Signal Machines: Euclidean dynamical system

Introduction and universalities

Florent Becker[1], Jérôme Durand-Lose[1]
Mohammad-Hadi Foroughmand-Araabi[2] and Sama Goliaei[3]

[1] Laboratoire d'Informatique Fondamentale d'Orléans, Université d'Orléans, france
[2] Sharif University of Technology, Tehran, Iran
[3] University of Tehran, Tehran, Iran

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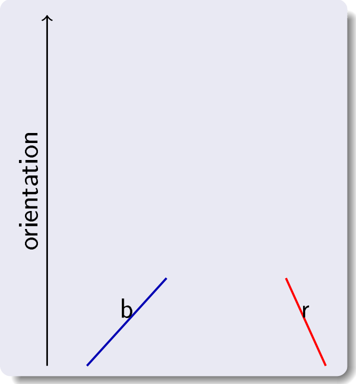
Self Completing Drawing

2D Euclidean Space

- color line segments
- orientation (not going back)



Self Completing Drawing

2D Euclidean Space

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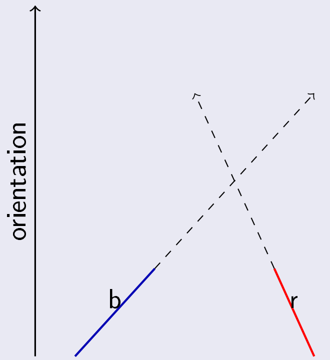
- orientation (not going back)

- Potential enlargement
- Intersection



Self Completing Drawing

2D Euclidean Space

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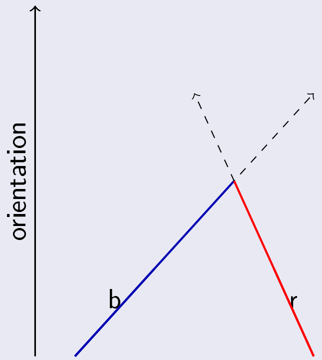
- Extension



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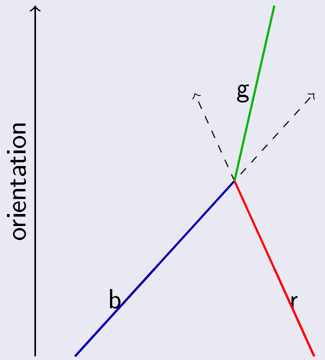
Rewriting/Collision rule

- $\{b, r\} \longrightarrow \{g\}$



Self Completing Drawing

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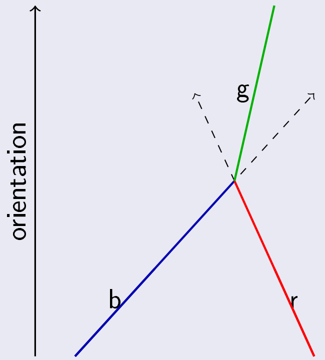
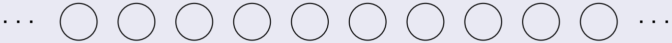


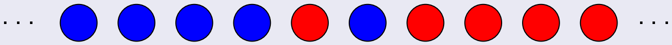
Direction/Slope Imposed by the Color

- (easier)
- origin of the model

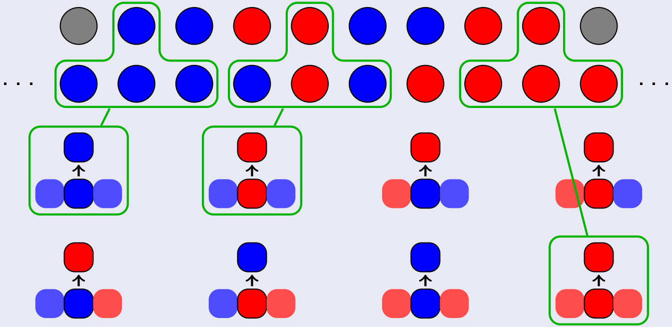
Cellular Automata



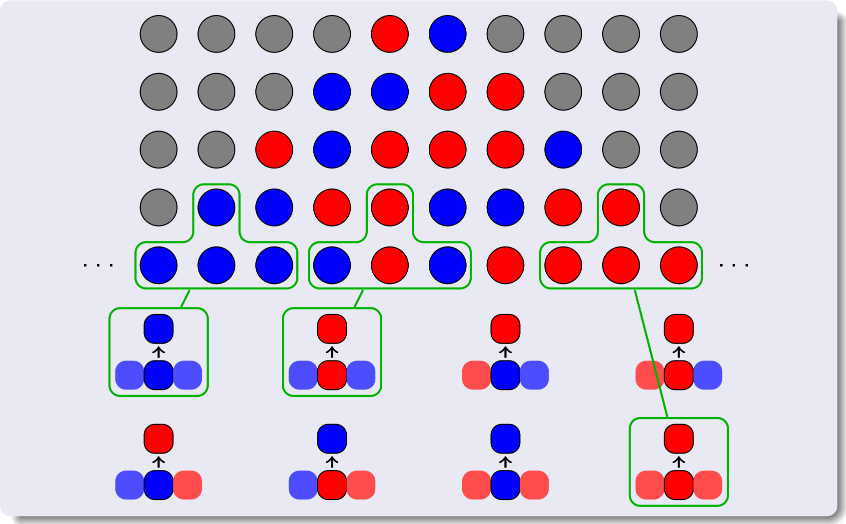
Cellular Automata



Cellular Automata



Cellular Automata



Cellular Automata: Signal Use

Firing Quad Synchronization [Goto, 1966]

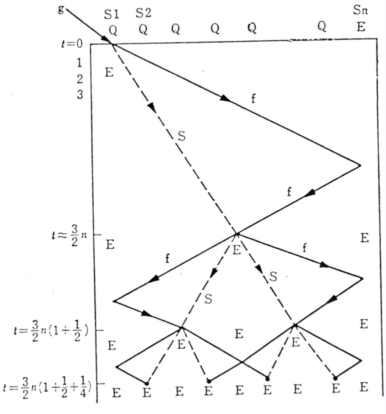
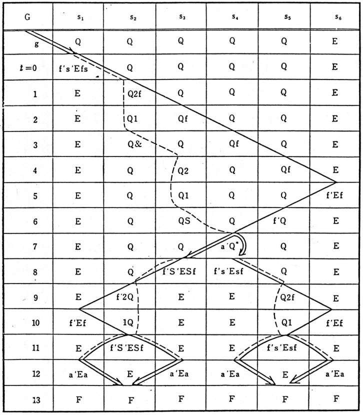


図 3·5 一斉射撃の問題（連続近似）



G	s_1	s_2	s_3	s_4	s_5	s_6
g	Q	Q	Q	Q	Q	E
t=0	f's'Efs	Q	Q	Q	Q	E
1	E	Q2f	Q	Q	Q	E
2	E	Q1	Qf	Q	Q	E
3	E	Q&	Q	Qf	Q	E
4	E	Q	Q2	Q	Qf	E
5	E	Q	Q1	Q	Q	f'Ef
6	E	Q	QS	Q	f'Q	E
7	E	Q	Q	a'Q*	Q	E
8	E	Q	f'S'ESf	f's'Esf	Q	E
9	E	f'2Q	E	E	Q2f	E
10	f'Ef	1Q	E	E	Q1	f'Ef
11	E	f'S'ESf	E	E	f's'Esf	E
12	a'Ea	E	a'Ea	a'Ea	E	a'Ea
13	F	F	F	F	F	F

図 3·6 一斉射撃解 ($n=6$)

CA: Signal Design

Generation of Primes [Fischer, 1965]

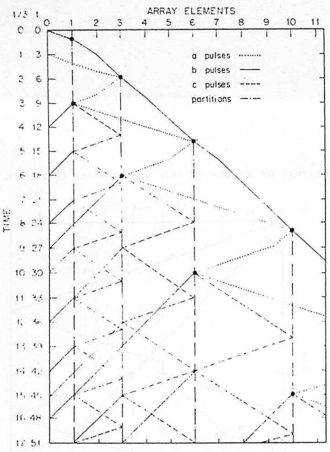
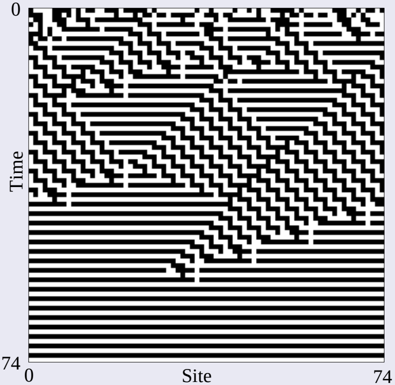


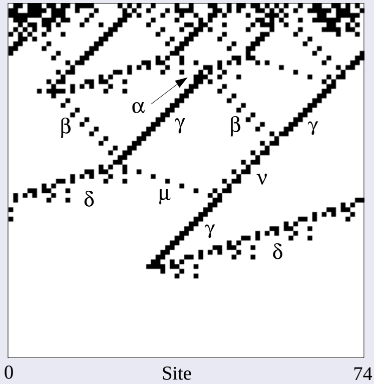
FIG. 2. Solution to the prime problem

CA: Signal Analyzing

(Evolutionary generated) Automatic blinking [Das et al., 1995]

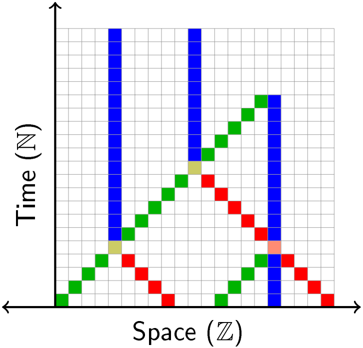


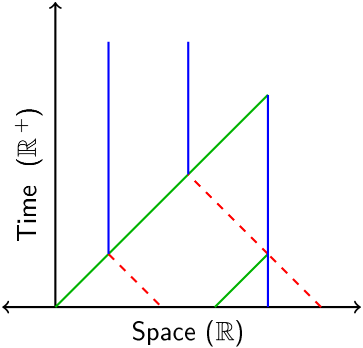
(a) Space-time diagram.



(b) Filtered space-time diagram.

Signals





- Signal (meta-signal)
- Collision (rule)

Vocabulary and Example: Find the Middle

Meta-signals (speed)

M (0)

Collision rules

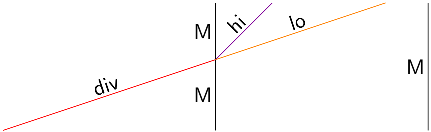
Vocabulary and Example: Find the Middle

Meta-signals (speed)

M	(0)
div	(3)

Collision rules

Vocabulary and Example: Find the Middle



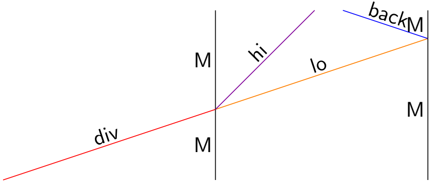
Meta-signals (speed)

M	(0)
div	(3)
hi	(1)
lo	(3)

Collision rules

$\{$ div, M $\} \rightarrow \{$ M, hi, lo $\}$

Vocabulary and Example: Find the Middle



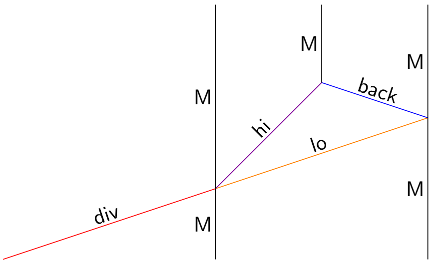
Meta-signals (speed)

M	(0)
div	(3)
hi	(1)
lo	(3)
back	(-3)

Collision rules

{ div, M } $\rightarrow$ { M, hi, lo }
{ lo, M } $\rightarrow$ { back, M }

Vocabulary and Example: Find the Middle



Meta-signals (speed)

M	(0)
div	(3)
hi	(1)
lo	(3)
back	(-3)

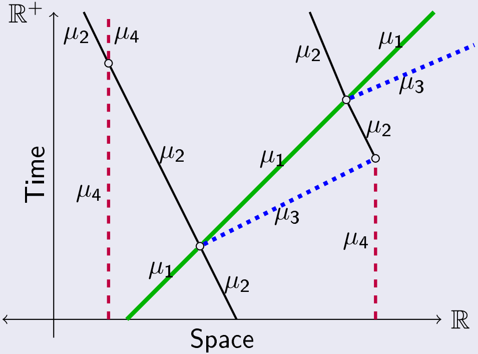
Collision rules

$\{$ div, M $\} \to \{$ M, hi, lo $\}$

$\{$ lo, M $\} \to \{$ back, M $\}$

$\{$ hi, back $\} \to \{$ M $\}$

Another Example

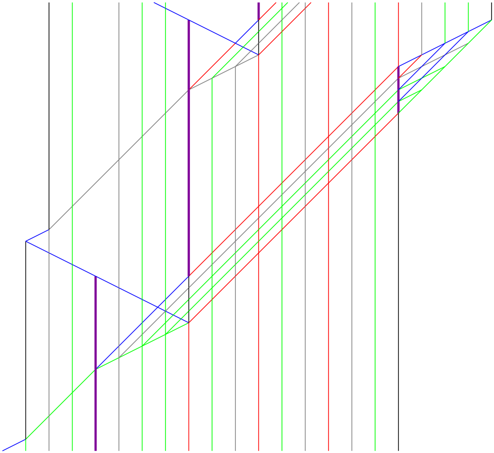


	Speed
μ_1	1
μ_2	$-1/2$
μ_3	3
μ_4	0

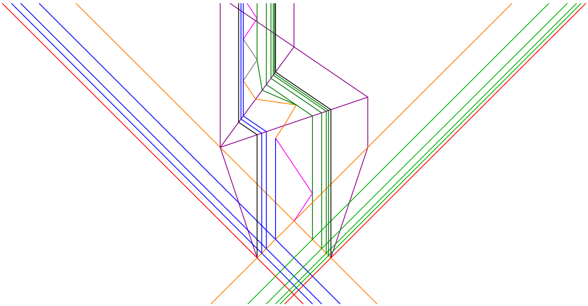
Collision rules

$$\{\,\mu_1, \mu_2\,\} \rightarrow \{\,\mu_2, \mu_1, \mu_3\,\}$$
$$\{\,\mu_3, \mu_4\,\} \rightarrow \{\,\mu_2\,\}$$
$$\{\,\mu_4, \mu_2\,\} \rightarrow \{\,\mu_2, \mu_4\,\}$$

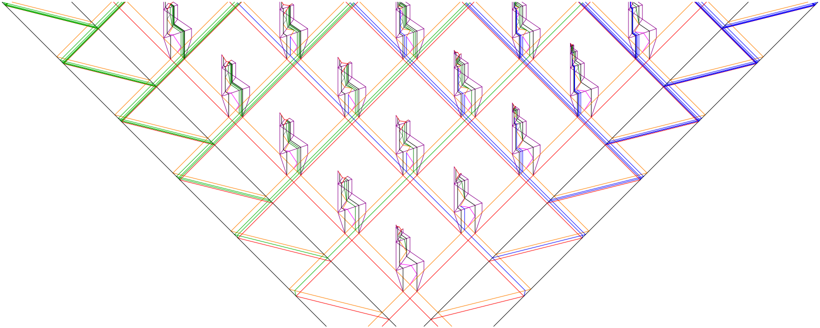
Complex Dynamics



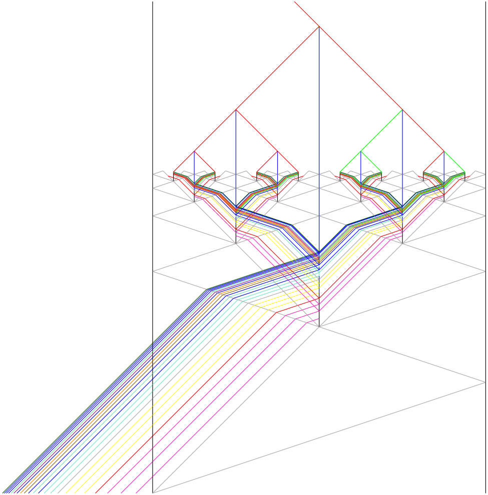
Complex Dynamics



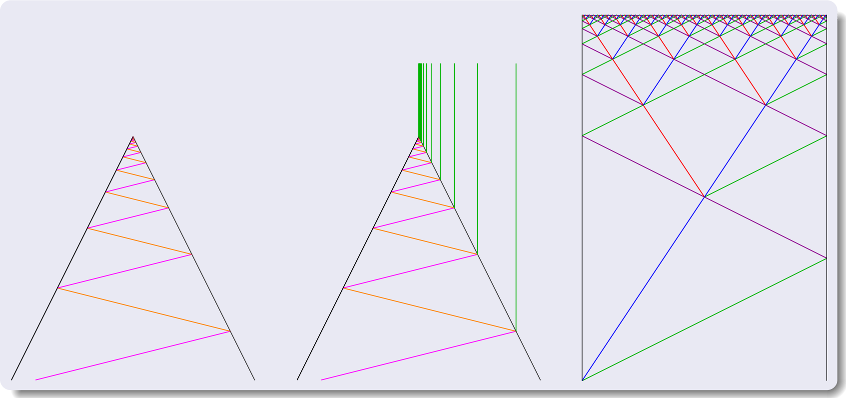
Complex Dynamics



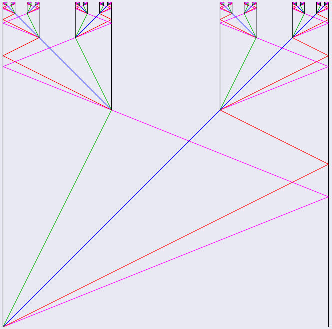
Complex Dynamics



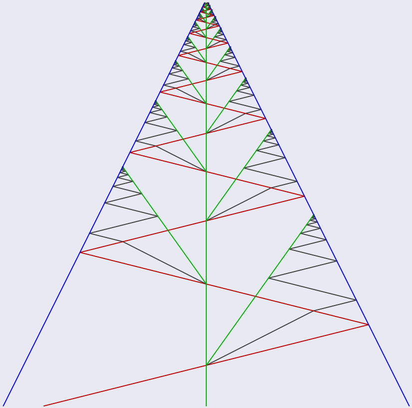
Examples



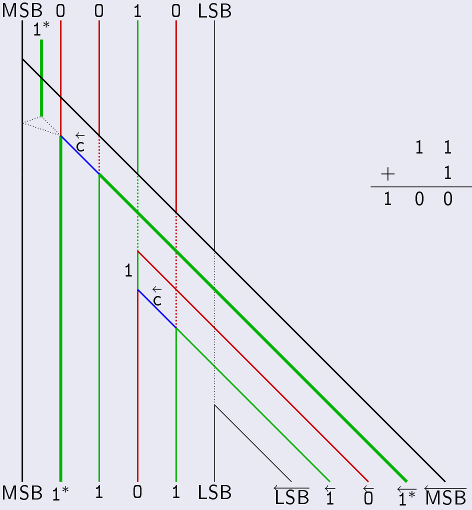
Cantor of any Hausdorff Dimension [Senot, 2013]



Second Order



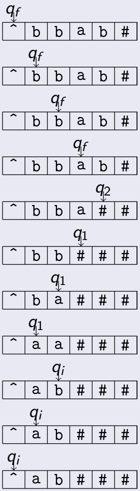
Adding



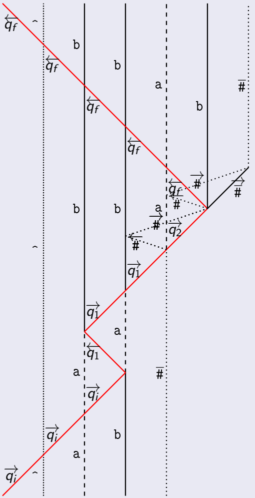
		1	1	0	1
+			1	0	1
	1	0	0	1	0

(Turing)-Computing

Turing Machine

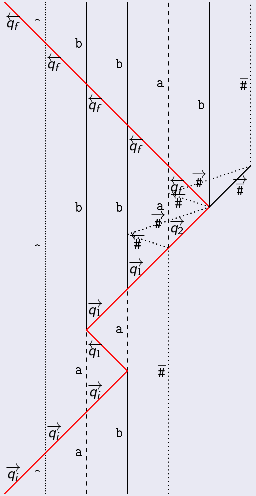


Simulation



(Turing)-Computing

Simulation



Rationnal Machine

- speeds $\in \mathbb{Q}$
- initial positions $\in \mathbb{Q}$
- $\Rightarrow$ coordinates of any collision $\in \mathbb{Q}$
- exact computation on a computer/TM

Undecidability

- finite number de collisions
- meta-signal appereance
- use of a rule
- disappearing of all signals
- involvement of a signal in any collision
- extension on the side, etc.

Concept

- *to represent* all *others*
- capability of any/all
- most general (universal)

Examples

- micro-processor, FPGA, JVM
- Java, C, Php
- Turing machine + Church-Turing Thesis $\rightsquigarrow$ *computability theory*

For dynamical systems

Intrinsic Universality

Being able to *simulate* any other dynamical system of the its *class*.

Cellular Automata

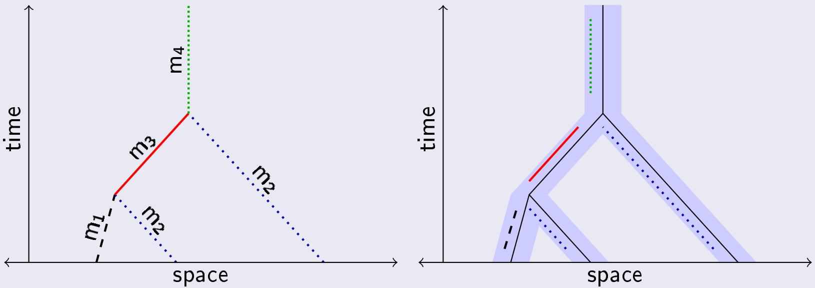
- regular [Albert and Čulik II, 1987, Mazoyer and Rapaport, 1998, Ollinger, 2001]
- reversible [Durand-Lose, 1997]

Tile Assembly Systems

- possible at T=2 and above [Woods, 2013]
- impossible at T=1 [Meunier et al., 2014]

Simulation for Signal Machines

Space-Time Diagram Mimicking



Signal Machine Simulation

$\mathcal{U}_S$ simulates $\mathcal{M}$ if there is function from the configurations of $\mathcal{M}$ to the ones of $\mathcal{U}_S$ s.t. the space-time issued from the image always mimics the original one.

Our result [Submitted]

Theorem

For any finite set of real numbers $\mathcal{S}$, there is a signal machine $\mathcal{U}_\mathcal{S}$, that can simulate any machine whose speeds belong to $\mathcal{S}$.

Theorem

The set of $\mathcal{U}_\mathcal{S}$ where $\mathcal{S}$ ranges over finite sets of real numbers is an intrinsically universal family of signal machines.

Rest of the talk

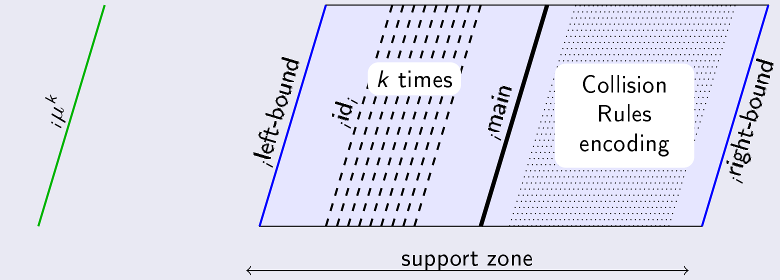
Let $\mathcal{S}$ be any finite set of real numbers,
let $\mathcal{M}$ be any signal machine whose speeds belongs to $\mathcal{S}$,
$\mathcal{U}_\mathcal{S}$ is progressively constructed as simulation is presented.

Macro-Signal

- Meta-signal of $\mathcal{M}$ identified with numbers
- Unary encoding of numbers

Macro-Signal Structure

${}_i\mu^k$: kth signal, ith speed



Global scheme

When Support Zones Meet (rough vision)

- Start the macro-collision (if applicable)

Global scheme

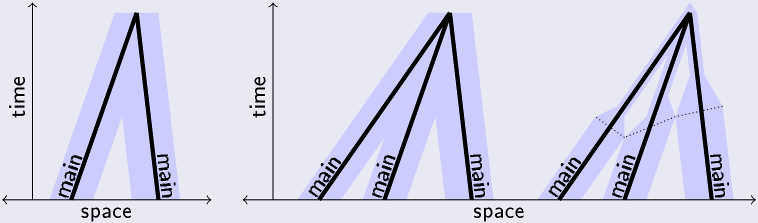
When Support Zones Meet (rough vision)

- Start the macro-collision (if applicable)

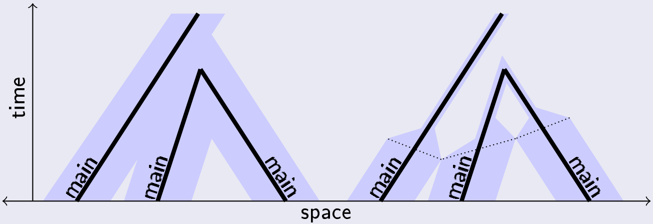
When Support Zones Meet

1. provide a delay
2. test if macro-collision is appropriate and what macro-signals are involved
3. if OK
    1. start the macro-collision

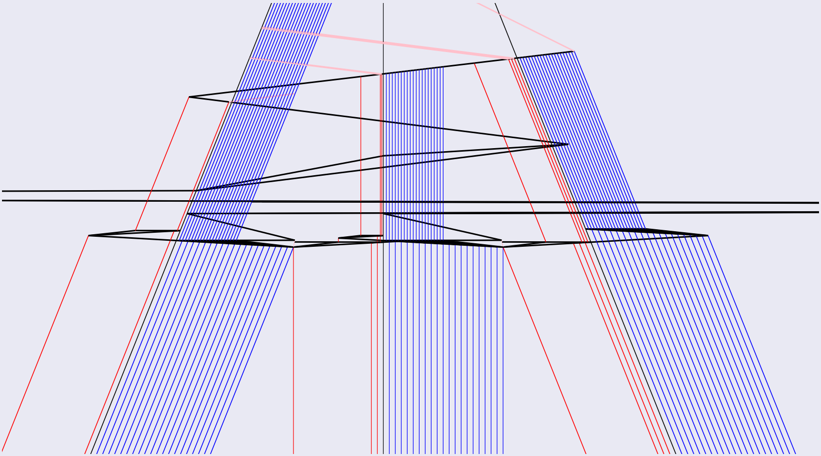
Good (?) Cases



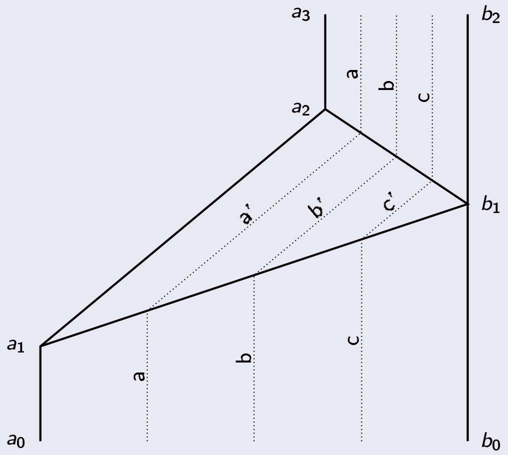
Bad Case



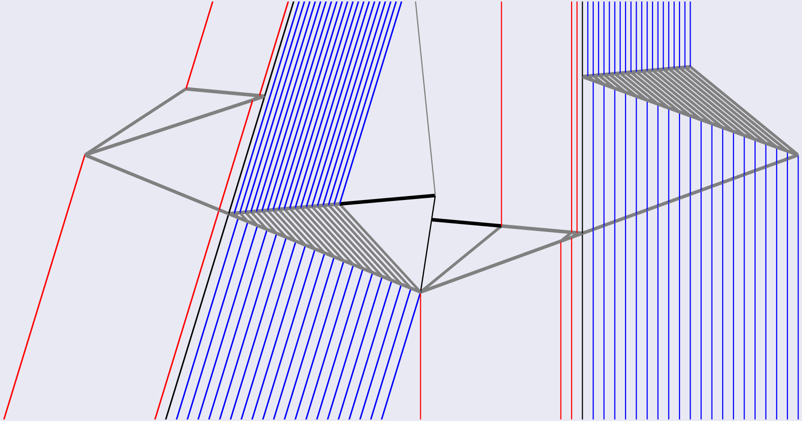
Whole Preparation (cropped on both side)



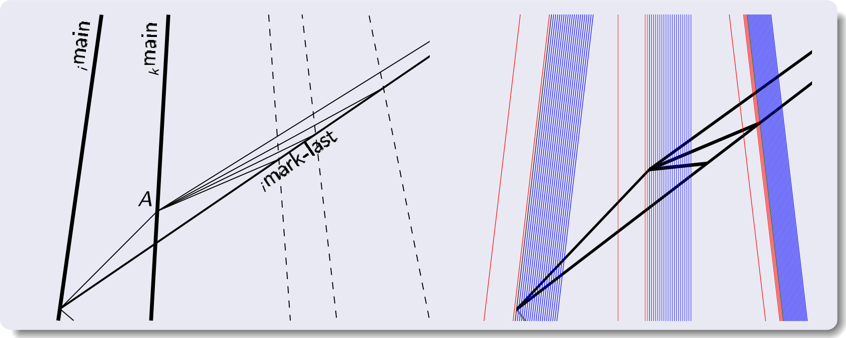
Shrinking Unit



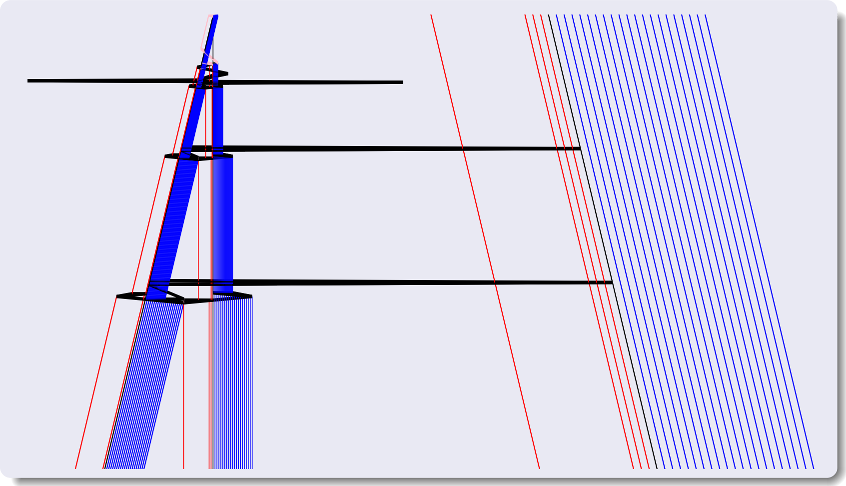
Shrink



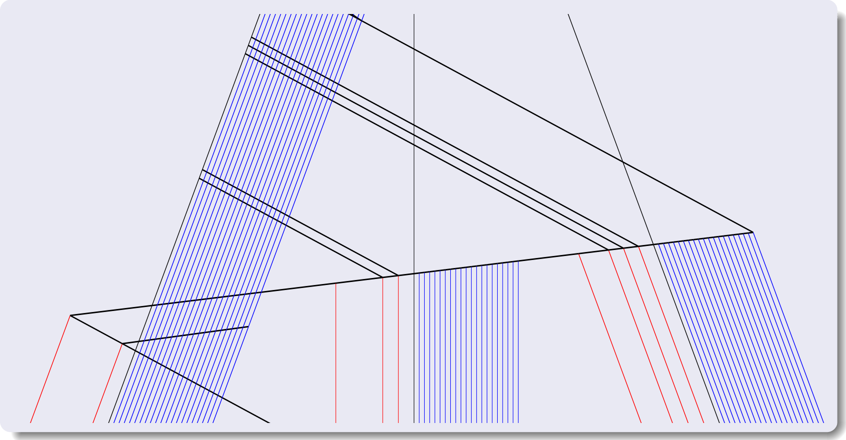
Testing for Other main Signals



Detecting Potential Overlaps



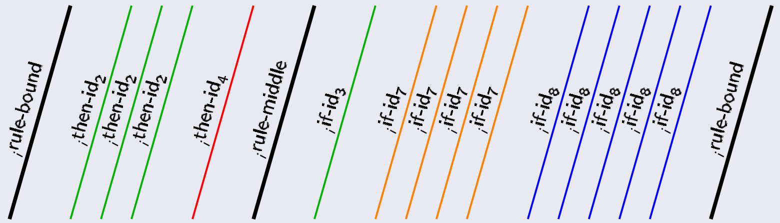
Removing Unused Tables and Sending ids to Table



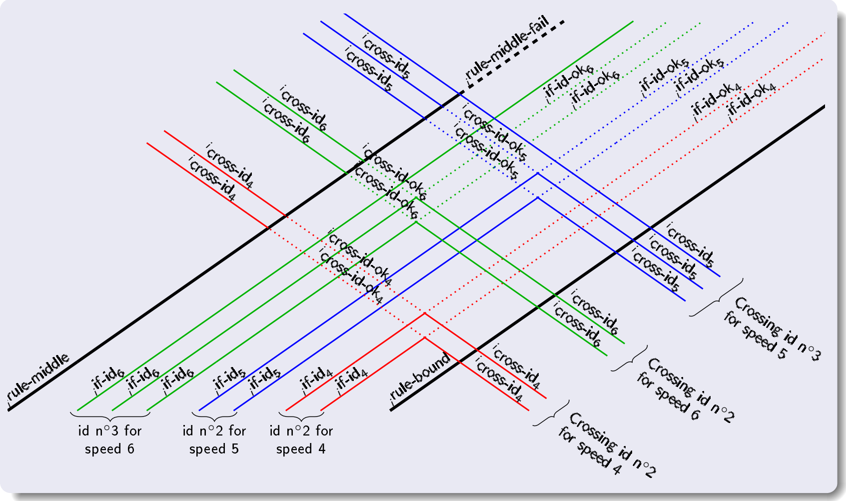
Collision Rules Encoding

One rule after the other

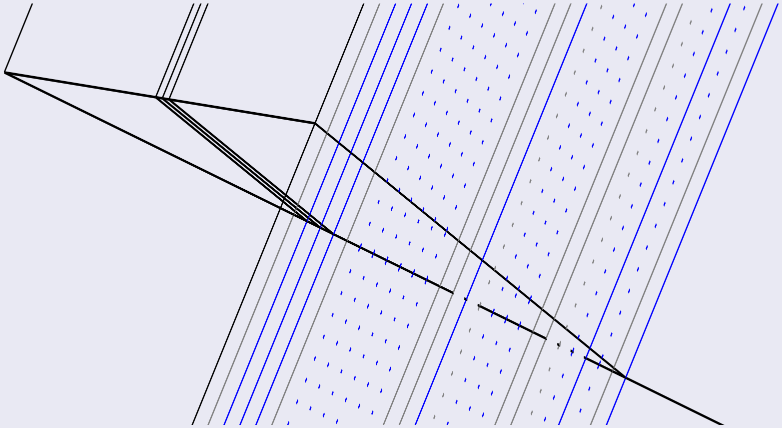
Encoding of $\{\, {}_3\mu^1,\ {}_7\mu^4,\ {}_8\mu^5 \,\} \rightarrow \{\, {}_2\mu^3,\ {}_4\mu^1 \,\}$ in the direction i.



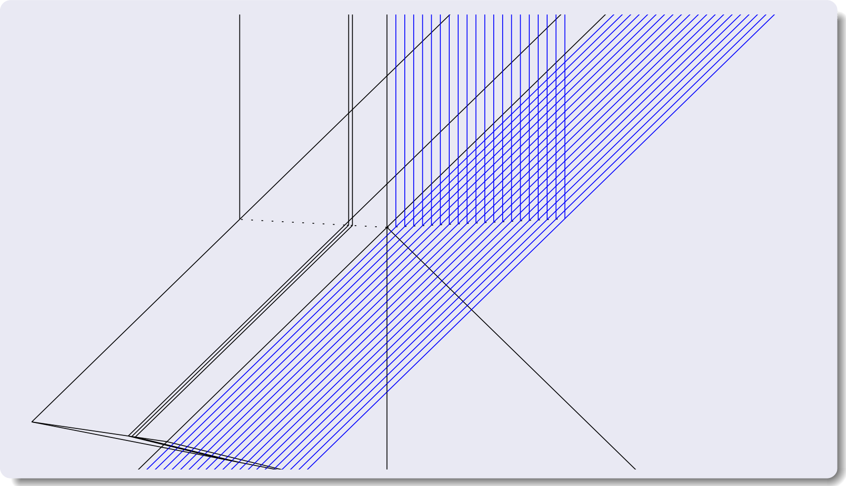
Comparison of id's in the if-part of a Rule



Rule Selection



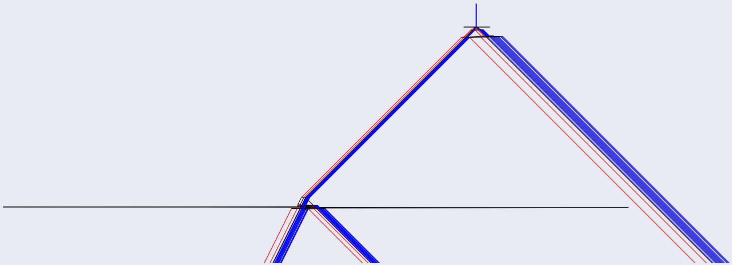
Generating the Output



All Together

Signal Machines

- Rich world



- Theorems are proved

Open problems

- single intrinsically universal signal machine (with amended simulation definition)
- discretization into CA (Tom BESSON's Theses)
  into Tile Assembly System
- robustness
- complexity (non-det. signal machines), ordinal clocking

References

- Visual introduction (not much)
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- Articles by JDL can be accessed at
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