \]

**quiescent state**

- Let \( N \) be total number of rules, and \( b \mu \) the number of rules that map to the other states.
- Let \( \lambda \) be \( \frac{N}{b \mu - N} \) for the quiescent state (inactive or off), and others will map into the cell to the quiescent state.
- Split rule types into two distinct sets. One set includes all rules that map a cell in the quiescent state into the quiescent state, and another set includes all rules that map a cell in the quiescent state into other states.
- If Class IV is truly between Class II and Class III, there must be some way to distinguish these classes.

**Tanton’s Lambda Parameter**
the most heterogeneous rule tables.

\[ \frac{2}{T} - 1 = 1 \]

represents the most homogeneous rule table, and \( \lambda = 1 \) respectively.

\[ \lambda = 1 - \frac{2}{T} \]

state stability speaking, all states will be represented equally.

\[ \lambda = 1 \]

means all rules map to non-quiscent states;

\[ \lambda = 0 \]

means all rules map to the quiscent state.

Values of Lambda Parameter
Regions of rule space.

Complex cases reside somewhere between the periodic and the random.

- For the complex Class IV, the average of the three $\lambda$ values is 0.50184.
- Which is near the extreme of $\lambda = 0.8$.
- For the random-like Class III, the average of the three $\lambda$ values is 0.8164867.
- For the random-like Class II, the average of the six $\lambda$ values is 0.43941967.
- Of $\lambda = 0$. 0.22823267. They have simple behavior because they are near the extreme.
- For the fixed point-like Class I, the average of the three $\lambda$ values is

Examples
GA Rule Space Characterized by the $\lambda$ Parameter
prove the possibility of life appearing in these universes.

capability to construct arbitrary complex structures, is not sufficient to

2. The universal computation capability of some cellular automata, i.e., their

do complex natural systems.

autonomous behavior may then yield rather general results on the behavior

mathematically modeled provided by cellular automata. Knowledge of cellular

systems may lie in the same universality classes as the idealized

virtual completely known universes. Thus complex physical and biological

I. Cellular automata are abstract structures which make it possible to study

Summary