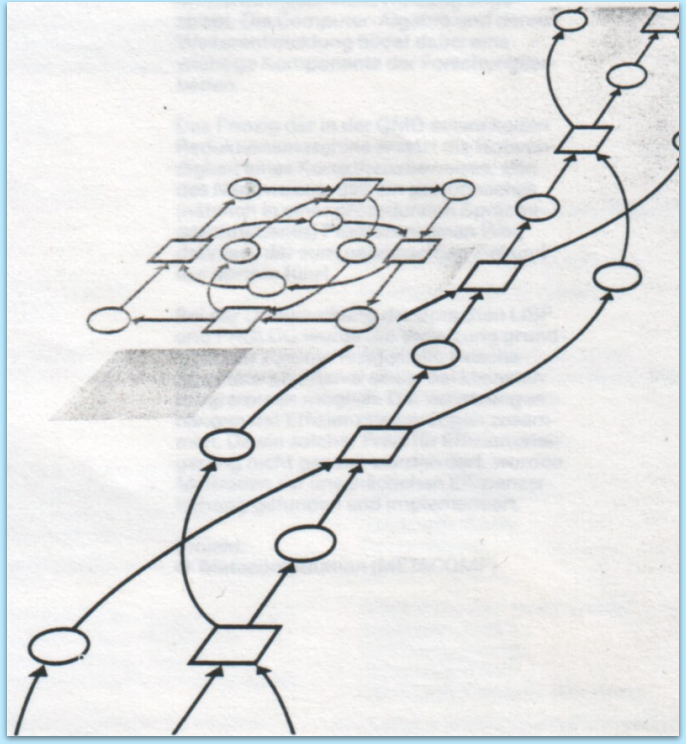
Petri's nets

and the physical basis of information flow

Rüdiger Valk,
University of Hamburg

When I met Carl Adam:

- **before 1970 as a student at the GMD**
- **at the 1st Advanced Course at Hamburg 1979**



appointment as a professor: 1987 Petri

Universität Hamburg
Verwaltung
-142-

24.11.1987

Berichte

1. An
-33-

Betr.: Verleihung der akademischen Bezeichnung "Professor" nach § 17 Abs. 1 HmbHG an Herrn Dr. Carl Adam Petri

Der Akademische Senat hat in seiner 399. Sitzung am 19.11.1987 mit 2o : 0 : 0 Stimmen beschlossen, den ihm unterbreiteten Vorschlag des Fachbereichs Informatik, Herrn Dr. Petri die akademische Bezeichnung "Professor" zu verleihen, als seinen Antrag an den Präses der Behörde für Wissenschaft und Forschung weiterzuleiten.

Anliegend werden die vom Fachbereich Informatik mit Schreiben vom 2.6.1987 eingereichten Unterlagen mit der Bitte um weitere Veranlassung übersandt.

Huh

Anlagen

2. Ø an den Sprecher des
Fachbereichs Informatik
Herrn Professor Dr. Kaiser

3. Ø -14-/-141- m.d.B.u.K.

4. z.d.A.

first lectures 1988/89

Prof. C. A. Petri 2.6.1988

Vorschlag

Im WS 88/89:

Vorlesung: Allgemeine Netztheorie I, II

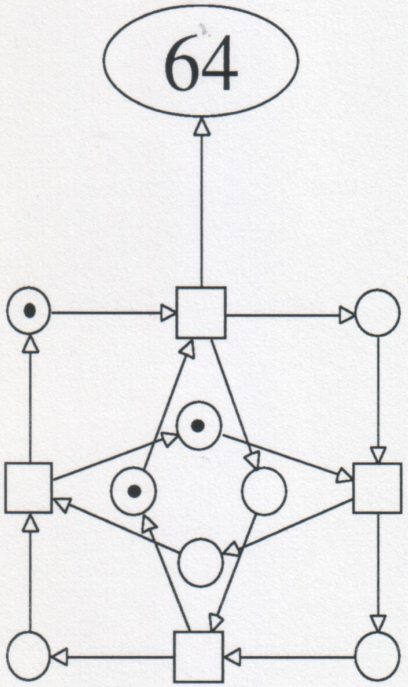
Voraussetzung: keine; doch Vorl. SS 88 nützlich.

Inhalt: ANT I Einführung = Kurzfassung der Vorlesung SS 88
ANT II Mathematische Methoden; Anwendungen

Zeit: Okt. + Nov. 88
nicht Mo, nicht Fr.
nicht vor 11 h „not before 11:00“
nicht mehr als 56 Std im Semester

Sprechstunden: 3h im Anschluß an die Vorlesungen (tägl.)
„consultation 3 hours following the lectures (daily)“

celebration of his 65th birthday ...



Einladung

zu einem

Empfang

anläßlich

des Festkolloquiums

zum 65. Geburtstag von

Prof. Dr. Carl Adam Petri

Montag, den 17.6.1991

Raum 105

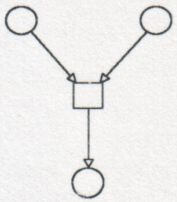
(über dem Saal des Kolloquiums)

im Anschluß an das Kolloquium

ca 17.30 Uhr

Prof. Dr. R. Valk
Universität Hamburg

Prof. Dr. W. Reisig
Gesellschaft für Informatik



... including technical talks of R.Milner, W.Reisig and E.Schnieder

Prof. Dr. Rüdiger Valk
Fachbereich Informatik

Prof. Dr. Klaus Lagemann
Sprecher des Fachbereichs Informatik

***

Glückwünsche/Congratulations

Prof. Dr. Barbara Vogel
Vizepräsidentin der Universität Hamburg

Prof. Dr. Wilfried Brauer
Technische Universität München

Prof. Dr. Ing. Hermann Flessner
Fachbereich Informatik

***

Kolloquium/Colloquium

Prof. Dr. Robin Milner
University of Edinburgh

Automata, Algebra and Concurrency

Pause/Break

Prof. Dr. Wolfgang Reisig
Technische Universität München

Petri Nets: Fundamentals, Essentials, Consequences

Prof. Dr. Eckehard Schnieder
Technische Universität Braunschweig

Which Theory Matches Embedded Systems — Petri Nets as a Formal Basis

***

one-week lectures in 1994 ...

Einladung zur Teilnahme an der Veranstaltung "Allgemeine Netztheorie" vom 28.-31.März

Veranstaltungs-Nr. 18.231

Veranstalter: Carl Adam Petri

Zeit: Mo. 28. - Do. 31. März 1994, 13:00 Uhr bis ca. 19:00 Uhr

Raum: VC-221 (Haus C, Obergeschoß), Vogt-Kölln-Str. 30, 22527 Hamburg

Inhalt: Die Allgemeine Netztheorie bildet den Ansatz zu einer umfassenden mathematischen Systemtheorie unter besonderer Beachtung der Verträglichkeit mit physikalischen Grundprinzipien. Sie ist einsetzbar für grundlagennahe ebenso wie für anwendungsnahe Bereiche verschiedener Disziplinen. Der Schwerpunkt wird hier auf die Informatik gelegt; thematisiert werden sollen:

1. Einführung; Stetigkeit und Unschärfe
2. Grundlegende Definitionen der Netztheorie
3. Situationen in markierten Netzen; Sicherheit, Hochsicherheit
4. Metriken in markierten Netzen
5. Operative Topologie; Piles, eine Verallgemeinerung von Netzen
6. Hochsichere Konstruktionen; Orthoide und Zykloide
7. Die Lorentz-Transformation in quantisierter Raumzeit
8. Informationsflußgraphen; Bitströme, Informationsbilanz
9. Die Annahme des maximales Schrittes; Informatisierung, Powertape, Berechenbarkeit bei Nebenläufigkeit

Vorgehen: Die Veranstaltung wird als Kompaktseminar durchgeführt.

Von C.A. Petri bereits zur Verfügung gestellte Unterlagen liegen im Raum VC-117 vor.

Ansprechpartner:

Prof. Dr. R. Valk (VC-219, Tel. 54715-408)
Uwe Fenske (Tel. 313038)
Mark-Oliver Stehr (VC-117, Tel. 54715-231)
Stefan Haar (Tel. 6525557)

... and in 2004

Die mathematischen, physikalischen und technischen Prinzipien der Konstruktion von Modellen verteilter Systeme werden veranschaulicht und für die Anwendung aufbereitet. Sie werden neu zusammengestellt und in der Form von einfachen Axiomen vorgelegt; die Abweichung von klassischen Methoden wird begründet und erläutert.

Vorgeführt wird die direkte Bestimmung der wichtigsten Netzeigenschaften ohne Simulation, Visualisierung der Netzstruktur, und

Mo 27.09. – Fr. 01.10.04
14:15 – 16:00

Zuse-Hörsaal (Haus B)
Hamburg-Stellingen

... and in 2004

Prof. Dr. Carl Adam Petri
Ehrenprofessor des
Fachbereichs

Systematik der Netzmodellierung

Die mathematischen, physikalischen und technischen Prinzipien der Konstruktion von Modellen verteilter Systeme werden veranschaulicht und für die Anwendung aufbereitet. Sie werden neu zusammengestellt und in der Form von einfachen Axiomen vorgelegt; die Abweichung von klassischen Methoden wird begründet und erläutert.

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Mo 27.09. – Fr. 01.10.04
14:15 – 16:00

Zuse-Hörsaal (Haus B)
Hamburg-Stellingen

... and during many other events (Conference at Eindhoven, 2003)

On the Physical Basics of Information Flow

C.A.Petri

Results obtained in co-operation with
KONRAD ZUSE
1910 - 1995

On the Physical Basics of Information Flow

C.A.Petri

Results obtained in co-operation with
KONRAD ZUSE
1910 - 1995

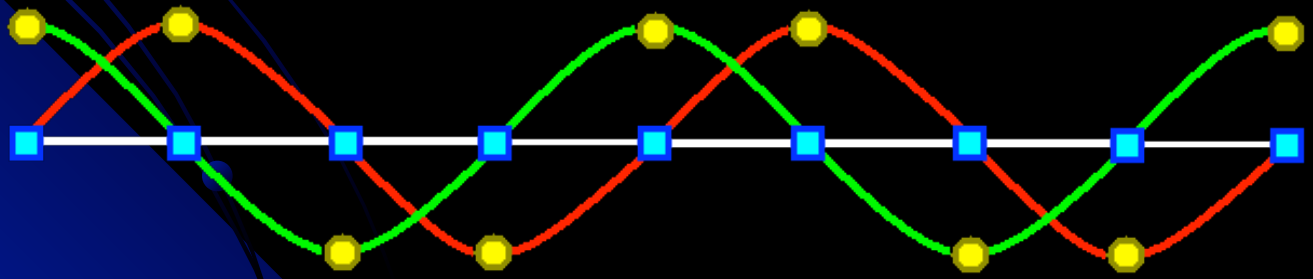
INNOVATIONS

- Revised Order Axioms for Measurement
- Synthesis of „Discrete“ and „Continuous“
- Derivation of Computing Primitives from smallest closed Signal Spaces

Procedure

By means of NET modelling, Petri translates the main tenets of modern Physics into their combinatorial form.

In that form, they are independent of scale, and relate to direct experience as well as to the sub-microscopic level.



Essentials of Net Theory

1. TWO kinds of world points:

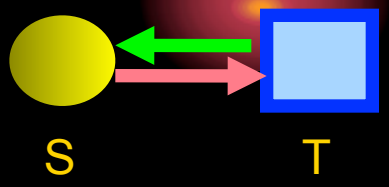
elements: STATES and TRANSITIONS

e.g. Substances and Reactions

2. TWO relations between world points:

arcs: GIVE and TAKE

e.g. Creation and Annihilation



3. TWO kinds of **continuity** expressible:

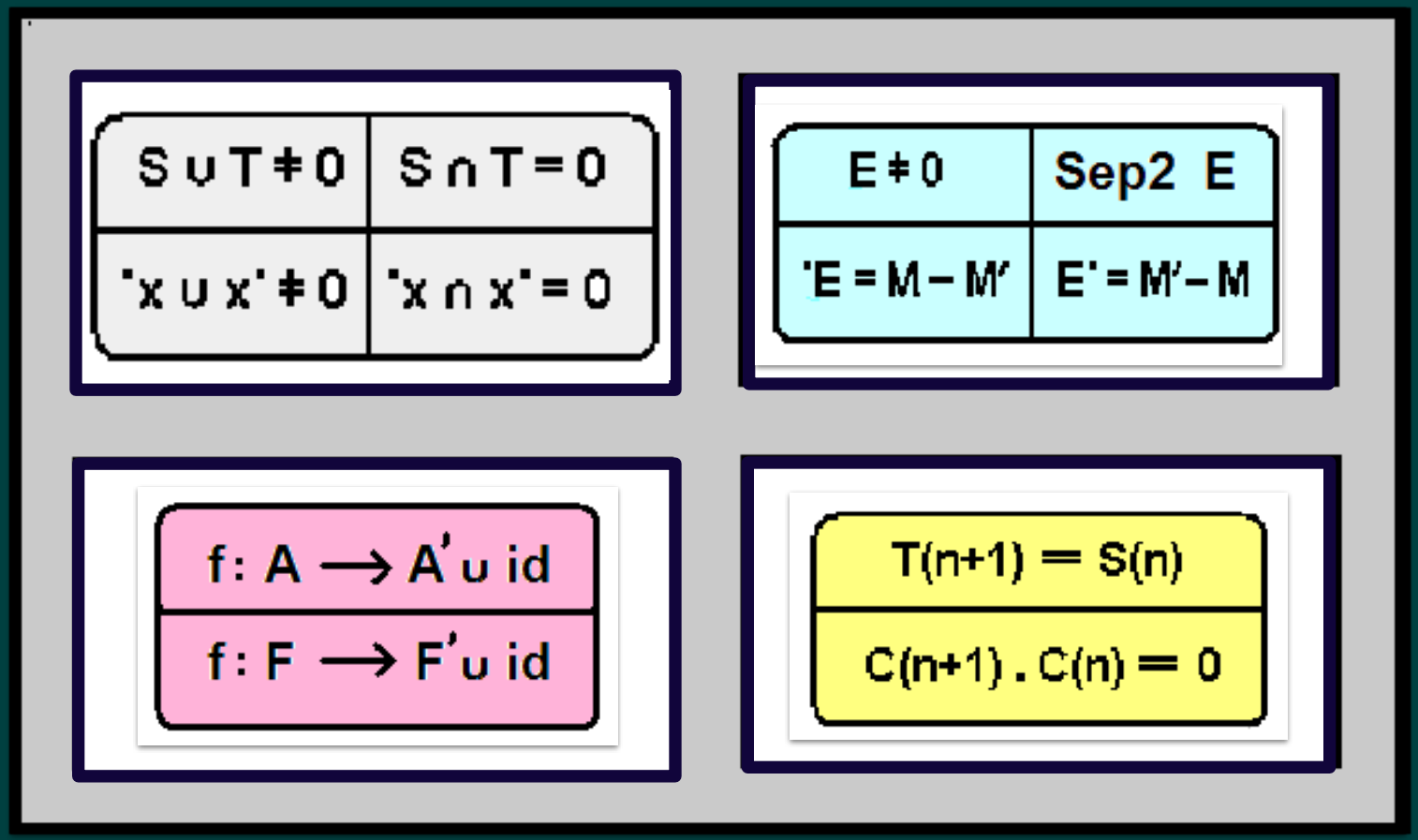
Mathematical continuity (“connected and compact”)

Experienced continuity (“connected indifference”)

The Framework for Axioms

nets

occurrence

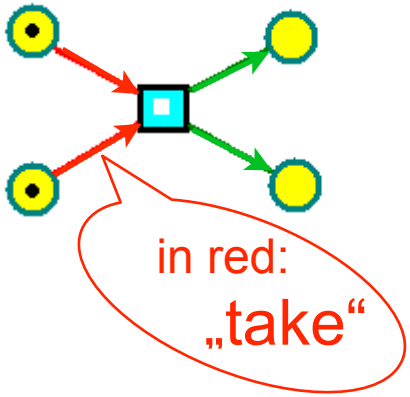


net morphism

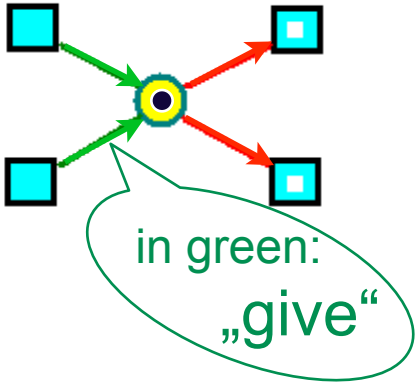
piles

The Elements Used in Construction

collection



decision



The Elements Used in Construction

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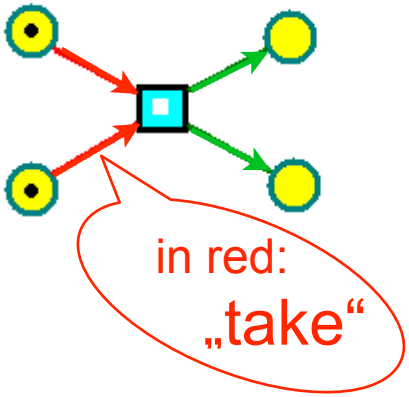
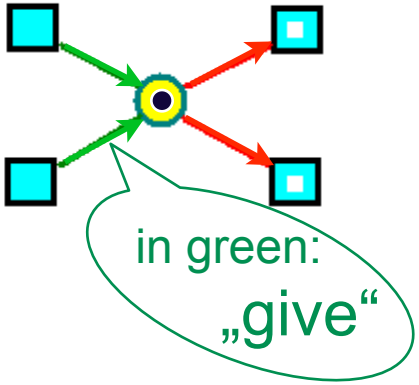
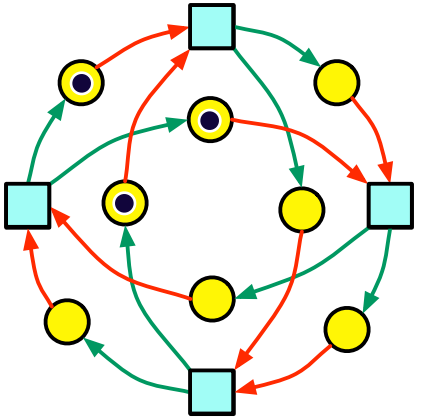


decision

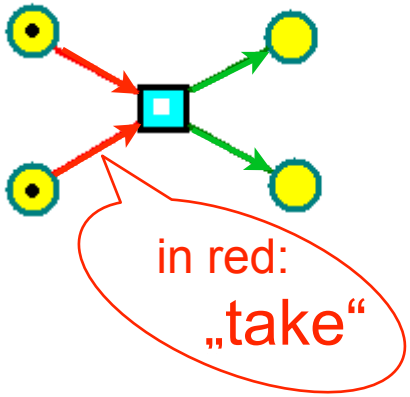




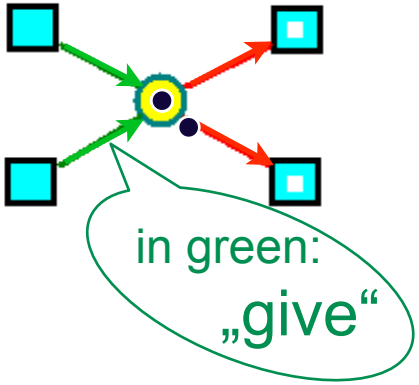
Oscillator

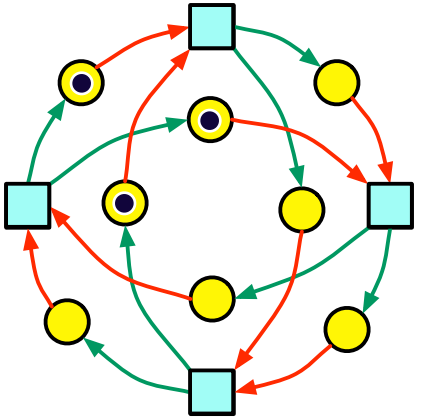
The Elements Used in Construction

collection



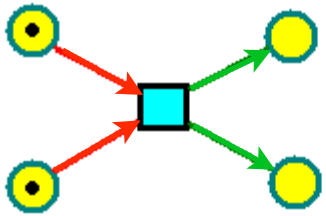
decision





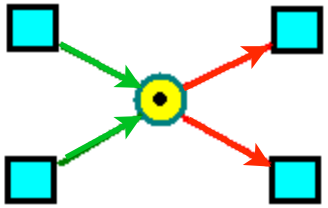
Oscillator

NET TOPOLOGY



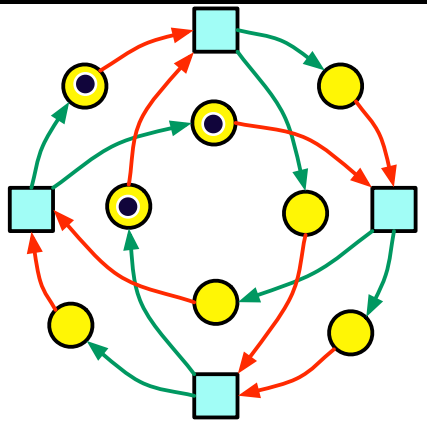
open subnet

The transition is completed by four states



closed subnet

The state is completed by four transitions

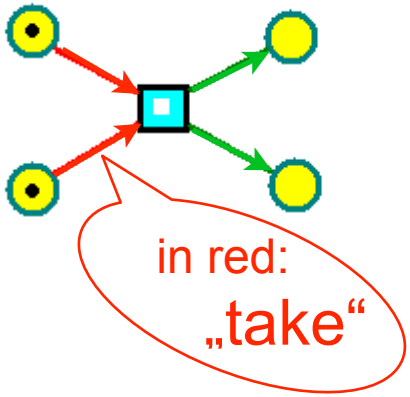


open subnet

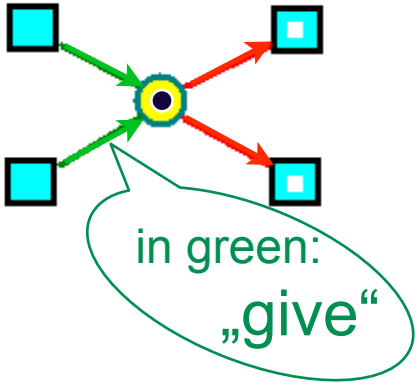
The eight uncompleted states form the border

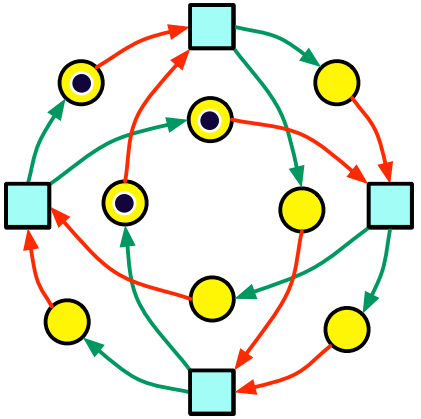
The Elements Used in Construction

collection



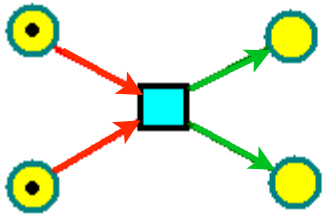
decision





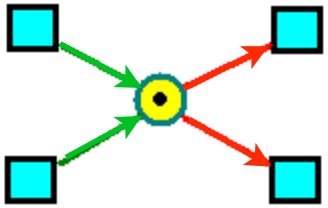
Oscillator

NET TOPOLOGY



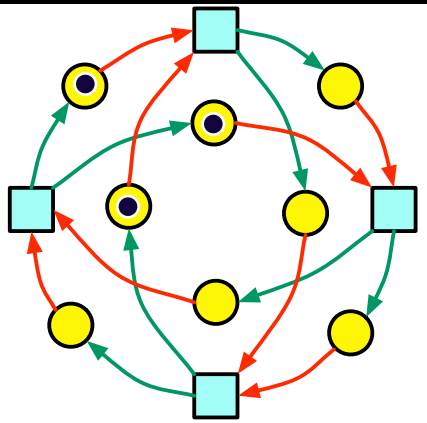
open subnet

The transition is completed by four states



closed subnet

The state is completed by four transitions



open subnet

The eight uncompleted states form the border

Measurement

in the classical sense

as related to

the Uncertainty Principle

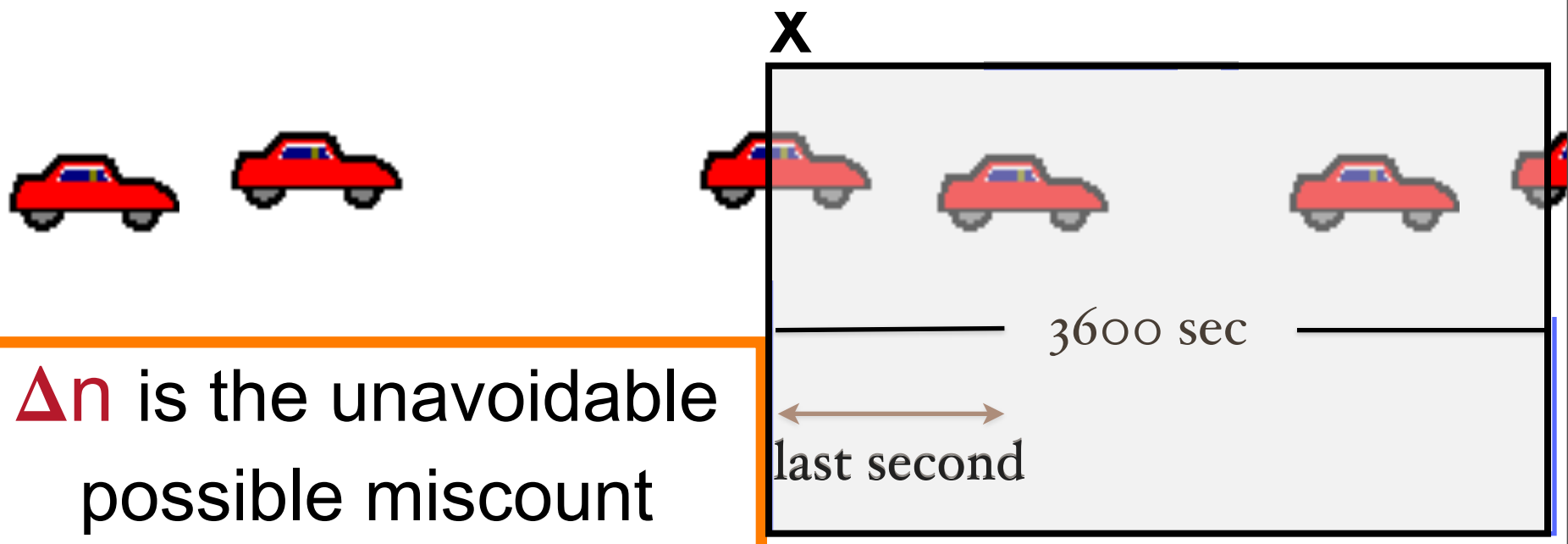
Four Theses on Measurement

- Every act of Measurement occurs in a Time Window.
- Measurement is, in essence, equivalent to Counting. *)
- Continuous change (e.g. motion) goes unnoticed if not articulated by perceptible non-zero changes.
- Counting leads to a unique result only if the set of objects to be counted and the Time Window are under complete control.

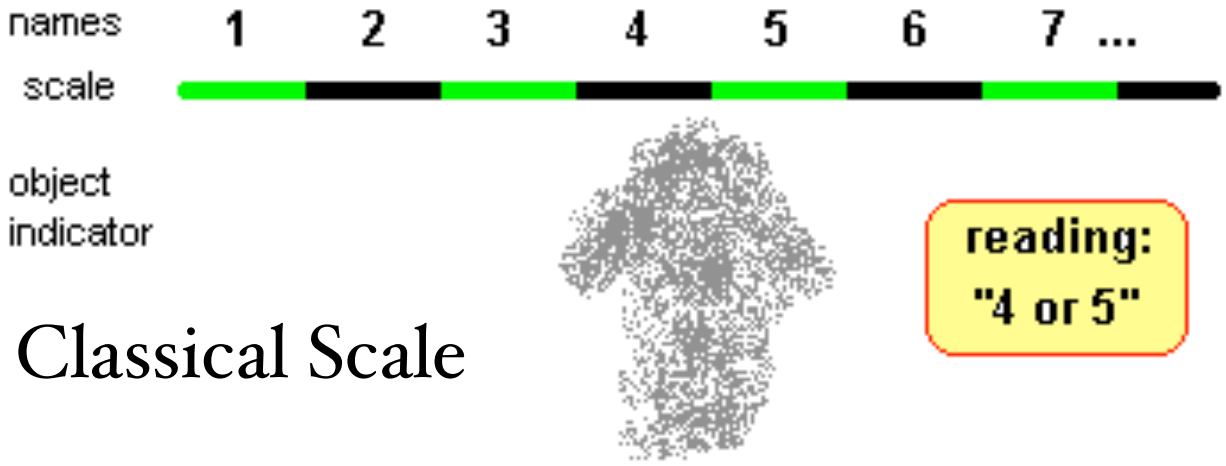
*) SI: 1 second := 9 192 631 770 periods (^{133}Cs line)

Law of Uncertainty of Counting of indpendent events:

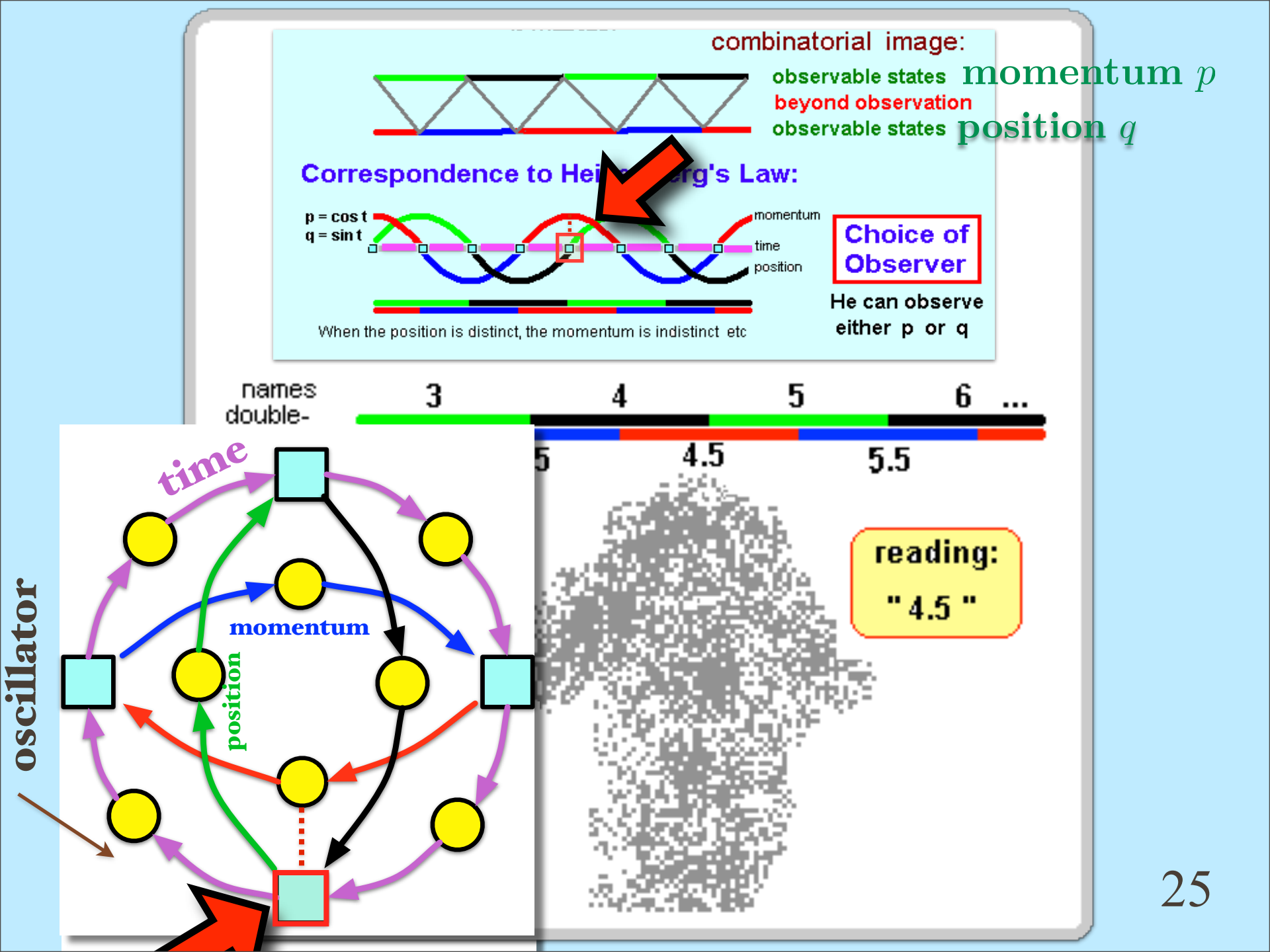
Traffic Statistics: How many cars pass point X in one hour?



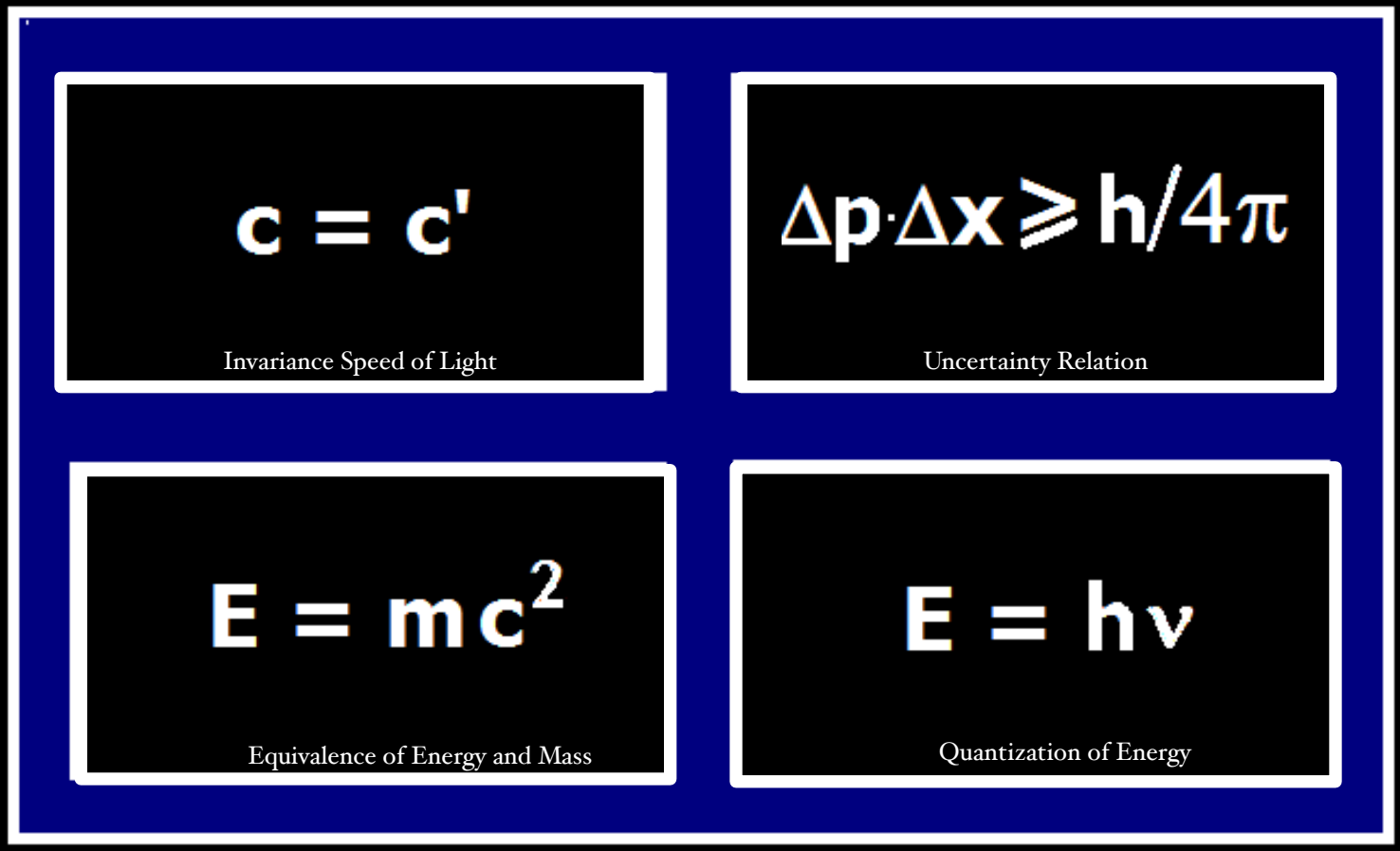
Δn is the unavoidable possible miscount



Classical Scale


combinatorial image:
observable states
beyond observation
observable states
momentum p
position q
Correspondence to Hei rg's Law:
p = cos t
q = sin t
momentum
time
position
Choice of Observer
He can observe either p or q
When the position is distinct, the momentum is indistinct etc
names
double-
3
4
5
6
...
4.5
5.5
reading:
" 4.5 "
oscillator
time
momentum
position

The Main Principles of Modern Physics



Relativity **Quantum Physics**

$$x' = \frac{(x - vt)}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad y' = y \qquad z' = z \qquad t' = \frac{(t - \frac{vx}{c^2})}{\sqrt{1 - \frac{v^2}{c^2}}}$$

n

$$x' = L(x - vt)$$
$$t' = L(t - wx)$$

Invariance Speed of Light

no mention of c !

$$L = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$w := \frac{v}{c^2}$$

slowness

$$[\frac{sec}{m}]$$

These results pertain also to macroscopic levels!

Slowness Effects

car *gap*

This motion proceeds fastest if there is just one gap in front.

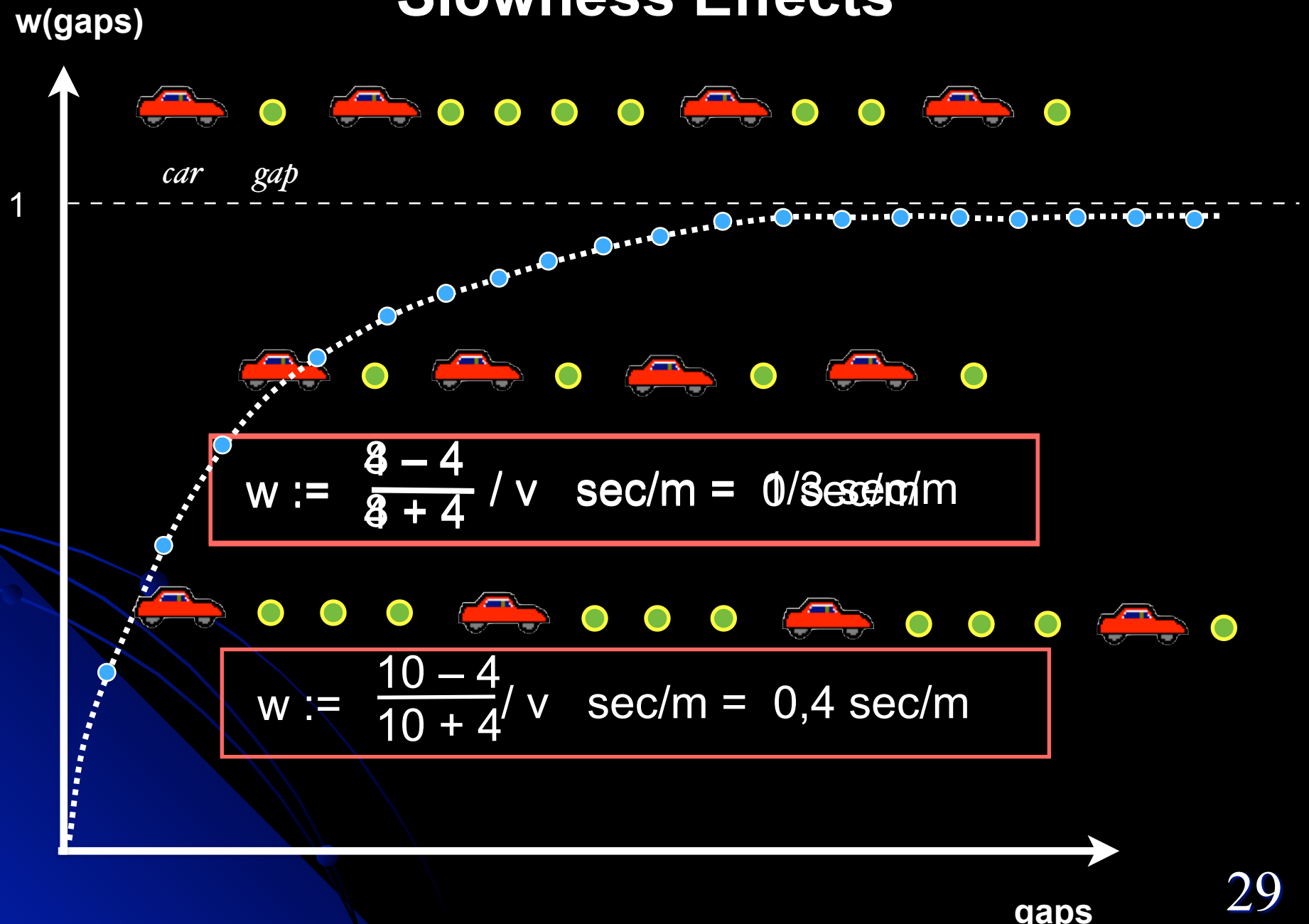
Otherwise, we define SLOWNESS w as the quotient

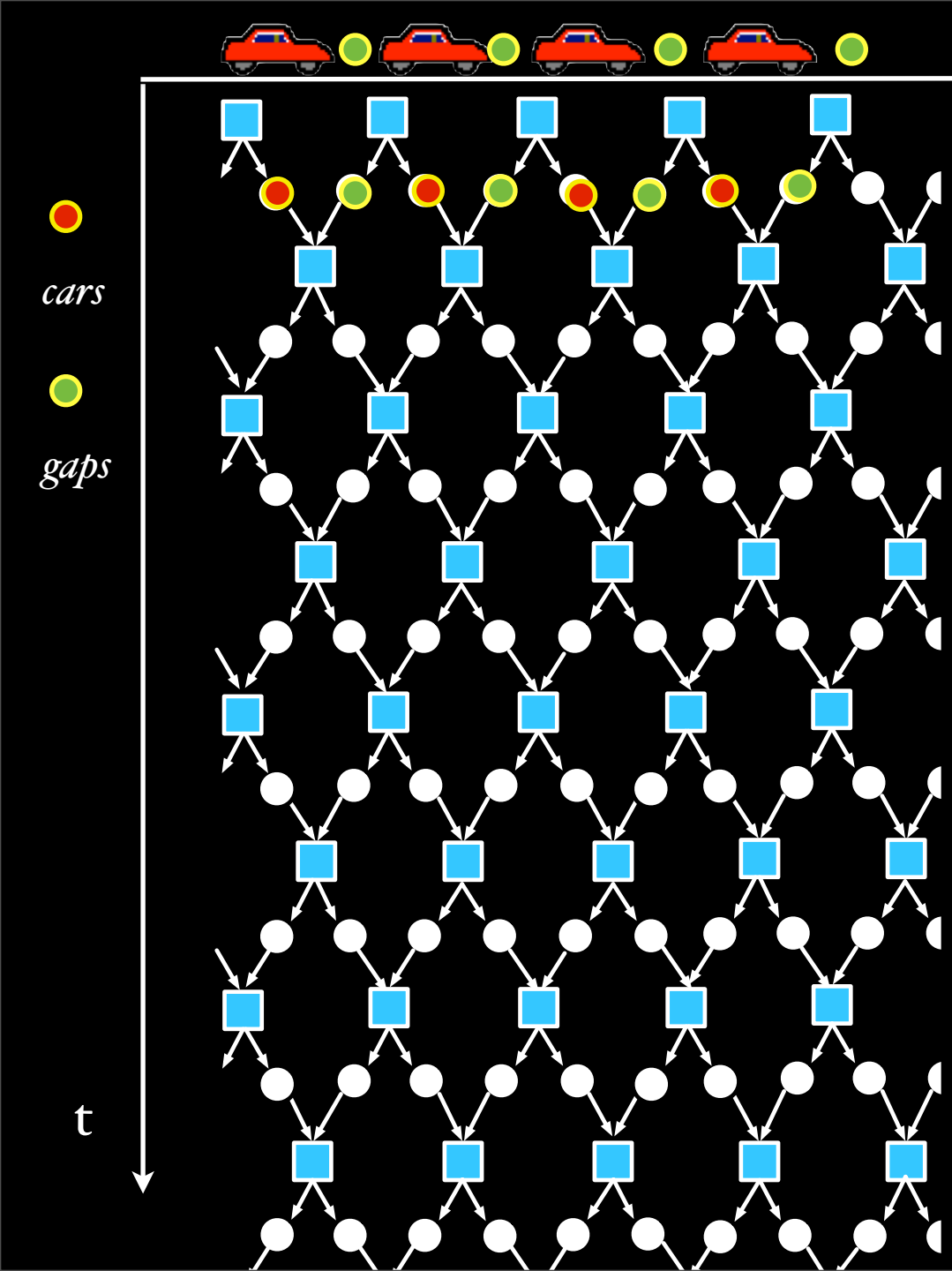
$$w := \frac{\text{gaps} - \text{cars}}{\text{gaps} + \text{cars}} / v\ (\text{cars}) \qquad \text{sec/m}$$

$$w := \frac{8 - 4}{8 + 4} / v \quad \text{sec/m} = 1/3\ \text{sec/m}$$

The concept of slowness is a key to understanding repetitive GROUP behaviour. It can be applied to Organization, to Work Flow (**Just-in-time Production**), and to Physical Systems.

Slowness Effects





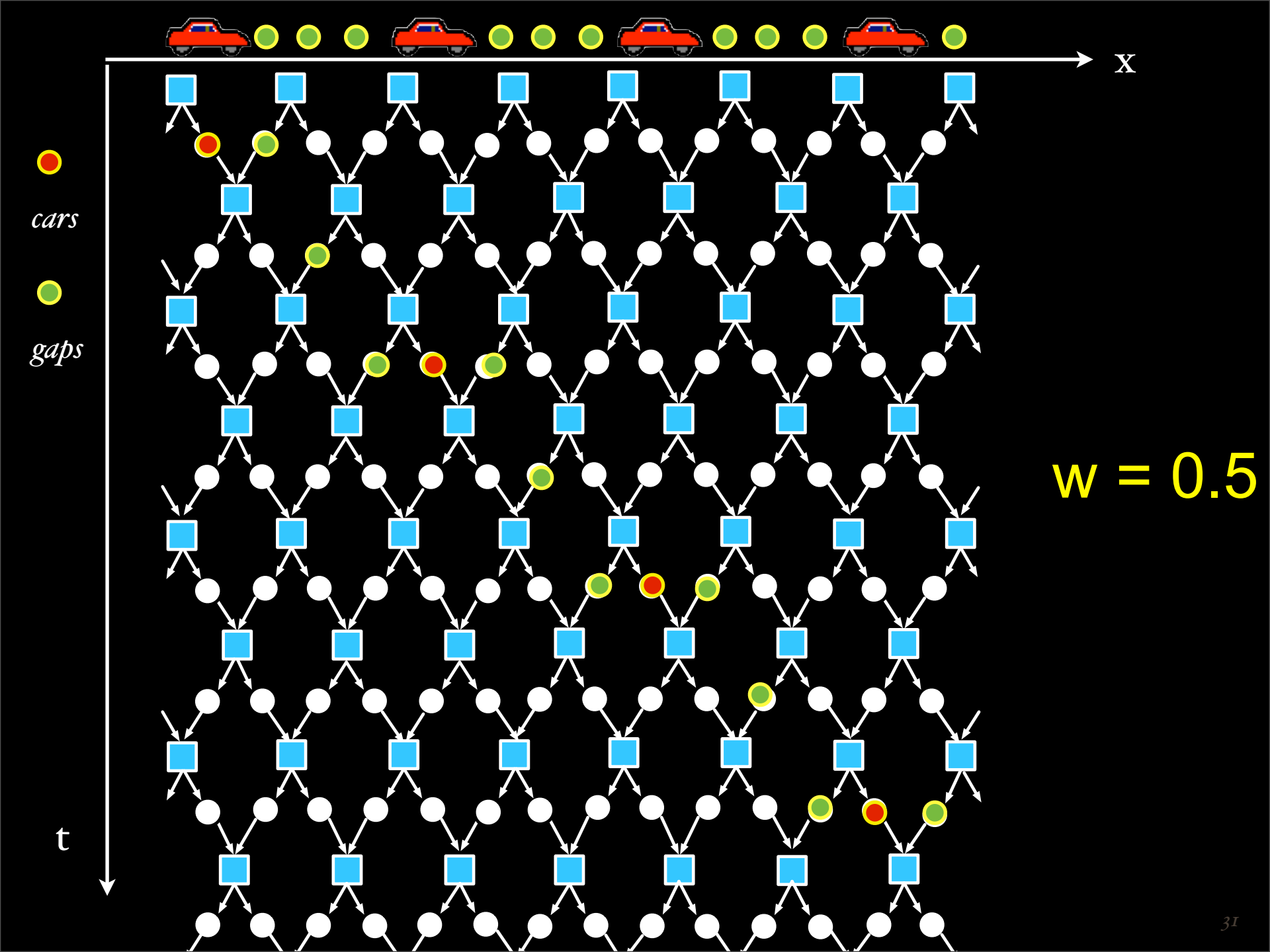
from

Minkowski Space

to

Petri's
„natural coordinates“

$w = 0$


x
cars
gaps
t
w = 0.5

We saw:

The concept of SLOWNESS has its origin in Physics:

It appears in the symmetrical Lorentz Transformation

$$x' := L (x - v t) ; \quad t' := L (t - w x); \quad w := v / c^{2}$$

w is measured in seconds (lost) per meter

v is measured in meters (gained) per second

Hence, we saw an example of translation to macroscopic level .

Determinism

Petri and Zuse saw no chance to implement their deterministic approach to Information on the level of Quantum Mechanics, because Observation and Measurement have unpredictable outcomes there.

Therefore, they ended the co-operation.

Re-started in 2002:

Petri saw a new chance for completing their work by following the guidelines of Nobel Laureate Gerard `t Hooft who proposes a deterministic model on an essentially finer scale.

Gerard 't Hooft

writes in „Determinism beneath Quantum Mechanics“ (2002):

“Contrary to common belief, it is not difficult to construct deterministic models where stochastic behaviour is correctly described by quantum mechanical amplitudes, in precise accordance with the Copenhagen-Bohr-Bohm doctrine. .....

Gerard 't Hooft

Conclusion of Gerard 't Hooft:

Nature's fundamental laws are defined at the Planck scale.

At that scale, all we have is bits of information.

Determinism excludes the **Creation** of Information.

Petri goes one **tentative** step further to forbid **the Destruction** of Information, in order to establish a

Law of Conservation of Information

as a prototype of Conservation Laws in general.

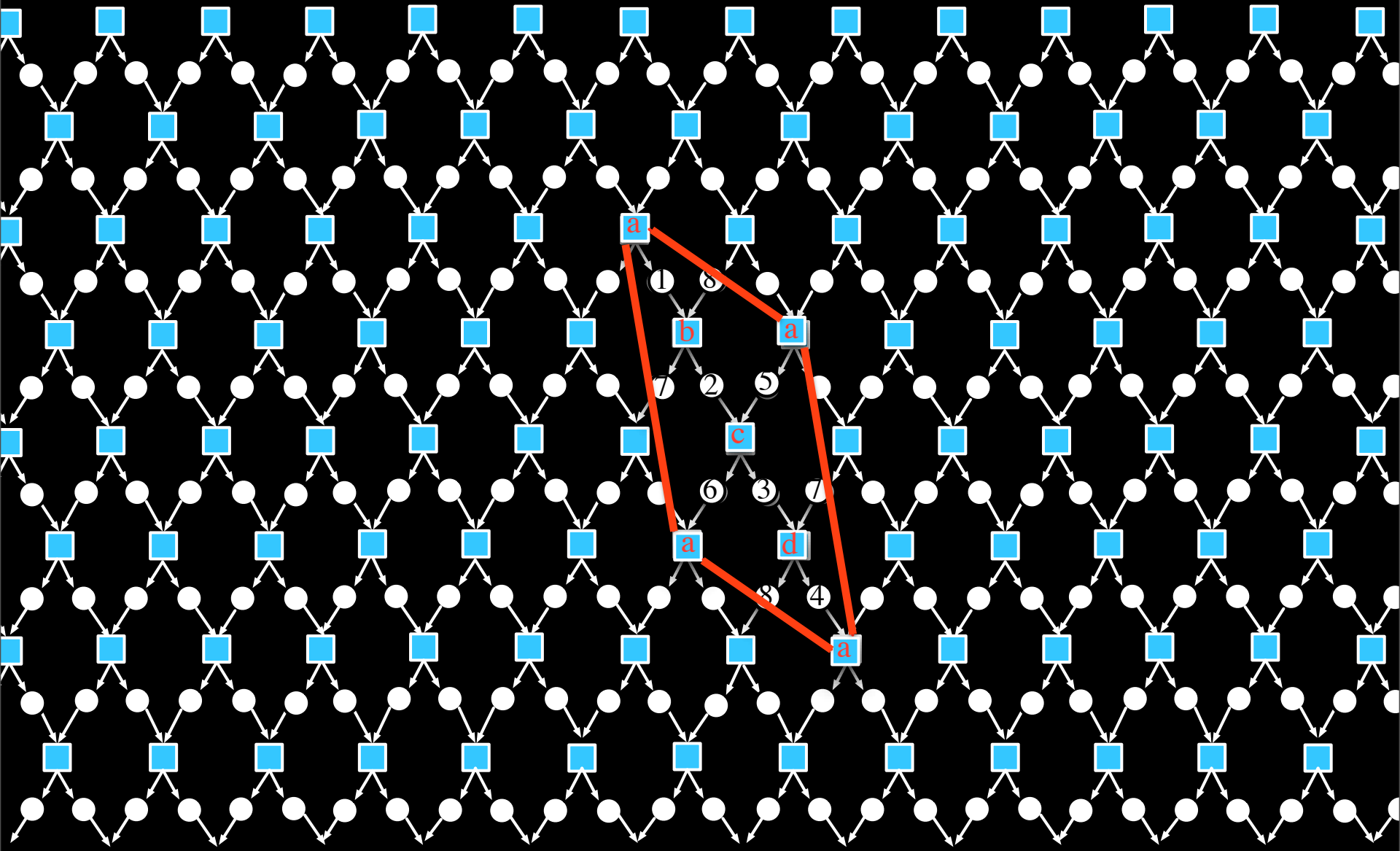
Accordingly, he describes the physical Universe in terms of **Signal Flow** and – equivalently – of **Information Flow.**

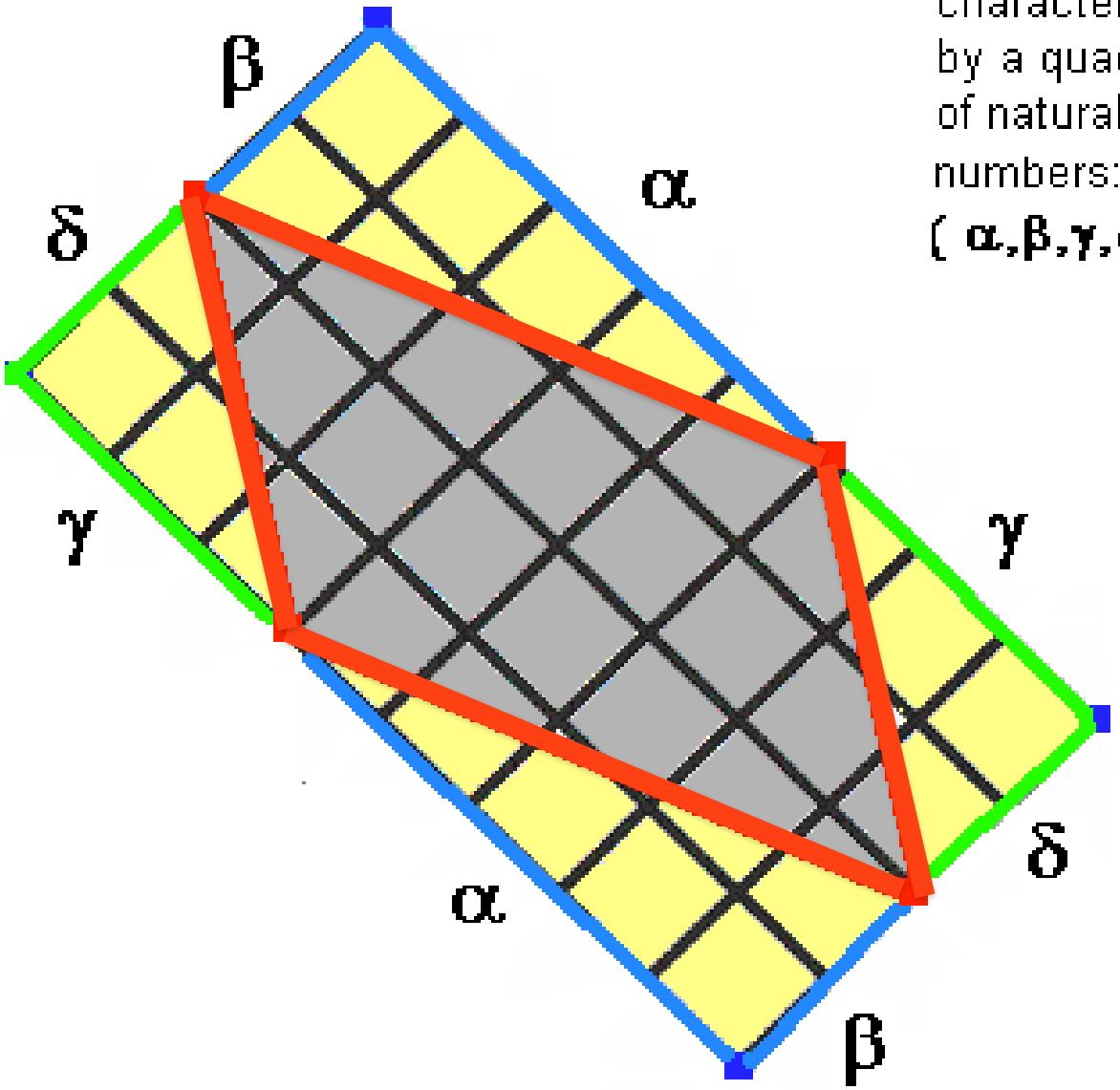
He derives the **Information Operators** from the idea of space-time periodic movement of Signals in an

INTEGER MINKOWSKI SPACE

Petri's „natural coordinates"

Petri‘s „natural coordinates“

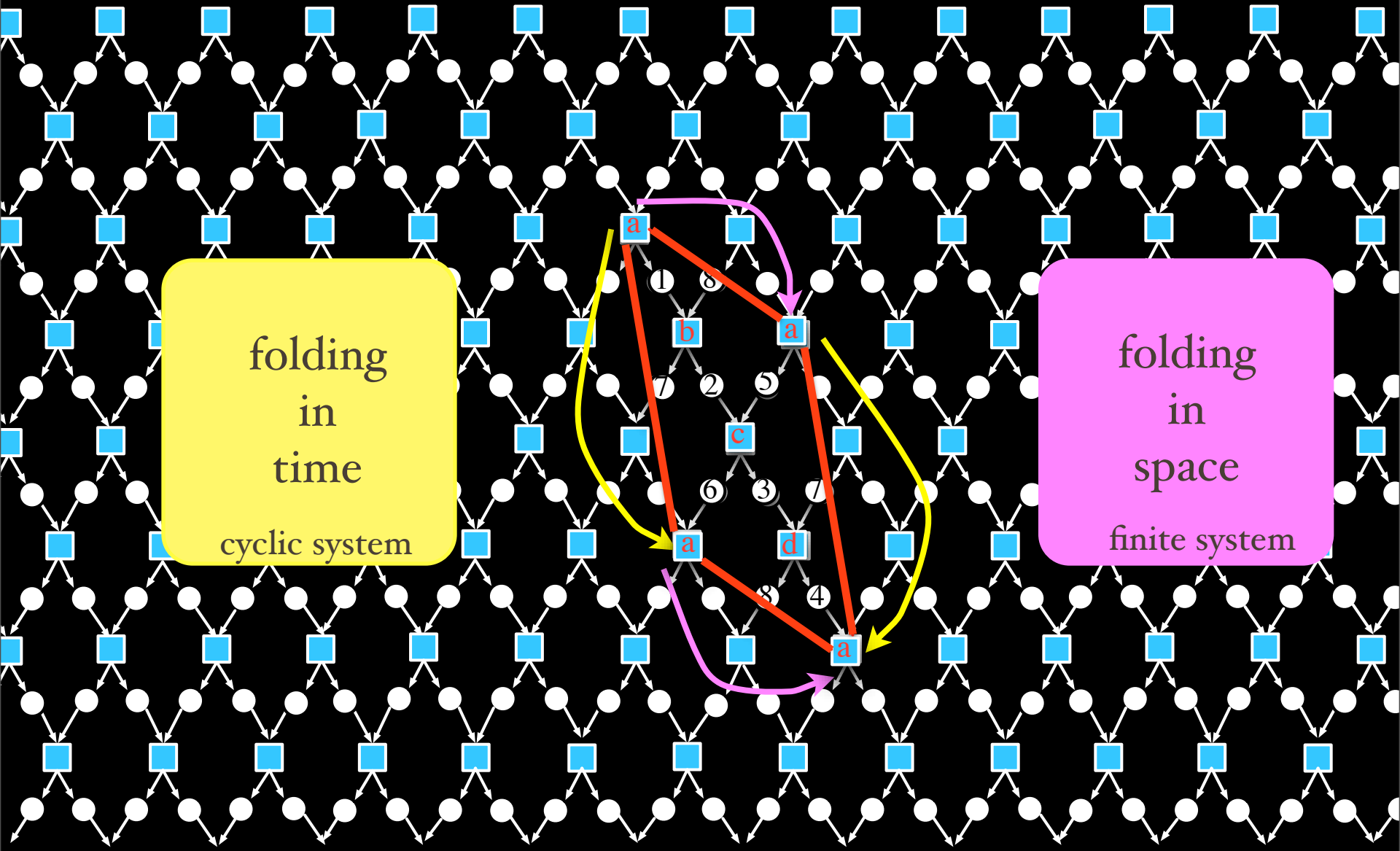




Repetitive behavtour is characterized by a quadruple of natural numbers:

(α,β,γ,δ)

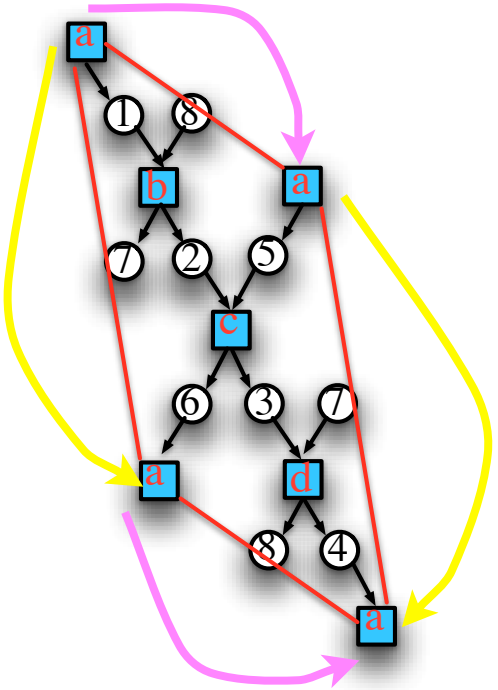
Petri's „natural coordinates“



Petri's „natural coordinates“

folding
in
time

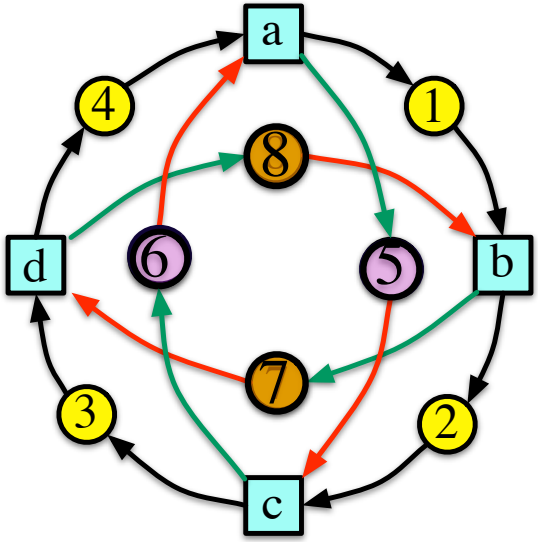
cyclic system



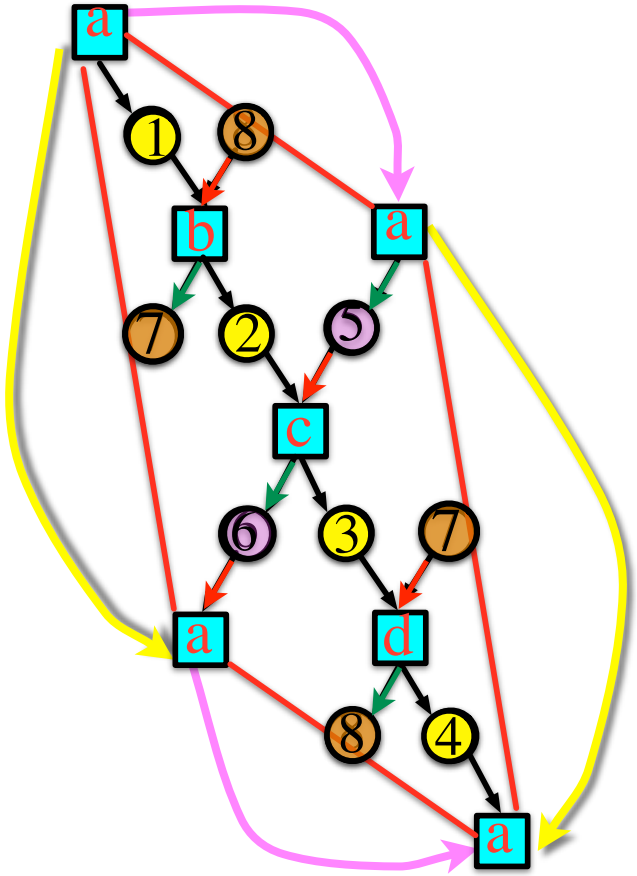
folding
in
space

finite system

Petri's „natural coordinates“



Oscillator !

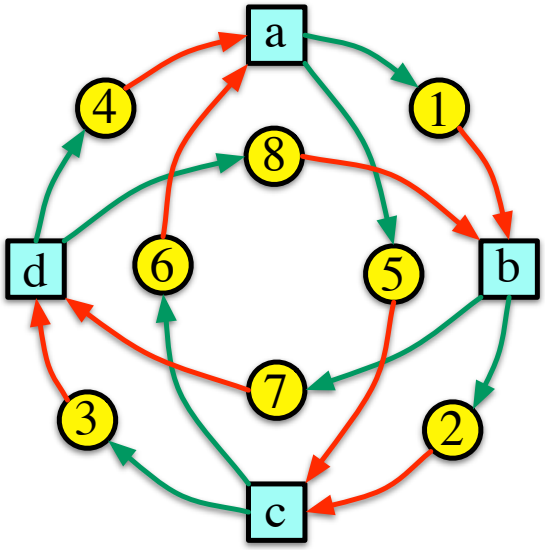


Folding the Space-Time image of a parallelogram to a „Cycloid“ represents signal movement periodic in space and time.

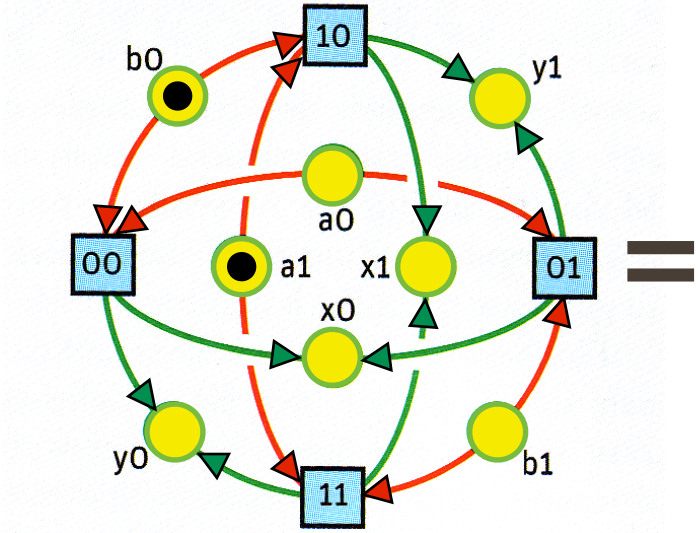
New orientation of arrows!

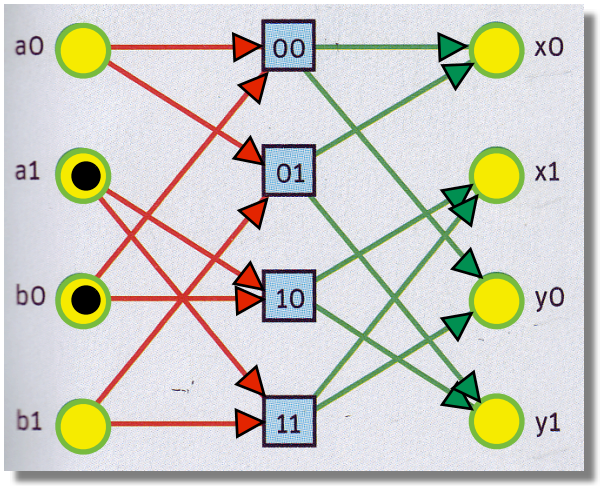
x = a
y = a XOR b

Exclusive OR



oscillator





isomorphic graph

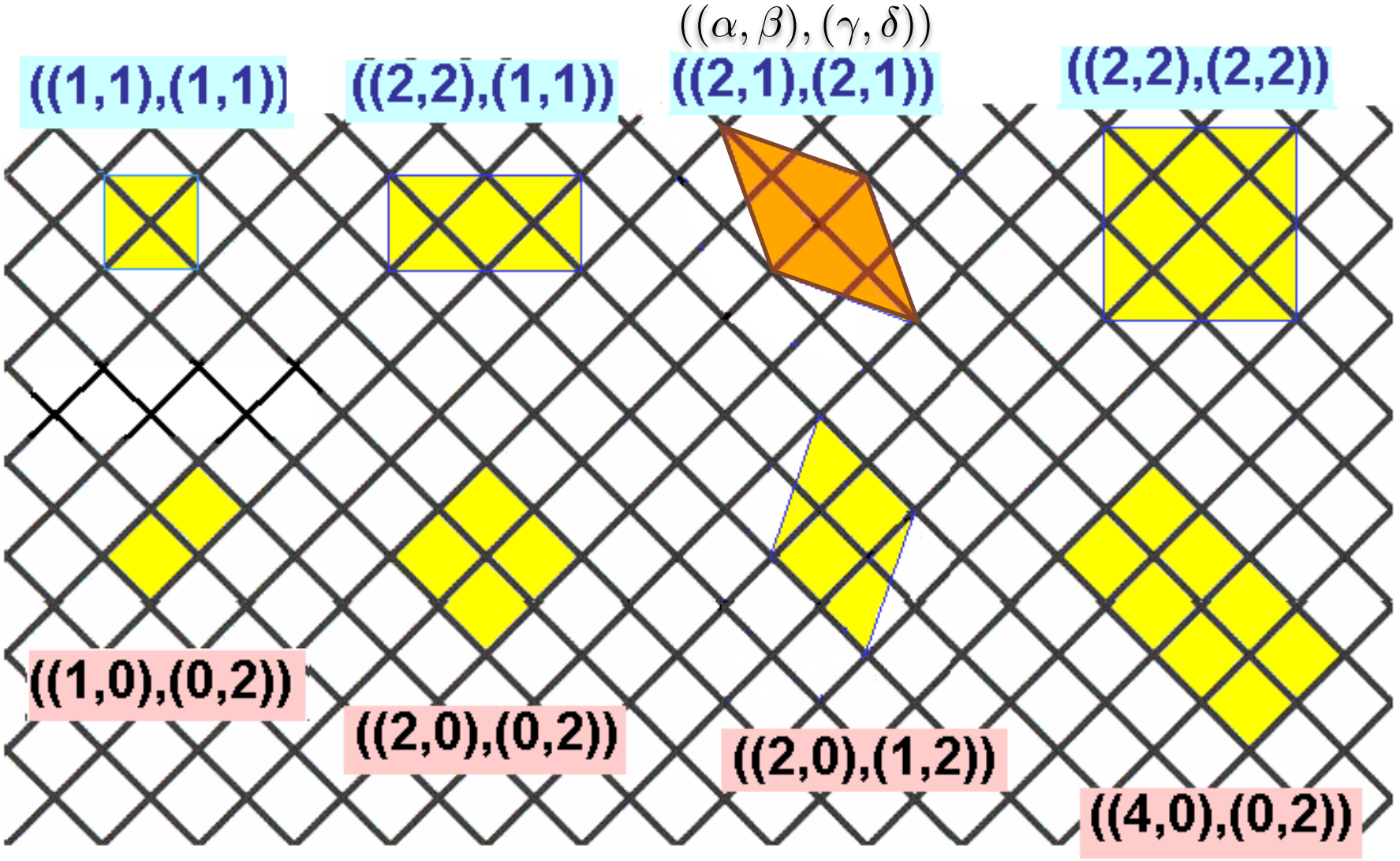
Information Operators are derived from the idea of space-time periodic movement of Signals in an INTEGER MINKOWSKI SPACE

A central idea of Combinatorial Modelling:

The use the **Trajectories of Particles**

as NATURAL COORDINATES

The smallest regular patterns of behavior



LT-compatible and degenerate Cycloids

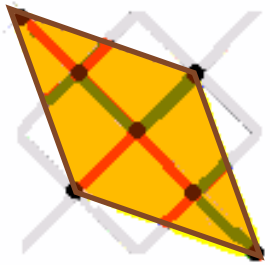
The smallest lossfree Boolean Transfe

$((\alpha, \beta), (\gamma, \delta))$

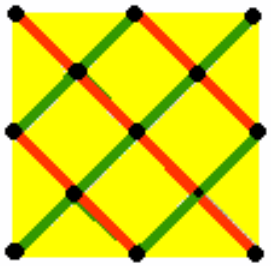
Bit-pair-Equality

Synchronizer, Bit Exchange

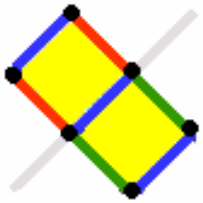
XOR-Transfer



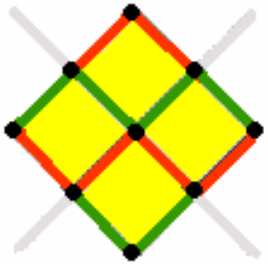
Majority Transfer



$((4, 0), (0, 2))$

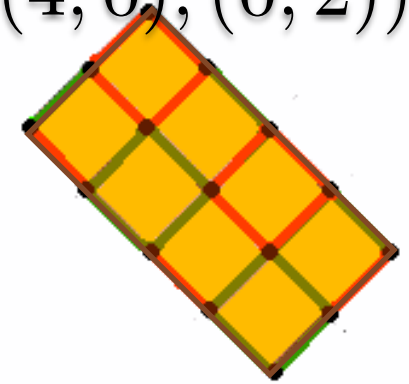


Dual of the two-state Automaton (not a net!)



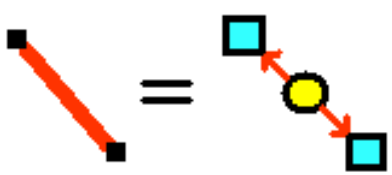
Synchronizer, Bit Exchange

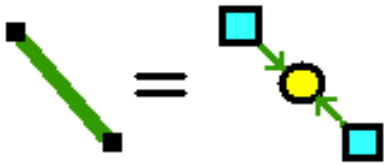
XOR-Transfer



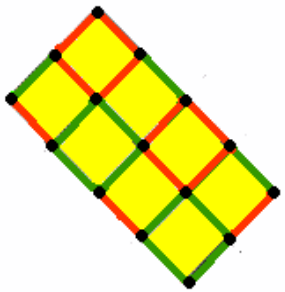
Quine Transfer = conditional Bit Exchange

Legend:





How the Net constructs can be generated from the rough images

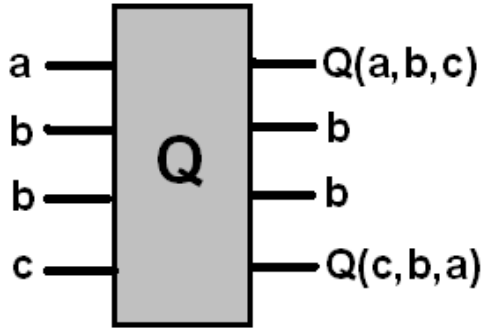


Quine Transfer = conditional Bit Exchange

Quine's Function Q(a,b,c)

means

if b = 0 **then** a **else** c

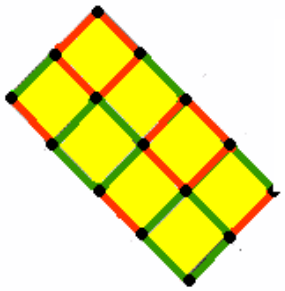


block image

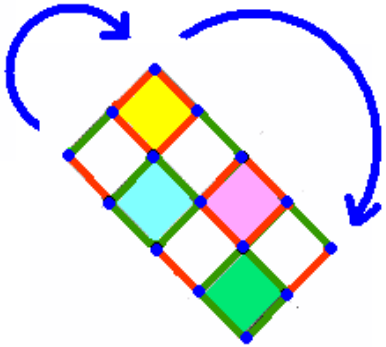
define usage

Information Flow Graph

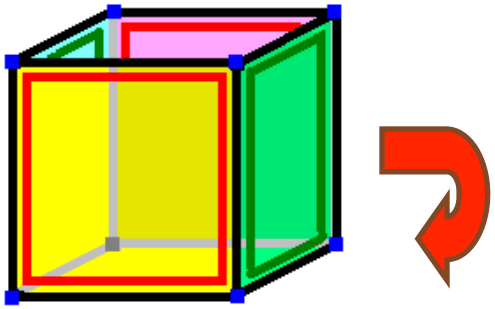
How the Net constructs can be generated from the rough images



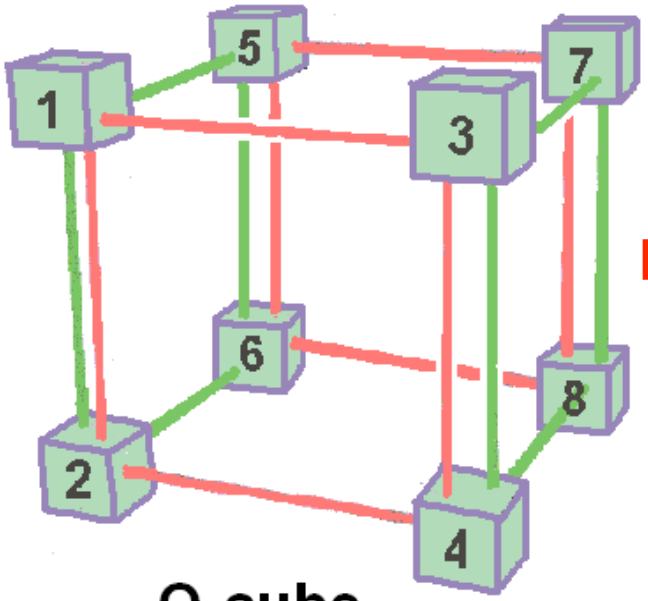
Quine Transfer
= conditional
Bit Exchange



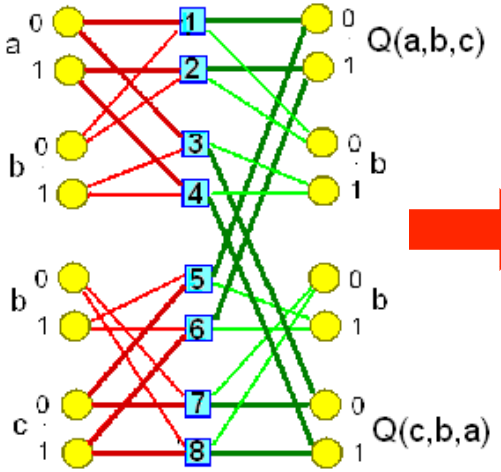
input- and output
squares



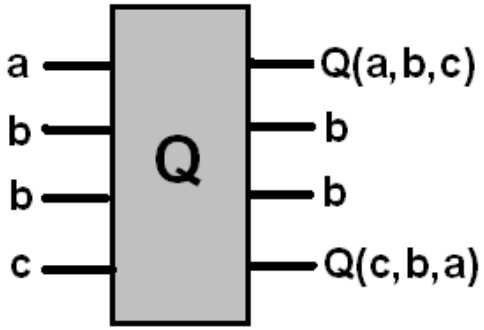
on a cube



Q cube



apply legend
and unfold
define usage



block image

Information
Flow Graph

The Behaviour Net of this „Universe“ is **periodic** because of the finiteness of that Universe. Its size can be estimated as **2^2^2^2^2^2** .

It consists of cyclic **Signal Histories over all time**

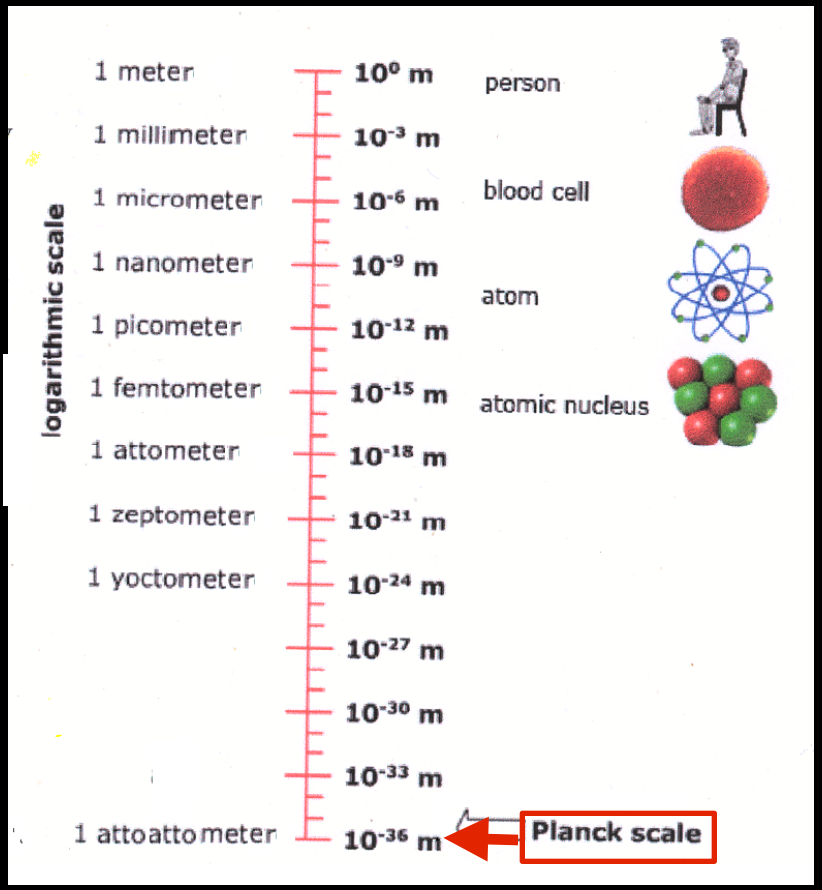
If Information loss occurs, the Behaviour Net is not periodic, nor are the Signal Paths cyclic. Determinism is still holding.

`t Hooft likes that better .

The Planck scale:

On this scale, the unit of length is 1.6 atto-atto-meters (10^-36 m), the unit of time is 5.4 10^-44 sec.

This is the scale for describing „Quantum Foam“ (Zuse‘s words), the scale of String Theories, where gravity, Quantum Field Theory,and General Relativity are included; as yet an unfinished research project.



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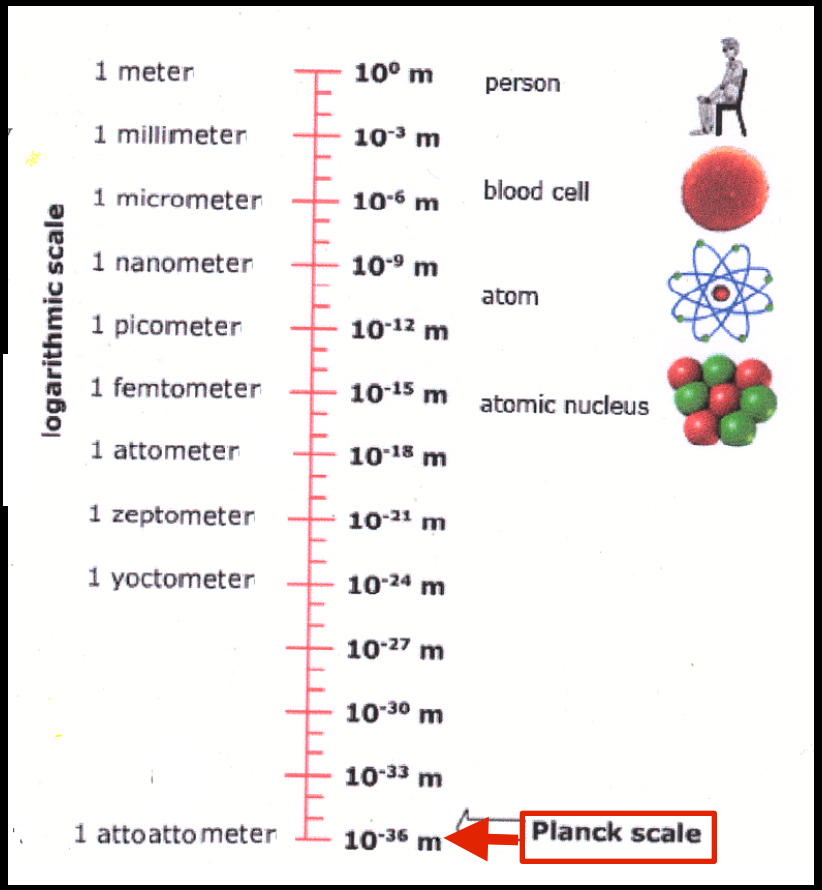


A corresponding particle accelerator for experimental research should have the size of our solar system.

To come to the end

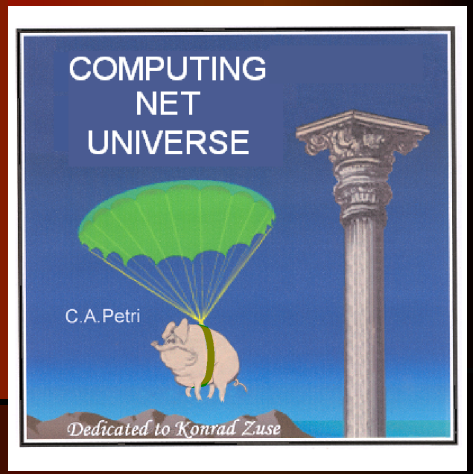
by these slides, partially based on Petris original setting

I hope to have given you

some insight into those of Petri‘s

contributions, he supposed to be essential !

THANK YOU !



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