Organic Computing: Life without Software

NEURO-iT Workshop Bonn

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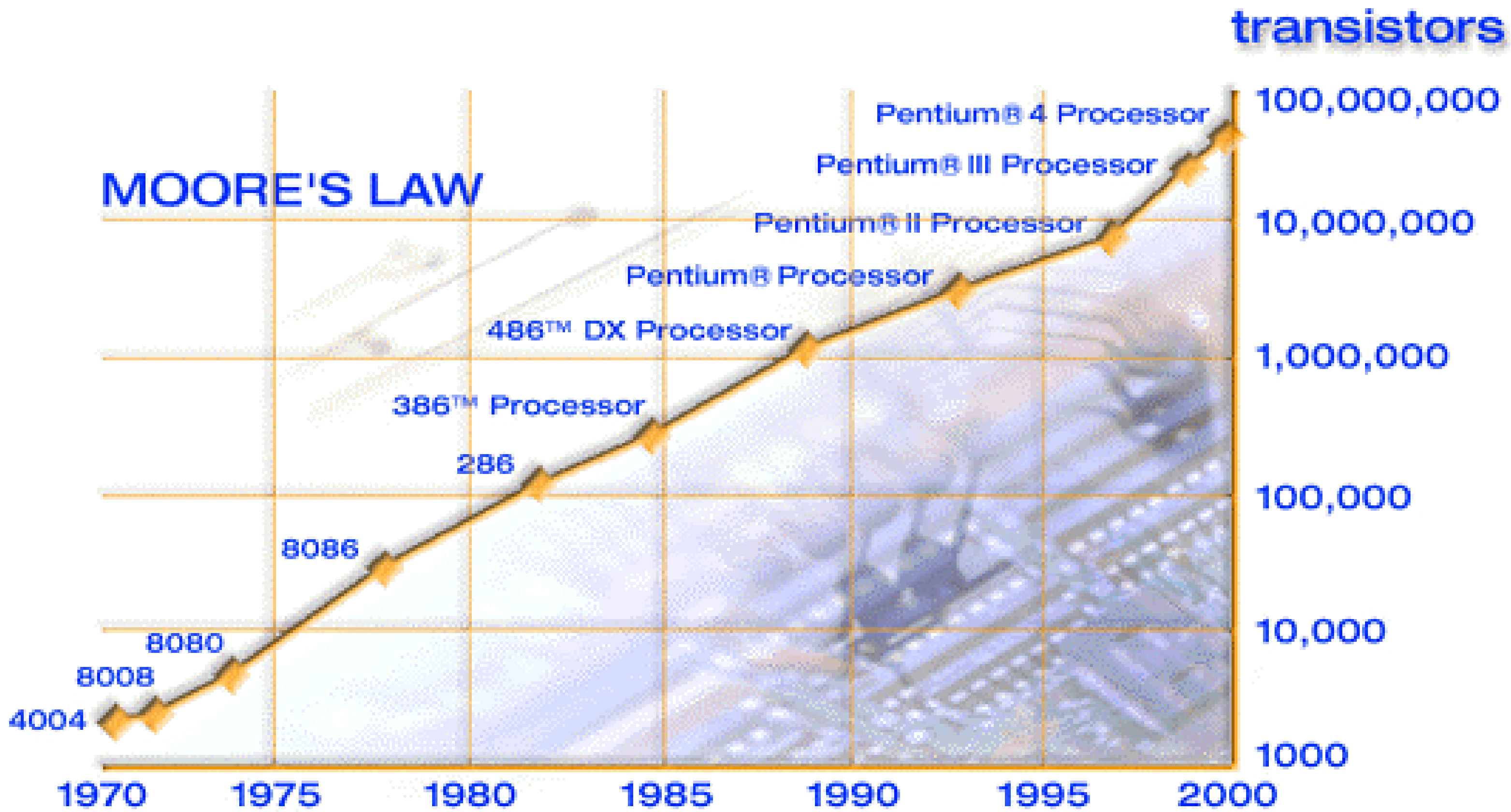


Chip complexity doubles every 18 months

Expectations

More Complex Functions

Flexibility, Robustness

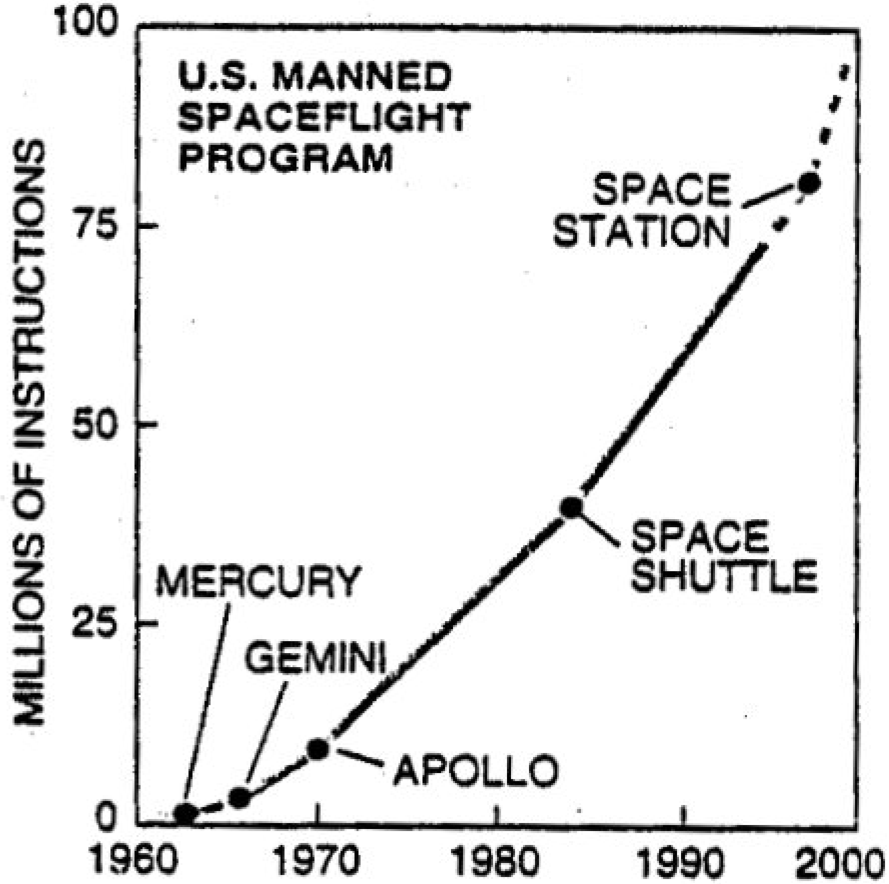
Adaptivity, Evolvability

Autonomy

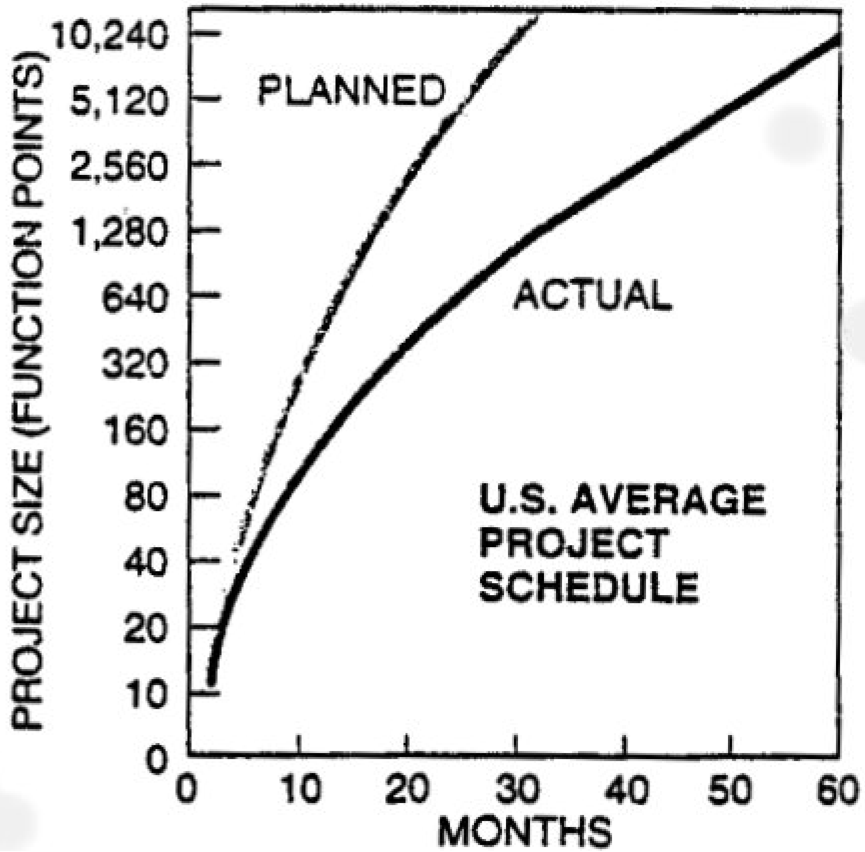
User Friendliness

Situation Awareness

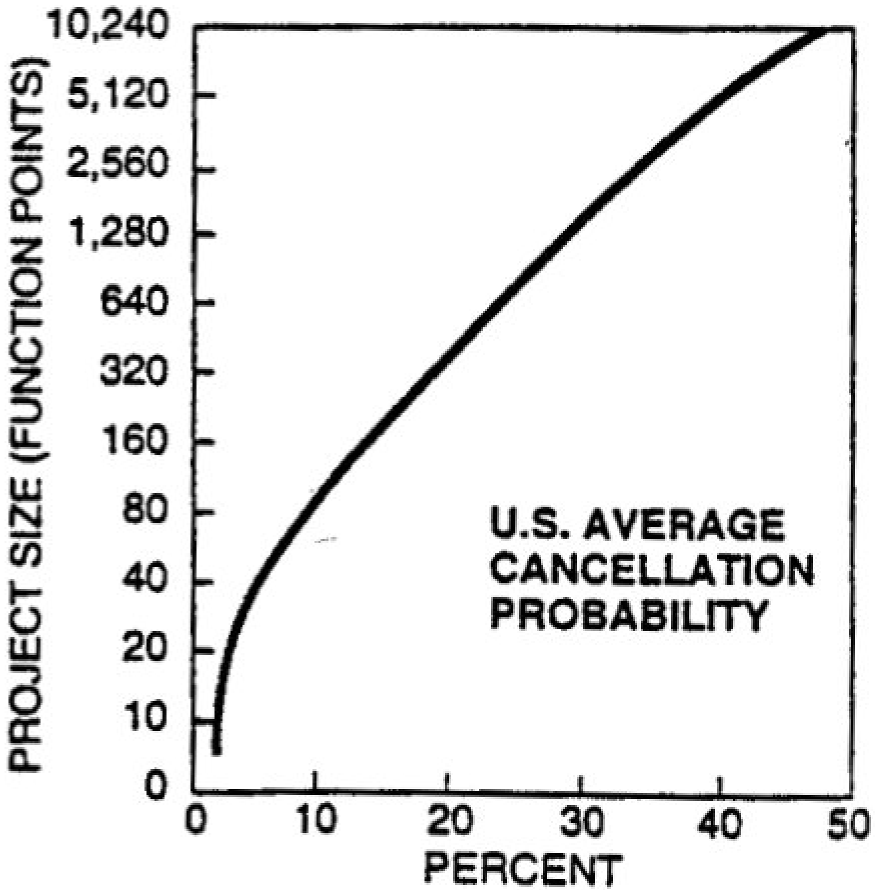
We expect our systems to become intelligent!



SOURCE: Barry W. Boehm



PROJECT SIZE (FUNCTION POINTS)
10,240
5,120
2,560
1,280
640
320
160
80
40
20
10
0
PLANNED
ACTUAL
U.S. AVERAGE
PROJECT
SCHEDULE
0
10
20
30
40
50
60
MONTHS



SOURCE: Software Productivity Research

NIST study 02: yearly US losses due to SW failure: $ 60 Billion

…and what if IT systems grow
by another factor of ten thousand?

Life: Computing without Software

- Living Cell: as complex as PC, but
  flexible, robust, autonomous, adaptive, evolvable, situation aware
- Organism: more complex than all existing software
- Human Brain: intelligent, conscious, creative
  It is the source of all algorithms!!
  Estimated computing power: 10^{15} OPS
  PC today 10^{9} OPS,
  By Moore's Law, the PC will equal the brain in 30 years
- But: Life is not digital, not deterministic, not algorithmic

Evolving Computing Needs:

- From Algorithms …
  Arithmetic, Accounting, Differential Equations
- … to Systems
  Coordination of Sub-Processes
  Communication
  Perception
  Autonomous Action

A New Computing Paradigm:

Organisms are Computers

Computers should be Organisms

Organic Computing

Algorithmic Division of Labor

Human:

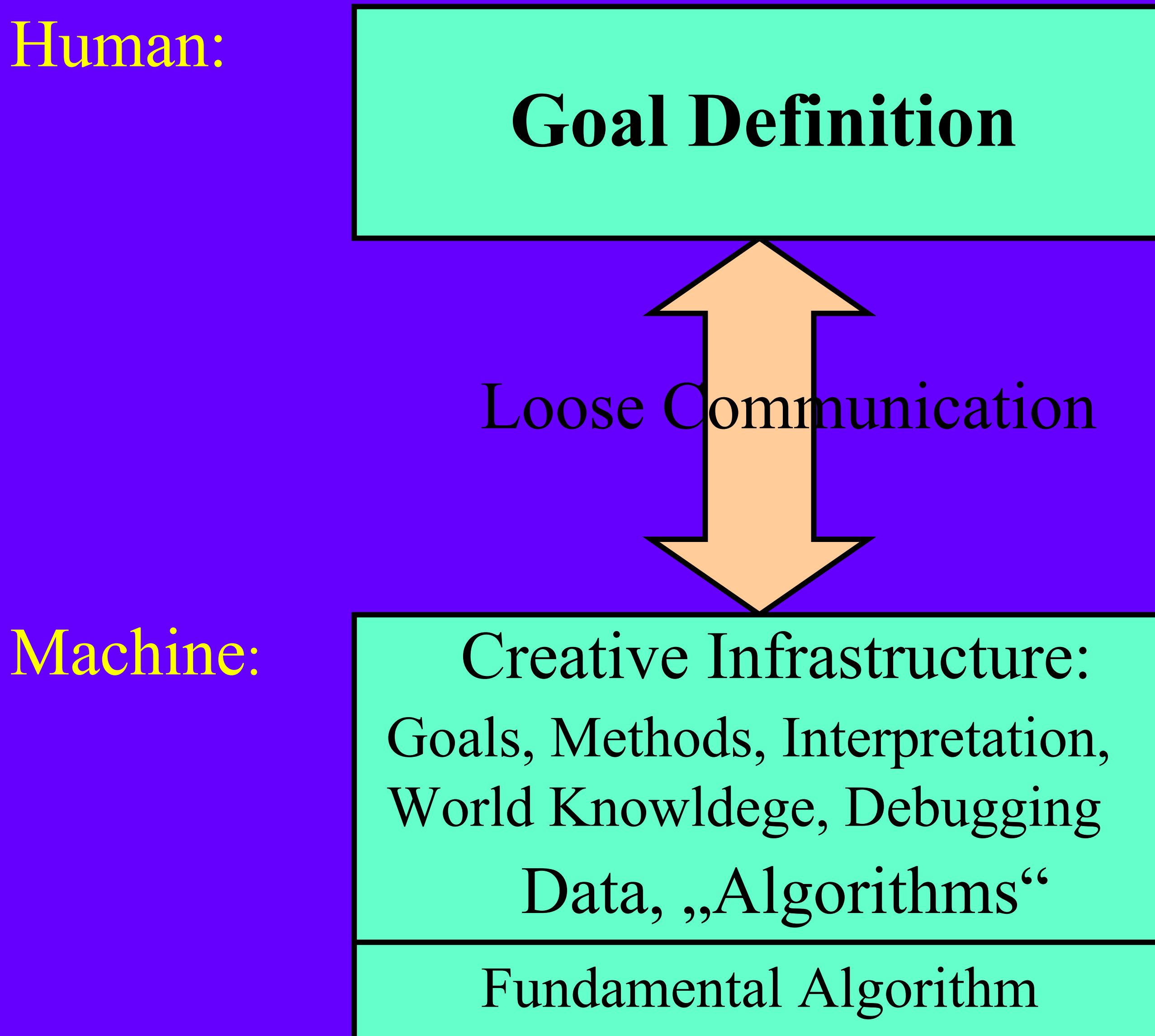
Creative Infrastructure:
Goals, Methods, Interpretation,
World Knowledge, Diagnostics

Detailed Communication

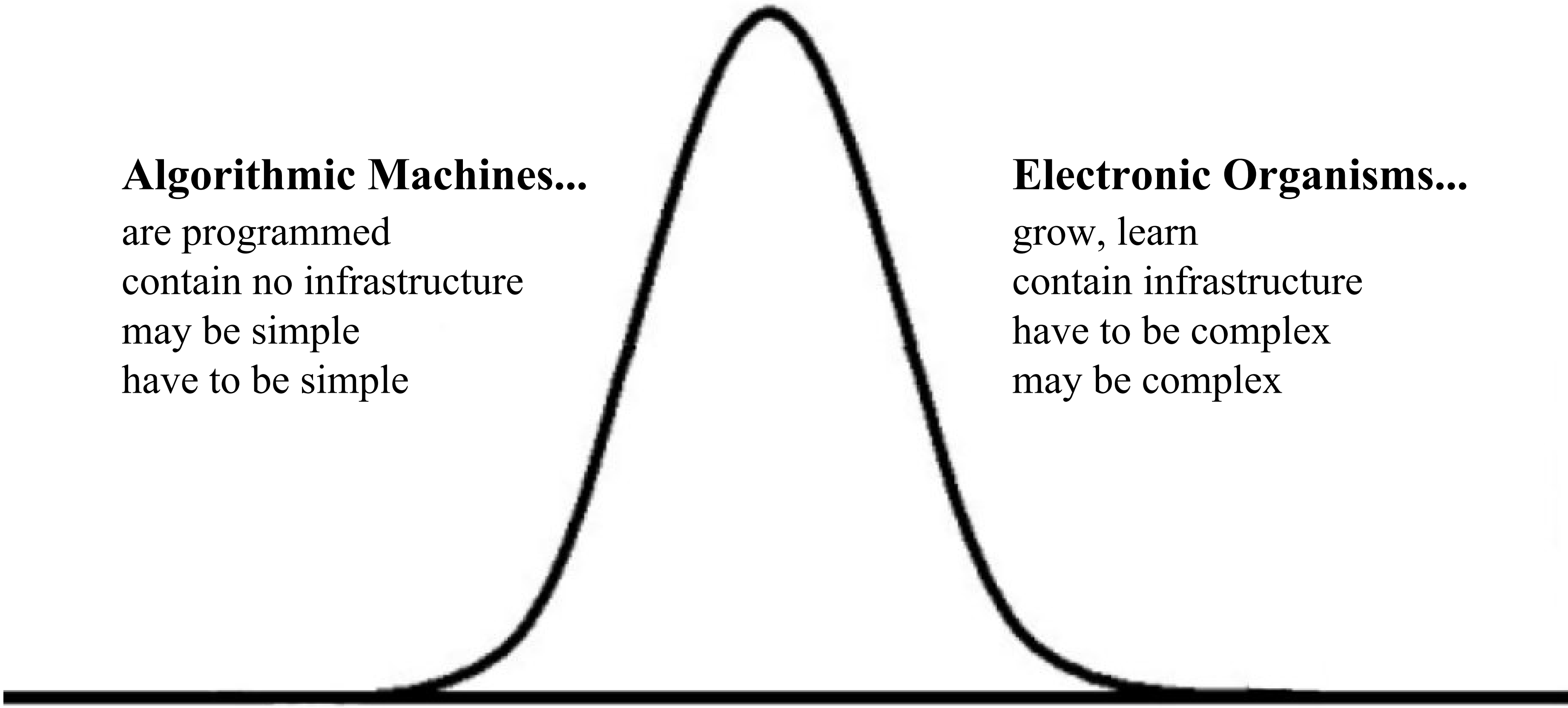
Machine:

Algorithms:
deterministic, fast, clue-less

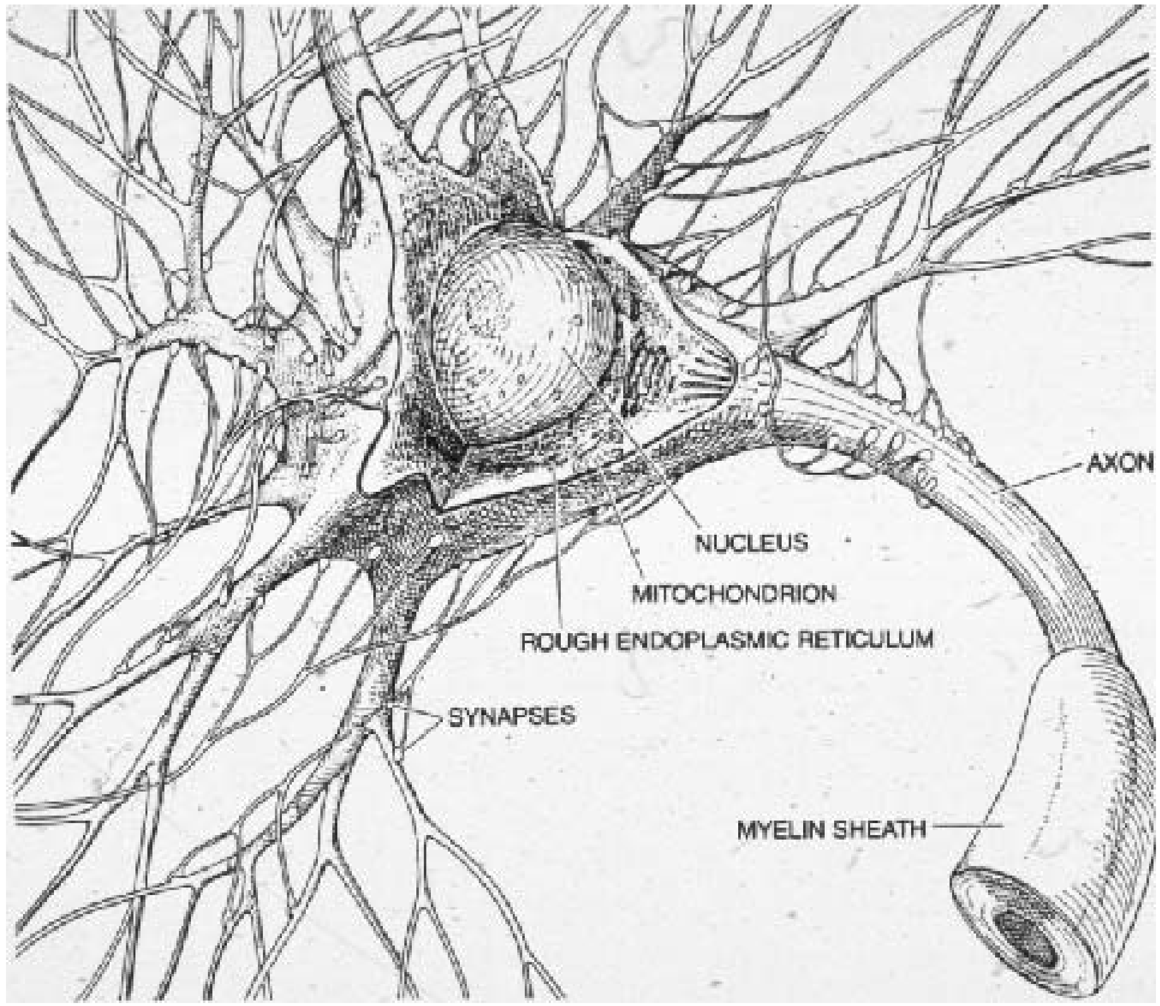
Organic Computers



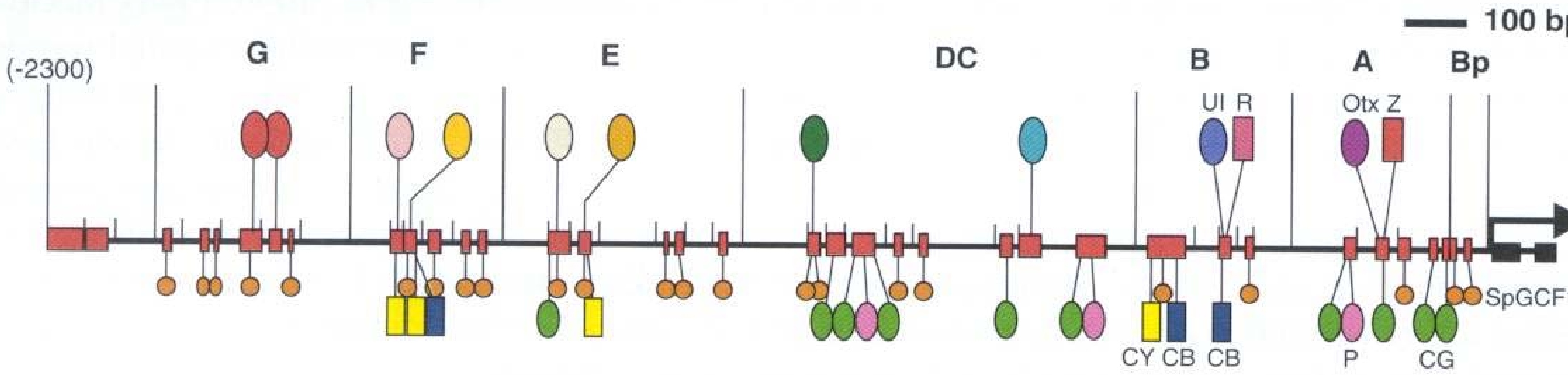
Electronic Organisms



Constraints set by Neuroscience



Constraints set by Molecular Biology



G Positive booster

F } Repression in adjacent ectoderm
E

DC Repression in skeletogenic mesenchyme

B Expression in midgut of late embryo

Controls late rise in expression

Activates switch resulting in exclusive use of its own inpu

A Expression in vegetal plate in early embryo

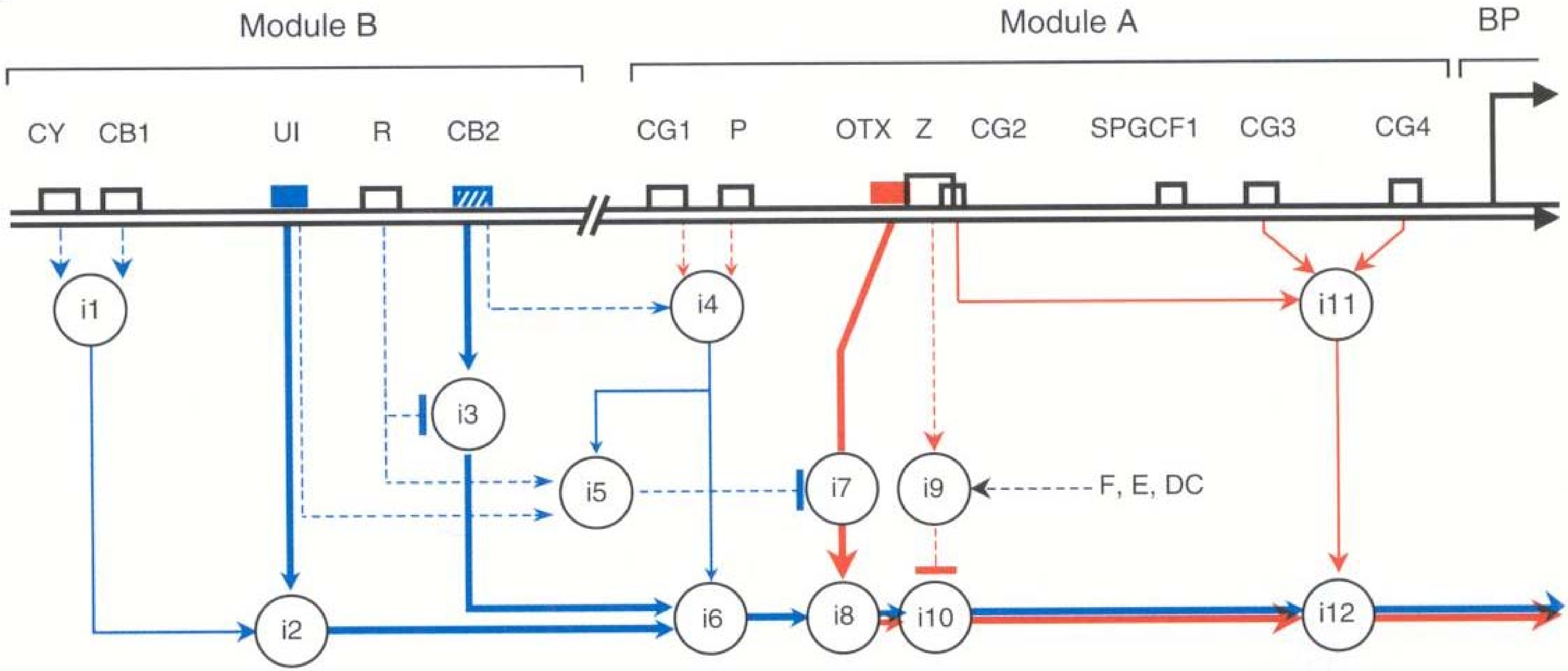
Sole communication to BTA for whole system

Synergistic amplification of B input

Transduction of FE, DC repression

Davidson 1

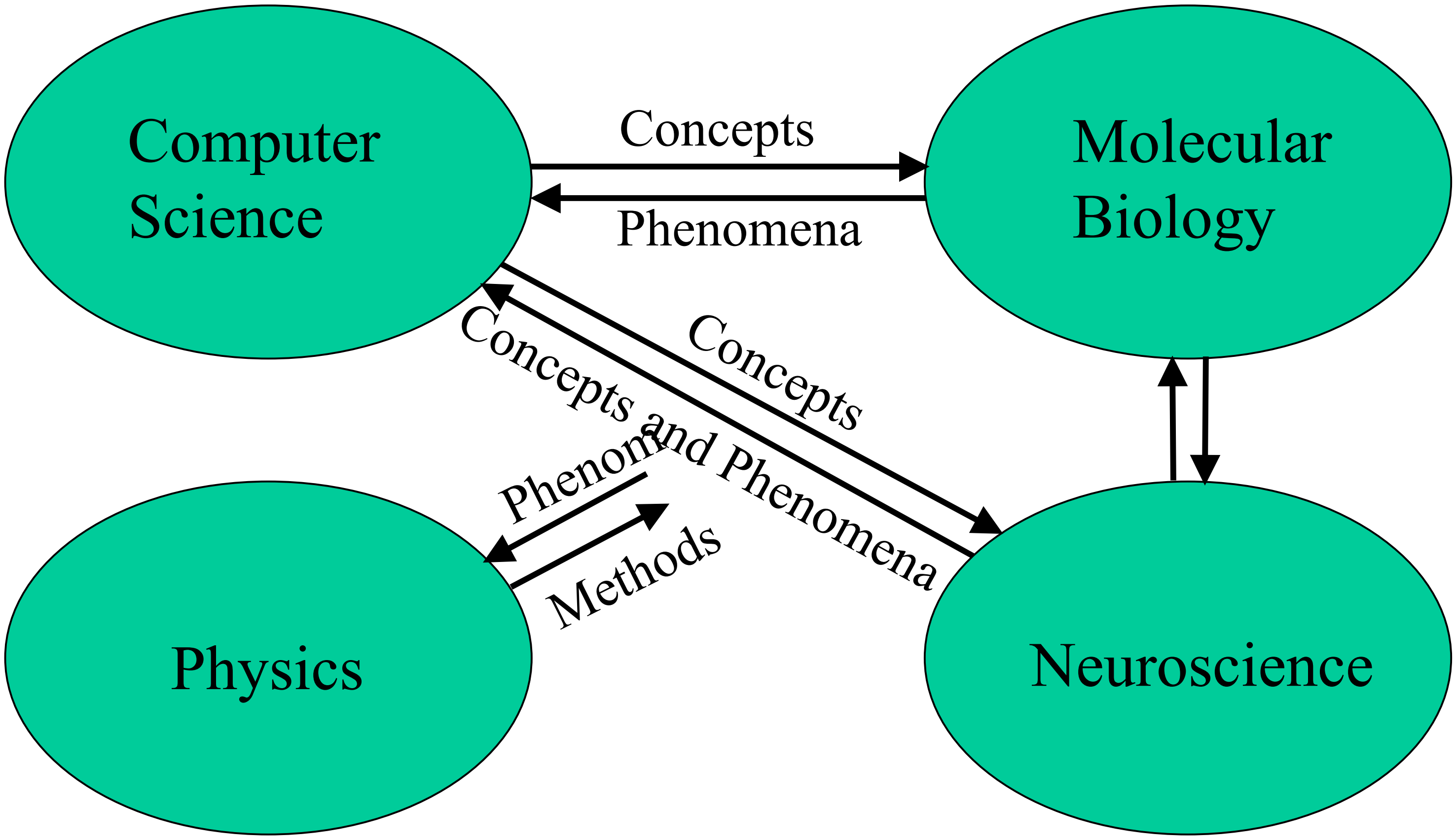
C



Module B
Module A
BP
CY
CB1
UI
R
CB2
CG1
P
OTX
Z
CG2
SPGCF1
CG3
CG4
i1
i2
i3
i4
i5
i6
i7
i8
i9
i10
i11
i12
F, E, DC

Davidson 2

Interdisciplinary Cooperation



Existing Efforts

Neural Networks

Fuzzy Logic

Genetic Algorithms

Artificial Life

Autonomous Agents

Amorphous Computing

Belief Propagation

Production Systems

Some Current Initiatives

- IBM‘s Autonomic Computing Campaign

  www.ibm.com/research/autonomic

- Organic Computing Web Site

  www.organic-computing.org

- Britain’s Foresight program:

  Cognitive Systems Project
  www.foresight.gov.uk

- GI (Gesellschaft für Informatik):

  Organic Computing Initiativex
  www.organic-computing.de

- DFG: Cognitive Systems Center

  Call for proposals

Issues

- A Generic Data Architecture
- A Generic Process Architecture: Self-Organization
- Autonomous Sub-System Integration
- Goal Definition
  by Humans
  by Self-Organization
- Instruction (Man-Machine Interfaces!)
- Autonomous Learning from the Natural Environment

The Neural Gap

Algorithmic Computing

universal but dependent on man

Neural Computing

adaptive but not universal

The Dynamic Link Architecture

…as theory of the brain's function

Generic data structure: Graphs

Nodes: (groups of) Neurons as elementary Symbols

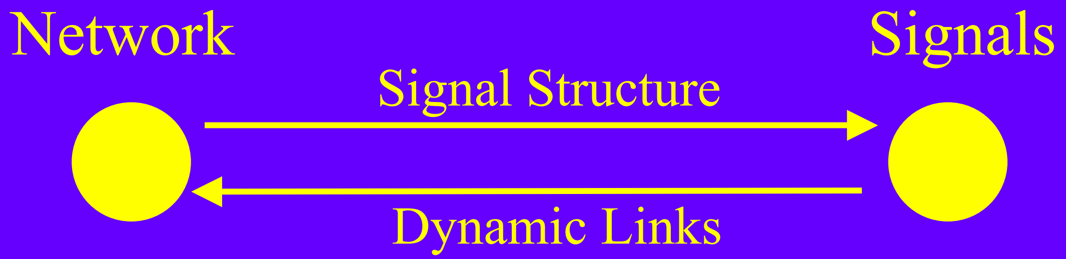
Links: basis for compositionality

Generic process structure: Network Self-Organization

Creating a structured universe

Important process: recognition of isomorphy

Rapid Network Self-Organization



Characterization of Attractor Networks:

- Redundant Pathways
- Sparcity

The Learning Problem

- Central problem: recognize *significant* connections and patterns
- Associative Memory: *all* connections are strengthened
  Result: monolithic attractor states
- NN learning: significance defined as statistical recurrence
  Result: learning time explodes beyond 100 bit input patterns
- Required: a definition of significance that …
  - can be diagnosed in individual scene
  - incorporates purpose
- Statistics is context-dependent
  Result: learning deadlock
  without (context-) recognition no learning,
  without learning no recognition

Schema-Based Learning

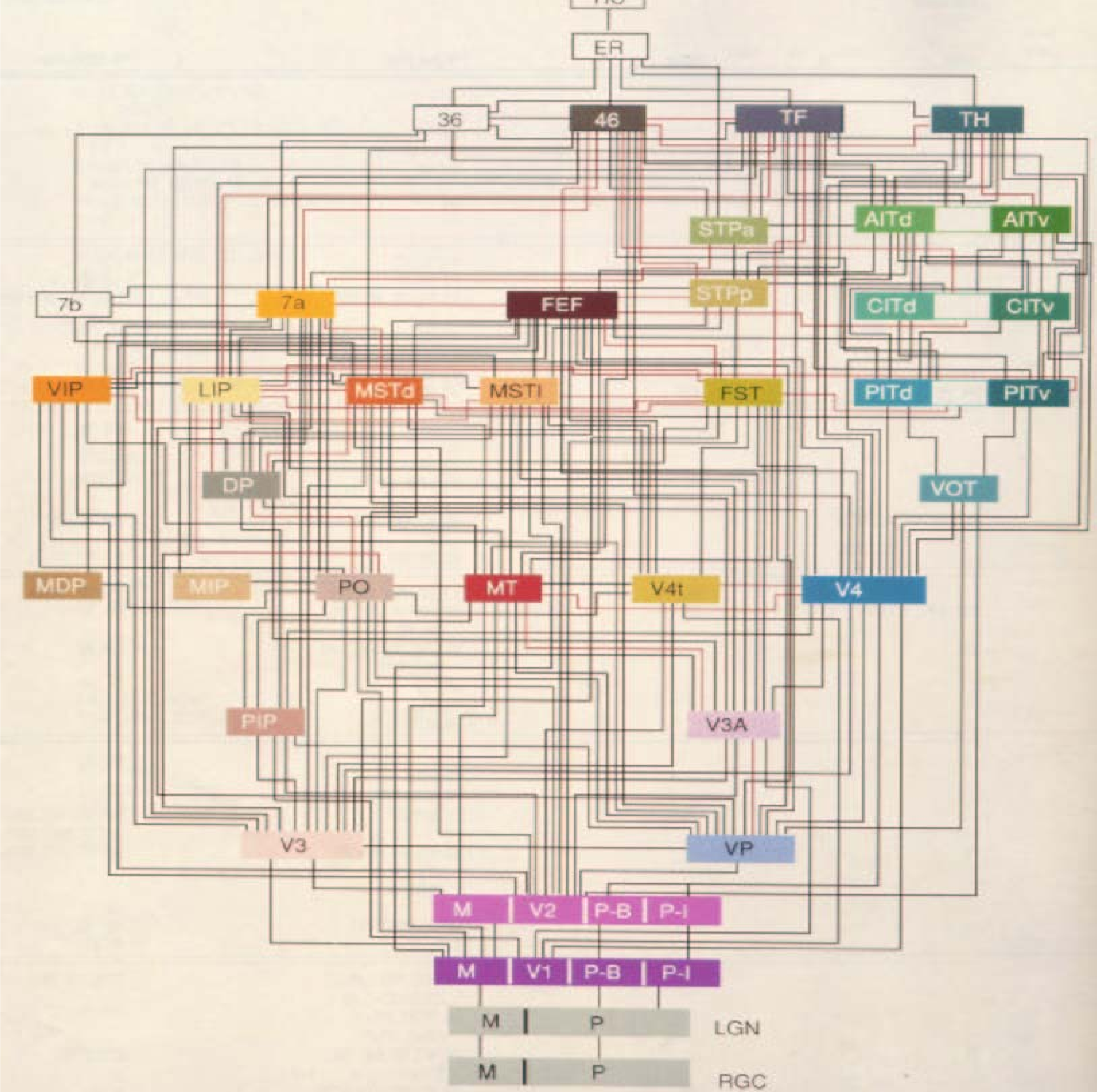
Functional significance defined by pre-existing schemas (originating from evolution, culture, learning or design)

A schema is a flexible description of a situation

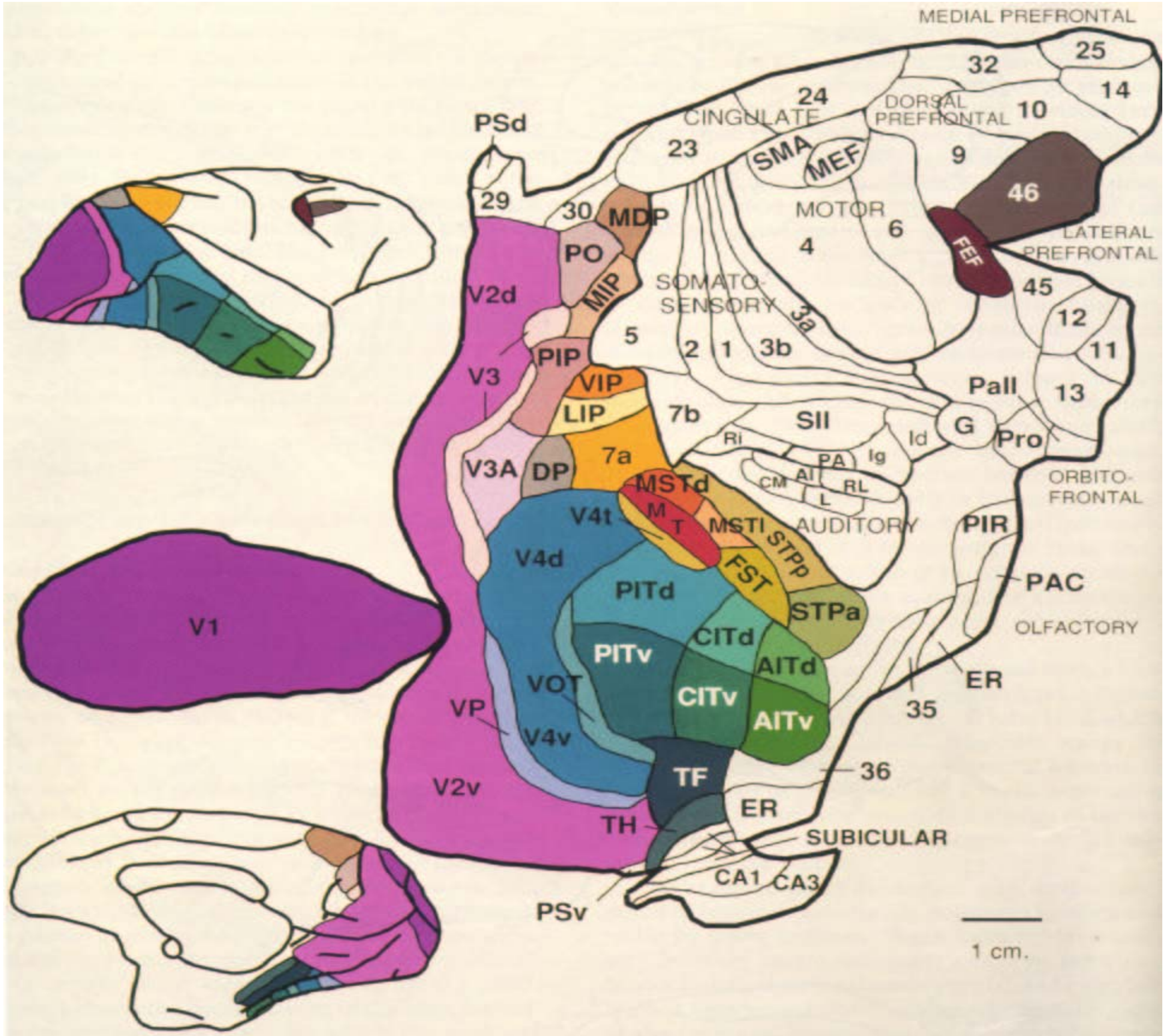
Learning proceeds by …

1. Recognizing a schema
2. Extracting the recognized elements
3. Compacting such examples by statistical means

Vision as Major Application Domain

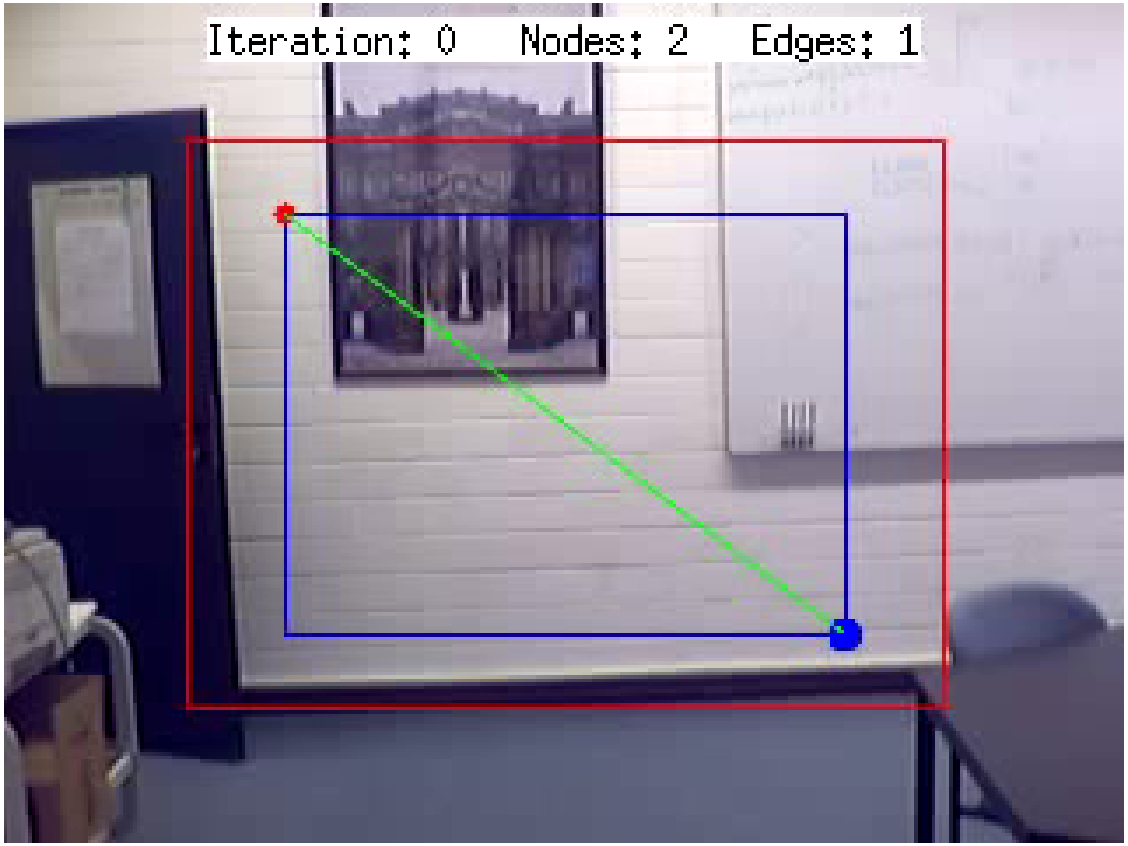


ER
36
46
TF
TH
STPa
AITd
AITv
7b
7a
FEF
STPp
CITd
CITv
VIP
LIP
MSTd
MSTl
FST
PITd
PITv
DP
VOT
MDP
MIP
PO
MT
V4t
V4
PIP
V3A
V3
VP
M
V2
P-B
P-I
M
V1
P-B
P-I
M
P
LGN
M
P
RGC

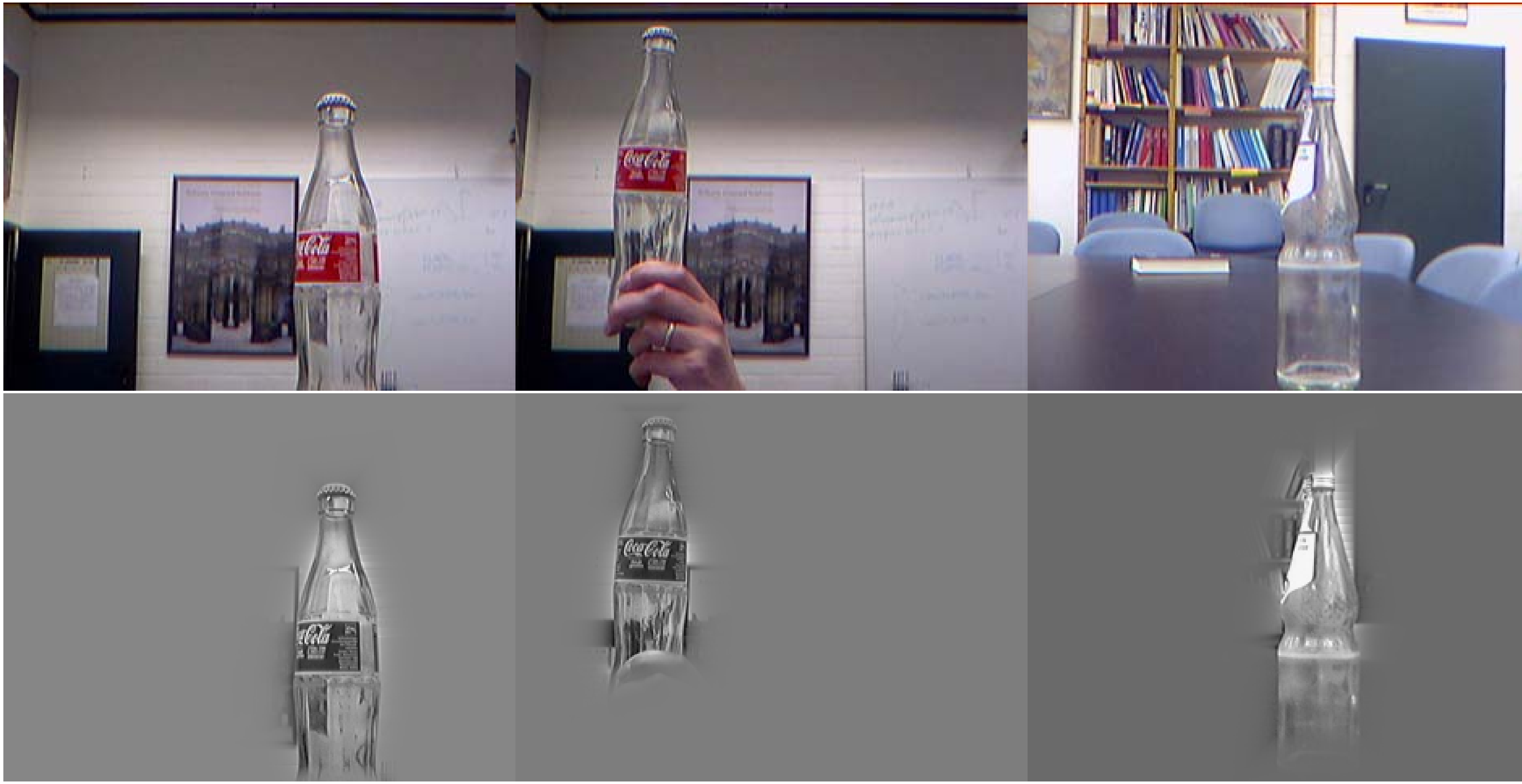


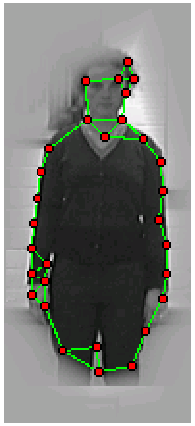
MEDIAL PREFRONTAL
25
32
14
24
10
CINGULATE
DORSAL PREFRONTAL
PSd
23
SMA
MEF
9
29
30
MDP
MOTOR
46
6
LATERAL PREFRONTAL
PO
4
FEF
V2d
MIP
SOMATO-SENSORY
45
3a
12
5
2
1
3b
11
PIP
V3
VIP
Pall
13
LIP
7b
SII
G
Ri
Id
Pro
7a
PA
Ig
V3A
DP
CM
AI
RL
ORBITO-FRONTAL
MSTd
L
V4t
M
T
MSTl
AUDITORY
PIR
STPp
V4d
FST
PAC
PITd
STPa
V1
CITd
OLFACTORY
PITv
AITd
VOT
ER
CITv
VP
35
AITv
V4v
36
TF
V2v
ER
TH
SUBICULAR
CA1
CA3
PSv
1 cm.

One-Click Learning



Hartmut Loos





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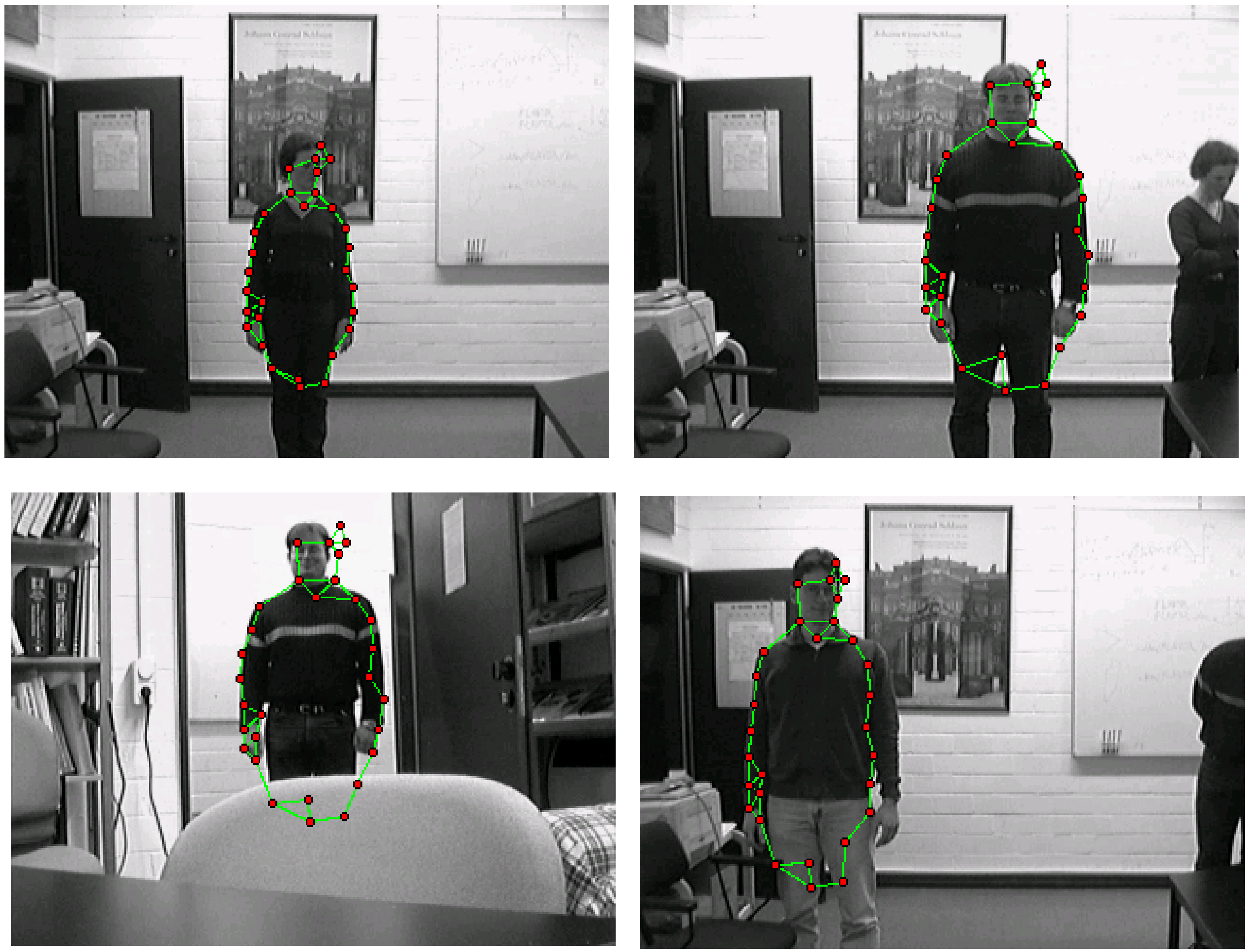

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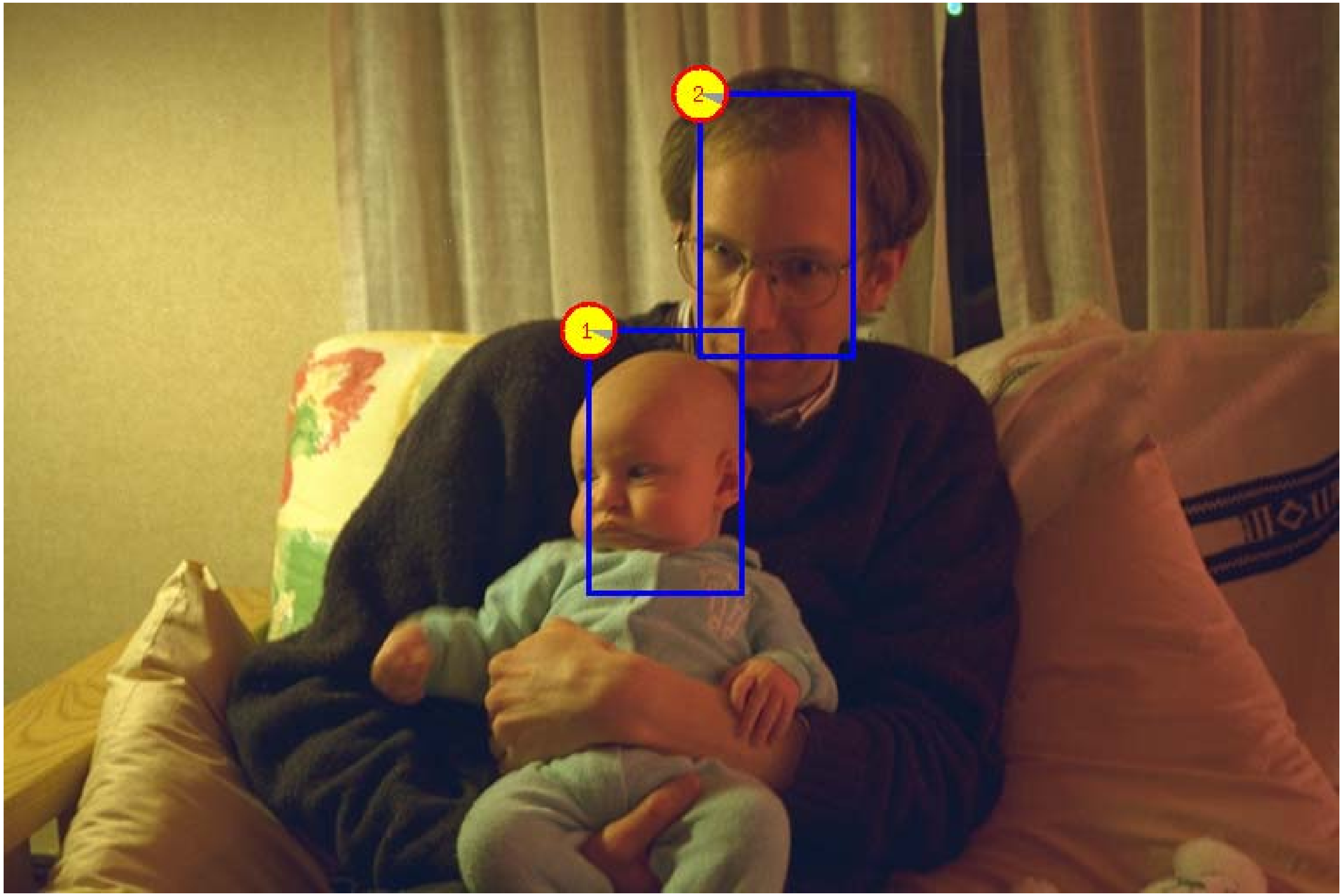
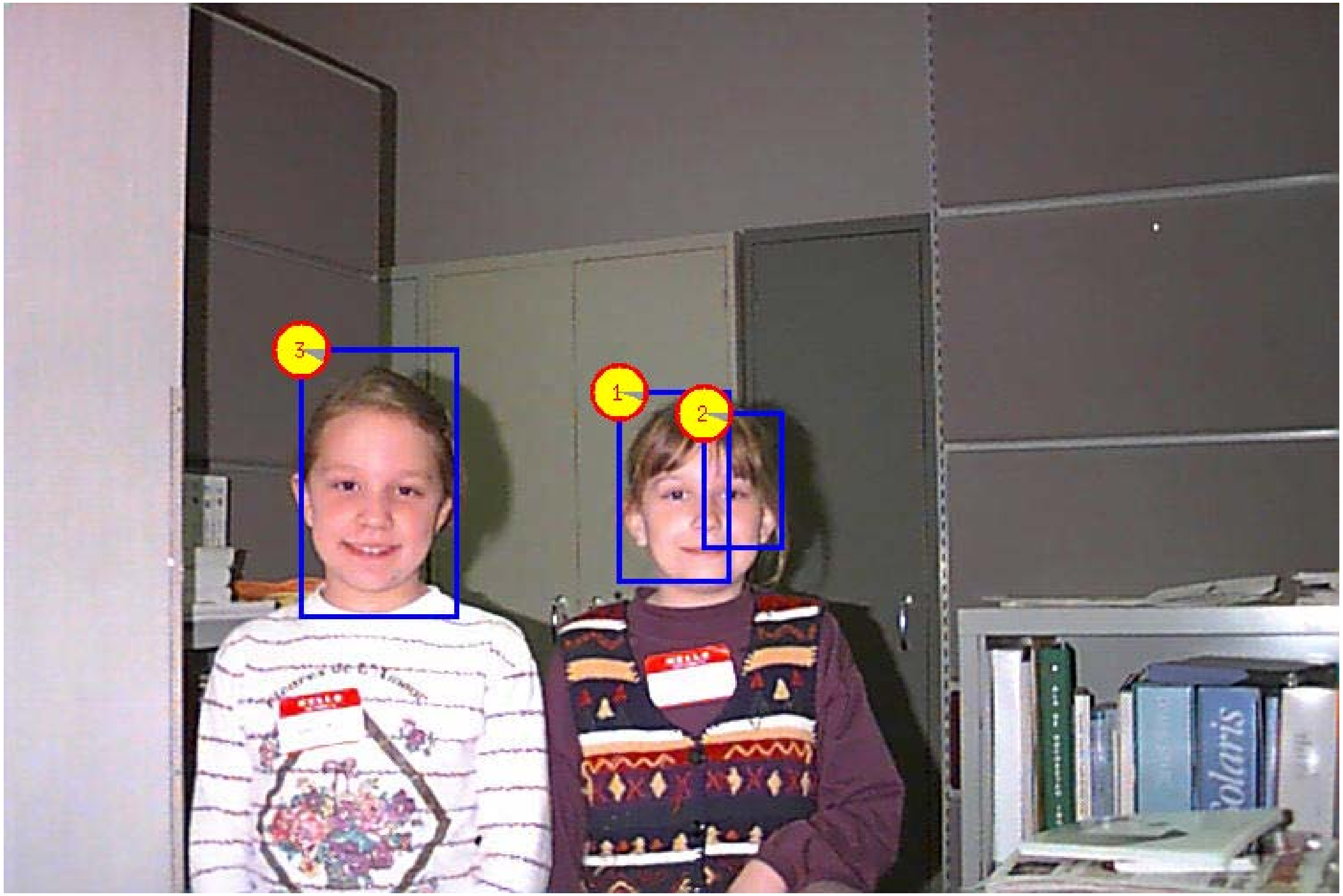
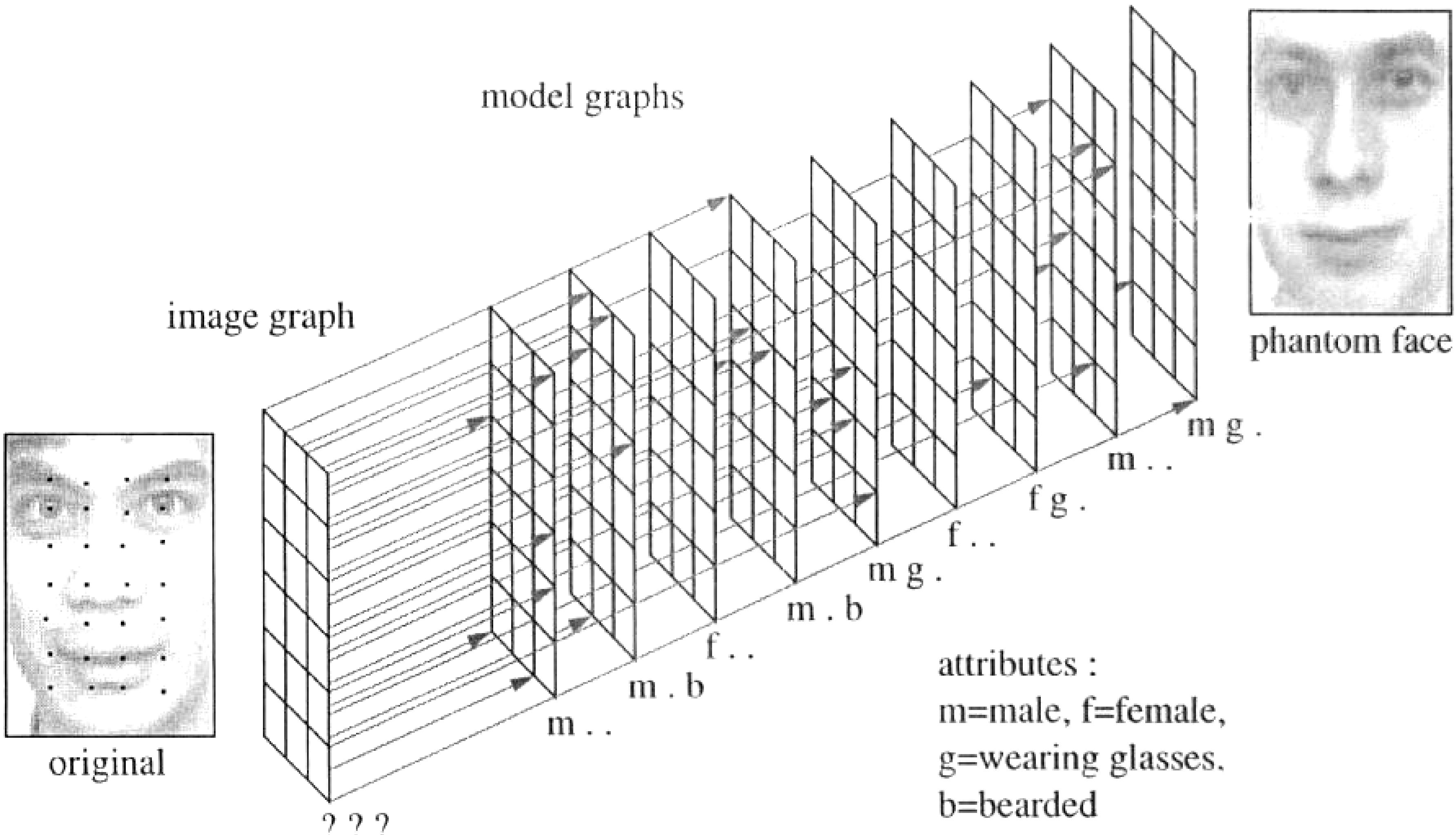

2
1

Kodak Data Base: failures

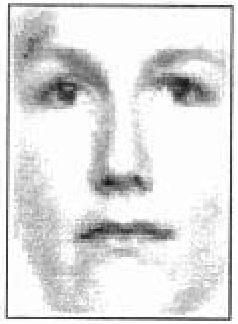


Interpreting Faces by Bunch Graphs



Laurenz Wiskott

original | phantom face | model attributes




f	f	f	f	.	.	.	.
f	f	f	m	.	.	.	.
f	f	m	m	.	.	.	.
f	f	f	f	.	.	.	.
f	f	f	f	.	.	.	.
f	f	f	f	.	.	.	.
f	f	f	f	.	.	.	.

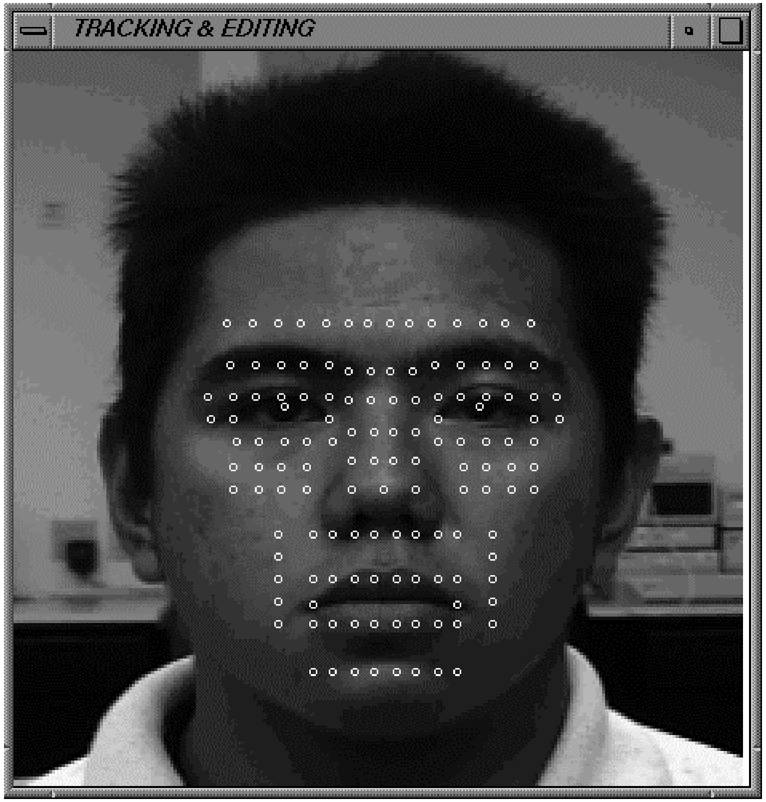
attributes determined: person is female, has no glasses, and is not bearded

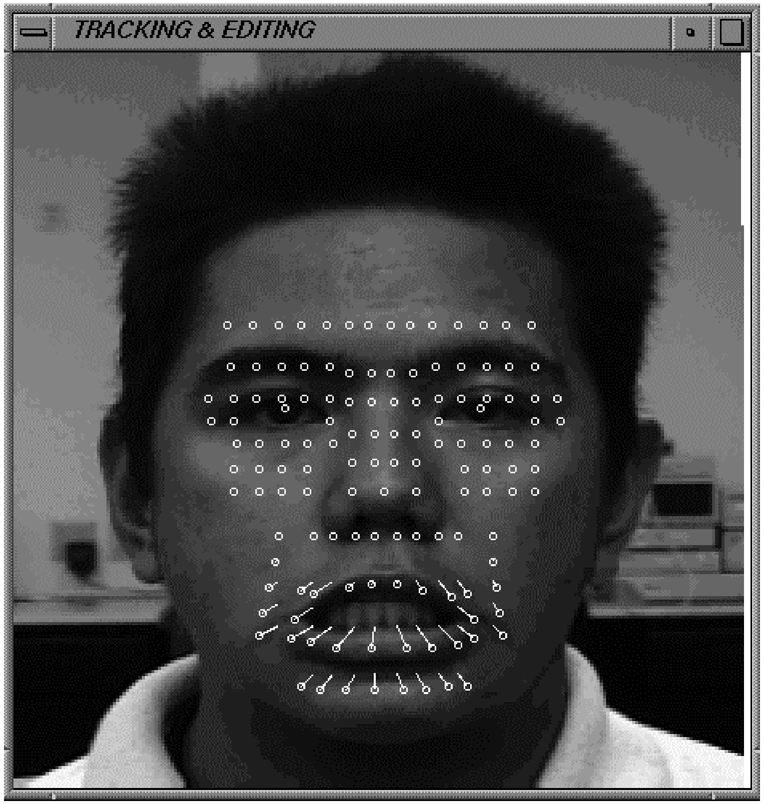

m	m	m	m	.	.	.	g
m	m	f	m	g	g	g	g
m	f	m	m	g	g	g	g
f	f	f	m	g	g	g	g
f	f	f	f	.	.	.	.
f	f	f	f	.	.	.	.
f	f	f	f	.	.	.	.

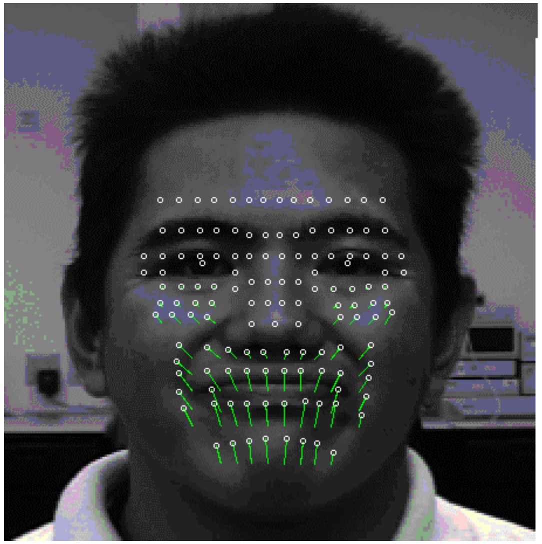
attributes determined: person is female, has glasses, and is not bearded

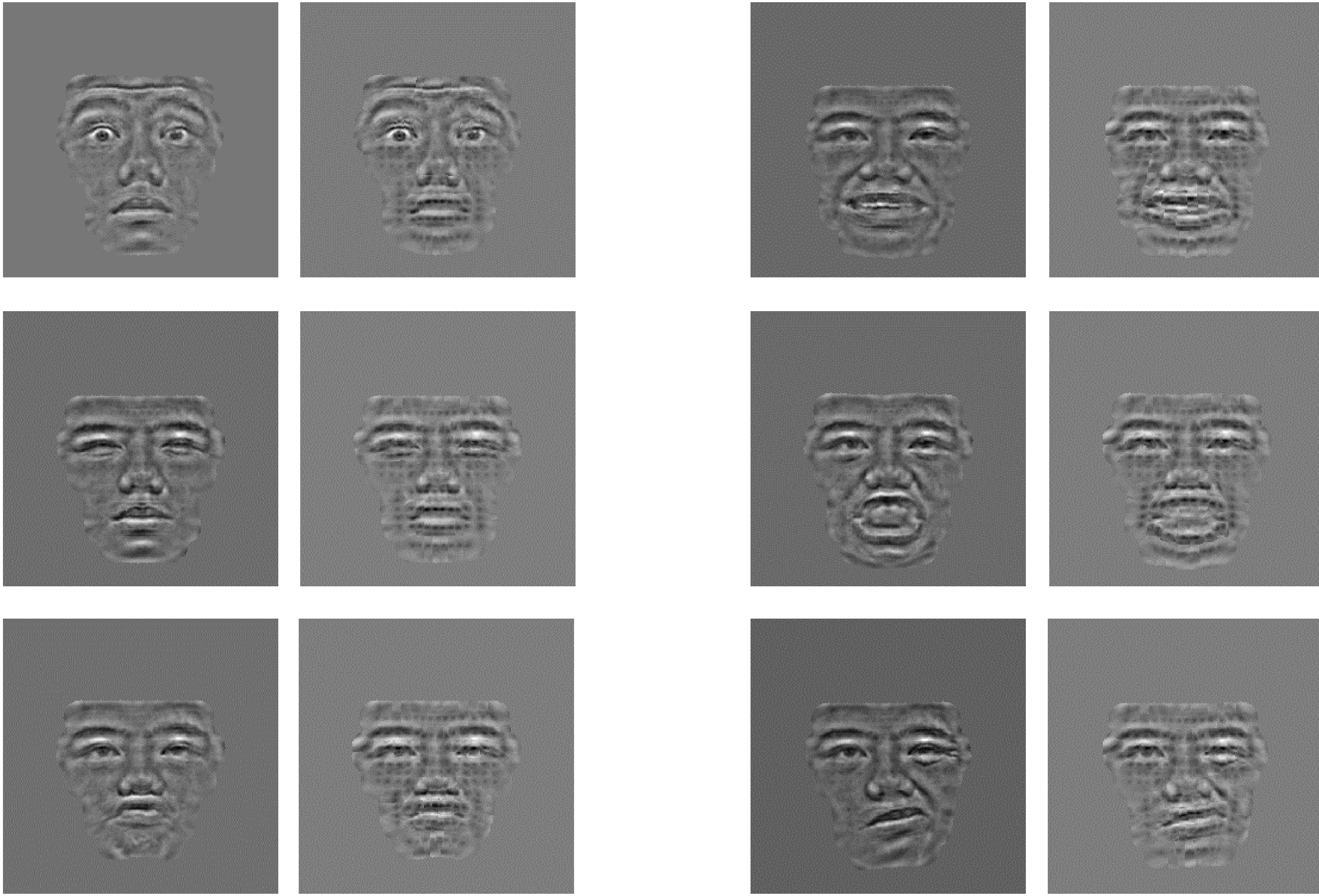

m	m	m	m	g	g	g	g
m	m	m	m	.	g	g	g
m	m	m	m	g	g	g	g
m	m	m	m	g	g	g	g
m	m	m	m	b	b	b	b
m	m	m	m	b	b	b	b
m	m	m	m	.	b	b	.

attributes determined: person is male, has glasses, and is bearded


TRACKING & EDITING


TRACKING & EDITING



Conclusions

- The complexity barrier to IT's progress forces major changes in system development methodology
- The algorithmic division of labor is a major stumbling block
- The example of living structures shows the way
- A generic system architecture must be a primary goal
- Present activities must be encouraged and coordinated
- As time frame for a major transformation of IT we must envisage 20 years