Algorithmic Composition

as patterns of intuition

iem

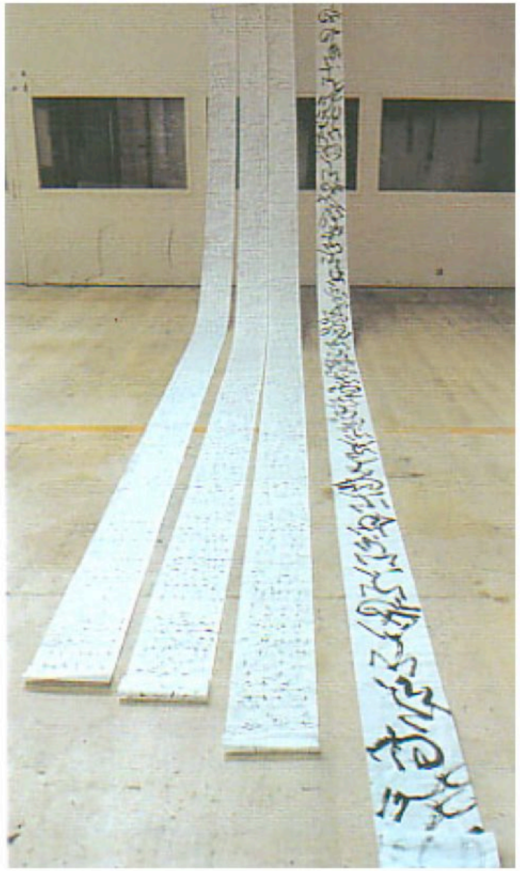
Guest Composers:
Self Similarity in Contemporary Music

Sound Engineer projects:
Comparision of Genetic Operations for Musical Structure Genesis

Computer Music projects:
Generative Trombone Solo

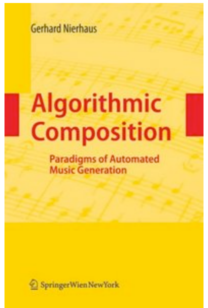
In Collaboraration with Composers:
Patterns of Intuition

Concerts - Collaborations



Algorithmic Composition - Paradigms of Automated Music Composition

?



Gerhard Nierhaus

Algorithmic Composition

Paradigms of Automated Music Generation

SpringerWienNewYork

- “A set of mathematical instructions that must be followed in a fixed order, and that, especially if given to a computer, will help to calculate an answer to a mathematical problem.”

  (Cambridge Advanced Learner’s Dictionary)

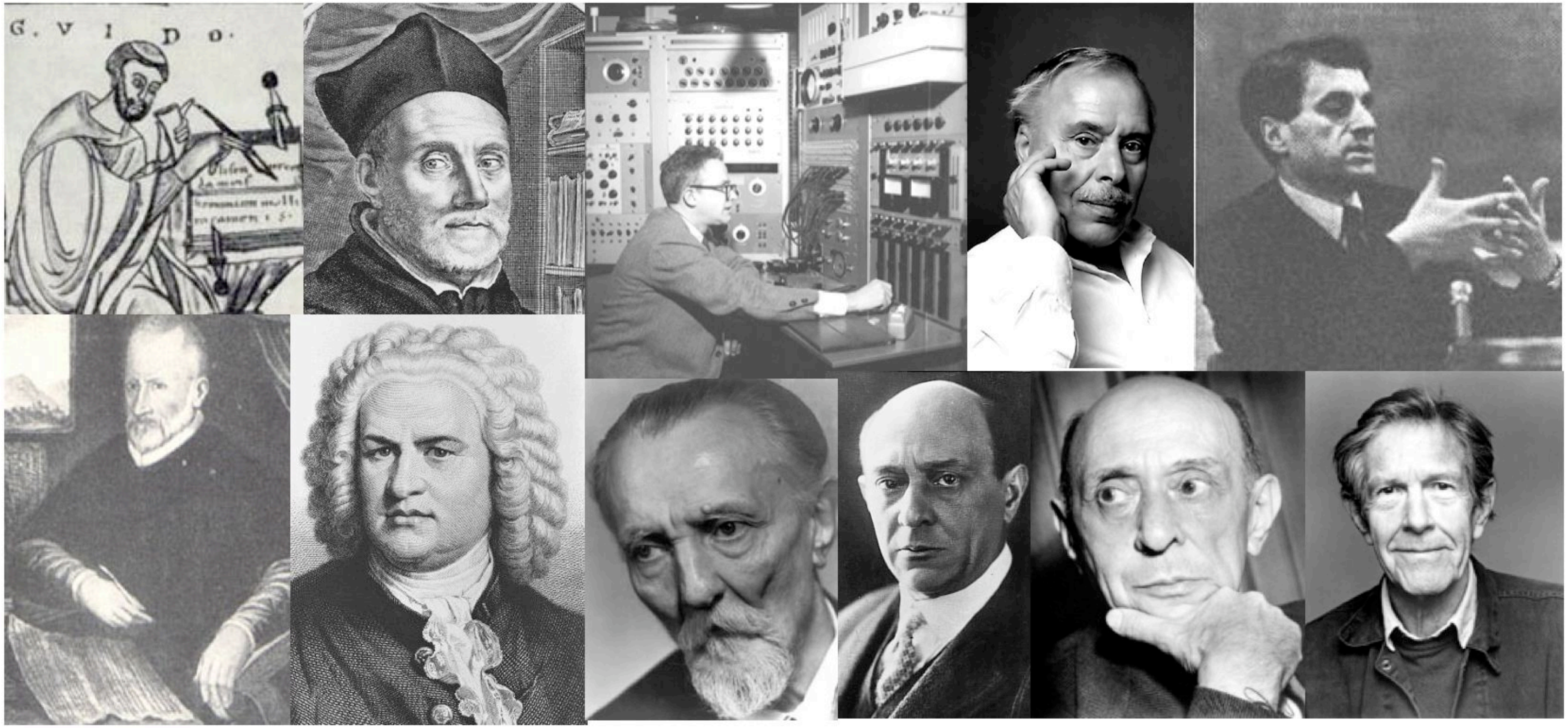
- “A systematic procedure that produces — in a finite number of steps — the answer to a question or the solution of a problem.”

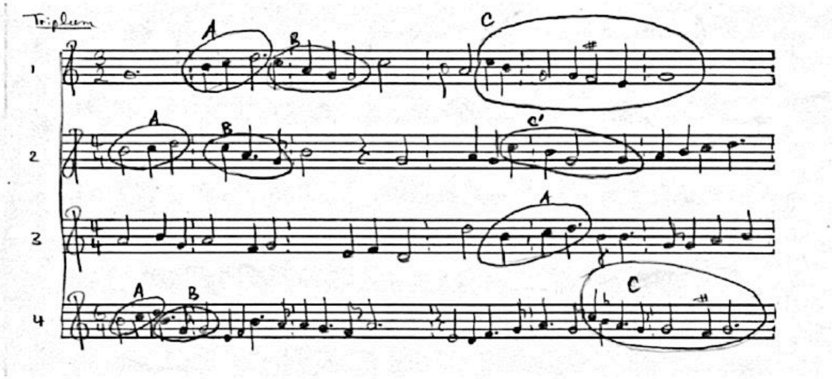
  (Encyclopedia Britannica Online)

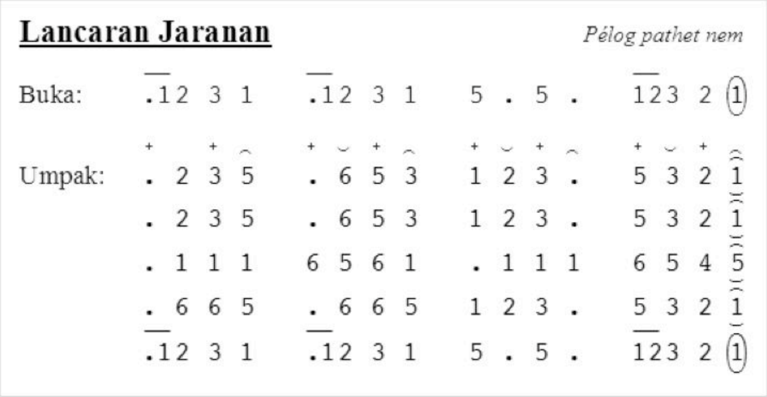
- “[...] (especially computing) a set of rules that must be followed when solving a particular problem.”

  (Oxford Advanced Learner’s Dictionary)

Algorithmic Composition - Computer Assisted Composition

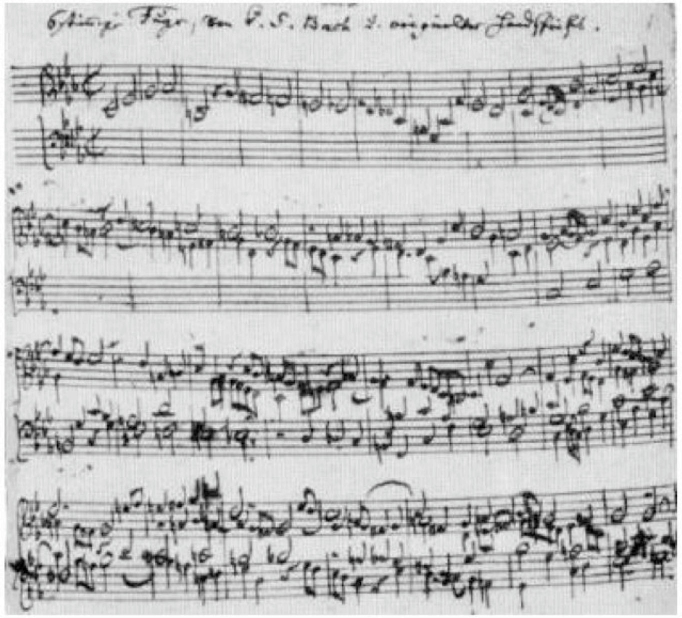

G.VIDO.

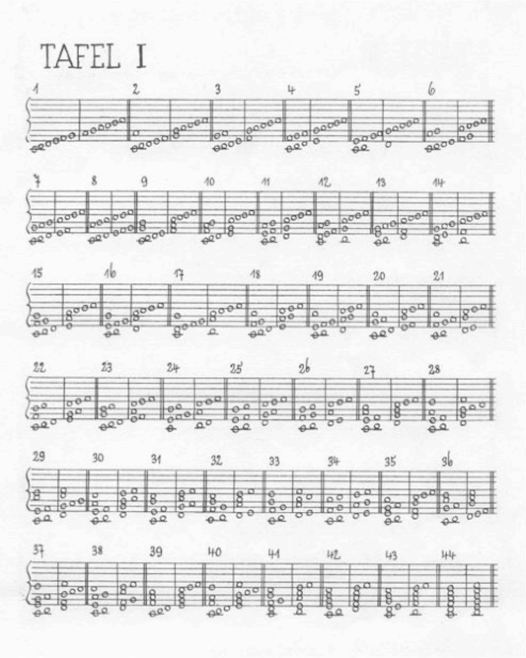

Triplum
1
2
3
4
A
B
C
C'



Lancaran Jaranan *Pélog pathet nem*

Buka:	.12 3 1	.12 3 1	5 . 5 .	123 2 ①
Umpak:	. 2 3 5	. 6 5 3	1 2 3 .	5 3 2 1
	. 2 3 5	. 6 5 3	1 2 3 .	5 3 2 1
	. 1 1 1	6 5 6 1	. 1 1 1	6 5 4 5
	. 6 6 5	. 6 6 5	1 2 3 .	5 3 2 1
	.12 3 1	.12 3 1	5 . 5 .	123 2 ①


6stimmige Fuge, von J. S. Bach d. originaler Handschrift.


TAFEL I
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
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29
30
31
32
33
34
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37
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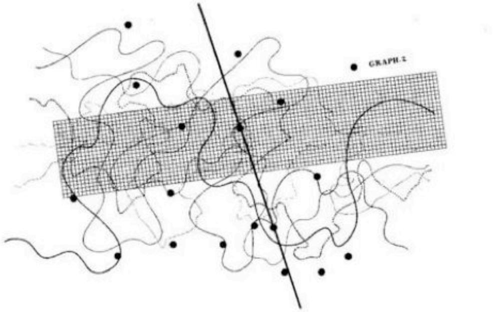
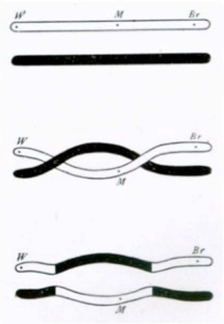
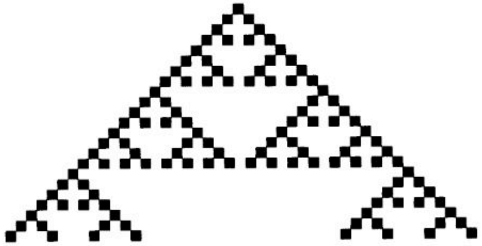
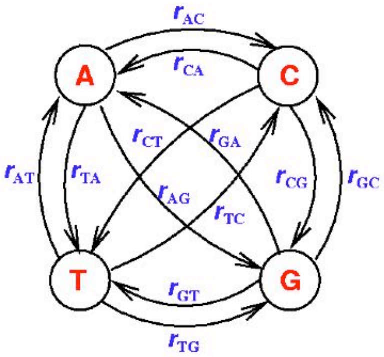
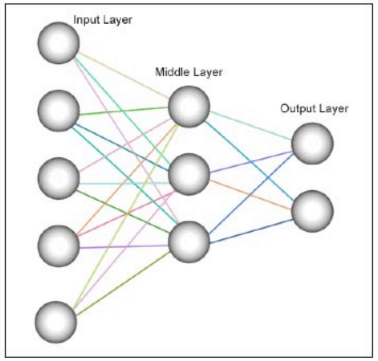
41
42
43
44

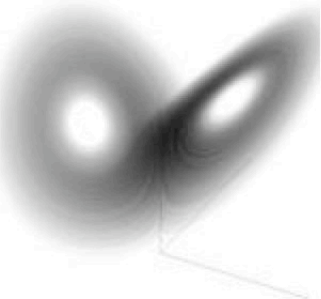


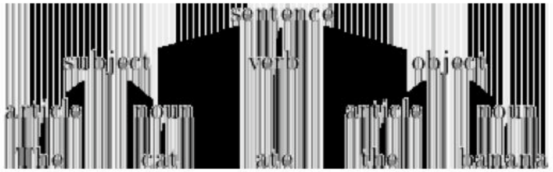

W
M
Br
W
Br
M
W
Br
M

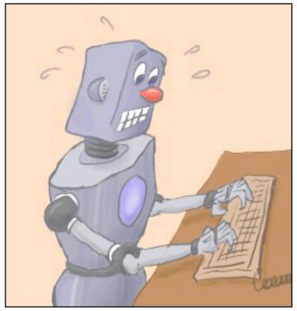



A
C
T
G
r_{AC}
r_{CA}
r_{CT}
r_{GA}
r_{AT}
r_{TA}
r_{CG}
r_{GC}
r_{AG}
r_{TC}
r_{GT}
r_{TG}


Input Layer
Middle Layer
Output Layer




sentence
subject
verb
object
article
noun
article
noun
The
cat
ate
the
banana



Algorithmic Composition

style imitation - genuine composition

Algorithmic Composition - Style Imitation

Representation of musical information

Evaluation of the results

Dominance of Style Imitation?

Aims of Style Generation?

... ?

Algorithmic Composition - Genuine Composition

Looking at paradigms:

Characteristics

Modifications

Representation

Mapping

Algorithmic Composition - Genuine Composition

Looking at implications:

Starting point: algorithm - musical idea

Push button - knowledge

Implications of a tool (Software)

Implication of the interaction cycle

Creation of a metaclass

„Classical Composition“ - „Algorithmic Composition“:

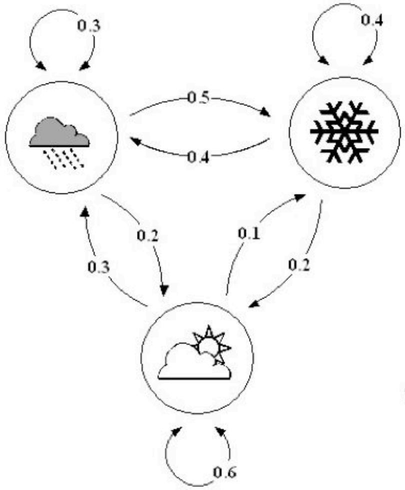
Experiences during writing - unfolding algorithm

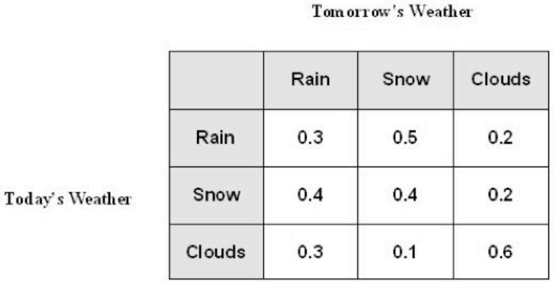
Time travel - The end to the beginning

„Intuition“ - „Formalization“: a contradiction ?

А. А. Марков (1886).

- Models

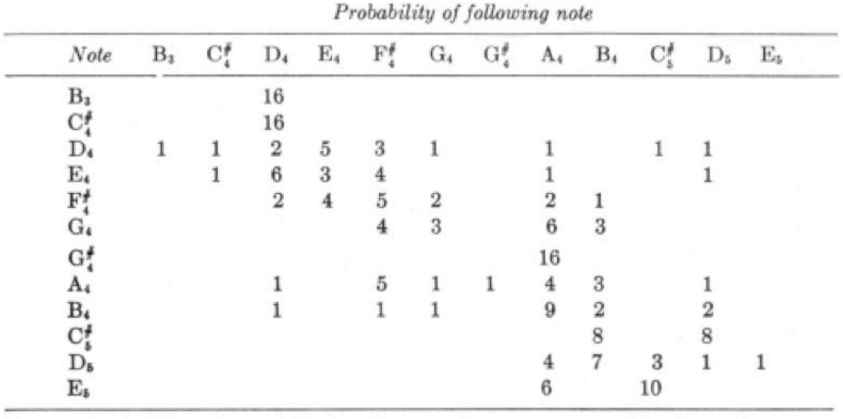




Tomorrow's Weather

Today's Weather

	Rain	Snow	Clouds
Rain	0.3	0.5	0.2
Snow	0.4	0.4	0.2
Clouds	0.3	0.1	0.6



Probability of following note

Note	B_3	$C^\sharp_4$	D_4	E_4	$F^\sharp_4$	G_4	$G^\sharp_4$	A_4	B_4	$C^\sharp_5$	D_5	E_5
B_3			16									
$C^\sharp_4$			16									
D_4	1	1	2	5	3	1		1		1	1	
E_4		1	6	3	4			1			1	
$F^\sharp_4$			2	4	5	2		2	1			
G_4					4	3		6	3			
$G^\sharp_4$								16				
A_4			1		5	1	1	4	3		1	
B_4			1		1	1		9	2		2	
$C^\sharp_5$									8		8	
D_5								4	7	3	1	1
E_5								6		10		

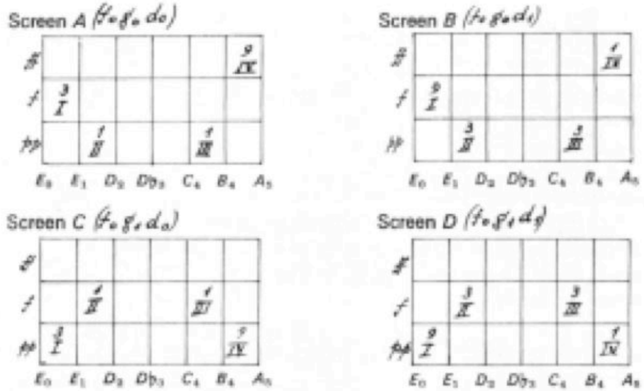
Probability of note following the preceding note expressed in sixteenths.

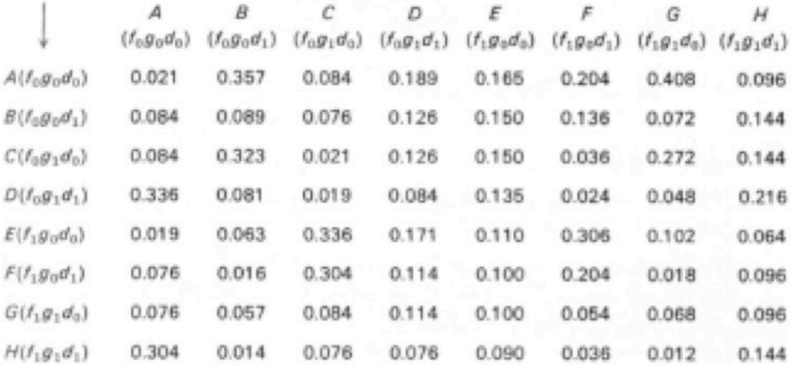
Harry F Olson (1967) - Stephen Foster songs

А. А. Марков (1886).

- Models

Analogique A (1958)

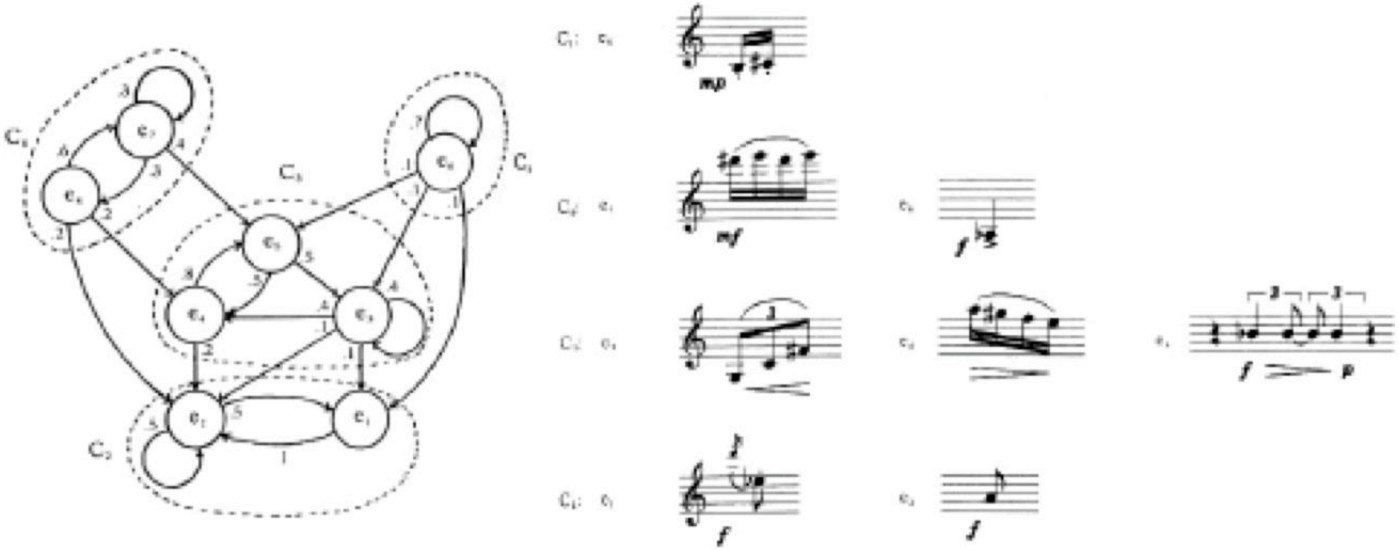

Screen A
Screen B
Screen C
Screen D
ff
f
pp
E_0 E_1 D_2 $D\flat_3$ C_4 B_4 A_5



↓	A $(f_0g_0d_0)$	B $(f_0g_0d_1)$	C $(f_0g_1d_0)$	D $(f_0g_1d_1)$	E $(f_1g_0d_0)$	F $(f_1g_0d_1)$	G $(f_1g_1d_0)$	H $(f_1g_1d_1)$
$A(f_0g_0d_0)$	0.021	0.357	0.084	0.189	0.165	0.204	0.408	0.096
$B(f_0g_0d_1)$	0.084	0.089	0.076	0.126	0.150	0.136	0.072	0.144
$C(f_0g_1d_0)$	0.084	0.323	0.021	0.126	0.150	0.036	0.272	0.144
$D(f_0g_1d_1)$	0.336	0.081	0.019	0.084	0.135	0.024	0.048	0.216
$E(f_1g_0d_0)$	0.019	0.063	0.336	0.171	0.110	0.306	0.102	0.064
$F(f_1g_0d_1)$	0.076	0.016	0.304	0.114	0.100	0.204	0.018	0.096
$G(f_1g_1d_0)$	0.076	0.057	0.084	0.114	0.100	0.054	0.068	0.096
$H(f_1g_1d_1)$	0.304	0.014	0.076	0.076	0.090	0.036	0.012	0.144

А. А. Марков (1886).

- Models



.3
.6
.4
.3
.2
.2
.7
.1
.1
.1
.8
.5
.5
.4
.4
.1
.2
.1
.5
.5
1
mp
mf
f
3
f
p
f
f

Jones (1981)

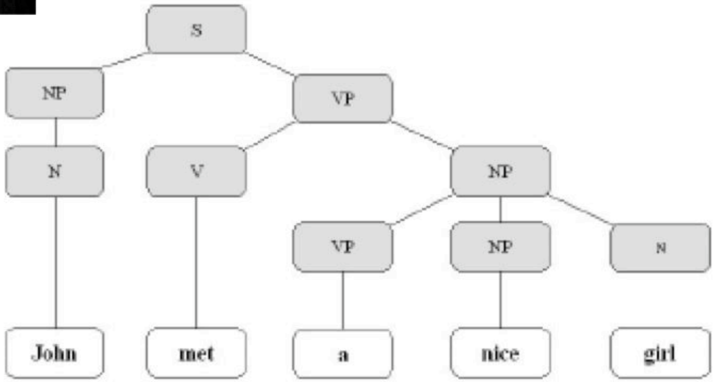
А. А. Марков (1886).

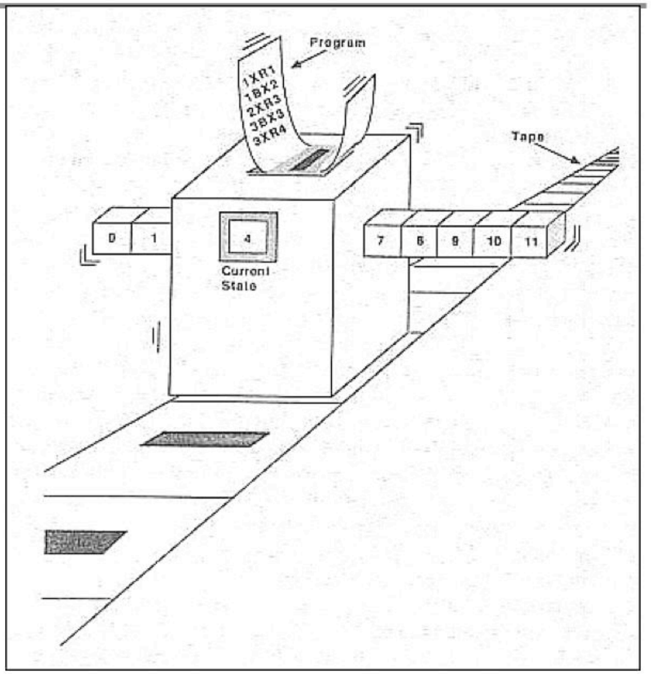
- Models

The evolution of „Power“ from its formulation
and ascent until a strange,
mysterious state of tranquillity...

In the Piece I used traditional compositional techniques,
such as imitation or inversion as well as improvisation
and five different Markov-Models for structuring
the succession of various playing techniques

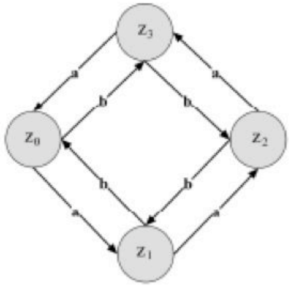
Generative Grammar


S
NP
VP
N
V
NP
VP
NP
N
John
met
a
nice
girl


Program
1XR1
1BX2
2XR3
3BX3
3XR4
Tape
0
1
4
Current State
7
8
9
10
11

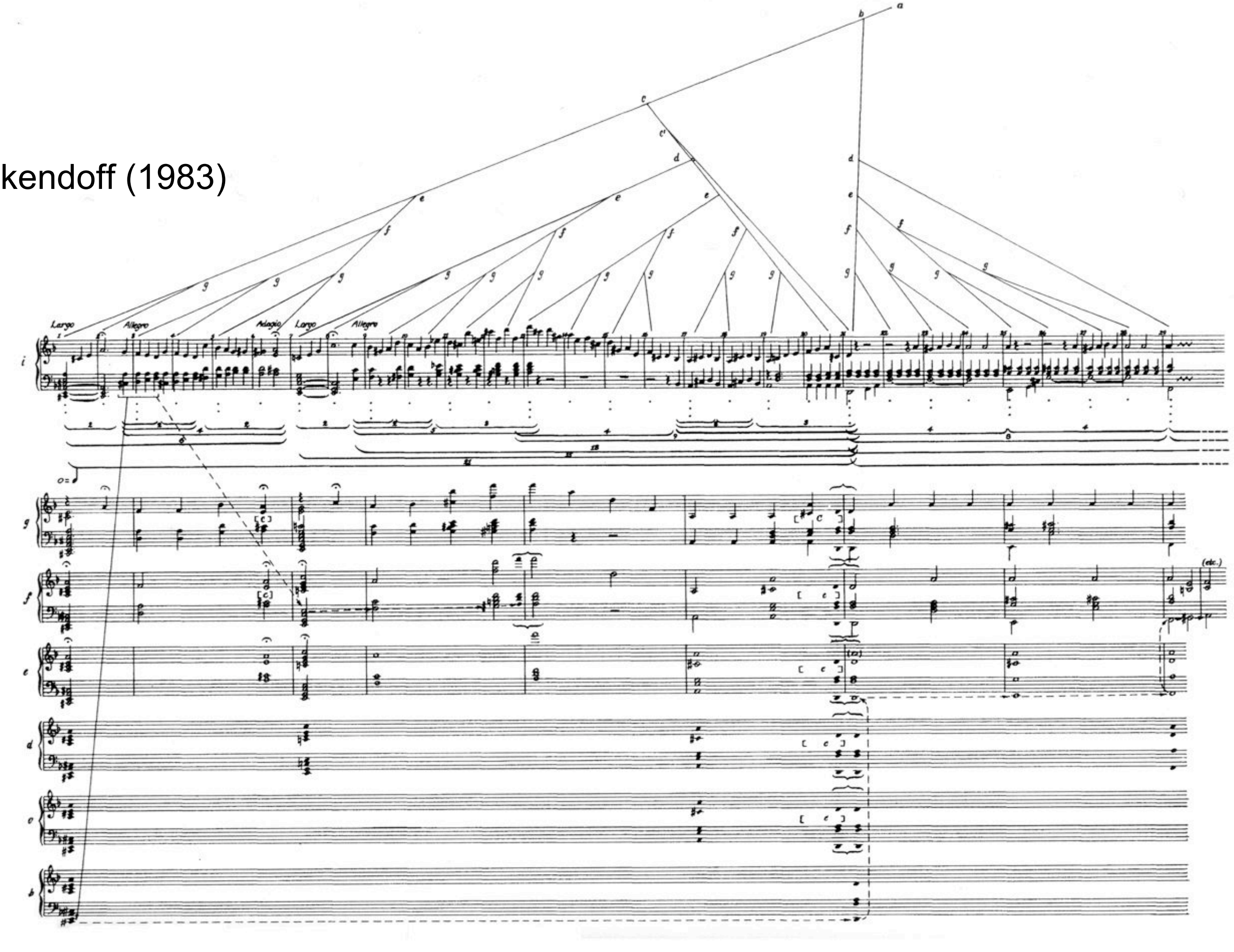
$S = \{z_0, z_1, z_3, z_3\}$
$\Sigma = \{a, b\}$
$F = z_3$

$\delta(z_0, a) = z_1 \quad \delta(z_0, b) = z_3 \quad \delta(z_1, a) = z_2 \quad \delta(z_1, b) = z_0$
$\delta(z_2, a) = z_3 \quad \delta(z_2, b) = z_1 \quad \delta(z_3, a) = z_0 \quad \delta(z_3, b) = z_2$

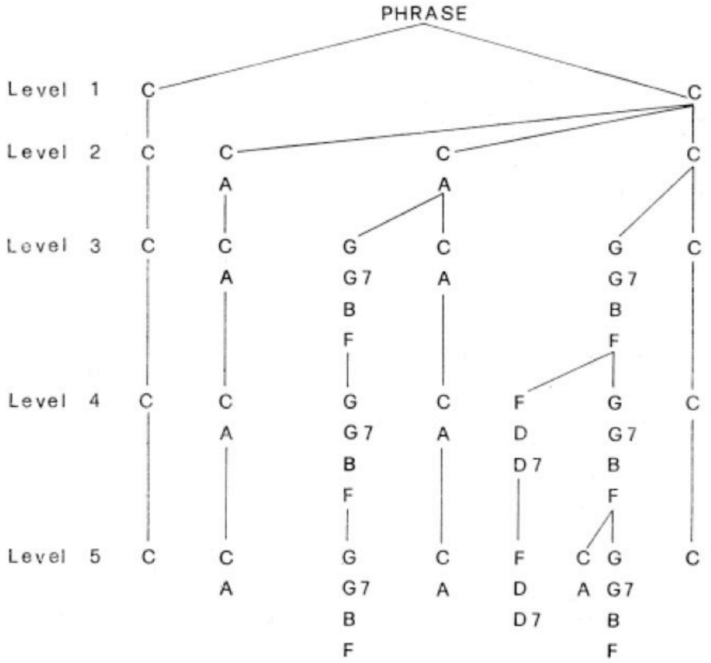

z3
z0
z2
z1
a
b
b
a
a
b
b
a

Generative Grammar

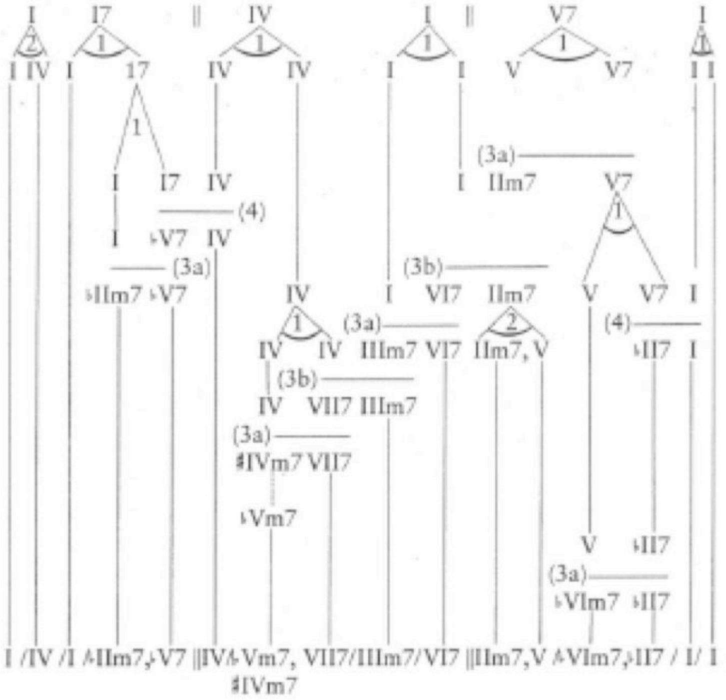
Lerdahl F, Jackendoff (1983)


a
b
c
c'
d
e
f
g
Largo
Allegro
Adagio
Largo
Allegro
i
(etc.)

Generative Grammar

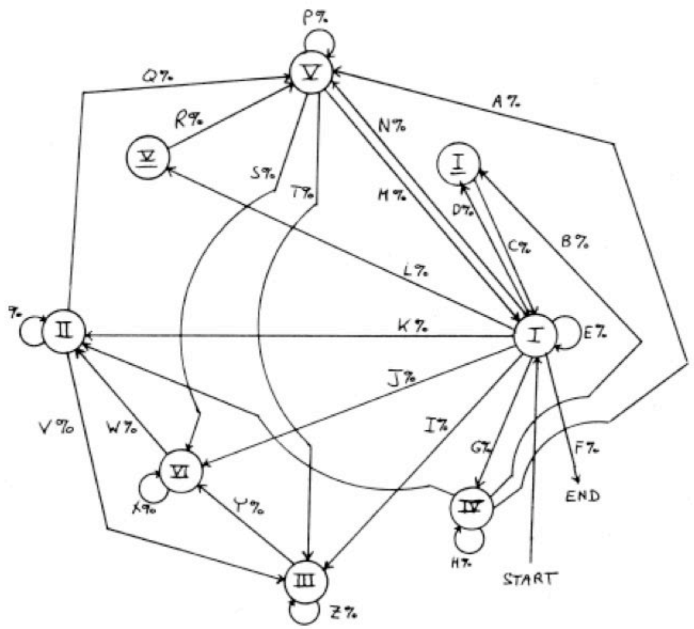

PHRASE
Level 1
Level 2
Level 3
Level 4
Level 5
C
A
G
G7
B
F
D
D7

Baroni M, Brunetti R, Callegari L, Jacoboni C (1982)

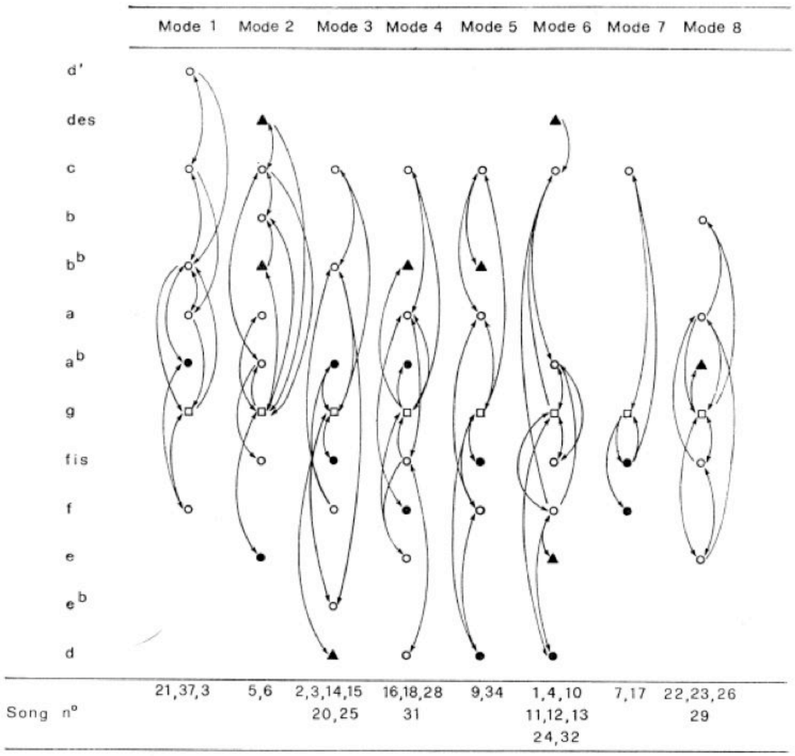

I
I7
IV
V7
(3a)
(3b)
(4)
I /IV /I ♭IIm7,♭V7 ||IV♭Vm7, VII7/IIIm7/VI7 ||IIm7,V ♭VIm7,♭II7 / I/ I
♯IVm7

Steedman M (1984)

Generative Grammar


P%
Q%
V
A%
R%
V
N%
S%
T%
M%
I
D%
C%
B%
L%
%
II
K%
I
E%
J%
V%
W%
I%
G%
F%
VI
Y%
X%
IV
END
H%
START
III
Z%

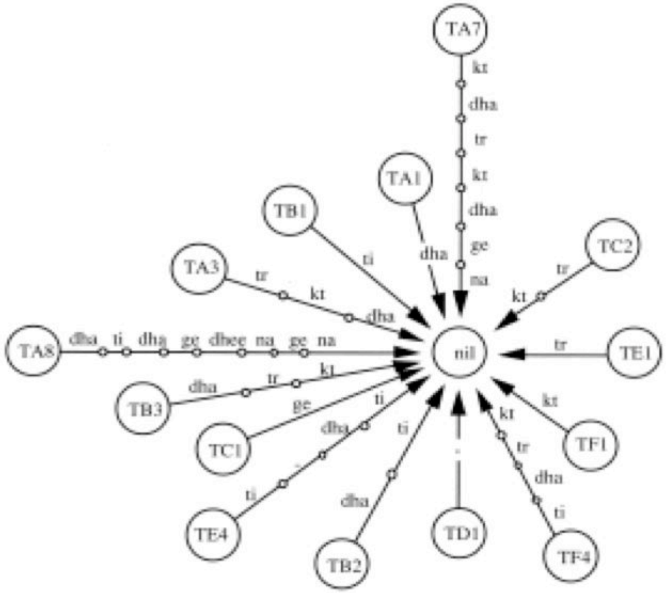
Rader GM (1974)


Mode 1
Mode 2
Mode 3
Mode 4
Mode 5
Mode 6
Mode 7
Mode 8
d'
des
c
b
b^b
a
a^b
g
fis
f
e
e^b
d
Song n°
21,37,3
5,6
2,3,14,15
20,25
16,18,28
31
9,34
1,4,10
11,12,13
24,32
7,17
22,23,26
29

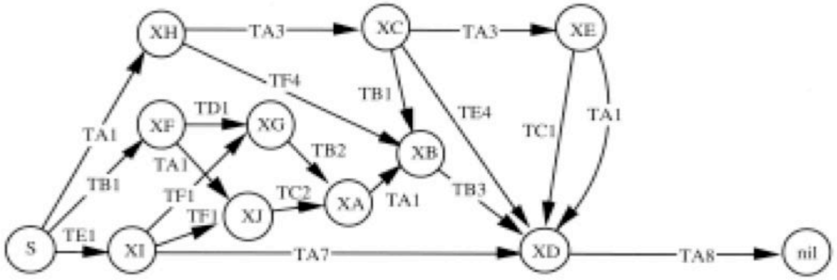
Pelinski R (1982)

Generative Grammar / Grammatical Inference

dha tr kt dha	tr kt dha ge	dha ti dha ge	dhee na ge na
dha tr kt dha	tr kt dha dha	dha ti dha ge	dhee na ge na
dha ti dha tr	kt dha tr kt	dha ti dha ge	dhee na ge na
dha ti kt dha	ti-dha ti	dha ti dha ge	dhee na ge na
dha ti kt dha	ti dha tr kt	dha ti dha ge	dhee na ge na
ti-dha ti	dha dha tr kt	dha ti dha ge	dhee na ge na
ti dha tr kt	dha dha tr kt	dha ti dha ge	dhee na ge na
tr kt dha ti	dha dha tr kt	dha ti dha ge	dhee na ge na
tr kt tr kt	dha dha tr kt	dha ti dha ge	dhee na ge na
tr kt dha tr	dha dha tr kt	dha ti dha ge	dhee na ge na


TA7
kt
dha
tr
kt
dha
ge
na
TA1
dha
TB1
ti
TC2
tr
kt
TA3
tr
kt
dha
TA8
dha ti dha ge dhee na ge na
nil
tr
TE1
TB3
dha
tr
kt
TC1
ge
ti
dha
ti
kt
TF1
kt
tr
dha
ti
TE4
ti
dha
TB2
TD1
TF4

Bel B, Kippen J
(1989, 1992 ...)


XH
TA3
XC
TA3
XE
TF4
TB1
TE4
TC1
TA1
TA1
XF
TD1
XG
TB2
XB
TA1
TB1
TF1
TC2
XA
TA1
TB3
XJ
TF1
S
TE1
XI
TA7
XD
TA8
nil

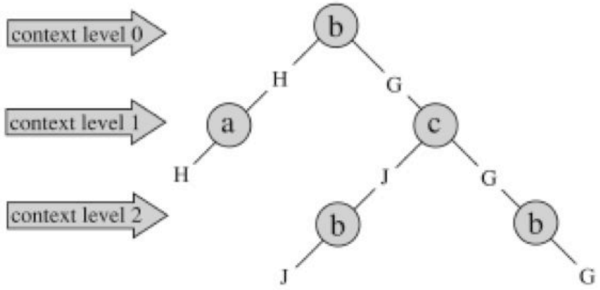
Generative Grammar / Grammatical Inference

Nevill Manning CG, Witten IH (1991)

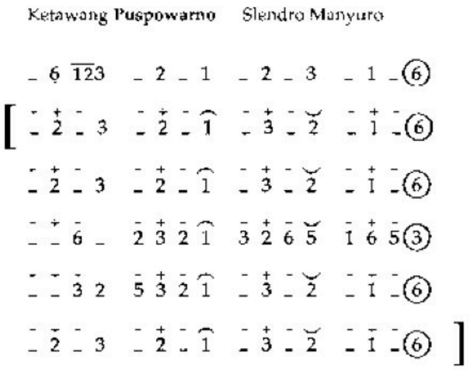
symbol number	the string so far	resulting grammar	remarks
1	a	S → a	
2	ab	S → ab	
3	abc	S → abc	
4	abcd	S → abcd	
5	abcdb	S → abcdb	
6	abcdbc	S → abcdbc	bc appears twice
		S → aAdA A → bc	enforce digram uniqueness
7	abcdbca	S → aAdAa A → bc	
8	abcdbcab	S → aAdAab A → bc	
9	abcdbcabc	S → aAdAabc A → bc	bc appears twice
		S → aAdAaA A → bc	enforce digram uniqueness. aA appears twice
		S → BdAB A → bc B → aA	enforce digram uniqueness
10	abcdbcabcd	S → BdABd A → bc B → aA	Bd appears twice
		S → CAC A → bc B → aA C → Bd	enforce digram uniqueness. B is only used once
		S → CAC A → bc C → aAd	enforce rule utility

Kohonen T (1989)

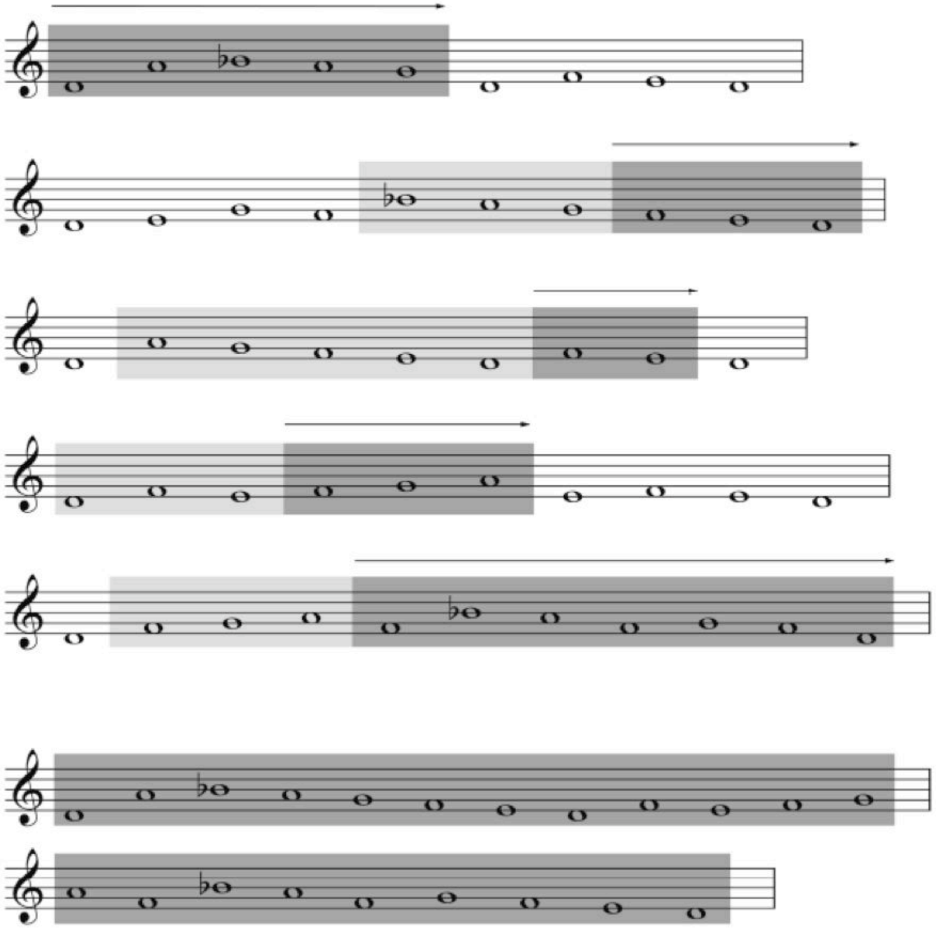
1	2	2	1	2	3	4	2	2	1	2	3	2	1
1	1	3	2	4	1	2	2	4	5	1	2	5	3
4	4	1	1	3	1	1	2	1	2	2	4	2	2
0	2	1	1	1	1	2	2	1	2	2	1	3	0
1	4	3	3	1	1	2	2	4	2	6	3	4	3
2	2	3	3	2	2	3	3	2	2	2	2	3	2
3	3	2	1	1	1	2	2	1	2	2	1	1	1
0	2	0	1	2	2	2	1	2	2	4	4	3	2
3	2	2	2	2	3	3	2	2	2	2	2	2	1
2	1	2	3	2	1	6	2	3	2	5	5	3	1
2	2	2	3	3	2	2	2	2	1	2	2	4	0
2	2	3	2	1	6	3	3	1	1	2	2	4	4
6	5	3	2	2	3	2	1	1	1	1	2	2	2



Generative Grammar / Grammatical Inference

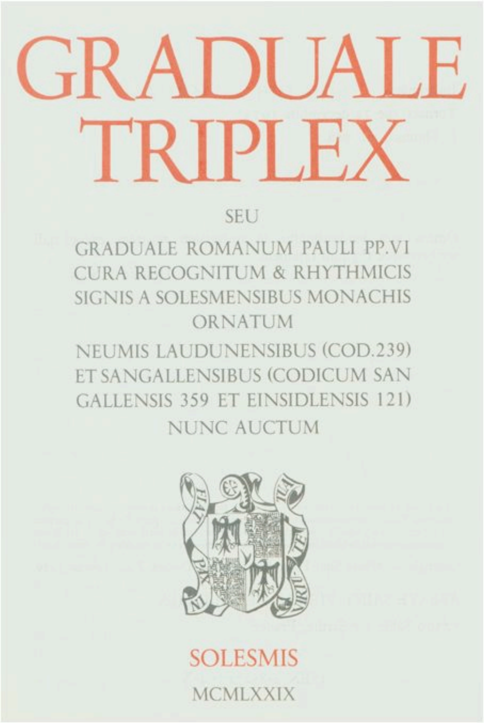

Ketawang Puspowarno
Slendro Manyuro

© Bali & Beyond 1997



Generative Grammar / Grammatical Inference

Knud Jeppesen
KONTRA
PUNKT
Breitkopf & Härtel Wiesbaden



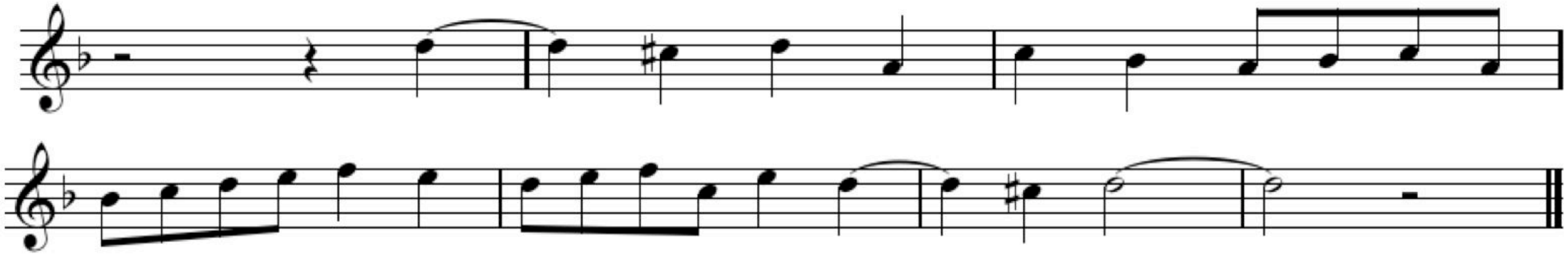
GRADUALE
TRIPLEX

SEU

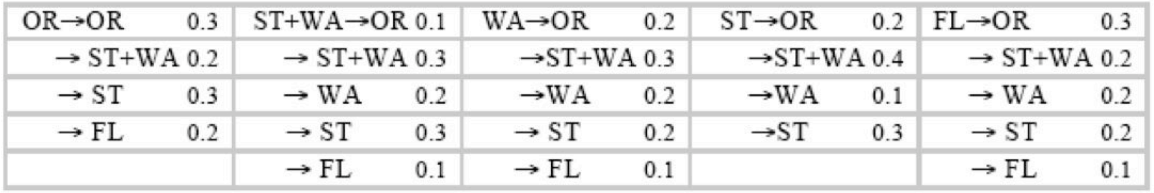
GRADUALE ROMANUM PAULI PP.VI
CURA RECOGNITUM & RHYTHMICIS
SIGNIS A SOLESMENSIBUS MONACHIS
ORNATUM

NEUMIS LAUDUNENSIBUS (COD.239)
ET SANGALLENSIBUS (CODICUM SAN
GALLENSIS 359 ET EINSIDLENSIS 121)
NUNC AUCTUM

SOLESMIS
MCMLXXIX

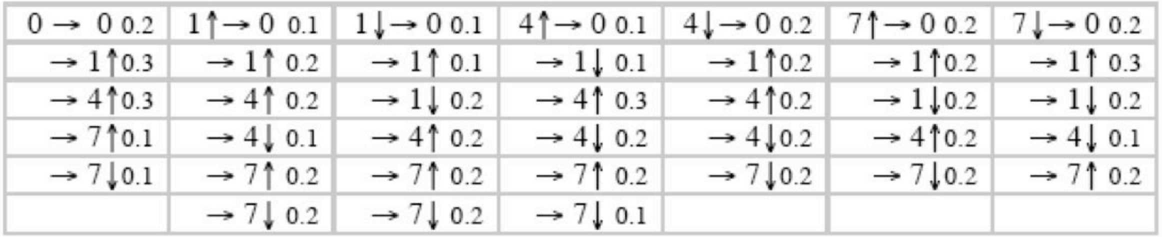


Generative Grammar



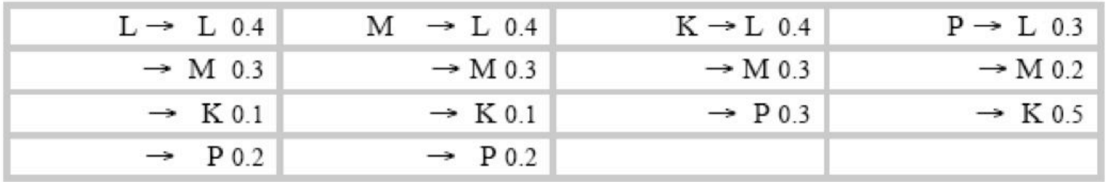
OR→OR 0.3	ST+WA→OR 0.1	WA→OR 0.2	ST→OR 0.2	FL→OR 0.3
→ ST+WA 0.2	→ ST+WA 0.3	→ST+WA 0.3	→ST+WA 0.4	→ ST+WA 0.2
→ ST 0.3	→ WA 0.2	→WA 0.2	→WA 0.1	→ WA 0.2
→ FL 0.2	→ ST 0.3	→ ST 0.2	→ST 0.3	→ ST 0.2
	→ FL 0.1	→ FL 0.1		→ FL 0.1

ST, ST → ST+WA
ST, OR, ST, OR → ST+WA
OR, OR, OR → EFFEKT
EF, EF, EF, EF → OR



0 → 0 0.2	1↑→ 0 0.1	1↓→ 0 0.1	4↑→ 0 0.1	4↓→ 0 0.2	7↑→ 0 0.2	7↓→ 0 0.2
→ 1↑0.3	→ 1↑ 0.2	→ 1↑ 0.1	→ 1↓ 0.1	→ 1↑0.2	→ 1↑0.2	→ 1↑ 0.3
→ 4↑0.3	→ 4↑ 0.2	→ 1↓ 0.2	→ 4↑ 0.3	→ 4↑0.2	→ 1↓0.2	→ 1↓ 0.2
→ 7↑0.1	→ 4↓ 0.1	→ 4↑ 0.2	→ 4↓ 0.2	→ 4↓0.2	→ 4↑0.2	→ 4↓ 0.1
→ 7↓0.1	→ 7↑ 0.2	→ 7↑ 0.2	→ 7↑ 0.2	→ 7↓0.2	→ 7↓0.2	→ 7↑ 0.2
	→ 7↓ 0.2	→ 7↓ 0.2	→ 7↓ 0.1			

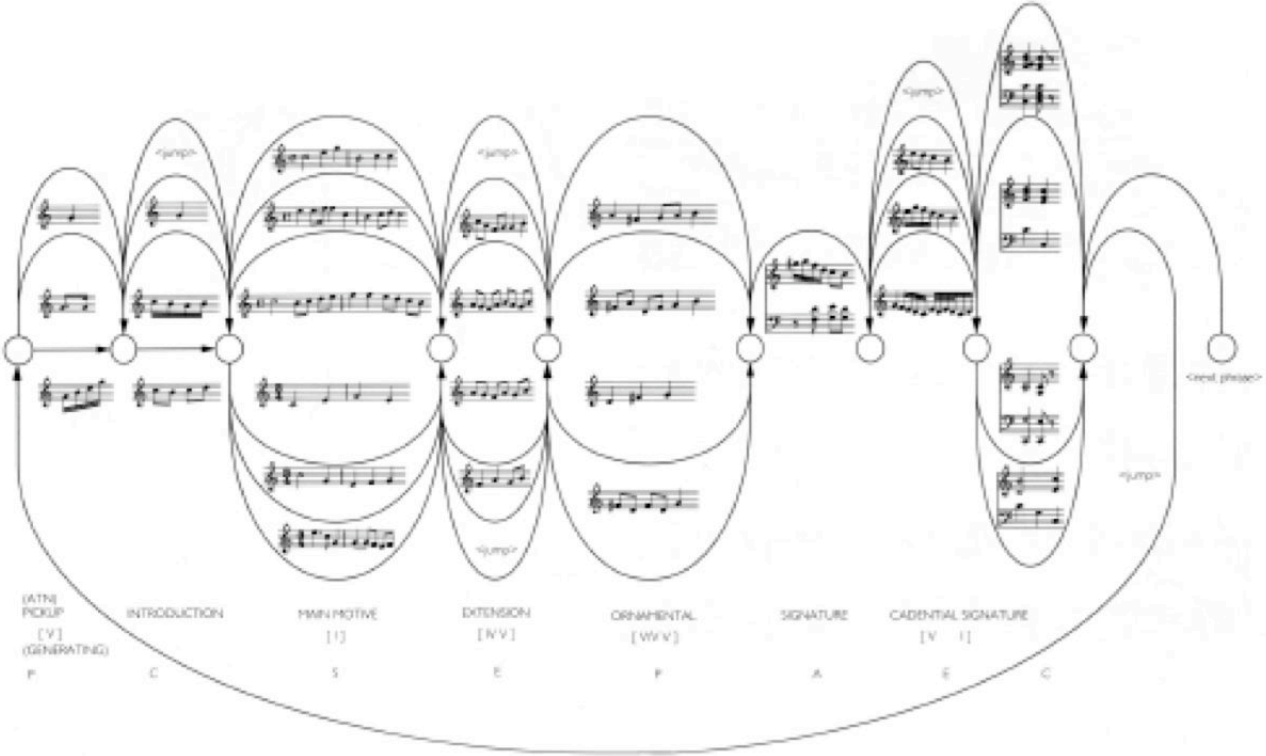
G, G →K
K, K, K, K → G
0, 0, 0 → 4↑



L → L 0.4	M → L 0.4	K → L 0.4	P → L 0.3
→ M 0.3	→ M 0.3	→ M 0.3	→ M 0.2
→ K 0.1	→ K 0.1	→ P 0.3	→ K 0.5
→ P 0.2	→ P 0.2		

L, L, L → M
M, M → L
K, P, K, P → L
P, K, P, K → L

Transition Networks



<jump>
<jump>
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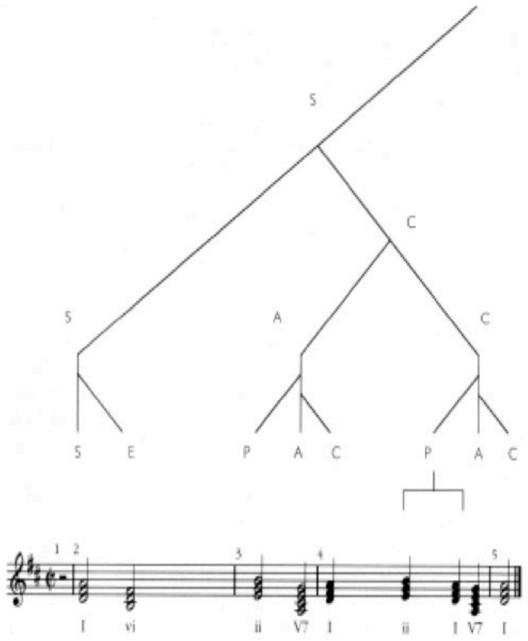
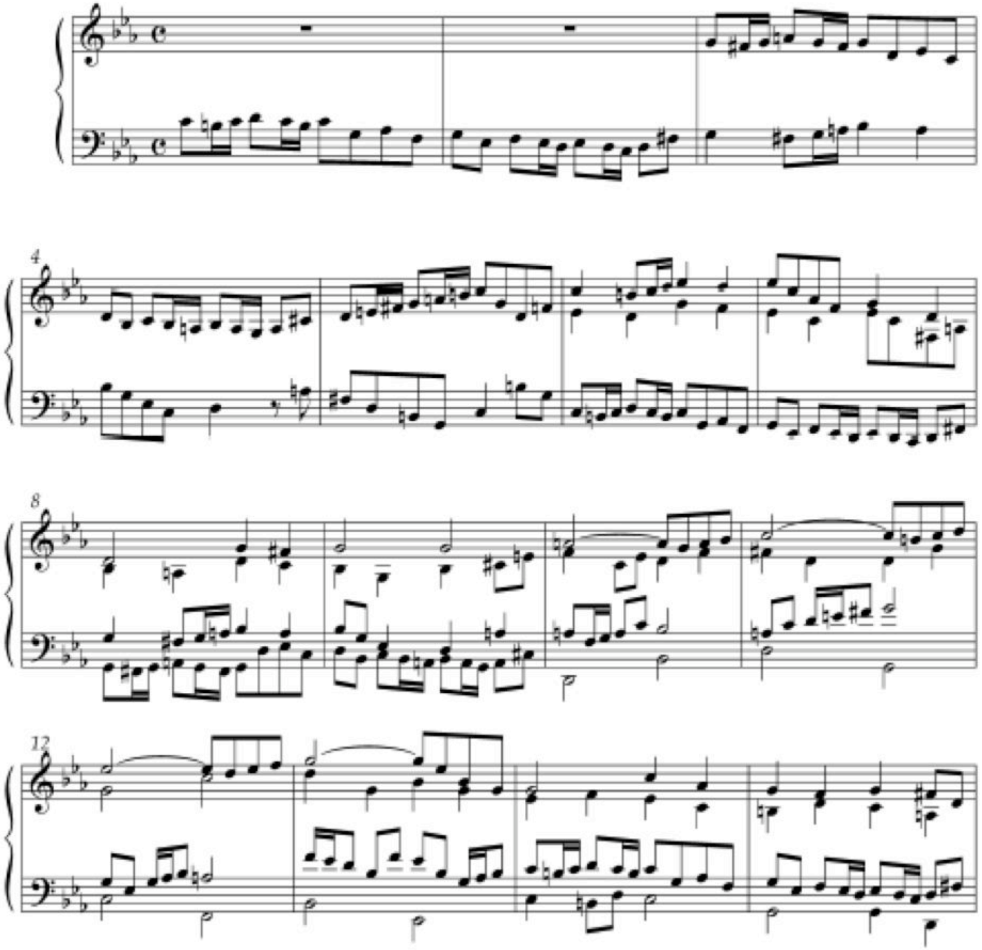
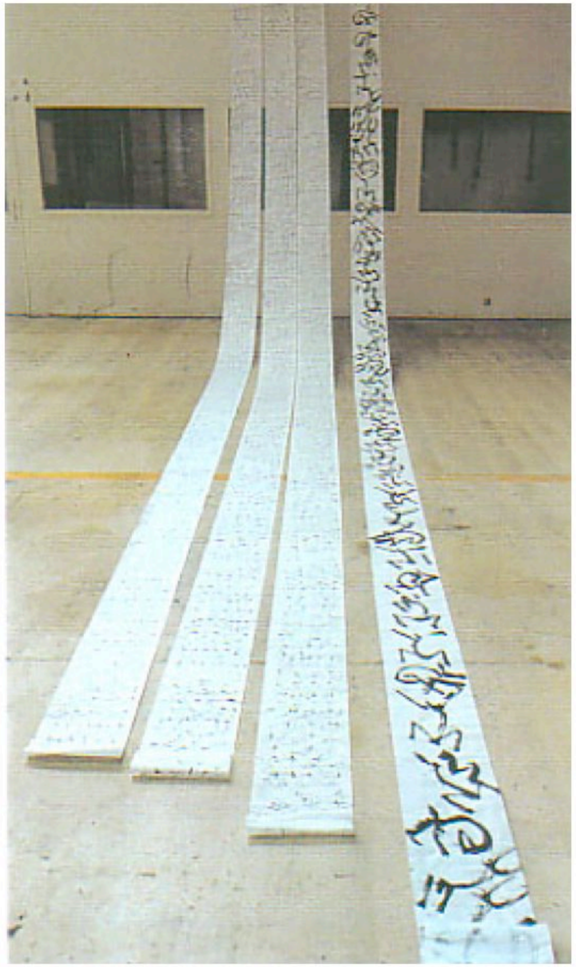
<next phrase>
(ATN)
PICKUP
[V]
(GENERATING)
INTRODUCTION
MAIN MOTIVE
[I]
EXTENSION
[IV V]
ORNAMENTAL
[VI V]
SIGNATURE
CADENTIAL SIGNATURE
[V I]
P
C
S
E
P
A
E
C

Transition Networks

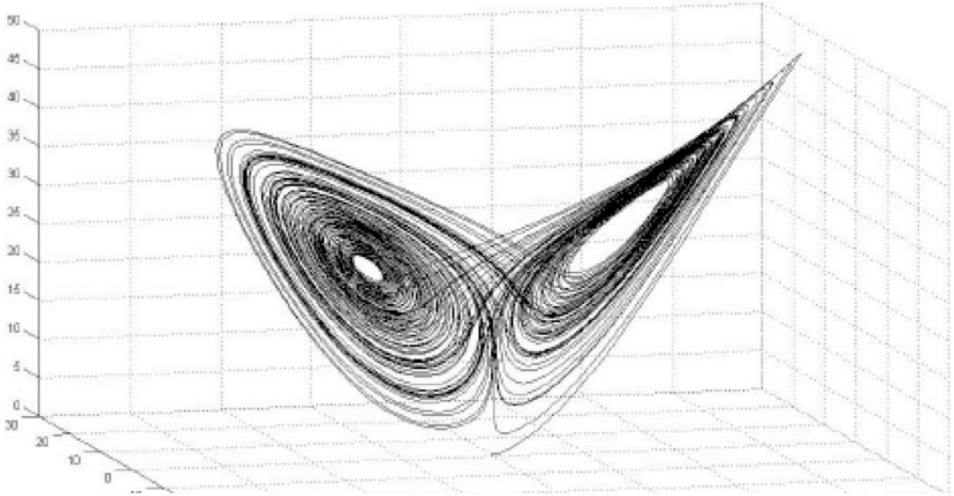

S
C
S
A
C
S
E
P
A
C
P
A
C
1
2
3
4
5
I
vi
ii
V7
I
ii
I
V7
I

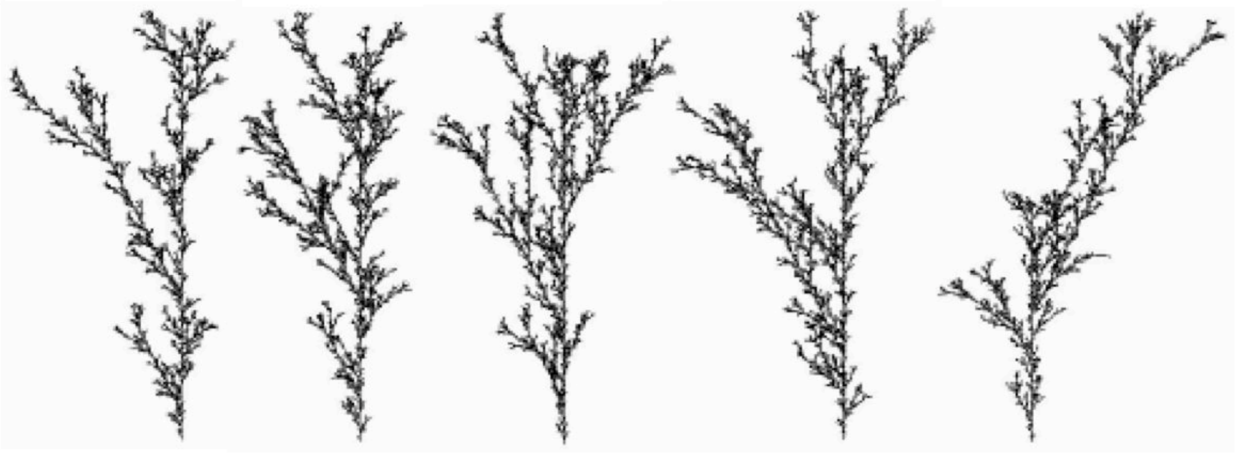


Transition Networks

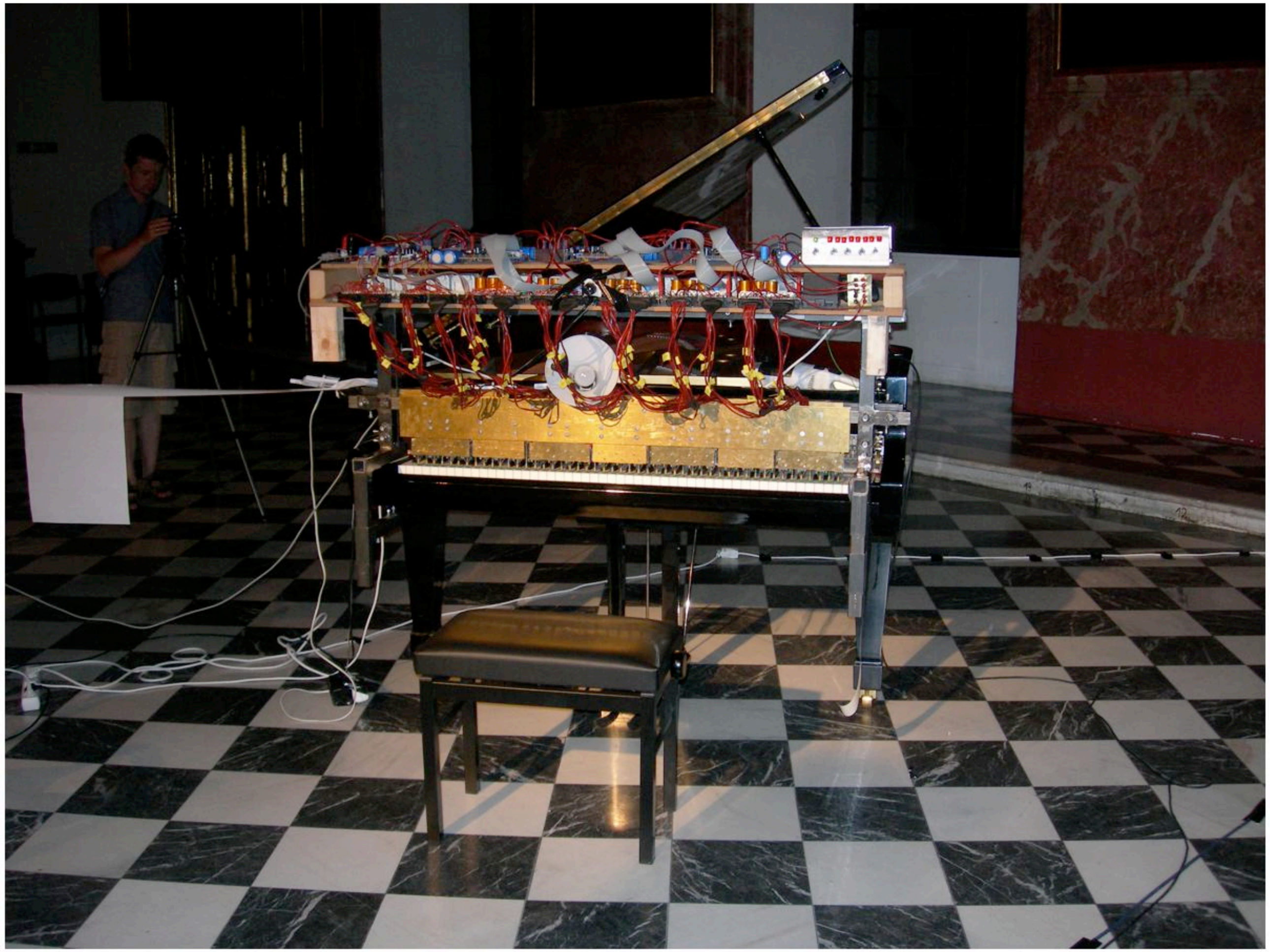


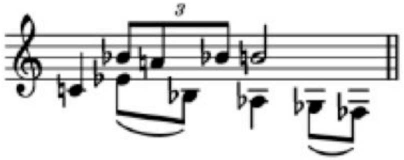
Chaos / Self Similarity



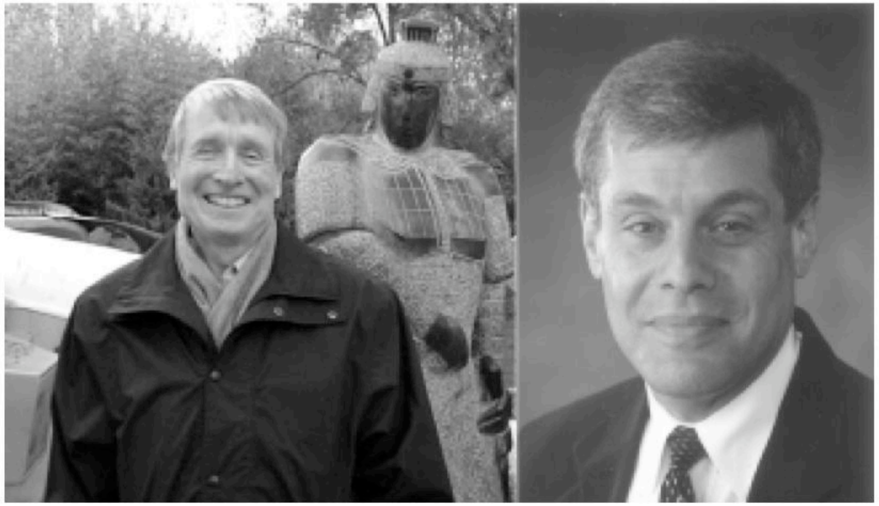


Chaos / Self Similarity

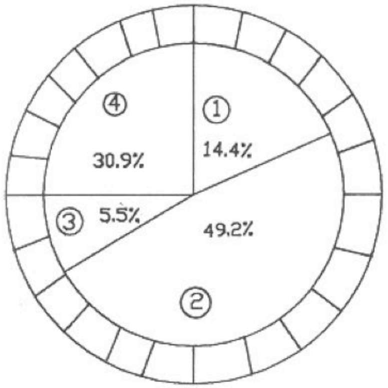


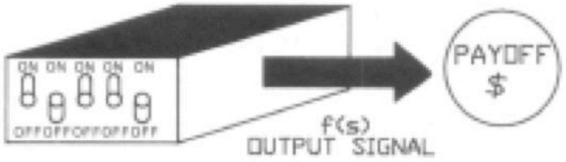


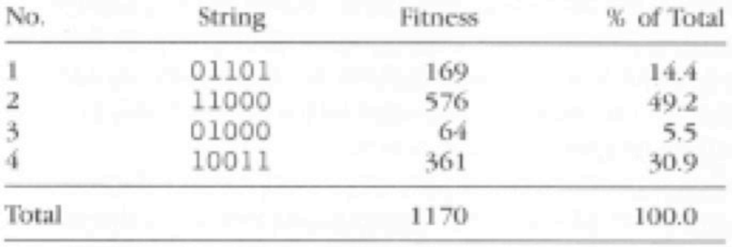
Genetic Algorithms



Goldberg DE (1989)

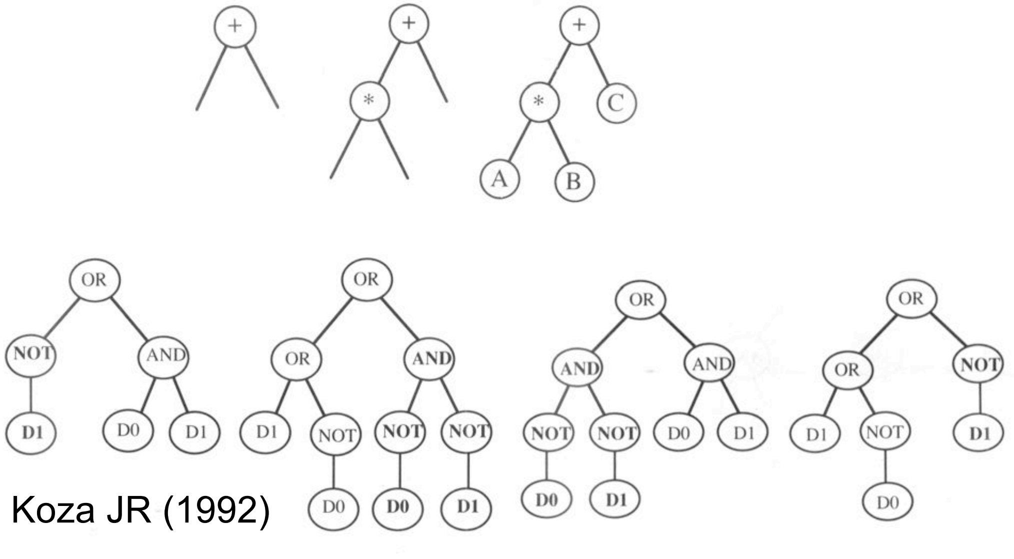



ON ON ON ON ON
OFF OFF OFF OFF OFF
f(s)
OUTPUT SIGNAL
PAYOFF
$



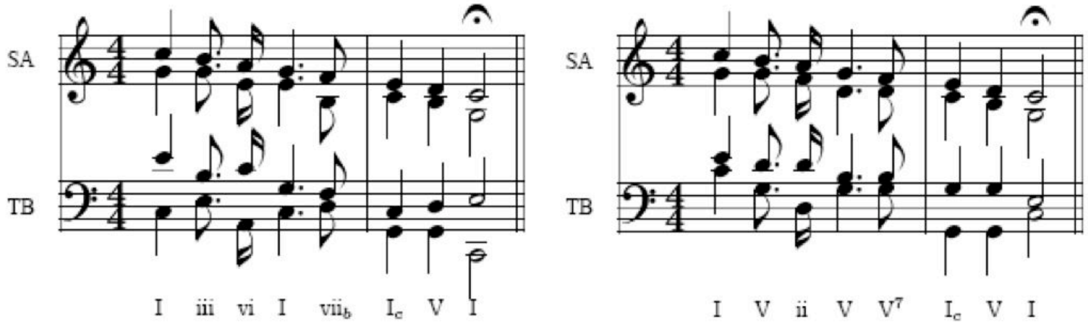
No.	String	Fitness	% of Total
1	01101	169	14.4
2	11000	576	49.2
3	01000	64	5.5
4	10011	361	30.9
Total		1170	100.0

Genetic Programming

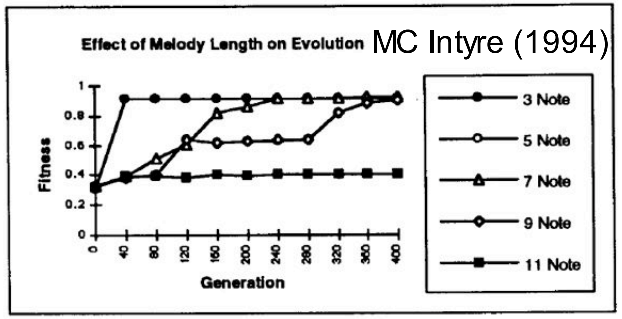

+
+
*
+
*
C
A
B
OR
NOT
AND
D1
D0
D1
OR
OR
AND
D1
NOT
NOT
NOT
D0
D0
D1
OR
AND
AND
NOT
NOT
D0
D1
D0
D1
OR
OR
NOT
D1
NOT
D1
D0

Koza JR (1992)

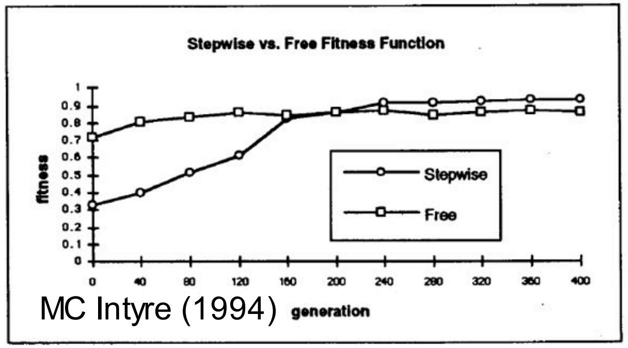
Genetic Algorithms


SA
TB
I iii vi I vii$_b$ I$_c$ V I
SA
TB
I V ii V V^7 I$_c$ V I

Phon-Amnuaisuk S, Wiggins GA (1999)

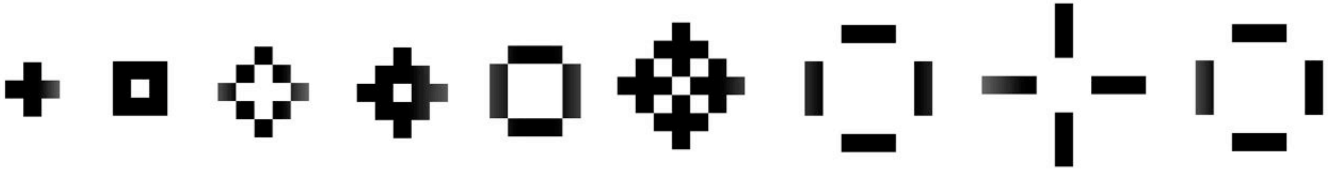


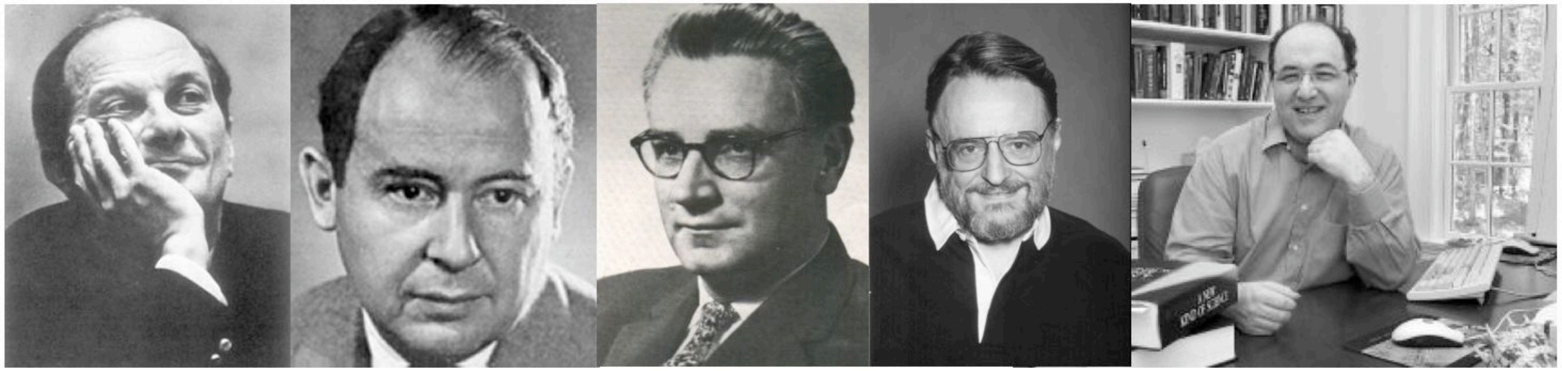
MC Intyre (1994)



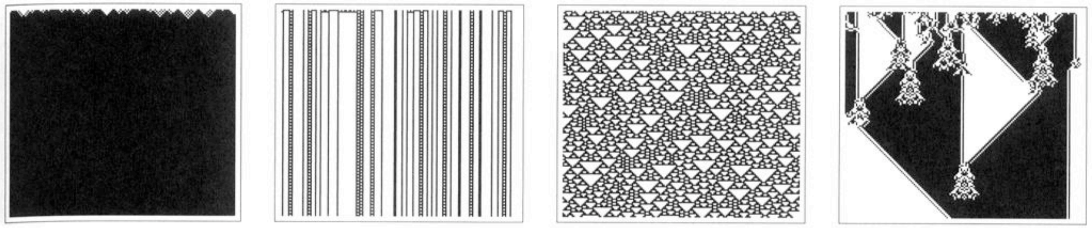
MC Intyre (1994)

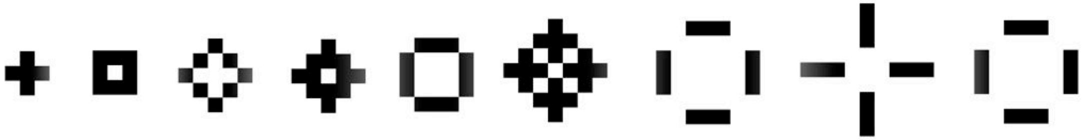
Cellular Automata

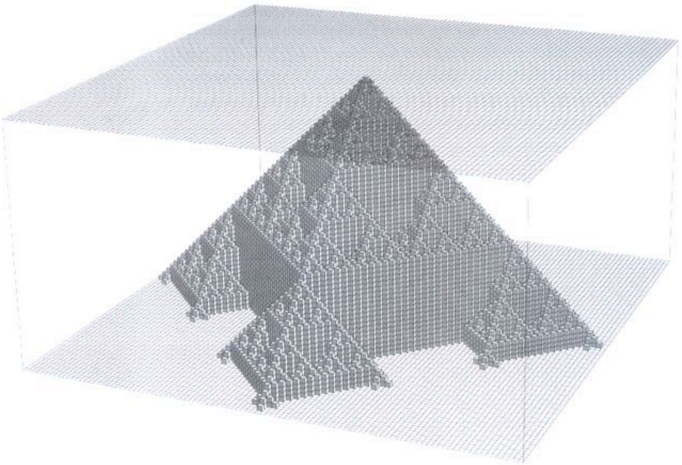


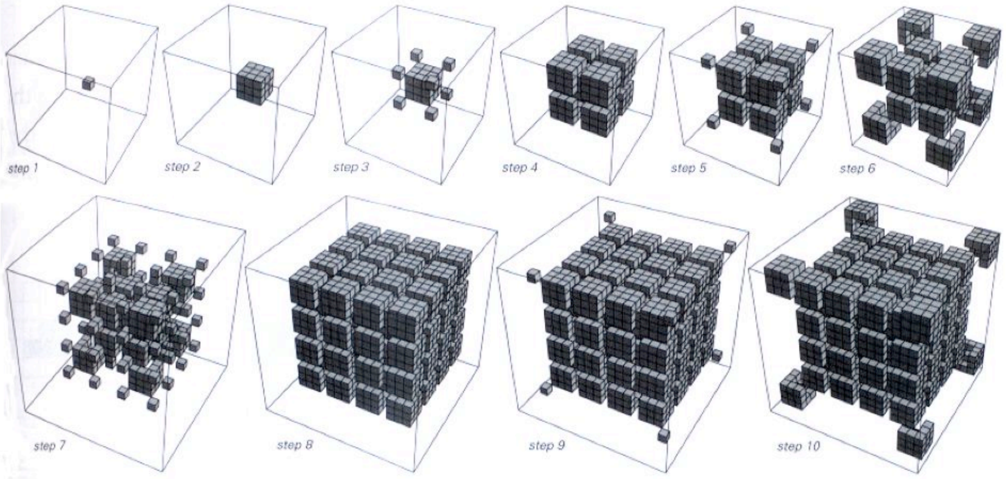


Cellular Automata



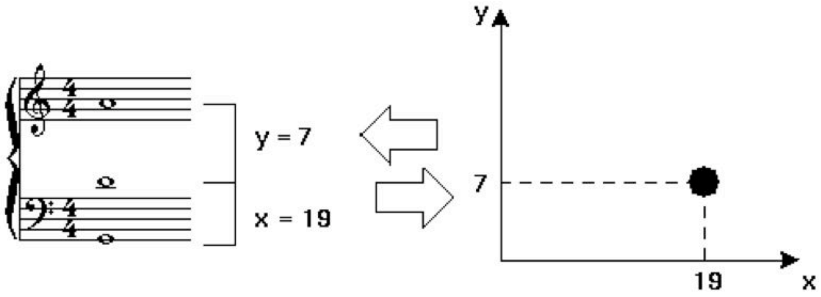


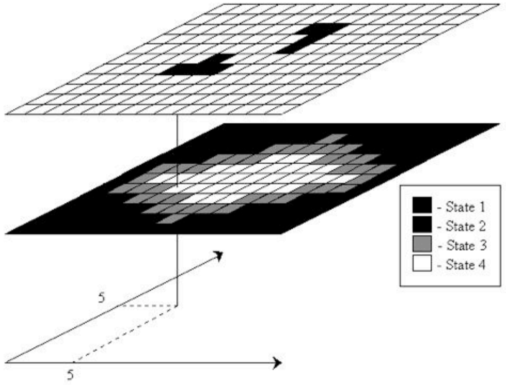



step 1
step 2
step 3
step 4
step 5
step 6
step 7
step 8
step 9
step 10

Cellular Automata

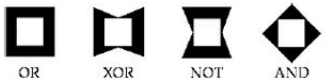
Miranda ER (2001, 2003...)

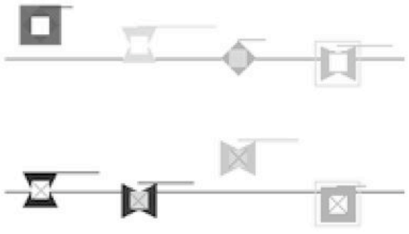

y = 7
x = 19
y
7
19
x

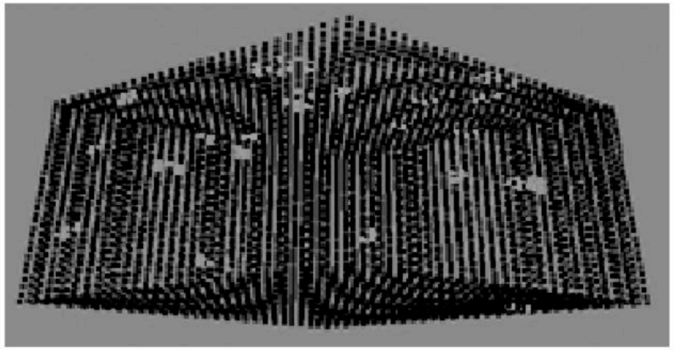

■ - State 1
■ - State 2
▨ - State 3
☐ - State 4
5
5

Dorin A (2000)

Dorin A (2002)

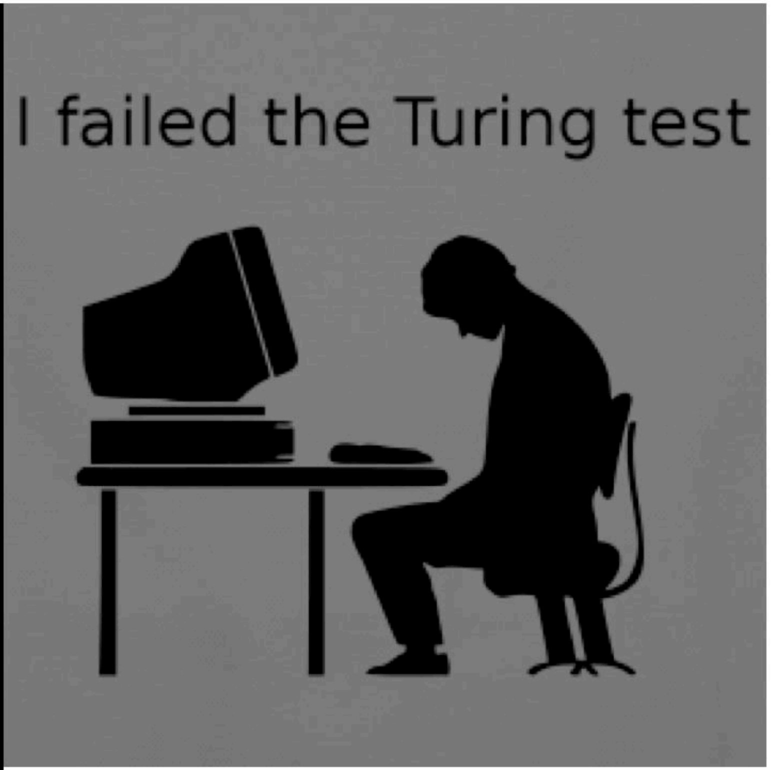

OR
XOR
NOT
AND





Cellular Automata

Artificial Intelligence


I failed the Turing test

Barr, Avron; Feigenbaum, Eward A. : The Handbook of Artificial Intelligence, Volume I.
London: Pitman Books Limited, 1981 – ISBN: 0 273 08540 9

Barr, Avron; Feigenbaum, Eward A. : The Handbook of Artificial Intelligence, Volume II.
London: Pitman Books Limited, 1981 – ISBN: 0 273 085553 0

Cohen, Paul R.; Feigenbaum, Eward A. : The Handbook of Artificial Intelligence, Volume III.
London: Pitman Books Limited, 1981 – ISBN: 0 273 08554 9

Russell, Stuart; Norvig Peter: Artificial Intelligence. A Modern Approach.
New Jersey: Prentice Hall Series in Artificial Intelligence, 1995 – ISBN: 0 13 103805 2

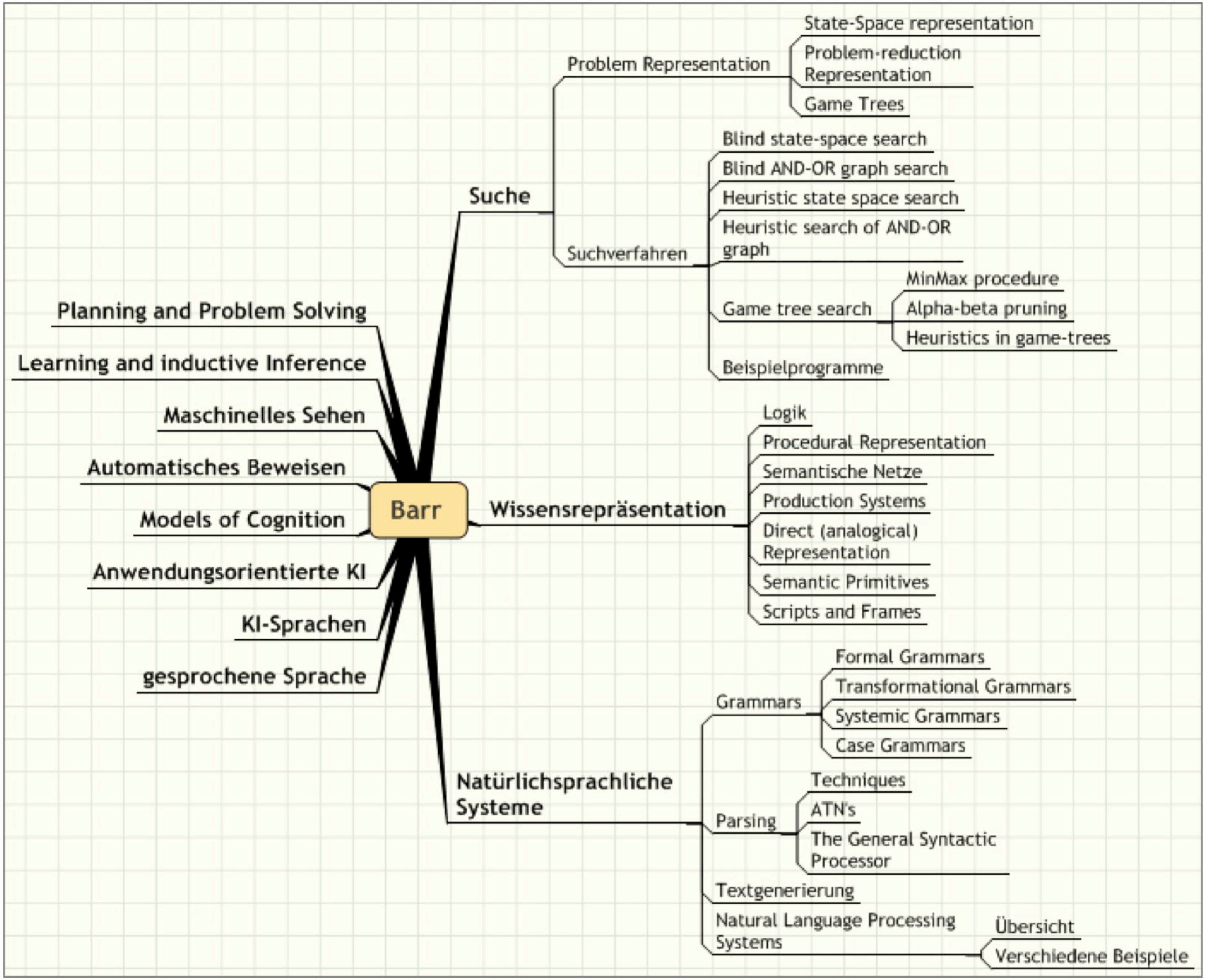
Winston, Patrick Henry: Artificial Intelligence.
Third Edition: Addison-Wesley Publishing Company, 1993 – ISBN: 0 201 53377 4

Kreutzer, Wolfgang; McKenzie, Bruce: Programming for Artificial Intelligence. Methods, Tools and Applications.
Addison-Wesley Publishing Company, 1991 – ISBN: 0 201 41621 2

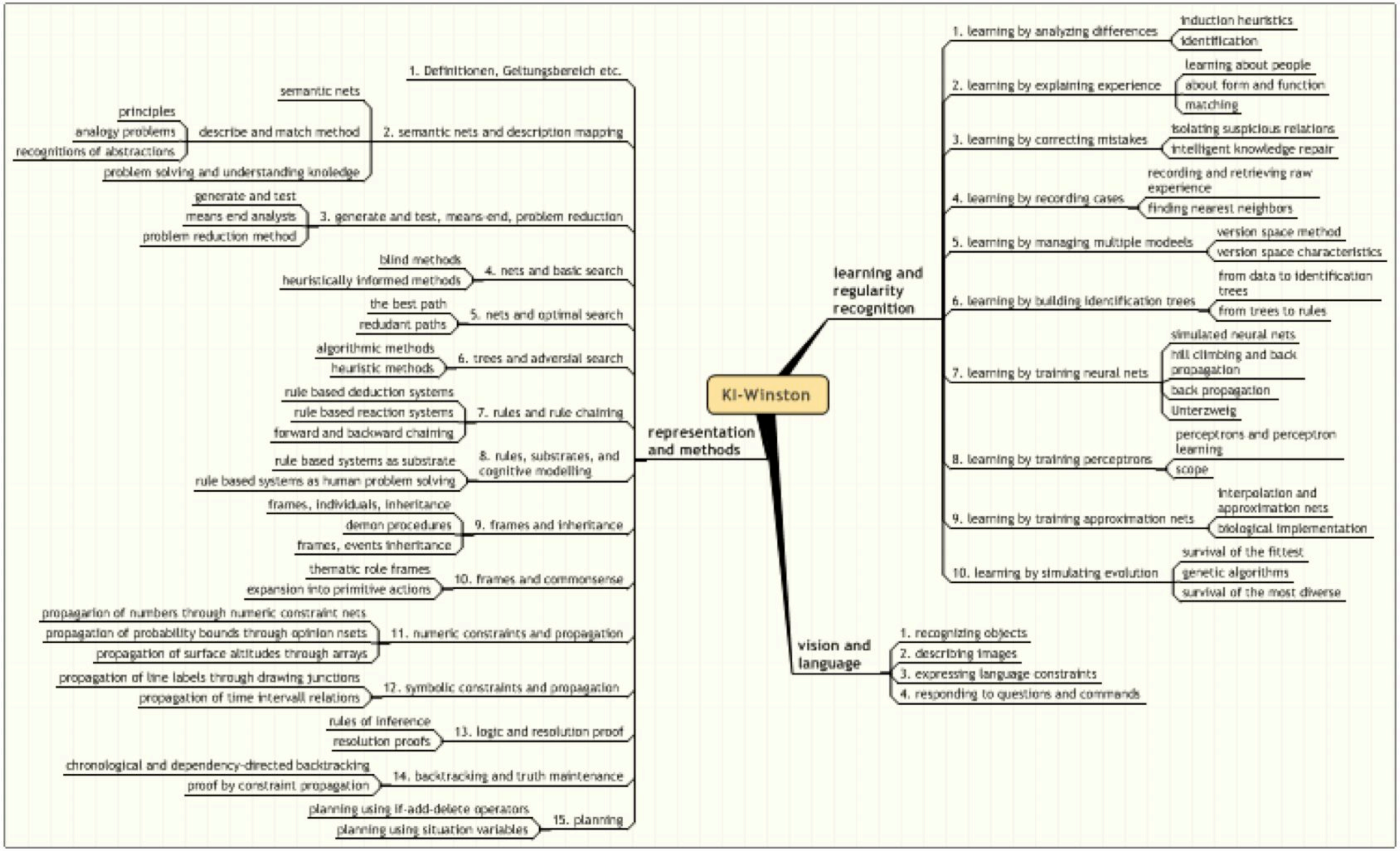
Görz, Günther: Einführung in die künstliche Intelligenz.
Addison-Wesley Publishing Company, 1993 – ISBN: 3 89319 507 6

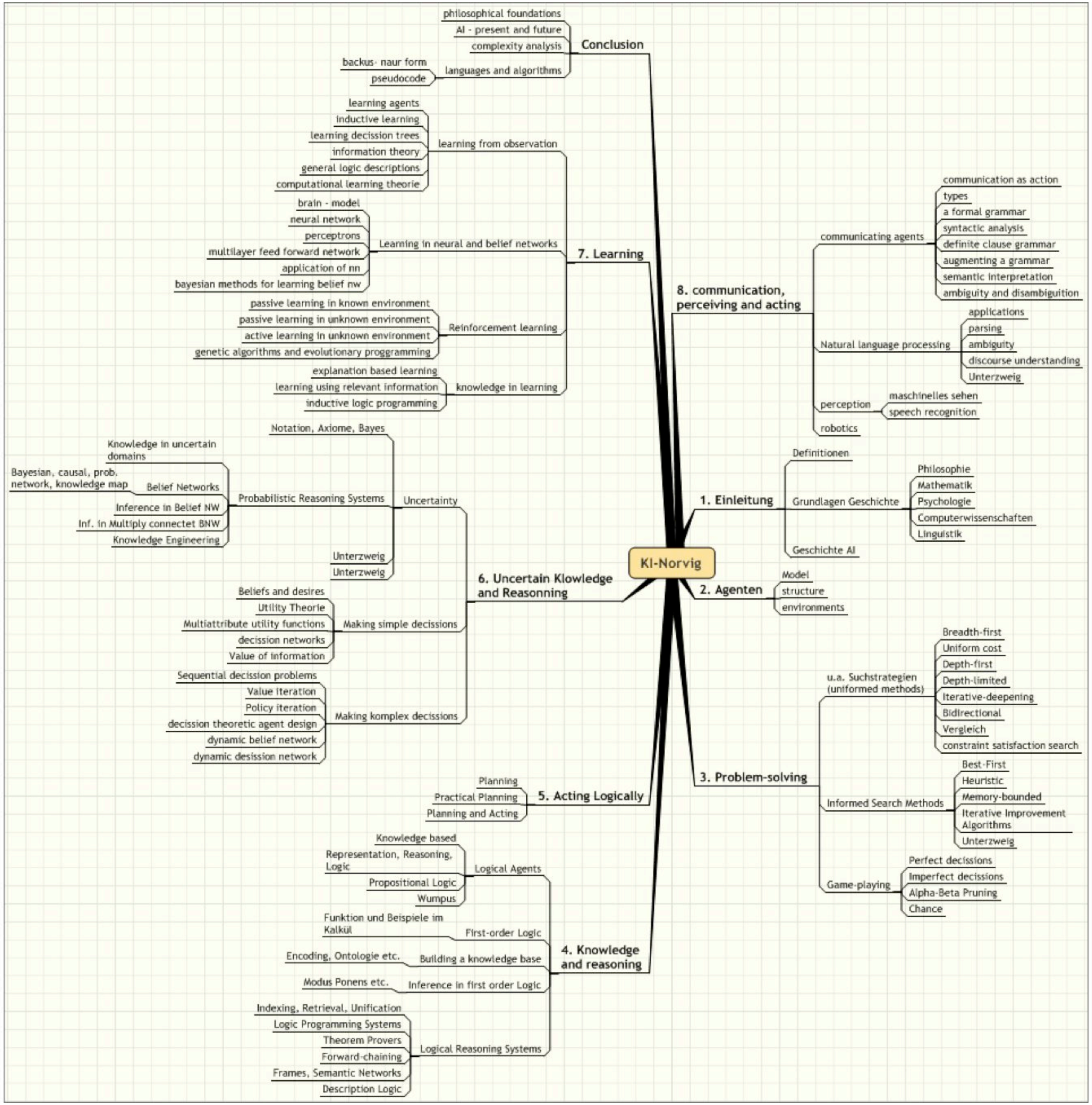
Luger, George F.: Künstliche Intelligenz. Strategien zur Lösung komplexer Probleme.
4. Auflage: Pearson Education Deutschland, 2001 – ISBN: 3 8273 7002 7

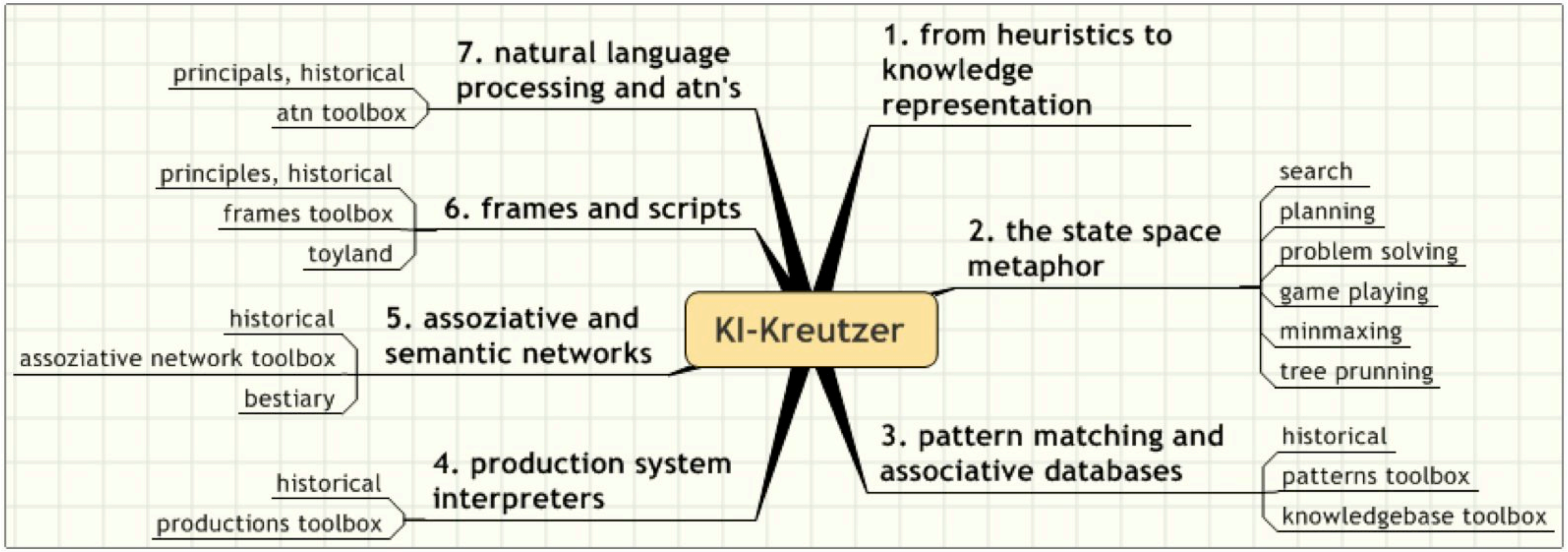
Lämmel, Uwe; Cleve Jürgen: Lehr- und Übungsbuch Künstliche Intelligenz.
Fachbuchverlag Leipzig im Carl Hanser Verlag, 2001 – ISBN: 3-446-21421-6

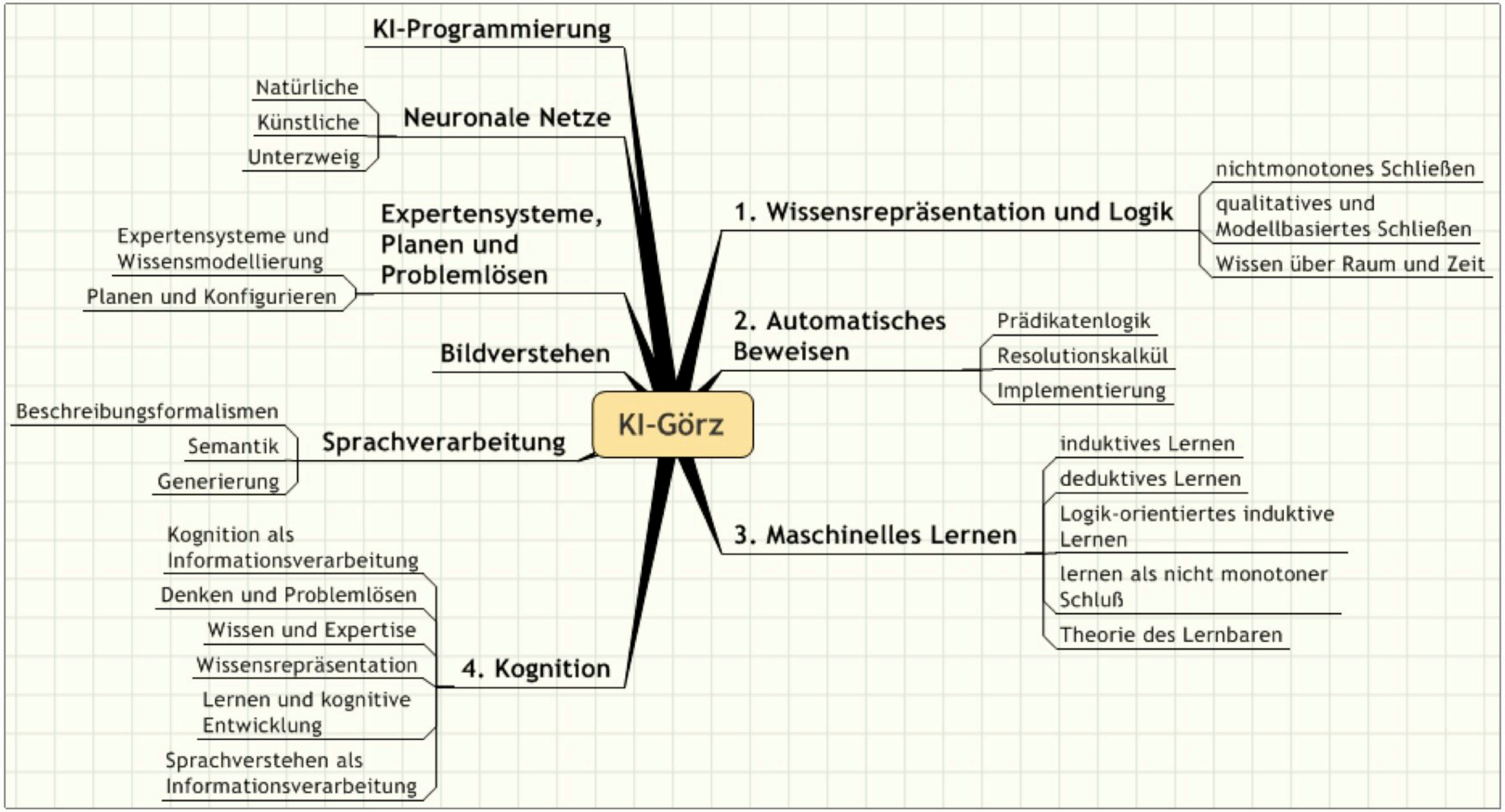


- **Barr**
  - **Suche**
    - Problem Representation
      - State-Space representation
      - Problem-reduction Representation
      - Game Trees
    - Suchverfahren
      - Blind state-space search
      - Blind AND-OR graph search
      - Heuristic state space search
      - Heuristic search of AND-OR graph
      - Game tree search
        - MinMax procedure
        - Alpha-beta pruning
        - Heuristics in game-trees
      - Beispielprogramme
  - **Wissensrepräsentation**
    - Logik
    - Procedural Representation
    - Semantische Netze
    - Production Systems
    - Direct (analogical) Representation
    - Semantic Primitives
    - Scripts and Frames
  - **Natürlichsprachliche Systeme**
    - Grammars
      - Formal Grammars
      - Transformational Grammars
      - Systemic Grammars
      - Case Grammars
    - Parsing
      - Techniques
      - ATN's
      - The General Syntactic Processor
    - Textgenerierung
    - Natural Language Processing Systems
      - Übersicht
      - Verschiedene Beispiele
  - **Planning and Problem Solving**
  - **Learning and inductive Inference**
  - **Maschinelles Sehen**
  - **Automatisches Beweisen**
  - **Models of Cognition**
  - **Anwendungsorientierte KI**
  - **KI-Sprachen**
  - **gesprochene Sprache**

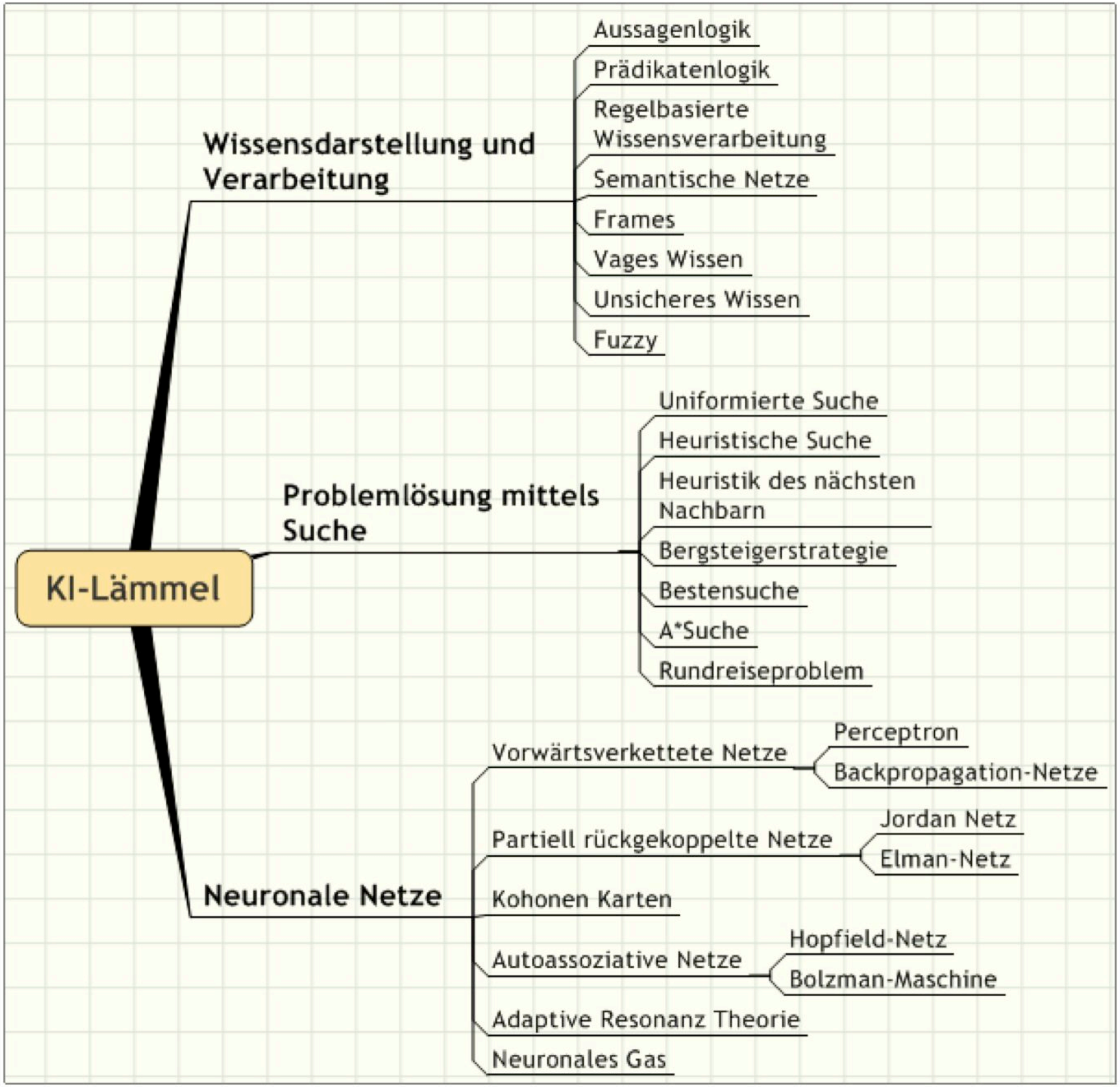

KI-Winston
representation and methods
1. Definitionen, Geltungsbereich etc.
2. semantic nets and description mapping
semantic nets
describe and match method
principles
analogy problems
recognitions of abstractions
problem solving and understanding knoledge
3. generate and test, means-end, problem reduction
generate and test
means end analysis
problem reduction method
4. nets and basic search
blind methods
heuristically informed methods
5. nets and optimal search
the best path
redudant paths
6. trees and adversial search
algorithmic methods
heuristic methods
7. rules and rule chaining
rule based deduction systems
rule based reaction systems
forward and backward chaining
8. rules, substrates, and cognitive modelling
rule based systems as substrate
rule based systems as human problem solving
9. frames and inheritance
frames, individuals, inheritance
demon procedures
frames, events inheritance
10. frames and commonsense
thematic role frames
expansion into primitive actions
11. numeric constraints and propagation
propagarion of numbers through numeric constraint nets
propagation of probability bounds through opinion nsets
propagation of surface altitudes through arrays
12. symbolic constraints and propagation
propagation of line labels through drawing junctions
propagation of time intervall relations
13. logic and resolution proof
rules of inference
resolution proofs
14. backtracking and truth maintenance
chronological and dependency-directed backtracking
proof by constraint propagation
15. planning
planning using if-add-delete operators
planning using situation variables
learning and regularity recognition
1. learning by analyzing differences
induction heuristics
identification
2. learning by explaining experience
learning about people
about form and function
matching
3. learning by correcting mistakes
isolating suspicious relations
intelligent knowledge repair
4. learning by recording cases
recording and retrieving raw experience
finding nearest neighbors
5. learning by managing multiple modeels
version space method
version space characteristics
6. learning by building identification trees
from data to identification trees
from trees to rules
7. learning by training neural nets
simulated neural nets
hill climbing and back propagation
back propagation
Unterzweig
8. learning by training perceptrons
perceptrons and perceptron learning
scope
9. learning by training approximation nets
interpolation and approximation nets
biological implementation
10. learning by simulating evolution
survival of the fittest
genetic algorithms
survival of the most diverse
vision and language
1. recognizing objects
2. describing images
3. expressing language constraints
4. responding to questions and commands


KI-Norvig
1. Einleitung
Definitionen
Grundlagen Geschichte
Philosophie
Mathematik
Psychologie
Computerwissenschaften
Linguistik
Geschichte AI
2. Agenten
Model
structure
environments
3. Problem-solving
u.a. Suchstrategien (uniformed methods)
Breadth-first
Uniform cost
Depth-first
Depth-limited
Iterative-deepening
Bidirectional
Vergleich
constraint satisfaction search
Informed Search Methods
Best-First
Heuristic
Memory-bounded
Iterative Improvement Algorithms
Unterzweig
Game-playing
Perfect decissions
Imperfect decissions
Alpha-Beta Pruning
Chance
4. Knowledge and reasoning
Logical Agents
Knowledge based
Representation, Reasoning, Logic
Propositional Logic
Wumpus
First-order Logic
Funktion und Beispiele im Kalkül
Building a knowledge base
Encoding, Ontologie etc.
Inference in first order Logic
Modus Ponens etc.
Logical Reasoning Systems
Indexing, Retrieval, Unification
Logic Programming Systems
Theorem Provers
Forward-chaining
Frames, Semantic Networks
Description Logic
5. Acting Logically
Planning
Practical Planning
Planning and Acting
6. Uncertain Klowledge and Reasonning
Uncertainty
Notation, Axiome, Bayes
Probabilistic Reasoning Systems
Knowledge in uncertain domains
Belief Networks
Bayesian, causal, prob. network, knowledge map
Inference in Belief NW
Inf. in Multiply connectet BNW
Knowledge Engineering
Unterzweig
Unterzweig
Making simple decissions
Beliefs and desires
Utility Theorie
Multiattribute utility functions
decission networks
Value of information
Making komplex decissions
Sequential decission problems
Value Iteration
Policy iteration
decission theoretic agent design
dynamic belief network
dynamic desission network
7. Learning
learning from observation
learning agents
inductive learning
learning decission trees
information theory
general logic descriptions
computational learning theorie
Learning in neural and belief networks
brain - model
neural network
perceptrons
multilayer feed forward network
application of nn
bayesian methods for learning belief nw
Reinforcement learning
passive learning in known environment
passive learning in unknown environment
active learning in unknown environment
genetic algorithms and evolutionary proggramming
knowledge in learning
explanation based learning
learning using relevant information
inductive logic programming
8. communication, perceiving and acting
communicating agents
communication as action
types
a formal grammar
syntactic analysis
definite clause grammar
augmenting a grammar
semantic interpretation
ambiguity and disambiguition
Natural language processing
applications
parsing
ambiguity
discourse understanding
Unterzweig
perception
maschinelles sehen
speech recognition
robotics
Conclusion
philosophical foundations
AI - present and future
complexity analysis
languages and algorithms
backus- naur form
pseudocode

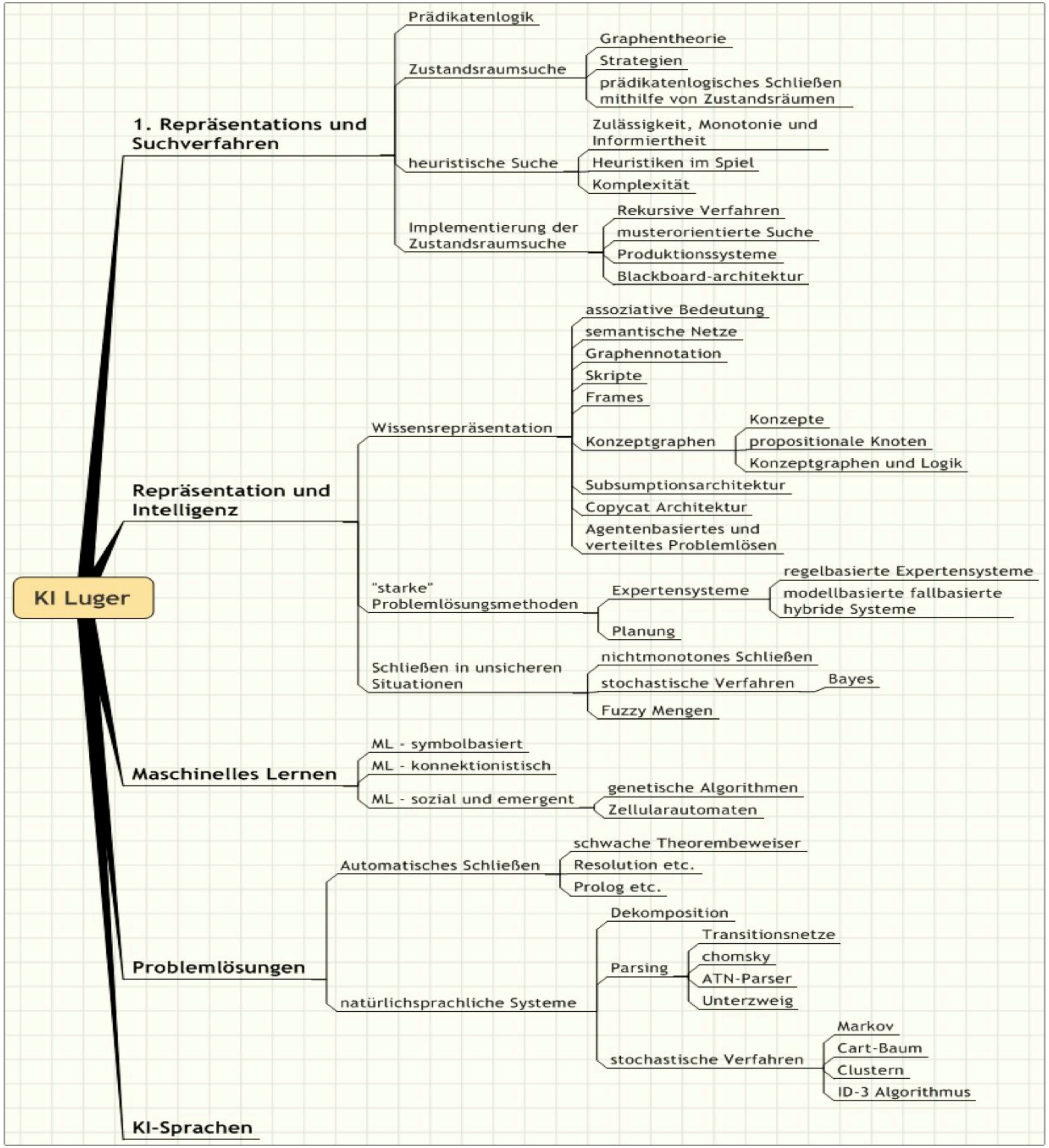

KI-Kreutzer
1. from heuristics to knowledge representation
2. the state space metaphor
search
planning
problem solving
game playing
minmaxing
tree prunning
3. pattern matching and associative databases
historical
patterns toolbox
knowledgebase toolbox
4. production system interpreters
historical
productions toolbox
5. assoziative and semantic networks
historical
assoziative network toolbox
bestiary
6. frames and scripts
principles, historical
frames toolbox
toyland
7. natural language processing and atn's
principals, historical
atn toolbox

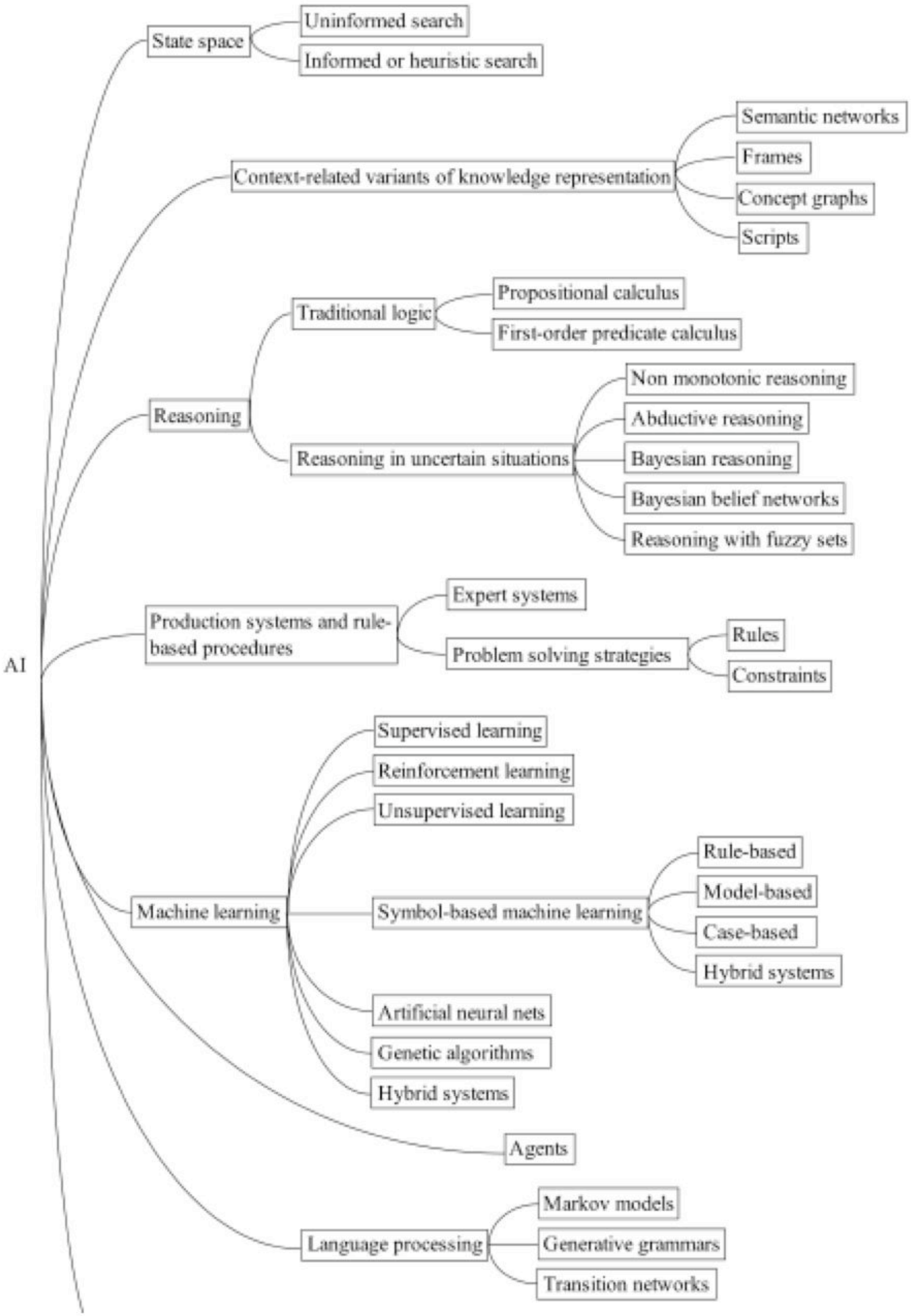


- KI-Görz
  - KI-Programmierung
  - Neuronale Netze
    - Natürliche
    - Künstliche
    - Unterzweig
  - Expertensysteme, Planen und Problemlösen
    - Expertensysteme und Wissensmodellierung
    - Planen und Konfigurieren
  - Bildverstehen
  - Sprachverarbeitung
    - Beschreibungsformalismen
    - Semantik
    - Generierung
  - 4. Kognition
    - Kognition als Informationsverarbeitung
    - Denken und Problemlösen
    - Wissen und Expertise
    - Wissensrepräsentation
    - Lernen und kognitive Entwicklung
    - Sprachverstehen als Informationsverarbeitung
  - 1. Wissensrepräsentation und Logik
    - nichtmonotones Schließen
    - qualitatives und Modellbasiertes Schließen
    - Wissen über Raum und Zeit
  - 2. Automatisches Beweisen
    - Prädikatenlogik
    - Resolutionskalkül
    - Implementierung
  - 3. Maschinelles Lernen
    - induktives Lernen
    - deduktives Lernen
    - Logik-orientiertes induktive Lernen
    - lernen als nicht monotoner Schluß
    - Theorie des Lernbaren

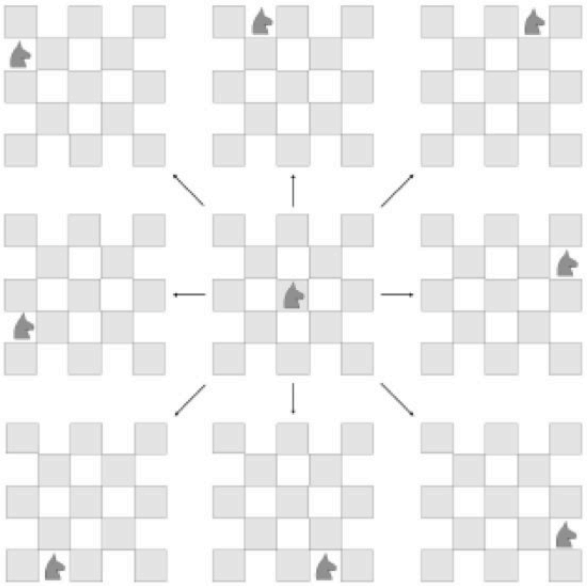


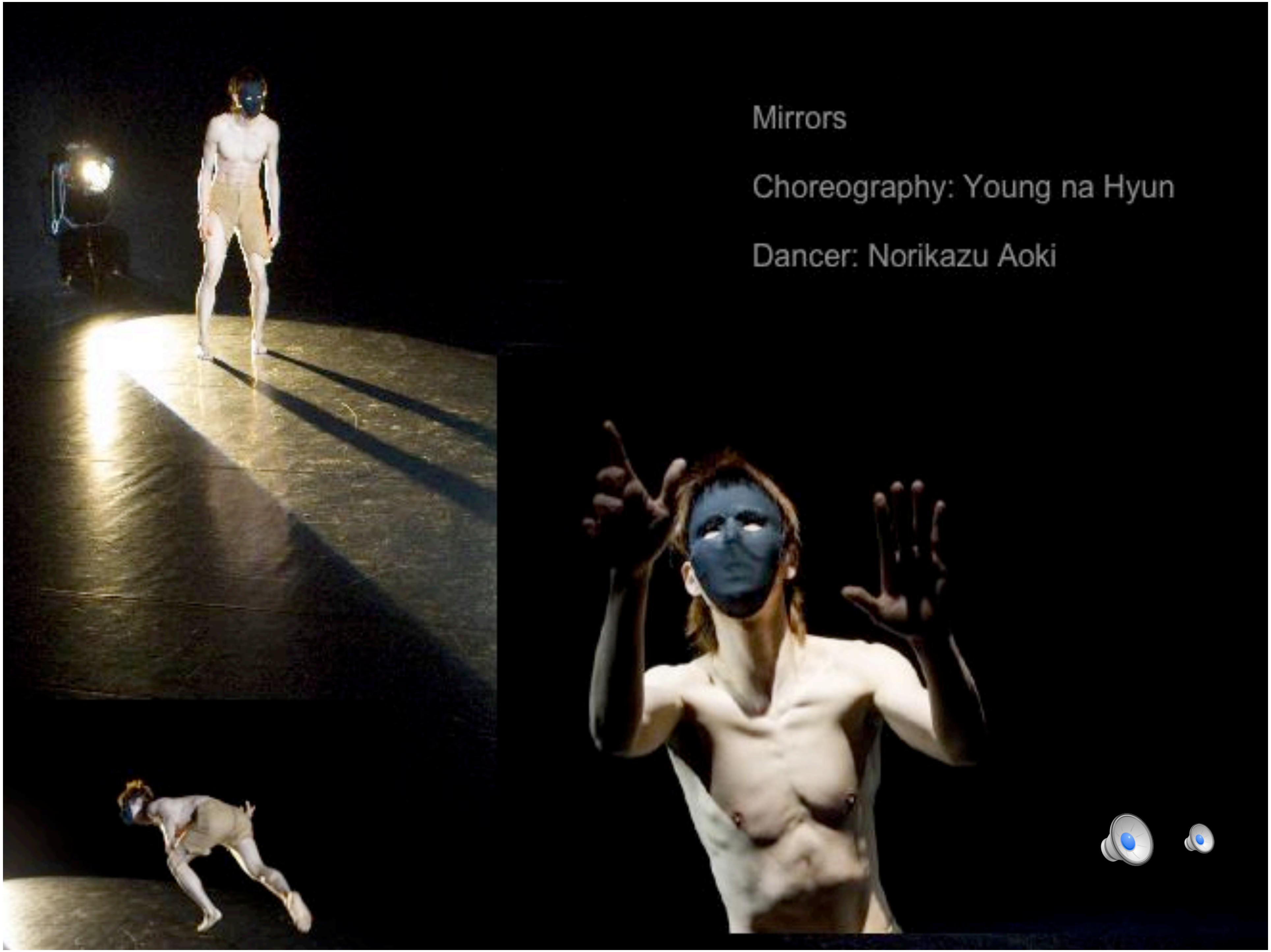
- KI-Lämmel
  - **Wissensdarstellung und Verarbeitung**
    - Aussagenlogik
    - Prädikatenlogik
    - Regelbasierte Wissensverarbeitung
    - Semantische Netze
    - Frames
    - Vages Wissen
    - Unsicheres Wissen
    - Fuzzy
  - **Problemlösung mittels Suche**
    - Uniformierte Suche
    - Heuristische Suche
    - Heuristik des nächsten Nachbarn
    - Bergsteigerstrategie
    - Bestensuche
    - A*Suche
    - Rundreiseproblem
  - **Neuronale Netze**
    - Vorwärtsverkettete Netze
      - Perceptron
      - Backpropagation-Netze
    - Partiell rückgekoppelte Netze
      - Jordan Netz
      - Elman-Netz
    - Kohonen Karten
    - Autoassoziative Netze
      - Hopfield-Netz
      - Bolzman-Maschine
    - Adaptive Resonanz Theorie
    - Neuronales Gas


KI Luger
1. Repräsentations und Suchverfahren
Prädikatenlogik
Zustandsraumsuche
Graphentheorie
Strategien
prädikatenlogisches Schließen mithilfe von Zustandsräumen
heuristische Suche
Zulässigkeit, Monotonie und Informiertheit
Heuristiken im Spiel
Komplexität
Implementierung der Zustandsraumsuche
Rekursive Verfahren
musterorientierte Suche
Produktionssysteme
Blackboard-architektur
Repräsentation und Intelligenz
Wissensrepräsentation
assoziative Bedeutung
semantische Netze
Graphennotation
Skripte
Frames
Konzeptgraphen
Konzepte
propositionale Knoten
Konzeptgraphen und Logik
Subsumptionsarchitektur
Copycat Architektur
Agentenbasiertes und verteiltes Problemlösen
"starke" Problemlösungsmethoden
Expertensysteme
regelbasierte Expertensysteme
modellbasierte fallbasierte hybride Systeme
Planung
Schließen in unsicheren Situationen
nichtmonotones Schließen
stochastische Verfahren
Bayes
Fuzzy Mengen
Maschinelles Lernen
ML - symbolbasiert
ML - konnektionistisch
ML - sozial und emergent
genetische Algorithmen
Zellularautomaten
Problemlösungen
Automatisches Schließen
schwache Theorembeweiser
Resolution etc.
Prolog etc.
natürlichsprachliche Systeme
Dekomposition
Parsing
Transitionsnetze
chomsky
ATN-Parser
Unterzweig
stochastische Verfahren
Markov
Cart-Baum
Clustern
ID-3 Algorithmus
KI-Sprachen



- AI
  - State space
    - Uninformed search
    - Informed or heuristic search
  - Context-related variants of knowledge representation
    - Semantic networks
    - Frames
    - Concept graphs
    - Scripts
  - Reasoning
    - Traditional logic
      - Propositional calculus
      - First-order predicate calculus
    - Reasoning in uncertain situations
      - Non monotonic reasoning
      - Abductive reasoning
      - Bayesian reasoning
      - Bayesian belief networks
      - Reasoning with fuzzy sets
  - Production systems and rule-based procedures
    - Expert systems
    - Problem solving strategies
      - Rules
      - Constraints
  - Machine learning
    - Supervised learning
    - Reinforcement learning
    - Unsupervised learning
    - Symbol-based machine learning
      - Rule-based
      - Model-based
      - Case-based
      - Hybrid systems
    - Artificial neural nets
    - Genetic algorithms
    - Hybrid systems
  - Agents
  - Language processing
    - Markov models
    - Generative grammars
    - Transition networks





Mirrors

Choreography: Young na Hyun

Dancer: Norikazu Aoki

Patterns of Intuition

„Clarification of compositional strategies and musical intuitions through the fragmentation and objectification of the creative process within the framework of generation-evaluation cycles.”