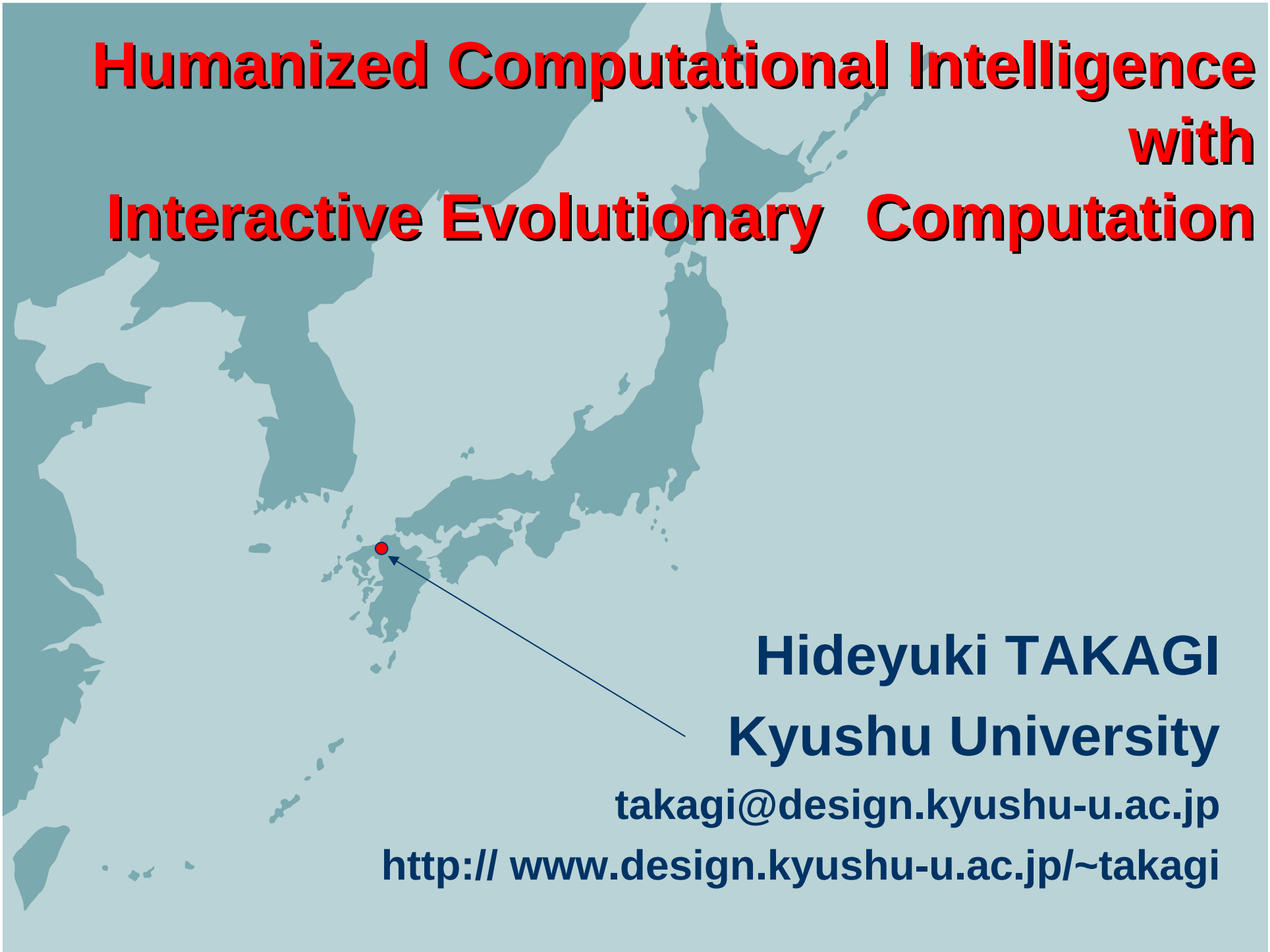
Humanized Computational Intelligence with Interactive Evolutionary Computation



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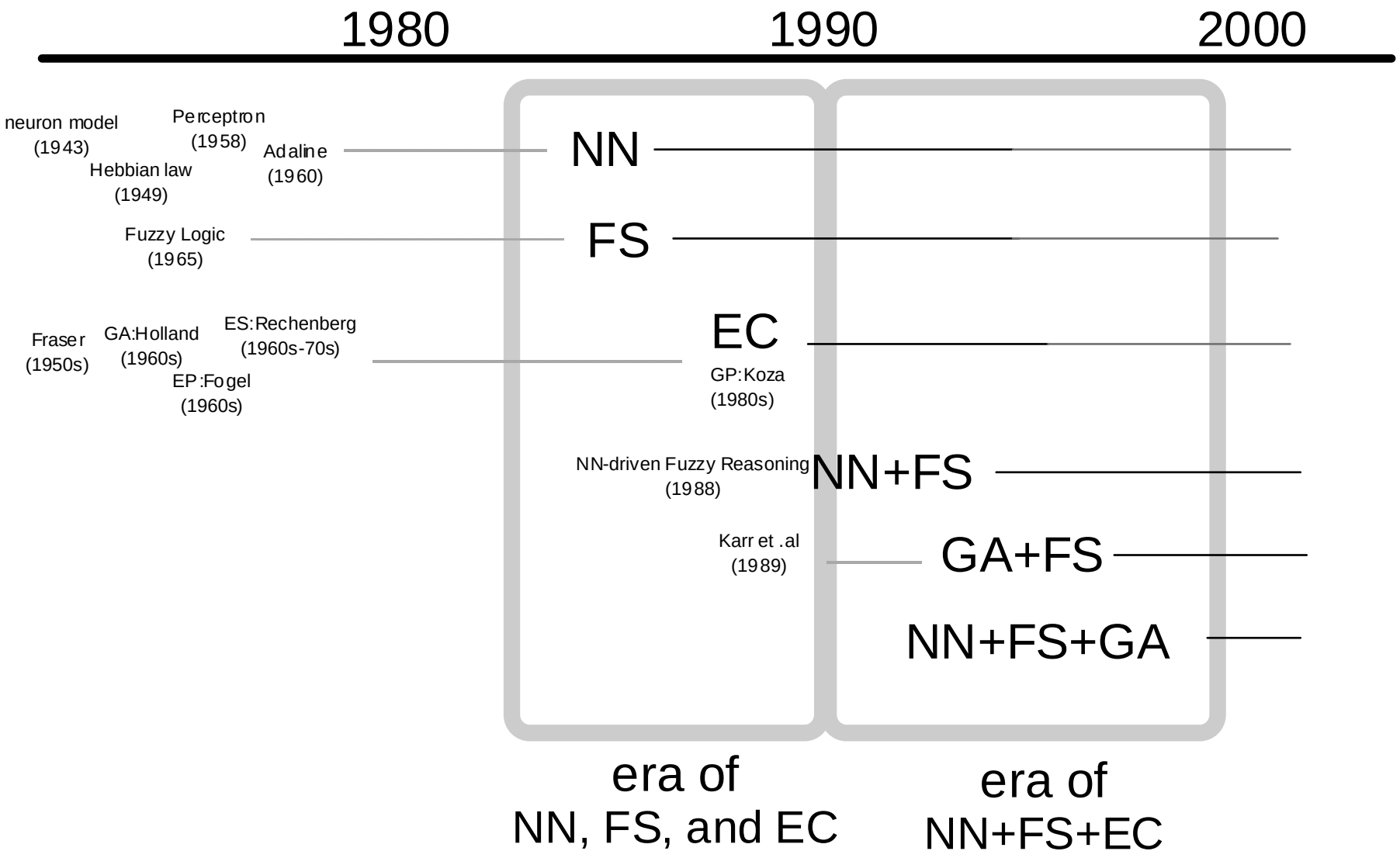
http:// www.design.kyushu-u.ac.jp/~takagi

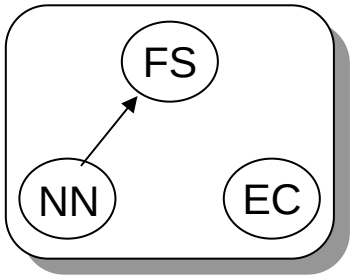
Today's Talk

- Part 1 Humanized Computational Intelligence
  Hideyuki Takagi,
  "Fusion Technology of Neural Network and Fuzzy Systems: A Chronicled Progression from the Laboratory to Our Daily Lives,"
  Int. J. of Applied Mathematics and Computer Science, vol.10, no.4, pp.647-673 (2000).

- Part 2 Interactive Evolutionary Computation
  Hideyuki Takagi,
  "Interactive Evolutionary Computation: Fusion of the Capacities of EC Optimization and Human Evaluation,"
  Proceedings of the IEEE, vol.89, no.9, pp.1275-1296 (2001).

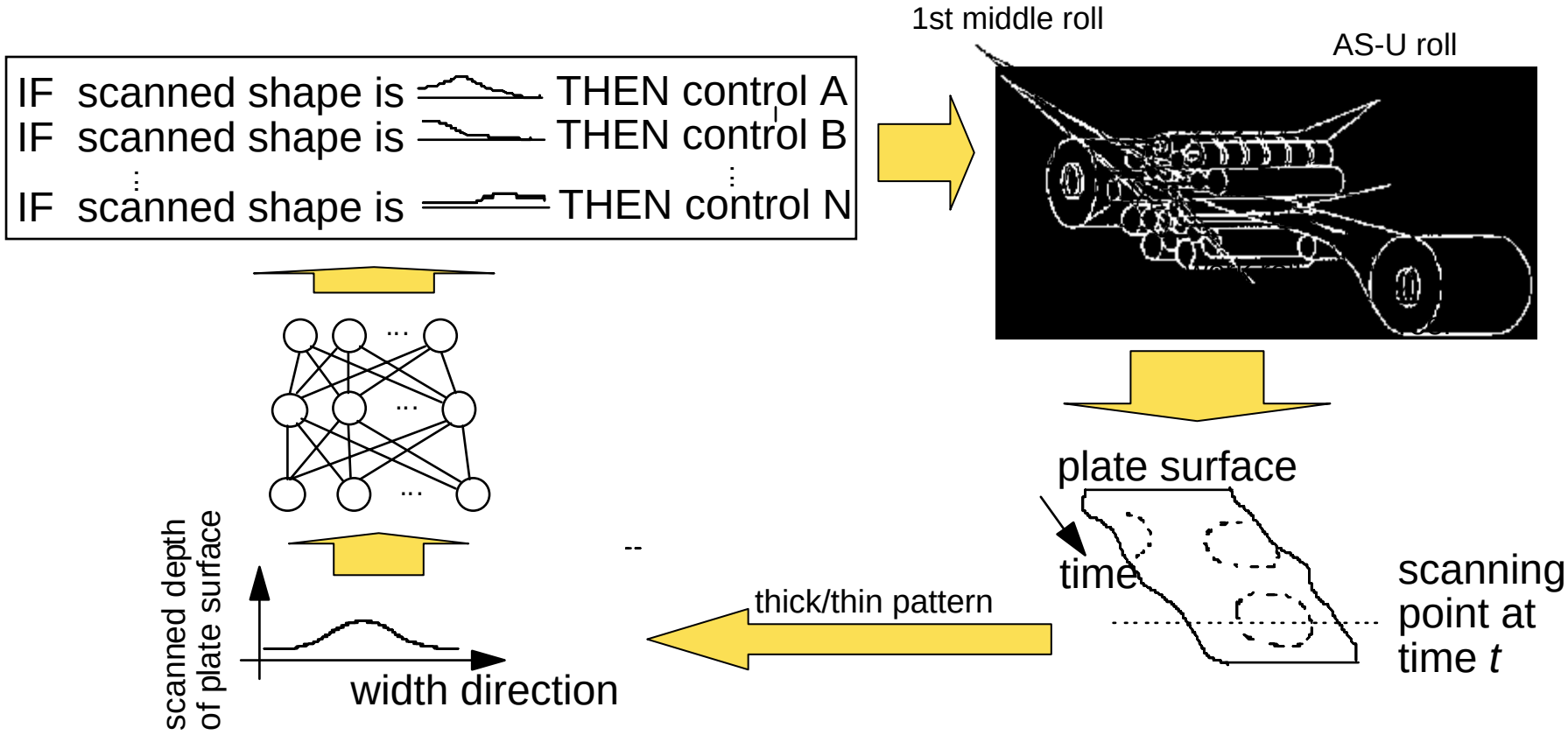
Historical View

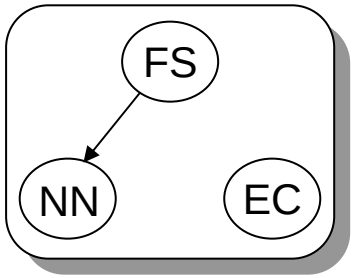




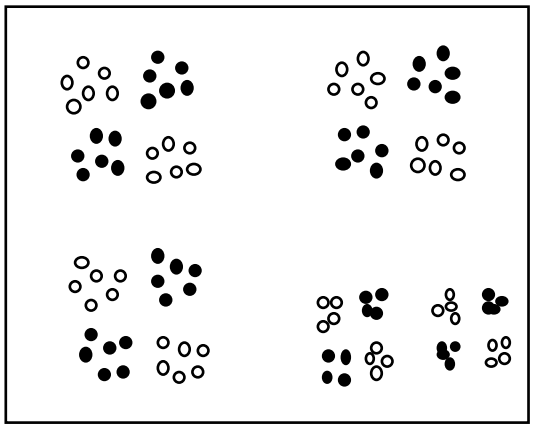
Auto-Designing FS Using NN

Many consumer products and industrial systems.
washing machines, vacuum cleaners, rice cookers,
copy machines, microwave ovens, electric thermos pos, ….



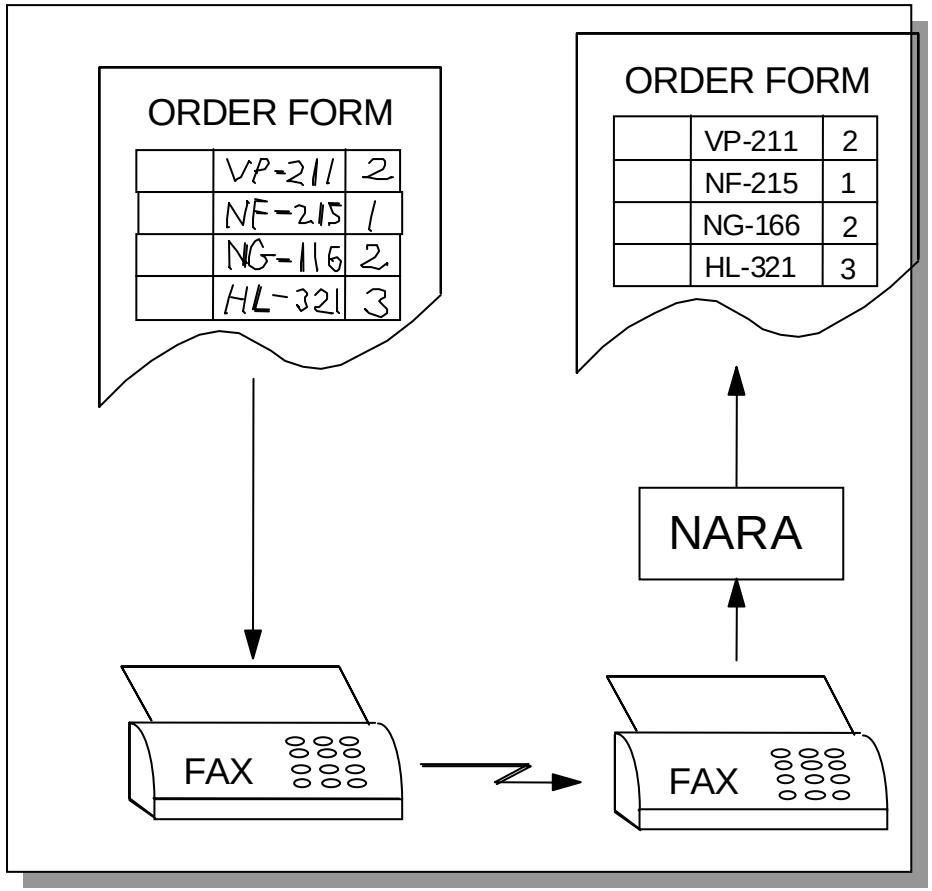


Embedding Explicit Knowledge in NN Structure

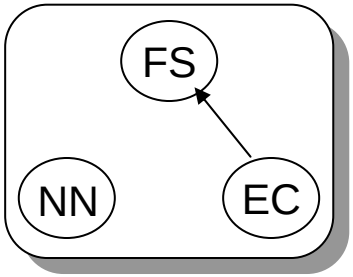


	training data	test data
conventional NN	50%	50%
NARA	85	83
improved NARA	94	89

NARA model



NARA-based FAX Order System



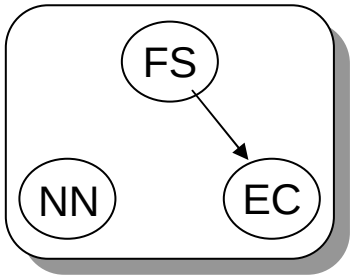
Auto-Designing FS Using GA

Membership functions in antecedents, consequents parameters, and the number of rules can be simultaneously auto-designed by GA.

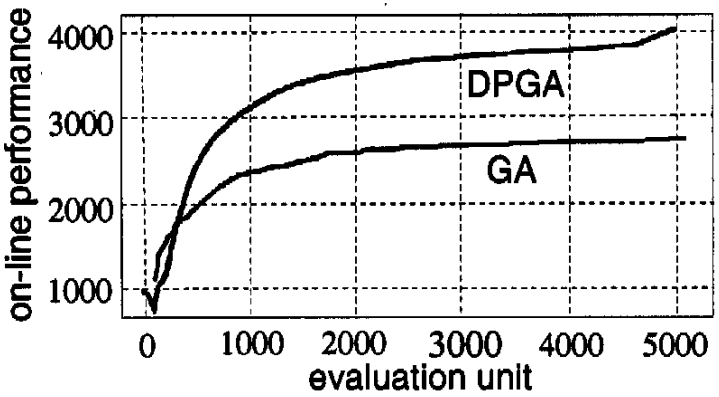
Many Korean Consumer products

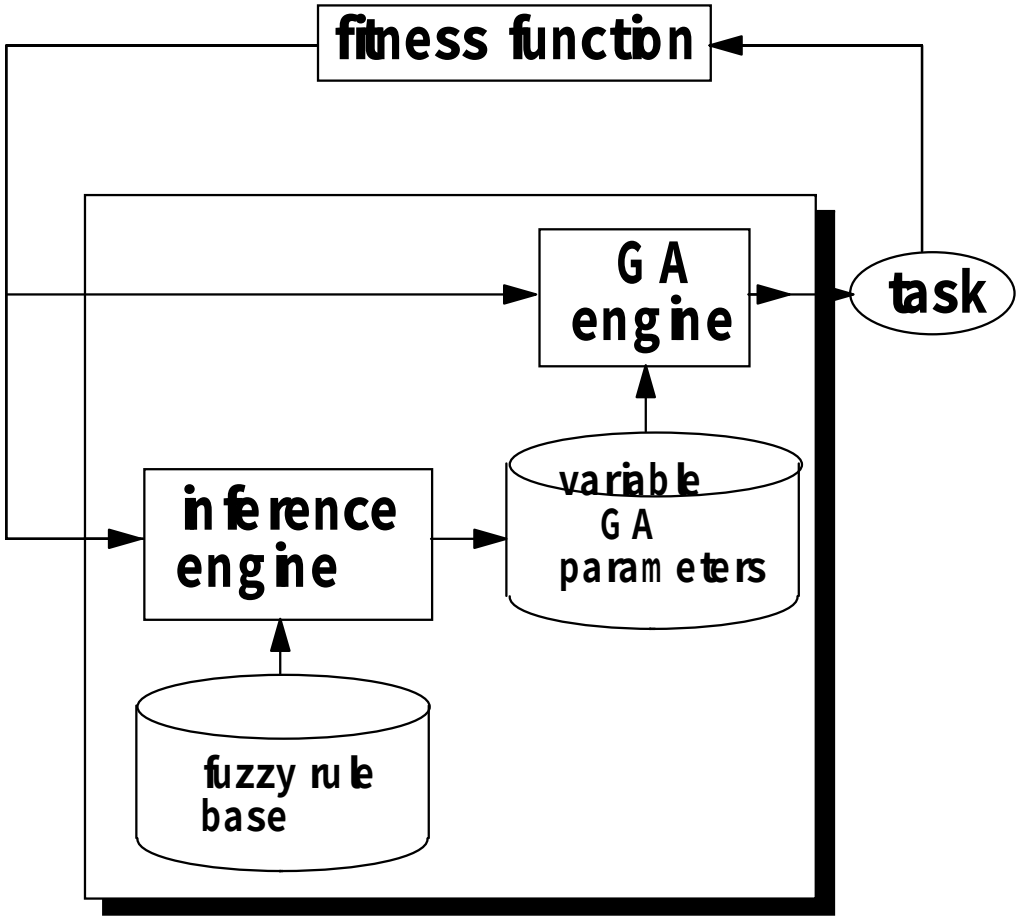
Samsung
- refrigerators (1994)
  - cool air flow control by FS
- washing machine (1995)
  - motor control for lingerie washing by FS

LG Electronics
- dish washers, rice cookers, microwave ovens
  - neuro-fuzzy estimation or control
- refrigerators, washing machine, vacuum cleaners
  - fuzzy control

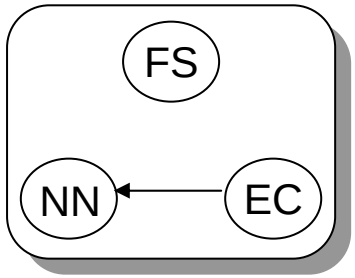


Fuzzy Control of GA Parameters

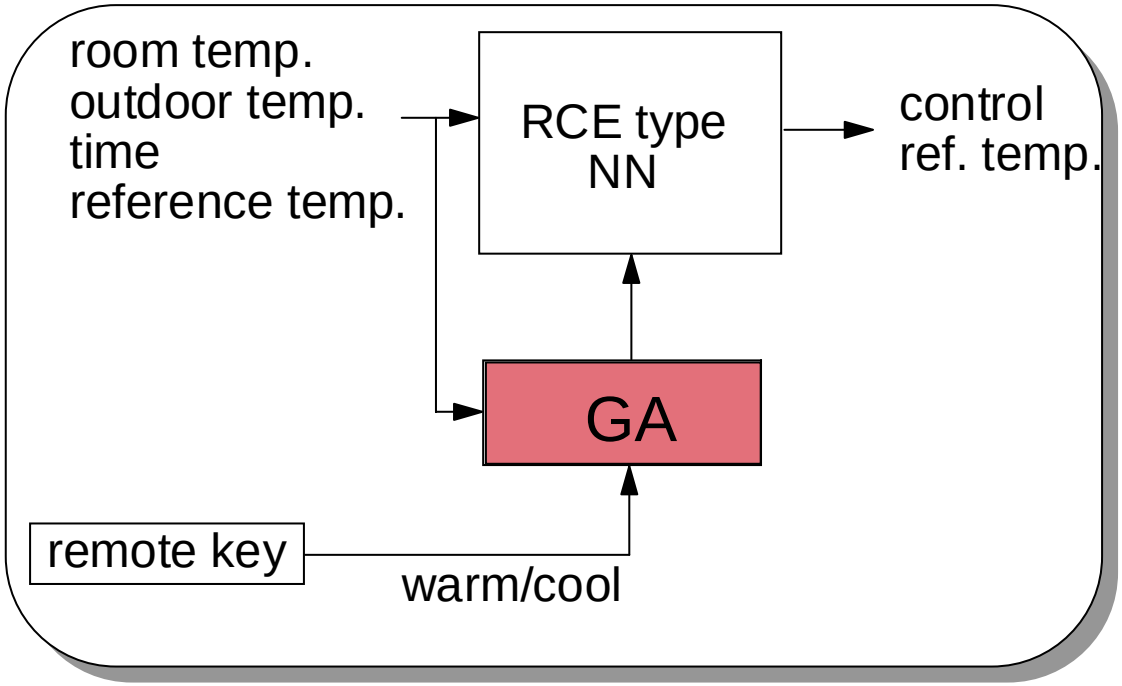




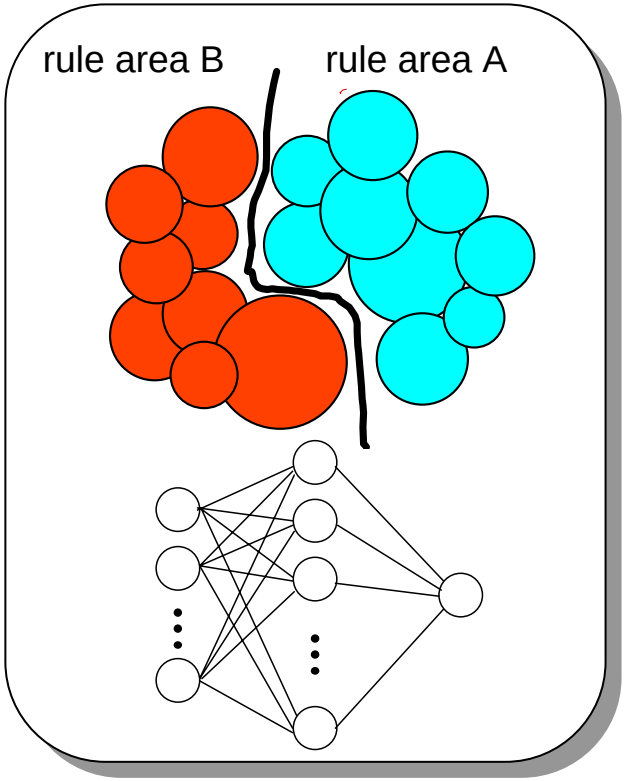
Dynamic Parametric GA



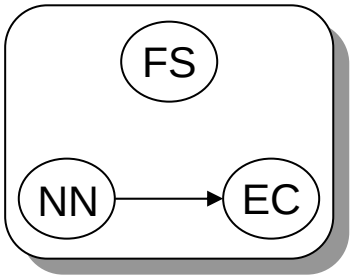
User Trainable NN Based on GA



Air conditioner (LG Electronics)



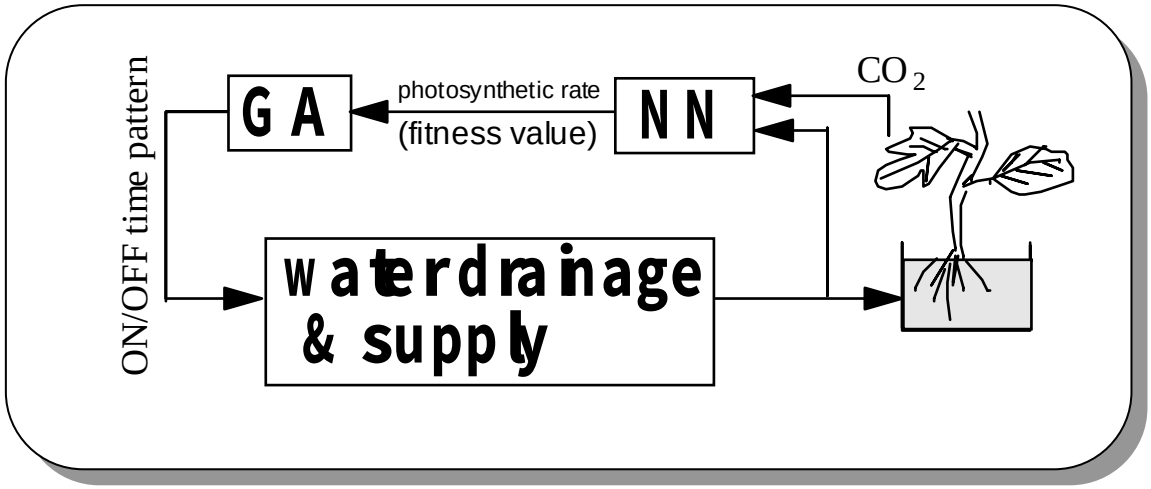
RCE type of NN



NN fitness function of GA

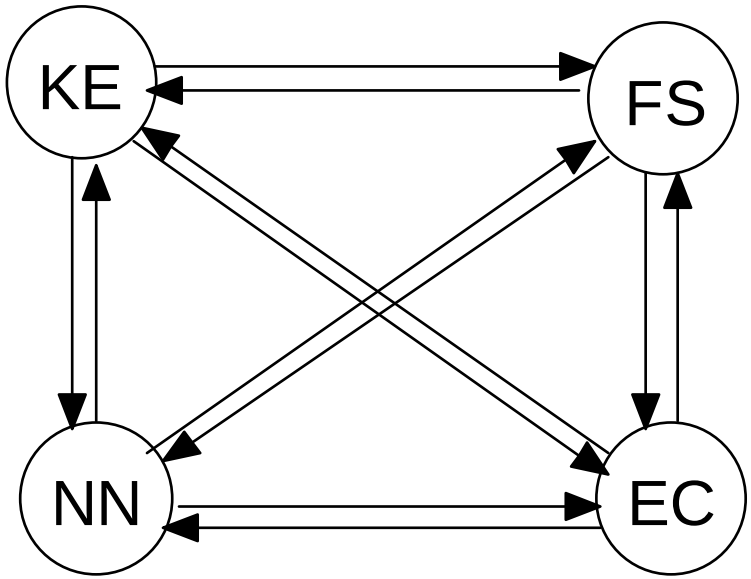
GA for on-line process control

How to find the best GA individual
without applying to the actual process ?



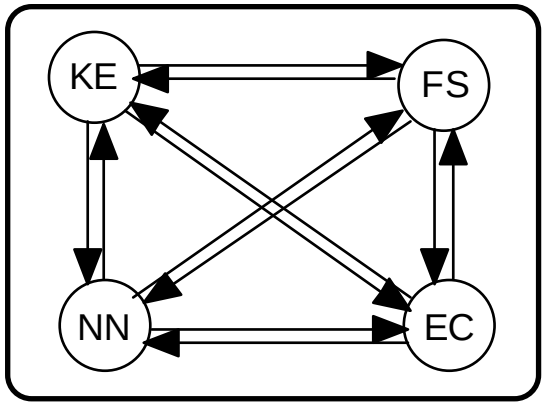
Water control for a hydroponic system

Cooperation of Computational Intelligence



Powerful cooperative technologies
have been developed for these 10 years.

What Comes Next ?



computer

+

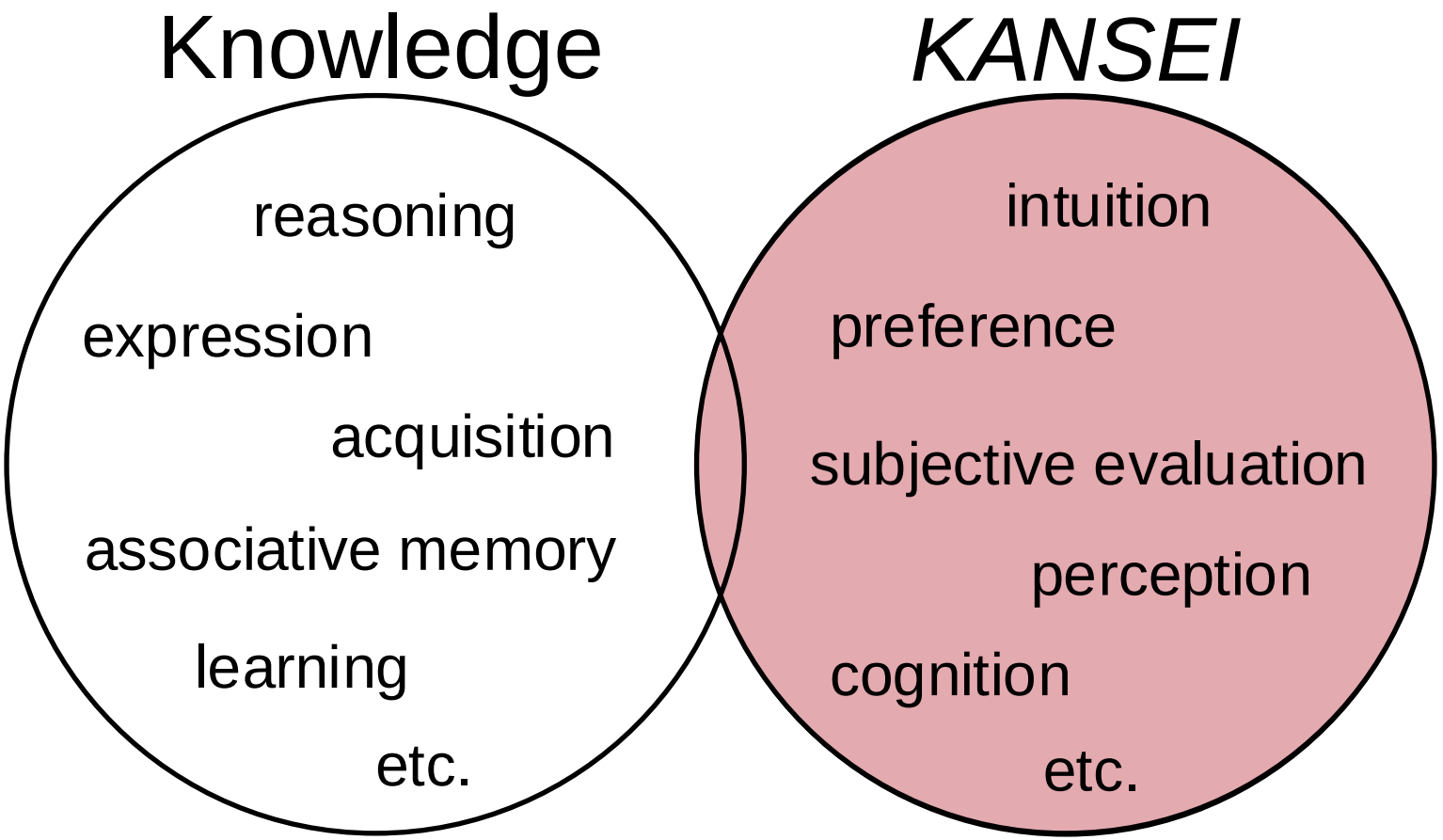
real human

- System optimization based on human evaluation
- Computer support system for creativity, psychological and physical satisfaction

Analytical Approach and Synthetic Approach

- Conventional AI approach is to model human or biological intelligence.
- Computational intelligence research has been biased to this analytical approach too much.
- Human is superior to its model.
- A synthetic approach is to directly embeds a human into a system instead of its model.

Two Different Human Capabilities



Humanized technology

ROBOTICS, CONTROL

natural environment

location,
speed,
obstacles,
…

human environment

preference,
subjective evaluation
emotion
…

DATA MINING

acquired knowledge

database → mining → IF … THEN …
IF … THEN …

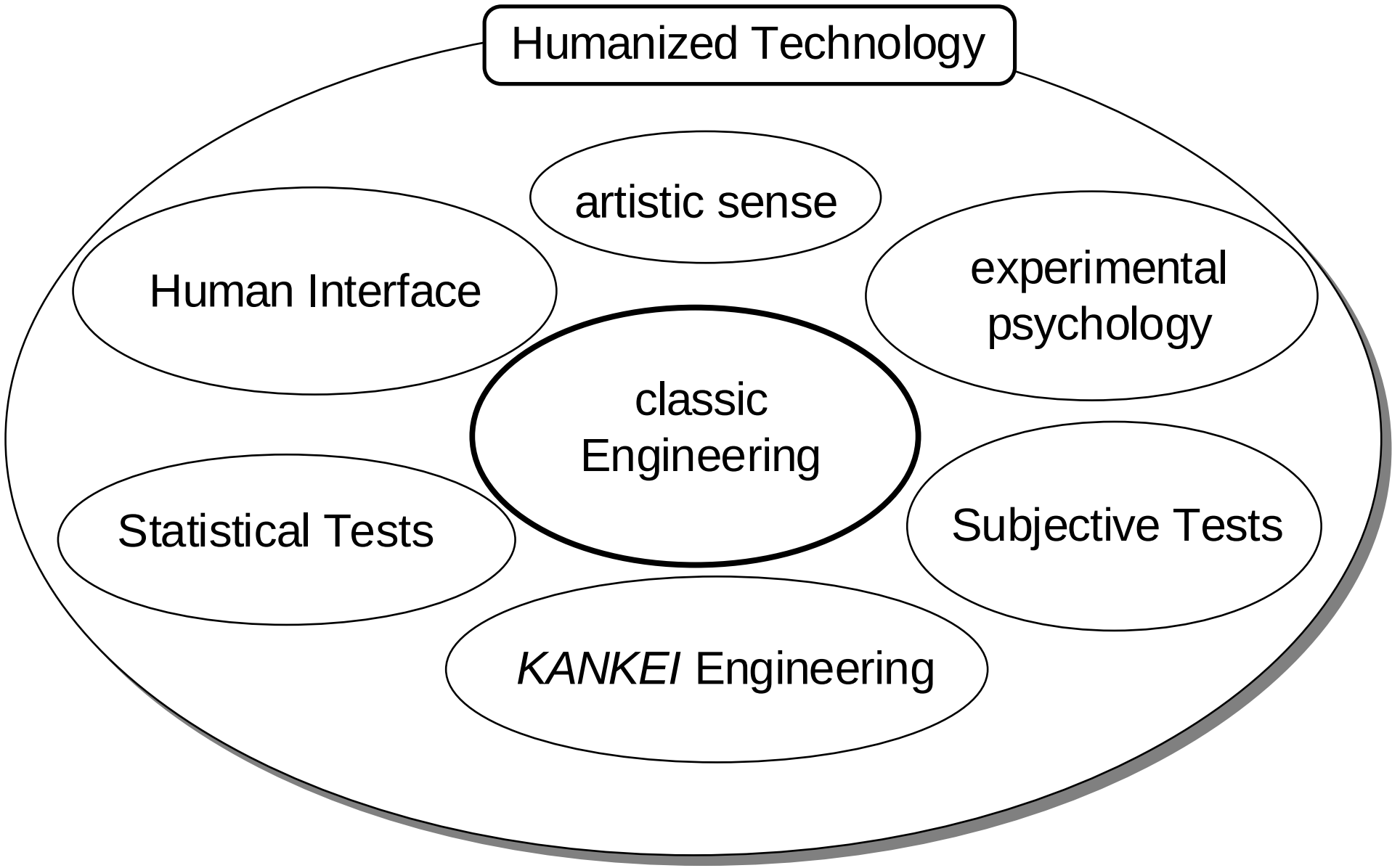
qualifying the knowledge

SINGNAL PROCESSING

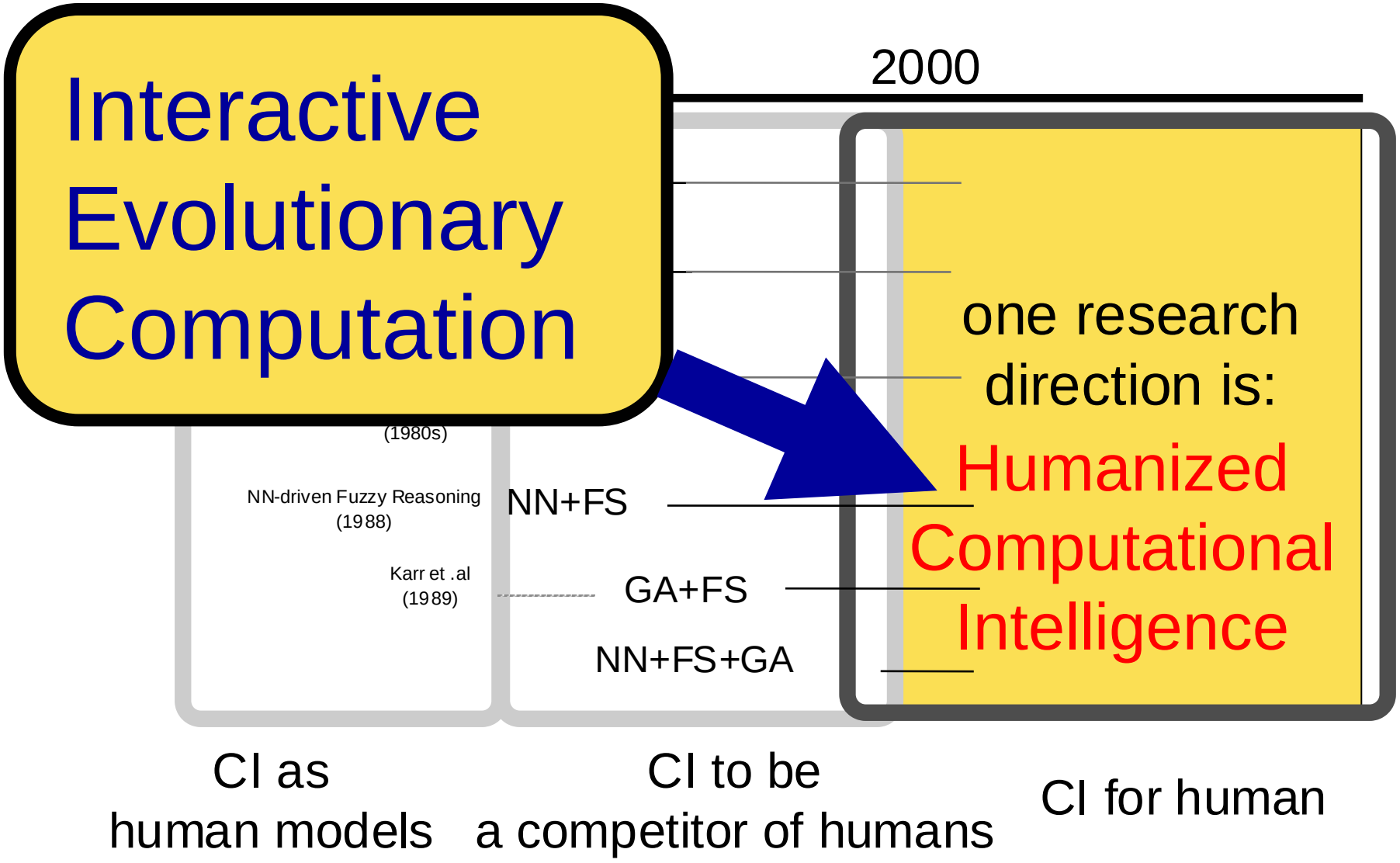
physical measurement

filter design → S/N ratio

human perception


Humanized Technology
artistic sense
Human Interface
experimental psychology
classic Engineering
Statistical Tests
Subjective Tests
KANKEI Engineering

Direction of Computational Intelligence

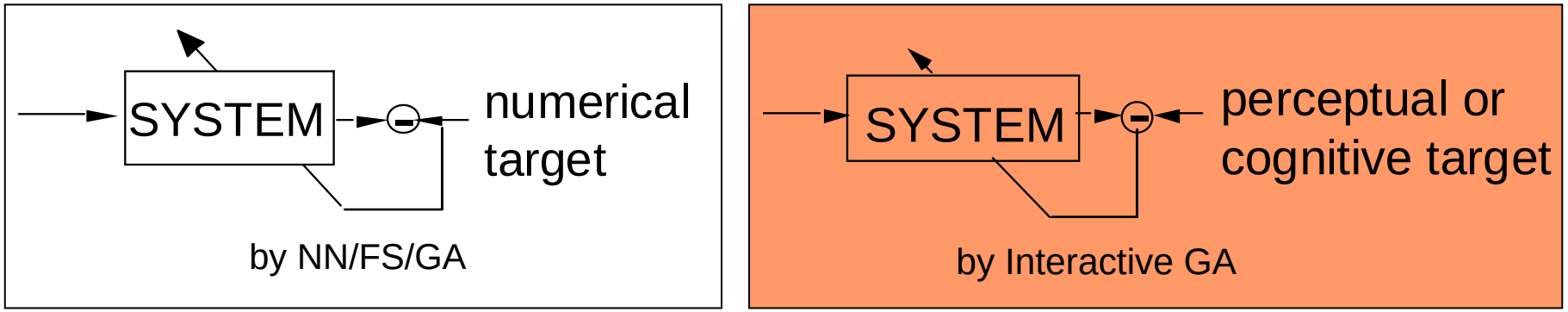


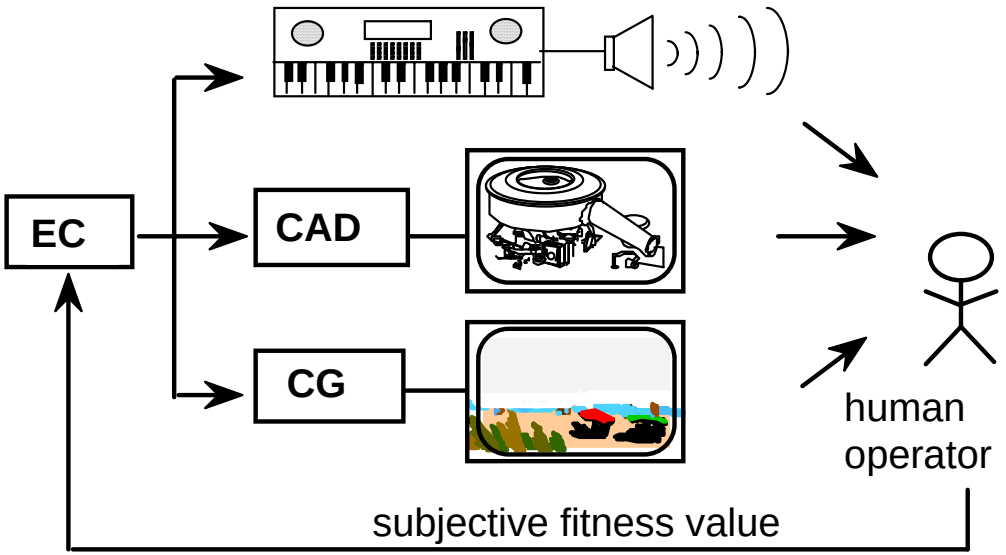
Part II Applications of Interactive Evolutionary Computation

Hideyuki Takagi, "Interactive Evolutionary Computation: Fusion of the Capacities of EC Optimization and Human Evaluation," Proceedings of the IEEE vol.89, no.9, pp.1275--1296 (Sept., 2001).

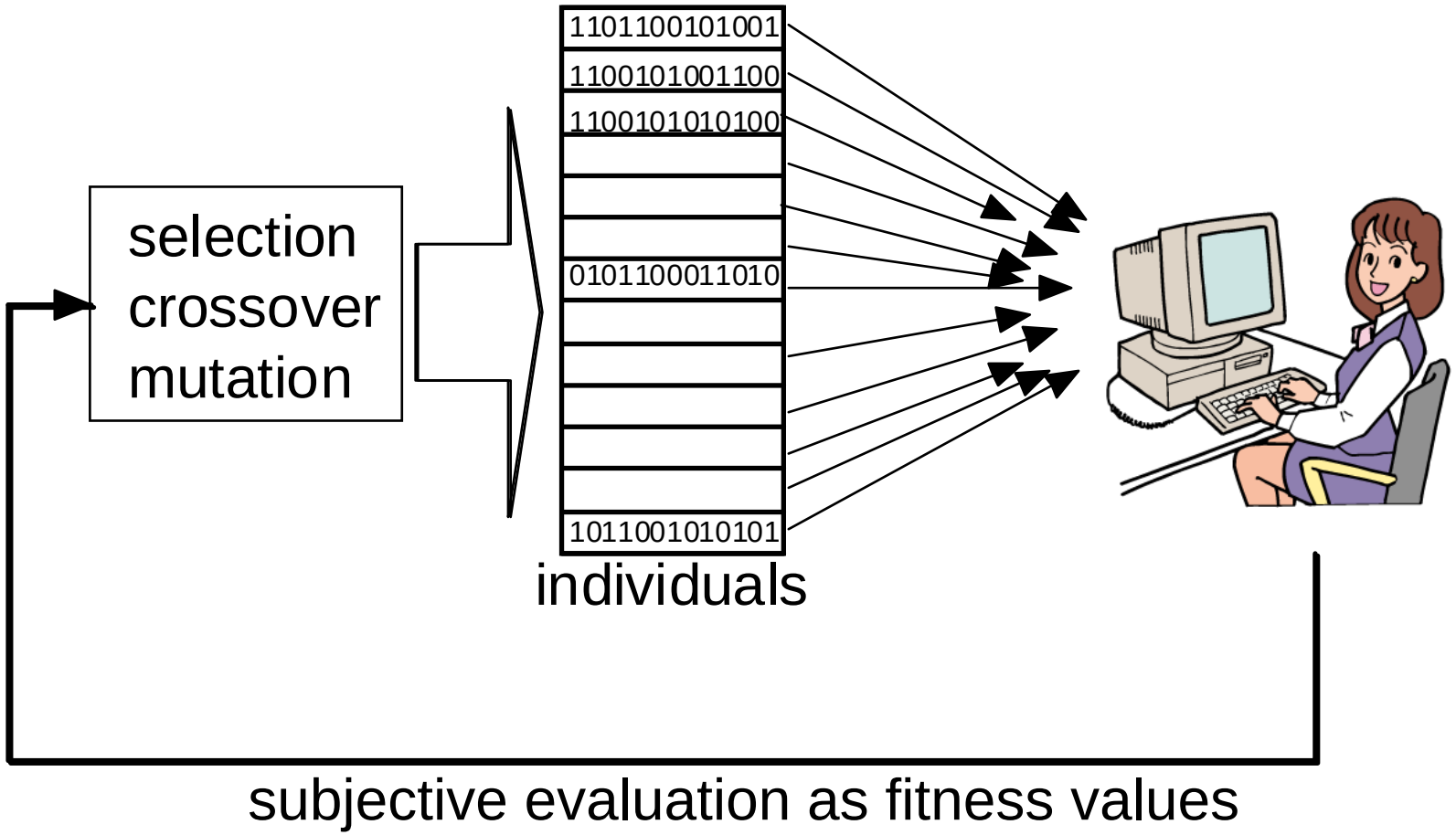
CONTENTS

What is IEC ?


SYSTEM
numerical target
by NN/FS/GA
SYSTEM
perceptual or cognitive target
by Interactive GA

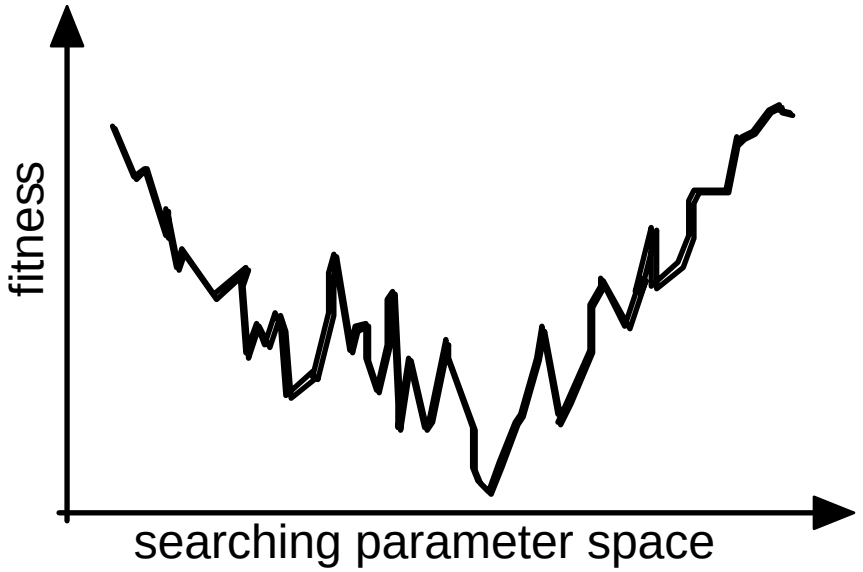

EC
CAD
CG
human operator
subjective fitness value

Interactive EC user evaluates multiple individuals in each generation

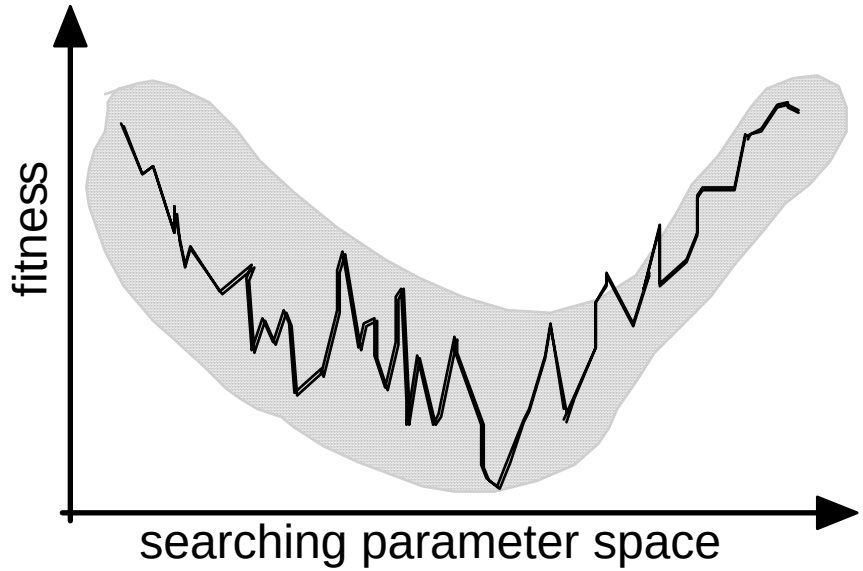


Searching spaces of interactive EC tasks is generally simple, because .....

Any searching points that human operators cannot distinguish are same for human.



normal EC search



interactive EC search

Statistics of IEC Papers

	'80s	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	total
graphic art & CG animation	2		3	2	4	5	5	2	2	4	9	4	42
3-D CG lighting design								1	3	1			5
music					1	3	3	1		1	3	5	17
editorial design									1		1	2	4
industrial design				2	2	1	5	4		2	4	9	29
face image generation			1		1	1	2		1	4	5	1	16
speech processing & prosodic control							2	1	2		1	1	7
hearing aids fitting										2	7	5	14
virtual reality								1	1				2
database retrieval								2	1	8	8	1	20
knowledge acquisition & data mining							5	3	3	1	4		16
image processing									1	2			3
control & robotics				1				2		3	4	4	14
internet										1	2	1	4
food industry								1	1				2
geophysics											1	2	3
art education												2	2
writing education									1	3			4
games and therapy								1	1	1			3
social system										1			1
discrete fitness value input method								5		2			7
prediction of fitness values							1	2	1	8	3	1	16
interface for dynamic tasks						1					1	3	5
acceleration of EC convergence								1	1	3	1		7
combination of IEC and non-IEC								1	2				3
active intervention			1								3	2	6
total	2	0	5	5	8	11	23	28	22	48	57	43	252

Researches on Interactive EC

@Takagi Laboratory

application-oriented

(1) 3-D CG lighting design support
(2) montage image system
(3) speech processing
(4) hearing-aid fitting
(5) virtual reality in robot control
(6) media database retrieval
(joint1) virtual aquarium
(joint2) geoscientific simulation
(joint3) 3-D CG modeling education
(joint3) fireworks animation design
(joint4) mental disease diagnosis
(joint5) underground water management
(joint6) MEMS design

interface research

(1) input interface
  1.1 discrete fitness value input method
(2) display interface
  2.1 prediction of user's evaluation char's
  2.2 display for time-sequential tasks
(3) acceleration of GA convergence
  3.1 approximation of EC landscape
(4) active user intervention to EC search
  4.1 on-line knowledge embedding
  4.2 Visualized IEC

IEC Research Categories

graphic art & CG animation
3-D CG lighting design
music
editorial design
industrial design
face image generation

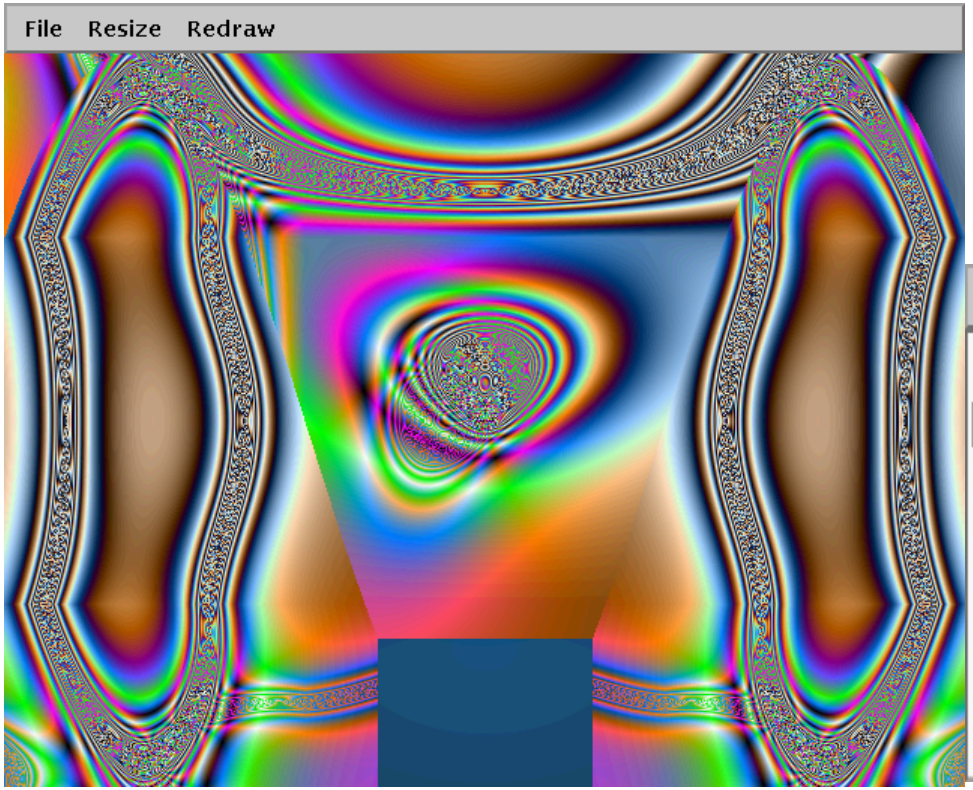
discrete fitness value input method
prediction of fitness values
interface for dynamic tasks
acceleration of EC convergence
combination of IEC and non-IEC
active intervention
Visualized IEC

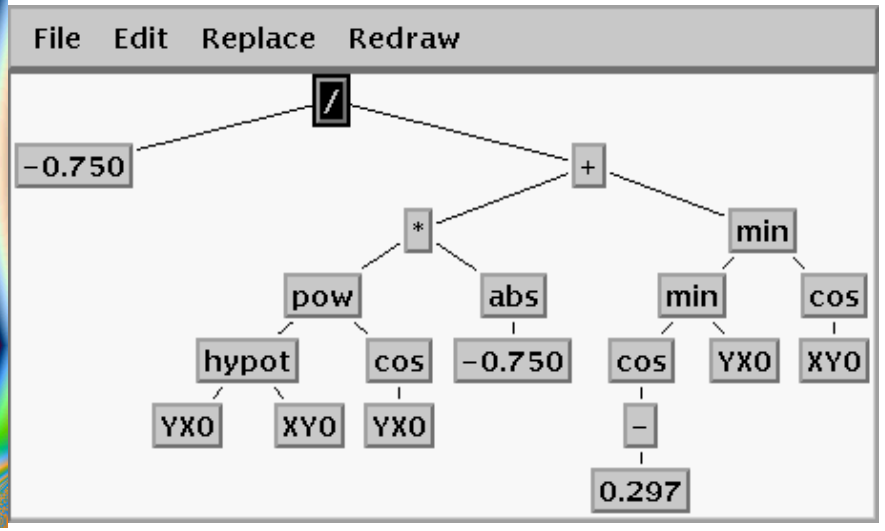
speech processing
hearing aids fitting
virtual reality
database retrieval
data mining
image processing
control & robotics
internet
food industry
geophysics

art education
writing education
games and therapy
social system

CONTENTS

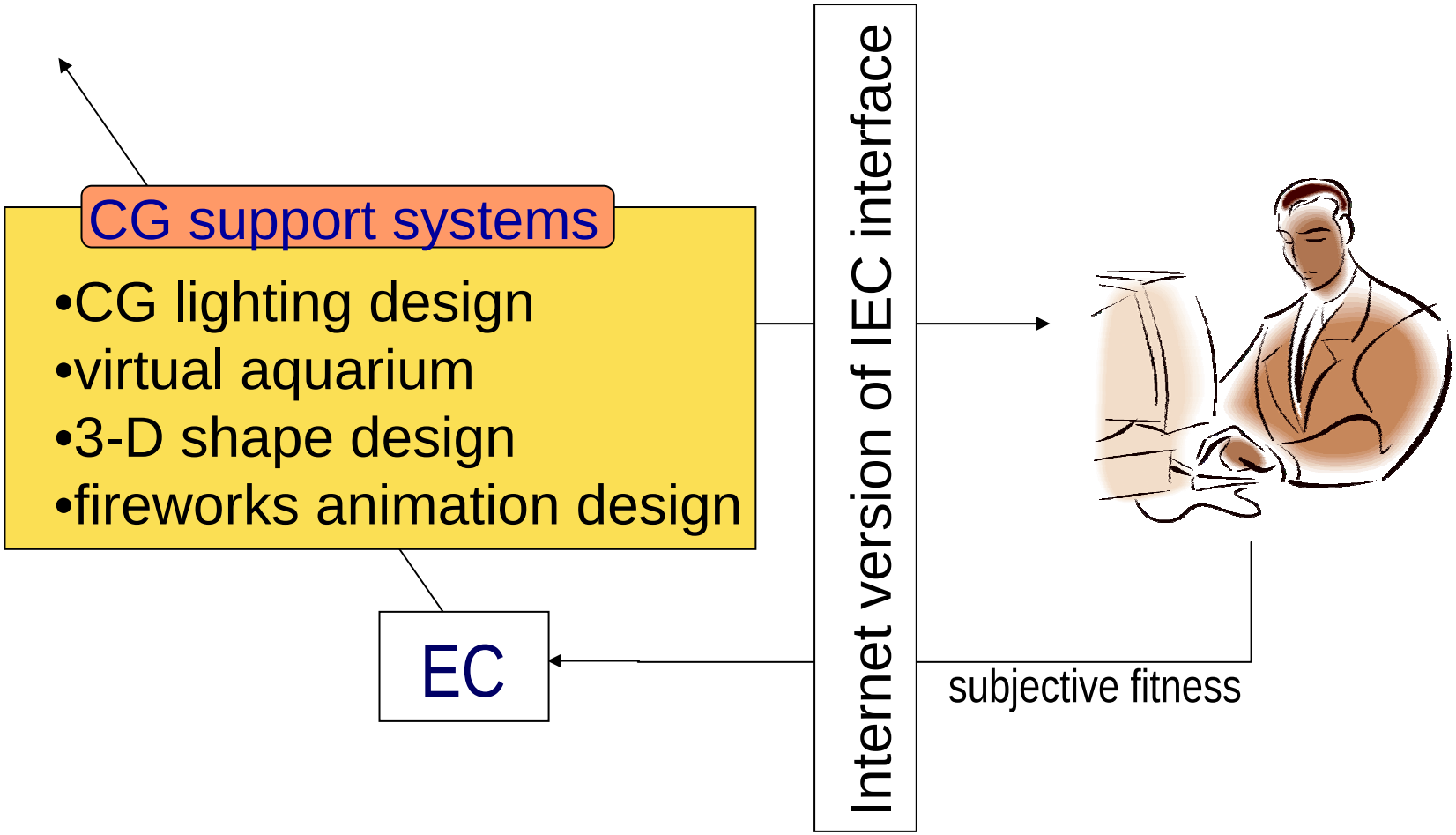
Interactive GP for Graphic Art





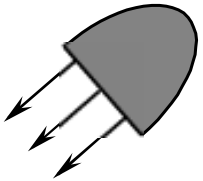
System designed by Tatsuo UNEMI

Our IEC-based CG Education Projects

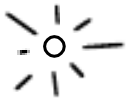


3-D CG is Simulation of Photograph:

CG Lighting is important
as same as that of photograph



type: directional
switch: on
luminance: L
(color: (h, c))
direction: (θ, ϕ, *)



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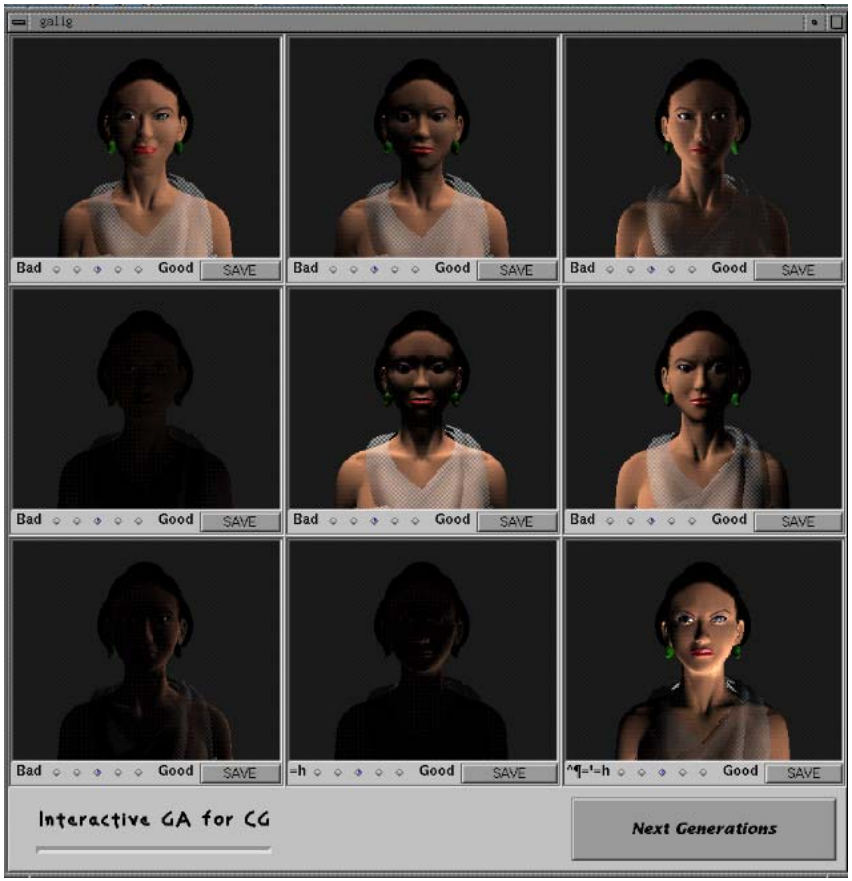
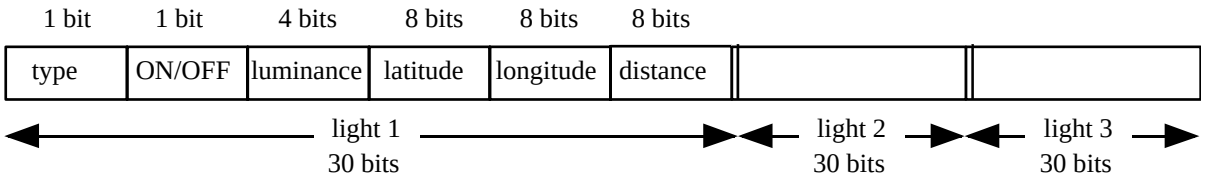
luminance: L
(color: (h, c))
location: (θ, ϕ, d)

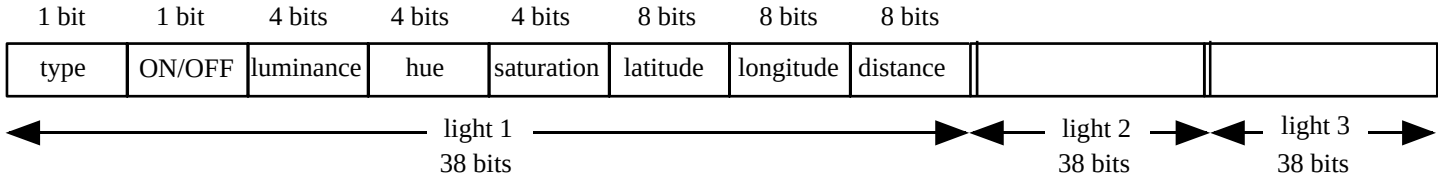


GUI for IGA-based Lighting Design and GA Coding

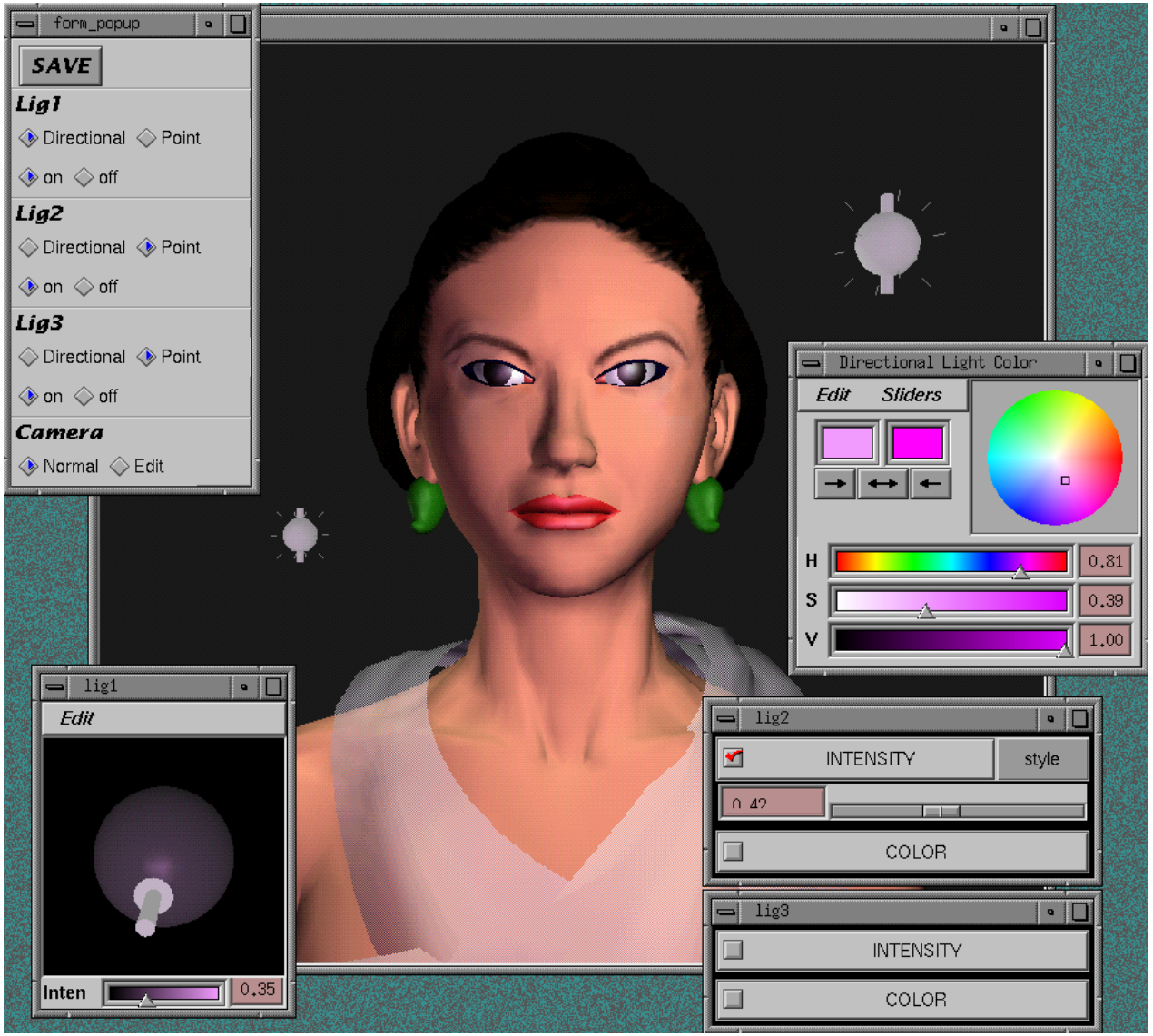
monochrome lighting



color lighting



GUI for Manual Lighting Design



IGA for 3D CG Lighting Design

By K. Aoki and H. Takagi

Gloomy impression | Cheerful impression | Heroine movie star | Wicked movie star

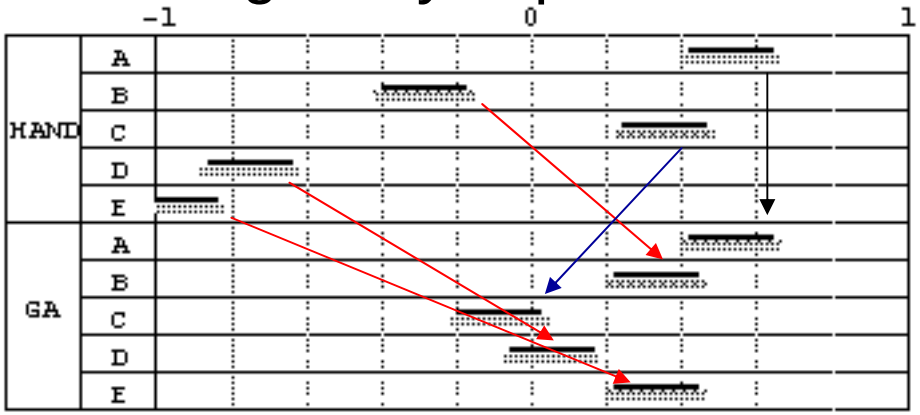
by Interactive GA

by HAND

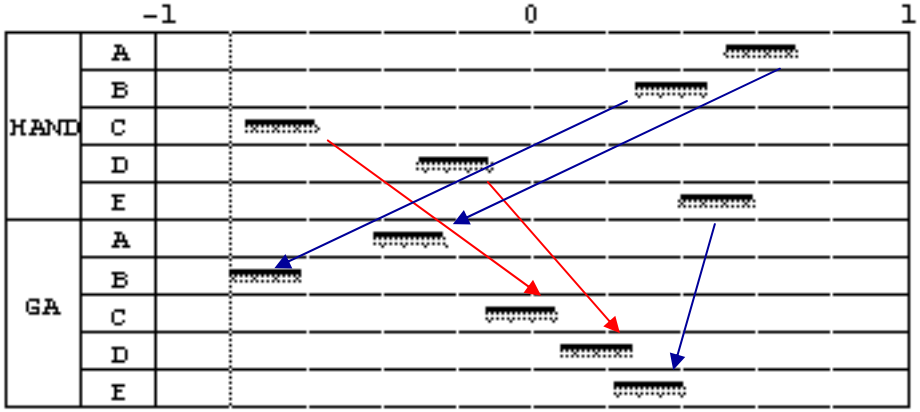
Result of Subjective and Statistic Tests

1% level of significance　　5% level of significance

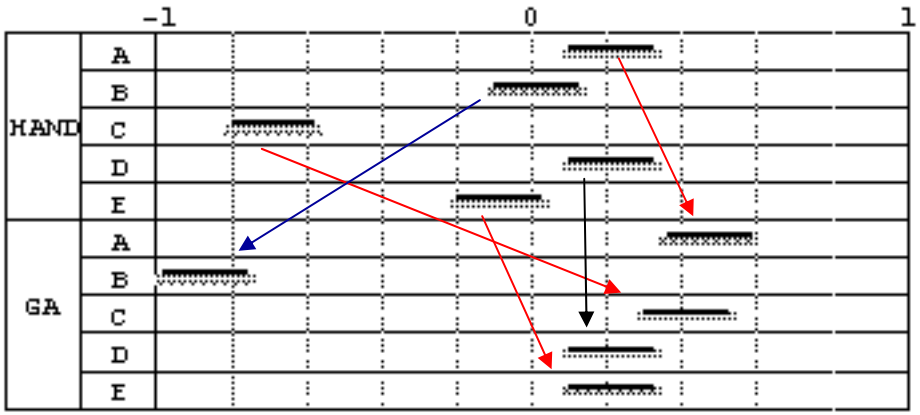
gloomy impression



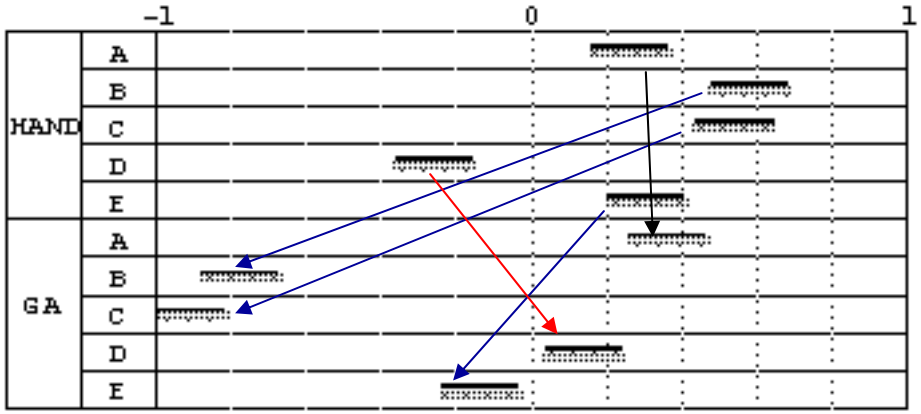
heroine impression



cheerful impression



villain impression

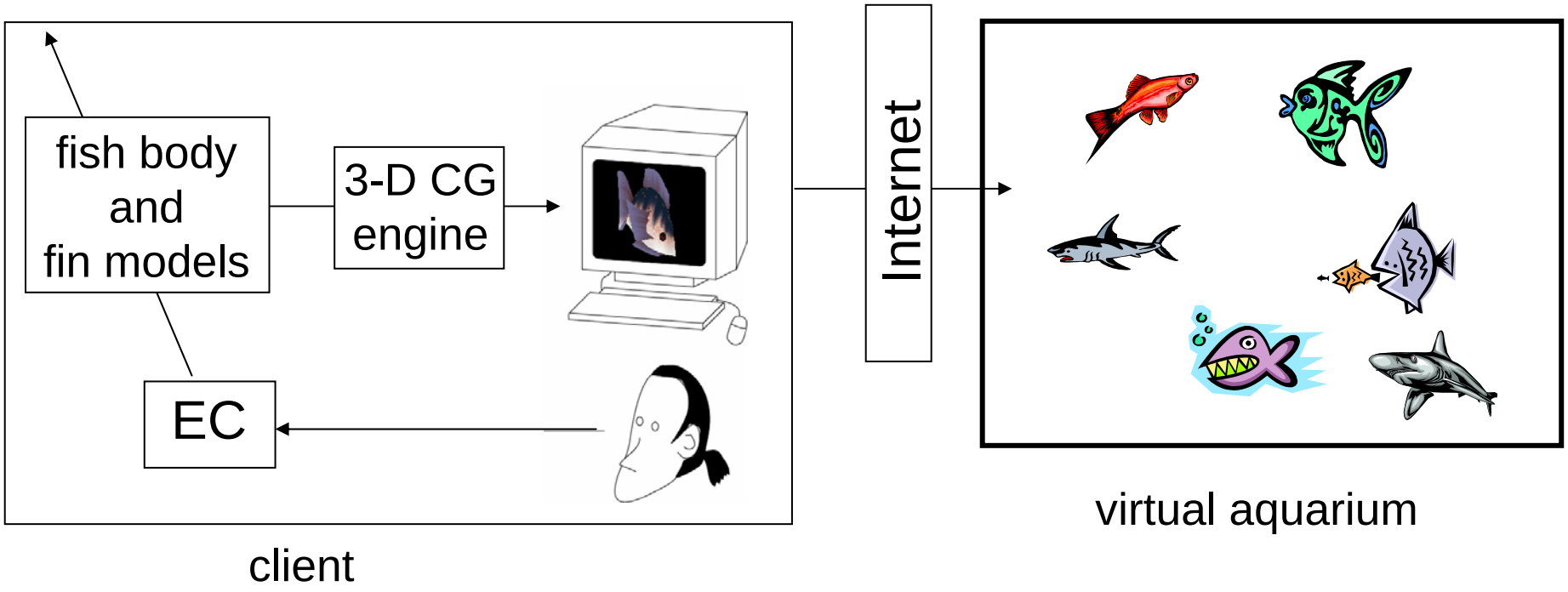


IGA-based lighting design looks effective for beginners.

Virtual Aquarium

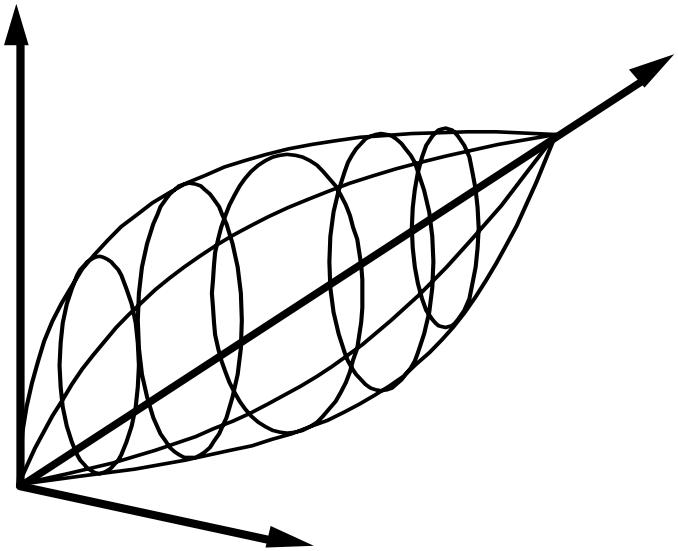
by Y. Todoroki, H. Takagi,et al.

Visitors create their own fishes at home or school and enjoy to see the fishes swimming at an aquarium.

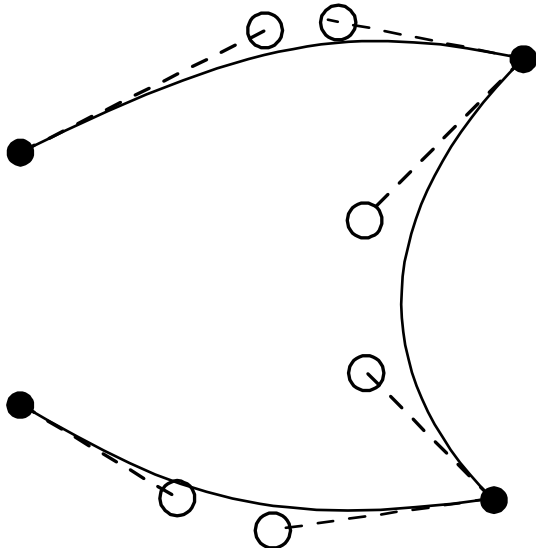


Fish Shape Modeling by Math Functions

body

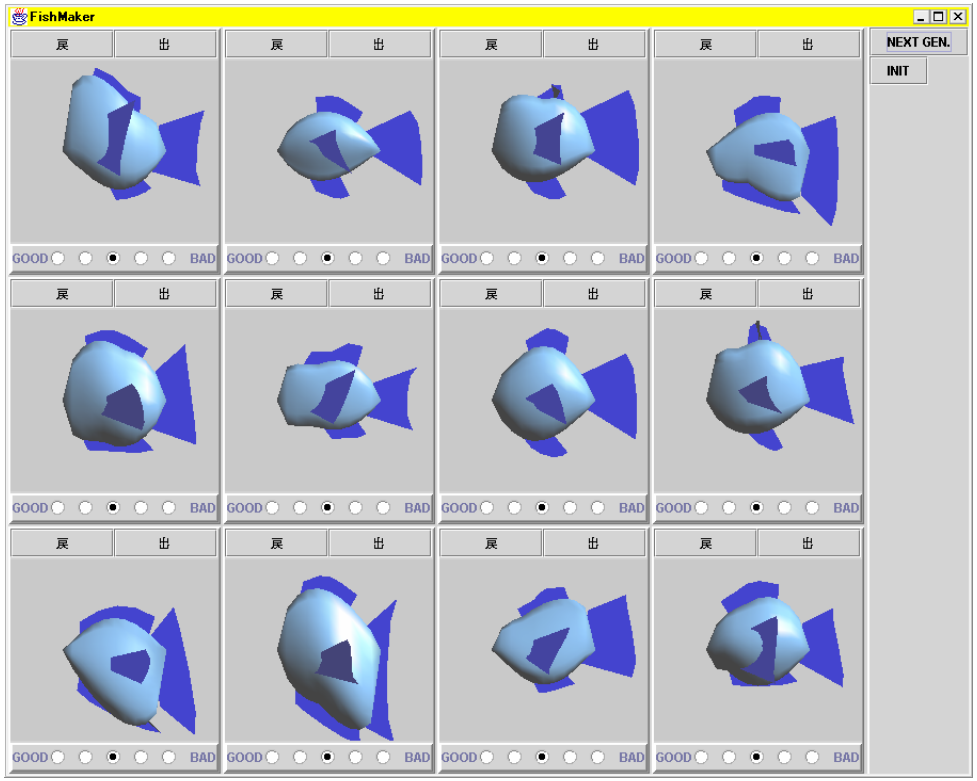


fin



by 3 Bezier curves

User Interface and Created Sample Fishes

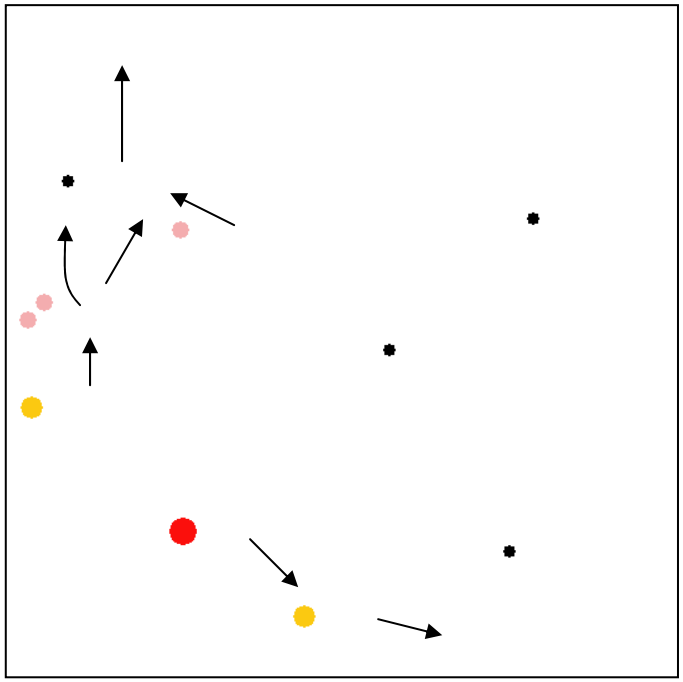


Autonomous Fish Behavior Model

BOID : mutual fish positions and predation relationship

Behavior decision rules

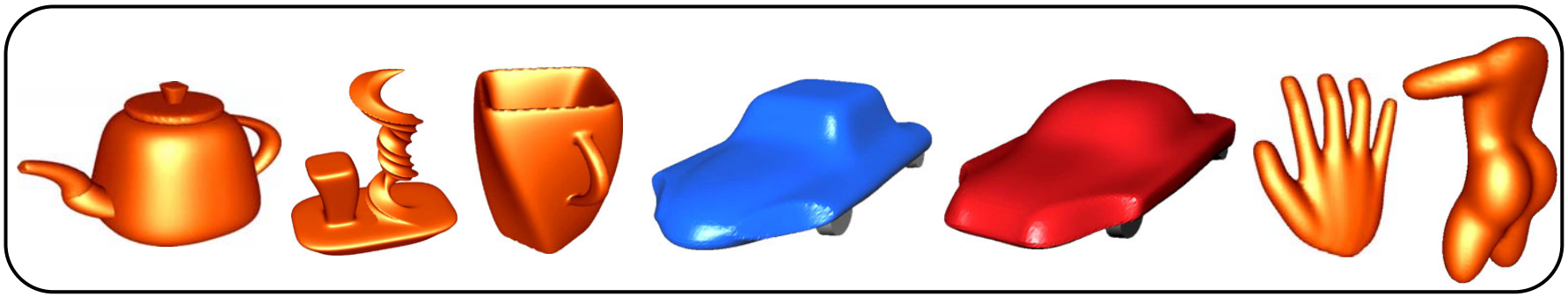
1. Chase the nearest prey fish.
2. Escape from the nearest predator.
3. Keep a certain distance from other fishes.
4. Each class of fishes has own max. speed.



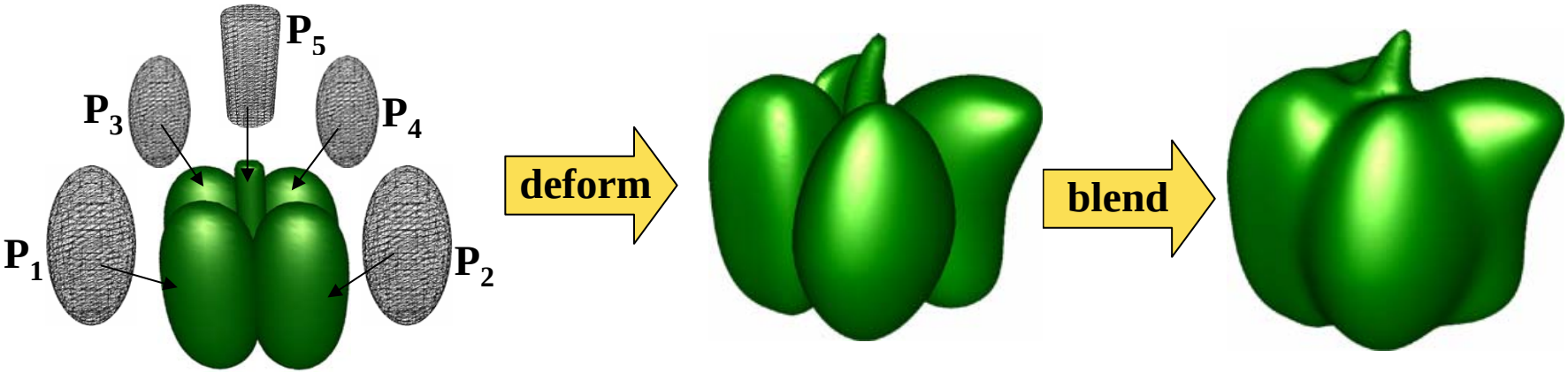
Education of Imagination and Creativity for 3D Shape

It is difficult and time consuming for computer beginners (artist, non-technical student etc.) to acquire 3D modeling skill.

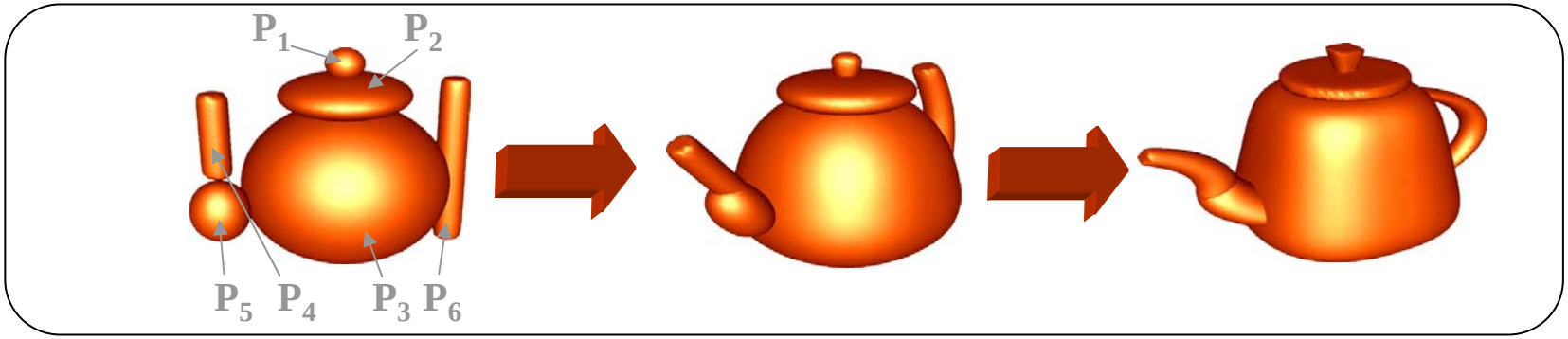
Apply IEC to support CG skill and focus on educating imagination and creativity.



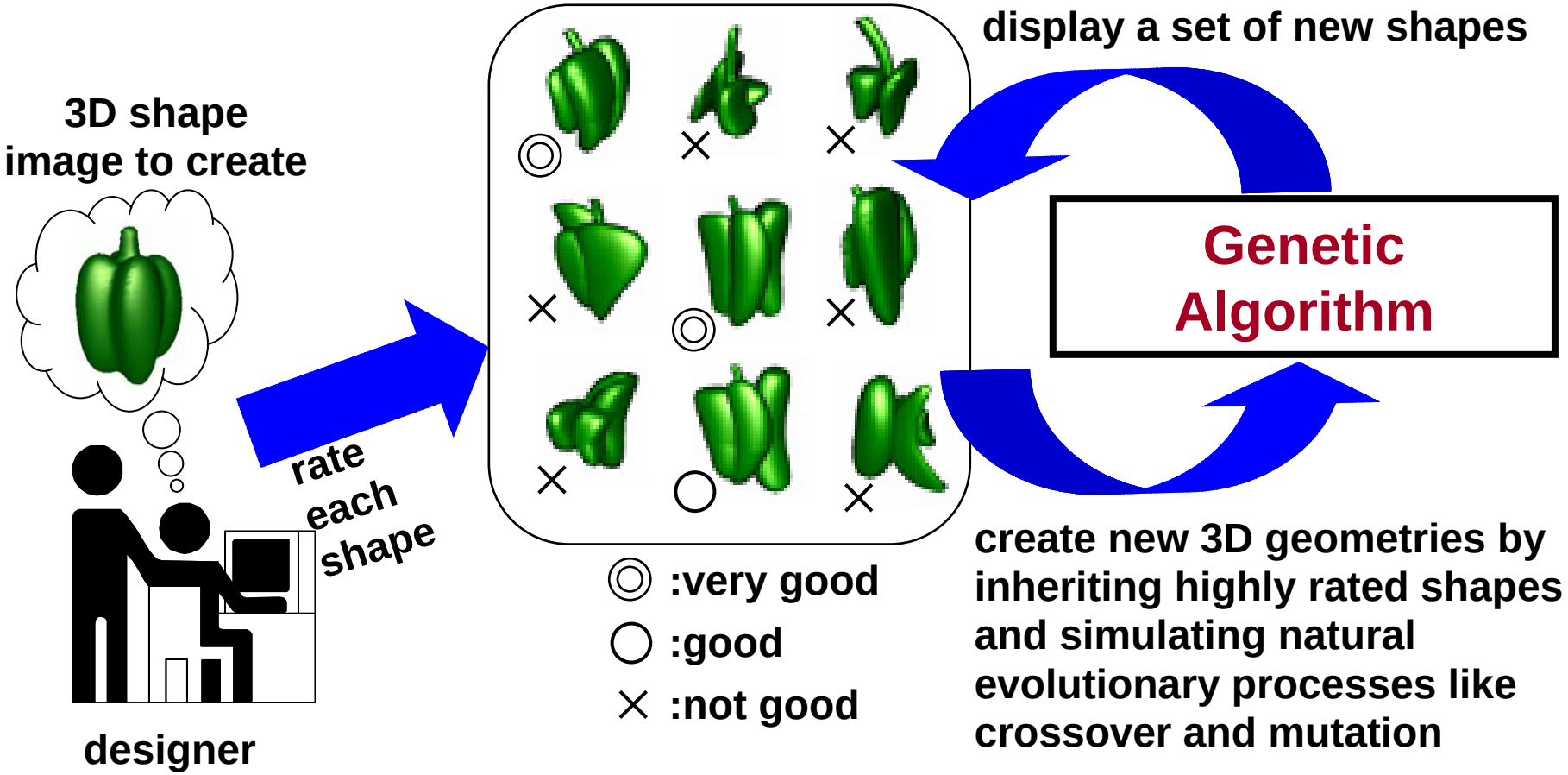
3D Model Example



IEC changes shape parameters based on user's imagination



IEC-base 3D Modeling Concept

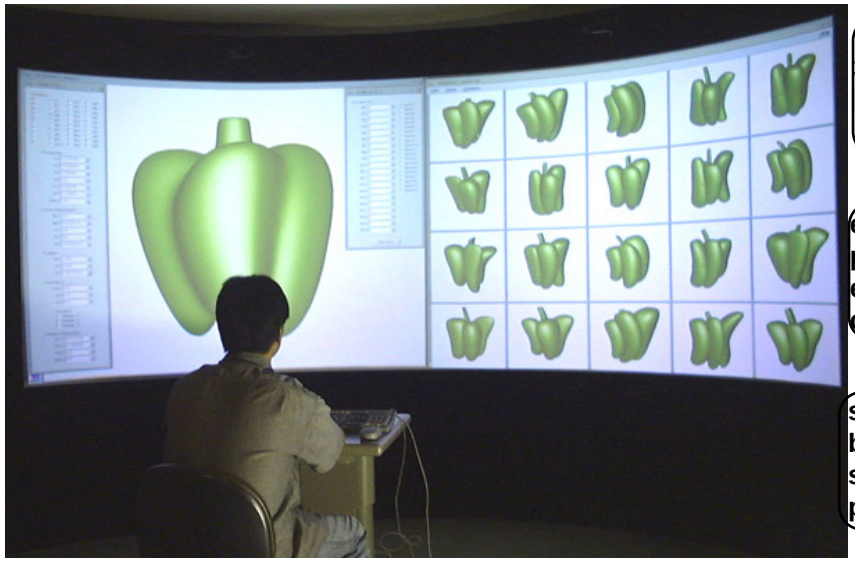


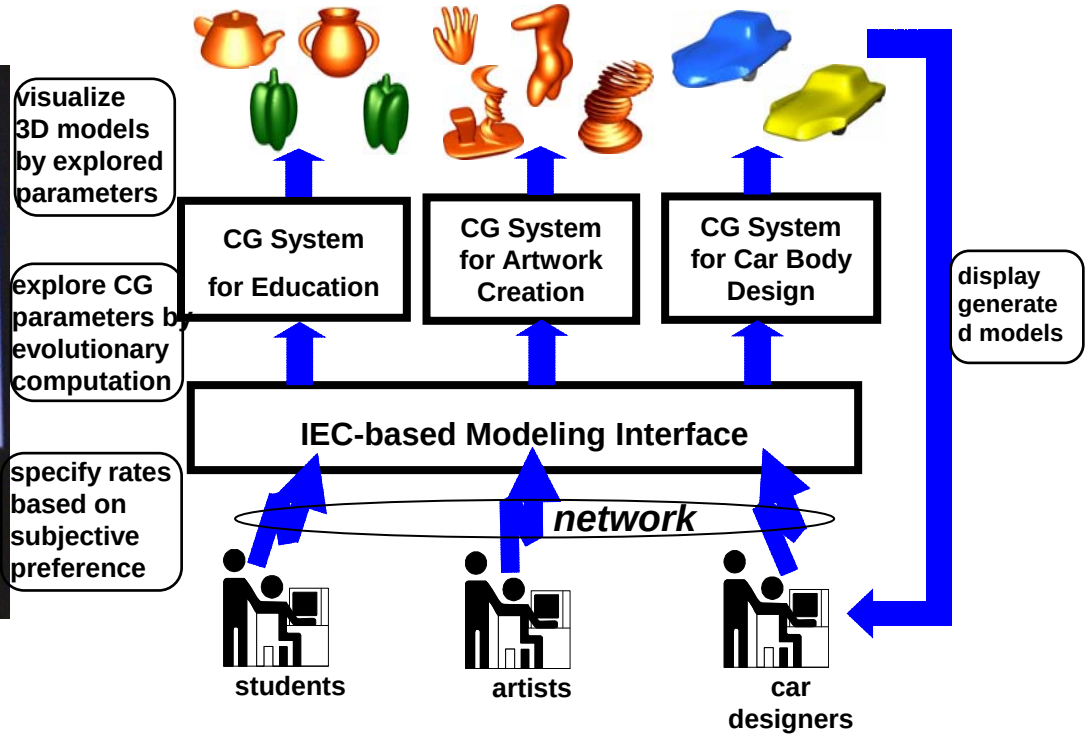
Subjective Test

Only **48** (8 parameters ✕6 primitives) parameters are modified by GA

	Realistic Examination 	**Creative Examination ferocious green pepper**
Quality	Manual >> IEC	Manual = IEC
Operability	Manual > IEC	Manual < IEC

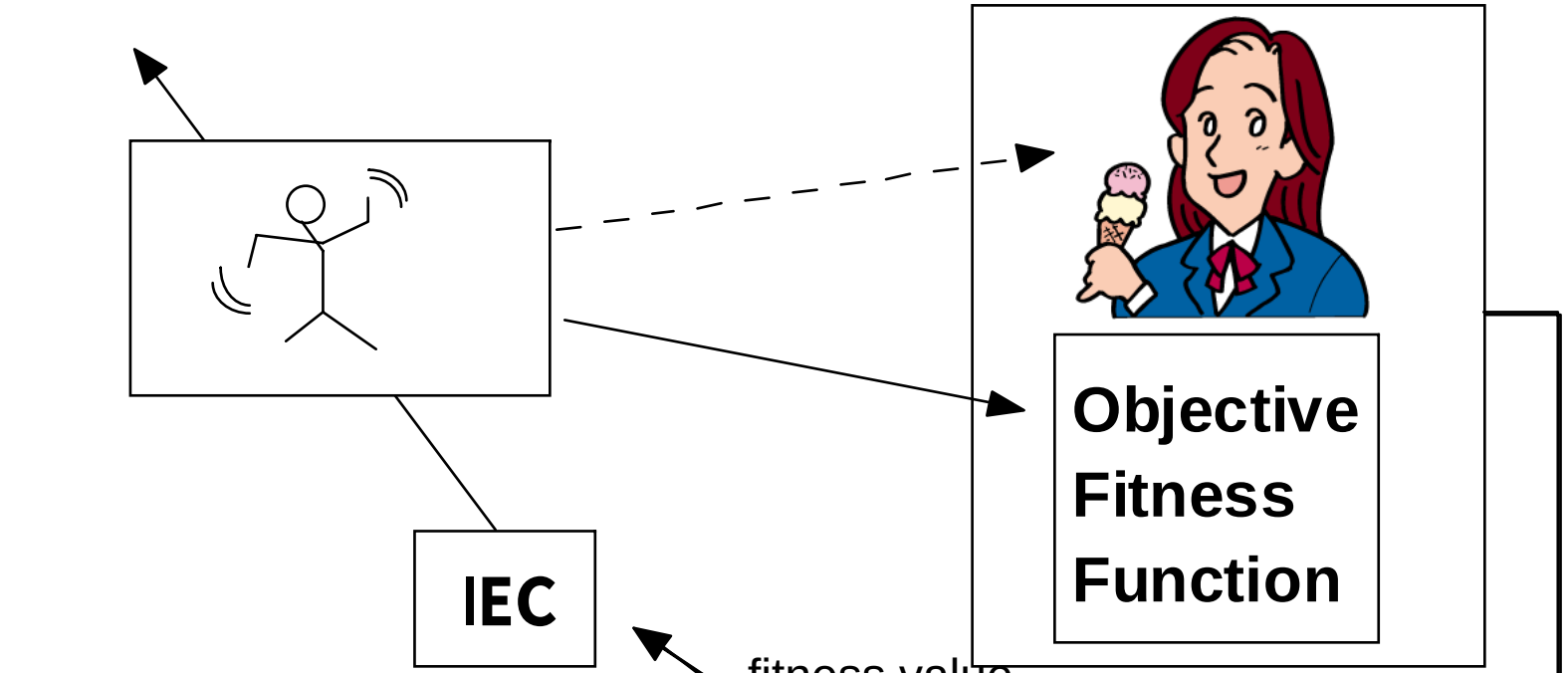
Internet version of IEC 3-D Modeling Education System

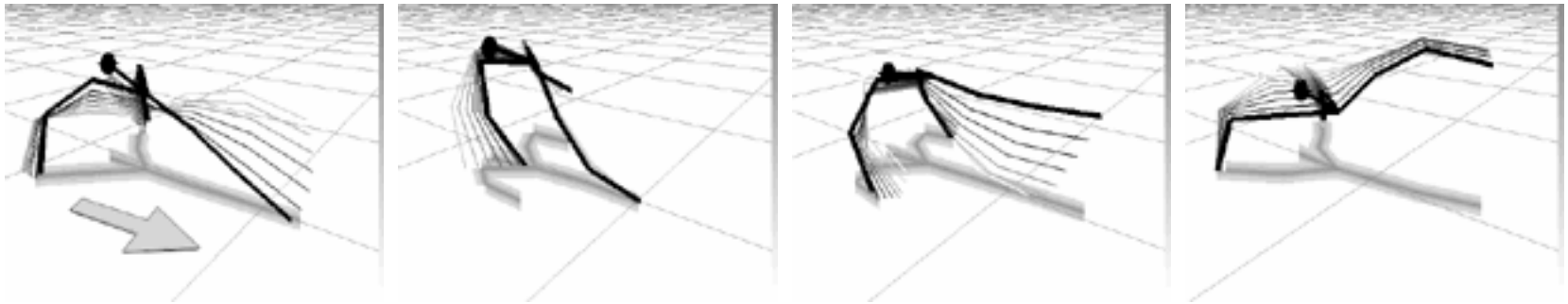




Evolution of Funny Animated Figures

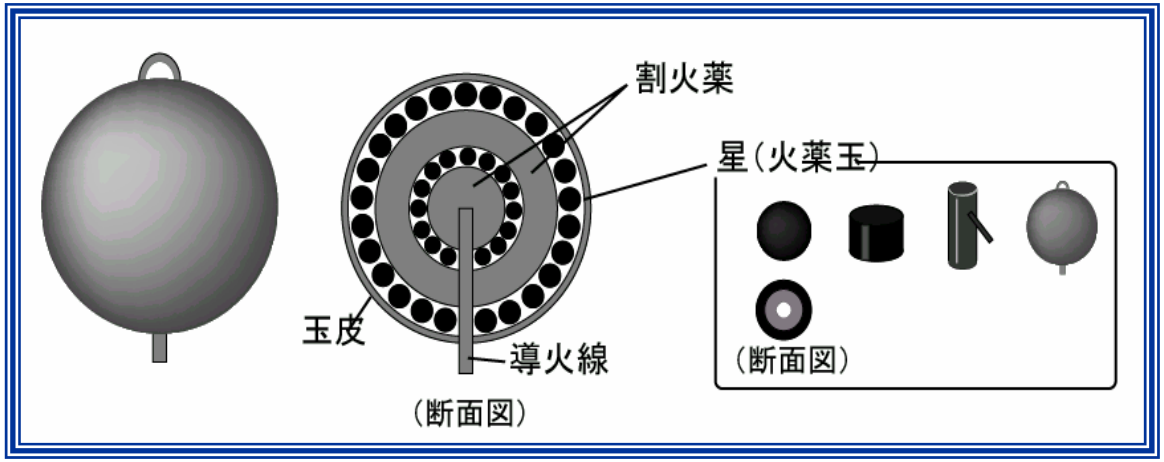
by Jeffrey Ventrella





Design of Fireworks CG Animation
- parameter setting -

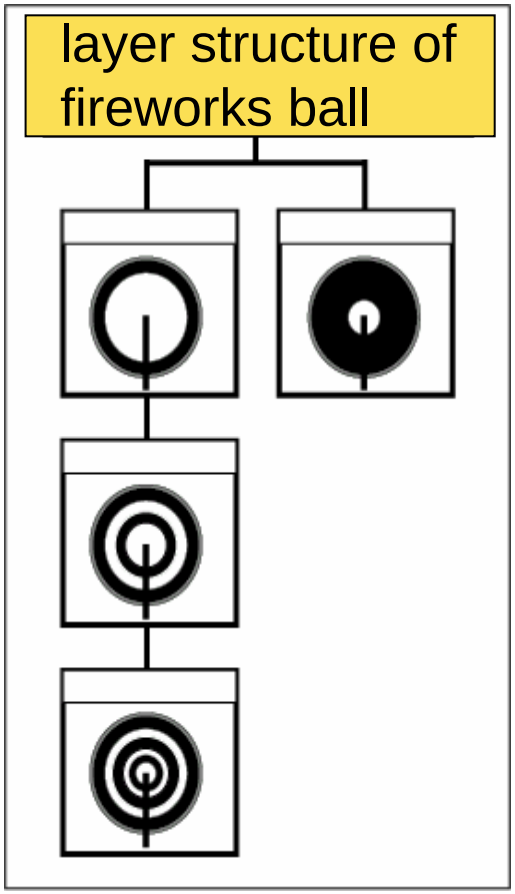
by K. Aoki, C. Tunetou, and H. Takagi

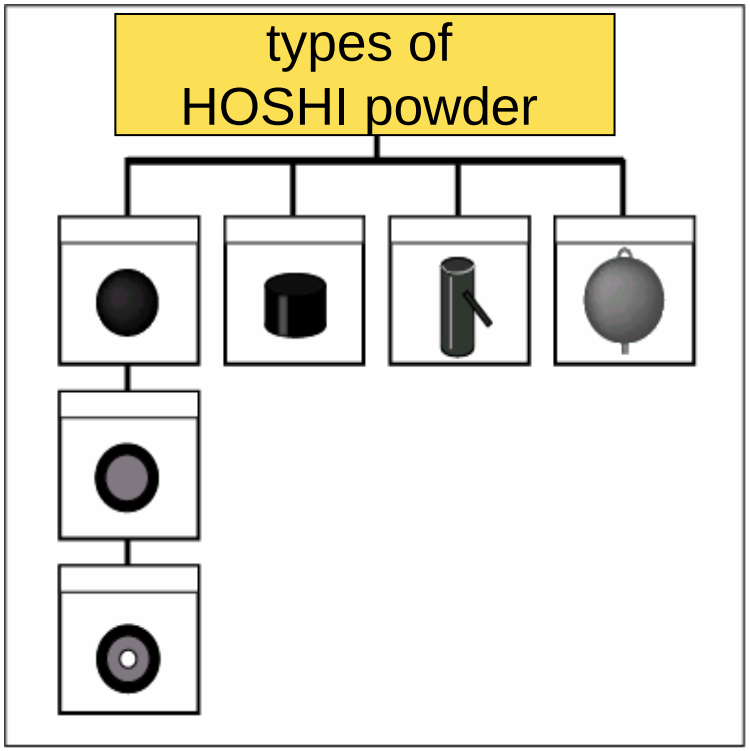


Some of real-fireworks parameters are used in our design support systems.

structure of fireworks ball
types of HOSHI powder
kinds of powder
layout of HOSHI powder
etc.

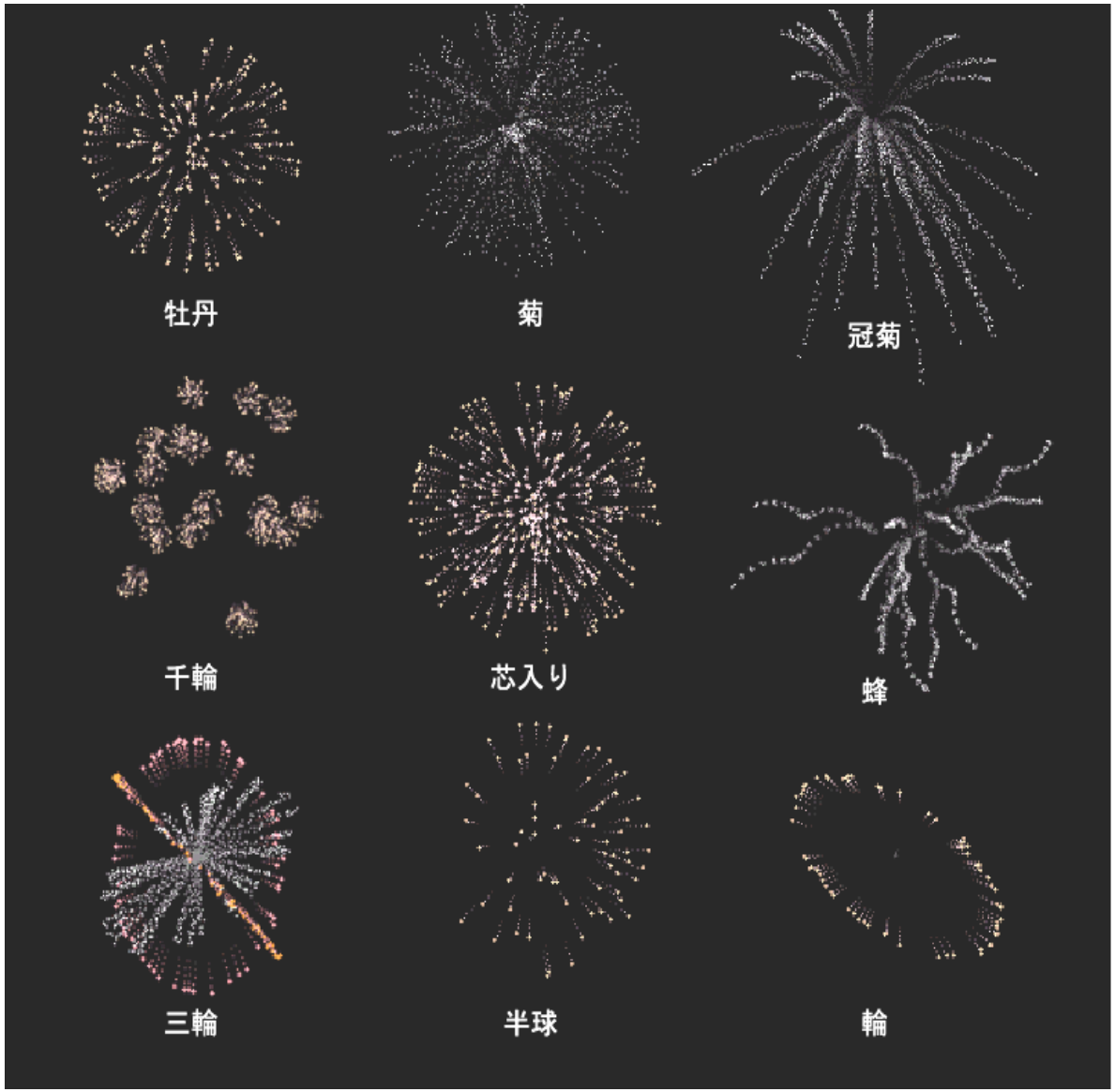
Design of Fireworks CG Animation
- structure design -





The structures of others are as well.

Example of Student's Works



CONTENTS

Montage Image (1/2)

by C. Caldwell and V.S. Johnston (1991)

type and position of one of 32 foreheads	X	eyes and their separation	X	shape and position of nose	X	shape and position of mouth	X	shape and position of chin	=	3.4×10^{10} faces
7 bit		7 bit		7 bit		7 bit		7 bit		

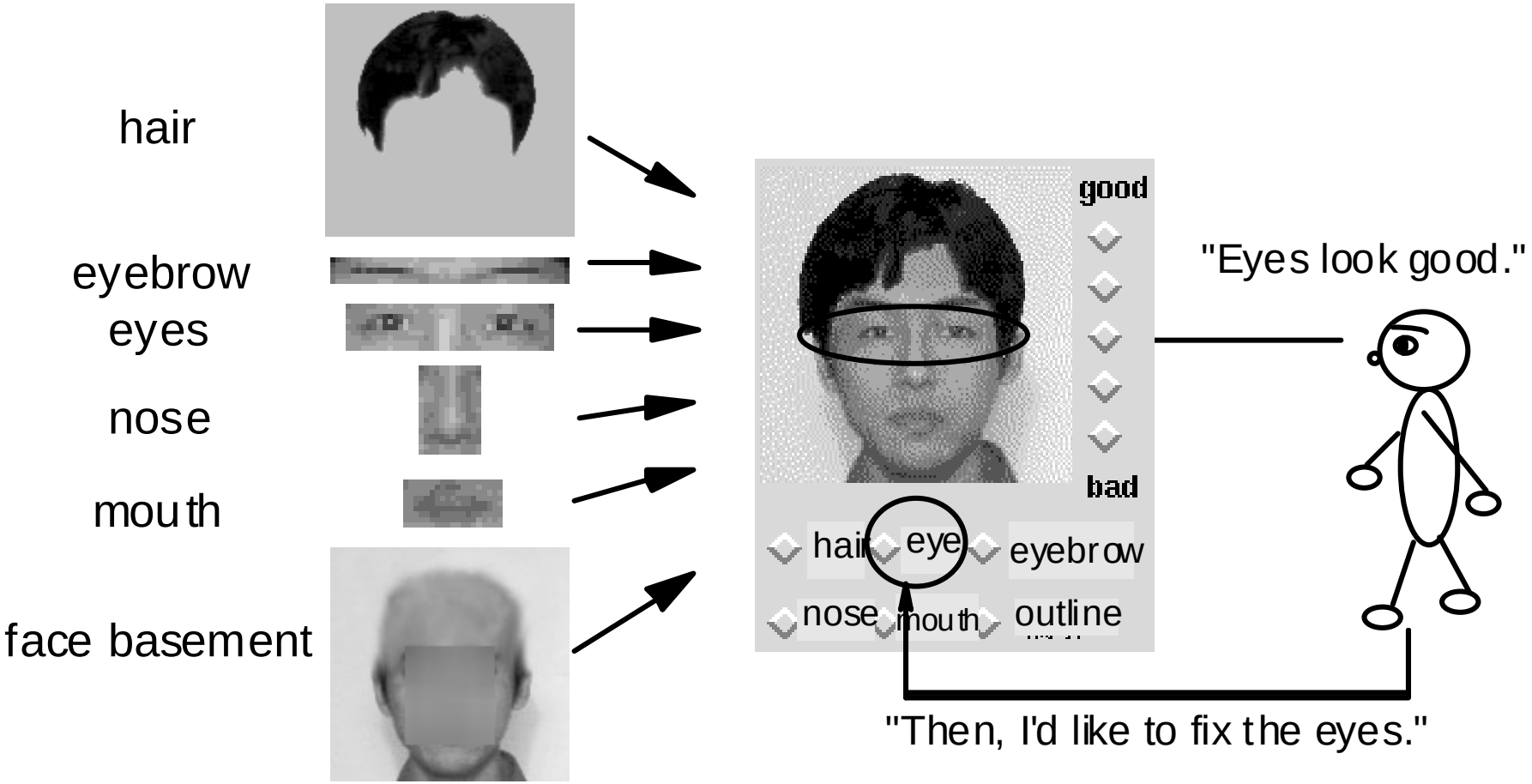
target face

montage face

three days later, 10 GA generations

Montage Image (2/2)

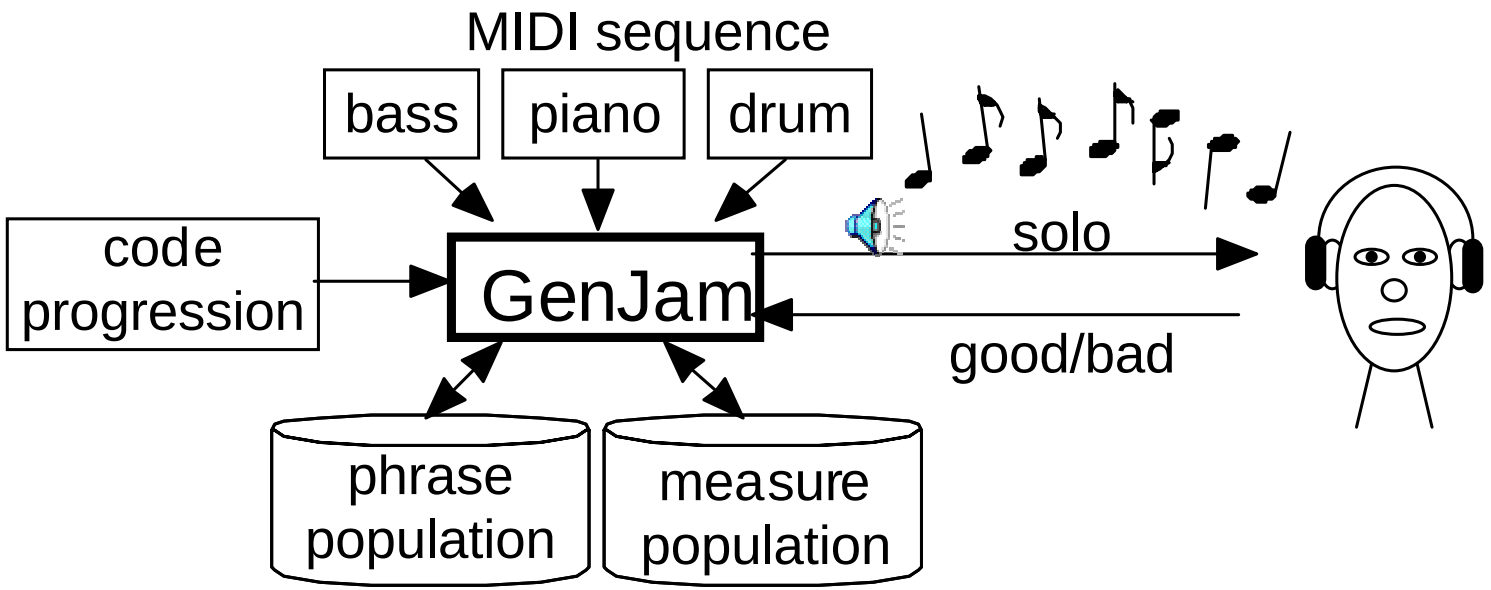
by H. Takagi and K. Kishi



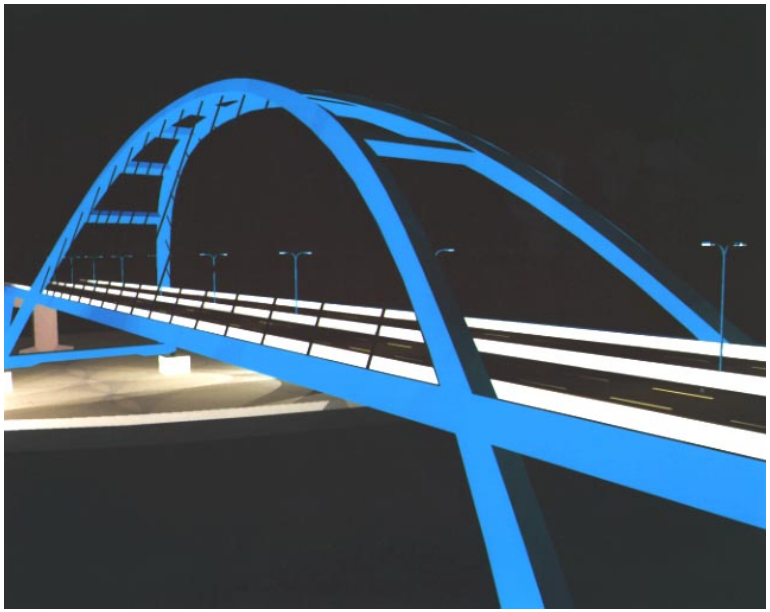
IGA for Music

Sonomorphs: Melody Generator — by G. L. Nelson (1993)

GenJam: Jazz Solo Generator — by J. A. Biles (1994)

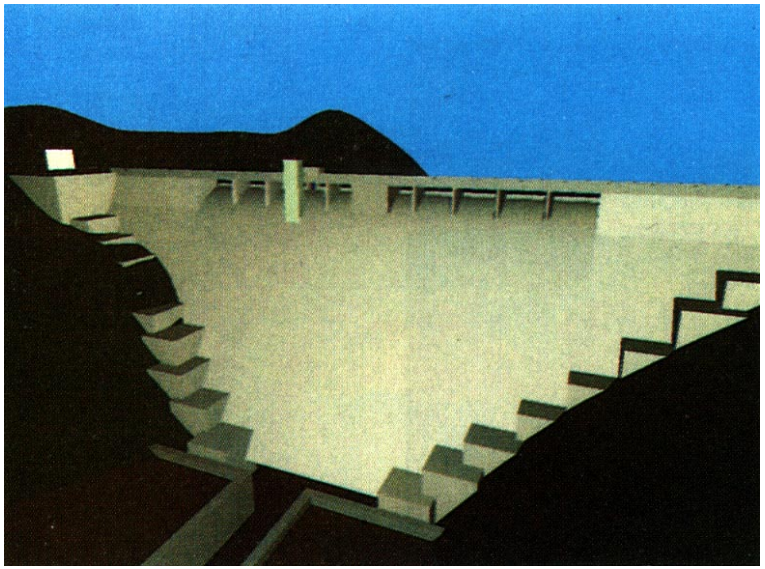


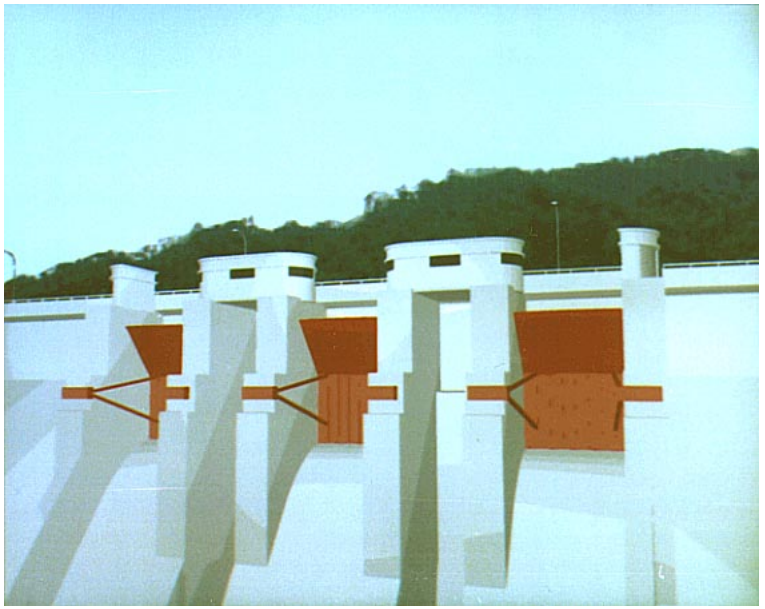
Rhythm Generator — by D. Horowithz (1994)



Industrial Design

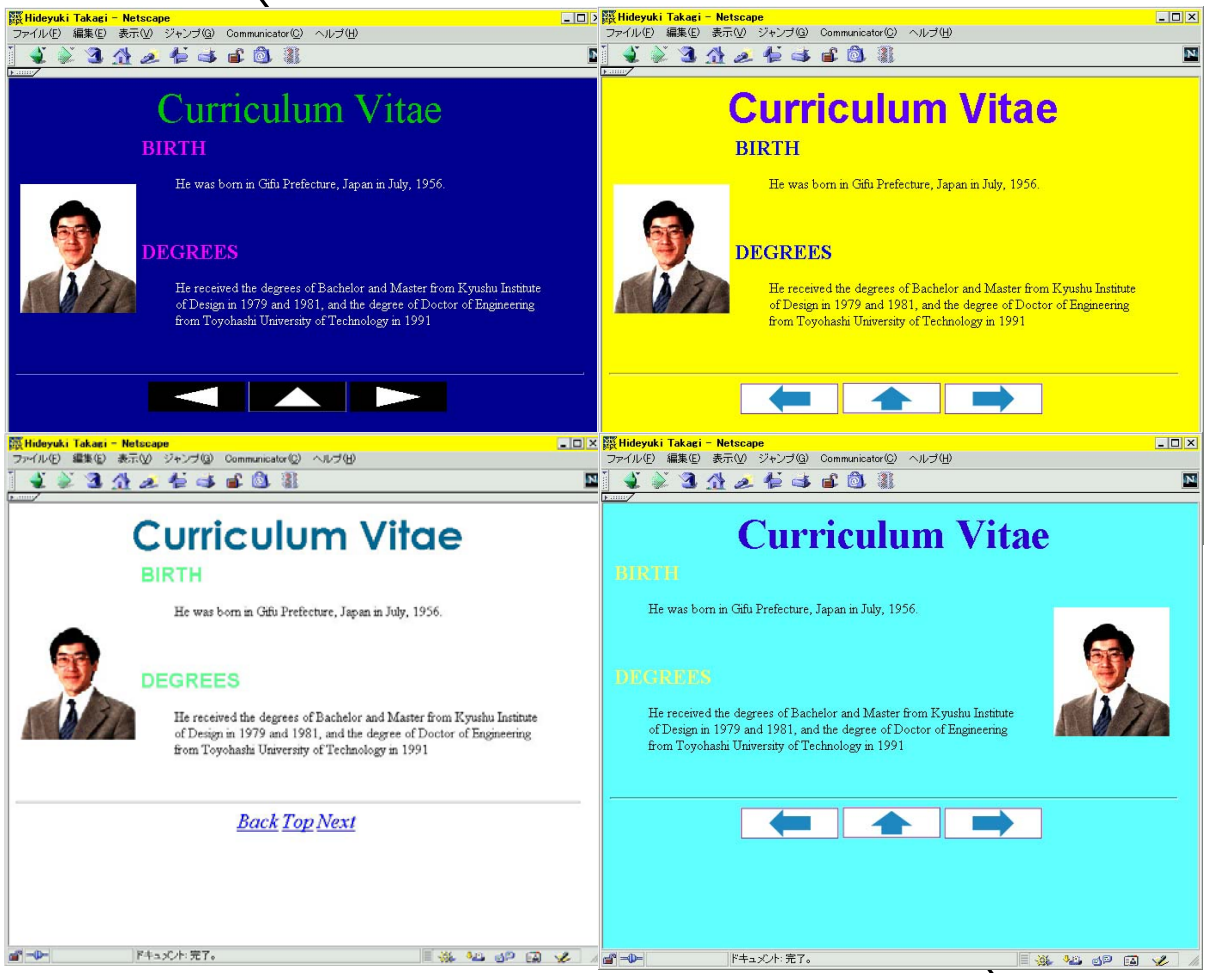
by H. Furuta





HTML Design

by N. Monmarche et al.



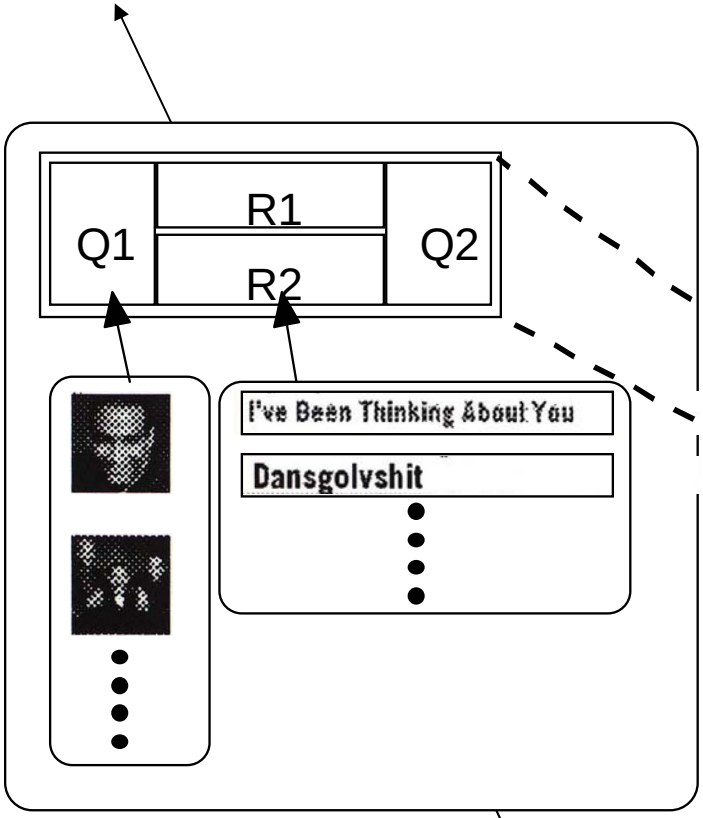
Looks nice !

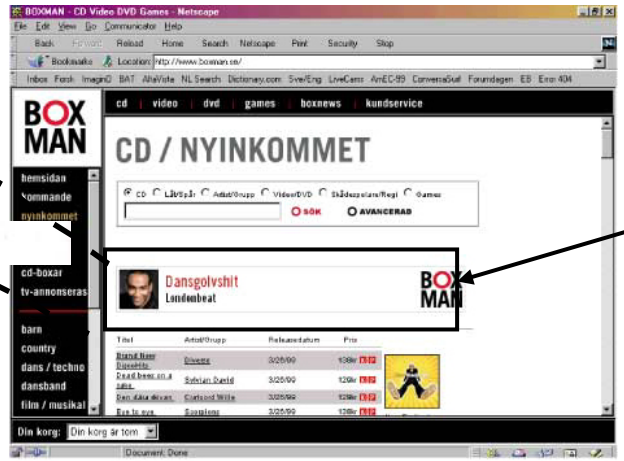
EC

font of letters, colors of letters and background, and etc...

Evolutionary Banner

by R. Gatarsk





Visitors who click the banner

EC

Color Poster Design

By T. Obata and M. Hagiwara

Stability 1.0,
Power 0.5,
etc. . . .

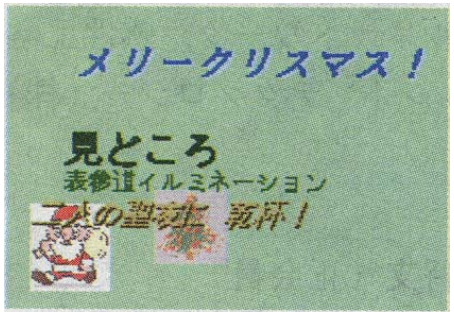
Making Layout with IEC

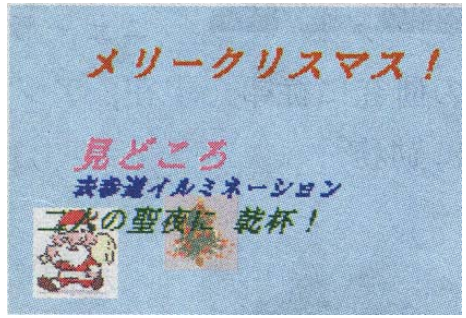
Vigor 1.0, etc. . .

Changing Colors and Fonts with IEC

Completed Poster

Colors and fonts are VIGOR, and layout is STABILITY.





Colors and fonts are CLEAN, and layout is ELEGANT.

CONTENTS

Why IEC-based Signal Processing?

There are many cases that SP users are not SP experts but need to design SP filters.

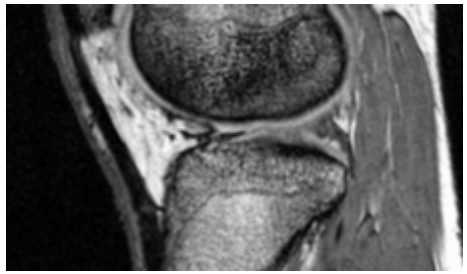
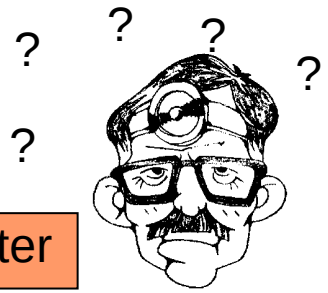


image filter

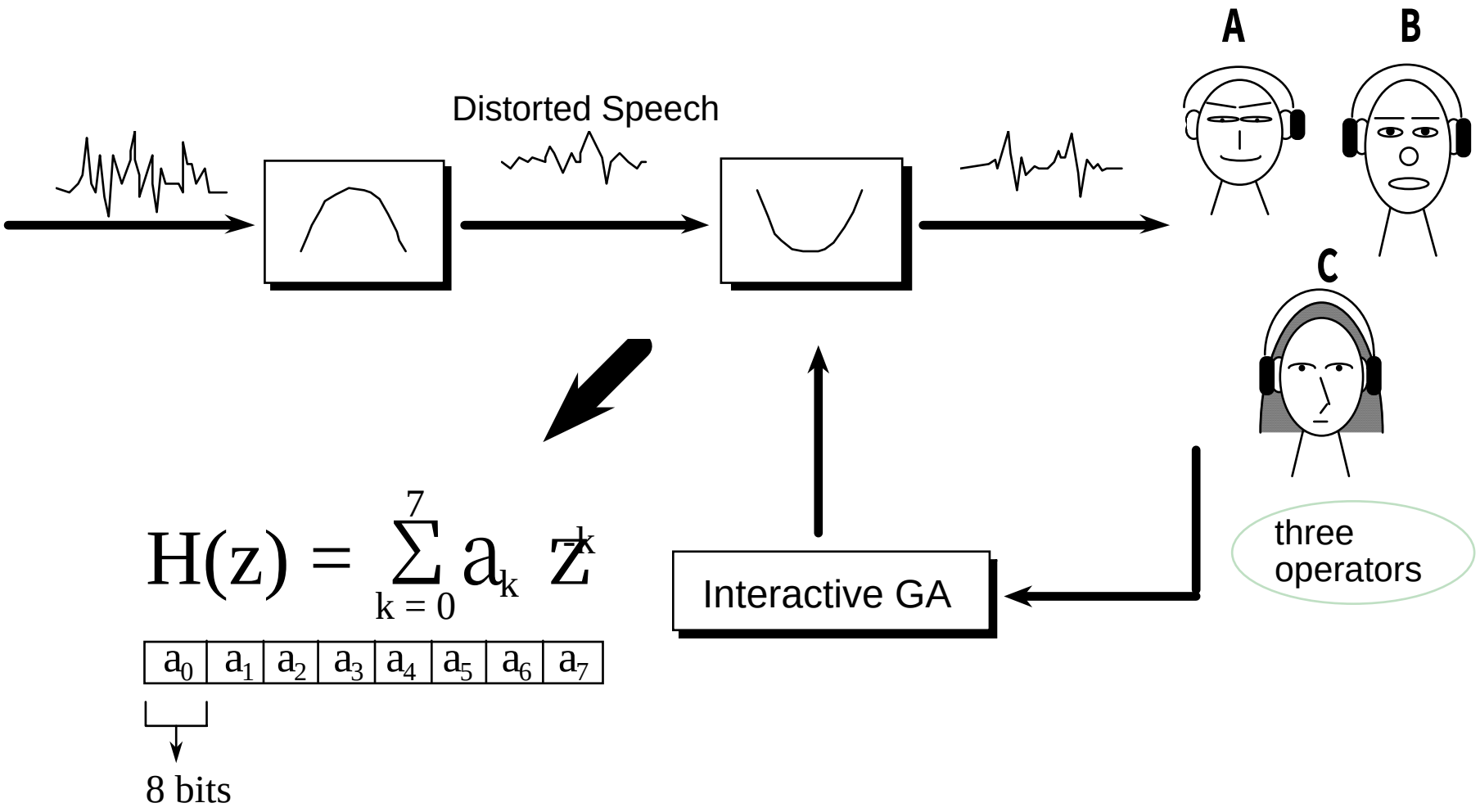


hearing aid

Solution is auditory-SP and visual-based SP without any SP knowledge.

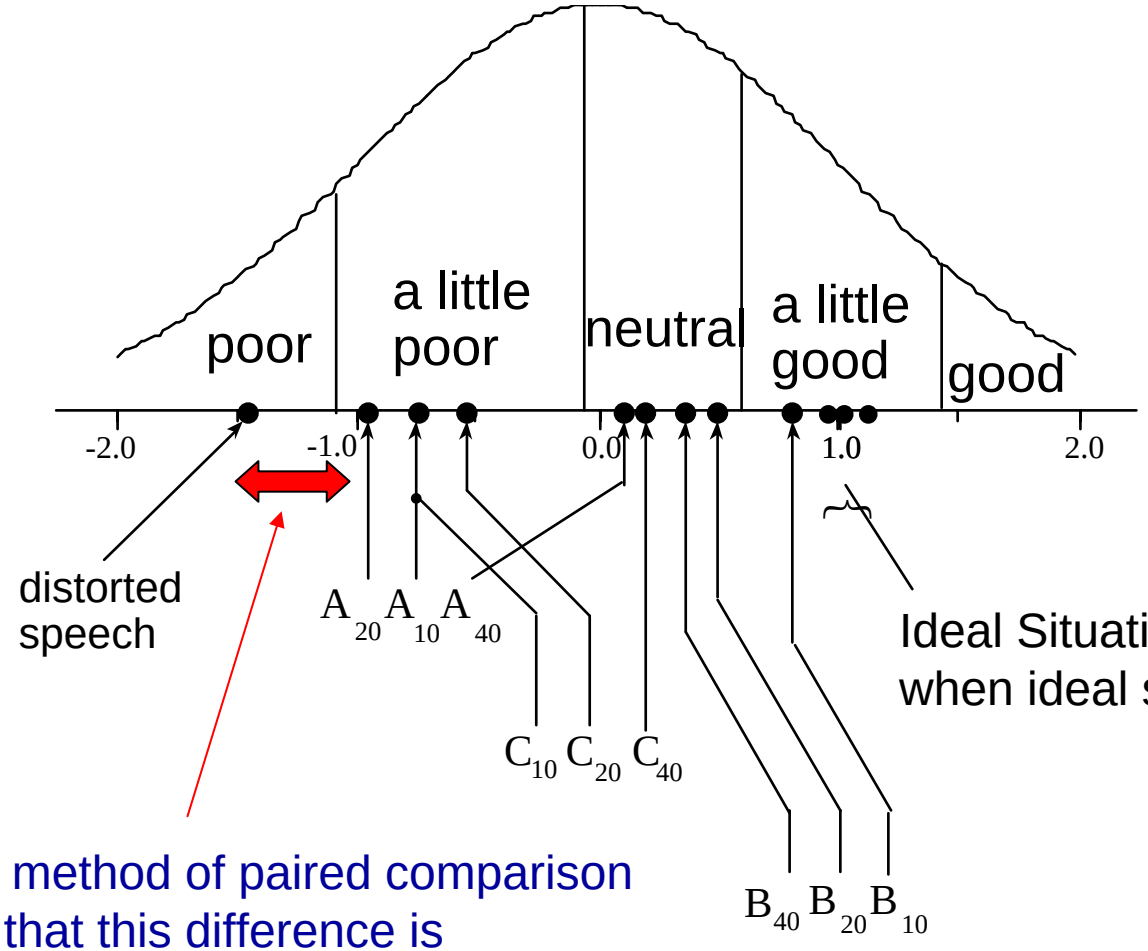
IEC realizes this approach.

Recovering Distorted Speech



Experimental Result

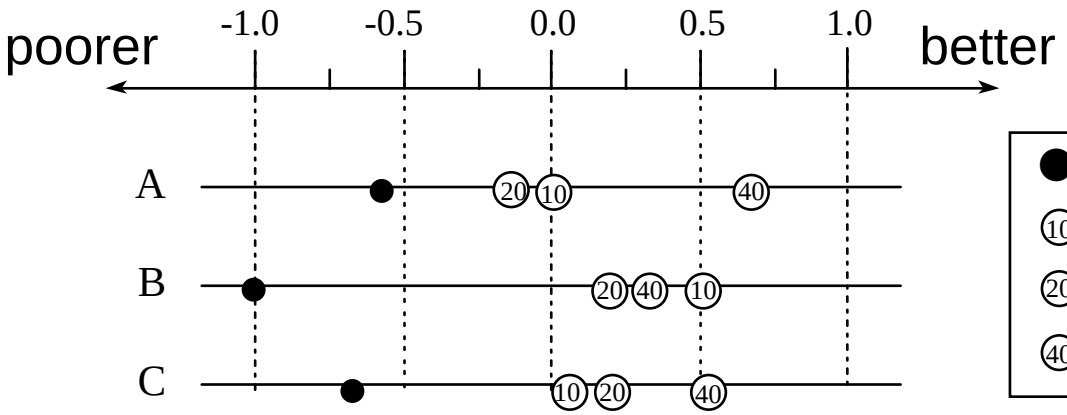
-- Method of Successive Categories --



Sheffe's method of paired comparison showed that this difference is significant ($p<0.01$).

Experimental Result

Sheffe's Method of Paired Comparisons



●: distorted speech

⑩ 10th generation of recovering speech

⑳: 20th generation of recovering speech

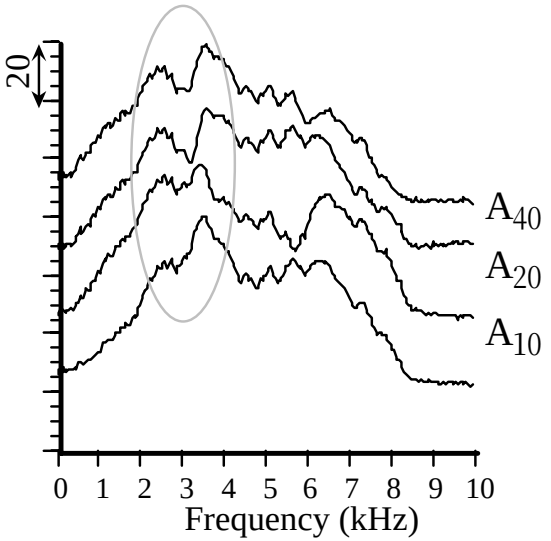
㊵ 40th generation of recovering speech

operators	combinations					
	● vs. ⑩	● vs. ⑳	● vs. ㊵	⑩ vs. ⑳	⑩ vs. ㊵	⑳ vs. ㊵
A	○	○	○		○	○
B	○	○	○	○	○	
C	○	○	○		○	○

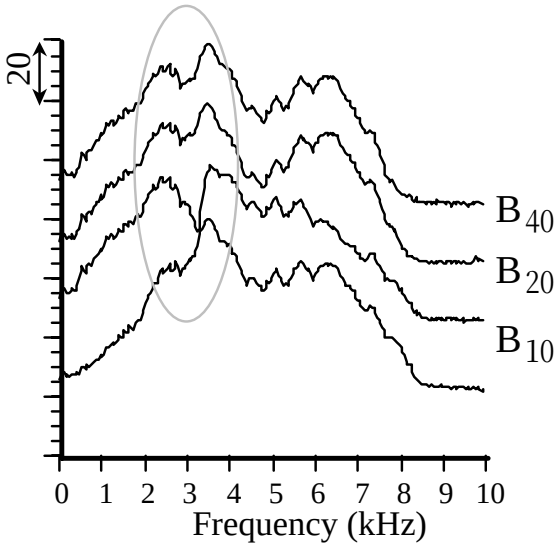
difference is significant ($p<0.01$)

How Distorted Speech was Recovered?

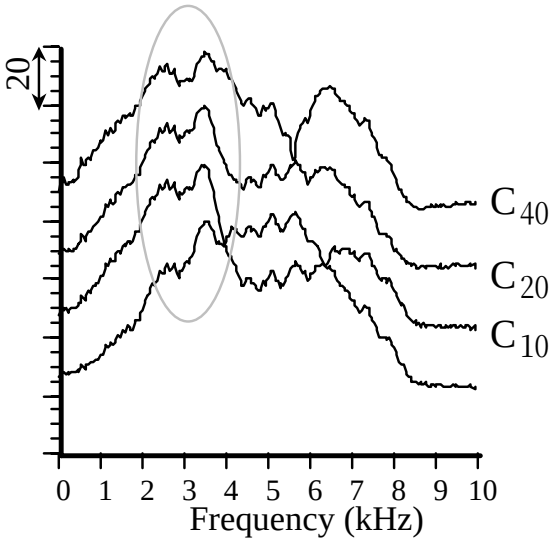
Formant area was mainly recovered



(i) A



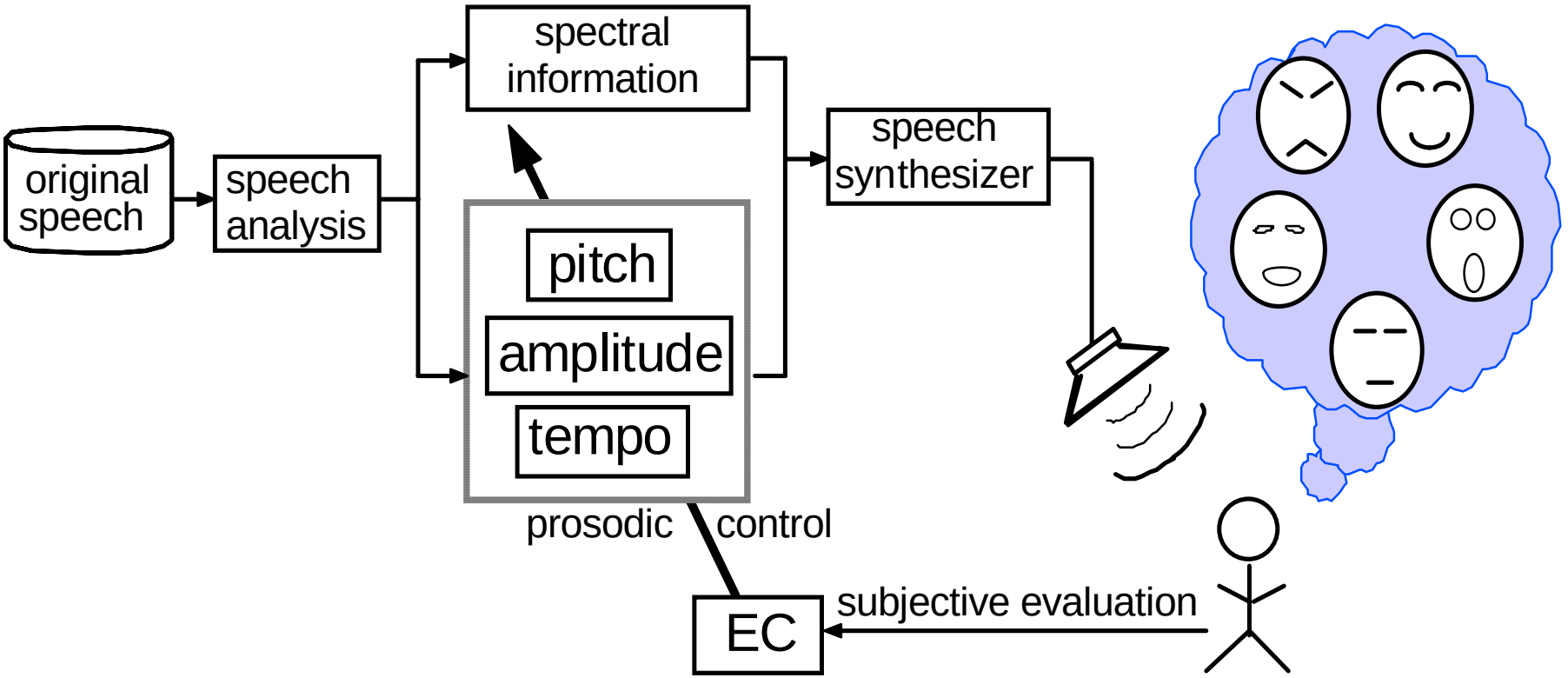
(ii) B



(iii) C

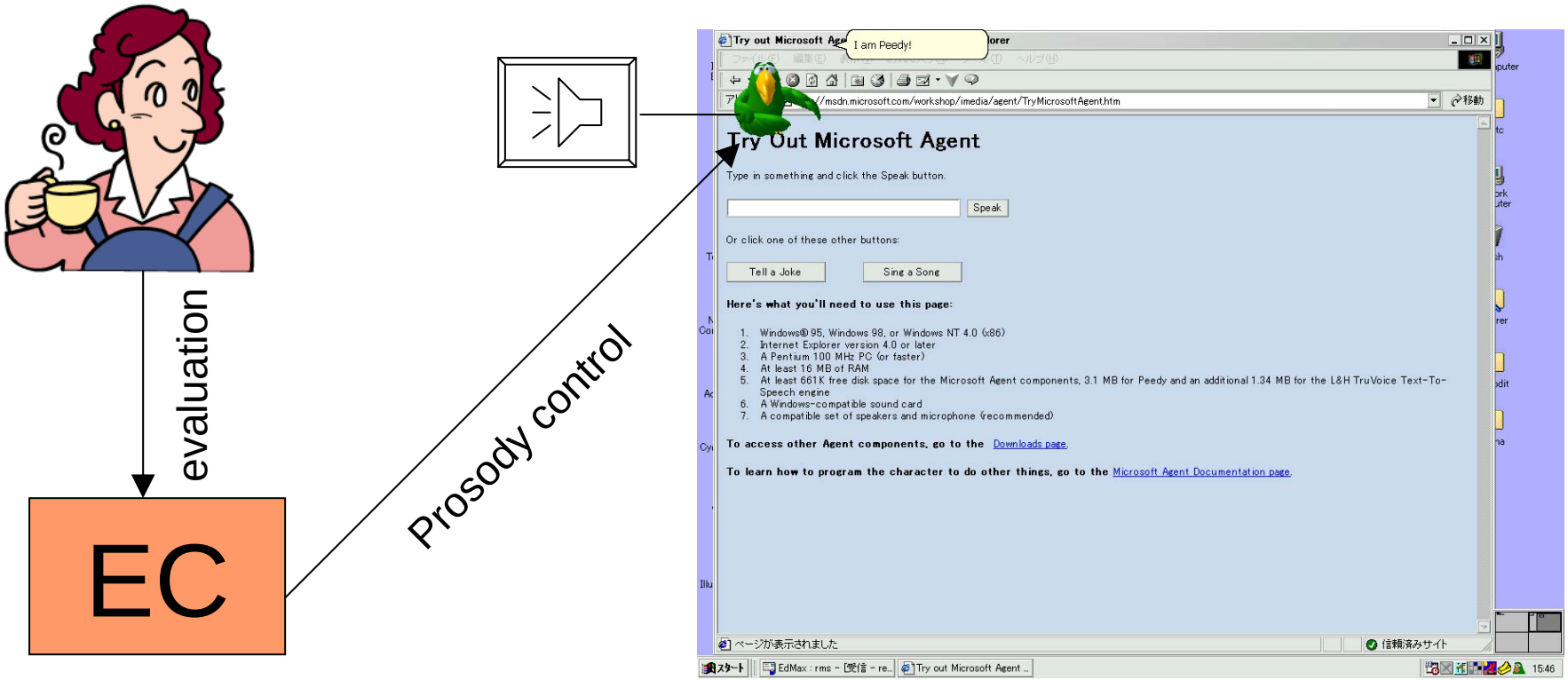
Voice Conversion by Interactive EC

by Y. Sato et al.

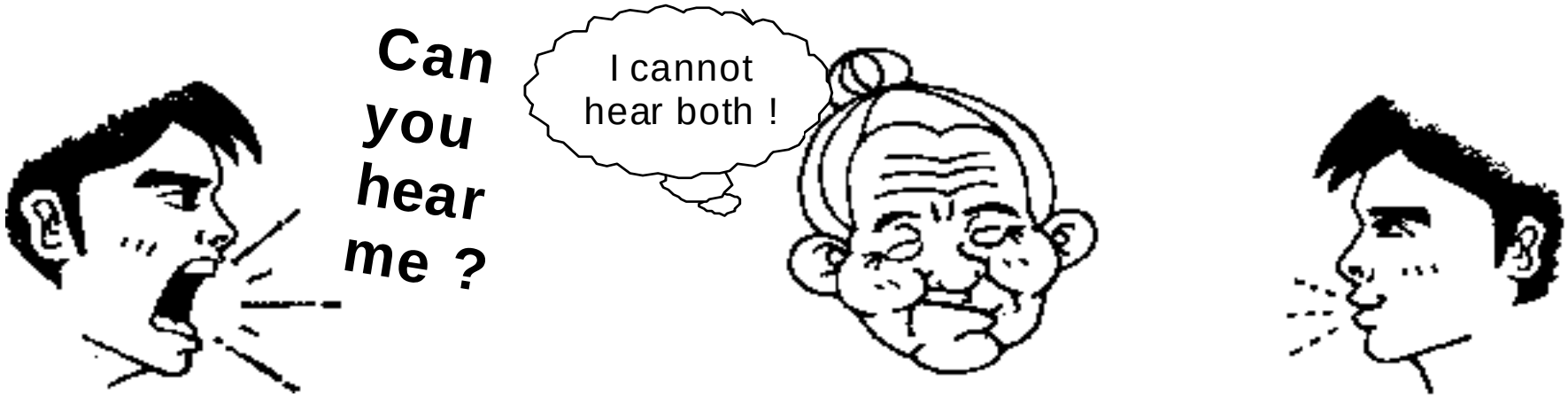


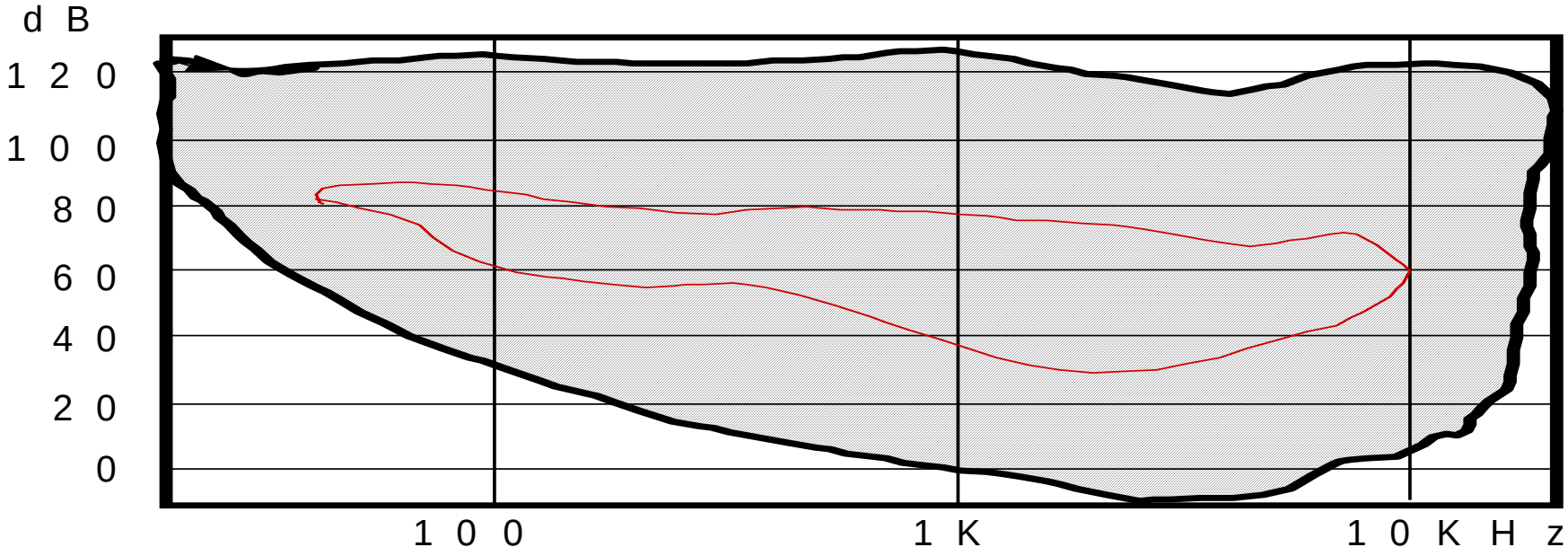
IEC for Agent's Voice Design

By T. Morita, S. Iba and M. Ishizuka

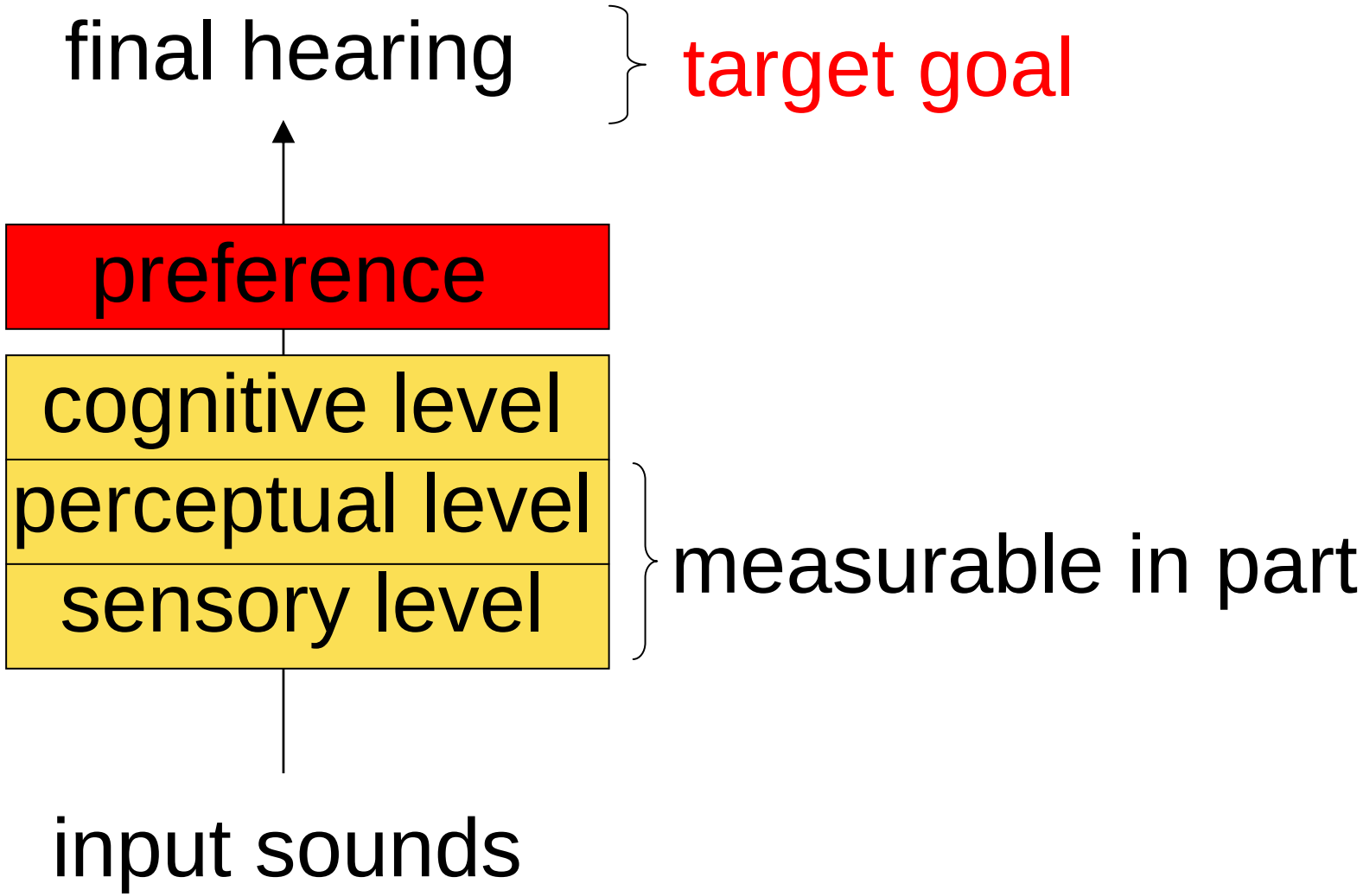


Hearing Compensation is Difficult

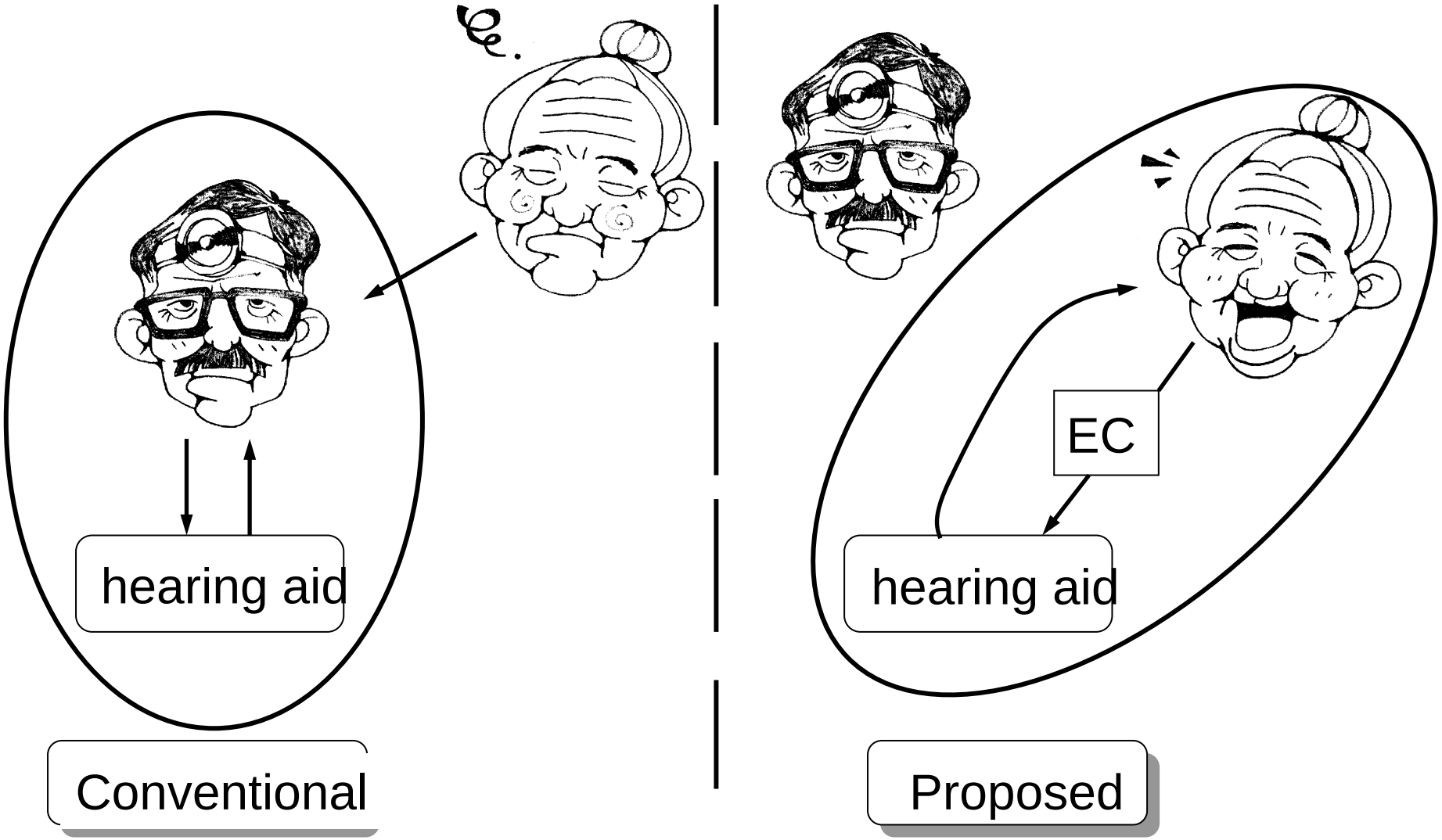




Ideal Goal is Far



Tuning System based on How User hears



Evaluation

One – Two Weeks Later (5 subjects)

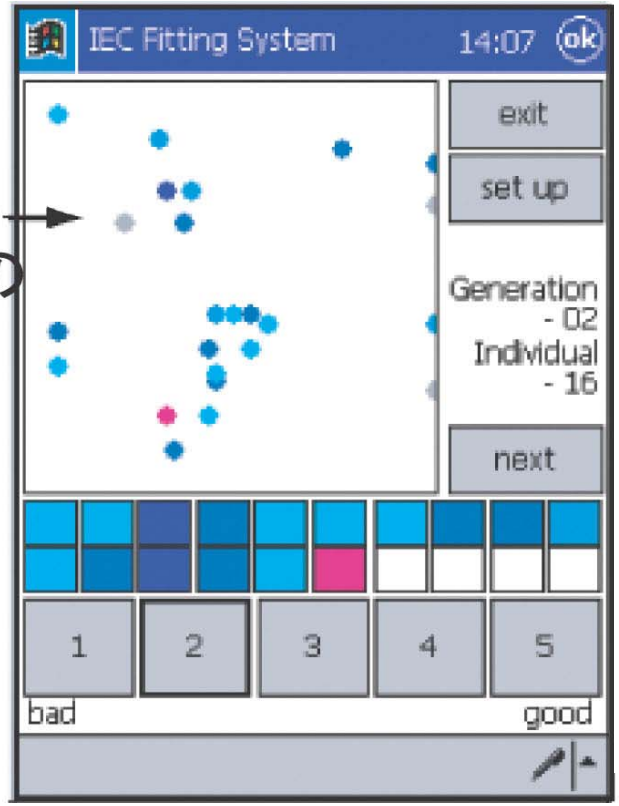
evaluation	IEC Fitting vs. audiologist fitting
monosyllable articulation	≒
sound quality	≒
fitting time	IEC < audiologist

Six Months Later (4 subjects)

evaluation	IEC Fitting vs. audiologist fitting
sound quality	≒
APHAB	≒

Visualized IEC Fitting on a PDA

(a)
写像後の
個体群



Visualized EC: parameters in an n-D EC landscape are mapped on a 2-D space for visualization.

IEC Fitting: IEC-based hearing aid fitting

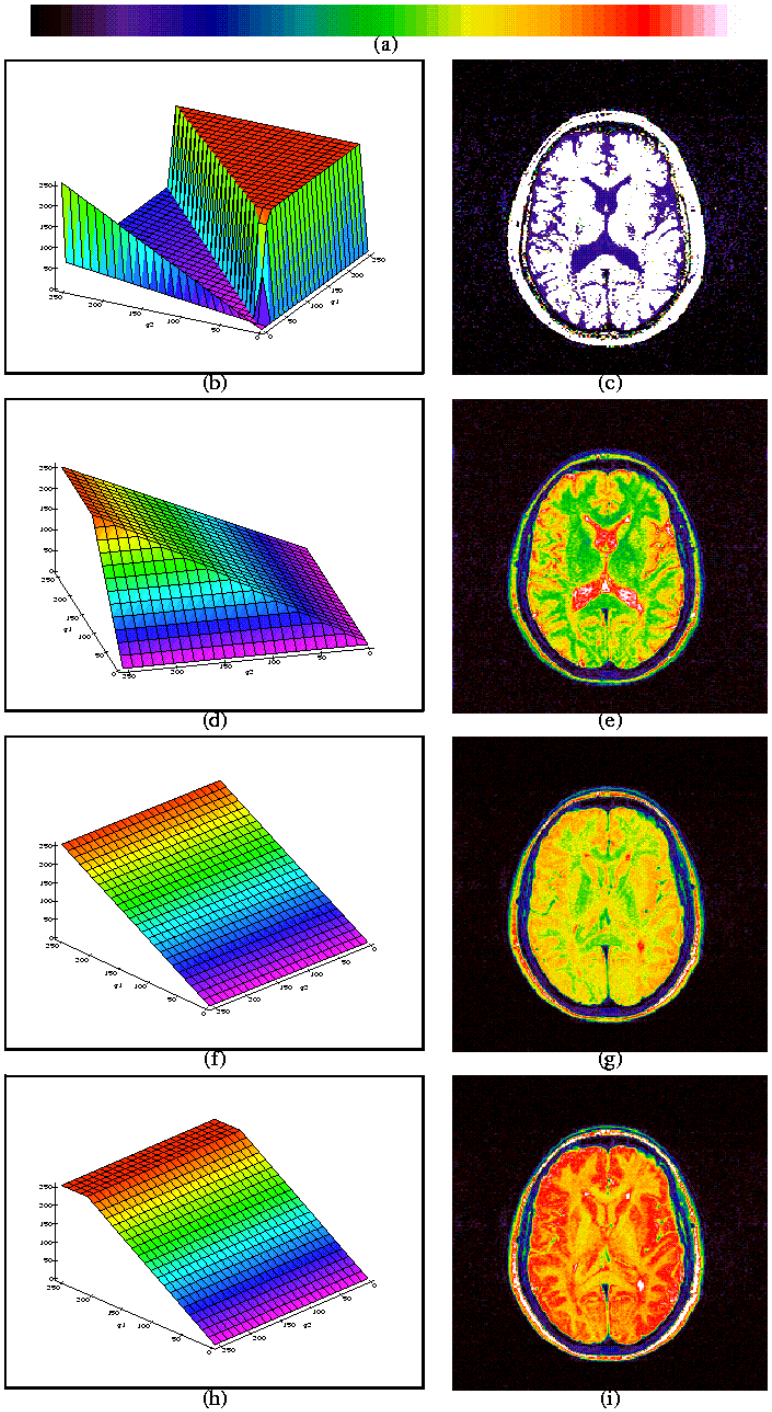


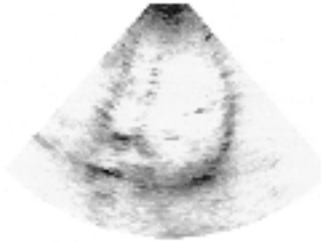
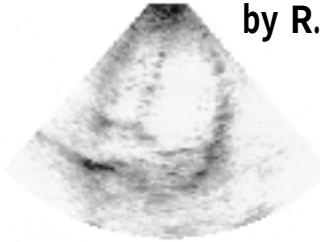
Image Enhancement using Interactive GP

by R. Poli and S. Cagnoini

Image enhancement filter evolves according to how processed images look well.

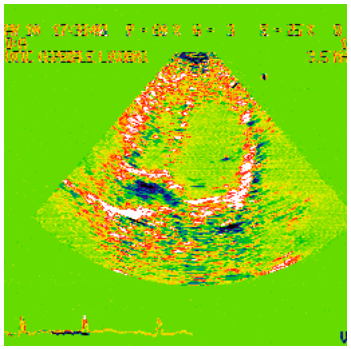
Echo-Cardiographic Image

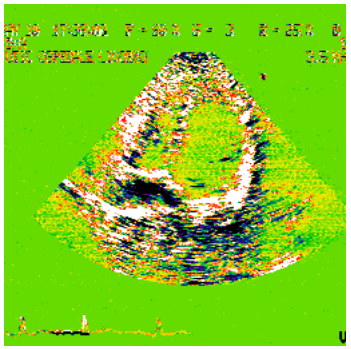
by R. Poli and S. Cagnoni (1997)

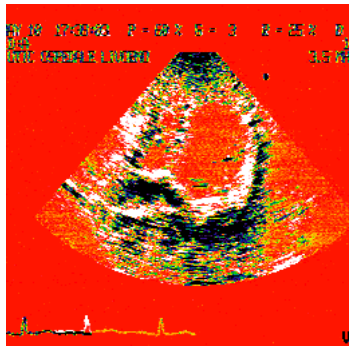

+

=

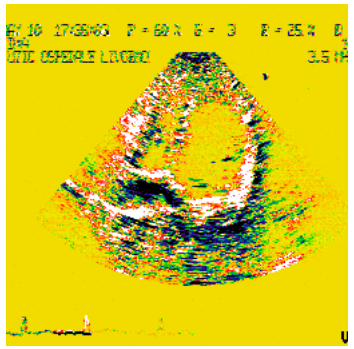
diastole of patient A

systole of patient A


(1)


(2)


(3)


(4)

(1) $0.554695 - g_1 g_2 - g_1^2 g_2 + g_2 - g_1 + g_2$

(2) $0.832041 - g_1 g_2 - 2g_1 + 2g_2 - g_1^2 g_2 + g_2 + min(-0.277346 - g_1 + g_2, \max(g_1 g_2 - g_1))$

(3) $g_1 g_2 - g_2^2 + 2g_2 - 3g_1 - g_1 g_2 + 0.854702 + min(2g_2 - 2g_1, -g_1(g_2 - g_1))$

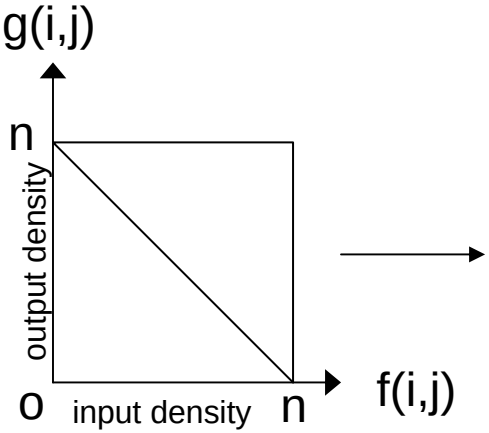
(4) $g_1 g_2 - g_2^2 + 2g_2 - 2g_1 g_2 g_1^2 + 0.64861 + g_2 - g_1$

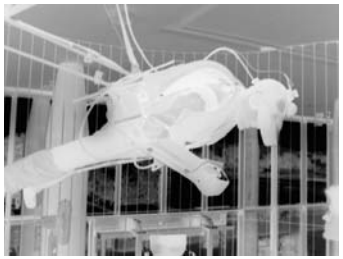
Non-linear Density Transformation by Using of GP

- linear density transformation

ex.invert

input

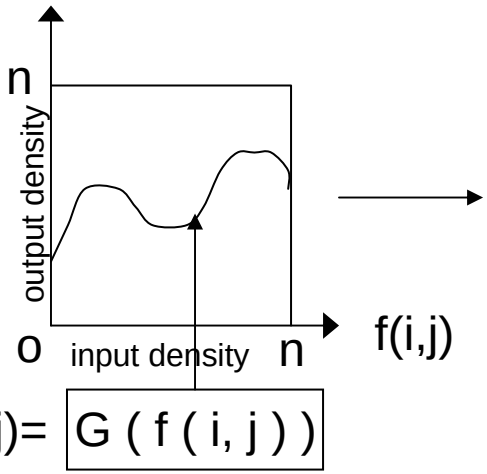




output

- non-linear density transformation by using GP

input

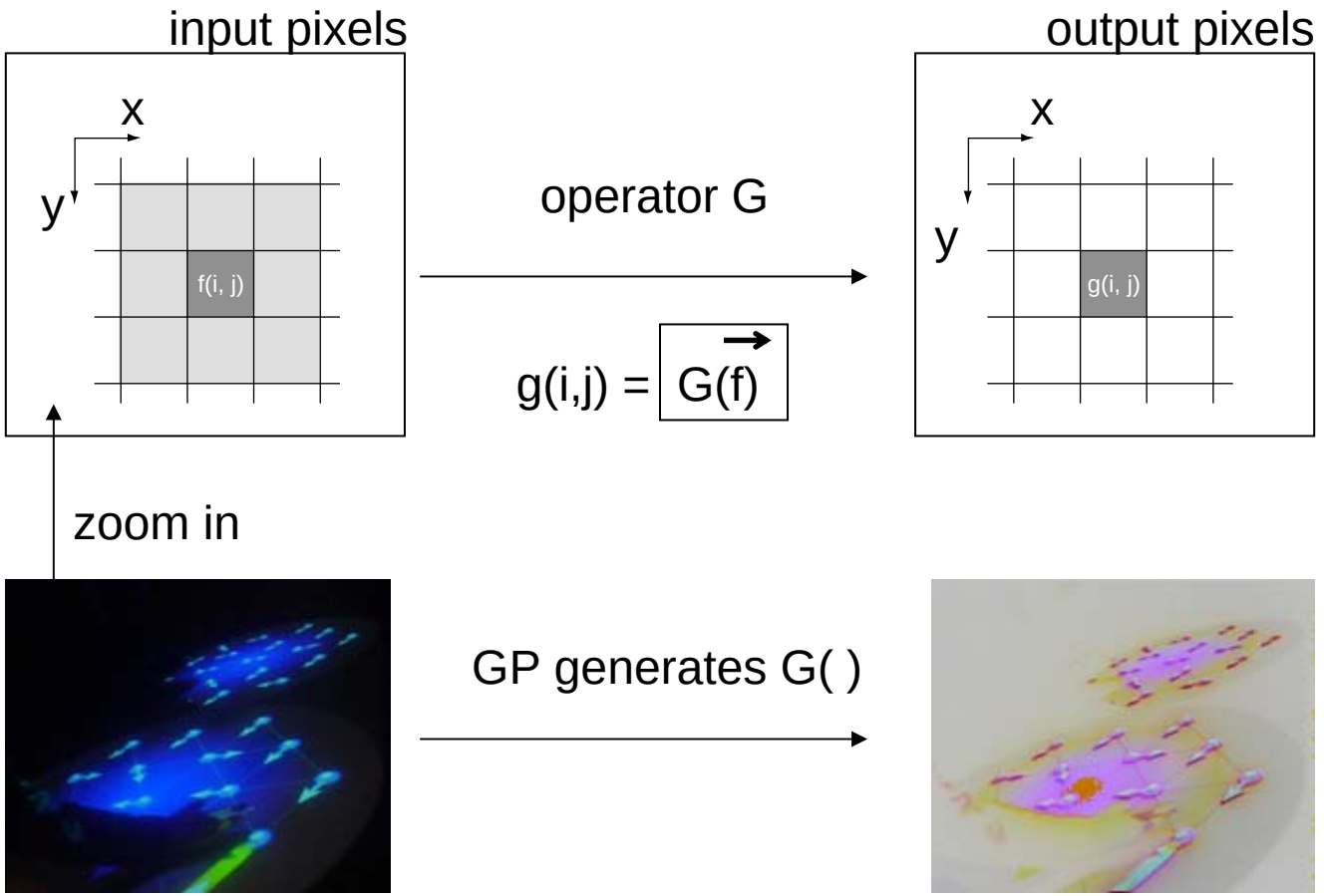


g(i,j)= G (f (i, j))

generated by GP

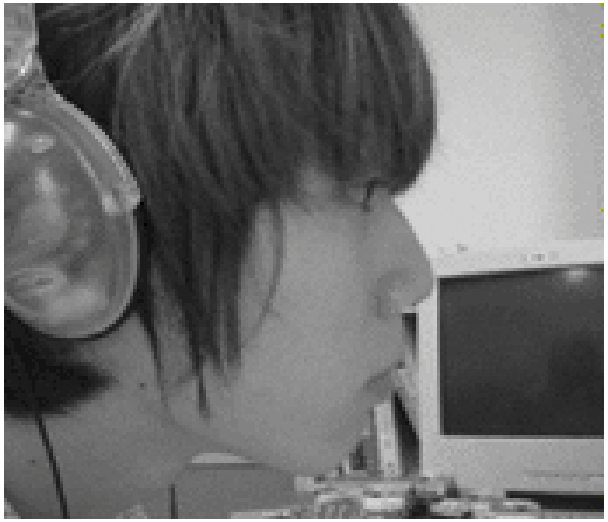
output

GP-Based Image Filter by Using Neighborhood Pixels Information



G=max[abs(f(i,j-1)),max{-0.41,0.79+sin(min(f(i+1,j-1),-0.03))-f(i+1,j+1)}]

Experiment of IGP-Based Edge Detection



input image

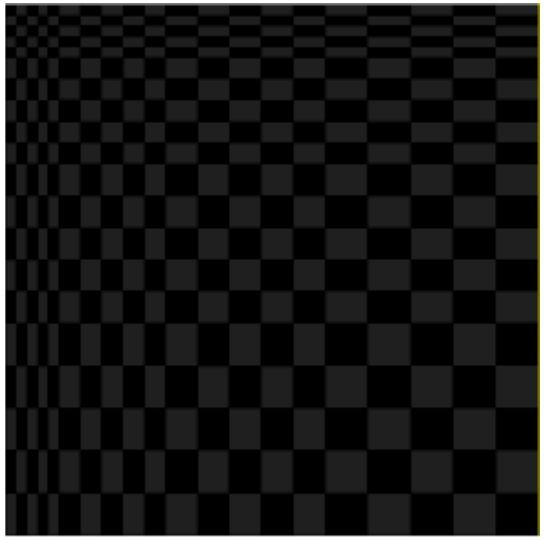
conventional math-based filter

Laplacian filter

IEC-based filter

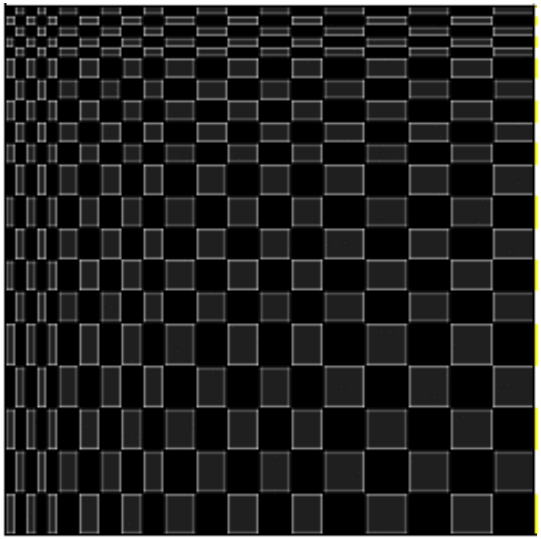
2nd generation

Experiment of IGP-Based High Pass Filter Design



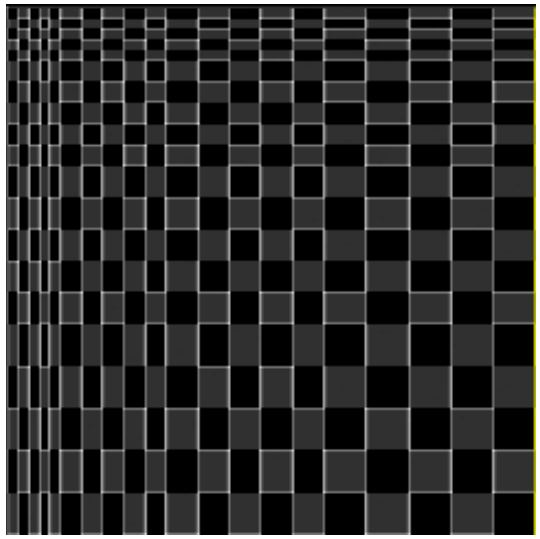
input image

conventional math-based filter



high-pass filter

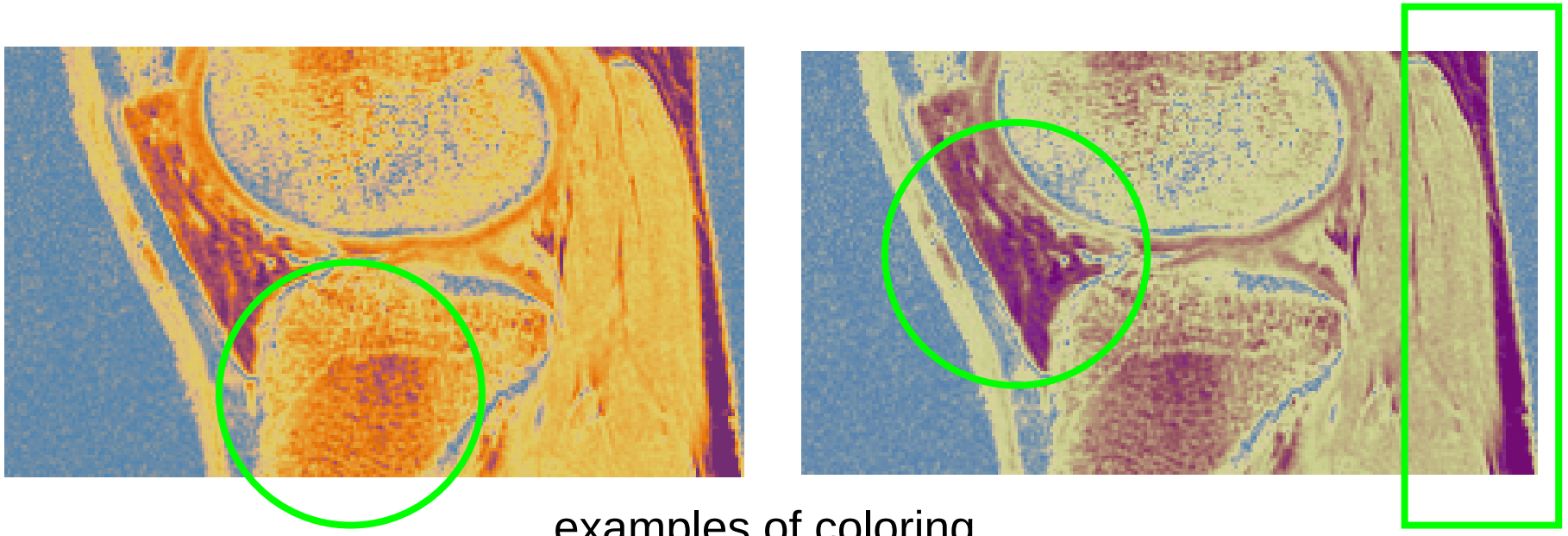
IEC-based filter



6th generation

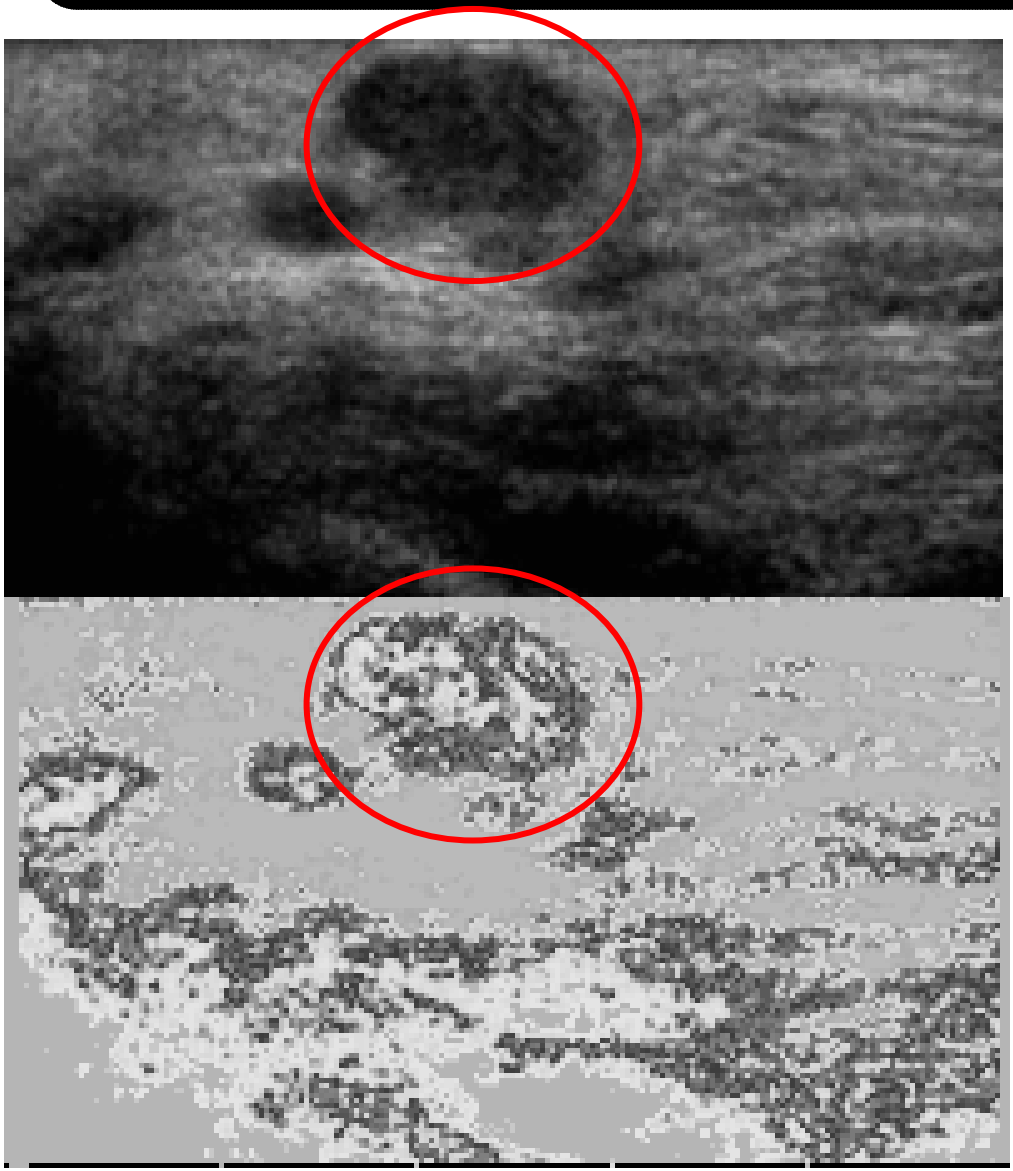
IEC-based Color Filter Design

input image



examples of coloring

Image Enhancement Filter Design by a Medical Doctor



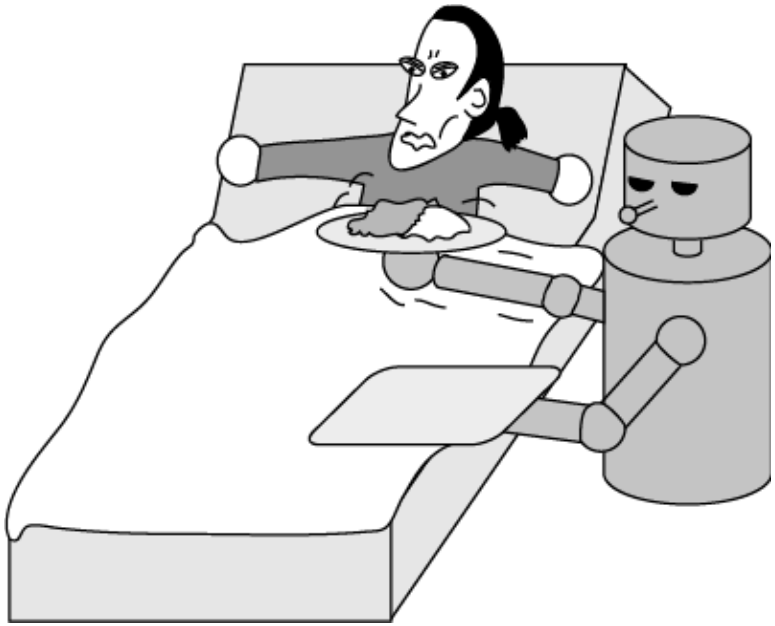
original ultrasonic image of a lymph node

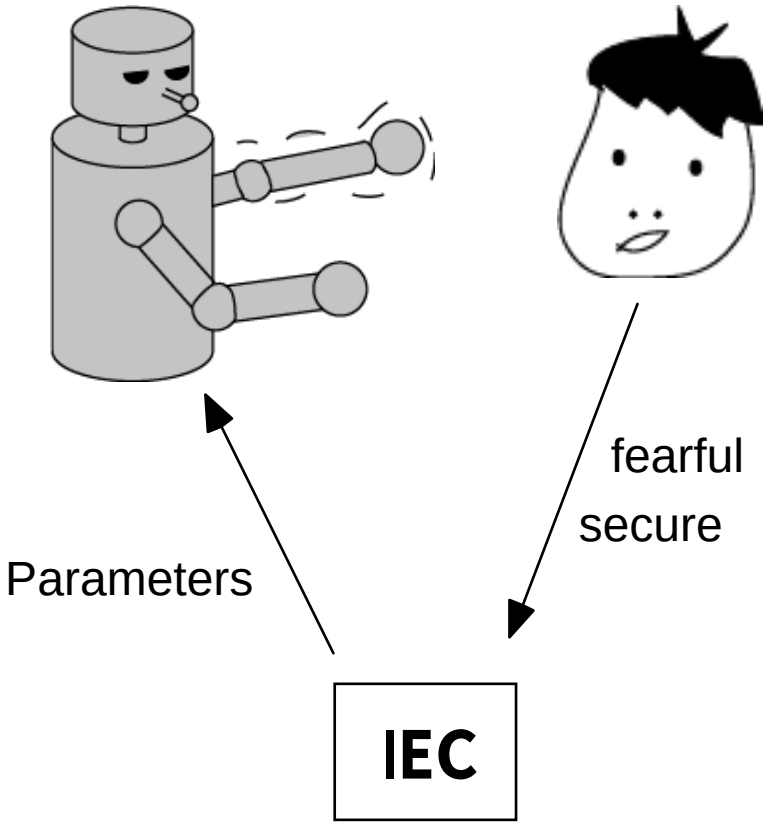
Enhanced Image after 12 IEC generations

CONTENTS

Human Friendly Trajectory Control of a Robot Arm

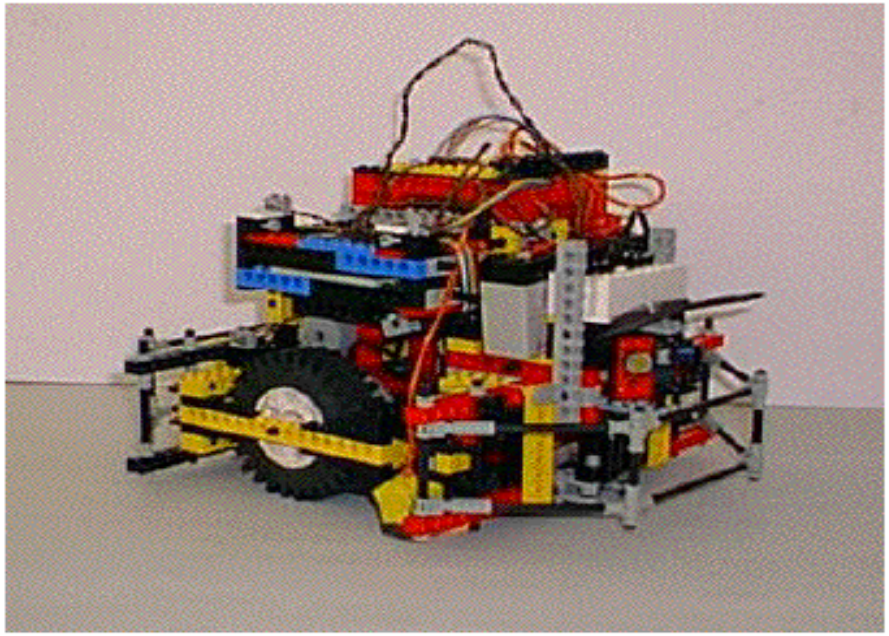
by **N. Kubota, K. Watanabe and F. Kojim**



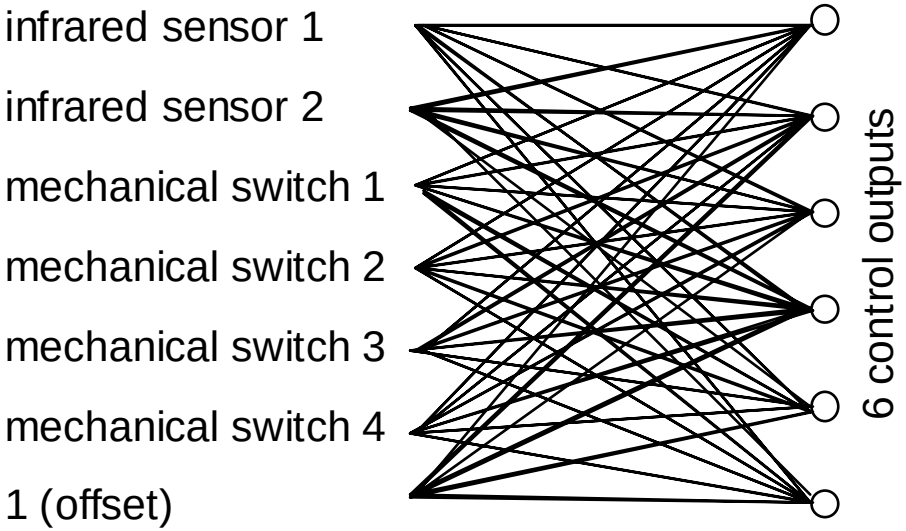


NN Controller for LEGO Jeep-Robot

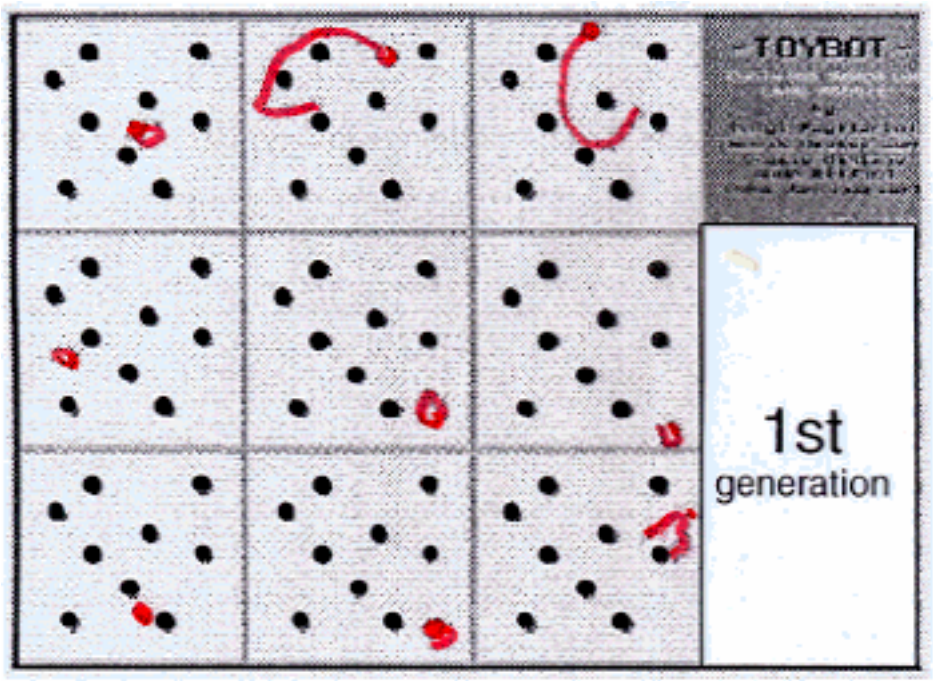
by H. H. Lund, O. Miglimo, L. Pagliarini, A. Billard, and A.

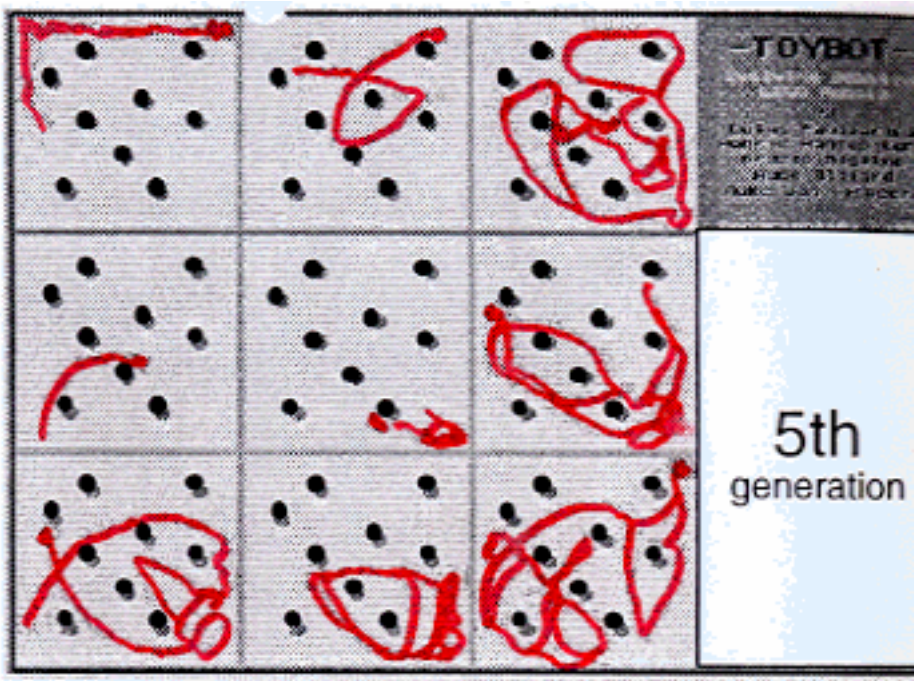


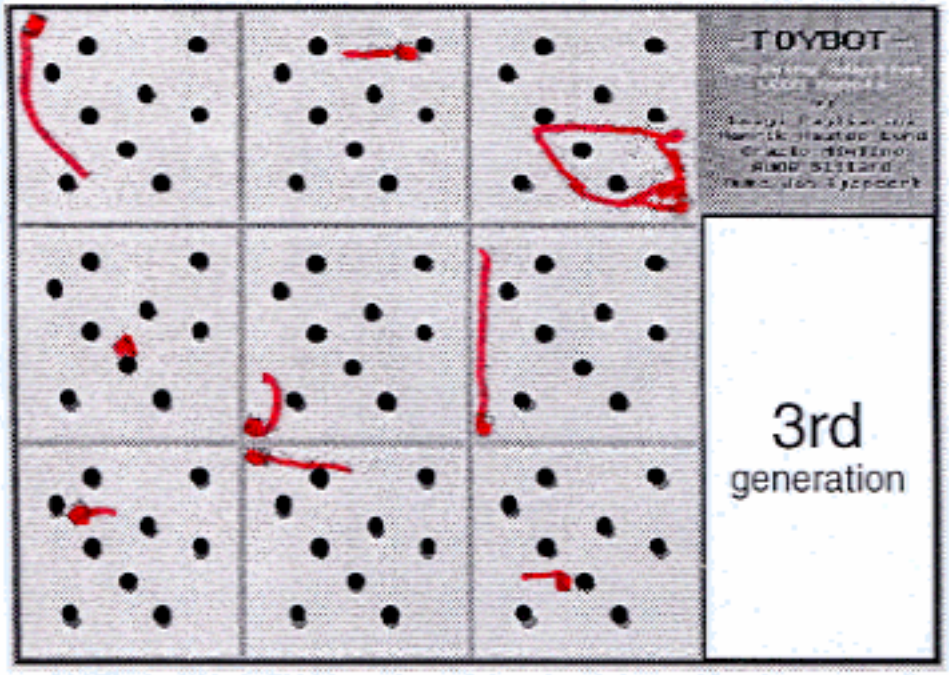
1. Children want to make a robot avoiding obstacles.
2. Children cannot make a program of its controller but can choose better robot moving.
3. Let's evolve the robot controller according to the children's choice.

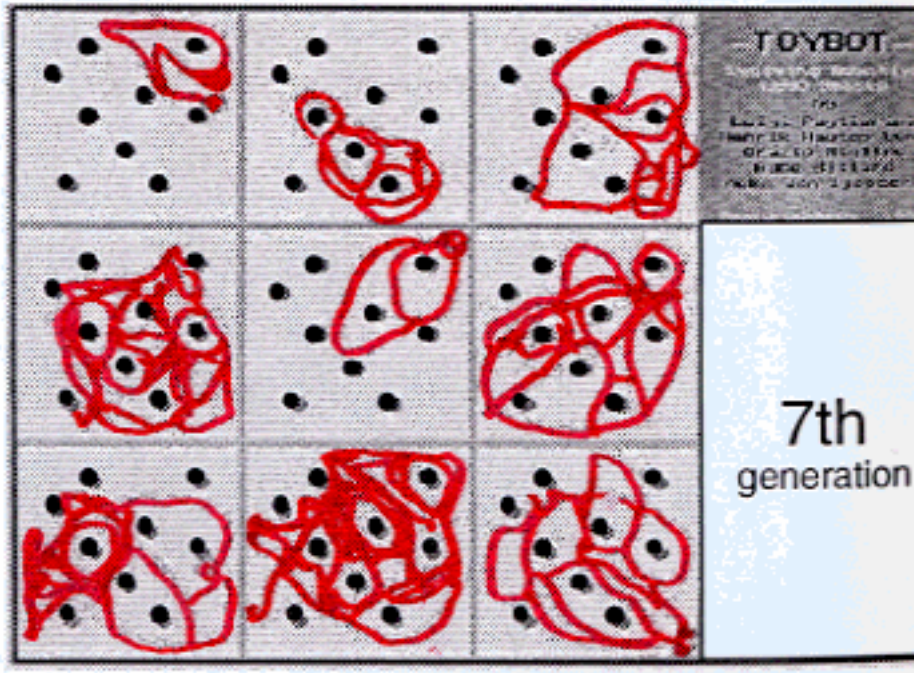


$$y_j = \sum_{i=1}^{n} w_{ij} x_i + w_{0j}$$

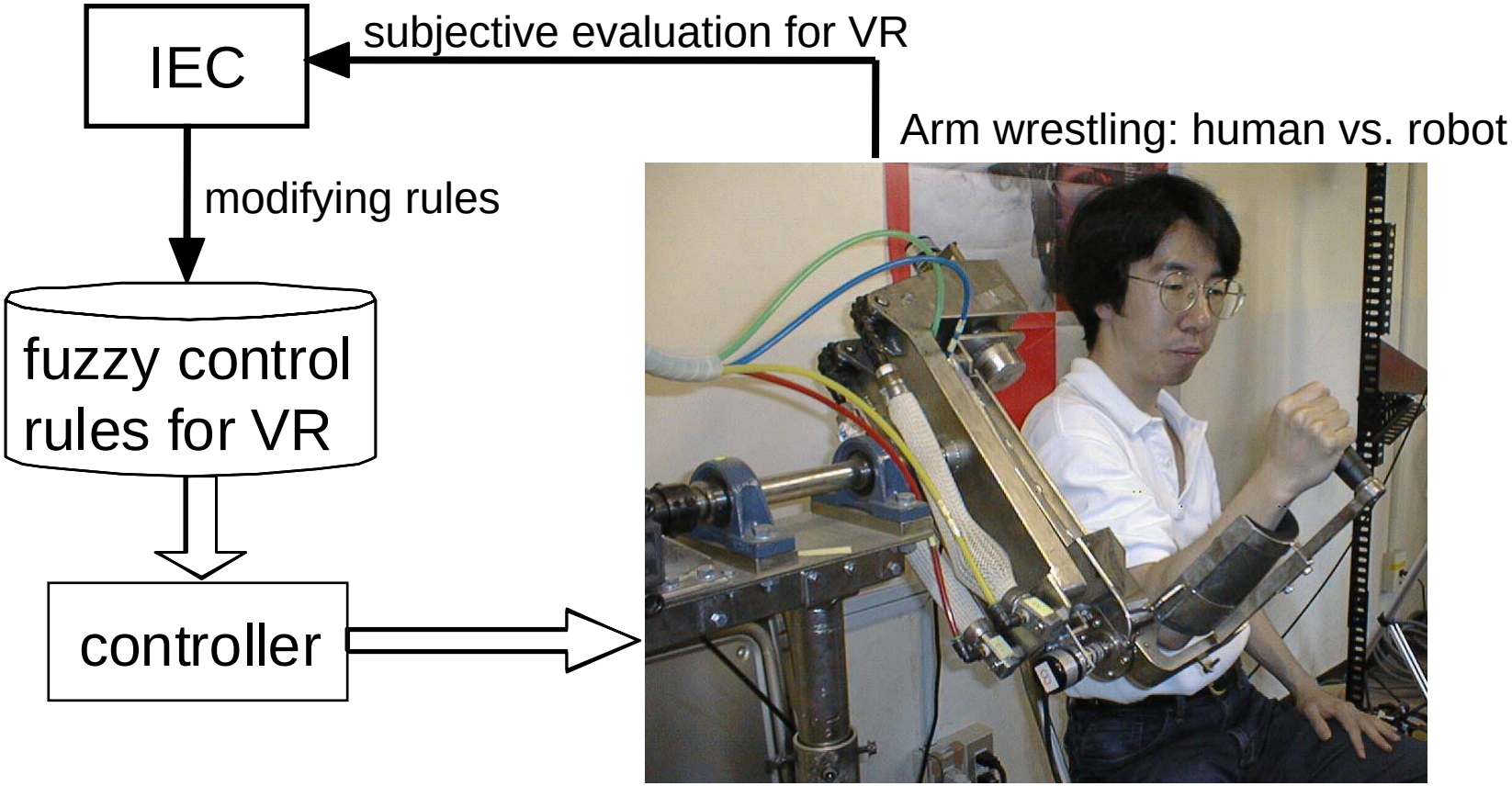

-TOYBOT-
1st
generation


-TOYBOT-
5th
generation


-TOYBOT-
3rd
generation


-TOYBOT-
7th
generation

Interactive EC for Virtual Reality

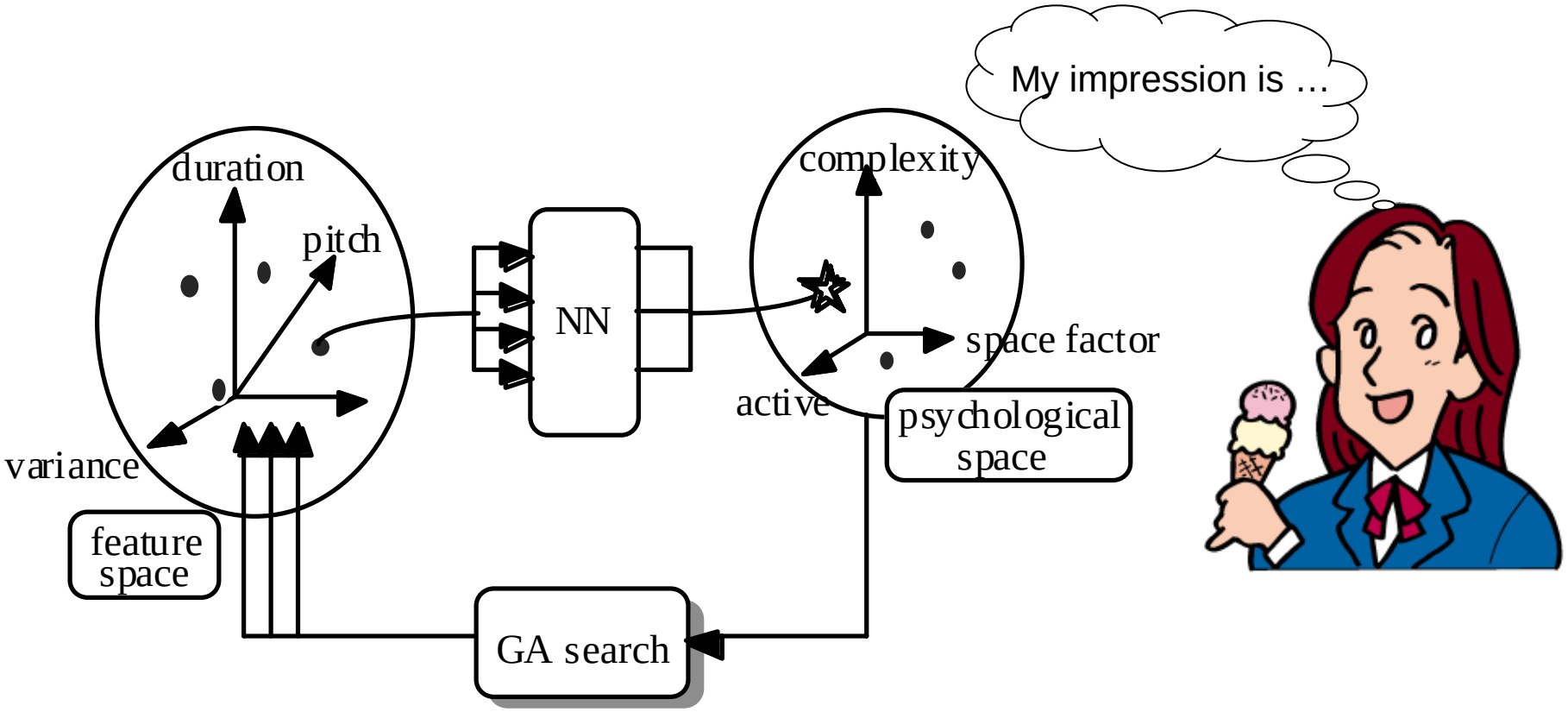


by S. Kamohara, H. Takagi, and T. Takeda

CONTENTS

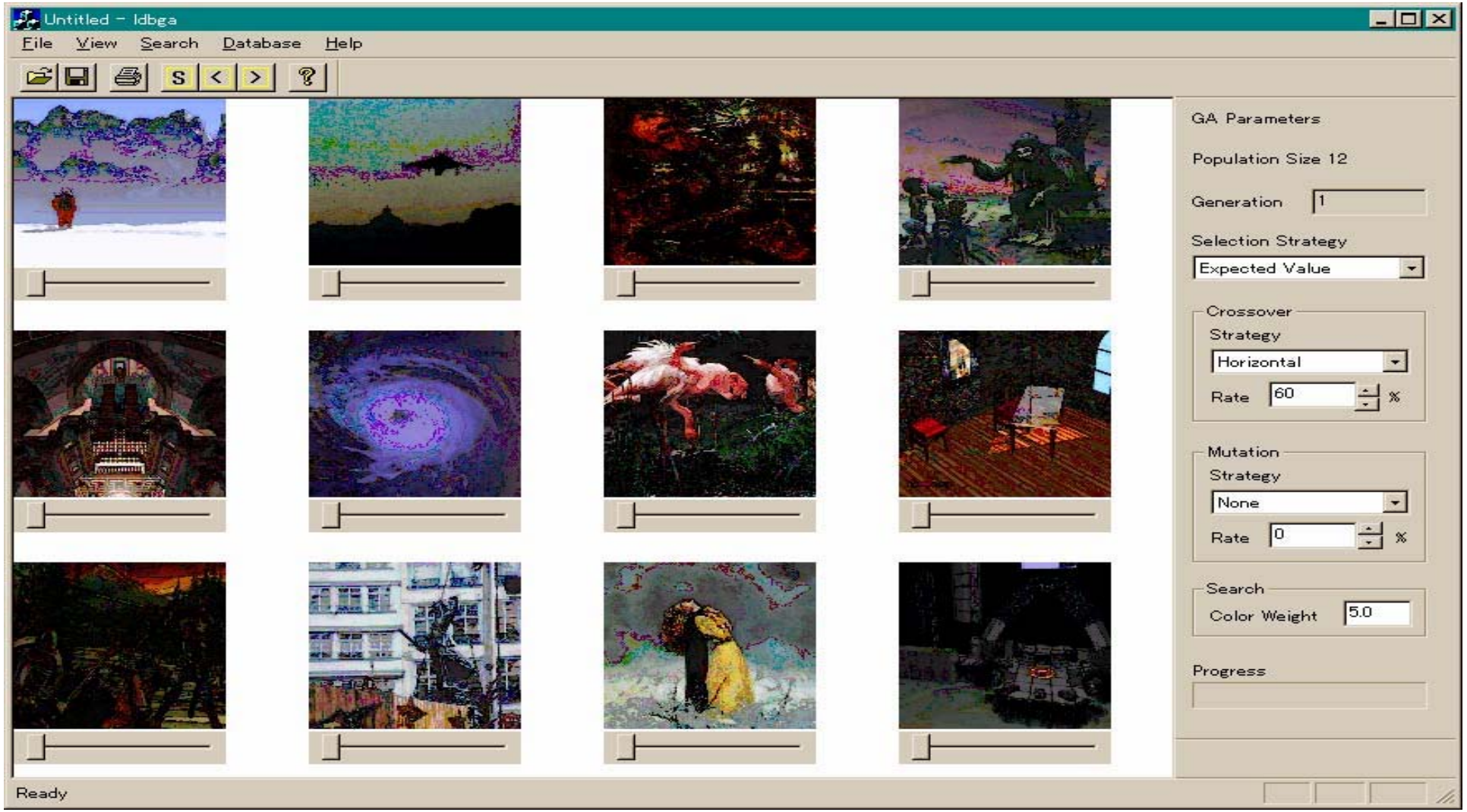
Media DB Retrieval & Media Converter

by H. Takagi et al.



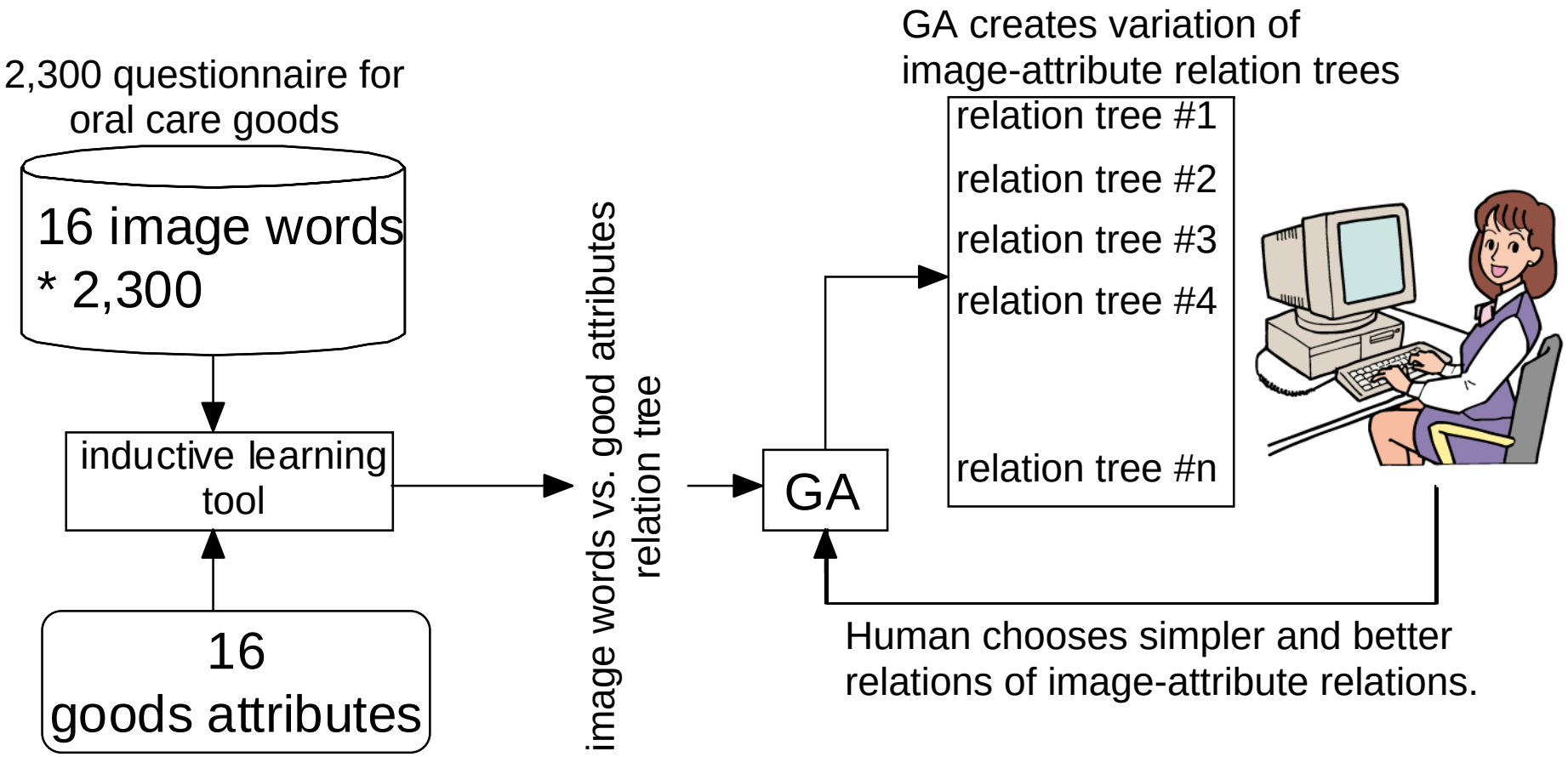
IEC-based Image DB Retrieval

by S.-B.- Cho, et al.



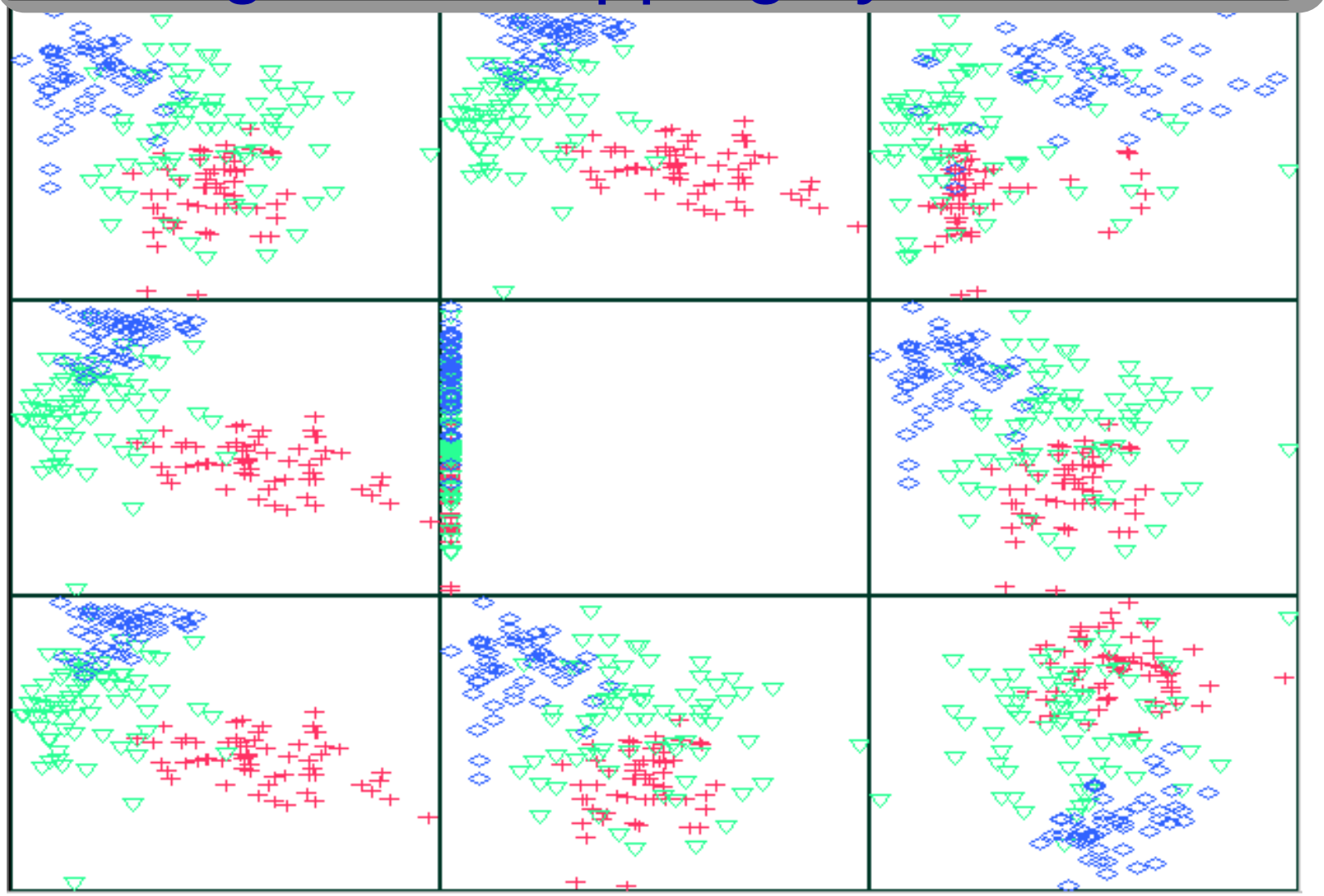
Interactive EC for Data Mining

by T. Terano, Y. Ishino, et al.



Visual Data-mining Through 2-D Mapping by GP

by Venturini

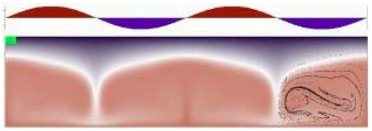


for example,

X = (x1-u) / (87.3 / x12) Y = (46.7 * x6) * (25.2 + 81.0)

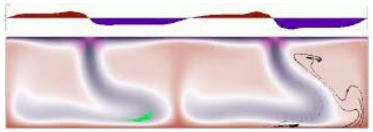
CONTENTS

Geological Modeling Based on Interactive EC

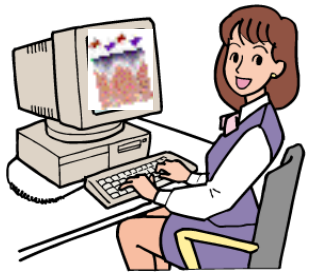


estimated initial condition of geological features

Visualization of geological history based on L. Moresi's forward code



observed current condition



geoscientist

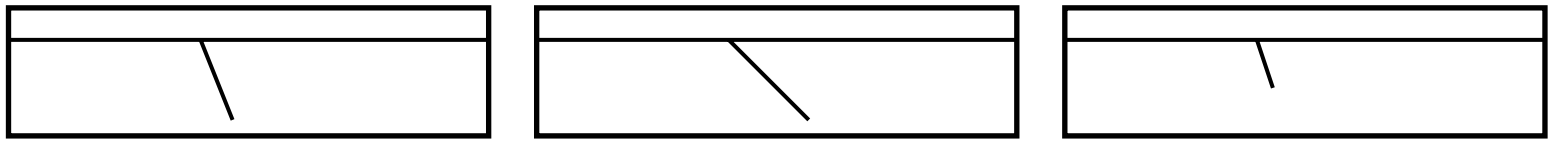
a priori geological knowledge
subjective evaluation

Evolutionary Computation

model parameters

Difficulty

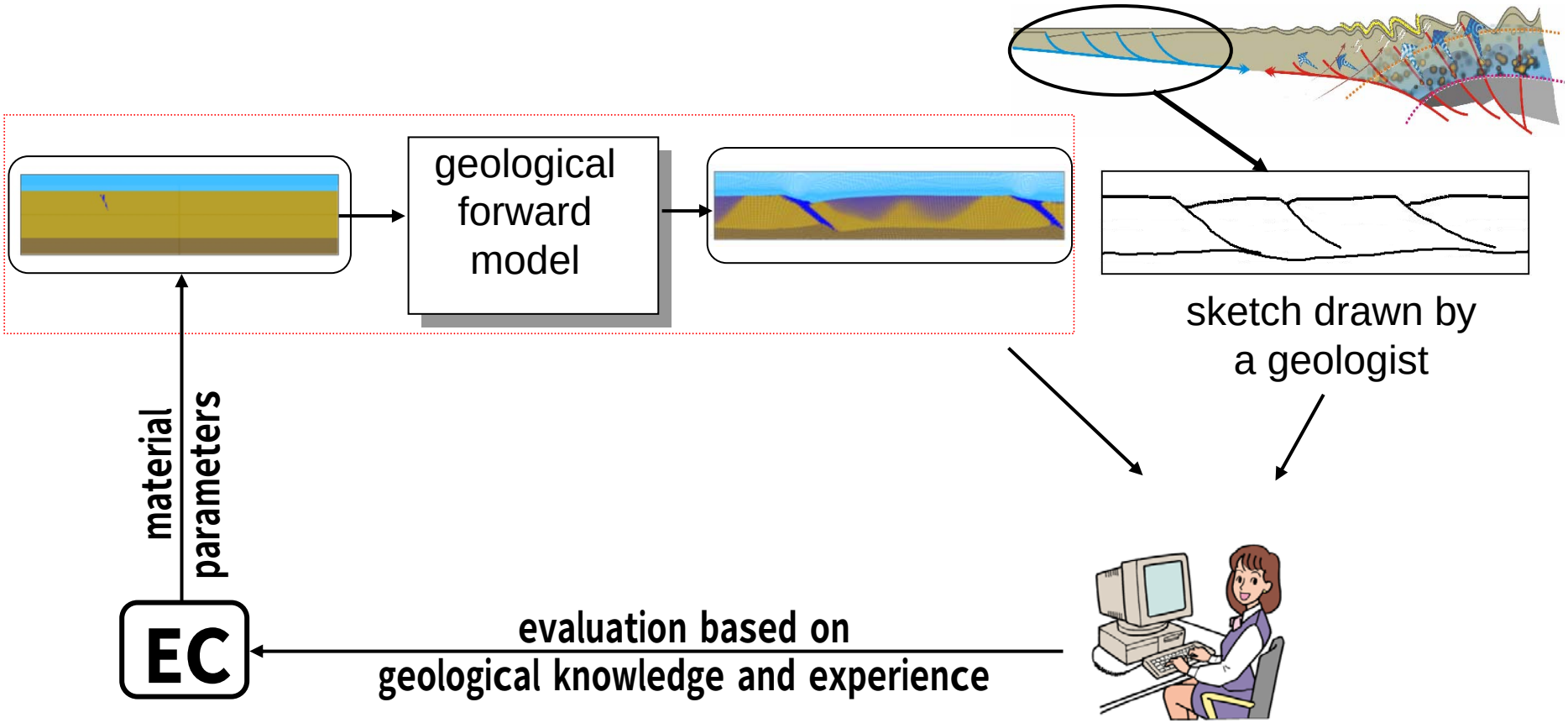
- many variables
  - strength, depth, stress, etc.
- no numerical target
  - Numerical similarity may not mean qualitative similarity, such as wrong fault inclination, wrong depth extent.
  - Help of geologists is necessary.



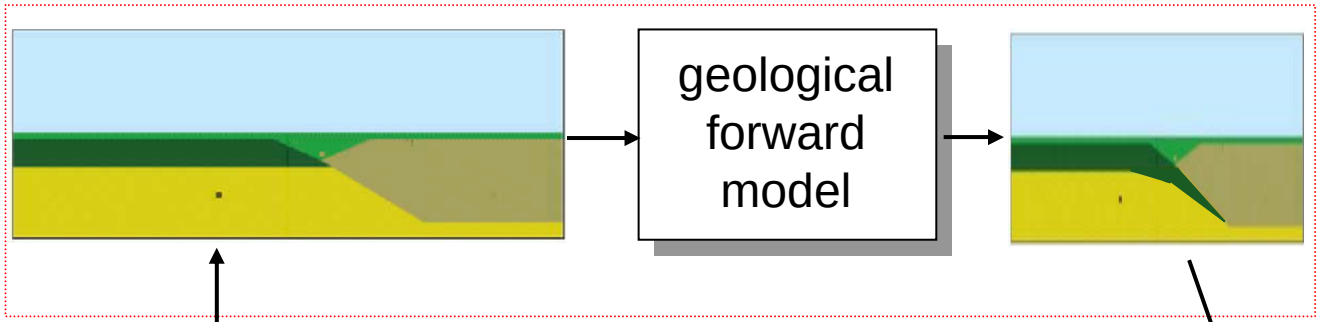
- computational optimisation with human judgement
  - Computational optimisation methods to search material parameters are required besides geologist’s judgement.

IEC-based Modelling of Extension of the Earth's Crust

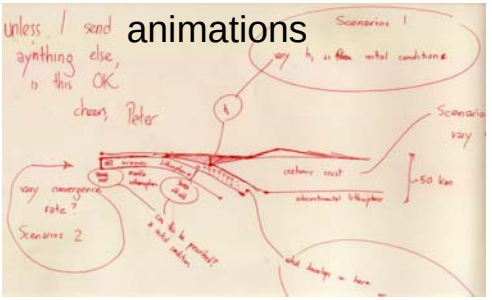
by C. Wijins et al.



IEC-based Modelling of Subduction of Oceanic Crust



geological forward model



animations

material parameters

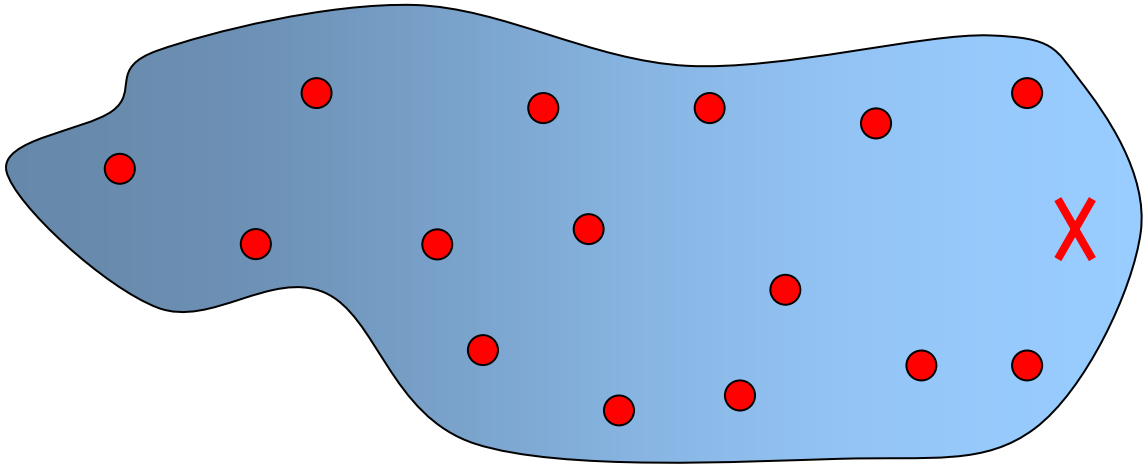
- Strength of continental/oceanic crust
- Convergence rate
- Depth of sedimentary wedge

EC

evaluation based on geological knowledge and experience

Multi-Objective Optimization: Underground Water Management

joint research with UIUC



- Choosing dug wells, ●, for obtaining underground data to estimate the underground water situation of the new target well, X.
- Four objectives (to minimize the cost, maximize the precision, and others)
- We want to use domain expert knowledge. <== IEC

Multi-Objective Optimization: MEMS Design

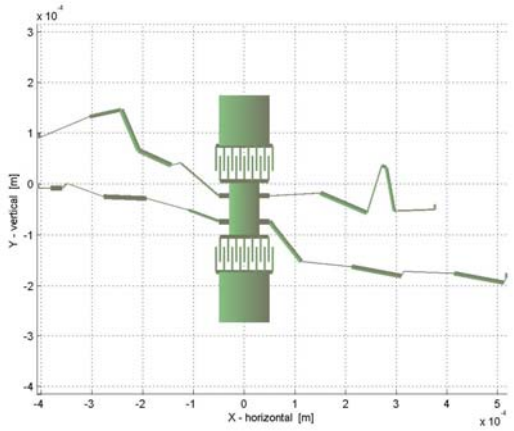
Kamalian, Takagi, and Agogino

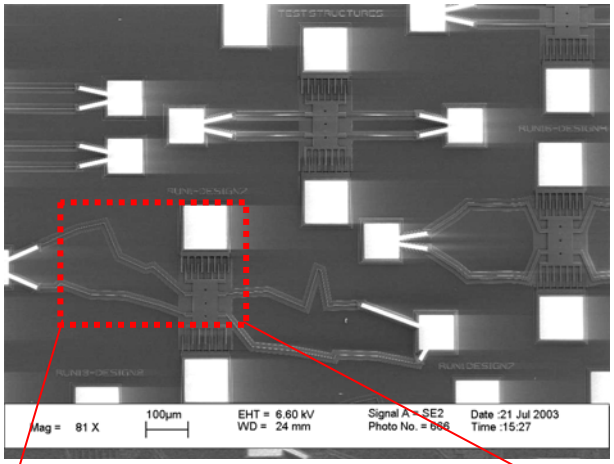
MEMS (Micro Electronic Mechanical Systems) for Sensors, Robotics, Communications, Biotechnology, Energy Generation

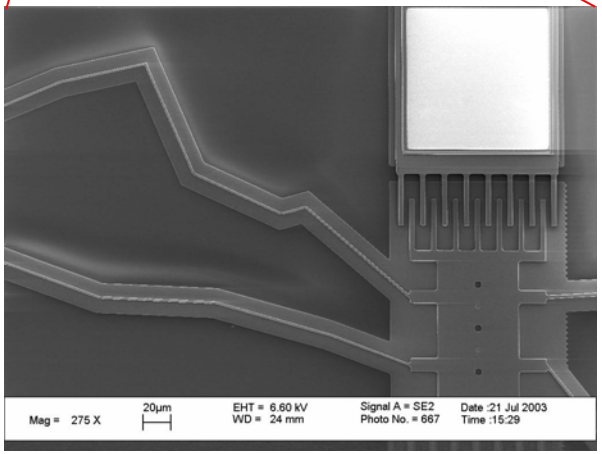
- Multi-objective optimization for given specification:
  receiving frequency, strength, and others.
- We want to use domain knowledge for circuit design.

Multi-Objective Optimization: MEMS Design

joint research with UC Berkeley







IEC+EMO > EMO

(99% significant by Wilcoxon matched-pairs signed-ranks test .)

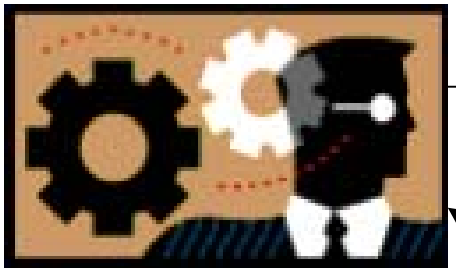
IEC Results

- User tests performed with 12 students:
  - 10 did better with IEC
  - 1 did worse
  - 1 tie
- By sign test, IEC is better with 98% significance
- By the Wilcoxon Matched-Pairs Signed-Ranks test, IEC is better with 99% significance

		IEC+EMO	EMO	
User #	Expert?	# of 5's	# of 5's	sign
1	Y	7	9	-1
2	Y	12	6	1
3	Y	7	3	1
4	N	6	2	1
5	Y	4	4	0
6	Y	11	9	1
7	N	8	7	1
8	Y	1	0	1
9	N	6	3	1
10	N	12	7	1
11	N	9	2	1

- Insufficient sample size to make judgment about whether or not MEMS experience has impact

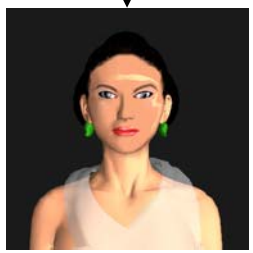
Psychotherapy / Diagnostics



mental patient
(schizophrenics)

IEC-based CG
Lighting Design

sad



happy

emotion range of the patient

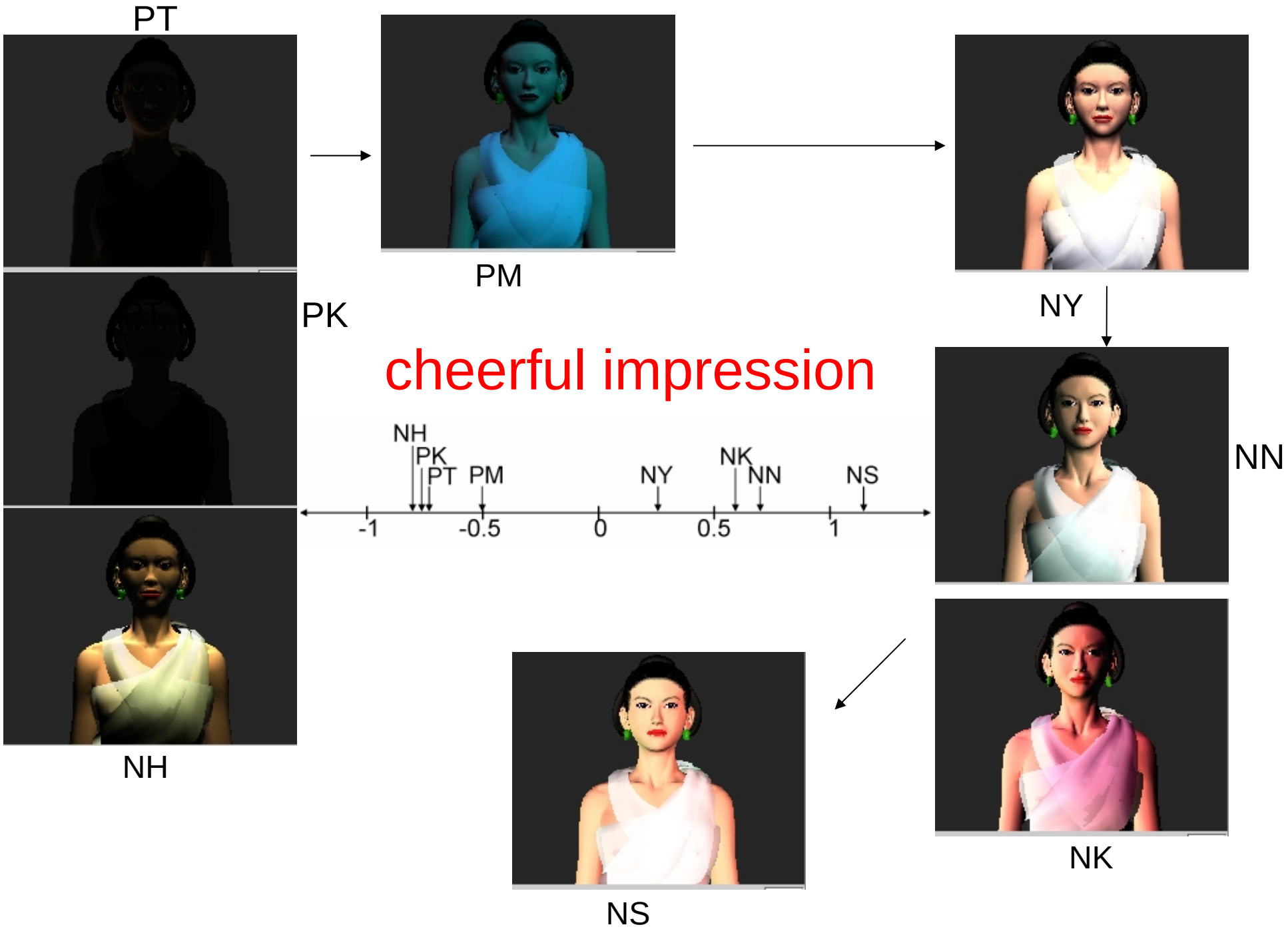
Umm, still
his range is
narrower.

psychotherapist
psychiatrist

sad

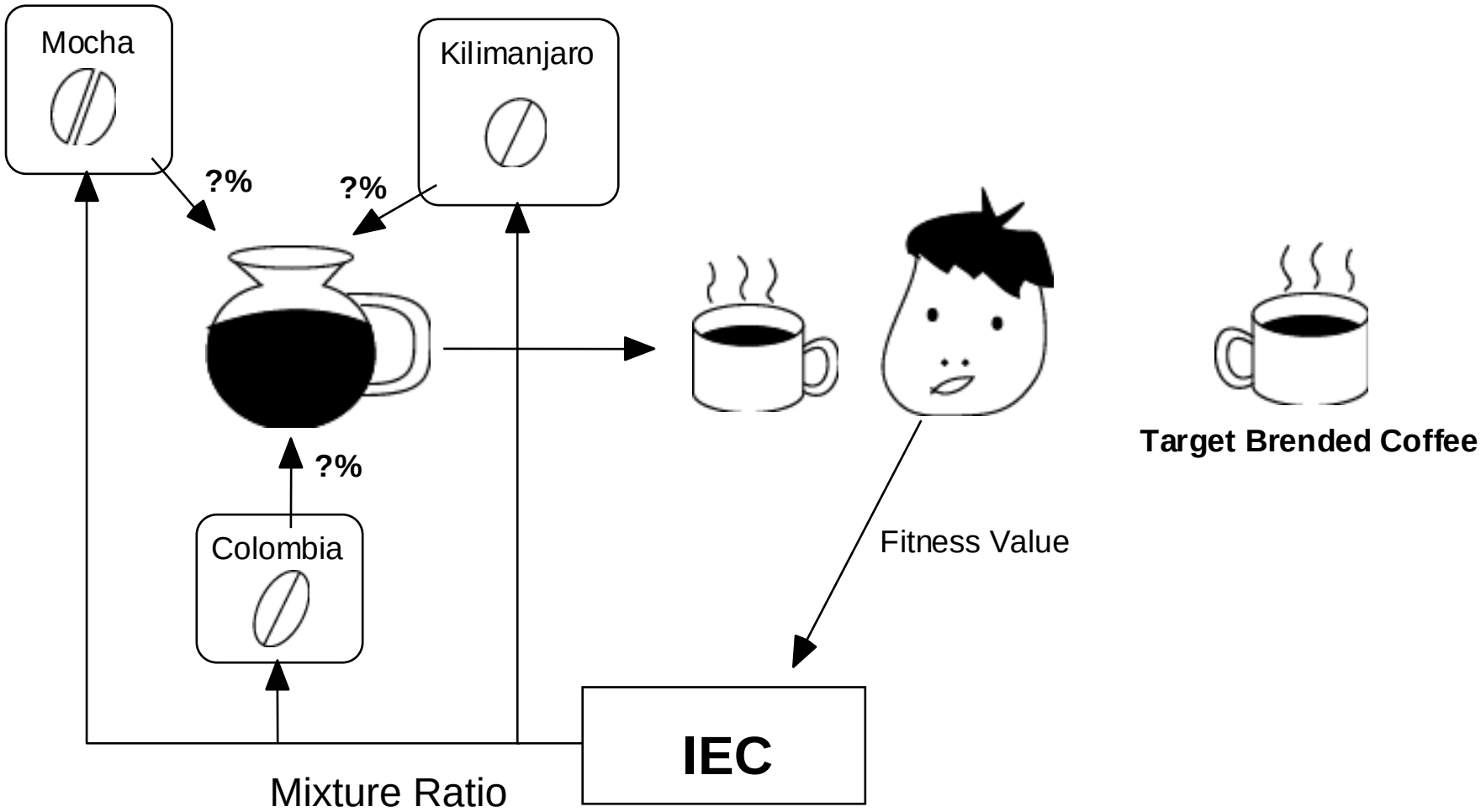
happy

emotion range of normal persons


PT
PM
NY
PK
cheerful impression
NH
PK
PT
PM
NY
NK
NN
NS
-1
-0.5
0
0.5
1
NN
NH
NS
NK

Evolving Blends of Coffee

by M. Hardy

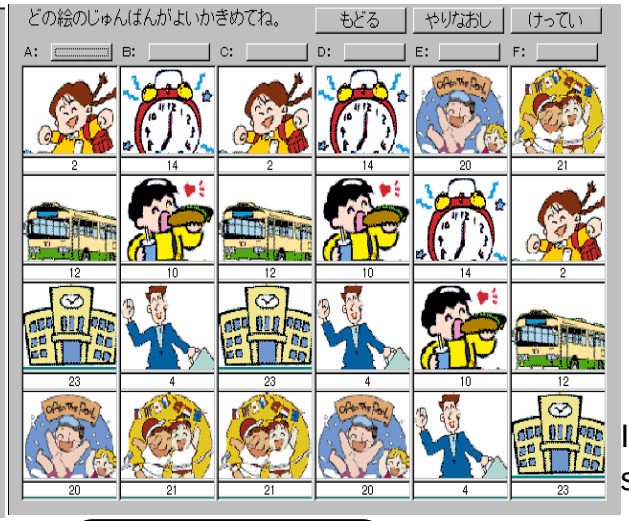


Simulated Breeding for Composition Support System

by K. Kuriyama, T. Terano, and M. Numao

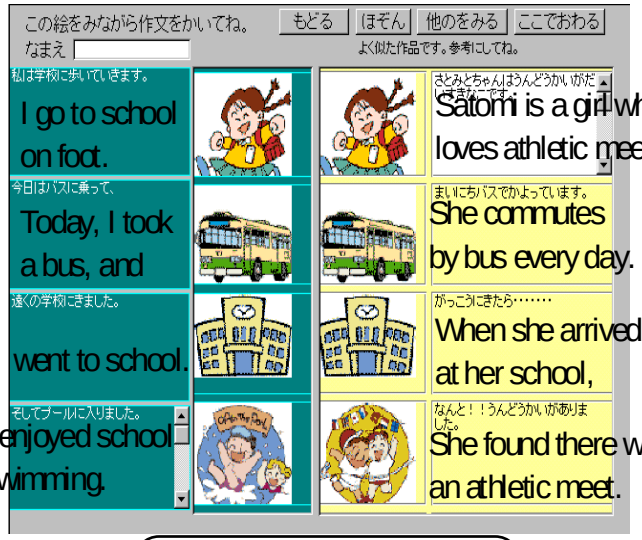
INITIAL DISPLAY

Two sequences of four scenes are chosen as parents.



EVOLVED SEQUENCES

Two better sequences are chosen as parents.



FINAL DISPLAY

Composition and comparison with similar composition.

Researches on Interactive EC

@Takagi Laboratory

application-oriented

(1) 3-D CG lighting design support
(2) montage image system
(3) speech processing
(4) hearing-aid fitting
(5) virtual reality in robot control
(6) media database retrieval
(joint1) virtual aquarium
(joint2) geoscientific simulation
(joint3) 3-D CG modeling education
(joint3) fireworks animation design
(joint4) mental disease diagnosis
(joint5) underground water management
(joint6) MEMS design

interface research

(1) input interface
  1.1 discrete fitness value input method
(2) display interface
  2.1 prediction of user's evaluation char's
  2.2 display for time-sequential tasks
(3) acceleration of GA convergence
  3.1 approximation of EC landscape
(4) active user intervention to EC search
  4.1 on-line knowledge embedding
  4.2 Visualized IEC

CONCLUSION

- We overviewed the chronicled progression of computational intelligence research especially on NN, FS, and EC.
- One of the future directions of the computational intelligence research is humanized computational intelligence.
- Interactive EC is one of such technologies.
- The Interactive EC has higher potential to be applied to wide variety of fields.

Further Information

- Overview Paper of NN/FS/EC
  - Hideyuki Takagi, "Fusion Technology of Neural Networks and Fuzzy Systems: A Chronicled Progression from the Laboratory to Our Daily Lives," Int'l J. of Applied Mathematics and Computer Science, vol.10, no.4, pp.647--673 (2000).
- Survey Paper of Interactive EC
  - Hideyuki Takagi, "Interactive Evolutionary Computation: Fusion of the Capacities of EC Optimization and Human Evaluation," Proceedings of the IEEE vol.89, no.9, pp.1275--1296 (Sept., 2001).
- Personal Contact
  - takagi@kyushu-id.ac.jp
  - http://www.kyushu-id.ac.jp/~takagi